



DEPARTMENT OF ENERGY

The Public Inquiry into the Piper Alpha Disaster

The Hon Lord Cullen



VOLUME ONE



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OFFICE COPY

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by the Secretary of State for Energy
by Command of Her Majesty
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Frontispiece

A fast rescue craft near the 20ft level some time after the first riser rupture: photograph taken by Mr Miller from the *Tharos*.

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The Rt Hon John Wakeham MP
Secretary of State for Energy
Department of Energy
1 Palace Street
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19 October 1990

Dear Secretary of State,

PIPER ALPHA PUBLIC INQUIRY

On 13 July 1988 I was appointed by your predecessor as Secretary of State to hold a public inquiry to establish the circumstances of the accident on Piper Alpha and its cause. The public inquiry has been completed and I now enclose my Report which deals with all matters with the exception, as stated in paragraph 2.28, of any question as to the making of a direction in regard to costs.

Yours sincerely,

W Douglas Cullen

W DOUGLAS CULLEN

THE MINERAL WORKINGS (OFFSHORE INSTALLATIONS) ACT 1971 (c. 61)
THE OFFSHORE INSTALLATIONS (PUBLIC INQUIRIES) REGULATIONS 1974
(SI 1974/338)

WHEREAS on 6th July 1988 an accident involving loss of life occurred on and in connection with the operations of the offshore installation known as Piper Alpha situated in the United Kingdom sector of the continental shelf:

NOW THEREFORE the Secretary of State, in exercise of the powers conferred on him by the above-mentioned Regulations, hereby-

- (1) directs that a public inquiry be held to establish the circumstances of the accident and its cause;
- (2) appoints the Honourable Lord Cullen, a Senator of the College of Justice in Scotland, to hold the inquiry and to report to him on the circumstances of the accident and its cause together with any observations and recommendations which he thinks fit to make with a view to the preservation of life and the avoidance of similar accidents in the future.



13th July 1988

Secretary of State for Energy

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Robert Gibson

Frontispiece and Plates 14-16(b), 17(b) and 18(a)

Charles A Miller

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Highlands and Islands Development Board

Plates 3, 4 and 6-9

Borowski (Photographers)

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Fleumer (Aerial Photography)

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Osborne Boats Ltd

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Lindsay M T Macdonald

Plate 18(b)

Theodorus Vanus

Plate 19(a)

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Plates 20(a) and (b)

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Plates 21, 22(a) and 23

Grampian Police

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Tucker Robinson

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Hank Johnson Flags

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Petresco

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SECTION ONE: INTRODUCTION

Chapter 1

Executive Summary

1.1 Through the Inquiry I sought the answers to 2 questions -

- What were the causes and circumstances of the disaster on the Piper Alpha platform on 6 July 1988? and
- What should be recommended with a view to the preservation of life and the avoidance of similar accidents in the future?

1.2 In Chapters 4-10 I review the events which occurred in the disaster and its aftermath. In Chapters 11-15 I am concerned with the background to the disaster and deal with a number of further matters which were investigated in the light of what happened. In Chapters 16-22 I consider what is required for the future: and in Chapter 23 I set out my recommendations.

1.3 The present chapter should be understood as giving only a brief indication of the content of what follows in later chapters. The latter contain my full conclusions and observations together with the supporting reasoning and such of the evidence as I have considered it necessary to set out.

1.4 The first event in the disaster was an initial explosion at about 22.00 hours. In **Chapter 5** I conclude that it was in the south-east quadrant of C Module, the gas compression module, and was due to the ignition of a low-lying cloud of condensate.

1.5 As most of the equipment on the platform was not recovered from the wreckage and as key witnesses did not survive the disaster a number of possible explanations for the leak of condensate are considered in **Chapter 6**. Particular attention was given in the Inquiry to events after 21.45 hours when one of the two condensate injection pumps tripped. I conclude that the leak resulted from steps taken by night-shift personnel with a view to restarting the other pump which had been shut down for maintenance. Unknown to them a pressure safety valve had been removed from the relief line of that pump. A blank flange assembly which had been fitted at the site of the valve was not leak-tight. The lack of awareness of the removal of the valve resulted from failures in the communication of information at shift handover earlier in the evening and failure in the operation of the permit to work system in connection with the work which had entailed its removal.

1.6 **Chapter 7** is concerned with the way in which the disaster developed. The initial explosion caused extensive damage. It led immediately to a large crude oil fire in B Module, the oil separation module, which engulfed the north end of the platform in dense black smoke. This fire, which extended into C Module and down to the 68 ft level was fed by oil from the platform and by a leak from the main oil line to the shore, to which pipelines from the Claymore and Tartan platforms were connected. At about 22.20 hours there was a second major explosion which caused a massive intensification of the fire. This was due to the rupture of the riser on the gas pipeline from Tartan as a result of the concentration and high temperature of the crude oil fire. It is probable that this rupture would have been delayed if oil production on the other platforms had been shut down earlier than it was. The fire was further intensified by the ruptures of risers on the gas pipeline to the Frigg disposal system and the gas pipeline connecting Piper with Claymore at about 22.50 and 23.20 hours respectively. The timing of the start of depressurisation of the gas pipelines could not have had

any material effect on the fire at Piper. The OIMs on Claymore and Tartan were ill-prepared for an emergency on another platform with which their own platform was connected.

1.7 The initial explosion put the main power supplies and the Control Room at Piper out of action. It appears that the emergency shutdown system was activated and the emergency shutdown valves on the gas pipeline risers probably closed although extended flaring pointed to a failure of the valve on the Claymore riser to close fully. The other emergency systems of the platform failed immediately or within a short period of the initial explosion. In particular the fire-water system was rendered inoperative either due to physical damage or loss of power. However, at the time of the initial explosion the diesel fire pumps were on manual mode so that, even if they had not been disabled, they would have required manual intervention in order to start them.

1.8 In **Chapter 8** I describe the effects of events on the platform personnel. Of the 226 men on the platform, 62 were on night-shift duty; the great majority of the remainder were in the accommodation. The system for control in the event of a major emergency was rendered almost entirely inoperative. Smoke and flames outside the accommodation made evacuation by helicopter or lifeboat impossible. Diving personnel, who were on duty, escaped to the sea along with other personnel on duty at the northern end and the lower levels of the platform. Other survivors who were on duty made their way to the accommodation; and a large number of men congregated near the galley on the top level of the accommodation. Conditions there were tolerable at first but deteriorated greatly owing to the entry of smoke. A number of personnel, including 28 survivors, decided on their own initiative to get out of the accommodation. The survivors reached the sea by the use of ropes and hoses or by jumping off the platform at various levels. 61 persons from Piper survived. 39 had been on night-shift and 22 had been off duty. At no stage was there a systematic attempt to lead men to escape from the accommodation. To remain in the accommodation meant certain death.

1.9 Many organisations, vessels and aircraft were involved in the rescue and subsequent treatment of survivors, as I narrate in **Chapter 9**. There was some initial delay and confusion onshore due to the lack of accurate information. However, this did not affect the toll of death and injury. The events demonstrated the value of fast rescue craft and the bravery of their crews in getting close to the platform even where the fire was raging at its fiercest. They also demonstrated the shortcomings of the type of standby vessel which was in attendance at Piper.

1.10 **Chapter 10** shows that the bodies of 135 of the 165 personnel on Piper who died as a result of the disaster were later recovered. The principal cause of death in 109 cases (including 79 recovered from the accommodation) was inhalation of smoke and fire. 14 apparently died during an attempt to escape from the platform. Few died of burns.

1.11 **Chapter 11** shows that the failure in the operation of the permit to work system was not an isolated mistake but that there were a number of respects in which the laid down procedure was not adhered to and unsafe practices were followed. One particular danger, which was relevant to the disaster, was the need to prevent the inadvertent or unauthorised recommissioning of equipment which was still under maintenance and not in a state in which it could safely be put into service. The evidence also indicated dissatisfaction with the standard of information which was communicated at shift handover. This had been the subject of criticism in the light of a fatality in September 1987.

1.12 As regards the fire-water system I find in **Chapter 12** that the practice of keeping the diesel fire pumps on manual mode during periods of diving was peculiar to Piper and in spite of an audit recommendation that it should be changed. It inhibited the

operability of the system in an unnecessary and dangerous way. Further it is likely that if the fire-water system had been activated a substantial number of the deluge heads in C Module would have been blocked with scale. This was a problem of long standing but by the time of the disaster the necessary replacement of the distribution pipework had not been carried out.

1.13 Evidence as to training for emergencies, to which I refer in **Chapter 13** showed that the induction was cursory and, in regard to demonstrating lifeboats and life rafts, not consistently given. Muster drills and the training of persons with special duties in an emergency did not take place with the frequency laid down in Occidental's procedures. The OIMs and platform management did not show the necessary determination to ensure that regularity was achieved.

1.14 I point out in **Chapter 14** that Occidental management should have been more aware of the need for a high standard of incident prevention and fire-fighting. They were too easily satisfied that the permit to work system was being operated correctly, relying on the absence of any feedback of problems as indicating that all was well. They failed to provide the training required to ensure that an effective permit to work system was operated in practice. In the face of a known problem with the deluge system they did not become personally involved in probing the extent of the problem and what should be done to resolve it as soon as possible. They adopted a superficial attitude to the assessment of the risk of major hazard. They failed to ensure that emergency training was being provided as they intended. The platform personnel and management were not prepared for a major emergency as they should have been. The safety policies and procedures were in place: the practice was deficient.

1.15 In **Chapter 15** I examine the involvement of the Department of Energy with safety on Piper in the year up to the disaster. Installations such as Piper were subject to regular inspections, the purpose of which was, by means of a sampling technique, to assess the adequacy of the safety of the installation as a whole. Piper was inspected in June 1987 and June 1988. The latter visit was also used to follow-up what Occidental had done in the light of the fatality, which was in part due to failures in the operation of the permit to work system and the communication of information at shift handover. The findings of those inspections were in striking contrast to what was revealed in evidence at the Inquiry. Even after making allowance for the fact that the inspections were based on sampling it was clear to me that they were superficial to the point of being of little use as a test of safety on the platform. They did not reveal a number of clear cut and readily ascertainable deficiencies. While the effectiveness of inspections has been affected by persistent under-manning and inadequate guidance, the evidence led me to question, in a fundamental sense, whether the type of inspection practised by the DEN could be an effective means of assessing or monitoring the management of safety by operators.

1.16 I turn now to those chapters which are concerned with the future. By way of background to what follows, **Chapter 16** provides a brief outline of the existing United Kingdom offshore safety regime and, by way of comparison, the onshore safety regime and the Norwegian offshore safety regime.

1.17 The disaster involved the realisation of a potential major hazard in that an explosion following a hydrocarbon leak led to the failure of gas risers which added very large amounts of fuel to the fire. Although such remote but potentially hazardous events had been envisaged Occidental did not require them to be assessed systematically; nor did the offshore safety regime require this. As I set out in **Chapter 17**, I am satisfied that operators of installations, both fixed and mobile and both planned and existing, should be required by regulation to carry out a formal safety assessment of major hazards, the purpose of which would be to demonstrate that the potential major hazards of the installation and the risks to personnel thereon have been identified and appropriate controls provided. This is to assure the operators that their operations are safe. However it is also a legitimate expectation of the workforce and the public that

operators should be required to demonstrate this to the regulatory body. The presentation of the formal safety assessment should take the form of a Safety Case, which would be updated at regular intervals and on the occurrence of a major change of circumstances.

1.18 Offshore installations have the unique requirement to be self-sufficient in providing immediate protection to personnel in the event of an emergency. I consider, as I set out in **Chapter 19**, that there should be a temporary safe refuge for personnel which should be a central feature of the Safety Case. Such a refuge should be able to provide temporary protection for personnel while the emergency is being assessed and preparations are made for evacuation should that be directed. The events which the refuge should be able to withstand and the acceptance standards for the endurance time and the risk of failure should be specified in the Safety Case. Likewise, the Safety Case should deal with the passability of escape routes and the integrity of embarkation points and lifeboats. Since the formal safety assessment should cover the safe evacuation, escape and rescue of personnel, the Safety Case should demonstrate that adequate provision is made for this also, as I set out in **Chapter 20**.

1.19 The safety of personnel on an installation in regard to hazards at large is, as I point out in **Chapter 21**, critically dependent on the systematic management of safety by operators. The present offshore safety regime does not address this in any direct sense; and current measures are, in my view, ineffective for the purpose of ensuring that the management of safety by all operators is adequate. Each operator should therefore be required in the Safety Case to demonstrate that the safety management system of the company and that of the installation are adequate to ensure that the design and operation of the installation and its equipment are safe. The safety management system of the company should set out the safety objectives, the system by which those objectives are to be achieved, the performance standards which are to be met and the means by which adherence to those standards is to be monitored.

1.20 It is essential, as I state in **Chapter 21**, that there should be assurance that each operator's safety management system is in fact adhered to. It is inappropriate and impracticable for the regulatory body to undertake the detailed auditing of operator's compliance with it. Operators should therefore be required to satisfy themselves by means of regular audits that the system is being adhered to. On the other hand the regulatory body should be required to review operator's audits on a selective basis and itself to carry out such further audits as it thinks fit and by regular inspection verify that the output of the system is satisfactory. This involves a completely new approach to regulation in the United Kingdom offshore safety regime. However it is totally consistent with the Health and Safety at Work etc Act 1974 and the concept of self-regulation. It represents a logical development from the requirement of a Safety Case for each installation.

1.21 In **Chapter 21** I set out my general findings in regard to the existing safety regulations and guidance relating to them. Many regulations are unduly restrictive in that they are of the type which impose 'solutions' rather than 'objectives' and are out-of-date in relation to technological advances. Guidance notes are expressed, or at any rate lend themselves to interpretation, in such a way as to discourage alternatives. There is a danger that compliance takes precedence over wider safety considerations; and that sound innovations are discouraged. The principal regulations should take the form of requiring stated objectives to be met. Guidance notes should give non-mandatory advice. On the other hand I accept that in regard to certain matters it will continue to be essential that detailed measures are prescribed.

1.22 In **Chapter 21** I also reaffirm the need for a single regulatory body. This is of particular importance for the future in which a greater burden will be placed on the expertise, judgement and resources of the regulator upon which his confidence and that of the industry will rely.

1.23 As I set out in **Chapter 22**, developments in regulatory techniques, experience of the capabilities and approach of offshore and onshore regulators, the imminence of major changes in the offshore safety regime and the evidence which I heard in Part 1 of the Inquiry caused me to entertain the question as to the body which should be the regulatory body for the future offshore safety regime. The choice as a practical matter lies between the DEn and the HSE, in either case being suitably strengthened. I come to the conclusion that the balance of advantage lies in favour of the transfer of responsibility to the HSE. The decisive considerations in my mind arise from considering the differences in approach between these 2 bodies to the development and enforcement of regulatory control. These differences are discussed in **Chapter 22**. I am confident that the major changes which I have recommended are ones which are in line with the philosophy which the HSE has followed. This alternative is clearly preferable to the DEn even if it was given a higher level of manning with greater in-house expertise. I also attach importance to the benefits of integrating the work of the offshore safety regulator with the specialist functions of the HSE.

1.24 The above summary has concentrated on the major elements in my recommendations. However in Chapters 18, 19 and 20 I have discussed, in the light of the lessons of the disaster and the expert evidence given in Part 2 of the Inquiry what should be done with a view to the prevention of incidents causing fires and explosions (**Chapter 18**); the mitigation of incidents (**Chapter 19**); and evacuation, escape and rescue (**Chapter 20**). In each of these chapters I have endeavoured to take account of the current state of the relevant technology and the extent to which further work is required; and to identify those matters which should, in my view, be the subject of regulations, either in the form of those which set objectives or those which prescribe fundamental essentials for safety. These include recommendations as to the operation of the permit to work procedures, the fire protection provided on platforms, the means of escape from platforms to the sea and improvements in the standby vessel fleet.

Chapter 2

The Scope of the Inquiry

The circumstances of the Inquiry

2.1 The Piper Alpha disaster, which occurred on the evening of 6 July 1988, claimed the lives of 165 of the 226 persons on board and 2 of the crew of the FRC of the *Sandhaven* while it was engaged in the rescue of persons from the installation. The death toll was the highest in any accident in the history of offshore operations.

2.2 In the weeks and months that followed the bodies of 137 of the deceased were recovered. Of these 81 were recovered from the wreckage of the East Replacement Quarters (ERQ), most of them in October and November 1988 after the ERQ had been raised from the seabed and transported to Occidental's terminal at Flotta in Orkney. 30 of the deceased remain missing.

2.3 On the morning after the disaster all that remained of the topside of the installation consisted of the wreckage of A Module which contained the wellhead area. It took several days for a number of wellhead fires to be extinguished. On 7 December 1988 after inspection of the remaining structure and the seabed Occidental obtained conditional approval from the Secretary of State for Energy under Sec 4 of the Petroleum Act 1987 of a plan for the abandonment of the installation which included the toppling of its jacket. I had been consulted in regard to the implications of that operation and indicated that for my part I had no objection in principle to the proposal. On 28 March 1989 the jacket of the installation was toppled.

Events leading up to the opening of the Inquiry

2.4 In terms of a minute dated 13 July 1988 the Secretary of State for Energy, in exercise of the powers conferred upon him by the Public Inquiries Regulations, (1) directed "that a public inquiry be held to establish the circumstances of the accident and its cause"; and (2) appointed me "to hold the inquiry and to report to him on the circumstances of the accident and its cause together with any observations and recommendations which he thinks fit to make with a view to the preservation of life and the avoidance of similar accidents in the future".

2.5 On the same date the Secretary of State, in exercise of the power conferred on him by Reg 13 of the Inspectors and Casualties Regulations, and the Health and Safety Commission (HSC) in exercise of its power under Sec 14(1) and (2)(a) of the Health and Safety at Work etc Act 1974 (HSWA), directed and authorised Mr J R Petrie, Director of Safety of the Petroleum Engineering Division (PED) "to investigate and make a special report with respect to the occurrence of casualties suffered as a result of the accident on and in connection with the operations of the offshore installation ...".

2.6 In a statement made on 14 July 1988 in answer to a Parliamentary Question the Secretary of State explained that the Government intended that the public inquiry should be as full and far reaching as necessary. On the other hand the object of the investigation by Mr Petrie was that if any early, even if provisional, lessons could be learnt from the disaster, they should be extracted and guidance issued to operators of North Sea installations.

2.7 In these circumstances the technical investigation which was conducted by Mr Petrie with the assistance of a team of inspectors from the Department of Energy (DEn) and the Health and Safety Executive (HSE) was carried out as a first priority and before preparations for the public inquiry could begin. Mr Petrie presented an

Interim Special Report dated 15 September 1988 to the Secretary of State and the Chairman of the HSC. I will refer to it as the Petrie Report. Copies of the report were made available to the public from 29 September 1988 in accordance with my wishes and a Preliminary Hearing for the Inquiry was fixed for 11 November 1988. At the same time I also decided that copies of the report of the DEN into the accident which had occurred on Piper Alpha on 24 March 1984 should be made available to persons with an interest in it.

2.8 I wish to record my admiration for the amount of work which Mr Petrie's investigation was able to achieve within 2 months of the disaster. I am sure that the Petrie Report was of considerable assistance both to the public and to potential parties in obtaining an understanding of the technical background to the events. So far as the Inquiry is concerned, it formed part of the evidence. However the Inquiry proceeded on the basis that the fact that a matter was dealt with in the report did not exclude the hearing of evidence in regard to it or exclude the challenging of any findings which Mr Petrie had reached.

2.9 Mr Petrie submitted a Final Report dated 20 December 1988. This report dealt with a number of additional matters which had been left over for further consideration and was treated by me in the same way as the Interim Report.

2.10 In due course the DEN issued guidance to operators in a number of forms. These were drawn to the attention of the Inquiry in the course of Part 2. I have taken them all into account and will discuss them in this Report to the extent that seems to me to be appropriate.

2.11 By the time when the Inquiry opened on 19 January 1989 3 Assessors had been appointed to assist me under Reg 3 of the Public Inquiries Regulations. They were:-

- (i) Professor Frank Lees, Professor of Plant Engineering, Loughborough University of Technology;
- (ii) Mr G Malcolm Ford, CBE, formerly the Managing Director of Britoil plc; and
- (iii) Mr Brian Appleton, then Group Director, ICI Chemicals and Polymers Ltd.

To each of them I owe a great debt of gratitude for their knowledge, perception and selfless dedication. At every stage in the long task which this Inquiry has involved I have made great demands of them which they have more than fulfilled. However, for this report and any defects which it may have I bear the sole responsibility.

2.12 I appointed Messrs Cremer and Warner, Consulting Engineers and Scientists, to assist the Inquiry in the obtaining and preparation of technical evidence. Their work included: (i) the technical investigation of the ERQ and the AAW; (ii) assistance in the recovery of documents from the ERQ and the parties; the establishment of the technical library; and the identification and distribution of core documents; (iii) the supervision of a hazard and operability study of the operation of plant on Piper; (iv) technical support to the Crown Office and Counsel to the Inquiry; (v) the briefing and supervision of expert witnesses; and (vi) technical liaison with the parties and various regulatory bodies. Their work proved to be of great assistance in opening up and carrying through lines of investigation.

2.13 For the assistance of the Inquiry in the presentation of evidence the Solicitor-General for Scotland (Mr A F Rodger QC), Mr T C Dawson QC, Advocate-depute, Mr A P Campbell and Miss M Caldwell acted as Counsel to the Inquiry. Mr A D Vannet of the Crown Office acted as Solicitor to the Inquiry. I wish to express my thanks for the way in which they discharged their duties and assisted the Inquiry.

2.14 The administrative work in connection with the Inquiry was carried out by a Secretariat from the Scottish Office. I have had considerable support and assistance

from every member of that team. They have helped most willingly. I must make particular mention of Cathie Forbes who headed the team. Her unique blend of efficiency and charm helped immeasurably in the smooth running of the Inquiry. I am also most grateful to Betty Charles, my personal secretary, who uncomplainingly carried the heavy burden of typing the entire text of this report and the many preliminary drafts and revisions. In the task of marshalling information which became available to me through the evidence I was assisted by Mr Ralph Pride, BSc CChem FRSC. For that I am most grateful. Finally I should pay tribute to the skill and helpfulness of the team of shorthand-writers from the Palantype Reporting Service.

The Inquiry

2.15 This Inquiry was the first which took place under the Public Inquiries Regulations. In considering the scope of the Inquiry I treated the “accident” as comprehending all that involved loss of or danger to life from the stage of the initial ignition to the stage when the last survivor reached help. The Inquiry was plainly intended to be a wide-ranging one. On the other hand, I took the view, which I expressed at the outset, that my remit did not entitle me to embark on a roving excursion into every aspect of safety at work in the North Sea or into every grievance, however sincere or well-founded, that was entertained. Accordingly in considering whether a particular line of evidence should be explored, whoever raised it, the question which I posed for myself was whether there was any tenable connection between that line of evidence and the events that occurred. In the light of the terms of my remit I decided that it was appropriate to divide the Inquiry into 2 parts.

Part 1

2.16 This part of the Inquiry, which opened on 19 January 1989 and closed on 1 November 1989 was concerned with how and why the disaster happened. Accordingly it examined the physical conditions, events and human conduct which contributed to the occurrence of (a) the initial and later explosions and fires; and (b) the loss of or danger to life; along with the actions taken by those who were concerned with dealing with the emergency. While the holding of an inquiry under the Fatal Accidents and Sudden Deaths Inquiry (Scotland) Act 1976 is a matter for decision by the Lord Advocate I have endeavoured to conduct the Inquiry in such a way as to make any additional inquiry under that Act unnecessary. (See Sec 6(5) of the Mineral Workings (Offshore Installations) Act 1971 (MWA)).

2.17 It was obvious from the outset that the detailed investigation of what happened on the installation itself would be made extremely difficult by the fact that it was impossible to examine most of it and by the fact that so many of those who had been on the installation, and in particular had been at work there, had died in the disaster. Messrs Cremer and Warner identified for the Inquiry’s consideration a large number of possible scenarios for the initial explosion in addition to those which had been mentioned by Mr Petrie in his 2 reports. In order to find out whether and to what extent the range of possible causes should be narrowed down it was necessary, in addition to examining such evidence as survivors were able to give as to the events at or shortly before the time of the disaster, to look into conditions which had obtained on the installation during the preceding days, and to consider expert evidence as to the physical effects of given actions and process conditions.

2.18 From an early stage in this part of the Inquiry it became clear that there were a number of features in the physical arrangements on and the management of Piper Alpha which were such as to render it vulnerable to dangerous incidents, whether or not they contributed to the disaster. This led to a range of additional topics coming under consideration including permit to work procedure and practice, active fire protection and preparation for emergencies. This led the Inquiry to investigate how these deficiencies could have failed to be corrected by Occidental’s management of safety or detected by the regular inspections and surveys which were carried out by regulatory bodies.

2.19 In this part the Inquiry heard 58 of the 61 survivors give evidence. Each of them was given the opportunity of making any comment which he wished to make as to how the means of securing safety could be improved. The written statements of the remaining 3 survivors who for various reasons were unable to give evidence were read to the Inquiry. The Inquiry also heard the evidence of 38 witnesses as to the response both offshore and onshore to the emergency created by the disaster, the recovery and examination of the deceased and certain investigations by the police; 5 eye-witnesses as to what they saw and photographed; 8 witnesses who were present on other installations with which Piper Alpha was connected; 32 present and former employees of Occidental on a variety of technical and management matters; 14 present and former employees of other companies; 35 witnesses who gave evidence as independent experts or provided independent technical evidence; and 6 witnesses who gave evidence on behalf of regulatory and other bodies.

2.20 At an early stage in this part of the Inquiry and prior to the toppling of the jacket I heard evidence as to the feasibility and practical implications of operations to recover debris from the seabed. My sole concern with this matter was the possibility of recovery of evidence which would assist in the investigation of the disaster. I do not recommend that such recovery be attempted: and none of the parties invited me to make such a recommendation. I have been able to come to conclusions as to the causes of the disaster in the light of the evidence put before me at the Inquiry. In any event the practicability of recovery by any one given method is uncertain. The exercise would be fraught with danger to divers who took part in it. Even if parts of the debris which were of interest were still undamaged at the time when the operations were begun, they would be likely to be damaged in the course of them.

Part 2

2.21 This part of the Inquiry which opened on 2 November 1989 and closed on 15 February 1990. It was concerned essentially with the part of my remit which empowered me to make observations and recommendations with a view to the preservation of life and the avoidance of similar accidents in the future.

2.22 Prior to the opening of Part 1 I announced that the Inquiry would in due course be considering the following subjects with a view to possible recommendations. At that stage I felt able to anticipate that these would require to be examined in due course in the light of evidence in Part 1. The subjects were (i) the location and protection of accommodation; (ii) the means of mitigating the effects of explosion; (iii) the means of ensuring the integrity of emergency systems; and (iv) the means of ensuring safe and full evacuation. Parties were given the opportunity to propose further subjects for my consideration. As the evidence in Part 1 unfolded I added the following additional subjects: (v) permits to work; (vi) the control of the process; (vii) risk assessment; and (viii) the offshore safety regime. Each of those subjects was selected on the basis of its connection with what was learnt in Part 1 of the Inquiry.

2.23 In this part the Inquiry heard 33 witnesses who were employed by various operators in the United Kingdom Continental Shelf (UKCS) and the Norwegian Continental Shelf (NCS) or their associated companies; 3 witnesses from operators and technical associations; 4 witnesses from trade unions; 4 independent experts; 13 witnesses from regulatory and other bodies; and 7 witnesses in regard to permit to work (PTW) procedure; and emergency equipment, training and response.

2.24 The conduct of this part of the Inquiry was assisted by the fact that the United Kingdom Offshore Operators Association Ltd (UKOOA) represented the interest of its 36 members as well as of the Association itself. UKOOA offered to assist the Inquiry with evidence on a wide range of subjects and in most instances this invitation was taken up. The witnesses led by UKOOA included 30 of the total of 33 mentioned in the last paragraph. In each instance the written statement of the witness had the prior approval of a committee of UKOOA.

2.25 The witnesses mentioned in para 2.23 include the Director of the Safety and Working Environment Division, Norwegian Petroleum Directorate (NPD) and 3 witnesses from Statoil, which is wholly owned by the Norwegian State. I would like to record my gratitude of the help which was so readily and fully given by these witnesses and their organisations.

Costs and expenses

2.26 In terms of Reg 9(2) of the Public Inquiries Regulations it is provided that:-

“The court may direct that the costs of an inquiry shall be paid in whole or in part by any person who in the opinion of the court, by reason of any act or default on his part or on the part of any agent or servant of his, caused or contributed to the casualty or other accident the subject of the inquiry”.

2.27 On 1 November 1989 I heard a motion made on behalf of the Trade Union Group for a direction under this provision that the expenses of the Group so far as properly attributable to its participation in Part 1 of the Inquiry should be paid by Occidental. On 9 November 1989 I rejected this application as incompetent in respect that it did not relate to “the costs of an inquiry”. My reasons are set out in para A.10 of Appendix A to this Report.

2.28 As regards a possible direction under Reg 9(2) in regard to the proper “costs of an inquiry”, it was clear at the conclusion of the Inquiry that until my findings as to causation and contribution were known it was not practicable for such a direction to be discussed. However it was and is my view that my findings should be communicated in the first instance to the Secretary of State - as I do in this Report. It should therefore be understood that I have specifically reserved the exercise by me of any power which I have to make a direction under Reg 9(2). It is my intention that, following the publication of this Report, I should give parties having an interest in the making, or who may be affected by the making, of such a direction the opportunity of addressing me.

2.29 At the conclusion of the Inquiry Counsel for the Trade Union Group invited me to make a recommendation to the Secretary of State on an extra-statutory basis that payment of the costs incurred by MSF and T & GWU should be made out of central funds. For the reasons set out in para A.11 of Appendix A to this Report I recommend that these trade unions should receive a contribution towards their costs; and that 40% would be an appropriate proportion, the costs being taxed, failing agreement, by the Auditor of the Court of Session.

Procedure

2.30 Details as to procedure in connection with the Inquiry are set out in Appendix A.

Visits

2.31 In connection with our duties I and the Assessors on separate occasions visited the Claymore installation and the *Tharos*. My visit to the *Tharos* (on 1 September 1988) included a brief period in A Module of Piper Alpha. We together saw the ERQ at Occidental's terminal at Flotta; and the *Silver Pit*. The Assessors also visited the Gullfaks A installation operated by Statoil in the NCS.

The results of the Inquiry

2.32 Before arriving at a recommendation I have endeavoured to ensure (i) that it is needed in the interests of safety; (ii) that it is reasonably practicable to implement it; and (iii) that there is an adequate basis for it in the evidence at the Inquiry. I have taken account of evidence as to the actions taken by the industry and the regulatory

body in response to the disaster and the information which has come to light as a result of it. I have taken note also of the comments made by survivors and others on matters of safety in the light of events at the time of the disaster.

2.33 Finally I wish to record my appreciation and thanks for the immense amount of work put in by so many organisations and individuals to provide the Inquiry with evidence. That evidence was of a consistently high quality. While the conclusions and recommendations set out are my own I am conscious of how much is owed to that hard work. I trust that the impact of the Inquiry's recommendations does justice to the opportunity which the Inquiry has provided to point out a new and improved course in offshore safety.

Chapter 3

Piper Alpha

3.1 A description of the Piper platform, its context and its development, was given by Mr K R Wottge, Facilities Engineering Manager. Mr Wottge had been with Occidental at Aberdeen for 12 years. He had been involved with Piper for a long time and knew it well.

Development of the Piper field

3.2 The Piper oil platform was owned by a consortium consisting of Occidental Petroleum (Caledonia) Ltd, who had a 36.5% interest, Texaco Britain Ltd with 23.5%, International Thomson PLC with 20%, and Texas Petroleum Ltd with 20%. In the fourth offshore licensing round in March 1972 the Occidental Group was awarded 2 blocks, Blocks 14/19 and 15/17. Oil was discovered in the Piper field in Block 15/17 in January 1973. The reservoir covered an area about 12 square miles. It was named the Piper Field and was exploited by the Piper Alpha platform. The location of the Piper field in relation to the other oil and gas fields in the northern North Sea is shown in Plates 1 and 2. Fig 3.1 shows the Piper Alpha platform and the associated platforms and the Flotta terminal.

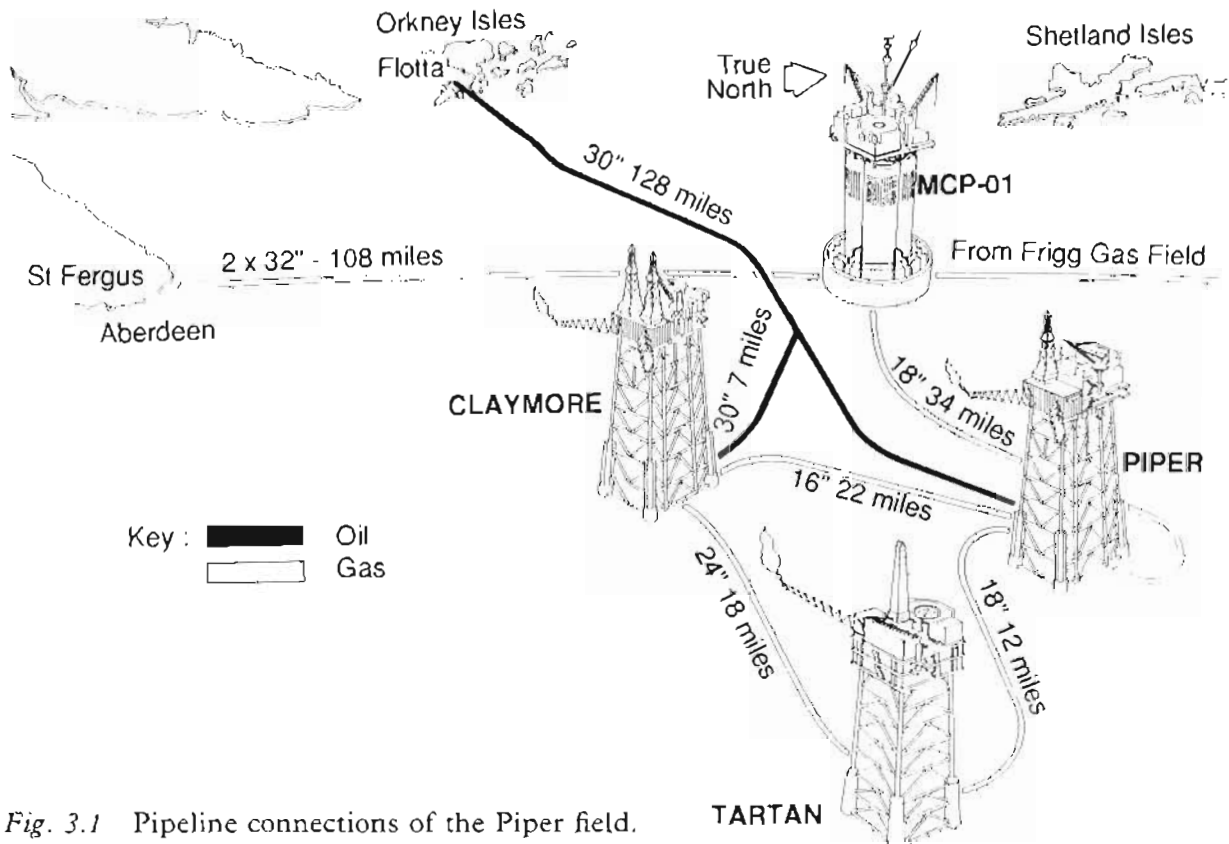


Fig. 3.1 Pipeline connections of the Piper field.

The Piper Alpha platform

3.3 The platform was located 110 miles north-east of Aberdeen, at latitude 58° 28' 01" north, longitude 00° 15' 36" east. The orientation of the platform was at 43 degrees to true north, or 317 degrees true bearing. In accordance with normal practice in the North Sea and with that of Occidental, directions are described hereafter in terms of platform north, rather than true north. The platform provided the facilities to drill wells to the producing reservoir and extract, separate and process the reservoir fluids, a mixture of oil, gas and water. Gas and water were separated from the oil in

production separators. Gas condensate liquid was separated from the gas by cooling and was then reinjected into the oil to be transported with it to shore and there separated out again. The design throughput of the platform was 250,000 bbl/d of oil.

3.4 The platform started production in late 1976. Initially only the oil was exported to the shore, by a pipeline to the oil terminal at Flotta; the gas was flared. This situation lasted until 1978, when to conform with the Government's gas conservation policy gas surplus to platform requirements was purified and pumped to the MCP-01 gas compression platform and mingled with Frigg gas pumped to the British Gas collecting plant at St Fergus.

3.5 The layout of the platform topsides is described in more detail below. Briefly, the production deck at 84 ft above mean sea level consisted of 4 production modules, A-D Modules. A Module contained the wellheads, B Module the production separators, C Module the gas compression plant, and D Module the electrical plant and various facilities. Above these modules on the 107 ft level were a number of other modules and above these living quarters. There was a helideck on top of the main quarters module. Below the production deck at the 68 ft level was the deck support frame (DSF) which held the condensate injection pumps and the pipeline terminations and pig traps, except for that of the main oil line (MOL), which was in B Module. Below this were 2 further levels, the 45 ft and 20 ft levels. Other features were the drilling rig above A Module, the 2 flare booms at the south-east and south-west corners at the end of A Module, and the cranes, one on the east and one on the west side between B and C Modules.

Platform as of 1988

3.6 The general aspect of the Piper platform in the first half of 1988 may be seen from some of the photographs, models and drawings made available to the Inquiry. These are Figs 3.2, 3.3, J.1 and J.2, which show elevations of the platform; Plates 3-5, which give views of the platform; Figs J.3-J.7, which give plans of the decks, modules and accommodation; and Model B, a 1:33 scale model of the production deck and deck support frame, modules from which are shown in Plates 6-9.

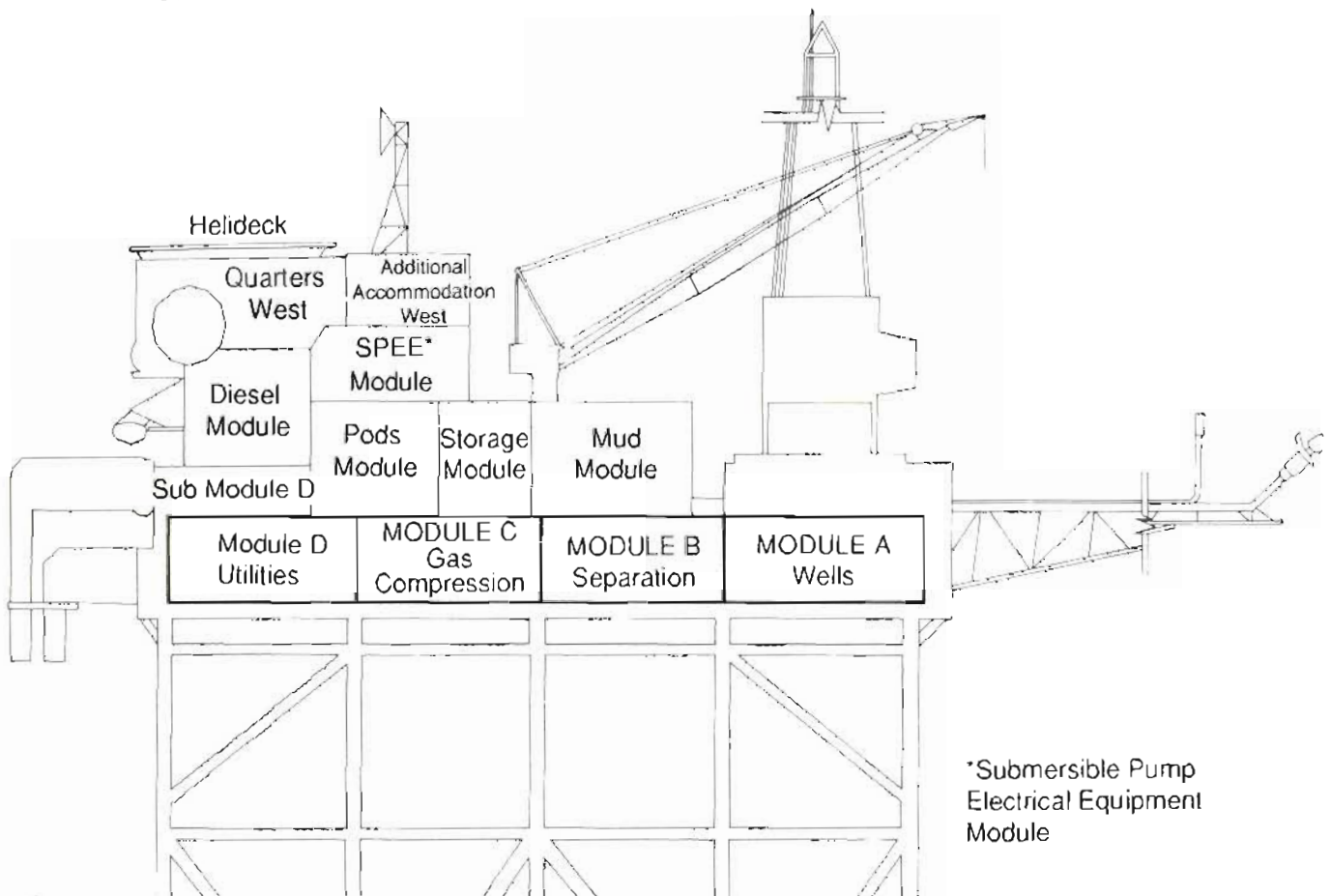


Fig. 3.2 The Piper Alpha platform: west elevation (simplified).

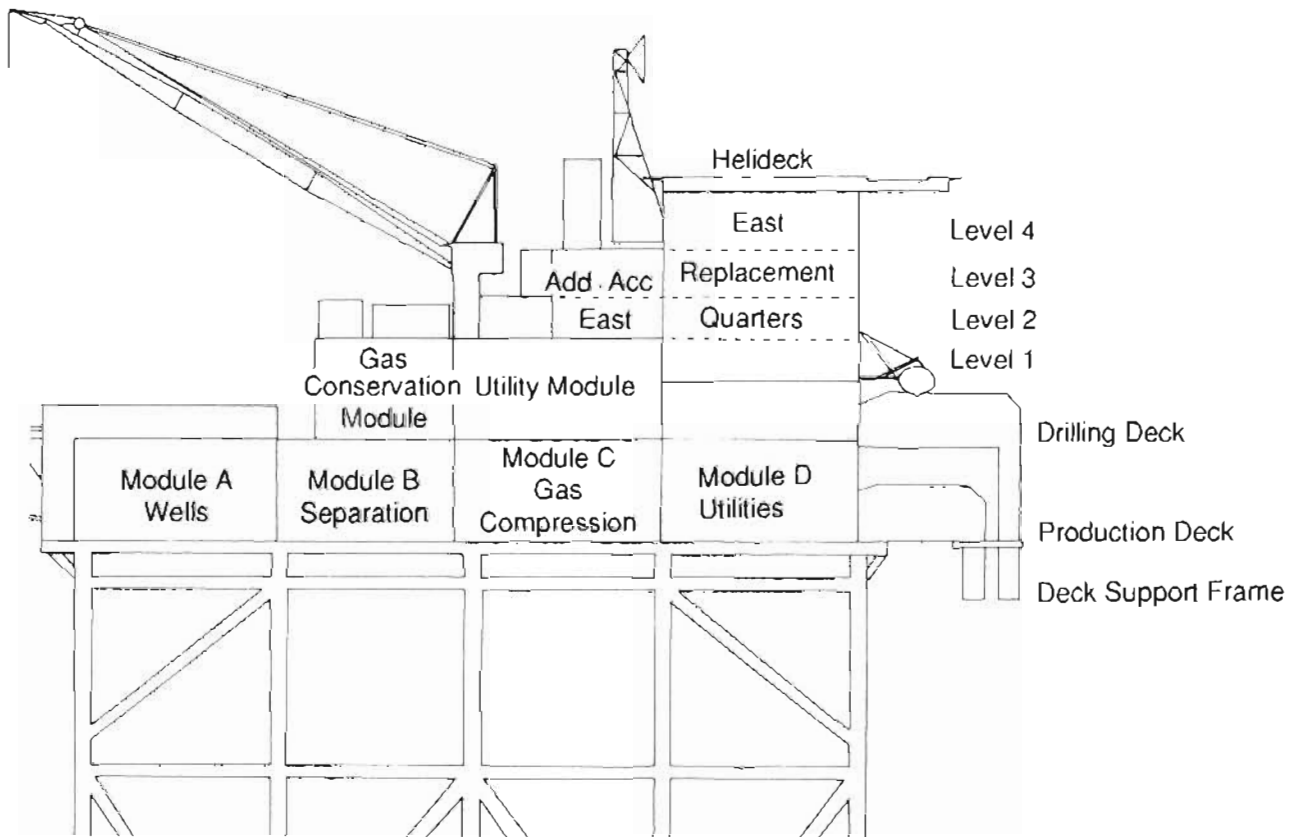


Fig. 3.3 The Piper Alpha platform: east elevation (simplified).

Operating modes

3.7 To enable Piper Alpha gas to be brought up to export requirements in 1978, first a gas dehydration unit and then a Joule-Thomson (JT) expansion valve were installed. In 1980 improved facilities for drying and expansion of the gas and a distillation column to remove methane gas from the condensate were installed. The dehydration unit was removed in 1983. The new Gas Conservation Module (GCM) occupied the space available after the second drilling derrick and support facilities were removed from the platform. The operation with the GCM in use was known as the phase 2 mode to differentiate it from the original phase 1 mode before gas treatment facilities were installed. Phase 2 was the normal mode of operation and the platform operated only in this mode from December 1980 to July 1988 with the exception of a period from April to June 1984, when it ran in the phase 1 mode, and of the period of a few days leading up to the disaster.

Jacket

3.8 The jacket was a steel structure standing in a water depth of 474 ft. On top of the jacket sat the deck support frame, the 68 ft level. Above the waterline there were 5 legs on each side of the platform. The east side was designated the A side and the west side the B side and the legs were numbered from south to north, those on the east side being therefore A1, A2, A3, A4, A5 and those on the west side B1, B2, B3, B4 and B5. The jacket was protected against corrosion by a cathodic protection system.

Topsides layout

84 ft level (production deck)

3.9 The production deck of the platform was on the 84 ft level and consisted of 4 modules, A-D Modules, all of approximately the same floor area.

A Module

3.10 A Module, the wellhead module, was located at the south end of the platform. The module was about 150 ft long east to west, 50 ft wide north to south and 24 ft high. Its floor was on the 84 ft level and its roof at the 107 ft level. This module contained the wellheads, or “Christmas trees”, of which there were 36, arranged in 3 rows of 12 each.

B Module

3.11 The next module going northwards was B Module, the production module. This module contained the 2 main production separators, large vessels in which the gas and water were separated from the oil, together with a smaller test separator. At the west end of the module were the main oil line (MOL) pumps.

C Module

3.12 Continuing northwards, the next module was C Module, the gas compression module. At the east end of C Module were 3 centrifugal compressors, each in a separate enclosure with its turbine. In the centre of the module were 2 reciprocating compressors. Between these 2 sets of compressors was the centrifugal compressor gas skid, containing separator vessels and heat exchangers.

D Module

3.13 D Module at the north end of the platform was essentially the power generation module. At the east end of D Module were the main electrical, or John Brown (JB), generators, with their exhausts projecting out of the north side of the platform. Between the generators and the wall between C and D Modules were the fire pumps. In the centre of the module was Electrical Room No 2, containing switchgear, and at the east end the Mechanical Workshop, the Instrument Workshop, the HVAC room, and the emergency generator and the Emergency Electrical Room.

3.14 In addition to D Module proper, there were 2 other associated modules: the D Module mezzanine level and Submodule D. The former was located in the upper part of D Module and the latter on top of D Module. D Module mezzanine level was limited to the west side. At its east end, and therefore located approximately half way between the east and west faces, was Electrical Room No 1. Next came the Control Room. At the west end were the Electrical Workshop and the Safety Office.

107 ft level

3.15 At the next level up, the 107 ft level, there were a further set of modules. On the west side, starting above B Module and running south to north, were the Mud Module, the Storage Module, the Pods Module and Submodule D, above D Module. On the east side, starting also at B Module and running south to north, were the Gas Conservation Module, or GCM, and the Utility Module, which contained utilities for the GCM, primarily electrical switchgear. Reverting to the west side, there were 2 other modules, the SPEE Module (or SPEEM) above the Pods Module and the Diesel Module above Submodule D. The SPEEM was the submersible pump electrical equipment module and the Pods Module another storage module. The Diesel Module, or Diesel Generator Module, contained the diesel-driven electrical generator for the drilling operations.

133 ft level (drill deck and pipe deck)

3.16 The drilling derrick stood above A Module and could track across the width of the platform. The pipe deck also stretched across the full width of the platform, and from the drilling derrick to the accommodation modules. There was a crane on each

side of the platform, at the join of B and C Modules. The pedestal of each crane was outside the face of the modules.

68 ft level (deck support frame)

3.17 The next level down from the production deck, or 84 ft level, was the 68 ft level, or deck support frame (DSF). At the centre of the 68 ft level were the riser terminations and pig traps for the Tartan and MCP-01 gas pipelines, under B Module, and the condensate injection pumps and the JT flash drum, under C Module. At the south end, under A Module, was the flare knockout drum and at the north end, under D Module, the Claymore gas riser termination and pig trap. On the west side at the centre there was the dive complex and in the corresponding position on the east side the produced water facilities.

Diving area

3.18 The dive complex at the 68 ft level consisted on the outboard side of the Dive Machinery Room, a switchgear room and a wet suit storage, and on the inboard side the Dive Workshop and Dive Offices and also a photographic laboratory, with to the south 2 decompression chambers. Below and inboard of the dive complex was the dive stage platform from which the divers descended into the water. Also at the platform was the divers' hut, or Wendy House. Since at this point there was no 68 ft level above, the hut was suspended from the 84 ft level. Intermediate between the dive complex and the dive stage platform both in plan position and level, suspended from the 68 ft level and entered from that level by a hatch, was the Dive Control Station, or gondola, from which the diving operations were controlled.

20 ft level

3.19 The lowest level on the platform was the 20 ft level. There was also a stage platform at the 45 ft level. Because of the proximity to the sea, access to levels below the 68 ft level such as the 20 ft and 45 ft levels was restricted to persons required to work there, on activities such as construction, maintenance and anode replacement.

Control Room and Radio Room

3.20 The Control Room was in D Module mezzanine level with its roof at the 107 ft level. The Radio Room was on the east side mounted on the Additional Accommodation East and with a view of the helideck.

Accommodation modules

3.21 The main quarters module, the East Replacement Quarters (ERQ), had 4 levels, Levels 1-4, denoted Decks A-D, respectively, and was the only accommodation at the bottom level, Level 1. At Level 2 there was in addition the bottom deck of the Additional Accommodation East (AAE). At Level 3 there were the top deck of the AAE and the bottom decks of 2 additional quarters modules, the Living Quarters West (LQW) and the Additional Accommodation West (AAW). At Level 4 there were the top decks of the LQW and AAW. The floor of A deck of the ERQ was at the 121 ft level and that of C Deck at the 147 ft level. A stairwell gave access to all 4 decks of the ERQ. Most of the module was bedrooms, either for 2 or for 4 men, with their own washing and toilet facilities.

3.22 A Deck consisted of the gymnasium, a changing room and bedrooms. Also in A Deck were the OIM's office, the general office and the production office. B Deck consisted of a changing room and bedrooms. It connected with the bottom deck of the AAE, which contained the laundry, the drilling offices, for Occidental and Bawden, and the construction offices, for the construction supervisor and the Offshore Projects Group (OPG), together with several other offices, were also on this deck.

3.23 C Deck contained the lounge, a changing room and bedrooms and also a switchgear room. It connected with the lower decks of the LQW and the AAE, the latter containing the recreation area, the TV lounge and the cinema. D Deck contained the dining-room and the kitchen, the store room and the plant room, for the heating, ventilation and air conditioning (HVAC) system; the kitchen and, apparently, the dining area too, was also referred to as the "galley". The reception area was also on this deck between the doorway to the LQW and the stairwell.

3.24 On the east face the ERQ had doors but no windows and on the north face windows but no doors. On Decks A-C the doors led out from the changing rooms and on D Deck from the dining-room. External stairways on the east face of the module led down from these exits to the 107 ft and 84 ft levels.

Emergency command centre

3.25 The reception area on D Deck of the ERQ was designated as an emergency command centre. It was from here that the Emergency Evacuation Controller would direct mustering and prepare and organise any evacuation required.

Offices, workshops, tea huts, etc

3.26 There were a number of offices, workshops, tea huts, etc, dispersed about the platform which figure in the accounts of the disaster and which therefore need to be mentioned. The constructors' tea hut and the drillers', or Bawden, tea hut were on the 147 ft level at the west wall of the AAE. The drill store, or White House, and the OPG Workshop, or fabrication shop, were at the south face of the LQW; they were on the 133 ft level, that of the pipe deck on to which they gave. The divers' hut, or Wendy House, was at the dive stage platform.

Helideck

3.27 The main helideck was on the roof of the ERQ at the 174 ft level. At the same level there was a second helideck on the roof of the LQW. There was access from the ERQ to the main helideck by 2 external stairways. One ran from a door at the reception area at the south-west corner of the ERQ and the other from a door in the dining area on the east face.

Risers

3.28 Piper was connected to other platforms and to shore by 4 pipelines, 1 oil and 3 gas (see paras 3.94-98). The risers of the MOL and the gas pipelines from Tartan and to Claymore came up the north face; that of the gas pipeline to MCP-01 up the east face. The MOL terminated in B Module and the 3 gas lines on the 68 ft level. The MOL came southwards just beneath the DSF at a level of 64 ft before rising into B Module.

Flare booms and heat shield

3.29 There were 2 flare booms, running out from A Module at the south-east and south-west corners of the platform. The provision of 2 flare booms allowed the flare used to be altered to suit the wind direction. The flare boom carried the high pressure (HP) flare, the low pressure (LP) flare and the atmospheric, or zero, vent. The HP flare was the main flare which took gas vented from high pressure sources. The LP flare burned gas from low pressure sources such as the deoxygenation towers. The zero vent, which was not continuous and had no flare, allowed intermittent venting of small volumes of gas at virtually atmospheric pressure. On the south face and round the east and west sides of A Module there was a heat shield, which consisted of 2 close mesh layers of wire and was intended to deflect radiant heat coming from the flare.

Production process

3.30 The flow diagram of the process operating in phase 1 mode is shown in Fig J.8 and a further diagram of the back end of the process in Fig 3.4.

Oil

3.31 The reservoir fluid from the production wells, a mixture of oil, gas and water, passed to the production separators operating at a pressure of 155 psia, where it was separated by gravity into the 3 phases. Oil from the 2 main separators was pumped by 2 booster pumps through metering equipment to the suction header of the MOL pumps, which then pumped it down the oil export pipeline to the Flotta terminal. Oil from the test separator was pumped by an oil transfer pump back to the 2 main separators.

Gas

3.32 The gas from the separators passed to the condensate knockout drum and into the 3 centrifugal compressors, where it was compressed to a pressure of 675 psia. It was then boosted to 1465 psia by the first stage of the 2 reciprocating compressors.

3.33 In phase 2 mode, the gas went next to the GCM, where it was passed through the molecular sieve driers. It was then cooled by reducing the pressure to about 635 psia across a turbo-expander and returned to the phase 1 plant at the outlet of the JT flash drum. Condensate formed in the GCM passed to a distillation column, the demethaniser, from which methane was taken off, and the stripped condensate taken back to the JT flash drum. In phase 1 mode the plant in the GCM was isolated and the gas from the first stage reciprocating compressor system was let down in pressure across the JT valve, PCV 721, into the JT flash drum. From the outlet of the JT flash drum the gas passed to the inlet of the second stage of the 2 reciprocating compressors, where it was compressed to 1735 psia. The high pressure gas from the second stage reciprocating compressors went 3 ways: to serve as lift gas or to MCP-01 as export gas or to flare.

Condensate

3.34 Condensate was knocked out of the gas at a number of points in the system and taken to the JT flash drum. This vessel served as a surge drum for the condensate pumps. Condensate was taken from the JT flash drum by 2 condensate booster pumps, which raised the pressure to 670 psia, and thence to the 2 condensate injection pumps, which raised it to 1100 psia. The condensate then passed through a meter into the MOL.

Produced water

3.35 The water from the production separators, known as the produced water, passed to the plate skimmer for further separation of oil and thence to the hydrocyclone, which separated out any remaining free oil; these units were both on the east side of the 68 ft level. The clean water then passed to the overboard dump.

Process plant

3.36 The process flow diagram, Fig J.8, shows the main items of equipment. Further details on the following items are given in Appendix F: centrifugal compressors (paras F.2-9); reciprocating compressors (paras F.10-14); JT flash drum and other condensate collecting vessels (paras F.15-18); condensate injection pumps (paras F.19-34);

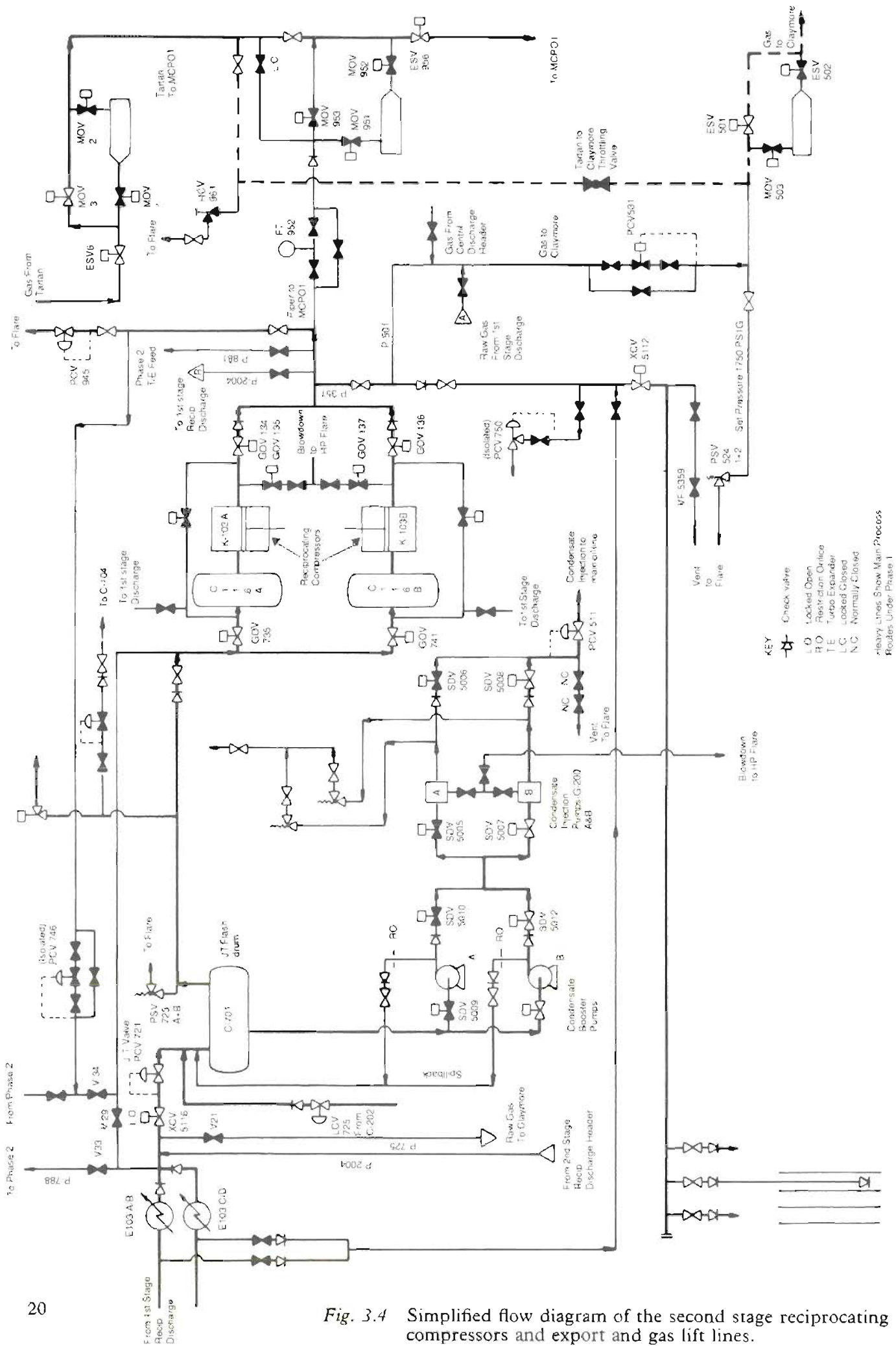


Fig. 3.4 Simplified flow diagram of the second stage reciprocating compressors and export and gas lift lines.

methanol injection system (para F.35); gas flaring and pressure relief (para F.36); and the Control Room (para F.37).

Wellheads

3.37 The line carrying oil from an individual well terminated in a Christmas tree. It passed first through a hydraulic master valve (HMV), which allowed the flow from the well to be shut off in an emergency, then into a manifold. The oil was taken off from this through pneumatic wing valves. The flow through a wing valve was adjusted by a choke valve and the oil then passed through a check valve, or non-return valve (NRV), into a header leading to one of the separators. There was a further valve down each well, the downhole safety valve (DHSV), which provided an additional means of shutting off the flow. There was a valve, XCV 5112, on the gas lift line just before it entered the gas lift manifold which supplied the individual wells. There was a further valve on the gas lift line to each individual well.

Separators

3.38 There were 2 main production separators and a smaller test separator. The separators were large vessels in which the oil, water and gas were separated and taken off as separate streams. In the bottom of the separator there was a weir and 2 liquid offtakes. The water collected behind the weir and was run off to the produced water system. The oil, which was lighter than the water, floated on it and flowed over the weir into the oil offtake. The gas passed through a filter pad to remove droplets and then went through the gas cooler to the condensate knockout drum. There were level control loops both on the water flow and on the oil flow from the separators. The oil was pumped from the separators manifold by 4 MOL pumps.

Centrifugal compressors

3.39 There were 3 parallel centrifugal compressor trains, located at the east end of C Module (see Fig J.4 and Plate 7), which compressed the gas to 675 psia. Each compressor was driven by its own gas turbine and each compressor set was housed in an individual enclosure, the gas turbine and the compressor being in separate compartments of the enclosure with the turbines outboard. The bulkhead between the compartments was designed to prevent any leak of flammable gas from the compressor entering the turbine compartment.

Reciprocating compressors

3.40 There were 2 parallel trains of reciprocating compressors with first and second stage compression. The first stage compression raised the pressure of the gas from about 675 psia to 1465 psia and the second stage to 1735 psia. The reciprocating compressor trains were located in the western half of C Module (see Fig J.4 and Plate 7). The 2 stages of compression in each train were performed by a single machine. There was a recycle loop around the first stage of each compressor and another recycle loop around the second stage. There were also facilities to unload the machines to allow them to operate at low gas flows.

JT flash drum and other condensate collecting vessels

3.41 Condensate in the gas leaving the separators was knocked out in the condensate knockout drum and pumped back to the separators by 2 condensate transfer pumps. The condensate suction vessel, located at the 68 ft level and operating at a pressure of 665 psia, collected condensate from the centrifugal compressor suction scrubbers. The condensate passed to the JT flash drum, also on the 68 ft level, entering the inlet pipe just downstream of the JT valve. In phase 1 operation the gas from the first stage of the reciprocating compressors passed through the JT valve, across which pressure was let down from 1435 psia to 635 psia. The Joule Thomson (JT) effect associated

with this reduction in pressure gave a fall in temperature of the gas causing liquid condensate to form. In phase 1 operation the JT flash drum received condensate from the JT valve and from the condensate suction vessel. It acted as a surge tank supplying the condensate pumps which pumped the condensate into the MOL. The level of condensate in the drum was maintained by a level controller which controlled the speed of the condensate injection pump.

Condensate disposal

3.42 Condensate from the JT flash drum was pumped into the MOL by a pair of condensate booster pumps in series with a pair of condensate injection pumps. Both sets of pumps were on the 68 ft level. A simplified flow diagram of the condensate injection pumps is given in Fig 3.5 and details of the pumps are shown in Fig J.9. Each pump was provided with an isolation or shutdown valve, a gas-operated valve (GOV), on the inlet and another on the outlet. On the suction side there was a manual isolation valve upstream of the GOV and a pulsation dampener downstream of it. On the discharge side there was a pulsation dampener, a high pressure trip and then an NRV upstream of the GOV.

3.43 There was normally one pump operating and one on standby. There was no automatic changeover for the pumps. If the working pump tripped out or stopped, it was necessary to go to the pumps and start the standby pump manually.

3.44 The pressure safety valve on A pump was PSV 504 and that on B pump PSV 505. These valves were located on the next level up, in C Module. The relief lines to the PSVs ran up through the floor of this module. The discharge lines from the PSVs then returned to the condensate suction vessel, which was in the ceiling of the 68 ft level. PSV 504 was located in C Module at a height of 15 ft.

3.45 Condensate from the discharge header of the condensate injection pumps on the 68 ft level passed in a 4 inch diameter pipe through an orifice meter to measure the flow rate. The line then passed up into C Module, ran horizontally west for a few feet and then turned south and passed through the B/C firewall into B Module. There it travelled south a few feet, turned west, then south and then briefly east to enter the MOL just upstream of the emergency shutdown valve (ESV), ESV 208. The passage of the line, 2-P-517-4"-F15, through C and B Modules is shown in Plates 6-8.

Methanol injection

3.46 Under phase 1 (wet gas) process conditions there existed a risk of formation of hydrates, which are crystalline, ice-like solids composed of hydrocarbons and water. Hydrate slugs and blockages were undesirable and could be hazardous. In accordance with industry practice, methanol was injected at strategic points to lower the hydrate formation temperature and so eliminate hydrates. The methanol injection points are shown in Fig J.8 and the methanol injection system in use in phase 1 operations on 6 July 1988 is described in Appendix F (para F.35).

Gas flaring, venting and pressure relief

3.47 There were a number of pressure control valves, PCVs, through which gas passed, or could be passed, to flare. There were a large number of pressure safety valves, PSVs, which protected vessels and equipment against over-pressure. In almost all cases there were a pair of PSVs; the condensate injection pumps were an exception, there being only one PSV on each pump. Some of the principal PCVs and PSVs are summarised in Table 3.1.

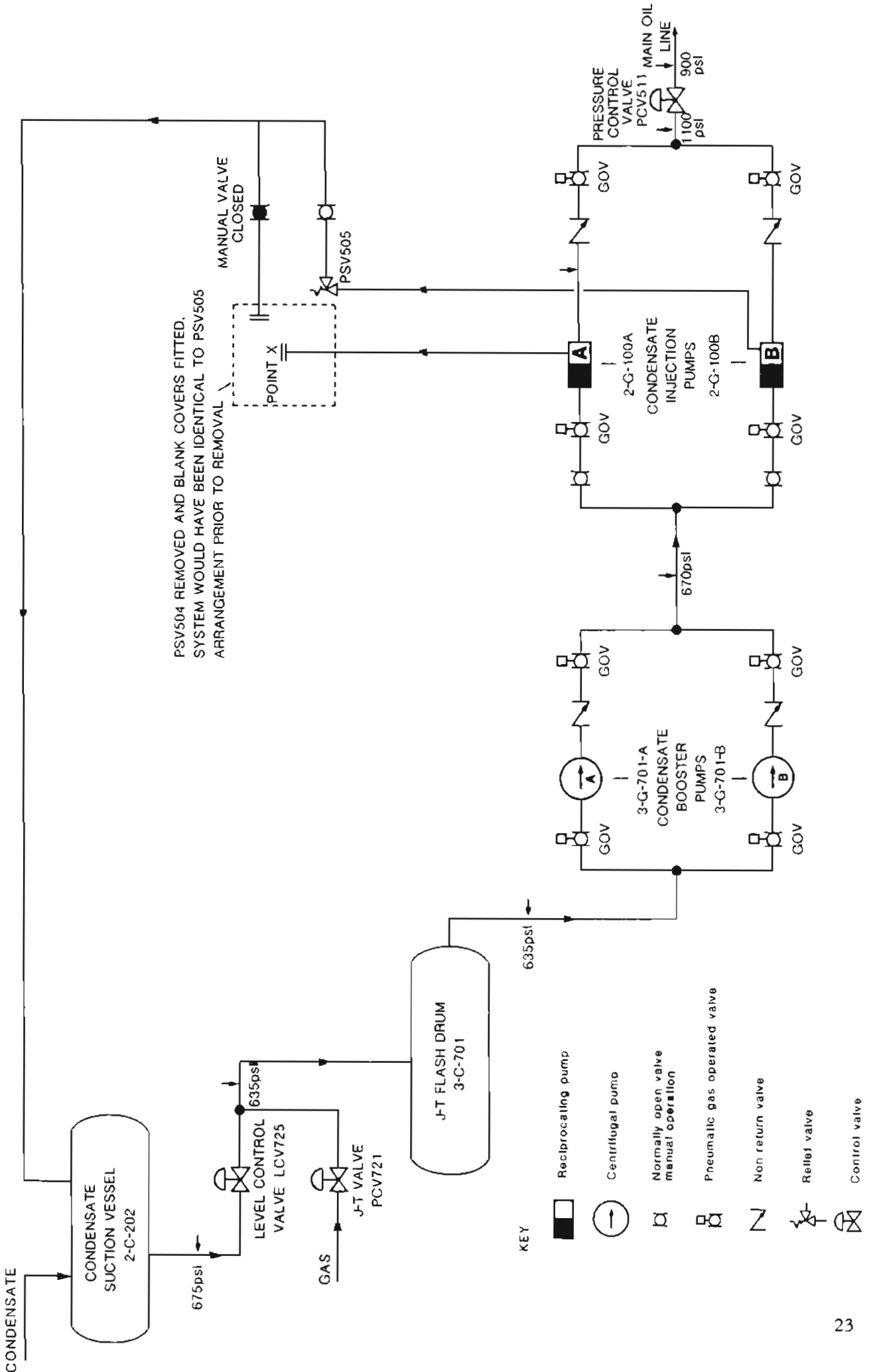


Fig. 3.5 Simplified flow diagram of the condensate injection pumps. See also Fig. J.9.

Control Room

3.48 The layout of the Control Room is given in Fig J.4(c) and some of the panels are shown in Plate 10(a). The instrumentation provided in the Control Room was oriented to monitoring rather than control. There were panel displays but few controls. The 2 principal panels were the main control panel, or mimic panel, and the main fire and gas (F&G) panel. There was also a separate alarm panel above the mimic panel.

3.49 Principal items of equipment had their own local control panels. If an alarm came up on any one of a number of instruments on the local panel, a "common alarm" would come up also in the Control Room. The Control Room operator would then radio the appropriate outside operator and ask him to investigate.

3.50 The gas detectors also were grouped in zones and an alarm on the F&G panel indicated only that one of the detectors in that particular zone had gone into alarm. However, in this case it was possible to determine which detector this was by going around the back of the panel and examining the individual gas detector modules.

3.51 If an item went into alarm, the alarm light for the particular equipment skid would be illuminated and the alarm annunciator, or buzzer, would sound; in most cases the light would also flash. The operator would then generally "accept" the alarm by pressing a button and silencing the buzzer. The alarm light would cease to flash but would stay on. In order to re-set it, it was necessary to go behind the panel. If, however, the alarm condition still existed the light would remain on.

3.52 There was also a computer VDU which showed the telemetry data, giving information on the status of the pipeline valves on the other platforms and the oil terminal.

3.53 The principal items of equipment were controlled from local control panels. For example, the centrifugal compressors and the condensate injection pumps could not be started and stopped from the Control Room but only at the local panels.

3.54 Facilities for emergency shutdown (ESD) available in the Control Room included a single button for initiation of platform ESD (PESD). On PESD the Emergency Shutdown Valve (ESV) on the main oil pipeline closed but not the ESVs on the 3 gas pipelines, that from Tartan and those to MCP-01 and Claymore. For these there were 3 further, separate buttons.

Platform systems

3.55 An account is now given of various platform systems. Further details on the following items are given in Appendix F: electrical supply system (para F.38); hazardous area classification (paras F.39-41); gas detection system (paras F.42-50); emergency shutdown system (paras F.51-63); and pipeline depressurisation facilities (para F.64).

Electrical supply system

Main generators and power supply

3.56 The main electrical supply came from 2 JB turbo-driven generators each rated at 24,000 kW and located in D Module (see Fig J.4). These generators had facilities for dual fuel firing. They were normally fired by fuel gas but could be fired by diesel. Changeover to diesel on falling fuel gas pressure was automatic.

3.57 The main generators supplied power to a 13,800V switchboard located in Electrical Room No 1 in D Module mezzanine level. Transformers located in D Module let the voltage from this switchboard down to 4,160V and 440V switchboards, located in Electrical Room No 2 in D Module, and to the drilling 600V switchboard,

located in the Diesel Module. This main 440V switchboard fed the 440V system and also an emergency 440V switchboard and a drilling 440V switchboard (see below). The 4,160V supply was used to drive motors in the 100-1000 horsepower range such as those on the water injection pumps, the MOL pumps and the condensate injection pumps. It was also the sole supply to the electrically driven utility and fire-water pumps. The 440V supply was used for smaller motors.

Drilling generators and power supply

3.58 There was a separate power supply for drilling, which also had its own emergency back-up. There was a diesel-driven generator located in the Diesel Module, with its own emergency generator in the same module. The generator supplied the drilling 600V switchboard. Most of the drilling equipment ran off 600V DC. There was also in the module the drilling 440V switchboard. This supplied power to the quarters modules. Lighting for the quarters was supplied by a 208V switchboard fed from this 440V switchboard. When the drilling generator was on, it supplied the drilling 440V switchboard, and when it was not, the supply was from the main generators.

Emergency generators and power supply

3.59 There was in addition an emergency generator, turbine-driven and diesel-fired, rated at 800 kW and generating 440V, located at the west end of D Module, north of the Instrument Workshop (see Fig J.4(b)). This generator was designed to start up automatically on failure of the main generators. The emergency generator supplied the emergency 440V switchboard. Normally this switchboard was fed from the main 440V switchboard, but on loss of the main generator there was automatic switchover to the emergency generator. The function of the emergency generator was to supply critical services. These included HVAC, instrument air and strategic valves, and also emergency lighting. In the event of failure of the emergency generator, the emergency 440V switchboard could be supplied by the drilling generator, but this required manual changeover. The emergency 440V switchboard also fed the D Module 125V DC and 120V AC supplies.

Uninterrupted power supplies and other power supplies

3.60 Back-up for the D Module 125V DC and 120V AC supplies taken off the emergency 440V switchboard was provided by battery power supplies, the uninterrupted power supplies (UPS), located in D Module mezzanine level north of the Control Room. The function of the UPS was to provide power supplies to the critical systems during the momentary interruption while the emergency generator was coming up to speed or, in the event that this generator failed to start, to maintain that supply. There were 2 further UPS in the Utility Module, a 125V DC and a 120V AC UPS. In addition certain individual items of equipment had their own battery power supplies. These included a small number of emergency lights throughout the platform.

Power supplies to quarters and for lighting

3.61 Power was supplied to the accommodation from the drilling 440V switchboard. This switchboard could also relay power from the main generators. If the drilling generator was operating, the power supply for the quarters was taken from that generator, but if it was not operating, quarters power was supplied by the main generators. Power for lighting in the accommodation came from the drilling 208V switchboard. A limited proportion of the lighting, in the quarters and on the platform generally, was designated as emergency lighting. The emergency generator provided an emergency power supply for the emergency lighting in the quarters. The 125V DC UPS provided a back-up supply for the quarters emergency lighting. The emergency power supply for other emergency lighting on the platform was in the form of local

battery packs. The 120V AC UPS provided an emergency power supply to the general alarm and personal address (GA/PA) system. The 120V AC UPS in the Utility Module was also given as a supply to the GA system.

Protective systems

Hazardous area classification

3.62 Areas in which a hydrocarbon leak might occur and from which it is necessary to exclude ignition sources were classified in accordance with international codes on hazardous area classification. The code specifically referred to was the Institute of Petroleum (IP) code.

Firewalls

3.63 The ERQ and AAW had A60 exterior firewalls. There were A60 firewalls around the fire pumps. There were firewalls between A and B Modules, between B and C Modules, and between C and D Modules (the A/B, B/C and C/D firewalls, respectively). The C/D firewall was of double layer construction. Details of the construction of the B/C and C/D firewalls are given in Chapter 5. Each of these 3 firewalls was provided with a water curtain, fed from the fire deluge ring main, to provide enhanced endurance. The extent of openings in the firewalls was shown in Fig 4.7 of the Petrie Report, which showed a spring-loaded double door in the A/B firewall on the line of the MOL pig trap and a pulley weight-closing single door in the B/C firewall on the same line, and explicitly stated that there was no opening in the C/D firewall, again on the same line. Evidence given by operatives on the possible existence of apertures in the firewall between B and C Modules is described in Appendix F (paras F.68-69). The platform did not have blast walls.

Gas detection system

3.64 The platform was provided with an F&G detection system. There were gas detectors in A-C Modules and at the 68 ft level.

3.65 In general, gas detectors were grouped in zones with several in each zone. A gas alarm on the F&G panel in the Control Room indicated therefore that one of the detectors in the zone had detected gas, but did not indicate which one. To determine this it was necessary to go behind the panel and observe the particular instrument.

3.66 The gas detection system in C Module is shown in Fig J.10. The module was divided into 5 zones, C1-C5. C1 was the west end of the module, C2 the east end and C3-C5 centrifugal compressors A-C, respectively. The gas detectors in C Module were located mainly in the roof to detect gas lighter than air, essentially methane, although there were some at lower levels.

3.67 In general, the low gas alarm level was set at 15% of the lower explosive limit (LEL) and the high gas alarm level at 75% LEL. Detection of gas at the lower alarm level resulted in an alarm in the Control Room; it did not lead to any automatic action such as activation of the fire-water deluge. The Control Room operator would, however, instruct the outside operator to investigate.

3.68 There were also gas detectors on certain individual items of equipment in safe areas such as D Module, to shut the particular equipment down on detection of gas.

Fire detection system

3.69 The fire detectors consisted of ultra-violet (UV) flame detectors and heat detectors. There were fire detectors in A, B and C Modules and at the 68 ft level. Detection of fire by a fire detector was designed to activate automatically the fire-water deluge system. It was practice, therefore, to disable the automatic action of the

fire detection system in a particular zone if activities, such as welding, were taking place in that zone which might set off a spurious fire alarm. The fire detectors themselves were not disabled thereby and would still provide fire alarm.

Fire-water deluge system

3.70 The platform was provided with a fire-water deluge system. An area designated as a deluge area was protected by a deluge set fed by a ring main. On the production deck level there was foam deluge protection in the whole of A-C Modules and in part of D Module, including the fire pumps, whilst on the 68 ft level there was foam deluge at the Tartan and MCP-01 pig traps and water deluge at the condensate injection pumps, the Claymore pig trap, and part of the produced water area. There were fire-water ring mains on the 68 ft and 84 ft levels. The only part of the deluge activated automatically was that covering the area in the module where fire had been detected. Other parts of the deluge system could be brought on manually. The deluge system did not come on automatically on PESD. The ring mains were maintained full of sea water at a pressure of 110 psi by the utility pumps.

Fire pumps

3.71 The fire-water main for the deluge system was supplied by utility pumps and fire pumps. The utility water pumps provided cooling water for items such as the gas turbines and generators and for the lube oil systems. There were 4 pumps: 1 utility pump, 2 utility/fire pumps and 1 fire-water pump. Normally the utility pump, 1-G-124A, would be running to supply utility water and one of the utility/fire pumps, 1-G-124B, to supply utility water and keep the fire main pressurised. The former supplied primarily the utility main, although it could supply the fire main through a restrictor orifice plate. The latter supplied both the utility and fire mains. All 3 utility or utility/fire pumps were electrically driven and ran off the 4,160V switchboard supplied by the main generators and would be lost if this power supply failed; there was no alternative emergency power supply for these pumps. There was, however, a separate diesel-driven fire pump, 1-G-123, available to come in on loss of electrical power. In addition, utility/fire pump 1-G-124C also had a standby diesel drive. These 2 pumps were replacement pumps, installed in 1983. In a shutdown, pump 1-G-124C could be operated on diesel to provide cooling water for the main generators. With this exception, these 2 pumps would not normally be operating. If the pressure in the fire main fell, utility/fire pump 1-G-124C would come in to maintain the pressure. If the pressure continued to fall, then at a pressure of about 100 psi the diesel-driven fire pump 1-G-123 would start up automatically. The 4 pumps were located in D Module between the main generators and C Module (see Fig J.4(b)). The fire pump 1-G-123 and the utility/fire pump 1-G-124C were in a fireproof enclosure, and the utility pump 1-G-124A and the other utility/fire pump 1-G-124B were outside this enclosure to the west.

3.72 Stilling columns for the sea-water supply to the pumps were located on the east side of the platform near leg A4 (see Fig. 3.6). The pump intakes were at a level of about -120 ft. The intakes were some 5 ft apart and were furnished with protection cages to prevent divers from getting sucked in. The stilling columns were 2 ft diameter and the cages the same diameter and about 4 ft long. The 2 diesel-driven pumps, fire pump 1-G-123 and utility/fire pump 1-G-124C, could be put on manual start to protect divers against a sudden flow of water at the pump intakes. If these 2 pumps were on manual start, this was indicated in the Control Room by an alarm light. They could then be started only by going to the pumps themselves and starting them at the local control panel in the fireproof enclosure.

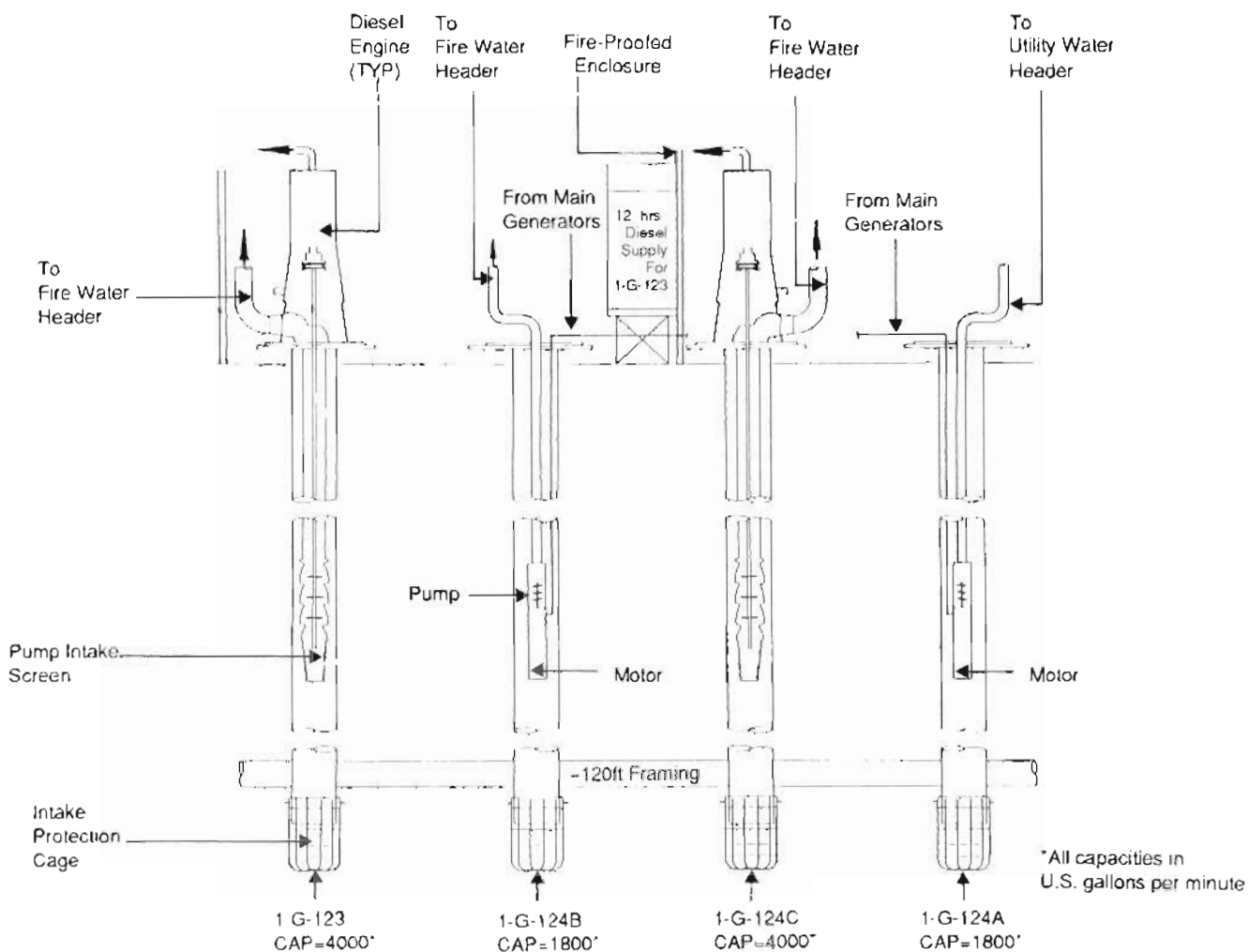


Fig. 3.6 The inlets of the fire pumps.

Foam system

3.73 In certain areas where an oil fire might occur there was automatic addition of a foam agent to the fire-water so that the fluid discharged was foam rather than water. An aqueous film forming foam system, located in Submodule D, injected foam into the fire-water header at specific deluge sets. Foam injection was by an electric pump backed up by a diesel-driven pump.

Other fire-fighting facilities

3.74 The fire-water and foam systems were supplemented by other fire-fighting systems and equipment, which included water hose reels, halon systems, twin agent units and fire extinguishers. In addition to the fire-water deluge system, there were fire-water hose reels and fire extinguishers at strategic points for local manual fire-fighting.

Emergency shutdown system

3.75 The platform was provided with an ESD system. The main ESVs are shown in Fig J.8. The main functions of the ESD system were:

- to shut down and isolate the flow from the reservoir
- to shut down and isolate the flow through the pipelines leaving and entering the platform

- to shut down all major items of process equipment
- to initiate automatic blowdown of platform inventories to flare.

Activation of PESD

3.76 A platform ESD (PESD) could be activated in a number of ways, automatic or manual. There were 2 systems, one pneumatic and one electrical, which could initiate a PESD automatically. The 2 systems had somewhat different direct effects. However, one of the effects of activation of the pneumatic system was to activate the electrical system and vice-versa. Hence the ultimate effects were the same. Pneumatic PESD was initiated by loss of pressure in a pneumatic pressure loop, maintained at 50 psi, which ran through the production modules. The loop had 58 fusible links which would melt in a fire and activate the ESD. The pneumatic loop also lost pressure if there was a loss of instrument air pressure. Electrical overall emergency shutdown (OESD), effectively PESD, was initiated by loss of power from the D Module 125V DC system. It was stated that loss of the main power supply would cause a PESD, but the mechanism by which this occurred was not clearly established.

3.77 PESD was activated automatically by a limited number of major process upsets. On the other hand shutdown of a major item of equipment did not necessarily involve a PESD. For example, high level in one separator would cause shutdown of that separator and of its associated wells, but not shutdown of the platform. As far as concerns fire, there was no mechanism other than the fusible links by which fire would activate the PESD. Neither a gas alarm nor a fire alarm would in itself initiate a PESD. Detection of gas at equipment located in a safe area activated shutdown of that equipment. This applied to the main generators and in this case the loss of main power would lead to a PESD. PESD could be activated manually from the Control Room or from manual push-buttons (break-glass time switches) at 20 locations on the platform. The procedure was that anyone aware of a possible hazard should contact the Control Room, but the purpose of having manual ESD points distributed around the platform was so that personnel could effect shutdown without having to communicate with anyone else and all operating personnel had the authority to initiate a PESD.

Pipeline shutdown

3.78 Each of the 4 pipeline ESVs could be closed by manual operation of its individual push-button in the Control Room. The MOL ESV, ESV 208, was the only one of the 4 valves which closed on PESD; those on the 3 gas pipelines did not. The 4 ESVs were fail-safe in that they closed on loss of power.

Communications systems

Personal address and general alarm system

3.79 The PA system, or tannoy, allowed persons at strategic points such as the Control Room or the Radio Room to address other personnel on all parts of the platform. It was piped into every bedroom in the accommodation and, although it was usually switched off in the bedrooms, it could be switched on from the Control Room so that personnel in their rooms could hear it. The GA system, or klaxon, also went to all parts of the platform, including the bedrooms.

Other internal communications

3.80 Piper was provided with 2 systems of telephones for internal communications. The main Mitel system had about 100 extensions throughout the platform. There was a separate manual sound-powered system for the drilling area. It was also possible to telephone the shore and the other platforms via the telecommunications links, described below. In addition, there were a number of ultra high frequency (UHF) radios.

External communications

3.81 The platform had 2 telecommunications links: a tropospheric scatter system and a direct line of sight microwave radio system. Piper was linked to the land station at Mormond Hill by a tropospheric link. There were line of sight links between Piper and Claymore, between Piper and Tartan, and between Piper and MCP-01, but these other platforms had no line of sight links with each other. The telecommunications links of Claymore and Tartan to shore were via Piper; they had no direct link. MCP-01, however, had its own tropospheric link to Mormond Hill, which therefore served as an alternative link for Piper, via the line of sight link to MCP-01. Mormond Hill was linked to Aberdeen by line of sight and there was a land line and radio link between Aberdeen and Flotta. The 2 telecommunications links carried telephone, telex, telemetry and computer traffic. The communications systems for Piper, Claymore and Tartan are illustrated in Fig 3.7. There was also a back-up INMARSAT system, which could relay by satellite a single telephone or telex channel. This was kept in a locker in the Plant Room in the AAW.

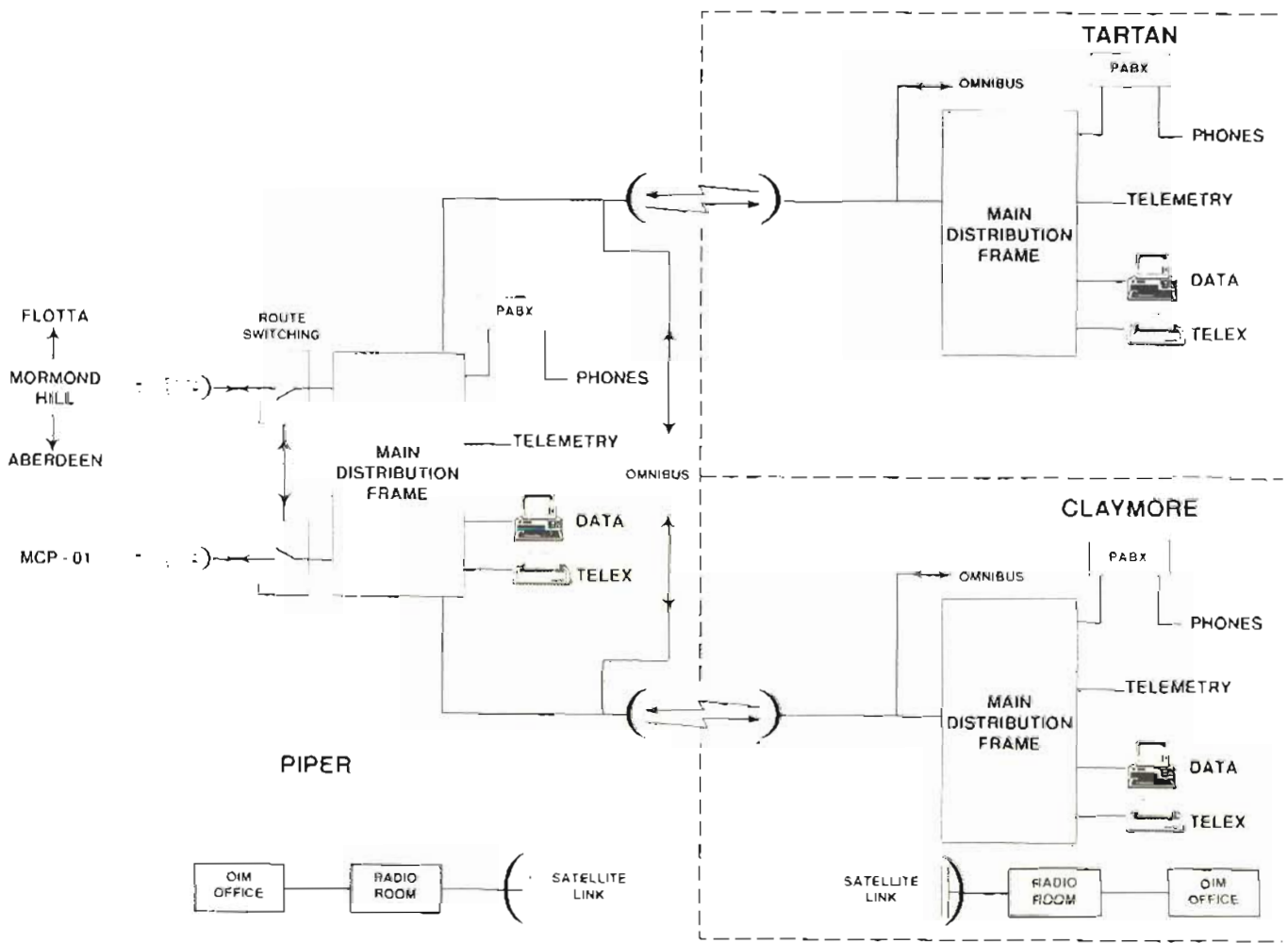


Fig. 3.7 Block diagram of the telecommunications system.

3.82 External communications could also be conducted by means of radio. There was a safety of life at sea (SOLAS) radio, the high frequency ship-to-shore (HF/SSB) radio, which operated at 2 megahertz and a very high frequency (VHF) radio for international marine, private marine and aircraft communications. There were some 50 hand held radio sets on the platform, of which 14 were the UHF sets already mentioned, and the rest VHF.

Evacuation and escape systems

Escape routes

3.83 There were escape routes on the platform with arrows painted to mark the routes and signs showing a general layout, an indication of the particular spot, and the direction of the lifeboats.

Life-saving appliances

3.84 The platform had a complement of 6 lifeboats and 13 life rafts, together with 31 life-buoys, 519 life-jackets and 12 knotted ropes. The maximum overnight capacity of the accommodation was 241 persons. There were 226 persons on board (POB) on 6 July.

Lifeboats

3.85 Lifeboats Nos 1, 2, 4 and 5 were located on the north face with lifeboats No 3 on the west face and No 6 on the east face, both towards the north end, as shown in Figs J.1 and J.2 and Plates 3-5. Lifeboat No 1 was at the 121 ft level and No 2 at the 124 ft level, lifeboat No 3 at the 107 ft level, and lifeboats Nos 4-6 at the 84 ft level. There was a seventh lifeboat ashore for maintenance at any given time. The lifeboats were totally enclosed motor propelled survival craft (TEMPSC). Each lifeboat held 47 people and was equipped with a water drench system to cool it in case it had to travel through a burning oil spill. An illustration of a lifeboat is given in Fig 3.8.

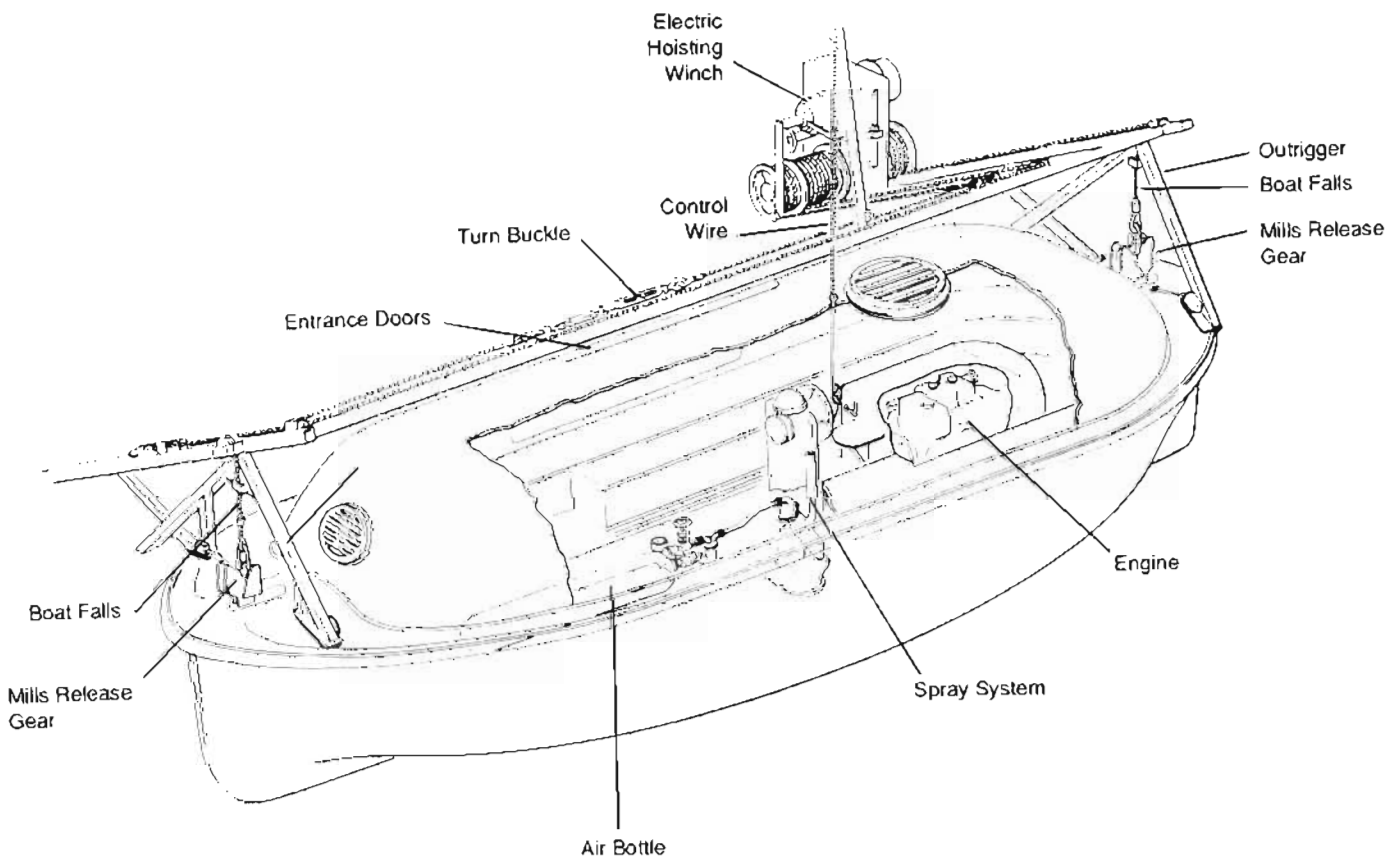


Fig. 3.8 A Piper lifeboat.

Muster points

3.86 The primary muster points were the lifeboat stations. Personnel were instructed that if a general alarm occurred, they should go to their lifeboat. There was an

additional, or secondary, muster area in the dining-room, or galley, which would be used for helicopter evacuation. Personnel were told that if it were necessary to muster in the galley they would receive instructions to this effect when they were at their lifeboats. Personnel who could not reach their lifeboats would receive instructions from the emergency command post in the reception.

Life rafts

3.87 There was a nominal complement of 13 25-man life rafts situated at the 68 ft level, but at any given time there would normally be one life raft away for servicing. The life rafts were held in glass-reinforced plastic, throw-over containers. A life raft on its launching platform is shown in Plate 12(b). Once in the water the inflation sequence was initiated by pulling a rope.

Escape to the sea

3.88 Situated next to each life raft to allow escape to the sea was a single knotted rope.

Other life-saving equipment

3.89 There were 31 life-buoys, or Perrybuoys, on the platform. There was a complement of 519 life-jackets, distributed at various points, including the accommodation, lifeboat stations and life rafts. For each man there was a life-jacket in his cabin and at his lifeboat station. Each person travelling to the platform was given a survival suit at the heliport. He retained it during his tour, keeping it in his cabin, and wore it on the return journey to shore. There were no additional survival suits located at strategic points such as the lifeboat stations. There were 2 types of breathing apparatus provided. There were 26 Draeger working breathing apparatus (BA) sets and 19 Draeger "saver" sets. The former were intended for working in an environment where there might be a leak of gas such as hydrogen sulphide. The latter were suitable only for shorter periods. The BA sets were distributed about the platform.

Permit to work and handover systems

3.90 In accordance with industry practice, maintenance and construction work on the platform was controlled by a permit to work (PTW) system. A PTW system is a formal procedure, involving the use of written permits, used to ensure that potentially dangerous jobs are done safely. The system is designed to ensure in general that responsibilities are defined, information is communicated, precautions are taken, equipment is taken out of, and returned to, service safely, and specifically that

- the equipment to be worked on is identified, the maintenance work to be done is specified and is approved by a senior supervisor, the Approval Authority
- the equipment is isolated from the rest of the process and remains so for the duration of the work and the safety precautions necessary for the work, such as gas testing or use of protective clothing, are listed prior to the issue of the permit; these actions are the responsibility of the Designated Authority
- the maintenance work is carried out as specified by the permit, the safety precautions listed are adhered to, and upon satisfactory completion of the work the permit is returned to the Designated Authority; these actions are the responsibility of the Performing Authority
- finally, the equipment is checked to confirm that the work has been satisfactorily completed and the isolations removed so that the equipment can be returned to service; these actions are the responsibility of the Designated Authority.

3.91 Occidental operated a PTW system on Piper in which the Approval Authority was the production superintendent, the Designated Authority the shift lead production operator, and the Performing Authority the shift maintenance lead hand or, alternatively, the supervisor of a group of contractors' personnel. The PTW form used by Occidental is shown in Fig 3.9. There was a blue form for cold work, a green form for electrical work and a pink form for hot work.

3.92 Under the system operated by Occidental, a PTW was suspended if the maintenance work ceased for any length of time, for example if the work stopped overnight or stopped to await the arrival of a spare part. A PTW was suspended by the Performing Authority returning the permit to the Designated Authority and both signing that the work was suspended, the permit being reissued when the work was to be resumed. During the interval the equipment remained isolated.

3.93 Information on maintenance work was also included in the handovers between personnel which took place at shift changeover and in various types of log.

Platforms and terminals linked by pipeline to Piper Alpha

3.94 Piper was linked by pipelines, 3 gas and 1 oil, to the 3 other platforms - Claymore, Tartan and MCP-01 - and to the oil terminal at Flotta (see Fig 3.1). On each of the 3 production platforms - Piper, Claymore and Tartan - condensate was injected into the main oil line. The emergency shutdown and other valves on Piper are shown in Figs J.8 and 3.10 and those on the whole pipeline system for the 4 platforms in the latter figure. The pig traps are shown in Figs J.3(c) and J.6.

Claymore platform

3.95 The Claymore platform was located at a point some 22 miles from Piper, approximately to the west. The platform, which was also operated by Occidental, is a production platform and started production after Piper in November 1977. Claymore was generally similar to its sister platform, Piper, as far as concerns structure. However, the reservoir fluid quality was quite different and Claymore exported oil but not gas, of which it had a deficiency. The Claymore oil export pipeline was tied in to the Piper oil export pipeline to Flotta. A gas pipeline was laid between Piper and Claymore to allow gas to be imported from Piper to make up Claymore's deficiency.

Tartan platform

3.96 The Tartan platform was located 12 miles from Piper, approximately to the south-west, and 18 miles from Claymore. The platform was a production platform and was operated by Texaco North Sea UK Ltd. Tartan produced both oil and gas for export. The oil export pipeline was routed via Claymore from which the oil went down the Claymore oil export line to Flotta. The Tartan gas export pipeline was routed via Piper, from which the gas went down the Piper gas export line to MCP-01 and thence to St Fergus.

MCP-01 platform

3.97 The MCP-01 platform was located some 34 miles from Piper, approximately to the north-west. The platform was a manifold compression platform (MCP) operated by Total Oil Marine plc to receive gas from the Frigg field, to compress it and transmit it to the gas terminal at St Fergus. In 1978 it also began to take gas by pipeline from the Piper platform.

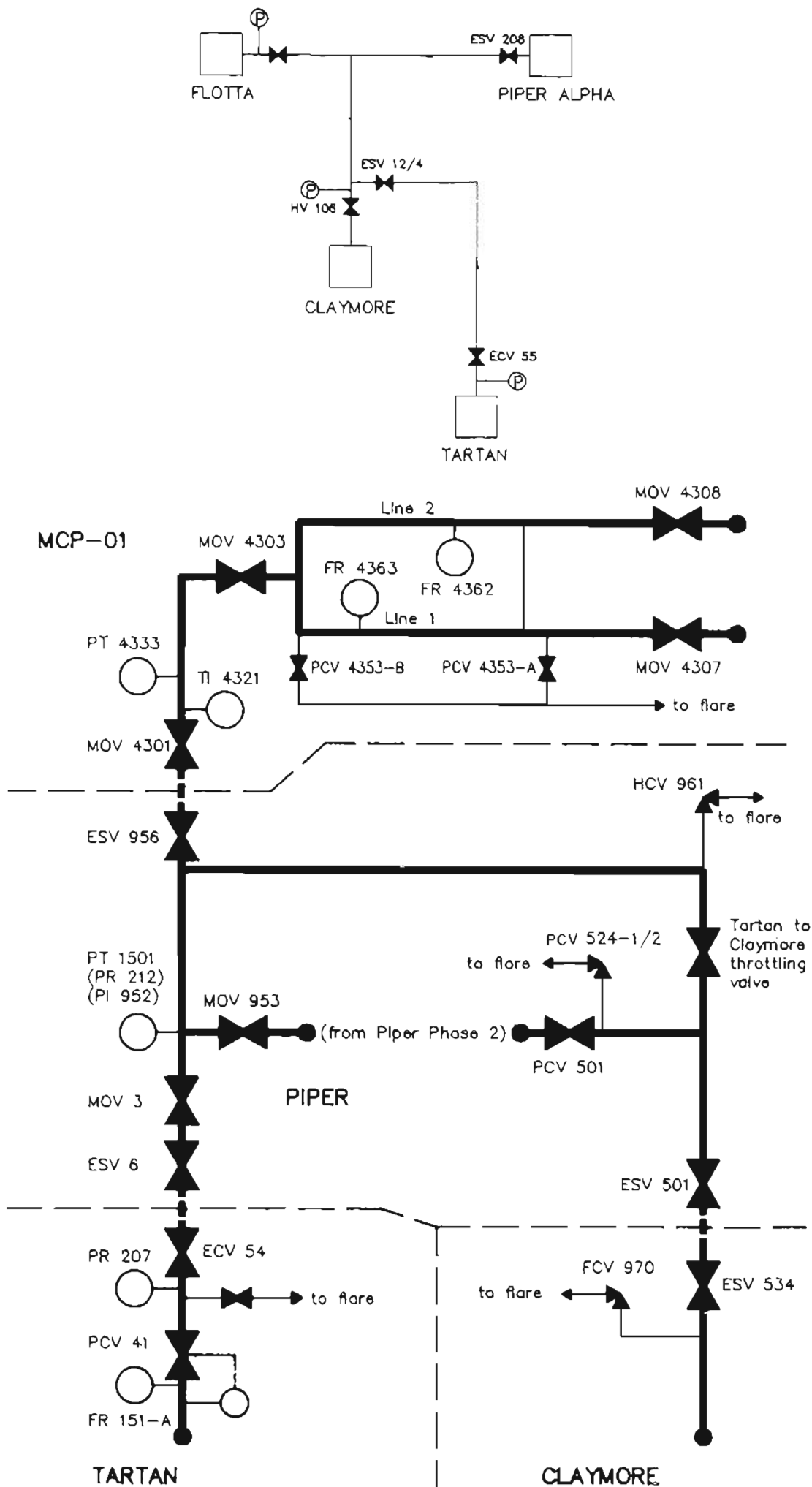


Fig. 3.10 Simplified flow diagram of the emergency shutdown of the oil and gas pipelines and of the gas flaring arrangements: (a) oil pipelines; and (b) gas pipelines.

Flotta

3.98 The oil terminal to which oil from Piper, Claymore and Tartan was pumped was at Flotta at Scapa Flow in Orkney. The function of the terminal was to separate from the oil the water, condensate and methane gas which it contained. The light components were taken out of the oil in 4 stabilising trains. The methane was burnt at the terminal as fuel gas and the oil and condensate were stored for transshipment, the latter as liquefied petroleum gas (LPG).

Piper gas export pipeline to Claymore

3.99 The gas pipeline from Piper to Claymore was 22 miles long and 16 inch diameter. There was an emergency isolation valve, ESV 501, on the line after the pig launcher, which was at the north end of the platform on the 68 ft level. There was an emergency isolation valve, ESV 534, at the Claymore end. The pressure in the line was allowed to vary, the line being topped up from Piper when the pressure fell due to gas offtake at Claymore. The policy was to keep the line at a pressure of 900-1000 psia in order to minimise the pressure drop between the Tartan and Claymore lines.

Tartan gas export pipeline to Piper

3.100 The gas export pipeline from Tartan to Piper was 12 miles long and 18 inch diameter. There was an emergency control valve, ECV 54, on the line at the Tartan end and an emergency shutdown valve, ESV 6, on the line at the Piper end. The latter valve was on the Tartan line as it entered the pig receiver at the 68 ft level. The pressure drop in the line was some 5 psi (0.3 bar) and the pressure and temperature of the gas in the line were essentially the same as those in the Piper-MCP-01 line.

Piper and Tartan gas export pipeline to MCP-01

3.101 The gas export pipeline from Piper to MCP-01 was 34 miles long and 18 inch diameter. There was an emergency isolation valve, ESV 956, on the line after the pig launcher, which was in the centre of the platform on the 68 ft level. There was an isolation valve, MOV 4301, at the MCP-01 end. The flowsheet pressure of the gas at the Piper end was 1735 psia. Typical conditions were pressure 1740 psia (120 bara), temperature 50°F (10°C), density 180 kg/m³.

Piper oil export pipeline to Flotta

3.102 The oil export pipeline, or MOL, from Piper to Flotta was 128 miles long and 30 inch diameter. This line was joined by the MOL from Claymore at a point 22 miles from Piper. There was an emergency isolation valve, ESV 208, on the Piper MOL. The pig launcher for the MOL was in B Module. ESV 208 was in that module on a vertical section of the line as it went down to the 68 ft level. The pressure of the oil at the delivery of the MOL pumps was 905 psia and the temperature 153°F.

Tartan oil export pipeline via Claymore to Flotta

3.103 The oil export pipeline from Tartan to Claymore was 18 miles long and 24 inch diameter. This line entered the MOL on Claymore downstream of its MOL pumps. There was an emergency isolation valve, ESV 55, on the line at the Tartan end and another one, ESV 12/4, at the Claymore end before the line joined the Claymore MOL.

Claymore export pipeline joining Piper-Flotta line

3.104 The oil export pipeline from Claymore to the junction with the MOL from Piper to Flotta, the Claymore T, was 7 miles long and 30 inch diameter. There was an isolation valve, HV 106, on the line at the Claymore end upstream of the tie-in of the Tartan MOL.

Routing of Piper gas to Claymore

3.105 Gas was routed from Piper to Claymore by taking gas from the discharge of the second stage reciprocating compressors and passing it to the pipeline to Claymore through PCV 501 (see Fig 3.4).

3.106 It was also possible to take gas back from the Claymore pipeline to provide fuel gas for the main generators in the event of loss of gas from the centrifugal compressors. Gas could be routed back to the discharge of these compressors via Valve 1, which was normally open, and via Valve 2 and PCV 501, which were normally shut. PCV 501 was at the west end of C Module adjacent to the B reciprocating compressor and Valve 2 was almost in the same location, just 3 or 4 ft to the east.

Routing of Tartan gas to Claymore

3.107 It was also possible to route Tartan gas to Claymore. This was done by opening the "Gas to Claymore" (GTC) valve on the line connecting the Tartan pipeline and the Claymore pipeline (see Fig 3.4).

3.108 The topping up of the Claymore line with Tartan gas was not usual practice. Normally in phase 2 operation Piper gas was used. But in phase 1 operation the Piper gas was wetter and the risk of hydrate formation or corrosion greater, and it was policy to use the drier Tartan gas.

Depressurisation facilities

3.109 There were on the 4 platforms facilities for depressurising the 3 gas pipelines by flaring the inventories, but they were limited by the gas flows which could safely be flared and such depressurisation normally took days rather than hours.

Status of Piper Alpha in early July 1988

3.110 There were various aspects of the platform in early 6 July which were unusual. There was a large construction programme and changeout of the GCM. This required changeover to, and operation in, phase 1 mode. This in turn resulted in a high level of flaring.

3.111 There was some evidence given of the existence of apertures in the firewall between B and C Modules. Details of this are given in Appendix F (paras F.68-69).

Work programme

3.112 In the period immediately preceding 6 July the platform was engaged in a work programme involving a number of major items, including

- installation of the Chanter riser (68 ft level)
- changeout of the GCM and changeover from phase 1 to phase 2 operation
- structural modifications to steelwork (B Module)
- overhaul of the prover loop and metering skid (B Module)
- work on the gas lift lines at the wellheads (A Module)

There were also various lesser projects.

Construction work

3.113 One major item of work was the installation of a riser for the flow line from the Chanter satellite field to the platform. The work done prior to 6 July consisted of preparatory work, principally the installation by the OPG of a gantry which projected

from the floor of the 84 ft level on the west face to the north of the crane pedestal and of a 6 inch oil flow line at the 68 ft level (see Plate 10(b)).

3.114 The prover loop and metering skid were situated in B Module just east of the MOL pumps. In the period 2-5 July, modifications to platform steelwork at the site of the prover loop were being done by the OPG. By 6 July the prover loop had been removed for repair, whilst work was being done on the metering skid. There was some evidence which implied the existence of an aperture in the deck of B Module at the prover loop. Details of this are given in Appendix F (para F.70).

3.115 During the period up to 6 July work was being done by the OPG on welding of gas lift lines to wellheads.

Phase 1 operation and GCM changeout

3.116 Production continued whilst the work just described was in progress, but since one of the tasks was the changeout of the GCM, it was necessary to change from the phase 2 mode of operation to the phase 1 mode. The last time the platform had operated in phase 1 mode had been in 1984.

3.117 The changeover took place on Sunday 3 July. At 06.00 hours the gas plant was shut down except that one centrifugal compressor was left running to supply fuel gas. By the afternoon things were ready for startup of phase 1 operation. Following depressurisation, valves were closed in a specific order to ensure that lines were at atmospheric pressure and were locked off. Valve status lists were maintained. The molecular sieve driers were spaded off, but not the GCM itself. Further details of the GCM changeover are given in Appendix F (paras F.65-66).

Maintenance work

3.118 On 3 July, while the gas plant was shut down and prior to startup of the phase 1 operation, the opportunity was taken to carry out various maintenance tasks. These included removal of a redundant vessel, 2-C-209, on the 68 ft level; changeout of the flare side isolation valves on PSV 524A, B on the gas to Claymore line in C Module, which were seized; and fitting the extra methanol injection line, a hose, from pump head F to the line upstream of the JT valve.

3.119 On 4 July MOL pump C tripped on high outboard bearing temperature. This was said to be either a genuine alarm due to a faulty bearing or an alarm caused by heat from the flare.

3.120 There were several leaks recorded on 4 July. One was a leak on a nipple on Valve 17 (the GTC valve). It was necessary to shut down, isolate and depressurise the line to allow maintenance to fit a new nipple. Another resulted from an attempt to insert a spade into a line under the floor of the GCM beneath the molecular sieve driers, which turned out to be pressurised. There was a release of gas, with a strong smell of hydrogen sulphide. Safety officers attended and the area was evacuated for a period. Another gas release was recorded that day due to the breaking of a pressurised line at the Christmas trees. A leak also occurred on 4 July on the LP suction pressure switch on condensate injection pump B. The switch was found to be rated below the 0-700 psi pressure range required at this point in phase 1 operation. The problem apparently arose because at some earlier time a switch suitable for pressures in both phases had been replaced by one suitable only for the lower pressure range in phase 2. After an abortive attempt to obtain a suitable switch from Claymore, a switch with a 0-3000 psi range was fitted.

3.121 Other maintenance work included the tail end of a PSV recertification programme, which involved some 300 valves, and a 24 month preventive maintenance (PM) on condensate injection pump A. This work is described in Chapter 6.

Operational aspects

3.122 In the period leading up to 6 July there were problems with the production separators. The amount of water coming from the wells was high. This water should have been removed in the separators but due to work on the Chanter riser modifications had been made to the dump line from the hydrocyclone to the sea. This increased the pressure drop and despite any compensatory action of the water level controller in opening wider the offtake valve, the head available was insufficient. A proportion of the water therefore passed not through the water removal system but into the oil. Hydrocarbons were also getting into the produced water. In June welding work was said to have set fire to gas discharged from the hydrocyclone.

3.123 In the week leading up to and on 6 July gas smells were reported on a number of occasions. Some incidents were attributed to hydrogen sulphide and others to attempts to light the flare. A gas release from the GCM on 4 July involved temporary evacuation. There were also various gas smells in the dive complex area in the period 3-6 July, leading on 5 July to a precautionary shutdown of the diving compressors.

3.124 For a period up to 6 July there had been a number of apparently spurious gas alarms on C centrifugal compressor. An opportunity was being awaited to change out the gas detectors.

Flare conditions

3.125 In phase 2 operation the volume of gas flared was of the order of 1-5 million standard cubic feet per day (MMSCFD). In phase 1 operation it was much greater, approaching 30 MMSCFD, or more in upset conditions. In the period leading up to 6 July there were reports of abnormally high levels of heat from the flare. One consequence of the high flare heat was the need to cool the oxygen cylinders, or quads, at the south-west corner of the dive complex platform on the west face. Hose cooling was applied to other equipment. Another effect reported in the period leading up to 6 July was icing of the 24 inch flare line passing through the dive area, the ice layer being estimated as 2 inches thick.

Status of Piper Alpha on 6 July 1988

Management of, and personnel on, platform

3.126 The management structure of the platform and the complement of personnel on the evening of 6 July are shown in Fig 3.11 and in Table 3.2. Some personnel described as off duty were on 24 hour call. Details of personnel involved in the events of that night are given in Chapter 6.

Construction activities

3.127 Work on the Chanter riser, including scaffolding and hot work, was in progress on the gantry on 6 July. Work continued in the evening. There was a hot work permit out for the 68 ft level. This was a category of work which would normally cease by 21.00 hours.

3.128 Another area of additional activity was the prover loop and metering skid in B Module. The state of the site early in the evening of 6 July was said to be quite unrecognisable; welding equipment and tools were lying about and the work in progress seemed to be extensive. There was no hot work permit out that evening for B Module.

Operational aspects

Production conditions

3.129 The record was available of the 24 hour average production conditions logged at 07.00 hours on 6 July. The oil production, expressed as oil and water leaving the

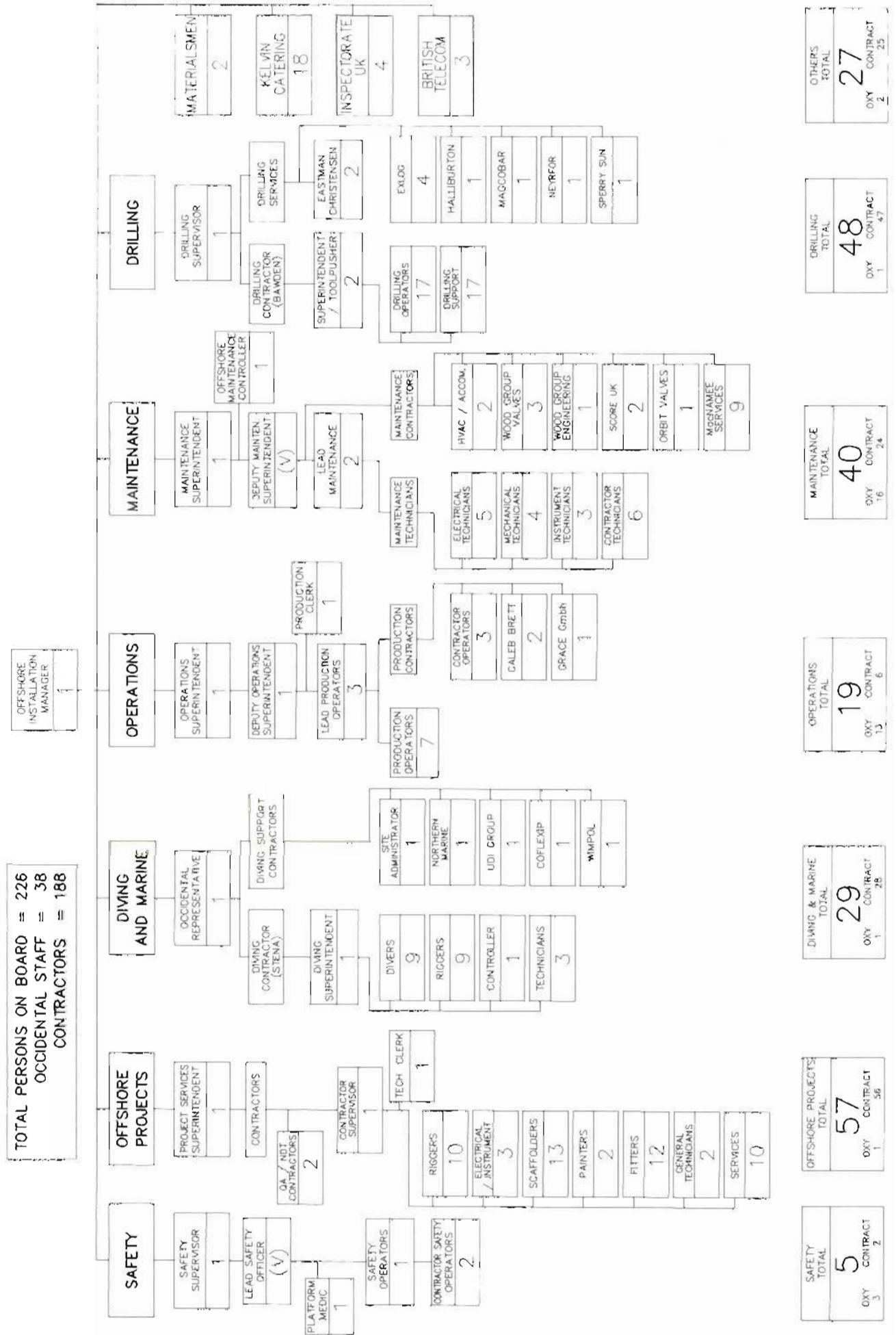


Fig. 3.11 Management structure of Piper Alpha, and of Occidental Petroleum (Caledonia) Ltd in relation to Piper.

separators was 138,294 barrels per day (BPD), corresponding to an oil export (stock tank barrels) of some 119,000 BPD. The condensate flow was 7,500 BPD. There was no export of Piper gas to MCP-01, but the export flow of Tartan gas across Piper was 33 MMSCFD. There was a lift gas circulation of 50 MMSCFD on Piper.

3.130 The flowsheet for the process on 6 July (PSK-A1-1229-1) computed subsequently by Occidental, is shown in Table J.1, which should be read in conjunction with the process flow diagram Fig J.8.

Water content of oil

3.131 On the evening of 6 July it was observed that the meter giving the water content in the MOL in the Control Room gave a value of about 10%. It was uncertain how long this situation had persisted; the figure was recorded by the chemist in his log for that evening, but he did not search back through the records. A value of about 2% or less was more normal. The higher figure was attributed to operational upsets in the production separators. The Control Room operator was unaware of a water content of 10%, which he considered would require action.

Gas in produced water

3.132 The produced water passed to a hydrocyclone to remove any free oil in the water. The discharge pipe from the hydrocyclone went down close to sea level and the water then fell into the sea. On 6 July there was scaffolding at the 20 ft level near the discharge pipe and welding work was going on. A hose pipe had been attached to the discharge pipe extending down to sea level. This was attributed to the need either to prevent gas being discharged in the area or to prevent workers there being splashed by the discharge; the sea was described as bubbling up, evidently due to gas. It was normal for there to be gas entrained in the water.

Welding activities and permits

3.133 On the evening of 6 July there was welding work going on at the 68 ft level and the automatic deluge system was therefore switched off, but the fire and gas detection system remained operational. A UV alarm in fact occurred at that level in the condensate pump area at about 20.15 hours that night, which was attributed to welding work on the Chanter riser. The Control Room operator had no recollection of any other hot work permits out, and, specifically, there was no such permit out for B Module. The deluge systems in A, B and C Modules were on automatic.

State of certain equipment

3.134 On 6 July the direct tropospheric link between Piper and Mormond Hill was down for servicing and the link in use was that via MCP-01.

3.135 The speed control setting on condensate injection pump B was faulty and it was not possible to turn it back to the zero setting; 40 rpm was the lowest setting attainable.

3.136 The injection points nominally served by the main methanol pump are given in Fig J.8. Several of these were not in use on 6 July. Head F was out of service for 4 hours on the evening of 6 July due to a leak. This reduced the flow of methanol to the JT flash drum by about a half during that period.

3.137 At the time of the initial explosion, one of the drilling diesel generators was operating, supplying power for drilling.

Environmental conditions

3.138 The weather conditions at Piper were recorded in the official log book of the *Tharos* at midnight on 6/7 July as follows: wind direction 160-170 degrees; wind speed

10-15 knots; sea conditions: significant wave 0.5-1.5m, maximum wave 2.0-3.0m; visibility 10+ miles. The wind direction given by the dynamic positioning system of the *Lowland Cavalier* at 22.00 hours was 164 degrees true and the estimates of wind speed and direction recorded by her watchkeeper were south-south-east 3 at 20.00 hours and south-south-east 4 at 24.00 hours. The first information on environmental conditions sent by the *Tharos* as on-scene commander (OSC) and recorded by Wick radio was as follows: wind direction 180 degrees true (due south); wind force: Beaufort Scale 5; sea height 4; swell height 2 (moderate); visibility 3 (good). The wind went from south-east to south-west during the incident and these data are consistent with a wind direction of 160-170 degrees true at its start.

Table 3.1 - Some principal pressure control and pressure safety valves

A—Pressure control valves

PCV 51/1,2	Inlet of centrifugal compressors to flare
PCV 1000A,B	Inlet of first stage reciprocating compressors to flare
PCV 721	JT valve at inlet of JT flash drum
DPCV 723A,B	Inlet of second stage reciprocating compressors to flare
PCV 945	Outlet of second stage reciprocating compressors to flare
PCV 501	Outlet of second stage reciprocating compressors to gas pipeline to Claymore
PCV 511	Outlet of condensate injection pumps

B—Pressure safety valves

PSV 155,156;157,158	Production separators A,B
PSV 728	Condensate knockout drum
PSV 200/1,2; 202/1,2; 204/1,2	Centrifugal compressors A,B,C
PSV 504; 505	Condensate injection pumps A,B
PSV 524A,B	Line downstream of PCV 501
PSV 130/1,2; 131; 133/1, 2 (also PSV 843/1,2)	Reciprocating compressors A,B
PSV 864	Fuel gas

Note:

See Fig J.8 for valve locations.

Table 3.2 - Personnel on platform on 6 July 1988

Category	On Duty	Off Duty	Total	Contractors ^(a)
OIM	-	1	1	-
Safety	1	4	5	2
Operations	7	12	19	6
Drilling	17	31	48	47
Maintenance	13	27	40	24
Marine & Underwater	20	9	29	28
Offshore Projects	2	55	57	56
Materials	1	1	2	-
Inspectorate UK	1	3	4	4
British Telecom	-	3	3	3
Kelvin Catering	-	18	18	18
Total	62	164	226	188

Note:

(a) Contractors are included in the previous columns. The total number of POB was 226.

SECTION TWO: THE DISASTER

Chapter 4

General History of Events

4.1 The purpose of this chapter is to provide a short account of the development of the disaster by way of introduction to Chapters 5-10 in which a more detailed account and explanation of events will be found.

4.2 An initial explosion occurred on the production deck of Piper at about 22.00 hours on 6 July 1988. This was followed immediately by a fire at the west end of B Module and a fireball which erupted from its west face. The fire spread rapidly in B Module and extended into C Module and down to the 68 ft level. From the outset dense black smoke from the fire engulfed the upper parts of the northern end of the platform. The initial explosion was followed by a series of smaller explosions. Most of the emergency systems of the platform, including the fire water system, failed to come into operation.

4.3 In response to the initial explosion the *Silver Pit* which was on standby duties off the north-west of the platform launched its fast rescue craft (FRC) and moved in towards the platform. The *Lowland Cavalier* which was close to the south-western corner of the platform broadcast a mayday. The *Tharos* which was about 550m off the west side of the platform launched her FRC and began to move in towards the platform. The *Maersk Cutter* which was off the north-eastern corner of the platform moved to the south and started fire-fighting. Thereafter a number of other vessels and FRCs became involved in a large operation for the recovery of survivors and the dead.

4.4 At the time of the initial explosion 226 persons were on board the platform, of whom 62 were on night-shift. The great majority of the remainder were in the accommodation. Between 22.04 and 22.08 hours 3 maydays were sent out from the Radio Room of the platform. The third announced that the room was being abandoned due to fire. Personnel in the accommodation began to assemble on D Deck of the ERQ. An emergency evacuation team assembled at the reception area, but owing to the flames and dense smoke outside the accommodation it was impossible for evacuation to be carried out by helicopter or lifeboats.

4.5 Diving personnel, who were on duty, assembled at the dive complex on the 68 ft level and, since it was impossible for them to go up to their lifeboat, were led to the north-west corner of the platform where they got down to sea level by means of a knotted rope. They were joined by personnel from D Module and lower levels of the platform. By 22.20 hours 22 survivors had left the platform.

4.6 The remainder of the survivors who were on duty mainly made their way to the accommodation where they joined those who were already there. The normal lighting in the accommodation had gone out shortly after the initial explosion. It was followed by emergency lighting which lasted for 10-15 minutes.

4.7 At about 22.20 hours there was a major explosion which was due to the rupture of the Tartan gas riser. This caused a massive and prolonged high pressure gas fire which generated intense heat. When the explosion occurred it caused a number of men at the north-west corner and other parts of the platform to jump into the sea. The effects of the explosion were felt on vessels several hundred yards away.

4.8 Most of those who were in the accommodation had congregated in the mess area on D Deck. Conditions there were tolerable at first but deteriorated due to the entry

of smoke. At 22.33 hours a message from Piper was received on the *Tharos*: "People majority in galley area. *Tharos* come. Gangway. Hoses. Getting bad."

4.9 Shortly before 22.45 hours the cascade from the fire monitors of the *Tharos*, which had been approaching the platform, began to reach it. The gangway of the *Tharos* was not landed on the platform.

4.10 A number of men, including 28 survivors, made their escape from the accommodation at various levels. Some went up to the helideck; most went down to the pipe deck, from which some went to the drill floor; others sheltered at the side of the pipe deck.

4.11 By about 22.50 hours about 39 survivors had left the platform. At that point a further massive explosion occurred. This is likely to have been caused by the rupture of the MCP-01 gas riser. It added to the intensity of the high pressure gas fire. The explosion destroyed the FRC of the *Sandhaven* and killed most of its occupants. Debris from the explosion was projected 800m and vibration was felt up to a mile away. The explosion caused men to jump off the helideck and other parts of the platform. The *Tharos* then pulled back. Structural collapse at the 68 ft level below B Module started.

4.12 The structural collapse of the platform was hastened by a series of major explosions, one of which was about 23.20 hours and was due to the rupture of the Claymore gas riser. Shortly thereafter the west crane collapsed from its turret. The drilling derrick collapsed across the pipe deck. The structure of the platform took a slight tilt to the east. This was followed by the sudden collapse of the pipe deck to the west. This forced men out of shelter on to the pipe deck. A number of survivors then had to jump off the pipe deck into the sea.

4.13 The ERQ, which had suffered severe external attack by fire on its east and north sides, suffered loss of structural support. It tipped to the west, probably crushing the LQW; and then tipped northwards into the sea. Between 22.30 and 00.45 hours the centre of the platform collapsed. The risers from the gas pipelines and the MOL were torn apart. The north side of the platform slowly collapsed until the AAW slipped into the water at about the latter time.

4.14 Meanwhile at about 23.27 hours a Nimrod aircraft, which functioned as a flying communications platform, reached the scene, followed shortly thereafter by helicopters from Lossiemouth, Boulmer and Shetland. These helicopters were used to transfer personnel, search for survivors and transfer the injured.

4.15 A total of 62 survivors from Piper (one of whom died later in hospital) and one survivor from the crew of the *Sandhaven's* FRC had by then reached a variety of vessels either by being picked up directly or having been picked up by the crew of FRCs. They were transferred to the *Tharos*, where medical attention was given. At 02.26 hours on 7 July the first casualties left the *Tharos* by helicopter for the shore. At 02.02 hours fire fighting had stopped. At 08.15 hours the survivors had all reached the shore.

4.16 Aircraft searched the area for survivors until the afternoon of 7 July; surface vessels did so until 22.45 hours on that date.

4.17 On 7 July the bodies of 15 personnel from Piper and 2 crew members of the *Sandhaven's* FRC were recovered from the surface of the sea. During the remainder of the month of July a further 27 bodies were recovered from the seabed. Between August and November a further 10; and one on 2 June of the following year. A total of 81 bodies were recovered from the ERQ, mainly after it had been recovered from the seabed and taken to Flotta in October 1988. The bodies of 30 personnel from Piper remain missing.

Chapter 5

The Initial Explosion

5.1 The initial explosion had all the characteristics of an explosion of a cloud of flammable gas, which must have formed as the result of a leak. The problem faced by the Inquiry in determining the source of that leak was peculiarly difficult in that there was available no physical evidence from the installation. Most of the first hand evidence obtained on the initial explosion came from survivors and observers at various distances from the platform. This evidence included what was seen and heard of the explosion itself and what was observed of the damage which it caused. This latter included observations both of damage to particular equipment and of the effects of damage on equipment function. Much evidence was heard from experts, but in contrast to the situation at most inquiries, in which experts are able to examine debris directly, in the present case experts giving evidence on matters such as equipment damage had to rely for information on this damage on eye-witness evidence.

5.2 In this chapter I consider the characteristics of the initial explosion and seek, in particular, answers to the following questions:

- When did the explosion occur?
- Where did the explosion occur?
- What was the size of the gas cloud?
- What was the fuel in the gas cloud?

There were gas alarms reported in C Module just before the explosion and a major fire in B Module just after it. It was fairly clear at an early stage that the explosion had occurred in one or other of these 2 modules. This led therefore to the questions:

- In which module did the explosion occur?
- If the explosion was not in B Module, what was the cause of the fire observed there within seconds?
- Whereabouts in the module did the explosion occur?

The nature of the explosion itself and the size of gas cloud give rise to the questions:

- What sort of an explosion occurred?
- What over-pressures did the explosion generate?
- Were these over-pressures sufficient to destroy the firewalls of the module?
- What was the source of ignition?

There were also certain features of the explosion which required explanation, including the questions:

- Were there further explosions almost within seconds of the initial explosion?
- How can the various experiences of personnel be explained?
- How can the various reported damage effects be explained?

5.3 The evidence on which I draw in this chapter is of 2 kinds. Firstly, there is the evidence of survivors and other eye-witnesses. This includes the observations of, and photographs taken by, persons off the platform; the noises heard by survivors just before the explosion; the effects of the explosion on survivors; and the damage done and debris created by the explosion. Secondly, there is a body of expert evidence commissioned prior to the Inquiry by other parties which bore on the nature of the explosion. In this chapter I use these 2 types of evidence to draw certain broad conclusions about the initial explosion and the leak which gave rise to it. The expert evidence considered here is that on the probable over-pressures generated given by Dr R A Cox of Technica Ltd, Dr J R Bakke of the Christian Michelsen Institute

(CMI), Dr N F Scilly of the HSE; the evidence of Dr Cox on the over-pressures required to cause failure of the firewalls in C Module; and an overview of both the eye-witness and expert evidence by Dr P A Cabbage, a consultant.

5.4 I begin with the accounts of eye-witnesses, including those on timing (paras 5.5-16); of photographs (paras 5.17-20); and of noises (paras 5.21-29). I then review the effects of the explosion on personnel, the damage and debris, and certain explanations of these (paras 5.30-62). From this evidence I draw certain conclusions about the location of the explosion, the fuel involved and the size of gas cloud (paras 5.63-79). I then consider the nature of the explosion itself, its strength and its effect on the firewalls (paras 5.80-102) and finally give my conclusions on the initial explosion (paras 5.103-110).

Eye-witness evidence

5.5 Mr D H Kinrade, the radio operator, was in the Radio Room at the time of the initial explosion. He turned round to his colleague Mr J Dawson, stepped across the room, and looked out to the south, all within a matter of seconds. He saw smoke and flames coming from the west face south of the crane pedestal. He had no recollection of anything on the east face.

5.6 Mr C A Miller, a mobile diving unit pilot, was on the deck of the *Tharos*, which was 550m off the west face of Piper, standing with his camera raised, intending to take some photographs for his child's school project. He heard a thump like a flare starting up, lowered his camera, and apparently looked at the flare. He did not see anything unusual immediately, but within a second or two observed grey smoke issuing from the west end of C Module. The next thing he saw, only a few seconds later, was thick black smoke and large flames, obscured by the smoke, coming out of the west end of B Module. He raised his camera and took his first photograph (Plate 14(a)).

5.7 Mr J Murray, a helicopter engineer, was in the heli-reception of the *Tharos* with Mr W J Flaws, a deck foreman on the vessel. There was a desk between them. Mr Flaws stood looking over the desk directly at Piper and Mr Murray stood on the aft side of the desk. He described his position as looking side on at the platform. He saw just to the right of the crane pedestal a vapour mist, orange or pinky-orange, which persisted for just a few seconds; he compared it to the flares used at airfields for scaring birds. A split second later he heard the explosion. He then saw at the same spot flame and orange smoke. The flame was being blown by the wind northwards and upwards, giving it an oval appearance. At that stage it was smaller than that shown in Mr Miller's first photograph.

5.8 As just described, Mr Flaws was standing facing the platform. He heard an explosion and looked up. He saw a cloud of smoke coming out from the far side of the platform and flames coming through the platform at the 84 ft level towards the *Tharos*; it was the smoke which caught his eye first. The smoke emerged beyond the outline of the platform; it was greyish and thick. The flames were orange in colour and moved horizontally rather than vertically. The flames were to the left of the crane pedestal; he was sure about the position. He continued looking at the platform for some seconds after the explosion. He saw no missiles coming from the platform.

5.9 Captain M Clegg, the master of the *Lowland Cavalier*, was on the bridge at the time of the initial explosion. The vessel was positioned 25m off the south-west leg of Piper with its stern towards the platform. It was 72m long with the bridge some 50m from the stern and some 15m above the waterline. Captain Clegg said he was at almost the same height as the 84 ft level, looking up at an angle of only a few degrees. He stated that he was looking at the platform at the time when the explosion occurred. He described it in the following words:

“Well, I actually saw the explosion; I did not hear it. I actually saw it before I registered anything else. What I saw I can only explain as like the starting of a gas

burner, a water heater. It seemed to go along the bottom of the platform; like a very light blue explosion or ignition more than anything else, then contracting again, and then a further explosion coming from a certain point which I believe to be below the crane pedestal and slightly to the left.”

5.10 Other descriptions of the explosion given by Captain Clegg are:

“What I saw was what afterwards seemed the igniting of some sort of gases within the platform and after that coming outwards from the platform smoke and flame which was probably the initial start of the explosion which came more and more as it went on, within seconds.”

and

“What I am saying is it went across the platform. It looked to be within inside the structure itself, not emanating from the structure. When the initial blast, if you want to call it that, had gone back, seconds or whatever afterwards it seemed to be coming from just to the right of the crane pedestal in the area that has been indicated around the ladder. That is the picture I have in my mind. That is all I can say.”

Another way he put it was that what he saw was like a body of gas igniting, flaring up and then contracting and dying out.

5.11 Captain Clegg described the flame as travelling from the crane pedestal in both directions, the one to the right being longer than the one to the left, although at one point he agreed the lengths were equal on the 2 sides, and at another he said the flame went further on the left. Then within a split second the flame contracted. The flame ran above and below the 84 ft level. He stated that he could not say for certain whether the initial ignition was to the left or right of the crane pedestal. Asked to identify the point on a photograph of the platform he indicated one to the right of the pedestal and towards the top of B Module, but said he could not be sure which side of the pedestal it occurred. However, he later stated that the order of events was the blue flame, smoke and then seconds later a bright flame emerging from the smoke; it was evidently this latter flame to which he was referring when first questioned about the “initial ignition”.

5.12 Captain Clegg had no recollection of hearing any sound associated with the blue flame. Asked whether he heard a ‘woomph’ he said “I did not hear the explosion. I felt it and saw it. I cannot say if I heard it or not.” Prior to this blue flame, he saw nothing; he did not see any smoke.

5.13 Captain C I Morton, master of the *Maersk Cutter*, was sitting drinking a cup of coffee on the bridge when he experienced the initial explosion as a shaking of his vessel, which was abeam to the east face of the platform, and thought perhaps it had struck something. The bridge gave a 360° field of vision. He went to look aft and then as he came back to look forward again he looked to the side at the platform; the time elapsed since the explosion was perhaps some 10 seconds. He saw a light grey cloud, which he described as like cement dust, in front of, and apparently issuing from, the centre of the east face; he believed it came from C Module. He made no mention of the fire on the north face or the large plume of black smoke drifting north which are seen on Mr Miller’s first photograph (Plate 14(a)).

Time of the initial explosion

5.14 There was a large volume of evidence which indicated that the initial explosion occurred at, or within 1 or 2 minutes of, 22.00 hours BST. Some half dozen witnesses on the platform were listening to radio or television, some having just tuned in for the news or sports programmes. Some heard the 10 o’clock time signal, others did not. None claimed to have heard more than the very start of the news programme.

5.15 On the *Maersk Cutter*, Captain Morton went to the mess room to get some milk. The 10 o’clock news on Radio 2 and ITV News at Ten had just started. He

went back up to the bridge, a matter of seconds, poured his coffee, and had just sat down to drink it when he felt the ship vibrate, presumably from the explosion. Captain Clegg, on the *Lowland Cavalier*, observed the development of an explosion on the west face of the platform. He instructed his second mate, Mr Barrie, to send a mayday signal. The ship's official log gave at 22.00 hours the entry "Explosion on Piper A". This log was made up from notes on a scrap of paper which had been written down as time allowed. On the *Tharos* events were logged by the officer of the watch, Mr D I Blair, in the manned control room scrap log. His first entry referred to an explosion on Piper at 22.01 hours. The Chief Engineer, Mr W N Paterson, responded to the explosion by initiating startup of the additional generators. This action was timed at 22.2.29 hours, ie 29 seconds after 22.02 hours, on the computer printout. At the time of the explosion he was in the forward control room and he estimated that it took no more than a minute to get from there to the engine control room. The official log of the *Tharos* had the explosion timed as 22.02 hours, which Captain A Letty stated was derived from the log of the radio operator, who would be meticulous in such matters.

5.16 Wick Radio picked up a mayday call "Explosion on board Piper A. No numbers of personnel known yet." from the *Lowland Cavalier* which was recorded in the radio telephone log at 21.01 hours GMT (22.01 hours BST). At the Flotta terminal the log, written up later by the panel operator, recorded a telemetry failure alarm at 22.00 hours and a fall in oil import at 22.02 hours. However, the recollection of the duty lead process operator, Mr L Stockan, was that the import reduction occurred at 21.55 hours. He also said that the telemetry fault alarms came up 7 minutes later at 22.02 hours. Despite repeated cross-examination, the witness was adamant that he had the time of the import reduction correct.

Photographic evidence

5.17 The explosion and fire on Piper were documented by an unusually large number of photographs, many taken within the first few minutes. A selection of these photographs is given in Plates 14-20. However, most of these are more relevant to the escalation rather than to the initial explosion and their consideration is deferred to Chapter 7. There are just 1 or 2 which have a significant bearing on the initial explosion.

5.18 As already described, Mr Miller was standing on the deck of the *Tharos* with his camera raised. His first photograph (Plate 14(a)) shows a fireball emanating from the west side of B Module just to the south of the crane pedestal. The timing of this photograph is not certain, but it is estimated in Chapter 7 that it was taken some 15 seconds after the initial explosion. Mr Miller's photographs were the only series started within seconds of the initial explosion.

5.19 A photograph (Plate 18(a)) taken by Mr L M T Macdonald, an electronic technician on the *Lowland Cavalier*, is also of interest in so far as it might bear on the state of the firewalls after the initial explosion. It was taken from the deck of the vessel about 30 seconds after that explosion.

5.20 A project to enhance photographs of the Piper disaster undertaken by the Hughes Aircraft Co, a sister company of Allison Gas Turbine in the General Motors Group, was described by Dr M E Stickney, a Senior Systems Engineer, led by Allison. He gave a demonstration of the application of computer-aided image enhancement techniques to Mr Miller's first photograph of the fireball in B Module (Plate 14(a)) and to Mr Macdonald's photograph of the fire in that module (Plate 18(a)). Dr Stickney was asked whether the photograph by Mr Miller could be used to estimate the temperature of and the fuel burning in the fireball. He said he was not himself able to assist on this and indicated that deductions would not be a straightforward matter. He was not able to say whether the fireball came from a small pipe or a large vessel. With regard to Mr Macdonald's photograph, the question was explored whether any information could be gleaned on the state of the B/C firewall. There was in C Module

a large white potable water tank and it would be expected that if there were a hole in the B/C firewall opposite this tank, light would be reflected from this object; white objects are particularly good diffuse reflectors. From the photographic enhancement done there was no evidence of such reflection. The question was explored to what extent this finding might be due to the limitations of the information on the negative. Dr Stickney agreed this was a limiting factor. It was also established that it was not possible to tell from the photographs how far into B Module the fire penetrated. Dr Stickney was able, however, to draw the conclusion from this photograph that the fireball did not project very far from the platform. The photograph showed no reflection off the heat shield. The Inquiry was invited to commission further work, but decided not to do so.

Noises associated with initial explosion

5.21 A number of survivors stated that they heard unusual noises just before the initial explosion. An account of these noises is given here, since they have potential bearing on the location of the explosion. The interpretation of these noises in relation to the cause of the explosion is given in Chapter 6. The noises were the subject of a report by Mr A H Middleton of Anthony Best Dynamics Ltd, which included a summary of survivors' evidence on the noises.

5.22 There were 5 survivors from the Mechanical (or Maintenance) Workshop. Mr D Ellington heard a very high pitched screaming noise. He thought it was some of the scaffolders "acting the goat". He believed the noise lasted some 10-15 seconds and stopped a few seconds before the explosion. Mr I Ferguson heard a high pitched scream which he put down to the air starter on a divers' unit on the 68 ft level. He did not think it sounded like escaping gas. It lasted less than a minute and stopped long enough before the explosion for the men to decide to make a cup of tea - he said a matter of minutes. He stated that the men in the tea room discussed the noise. Mr R J McGregor heard a "banshee" noise, which he attributed to the air starter on the crane. He stated someone in the tea room likened it to somebody strangling a woman. The noise was slightly louder than normal, but not particularly unusual. It did not sound like the centrifugal or reciprocating compressors venting. It lasted about half a minute and stopped just before the initial explosion. Mr D M Thompson heard a loud screech lasting for about 10 seconds; maybe 10 seconds later the initial explosion occurred. These 4 survivors were in the workshop tea room. The only one in the workshop itself, Mr C W Lamb, heard nothing. In the Instrument Workshop Mr N G Cassidy heard a very high pitched grinding noise, like "metal to metal grinding together", which he thought came from the 84 ft level and which he found frightening. The pitch and loudness stayed constant throughout. He was sure the noise was not the flare; it was a different quality such as he had not heard before. He believed that it went on for 3-4 minutes and that the initial explosion occurred directly the noise stopped.

5.23 Of the 10 survivors from the cinema, lounge and Bawden Office, 3 reported hearing a noise before the first explosion. Mr J S Meanen heard a loud wailing noise, very high pitched, which lasted 5 seconds. He likened it to a car slamming on its brakes and skidding, but much more high pitched. If there was a gap between the noise and the explosion, it was a very short one. Mr W J Lobban also heard a very loud or high pitched screeching noise but 1 or 2 minutes before the explosion; he too was unsure if it stopped before the explosion. Mr W P Barron stated that about 30 seconds before the initial explosion there was a sudden high pitched, hissing noise; he believed it stopped before the explosion. All 3 tended to attribute the noises which they heard to the flare, as did Mr W F Clayton who also heard a noise. The 6 other survivors questioned heard nothing unusual.

5.24 A noise prior to the initial explosion was heard by 4 of the 14 survivors from the diving area; all were in the Wendy Hut. Mr S J Middleton heard a very loud hissing noise like a bunsen burner at the flare stack. It was similar to noise he had

heard before, but louder. He did not associate it with any noise in the pipework in the dive area. He was certain the noise he heard was not that of the air starters on the diesel engine. He thought the noise ceased before the initial explosion but could not remember how long before. The 3 others attributed the noise they heard to the flare.

5.25 Survivors from the Bawden tea hut, the drill floor, the GCM, the Mud Module and the 20 ft level described noises just before the initial explosion which they associated with the flare. The occupants of the Control Room, Mr G Bolland and Mr A G Clark, and of the Radio Room, Mr Kinrade, heard no unusual noises from outside. Both rooms were well insulated for noise.

5.26 As far as concerns the sound of the initial explosion itself, most survivors described it as a single "thump", "whoomph", "bang" or "boom". Mr M J Bradley at the 20 ft level said it was like a gun going off. The diver under water, Mr G P Parrydavies, described it as a very loud bang. The noises associated with the initial explosion heard by Mr E C Grieve and Mr W H Young are described below. On the *Tharos* Mr Miller said he heard a thump. Mr Flaws said the explosion sounded like a large bang. Mr Murray said the explosion was a fairly loud bang; the conditions were calm, there was no wind howling and it was clearly audible. On the other hand Captain Clegg, on the bridge of the *Lowland Cavalier*, said he felt but did not hear the initial explosion. Likewise, Captain Morton on the *Maersk Cutter* felt vibration but did not really hear anything.

5.27 Three survivors in the vicinity of the dive complex heard just after the initial explosion a noise like escaping gas. One described it as a sort of high pitched whooshing like someone lighting an acetylene torch but a hundred times worse. He could not remember how long it went on but it seems to have been short-lived. However, the platform had gone so quiet that any noise would be noticeable.

5.28 In his analysis of the initial explosion Dr Cabbage made little use of accounts of the noise. Mr Middleton, whose evidence came after Dr Cabbage's, believed that the only survivors who heard a noise other than that of the flare were those in the Mechanical and Instrument Workshops and Mr Young on the 68 ft level and that this noise came from C Module. He stated that he had not investigated the possibility that the noise might have come from B Module, but said that if it did, it would have had to have been a very loud one.

Explosions reported within seconds of initial explosion

5.29 Several witnesses reported experiencing an explosion, or an event which might be interpreted as such, within seconds of the initial explosion. The only diver in the water, Mr Parrydavies, who was operating between legs B4 and A4, experienced a flash and a bang simultaneously. Some 10 seconds later there was a second flash and bang, indistinguishable from the first. Despite repeated questioning, he was quite clear that there were 2 events. One survivor from the Mud Module described the initial explosion as a thump. Seconds later there was another thump, perhaps not as big as the first. Another, who was in the doorway of the cinema by the projection room, experienced the explosion as 2 bangs, almost simultaneous. He recollected that after he had walked quite a short distance towards his cabin, there was another explosion, this time minor; the time elapsed since the initial explosion was perhaps 20 seconds. On the 20 ft level Mr N E Ralph experienced a second explosion, larger than the first but from the same area, but was unclear whether the interval between them was minutes or seconds.

Effects on personnel of initial explosion

5.30 The shock of the initial explosion was felt by people in various parts of the platform. Personnel in the Control Room and on the 68 ft and 20 ft levels were knocked over, as described below. All 5 occupants of the Wendy Hut were thrown to

the floor. Personnel in the dive gondola and dive module offices were lifted off their chairs and others in the LQW and ERQ were thrown off their beds. Of the 5 survivors from the Mechanical Workshop 1 was thrown forward in his chair by the collapse of the east bulkhead behind him, whilst 2 others experienced a rush of cold air. There were 2 survivors from the Instrument Workshop. One, who was standing at the north bench in the centre of the workshop, was knocked off his feet towards the east wall. The other, who was at the entrance, between the inner and outer doors, did not recall feeling any blast.

Control Room

5.31 Mr Bolland, the Control Room operator, was in the Control Room, facing the main F & G panel with his left hand out to accept a gas alarm. The blast of the explosion caught him on his right side and threw him some 15 ft to the north. His left thumb was cut and his right hip injured. If he was knocked unconscious, it was for no more than a second or two. The other occupant of the Control Room, Mr Clark, the maintenance lead hand, was standing on the west side of the control desk, facing north and experienced the explosion as a deep thump coming from C Module. It blew him some 6-8 ft against the well status board, which he hit with his whole body. He was hit with some force on the shoulder and side of the neck by the computer terminal. He fell to the floor but did not lose consciousness.

68 ft level

5.32 On the 68 ft level Mr Grieve was on the west side of condensate injection pump B when the initial explosion occurred. He heard a loud bang, which seemed to come from above, and fell, or was forced, down to the floor; he was not aware of any blast. Mr Young also was at the condensate injection pumps. He heard a short-lived loud rushing noise. He had just turned towards the stairs leading up to C Module and was facing north-west when there was a dull bang from an explosion above him. He felt a rush of hot air, hotter than body heat, and was blown on his back between the 2 pumps, losing his safety hat, ear defenders and glasses; he was unsure if he was knocked out. As he made his way towards the light on the west side, Mr Grieve turned round and saw an orange ball of flame coming down through, or under, the roof just between the 2 condensate injection pumps. The orange ball was about half the size of the pump skid and transparent, with no real body to it or power behind it. He made towards the Ansul fire-fighting unit, but the flame went out; it had lasted only 5 or 10 seconds. He was not aware of any damage to the floor above, but there were pipe penetrations. Mr Young observed in the roof space what he described as dust or gas, white or greyish in colour.

5.33 Also on the 68 ft level were 2 riggers working on the west side at the north landing just north of the dive complex. Mr D Elliott, who was standing facing west, was knocked over by the explosion, losing his hard hat and glasses; he did not hear anything or feel any shock wave. His first recollection was picking himself up and his first reaction was that the explosion had come from the Coflexip workshop on his left. It was his belief that the explosion came from directly behind and thus from inboard the platform. His colleague, Mr B Jackson, was standing on the north landing by the railings facing north. He had headphones on to communicate with dive control. The first thing he knew he had been knocked to the floor, losing his hard hat and headphones. He heard no noise, which he attributed to his wearing headphones, and was unaware of any blast. He did not lose consciousness. His first reaction was that the grit blasting compressor had blown up. There was thick black smoke coming from the 84 ft level above his head and falling down to the sea.

5.34 Just below the 68 ft level Mr C I Niven, a diver, was on the way up the stairs to the decompression chambers from the Wendy Hur, some 3 or 4 steps up from the latter and thus not able to see the chambers, being some 10-12 ft below their level. He was standing on the stairs, looking down to his left at the *Lowland Cavalier*, and

thus facing west. He heard a loud bang which he thought came from the oxygen quads, felt on his chest from the left the shock of a blast wave which seemed to be made visible by the burning particles in it and felt also a strong wind but he saw no flames or smoke. He believed the explosion came from the module which he initially referred to as C Module but later realised was B Module. He saw debris drifting down from below the area of the oxygen quads. He stepped back involuntarily and, expecting a fireball, dived into the Wendy Hut and was inside within 3 seconds.

20 ft level

5.35 On the 20 ft level there were 2 other riggers working. Mr Bradley was at the B4 leg just by the boat bumper, facing north. He heard an explosion, like a large gun going off; it appeared to come from above and behind him. The other rigger on this level was Mr Ralph, who was also by the B4 leg. His account was not completely clear. He referred to 2 explosions, separated by times which he described variously as seconds and minutes. One of these explosions he described as a loud bang, a shock wave and a flash of flame. The flame appeared to come from the same direction as the blast, from a point on the 68 ft level between legs A3 and A4 and inboard the platform from the east side by a quarter of the platform width. He thought the flash of flame was a distressed electric motor. One of the explosions knocked him against the leg so that he lost his safety helmet and glasses. He was facing east and received the full force of the explosion on his chest. Mr Ralph said he did not take much notice of the flame because he had got oil on his eyes. The oil was a light one, like diesel oil. He was unsure of its temperature but it was not hot oil. Mr Bradley said that Mr Ralph asked him whether he had oil on his face. His face was in fact speckled with drops of oil which Mr Bradley described as between a small finger nail and a thumbnail in size. This incident occurred within the first 2 minutes and while the 2 were still on the 20 ft level. Mr Ralph agreed that the 'oil' could possibly have been condensate.

Damage caused by initial explosion

5.36 The shock from the initial explosion caused minor damage in various parts of the platform. Analysing this damage, Dr Cabbage distinguished between areas where the items dislodged were fixed and those where they were not. Areas where unsecured items fell to the floor included the dive gondola, the Wendy Hut, the Oil Laboratory, the LQW and the ERQ. Fixed items fell in the Instrument Workshop, the Radio Room and the AAE. In certain areas more serious damage was reported, as described below.

Dive skid complex

5.37 There were 2 doors in the south-east corner of the main dive complex, containing the workshop and offices. Mr Niven stated that after the initial explosion one of them was hanging askew on its hinges. Mr E Z Amaira, another diver, said the inner door was not closing on its self-closer as it normally did. This was not noticed by 3 other survivors who also passed through. In the dive module offices most of the shelving and the wall and ceiling fittings fell down and one man was hit by falling ceiling. The Dive Machinery Room had double emergency doors facing south. Mr J O Wood, a diving technician, stated that both doors had been blown open and buckled at their hinges. He said that the explosion came through the ventilation trunking forcing the doors from the inside. Everything fell from the bulkhead panels, including lights, pipework and storage bins.

No 2 decompression chamber

5.38 To the south of the main dive complex were 2 decompression chambers. The outer entry lock door of No 2 decompression chamber, the more northerly, was observed by Mr Parrydavies to be off its hinges. This damage was also observed by 3 other survivors. According to Mr S R MacLeod, the diving superintendent, the

door and its hinge were very heavy, but where they joined there was a very weak pin, allowing rotational movement to assist the door seal.

Control Room

5.39 Mr Bolland's assumed that the initial explosion had blown in the Control Room wall between C and D Modules. The Control Room itself was devastated. Free-standing equipment and tables were thrown about the room. There was considerable debris of telephones, computer equipment and furniture scattered about. He described the smoke coming from the south end of the Control Room and drifting northwards. The main lighting had gone off, though he believed the emergency lighting came on initially. In any event visibility was poor and though he could see the smoke at the south end, he could not see the south wall.

5.40 It is convenient to mention here Mr Bolland's evidence of his observations and actions before he left the Control Room. He was pretty sure the mimic panel was intact, though he could not say if the lights were on; he was not able to see as far as the F & G panel. He went to the ESD button, which was in its usual place directly beneath the mimic panel and appeared intact, and pressed it. He did this as soon as he recovered himself, but he thought that the ESD system would already have operated. He did not press any of the 3 buttons for the 3 ESVs on the Tartan, Claymore and MCP-01 gas pipelines.

Mechanical and Instrument Workshops

5.41 Survivors from the Mechanical Workshop stated that the east bulkhead of the tea room was buckled, that the emergency door on the west face of this room was blown in and that the east bulkhead of the workshop itself was buckled. The south bulkhead of the workshop, facing C Module, was buckled inwards and the door on this bulkhead leading to the cable room or cupboard had been blown completely off its hinges.

Gas Conservation Module

5.42 Mr J A Craig was standing in the GCM when there was a massive explosion. Several flickering flames broke out along the north wall in the north-west corner of the module, which prevented him passing through the door into the Sack Module. These flames would have been located approximately above the second stage reciprocating compressor scrubber 1-C-116A in C Module.

Skid deck slot hatches

5.43 Two survivors described how slot hatches on the skid deck had lifted. Mr V Swales described the larger hatches, which covered a single well head, as of metal plate and frame construction, measuring some 9 ft x 5 ft and held in place by their own weight. In the centre of these was a smaller hatch 2.5 ft x 2.5 ft bolted on. He arrived on the skid deck some 6-7 minutes after the initial explosion to find that at least 1 or 2 of the larger hatches had lifted and quite a few of the smaller ones had been knocked off, maybe with only 1 bolt remaining to keep them from being blown away. Later he passed across this deck again but did not notice any difference in the state of the hatches. Lifting of the slot hatches was also observed by Mr S Rae, who stated that those which had lifted were mainly on the north side of the skid, west of the derrick; however, at the extreme west of the deck there were containers standing on the hatches.

A/B firewall

5.44 Several survivors gave evidence on the state of the A/B firewall. Of these witnesses the most positive was Mr J L Gutteridge, the toolpusher. He looked into A

Module from its south-west corner as he was making his escape. He saw various small fires in it, but he was sure that the A/B firewall was intact. Mr Rae went down the staircase on the south side of A Module into the module itself. He saw quite large flames from the west side of the module and various small fires at the north side. The whole of the north side was affected by smoke and sometimes flames. He was unable to say whether the A/B firewall was intact. He thought the flames and smoke might be seeping over the top of the firewall. Mr J M McDonald also went down the staircase on the south side of A Module. He saw the Christmas trees on fire in the western third of the module. He was unable to see the A/B firewall until he got down to the foghorn platform. When he got down there, he saw flames coming under A and B Modules. He could not see the separators in B Module and took this as evidence that the A/B firewall was intact. There were several other witnesses who had a view into A Module, but who were unable to say whether the A/B firewall had remained intact.

5.45 Attempts were also made to assess the state of the A/B firewall from the photographic evidence. Examination of Mr Miller's first photograph (Plate 14(a)) of the fireball in B Module immediately after the initial explosion showed flames either behind or reflected from the heat shield. Dr Stickney stated that the heat shield would not be a specular reflector and that therefore the flames seen would be behind the heat shield. There was, however, a passageway between the west side of the heat shield and the west end of the A/B firewall, so that flames observed behind the heat shield to the south of B Module were not evidence of any breach in that firewall. Other attempts to interpret photographic evidence to show that the A/B firewall was breached were unconvincing.

Lowland Cavalier

5.46 Some damage was also done to the *Lowland Cavalier*. Mr L M T Macdonald stated that all 4 windows in the starboard and rear sides of the handling shack at the stern of the vessel were smashed.

Debris from initial explosion

5.47 A few of the eye-witness accounts of the initial explosion mentioned ejection of debris or missiles from the platform. The principal missile was that observed by Mr G Carson, the medic on the *Silver Pit*, who was in the galley facing a porthole on the port side and pouring a cup of tea when the explosion occurred. Something flew past which was not bird-shaped and was big enough momentarily to blot out the 11 inch porthole. At the time the vessel was lying to the north of the platform with her bows pointing towards it. (The fact that it was the port-side porthole through which Mr Carson observed the flying object does not create a difficulty provided it is assumed that the vessel was lying somewhat to the north-west and with bows pointing roughly south south-east).

5.48 Evidence of another possible missile was the damage to the Chanter riser gantry observed by Mr Bradley. He identified the gantry as that shown in Plate 10(b). It projected from the platform on the west side between the 68 and 84 ft levels and was in 2 sections, the northerly having a projecting horizontal section with a triangular end and the southerly one with a rectangular end. Only the former was visible to him from the 20 ft level at the B4 leg. On this section a diagonal member running down from the 84 ft level to the projecting triangular end of the horizontal section had been crushed and twisted at the 68 ft level end by a force acting towards the north. Mr Bradley observed the damage from 50 ft below and some 5-10 minutes after the initial explosion. He was shown Mr Miller's 21st photograph, taken during the fire, and agreed this seemed to show the diagonal member undamaged, but he stuck to his statement that it had suffered damage. Mr Elliott also was questioned on the state of this gantry but had no recollection of any damage to it. Asked to estimate the diameter of the diagonal pipe, he thought it was about 10 inch.

5.49 The evidence of Mr Ralph should also be mentioned. He spoke of 2 explosions, separated by a time varying between soon after to a couple of minutes. The amount of debris which came out from the second was greater, but he saw some at the first one, and believed that oil drums and timber which he saw come out did so even with the first explosion.

5.50 Missiles were suggested as a potential cause of various types of damage from the initial explosion. The evidence on this is described in Chapter 7.

Platform vibration caused by initial explosion

5.51 A number of witnesses spoke of the severe vibration associated with the initial explosion. People were thrown off chairs or knocked over. Some thought that a container had been dropped or that a vessel had collided with the platform.

5.52 Dr Cubbage took the view that this vibration was a significant feature of the explosion and one which might in large part account for the physical forces experienced by personnel and causing damage to equipment. He compared the shock with that which might be produced by an earthquake. Earthquake induced accelerations are measured on the Modified Mercalli Intensity Scale: an acceleration of 100 mm/s² renders it difficult for people to remain upright, while one of 400 mm/s² is destructive to some buildings.

5.53 Dr Cubbage worked from the hypothesis that the initial explosion was in C Module. He presented the results of a computer simulation of the vibration which would be induced in the platform by an explosion. The simulation was performed by Offshore Design Engineering using the program FESDEC. The explosion was characterised by a pressure pulse of 0.68 bar (10 psi) and 0.4 seconds duration applied to the east face of C Module. This produced a lateral movement with a maximum acceleration of 360 mm/s², a maximum velocity of 60 mm/s and a maximum displacement of 30 mm. This acceleration is in Group 8 of the Mercalli Scale, which corresponds to shock sufficient to knock people over.

5.54 Dr Cubbage was questioned on several aspects of this work, which was a simplified study, done in a limited time. He was not able to speak to the errors in the model used. With regard to the simulation performed, the pressure pulse was applied to the compressor compartments and ducting at the east end of C Module. He stated that if these were blown away, and there was no direct evidence that they were, it was probable that the reaction would have been effective before they had time to move away. He agreed that there would be forces on the 2 firewalls and on the floor and the ceiling, but since in both these cases the forces would act in opposite directions, they would to some extent cancel each other out; it was desirable to take them into account also, but this would have been a much more complex exercise. With regard to the magnitude of the over-pressure, he accepted the value used was higher than that derived elsewhere in his report; the latter results were not available when the vibration study was commissioned. However, the acceleration was proportional to the over-pressure, so that an over-pressure of 0.34 (5 psi), half the value used, would give an acceleration of 180 mm/s², which came within Group 7 of the Mercalli Scale and still corresponded to shock sufficient to knock people over.

Hypothesis of a dive complex explosion

5.55 It was postulated by Dr Cubbage that there may have been a second explosion, almost coincident with the initial explosion, above the dive complex on the 68 ft level. He presented this hypothesis in his report as a possible explanation of the blue flame seen by Captain Clegg. He suggested that unburnt fuel might have been forced from C Module via B Module into the area of the dive complex, where it ignited. The blue flame described would be consistent with low velocity venting of unburnt gas. The amount of hydrocarbon involved might have been no more than half a kilogram.

5.56 He believed that such an explosion could have caused the damage effects observed at the dive complex. The effects on the complex were very localised and could have been caused by explosion of a semi-confined gas cloud. This could also have caused flames to be projected along the corridor between the Machinery Room and offices and the air cylinder bank, which may have allowed gas, flame and/or combustion products to invade the areas of the north landing and the Coflexip container and could account for some of the effects observed there. Dr Cabbage suggested that some of the effects experienced by Mr Bradley and Mr Ralph may have been due to a dive complex explosion, but did not attribute those felt by Mr Elliott and Mr Jackson to this cause. He agreed that such an explosion would fit with the fact of 2 flashes as reported by Mr Parrydavies, but not if there were a time interval between them of 10 seconds as reported by that witness; it would have to be more like 2-3 seconds. He was questioned whether such an explosion was consistent with the evidence of Mr Niven. He admitted that the fact that Mr Niven experienced no heat was a difficulty for his hypothesis.

5.57 Dr Cabbage believed that the gas for a dive complex explosion could have been unburnt fuel forced ahead of the flame travelling through C Module into B Module and then down into the dive complex area. Failure of the B/C firewall would allow unburnt gas to pass into B Module. He referred to the evidence of Mr M R Khan, the chemist, that the deck gratings in the area of the metering and prover loop skid were raised and also to the existence of other penetrations such as that around the MOL. He was evidently under the impression that removal of the grating meant that there was an opening to the deck below and was not aware of the evidence that the grating constituted a false floor above a solid deck. Questions were raised in cross-examination whether there could have been a sufficient flow rate of gas and whether gas would not have been dispersed by the wind. Asked whether an alternative possibility might be condensate flowing along the south wall of C Module and spilling over as heavy gas at the west side, he replied that this would require that it then went back inboard some 10 ft or so; he did not rule it out, but thought it unlikely. With regard to the source of ignition for the dive complex explosion, Dr Cabbage said he had assumed that this would be the flame continuing through the gas cloud which had been forced into B Module. He rejected the possibility that the damage to the decompression chamber and the Machinery Room of the dive complex might have been caused by an explosion in B Module or in both C and B Modules.

Interpretation of personnel and damage effects of initial explosion

5.58 The initial explosion affected personnel and caused damage in various parts of the platform. One of the principal tasks attempted by Dr Cabbage was to give an explanation of some of the more puzzling effects.

5.59 As far as concerns personnel, Dr Cabbage drew attention to the evidence of survivors who were thrown from chairs and beds. In seeking to explain the effects experienced by people who were knocked over by the explosion, he suggested that the severe vibration of the platform may have played a role. His explanation of the effects of the initial explosion on Mr Bollands and Mr Clark is given below. He believed these to be consistent with those of a blast wave from an explosion in C Module. Mr Elliott and Mr Jackson were standing on the north landing almost directly under the west end of C Module and about 10 ft out from the overhang. Dr Cabbage believed that the effects which they experienced were consistent with those to be expected from venting of the explosion from that end of the module, supplemented by platform vibration, and perhaps some effect from blast along the corridor of the dive complex. Dr Cabbage took the view that Mr Bradley and Mr Ralph at the 20 ft level probably experienced a number of different effects. To reach them the pressure wave from venting of the explosion at the west end of the C Module would have had to travel down some 60 ft and then eastwards some 30 ft; Mr Ralph said he was moved westwards. Probably therefore these men were affected not only by this venting but also by platform vibration and by any dive complex explosion.

5.60 The principal damage effects which Dr Cubbage addressed were those to the doors of No 2 decompression chamber and of the Dive Machinery Room. The circular door of the decompression chamber was described as 3 to 3½ ft diameter and 2-3 inch thick. The door, hinged at its northern end, was secured to a hinge arm by a boss which passed through a collar on the end of the hinge arm, the boss and collar being held together by a split pin. It was held at its southern end with a 'dog' swivel catch, secured with a screw. The door was described as off its hinges and lying in the bottom of the outer airlock. If the door had been swung open by an over-pressure in the region of the decompression chamber, it could have gone back to hit the curved side of the chamber. The only thing restraining the movement of the hinge arm would have been a 0.25 inch split pin. Dr Cubbage stated that it had been calculated that the over-pressure required to cause failure would have been between 0.5 and 3 psi (0.035 and 0.2 bar). However, he also stated that the damage might have been the result of platform vibration, but had done no calculations on this.

5.61 The Dive Machinery Room was fitted at the south end with double emergency, or fire, doors which opened outwards. One door was bolted at the top and bottom, the other was a crash door, latched with an emergency push bar. They were heavy metal doors each with 3 hinges. These doors were described as bowed outwards, or burst open, and were too distorted to close. Dr Cubbage stated that this type of door fitting is relatively weak. It would be easy for the bolts to be drawn out of the U-bracket into which they slotted when the doors were closed. He thought it likely that the doors had been sucked out by the negative pressure which follows the positive pressure of an explosion or by a vortex from the hypothesised dive complex explosion.

5.62 Overall, Dr Cubbage doubted whether the damage described in the dive complex area would have been caused by the initial explosion and preferred the explanation of a dive complex explosion together with platform vibration.

C Module as site of initial explosion

5.63 The evidence of survivors and other eye-witnesses points strongly to either B or C Module as the seat of the initial explosion. The evidence of the Control Room operator, Mr Bollands, was that a series of gas alarms culminating in the initial explosion came up in C Module. He gave no evidence of any gas alarm after 21.30 hours except in C Module. The effects of the initial explosion included blast effects felt by Mr Bollands and Mr Clark in the Control Room; a fire which occurred within seconds in B Module and became the main area of flame and smoke; emissions of smoke and outbreak of fire on the west face about the centre and at the 84 ft level; emission of smoke from the same level just north of centre on the east face; and blast effects felt by Mr Grieve and Mr Young on the 68 ft level. The explosion also apparently disabled the main power supply, for which the generators and switchboard were in D Module. There was no evidence given that the initial explosion was in D Module, A Module, the 68 ft level or, indeed, anywhere other than B or C Module.

5.64 The occurrence of gas alarms in C Module is clearly strong evidence of a flammable gas cloud in that module. The absence of gas alarms in other areas might in principle be due to disabling of the fire and gas alarm system; the main reason for this would be to prevent alarms being set off by welding work. Mr Bollands stated that although it was the practice to disable the automatic deluge system in an area if welding work was being done in that area, it was not the practice to disable the fire and gas detection system itself. As far as welding work on the night is concerned, it was his evidence that welding work was going on at the 68 ft level and that the automatic deluge system was therefore switched off, but the fire and gas detection system remained operational. A UV alarm in fact occurred at that level in the condensate pump area at about 20.15 hours that night. Mr Bollands said he was told this was due to welding work on the Chanter riser. He stated that he had no recollection of any other hot work permits out and, additionally, that there was no such permit out for B Module. The deluge systems in A, B and C Modules were on automatic.

5.65 Despite this strong evidence pointing to C Module as the site of the initial explosion, the facts that within seconds of the initial explosion a fire was observed at the west end of B Module which for some time was the main fire, giving rise to a large plume of smoke, and that once the initial explosion subsided there was little, if any, fire in C Module gave rise to the alternative hypothesis that the initial explosion may have occurred in B Module. Captain Clegg's evidence that the slow, blue flame which he saw extended right across the mouth of B Module provided some support for this. Although the investigative work performed prior to the Inquiry tended to concentrate on description and explanation of an initial explosion in C Module and although no explicit evidence was led by any party in support of the B Module hypothesis, it was kept alive during the Inquiry by persistent questioning. Some further support for the hypothesis came from some of the difficulties in the C Module theory. One such problem was the statements of the Control Room occupants that the rush of air which they experienced was cold rather than hot. However, it is shown in Chapter 6 that this particular effect is not inconsistent with an explosion in C Module.

5.66 The B Module hypothesis requires not only that the B/C firewall should be largely destroyed but also that serious damage should be effected to the C/D firewall. Such damage might be caused either by over-pressure or missiles. Assuming that the effects are broadly symmetrical, it would be expected that an explosion in B Module of the strength described would both destroy the A/B firewall and cause substantial damage to the heat shield. The evidence on the state of the A/B firewall has already been described. The testimony of the survivors indicated that it was substantially intact, whilst analysis of the photographs was inconclusive. Another pointer to the state of the A/B firewall was the damage to the skid deck slot hatches, which were located in the skid deck at the 107 ft level above A Module. The evidence of Mr Swales and Mr Rae that some of these hatches had lifted has been described. Dr Cabbage stated that his estimate of the over-pressure required to "just lift" the hatches was 0.003 bar (0.05 psi), a very low value, and that he would expect an explosion in B Module to have blown the hatches some distance. He explained the movement of the hatches as the result of vibration of the platform due to an explosion in C Module. More conclusive is the state of the heat shield as shown in photographs of the shield viewed from the south; one such photograph is shown in Plate 19(a). An explosion in B Module strong enough to do substantial damage to the C/D firewall would be expected to damage the heat shield also. It was Dr Cabbage's expectation that there would be damage from projectiles. No damage to the heat shield is apparent in these photographs.

5.67 I conclude from this evidence that the initial explosion occurred in C Module.

Location of initial explosion within C Module

5.68 The gas alarm pattern described by Mr Bolland was an initial low gas alarm in zone C3, C centrifugal compressor, followed after an interval by a further group of low gas alarms and a single high gas alarm; these low gas alarms were C2, C4 and C5 for C Module East and A and B centrifugal compressors, respectively, but he was not sure of the high gas alarm zone. The evidence of these gas alarms indicates a gas cloud in the south-east quadrant of C Module. The explosion damage to the main and emergency power supplies points to the eastern half of C Module as the site of the explosion and the absence of hot gas in the Control Room is unfavourable to an explosion in the north-east quadrant. Dr Cabbage stated that the gas alarms indicated a gas cloud in the east of the module and that ignition at the west end, which was more open, would not have given an explosion of sufficient strength, but felt unable to go beyond that.

5.69 From this evidence I conclude that much the most likely location of the initial explosion was the south-east quadrant of C Module.

Nature of fuel

5.70 The main hydrocarbon fuels on the platform were oil, gas and condensate. Oil itself cannot form a gas cloud, although volatile components in it conceivably might do so. Gas and condensate are, however, much more likely candidates. As far as concerns C Module, the 2 types of hydrocarbon stream present in the pipework and capable of forming a gas cloud were methane and condensate. The latter is conveniently approximated by propane, although the more volatile components in it should not be neglected. There are 2 principal pieces of evidence which bear on the choice between these 2 as the fuel in the gas cloud formed. These are the pattern of gas alarms in C Module and the slow, blue flame seen by Captain Clegg.

5.71 For an explosion of sufficient strength to have occurred in the module, it was necessary for a fairly large gas cloud to have built up. There were in C Module a number of gas detectors in the roof to pick up methane. There was in the east end of the module only one detector near the floor, apart from those at the centrifugal compressors. If the hydrocarbon released had been methane, it is difficult to see how a cloud of sufficient size could form without setting off a number of the gas alarms in the roof of the module. If on the other hand it was condensate, which is heavier than air, it is possible to envisage the formation of quite a large low lying cloud which might not set off the single gas detector. These qualitative arguments are confirmed by the wind tunnel tests described in Chapter 6.

5.72 The other main pointer is the evidence of Captain Clegg, who saw a slow, blue flame apparently at floor level in B and C Modules.

5.73 Dr Cabbage stated in his report that he based his assessment of the nature of the fuel entirely on Captain Clegg's evidence. Even so he clearly found difficulty with it. He thought the slow, low lying blue flame seen by Captain Clegg would be consistent with ignition of a lean mixture of gas heavier than air at the west end of C Module which then burnt towards the east end, but that this would not have generated a sufficiently high over-pressure. He did not think Captain Clegg would have seen such a flame from ignition at the east end. He was driven to postulate either a further source of ignition at the east end or a separate explosion in the region of the dive complex. He did not initially state whether he believed the gas was lighter or heavier than air, except to say the latter was consistent with the first interpretation of Captain Clegg's evidence. However, in cross-examination Dr Cabbage did confirm that he believed the gas was heavier than air. Still basing his view on Captain Clegg's evidence, he referred to the fact that a heavier-than-air gas was consistent with all the interpretations which he had put on this evidence and that there was no report of flame at a high level.

5.74 The possibility was explored that if the material released was condensate, heavy condensate gas would tend to flow by gravity along the floor of the module and possibly out the end and could thus give rise to secondary fires and explosions. The wind tunnel work, described in Chapter 6, showed that the ventilation conditions pertaining were unfavourable to any significant upwind gravity flow of gas. This does not, however, preclude flow of condensate liquid, at least over the solid part of the module floor.

5.75 The conclusion which I draw from the above is that the gas released was heavier than air and came from a leak of condensate.

Nature and volume of gas cloud

5.76 Evidence bearing on the volume of the gas cloud included the damage to the firewalls and the Control Room wall and the effects on personnel in the Control Room and the Mechanical Workshop as well as Captain Clegg's observations. The C/D firewall suffered severe damage towards the east and centre of the module, but the

sections of both the B/C and C/D firewalls at the extreme west end apparently survived. Mr Bolland and Mr Clark in the Control Room did not feel an inrush of hot gas, while 2 survivors in the Mechanical Workshop felt a rush of cool air.

5.77 In assessing the probable volume of the cloud, Dr Cabbage referred to these effects on personnel and observed that if the module had been full of gas, he would have expected Captain Clegg to see a large amount of flame issuing from the west side of the module. He believed that the cloud could not have exceeded two-thirds of the volume of the module, basing this estimate on the fact that the Control Room, which was not reached by the flames, was some one third of the way into the module from the west end. With regard to the height of the cloud Dr Cabbage was able to say little more than that he believed it was a low lying one. Its height would depend on the angle at which the jet issued. Since all the streams in C Module were at high pressure, the leak would be a high pressure jet, so that the cloud would be well mixed with air, although presence of obstacles would result in some lack of homogeneity. Dr Cabbage agreed that in forming a view on the size of the gas cloud he had in mind the minimum size of cloud required to give the over-pressures apparently experienced, as estimated by Technica and CMI, and by his own simulations.

5.78 I conclude from the above that the gas cloud was at the east end of the module, that it did not reach the Control Room and probably extended no further than the centre of the module and filled only the lower part of the east end. This would give a cloud volume of no more than 25% of the module and likely less.

Location and nature of source of ignition

5.79 Evidence on the source of ignition was limited to the interpretations which Dr Cabbage placed on the eye-witnesses' observations. He took the view that the initial explosion was that of a gas cloud in the east end of C Module ignited at that end. There remained the difficulty of explaining Captain Clegg's evidence. It was put to Dr Cabbage that ignition in the centre of the module rather than at the east end would have the advantage of giving a stronger explosion and that this might have been what Captain Clegg saw. Dr Cabbage replied that Captain Clegg was firm that the flame he saw was at the mouth of the module and that the only explanation he could give of this evidence of Captain Clegg, other than the hypothesis of a dive complex explosion, was that there were 2 sources of ignition, one at the east end and one at the west. He was unwilling to choose between these 2 explanations. Dr Cabbage's attention was drawn to a work permit approved at 18.30 hours on 6 July for hot work in a location known as the 'habitar' at the east end of D Module. He agreed that this could be a possible source of ignition for a gas cloud somewhere round the east side of D Module. Dr Cabbage assented to the proposition that a gas cloud in the module would almost certainly find a source of ignition. He mentioned hot surfaces, broken light fittings and sparks. With regard to the strength of any ignition source, Dr Cabbage stated that the amount of energy required to ignite the gas cloud concerned is very small.

Nature of initial explosion

5.80 Accounts of combustion phenomena were given by Dr Cox and by Dr Cabbage. Combustion of a flammable gas cloud may in principle be either a deflagration or a detonation. In a detonation the flame speed is very high, in excess of the speed of sound in the medium. In deflagrations the range of flame speeds which occur is wide, from speeds of a few metres per second up to those applicable to detonations, but in most cases the flame speed is much lower than in a detonation. The over-pressures generated in detonations tend to be much higher than those given by deflagrations. A completely unconfined flammable gas cloud normally burns as a deflagration. A flammable mixture burning in a pipe, on the other hand, tends to accelerate until detonation is reached. Combustion of a flammable mixture in a closed vessel normally gives a deflagration and this is also the type of combustion which would be expected

in a containment such as a module on a platform. Computer simulations of deflagrations in modules and of detonations in pipes were shown on video by Dr Bakke. The simulations included the effect of turbulence promoters.

5.81 The question of the type of explosion to be expected in a module was addressed by Dr Cox, by Dr Scilly and by Dr Cabbage. On the basis of his assessment of the turbulence promoters in the module, Dr Cox determined an empirical value of the ratio of the actual flame speed to the burning velocity and obtained flame speeds much less than those for detonation. Dr Scilly considered detonation highly unlikely, the gas cloud not being large enough and the turbulence promoters being insufficient. Dr Cabbage also judged detonation unlikely, the aspect (length/diameter) ratio of the module being too small.

Over-pressures generated by initial explosion

5.82 The magnitude of the initial explosion was one of the main features addressed in the Petrie Final Report, which included 2 annexes on the topic. Annex 3 gave computer simulations by the Christian Michelsen Institute (CMI) using their FLACS model and Annex 4A an analytical study by Dr N F Scilly and Dr D Carter. This work was spoken to by Dr J R Bakke and by Dr Scilly, respectively. In addition, there was made available to the Inquiry a study done for Occidental by Technica Ltd, spoken to by Dr R A Cox, of firewall failure. There was a further Technica report for Occidental, also spoken to by Dr Cox, on projectile damage, but the explosion models given in this latter report related to projectile velocity rather than explosion over-pressures and therefore it is not considered here. The Technica firewall study included results from the CMI FLACS computer code; this work was separate from that commissioned by the DEN. With regard to the FLACS model, this is described in Chapter 6 and Appendix G. The account here is confined to the results obtained by CMI for the DEN and for Technica. Estimates of the explosion strength were also made by Dr Cabbage. The evidence of these experts is summarised below. The account of Dr Cox's evidence is confined to the explosion over-pressures; the effects of these on failure of the firewall and on damage by projectiles are considered later in this chapter and in Chapter 7, respectively. Later in the Inquiry work was presented on the formation and explosion of a hydrocarbon gas cloud related to possible accident scenarios, utilising wind tunnel tests and further FLACS code simulations, respectively, and this is described in Chapter 6.

5.83 The outcome of this work was estimates of the over-pressures generated by the explosion. At a given point the over-pressure will rise to a peak value, which is referred to as the peak over-pressure. The maximum value of the peak over-pressures at the various points in the module is referred to here as the maximum peak over-pressure. Reference is also made to the dynamic pressure. This is the pressure associated with the wind effects generated by an explosion.

Evidence of Dr Cox

5.84 Taking first the Technica report on firewall failure and the supplement to this report, Dr Cox began with an account of the factors which influence the severity of a semi-confined gas explosion such as that occurring in a module. For a continuous leak the formation of the gas cloud will depend on the material leaking, its pressure and temperature, the hole size and location, and the ventilation rate. The over-pressures generated by ignition of the cloud will depend on the layout of the module, particularly obstacles and vent areas, and on the location of the ignition source. The speed of the flame through the flammable mixture depends partly on the burning velocity, which is a property of the mixture, and partly on the enhancement of this basic velocity caused by turbulence. A high flame speed and large flame area will result in rapid combustion, which will generate high over-pressures. These in turn will increase the bulk flow of the flammable mixture, thus creating a positive feedback loop.

5.85 Initially ranging estimates were made to obtain order of magnitude estimates of the over-pressure. An upper bound was obtained by assuming a module filled with a stoichiometric mixture of hydrocarbon and air and with no venting either through the walls or the ends. For this case the estimated peak over-pressure was 7-8 bar. Empirical formulae, or models, were then used to obtain estimates for the case where venting occurs. The vent area was assumed to be 50% of the areas of the 2 ends of the module; additional venting by firewall collapse was not taken into account. Two scenarios were considered. Case 1 was a stoichiometric mixture of hydrocarbons, consisting of 89% methane and 11% propane, filling the whole of the module; case 2 was the stoichiometric mixture filling only the intercooler section, and hence 25% of the module. The former was chosen as a 'worst case', the latter as a somewhat more realistic scenario. These empirical models gave estimates of the maximum peak over-pressure in the range 1-3.6 bar; the figures refer to the full range of results obtained for the 2 scenarios using the different methods. Values were quoted of several bar for case 1 and of about 1.2 bar for case 2.

5.86 Following these ranging calculations, more refined estimates were obtained using the FLACS code of CMI. The work was on similar lines to that done by CMI for the DEn, as described below. The layout of the equipment in C Module was entered into the code and the explosion of the flammable gas cloud was simulated. The details of and results for the 2 runs done by CMI for Technica are shown in Table 5.1, as Runs T1 and T2, corresponding to cases 1 and 2 as just described. In this work the vent area at the end of the modules was that obtained from the module layout entered into the computer, but again it was assumed that the firewalls would not fail. It was also necessary in this case to specify the location of the ignition source. For case 1 this was taken as being in the eastern end of the module and 1.5m off the floor. For case 2 it was taken as lying on the border between sections 3 and 4 and thus one quarter of the way in from the east end. In these simulations pressure measurement points were located along the centre line of the module, starting with P1 at the west end and ending with P10 at the east end. For case 1 the maximum peak over-pressure was about 0.45 barg with a duration of 0.4 seconds and for case 2 it was about 0.25 barg. In each case the peak over-pressures at points P9-P3 down the centre line of the module were broadly similar, with some tailing off at points P2-P1. (It should be noted that these points, which are not shown here, were different from those used in the CMI work for the DEn.) Significantly lower pressures were obtained at points P2-P1 and P10. For case 1 the peak over-pressure at points P2-P1 was about 0.2 barg and that at P10 about 0.3 barg. For case 2 the peak over-pressures at P2-P1 were "very low"; the values on the figures presented were about 0.05 and 0.02 barg, respectively. With regard to location of the ignition source, Dr Cox stated that for case 2 location of the source within the cloud rather than at its eastern edge might well have given higher over-pressures, particularly at points P2-P1.

5.87 The associated analysis of firewall failure showed that the firewalls would fail even at the lower of these 2 peak over-pressures, with the possible exception in the second case of the walls at the west end of the module. Thus venting would have occurred additional to that assumed in the simulation, so that the peak over-pressures predicted by the latter would be to that extent too high. The work did, however, serve its purpose of demonstrating that there would be firewall failure. Comparing the differences between the results of the empirical models and those of the computer simulations, Dr Cox adduced as features which may have been significant the enhancement factor used to obtain the flame speed in the former and the location of the ignition source in the latter. He was clear that the computer simulation was to be preferred and stated that if they had been able to wait for the CMI results they might have dispensed with the use of the empirical models. He was cross-examined on the scenarios chosen, the assumptions made for the simulations and on the results obtained. He agreed that the results would be sensitive to these assumptions. He pointed out that the purpose of the work was to determine whether the over-pressures generated would be sufficient to destroy the firewalls rather than to calculate over-pressures *per se* and that the results were sufficient for this purpose.

Evidence by Dr Bakke

5.88 Shortly after the Piper disaster CMI was commissioned by the DEN to perform simulations using the FLACS code for a number of scenarios of explosions in C Module. The report on this work was spoken to by Dr Bakke. The layout of C Module entered into the code is shown in Fig 5.1. The figure also shows the 8 points, P1-P8, at which the pressures were measured and the locations X and Y of the ignition sources. 5 cases were considered. Cases 1, 2 and 4 involved natural gas and cases 3 and 5 condensate. The module fill was 50% in each case, except for case 4, for which it was 30%. Wall failure was allowed for in all cases except case 5. For cases 1 and 4 the location of the ignition source was at the eastern end of the cloud, for cases 2, 3 and 5 at the centre of the module. The details of and results for these cases 1-5 studied by CMI for the DEN are given in Table 5.1 as runs 1-5. This work showed that there are a number of scenarios which would lead to pressures high enough to cause failure of the firewalls. It also illustrated a number of important trends. It showed that higher over-pressures are generated if the hydrocarbon cloud is larger, if there is no failure of the firewalls, if the ignition source is at the centre and if the fuel is condensate rather than natural gas. Further details of the work are given in Appendix G.

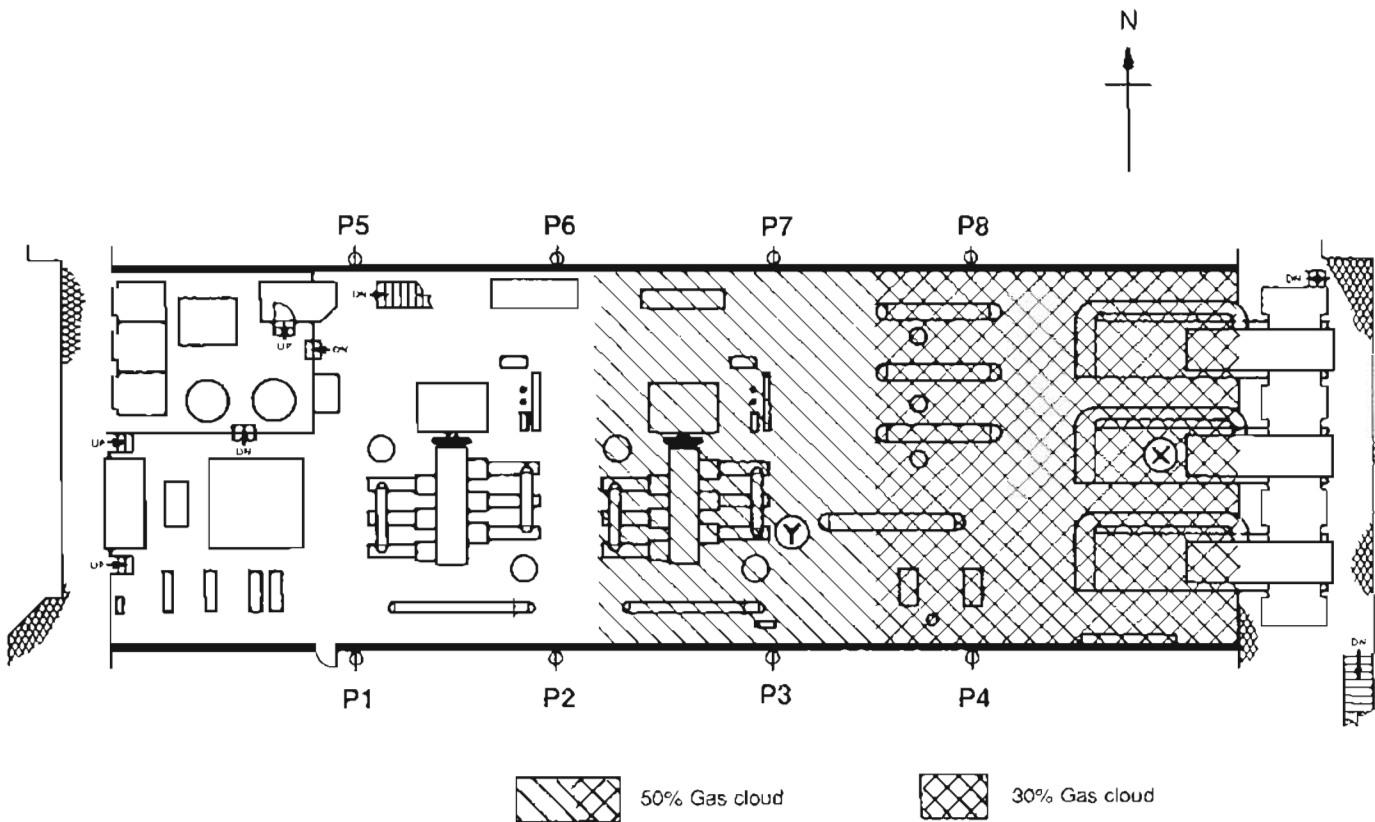


Fig. 5.1 Plan view of C Module, showing pressure points P1-P8, 30% and 50% fill gas clouds and ignition sources X and Y used in the CMI explosion simulations.

5.89 The approach taken in the work of Dr Cox and Dr Bakke just outlined was to explore a range of theoretical scenarios for the initial explosion and to identify those which might cause failure of the firewalls. Other studies were done, as described below, to try to deduce the over-pressure of the explosion from evidence of its other effects.

Evidence of Dr Scilly

5.90 A study to estimate the strength of the initial explosion based on the bodily translation suffered by Mr Bollands and Mr Clark was made by Dr Scilly and Dr

Carter of the HSE and was spoken to by Dr Scilly. The estimate was based on the use of a TNT equivalent model for the gas cloud explosion and on the assumption that the firewall between C Module and the Control Room gave way at a pressure well below the peak pressure attained in C Module. Both Mr Bolland and Mr Clark were thrown across the Control Room by the blast, but neither received serious injury. For a man in the standing posture exposed to a blast wave, data exist which give the degree of injury as a function of the impact velocity. Dr Scilly postulated that the injury received by these 2 was at the threshold of injury, which corresponded to an impact velocity of 10 ft/s. For a man weighing 160 lb and presenting an area of 9 ft² the dynamic pressure impulse required to achieve this velocity was 54 psi-ms. Taking a typical value for the dynamic duration time of 225 ms gave a dynamic pressure of 0.48 psi. There is a unique relationship between the dynamic pressure and the peak over-pressure such that for this case the latter was found to have a value of 4.5 psi. This value of the peak over-pressure related to the point where the 2 occupants were standing.

5.91 This peak over-pressure could have been given by a number of gas clouds of different shapes. Dr Scilly considered 3: hemispherical clouds of 3m and 6m radius and a cylindrical cloud of 7.5m radius and 6m height. For these clouds the volumes were respectively 57, 452 and 1060m³ and the peak over-pressures at the edge of the cloud 72, 23 and 16 psi. For stoichiometric mixtures these volumes equated to 4.4, 35.0 and 81.9 kg of propane or 3.7, 29.2 and 68.5 kg of methane, respectively. Dr Scilly suggested that the smaller release sizes, 4.4 kg for methane and 3.7 kg for propane, were unlikely. He therefore confined his attention to releases of between 35 and 82 kg for propane and between 29 and 69 kg for methane.

5.92 He gave estimates of the hole size necessary to obtain these releases. Assuming a release time of 30 seconds, the corresponding release rates were 1.2 to 2.7 kg/s for propane and 0.97 to 2.3 kg/s for methane. He estimated that these release rates might be given by the following conditions:

<i>Material</i>	<i>Pressure</i> (bar)	<i>Temperature</i> (°C)	<i>Hole size</i> (mm ²)
Propane	62	15	5.5-8.5
Methane	7.9	15	37-55
	49	32	15-23
	101	32	10-15

The set of conditions for propane was representative of that in the condensate lines and the 3 sets of conditions for methane of that between the production separators and the centrifugal compressors, that between the centrifugal compressors and the first-stage reciprocating compressors and that between the first and second-stage reciprocating compressors, respectively. The hole sizes given were consistent with a significant flange/gasket failure.

Evidence of Dr Cabbage

5.93 Dr Cabbage examined a number of effects of the initial explosion to try to deduce from them the over-pressures generated. These effects were the bodily translation of the occupants of the Control Room; the trace of the *Tharos* barograph; the damage to the windows of the *Lowland Cavalier*; and the over-pressure experienced by the Chief Engineer of that vessel. Taking first the effects on the occupants of the Control Room, he deduced from the fact that neither was severely injured that the impact velocity which they attained would be less than 8-10 ft/s, which had been shown by work at the Lovelace Institute to be equivalent to a dynamic pressure of 0.3 psi, for which the corresponding air velocity was 58 m/s. In turn this air velocity was related to the explosion over-pressure, or pressure difference between the module and the Control Room. Assuming no wall between these 2 spaces and an over-pressure of 0.5 bar, the air velocity would be 265m/s, or 5 times that apparently experienced

by the 2 occupants. This latter velocity would therefore be in keeping with a firewall failure resulting in a 20% wall porosity. Questioned about the failure of the wall between C Module and the Control Room, Dr Cabbage replied that the wall must have failed for anything to come into the room, and that, given that situation, he would not expect to learn much more from calculations on wall failure. Asked about the effect of his assumption on wall porosity, he agreed that if the porosity were higher, the explosion over-pressure would be less.

5.94 At the initial explosion the *Tharos* itself was some 550m off the west face of Piper, but its barograph, located in the forward control area, was some 620m off. The barograph trace showed between 22.00 and 24.00 hours a deflection equivalent to about 18 mbar. Although the over-pressure from a fuel-air explosion is inversely proportional to the distance in the far field, this relationship breaks down in the near field. For the latter an alternative decay law has been given by Butler and Tonkin; the relationship is valid where there is no significant confinement of the shock wave and the direction is normal to the vent opening, conditions satisfied in the present case. The over-pressure estimated using this equation was 0.675 bar. It was possible, however, that the barograph trace might derive from a later event on Piper when the *Tharos* was 60m and the barograph some 130m off the west face. In that case the trace would correspond to an over-pressure of 0.156 bar. Questioned on the significance of the barograph trace, Dr Cabbage stated that he could go no further than that it was not inconsistent with the other evidence. There was only a single vertical trace. The response characteristics of the instrument were unknown. Apart from its mounting on rubber feet, no special measures had been taken to isolate it from mechanical shocks, which could, therefore, mask the response to pressure changes.

5.95 The *Lowland Cavalier*, lying some 30m off the west face of Piper in line with leg B1, suffered damage to the windows of the handling shack, located near the stern of the vessel and some 45m from the face of C Module. The windows, which were understood to be of standard glass 4-6 mm thick and some 1 metre square, were blown into the shack. The pressure to break such windows is 50-70 mbar, though since the windows were held by a rubber grommet a lower pressure would have sufficed. The Butler and Tonkin equation was again used, although in this case the vessel was not square on to C Module. Assuming a pressure of 50 mbar on the windows, the explosion over-pressure obtained was 0.18 bar. If the explosion was assumed to have occurred in one half of the module, the explosion over-pressure obtained was 0.21 bar. Thus given the assumption on window strength, this case gave a lower bound for the explosion over-pressure of some 0.2 bar.

5.96 According to Captain Clegg, his Chief Engineer was blown from his position on the deck near the bridge superstructure into the bridge bulkhead. To have this effect the pressure exerted on his body would have to exceed 70 mbar. The Chief Engineer would have been some 50m from the crane pedestal. Use was again made of the Butler and Tonkin equation; the explosion over-pressure obtained was 0.39-0.48 bar.

5.97 From the foregoing investigations, Dr Cabbage concluded that the over-pressure generated by the initial explosion was in excess of 0.2 bar and probably in the range 0.4-0.7 bar. He later summarised his evidence to the effect that a reasonable range for the over-pressure was 0.3-0.7 bar.

5.98 Dr Cabbage gave consideration to the use of empirical equations to predict the over-pressures which might be generated by various theoretical release scenarios, but came to the conclusion that such equations could not be applied with any great confidence. He did, however, present results of explosion over-pressure calculations performed using the CLICHE code of British Gas. The code is based on a spherical flame front. It was originally intended for use in simulating explosions in vessels with a high degree of confinement and low flame speeds, but has since been extended to include an external explosion model and to allow investigation of the effects of different

fuels and flow conditions. It has been used successfully to study the effect of these parameters on flame acceleration through obstacles and to predict explosion pressures much higher than those for which it was originally designed. Two cases were studied using the CLICHE code. Both were for a 50% fill of the module with ignition at the east end of the cloud and with firewall failure. Case 1 was for natural gas and case 2 for propane. The vent area at the east end was taken directly from the model and was 25%; it was assumed there was no failure of the centrifugal compressor ductwork. The firewalls were assumed to fail, giving a porosity of 20%. The details of and results for these cases are shown in Table 5.1, where runs C1 and C2 correspond to cases 1 and 2, respectively. The maximum peak over-pressure shown is 0.4 bar for natural gas and 0.5 bar for propane. Run C1 is directly comparable with run 1 of CMI and it can be seen from the table that the results obtained are very similar.

Over-pressures required to destroy firewalls

5.99 Another indication of the over-pressures generated by the initial explosion is the pressures required to destroy the B/C and C/D firewalls. The strength of these firewalls is therefore considered here. However, consideration of the potential missiles from the failure of these firewalls is deferred to Chapter 7 dealing with escalation. As described above, failure of the firewalls in C Module was the subject of a report to Occidental by Technica, spoken to by Dr Cox. The objective of the work was to determine whether the firewalls of either C or B Modules would have failed under the transient pressure imposed by the explosion of a hydrocarbon gas cloud. The work thus involved identifying the mode of failure and the pressure level at which such failure would occur. An account of this work is given here. Further details of the work are given in Appendix G.

5.100 The B/C firewall was a single-layer 4.5 hour integrity wall. It consisted of an array of rectangular panels, bolted into rectangular frames, with adjacent frames bolted together, forming a 'lattice'. The lower edge of the wall was welded to the production deck and its top edge attached to the underside of the upper truss beam by an arrangement of bolted and welded joints. The wall was further supported by clamping to the truss columns. The firewall is illustrated in Fig 5.2; the figure is schematic and is not to a consistent scale. The view seen in the figure is that seen from the inside of C Module looking south. In the analysis of failure of the single-layer firewall the following failure modes were considered: panels, panel bolts, lattice framework, frame bolts, clamps and welds to the deck and to the truss. Dr Cox summarised the analysis as follows. The capacities of both panel and frame bolts would be exceeded at a pressure of about 0.1 barg. Of the 2, the frame bolts were more critical in that failure of these would lead to failure of the lattice. Failure of the clamps would occur at about 0.12 barg and of the panels themselves at about 0.15 barg. In effect, the firewall would disintegrate at over-pressures somewhere in the region of 0.1-0.15 barg. He took the effective failure pressure of the single-layer firewall as 0.1 barg. The behaviour of the single-layer firewall in failure would be as follows. At pressures below about 0.1 barg the panels would start to deflect; at about this pressure frame and panel bolts would start to fail; at pressures above it frames would start to separate and, where the lattice was still intact, panels would start to collapse, whilst the clamps holding the whole wall might start to fail.

5.101 The C/D firewall was a triple-layer 6 hour integrity wall. This wall also differed from the single-layer wall in that the panels were of different size; the frames were smaller, being 7 rather than 3 frames high; there was a complex offset bolting arrangement; the arrangement of the panel and frame bolts was different in detail; and the clamping arrangements were different. The firewall is illustrated in Fig 5.3; the figure is again schematic but in this case the panelling is on the remote side of the lattice. The view in the figure is that seen from the inside of D Module looking south. An analysis similar to that on the single-layer firewall was performed on the triple-layer firewall. Again the frame bolts were the weakest component. Failure of these bolts was predicted to occur at a pressure of 0.12 barg. Failure of the panel bolts in

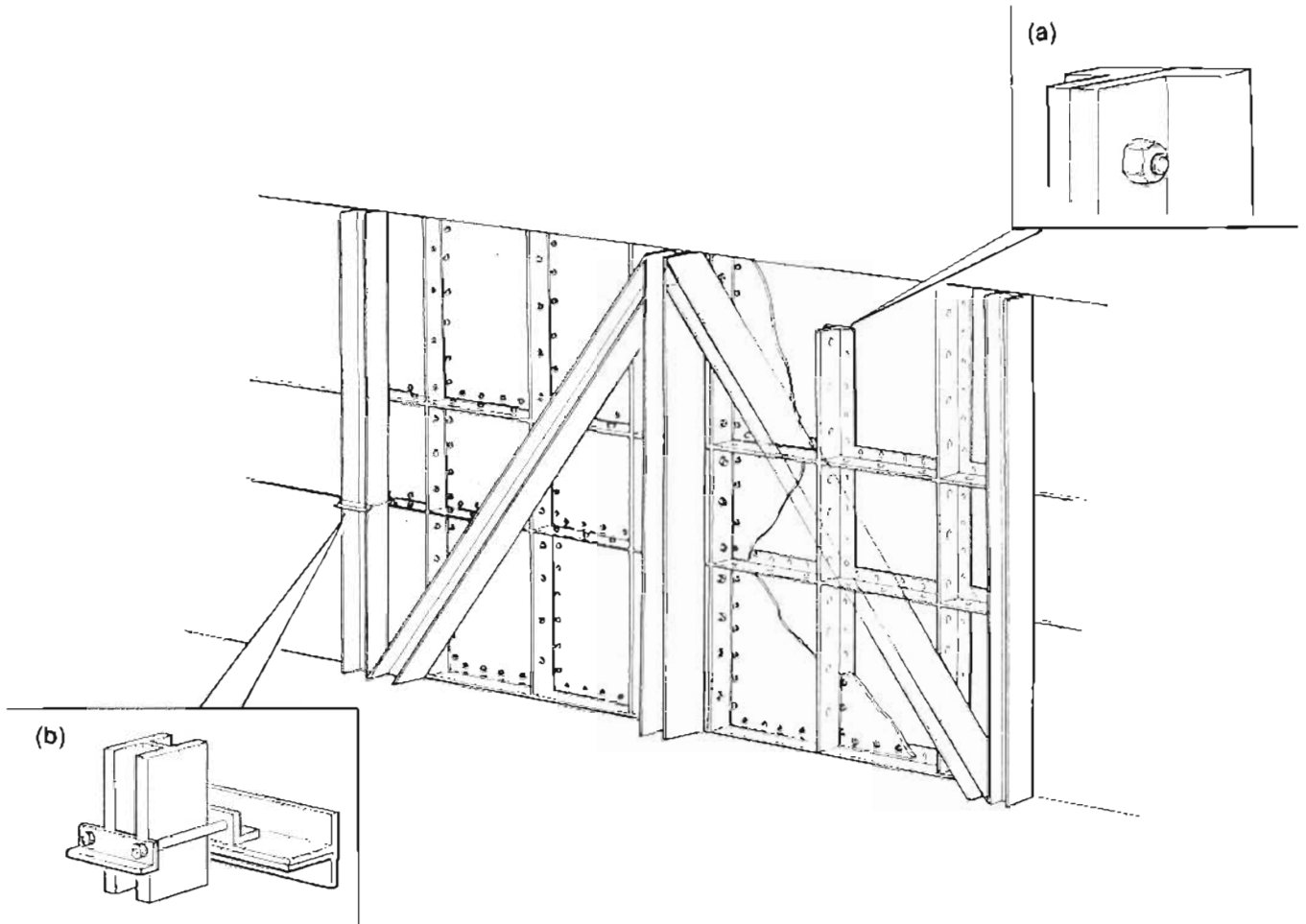


Fig. 5.2 Schematic of single-layer firewall between B and C Modules: insert (a) frame bolt; insert (b) clamps.

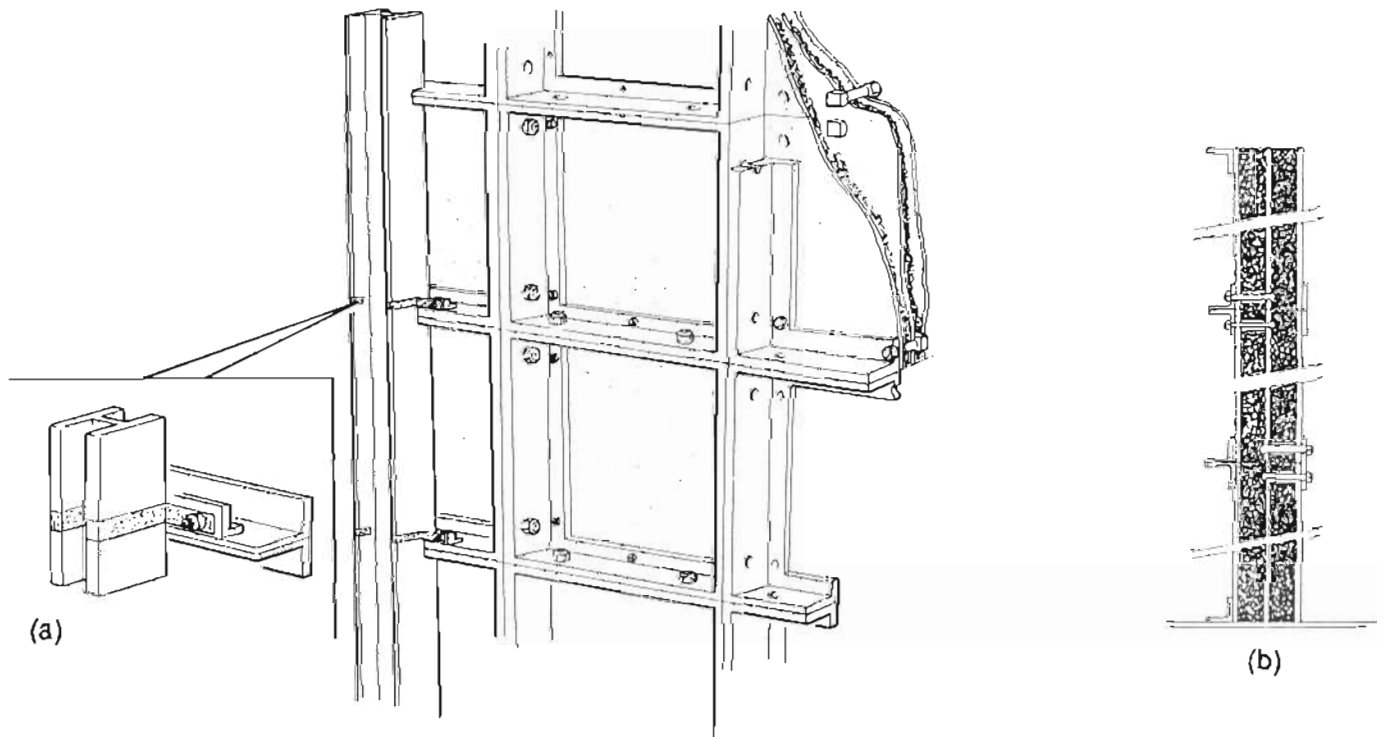


Fig. 5.3 Schematic of triple-layer firewall between C and D Modules: insert (a) clamps; insert (b) cross-section through fire wall, showing three sheets with mineral wool between.

shear loading or tearing of the panel would occur at about the same pressure. The outer sheet of the panels, supported only by very narrow bolts, would also start to fail at about 0.12 barg. However, the inner sheet, being more strongly supported, would not fail until a pressure of about 0.36 barg. This is a higher pressure than the failure pressure of the panels of the single-layer firewall because the panels of the latter are larger. Dr Cox took the effective failure pressure of the triple-layer firewall as 0.12 barg. As far as concerns the failure behaviour of the triple-layer firewall, at pressures below about 0.12 barg the panels would start to deflect; at about this pressure frame and panel bolts would start to fail and panels to tear; at pressures above it frames would start to separate and panels to separate from the frames but not to push through until higher pressures are reached.

5.102 This analysis therefore showed that the pressures required to destroy both the B/C and C/D firewalls, 0.1 and 0.12 barg, respectively, were less than most of the values estimated for the maximum peak over-pressure caused by the initial explosion.

Conclusions

5.103 I draw from this evidence the following conclusions. In terms of the basic questions on the initial explosion posed at the start of the chapter, the conclusions may be summarised as:

1. The explosion occurred at 22.00 hours BST.
2. The explosion was in C Module.
3. The explosion was in the south-east quadrant of C Module.
4. The cause of the fire in B Module was rupture of a pipe which resulted in a fireball and a large oil leak.
5. The 'second explosion' immediately after was probably the pipe rupture and fireball in B Module.
6. The fuel involved was condensate.
7. The gas cloud was a low lying cloud, filling no more than 25% of the module, probably less.
8. The mass of fuel within the flammable part of the cloud was probably in the range 30-80 kg.
9. The location and nature of the source of ignition are unknown, but the location was probably such as to favour high over-pressures.
10. The explosion was a deflagration.
11. The maximum peak over-pressure of the explosion was probably in the range 0.2-0.4 bar.

The explanation of the effects on personnel and of the damage to equipment are complex and are considered below.

5.104 The time of the initial explosion was about, and quite possibly almost exactly at, 22.00 hours BST. A number of witnesses recalled hearing the start of the 10 o'clock news. The *Lowland Cavalier* and the *Tharos* logged the event as 22.00 hours and 22.02 hours respectively, and Wick radio the mayday from the former at 22.02 hours.

5.105 The facts that the gas alarms occurred in C Module; that there was severe damage in D Module, particularly to the main and emergency electrical systems, and in the Control Room and Mechanical Workshop, indicating destruction of most of the C/D firewall; that the A/B firewall was apparently intact and that the heat shield on the south side of A Module was undamaged, are the principal factors in holding that the initial explosion was in C Module. The gas alarms were in the south-east quadrant of C Module. The explosion was strong enough to destroy most of the firewalls. There was, however, no inrush of hot gas into the Control Room. These facts point to the south-east quadrant as the location of the explosion within C Module.

5.106 The initial explosion was followed immediately by a large oil pool fire in B Module, giving rise to a massive plume of black smoke. A large fireball issued from the west end of the module. There was clearly a rupture of equipment containing hydrocarbons in that module. The fireball appears to have issued from a pipe. Several witnesses described as a "second explosion" an event which occurred within seconds, or maybe up to 20 seconds, of the initial explosion. One explanation is that this was the rupture and fireball in B Module. This fits in particular with the flash and bang experienced by Mr Parrydavies, though there must be some doubt as to how loud such an event would have been.

5.107 The strength of the initial explosion was such that it must have been caused by ignition of a gas cloud of considerable size. If the gas had been of positive or neutral buoyancy, a different pattern of gas alarms would be expected. The flame described by Captain Clegg was in the lower half of the module. These 2 factors point to a cloud of gas heavier than air, in other words condensate. However, although there is a minimum cloud size consistent with the strength of the explosion, there is also a maximum size. It is difficult to see how a cloud much larger than about 25% fill of the module could develop without setting off a different pattern of gas alarms. Moreover, the fact that there was no rush of hot gas into the Control Room is a further factor limiting cloud size. It is probable that the size of the gas cloud was appreciably less than 25% fill. The analysis of the explosion effects is relatively crude but points to a mass of fuel in the flammable part of the cloud within the range 30-80 kg.

5.108 There is little to assist in determining the location or nature of the ignition source. However, given the strength of the explosion and the limited size of the cloud, the location of the ignition source was probably such as to favour higher rather than lower over-pressures. It was the unanimous view of the expert witnesses that it was unlikely that the initial explosion was a detonation and this view is adopted. The explosion is therefore held to have been a deflagration. The over-pressure required to cause failure of the firewalls, about 0.1 bar, sets a lower limit to that of the initial explosion. Moreover, since failure seems to have occurred over a large proportion of both firewalls, the lower limit for the peak over-pressure at that point in the cloud where it was at a maximum is probably about 0.2 bar. Dr Cubbage's estimates of this maximum peak over-pressure based on various effects, including those on the occupants of the Control Room, ranged between 0.2 and 0.7 bar. Dr Scilly's estimate based only on effects in the Control Room was about 0.3 bar. All these estimates are very approximate. The higher values are more difficult to explain in terms of cloud size and ignition source. Hence the most probable range for the maximum peak over-pressure of the initial explosion is considered to be 0.2-0.4 bar.

5.109 With regard to the effects of the initial explosion on personnel, those experienced by Mr Bolland and Mr Clark in the Control Room and by Mr Elliott and Mr Jackson on the north landing are explicable in terms of an explosion occurring in, and venting from, C Module. The effects on Mr Bradley and Mr Ralph at the 20 ft level were more complex, but they are probably explicable in terms of an explosion venting from C Module and of platform vibration. No clear explanation emerged of the effects experienced by Mr Niven and the damage in the dive complex area, particularly that to the doors of the decompression chamber and the Dive Machinery Room. I note, however, the possibility that there may have occurred at the east end of C Module an external explosion, a phenomenon which was not considered in Part 1, but which was described in the evidence given by Dr Chamberlain in Part 2. In any event, these effects do not materially affect my conclusions.

5.110 The conclusions which I have just given relate to the initial explosion and to the flammable gas cloud involved. They are drawn from the evidence presented in this chapter. Further relevant evidence is given in Chapter 6 and results in some refinement, but no major revision, of these conclusions.

Table 5.1 - Details and results of explosion simulations using FLACS and CLICHE codes

Code	FLACS					CLICHE			
Sponsor	DEn					Technica		Inquiry	
Run	1	2	3	4	5	T1	T2	C1	C2
Type of fuel	NG	NG	C	NG	C	NG	NG	NG	P
Location of ignition source									
(a) in module	EE	M	M	EE	M	EE	M	EE	EE
(b) in cloud	E	C	C	E	C	E	E	E	E
(c) point X or Y in Fig 5.1	X	Y	Y	X	Y	-	-	-	-
Proportion of module filled (%)	50	50	50	30	50	100	25	50	50
Wall behaviour	FL	FL	FL	FL	FX	FX	FX	FL	FL
Over-pressure (barg)									
P1/P5	0.43/ 0.37	0.55/ 0.51	0.69/ 0.62	0.11/ 0.10	1.54/ 1.89	-	-	0.4	0.5
P4/P8	0.34/ 0.37	0.67/ 0.72	0.77/ 0.84	0.19/ 0.19	1.48/ 1.62	-	-	0.3	0.4

Notes:

- (a) NG = natural gas; C = condensate; P = propane
- (b) EE = east end; M = middle
- (c) E = edge; C = centre
- (d) FL = wall fails; FX = wall fixed, does not fail. For wall porosity after failure see Appendix G (para G.18).
- (e) The location of points P1-P8 is given in Fig 5.1
- (f) The over-pressures for Runs T1 and T2 were measured at different points. The maximum values for the 2 runs were 0.45 and 0.25 bar, respectively.
- (g) The over-pressures for Runs C1 and C2 were obtained by interpolation.
- (h) See also Table 6.2.

Chapter 6

Explanation of Initial Explosion

6.1 In the previous chapter I described the initial explosion and drew certain conclusions about it. In particular, I concluded that:

1. The explosion occurred at 22.00 hours BST.
2. The explosion was in the south-east quadrant of C Module.
3. The fuel involved was condensate.
4. The mass of fuel within the flammable part of the cloud was probably in the range 30-80 kg.

As far as concerns the leak, however, whilst it follows that it was one of condensate and that it occurred in the minutes leading up to 22.00 hours, I have at this stage drawn no conclusion as to the location of the leak, as opposed to that of the gas cloud, or as to the leak rate. It is to the leak, therefore, and the cause of the leak, that I now turn in this chapter. I describe first the events and activities centring on the Control Room (paras 6.2-17). Next I consider a body of evidence bearing on the characteristics of the leak, namely the noises heard just before the initial explosion (paras 6.18-22), wind tunnel tests on the formation of the gas cloud (paras 6.23-37), computer simulations of the explosion of the flammable gas cloud (paras 6.38-43), and source of ignition (paras 6.44-46), and give my observations on the leak (para 6.47). I then state scenarios to explain the leak (paras 6.48-54), explore these scenarios (paras 6.55-176) and finally give my conclusions on the cause of the leak together with certain observations (paras 6.177-197).

Events and activities centring on the Control Room immediately before initial explosion

6.2 Evidence on the events in the Control Room just before the explosion was given by Mr Bollands, the Control Room operator, and Mr Clark, the maintenance lead hand, and that on activities at the condensate injection pumps by these 2 and by Mr Grieve, the phase 2 operator, and Mr Young, an instrument technician. The other 2 principal participants, Mr R A Vernon, the lead operator, and Mr R M Richard, the phase 1 operator, died in the disaster. I begin by describing the events in the Control Room, and the evidence of its occupants on those at the condensate injection pumps. I defer my account of the evidence of Mr Grieve and Mr Young on the activities at these pumps. The personnel on duty on the night and on preceding shifts are shown in Table 6.1.

6.3 It is appropriate to mention at this juncture that the pressure safety valve, PSV 504, on condensate injection pump A had been removed for recertification work and had not been replaced. PSV 504, which was the only pressure safety valve on the pump, was just to the east of the reciprocating compressors in the south-east quadrant of C Module, as shown in Plate 9. PSV 504 was 15 ft above the floor of the module and there was scaffolding up, with a working platform to give access to the valve at waist height.

Condensate injection pumps

6.4 About 21.45-21.50 hours the working condensate injection pump, B pump, tripped. Evidence on this was given by the Control Room operator, Mr Bollands. He estimated the time of the trip as "10 to tenish". Mr Vernon was in the Control Room at the time and left at once. He did not say where he was going, but Mr Bollands was sure it was to the condensate pumps. Mr Bollands stated that, following normal procedure, he got in touch by radio with the phase 1 operator, Mr Richard who was probably in C Module. Mr Richard acknowledged and Mr Bollands told him that the

condensate pump had tripped. Mr Bolland did not know where Mr Richard was at the time, but he did not appear to be aware of the trip. Mr Richard did not reply, but Mr Bolland was confident that he would have gone straight to the pump. Mr Bolland believed that Mr Vernon left before contact was made with Mr Richard. Mr Grieve gave the time when he heard Mr Bolland call to Mr Richard as 21.45 hours, but was very unsure. On the other hand Mr Clark was quite firm that it was 21.45 hours when he was first contacted by tannoy to go to the Control Room; he looked at his watch, as was his habit.

6.5 While Mr Vernon was out an alarm came up in the Control Room for JCP 057, the local condensate injection pump panel. Mr Bolland interpreted it as the JT flash drum high level alarm. He pressed the button to acknowledge it; the light stayed on. He contacted Mr Richard. He told him that he had a JCP alarm and that it would be the JT flash drum high level alarm. Mr Bolland said it was standard practice on receipt of a JT flash drum high level alarm to unload the reciprocating compressors. This would reduce the flow of condensate into the JT flash drum. He believed that he asked Mr Richard to do this and that Mr Richard would have done so anyway as he went down to the 68 ft level. At this stage he regarded the situation as urgent, but there was no panic. He estimated that with the reciprocating compressors unloaded they would have about half an hour before they would need to shut down.

6.6 Mr Clark stated that unless recovered, loss of the condensate pump would lead in due course to loss of the gas plant and hence of the gas supply to the JB generators. If the automatic changeover to diesel fuel then failed, which it sometimes did, there would be a total loss of power and what he described as a "black start". He had experienced it quite a few times. He regarded this as a situation of some urgency. For example, if drilling were taking power from the main generators and they were down a hole and their own generator did not kick in quick enough, the drill could get stuck. There were differing views as to how frequent and how serious loss of power was and therefore how much pressure operators would be under to keep the plant running.

6.7 Soon afterwards Mr Vernon came back into the Control Room. Mr Bolland asked him what was the matter. Mr Vernon said B pump would not restart. He was not sure what the problem was, but mentioned lube oil and said that he could see quite a bit of oil around the pump. However, Mr Bolland said that he believed hydrates were also being considered as a cause of the trip. Mr Vernon said the A pump was out for maintenance. An instrument PM was underway on it and it was electrically isolated. He wanted to get the pump PTW signed off so that the pump could be electrically reinstated. He made no mention of PSV 504 being off. He got on the PA system to Mr Clark. Mr Vernon retrieved the PTW for A pump. Mr Bolland believed he got it from the box holding the permits for the 68 ft level, though he did not actually see him put his hand in the box. It was possible he had got it from the Safety Office. Mr Bolland understood the PTW was for an instrument PM. There were 2 red tags on it, which he interpreted to mean that the switchgear and the lube oil pump were both electrically isolated. Mr Bolland checked with Mr Vernon that the reciprocating compressors were unloaded and on recycle and was told they were; he was quite sure about this. He was rather less sure about his dealings with Mr Richard on this.

6.8 On the events which now followed there was some conflict between the evidence of Mr Bolland and Mr Clark. According to Mr Bolland, Mr Clark telephoned in and Mr Vernon told him that he wanted work stopped on A pump so that it could be electrically reinstated and started up. Mr Clark came down to the Control Room. Mr Bolland stated that Mr Vernon and Mr Clark signed off the tags together. He did not actually see them signing, but that was the procedure. He said he could recollect Mr Vernon speaking to Mr Clark. He also stated that Mr Clark tannoyed for the day electrician, Mr J J D Savage, from the Control Room; he did this by using the

telephone which accessed the PA system. He had to call twice before Mr Savage answered. Mr Clark then tried to get in touch with the night-shift electricians.

6.9 Mr Clark's recollection was different. He was in the maintenance superintendent's office with Mr K White, the acting maintenance superintendent, when he heard the tannoy call for him. He rang the Control Room. He was unsure who answered the 'phone, but he believed it was Mr Bollands; he did not recollect speaking to Mr Vernon either on the 'phone or in the Control Room. He was told that condensate injection pump B had tripped and could not be restarted. He stated that it was agreed on the 'phone to start the other pump. Mr Vernon would sign off the isolation tags and he, Mr Clark, would come down and sign them off also. He was unsure who first suggested this plan of action; it was instantaneous really. Mr Clark said he tannoyed for an electrician, Mr Savage, to contact him in the Control Room and then set off there. He believed that the only person there was Mr Bollands and that Mr Vernon was not there. He found the red tags, already signed off by Mr Vernon, on the desk, but no PTW. He was about to start signing the red tags when Mr Savage rang through; he spoke to Mr Savage while still signing the tags. Mr Savage said he was going off shift, so Mr Clark told him not to bother; he decided it would be quicker to get one of the 2 night-shift electricians who were on duty.

6.10 Some difficulty arose over the timing of Mr Clark's movements. He stated that he heard the tannoy message at approximately 21.45 hours; he was sure of this as it was his practice to look at his watch when he received a message. It was put to him that in his statement to Occidental he had given a time of 21.45-21.50 hours, but he stuck to his evidence that the call was at 21.45 hours. He stated that he left the maintenance office within 1 or 2 minutes of the tannoy call. He ran down so as to reach the Control Room before Mr Savage rang through. He estimated that his journey down to the Control Room would take 2-3 minutes. He stated that he had just arrived and was about to start on the red tags when Mr Savage rang in. He then signed the tags and checked the time on his watch as a few minutes past 10 (sic). It was put to him that there was a period of some 10 minutes unaccounted for, but he was unable to explain this. He agreed that some time must have elapsed between the initial trip of B pump and the tannoy call to him, since attempts had been made to restart B pump. He believed he may have had a conversation with Mr Bollands. He also said that he looked on the mimic panel to see if the reciprocating compressors were unloaded and saw that they were.

6.11 In any event, Mr Vernon went back down to the condensate injection pumps. Asked to estimate timings, Mr Bollands put the interval between Mr Vernon's departure and the initial explosion as some 5 minutes; the figure was approximate, it might have been 4, 6 or 7 minutes. Given that he was in a hurry, it would have taken him no more than 2 minutes to get down to the pumps. He would have had at least 3 minutes there before the initial explosion.

Compressor trips and gas alarms

6.12 About this point there began the sequence of trips and alarms which terminated in the initial explosion. Mr Bollands stated that 2 centrifugal compressors tripped; he was sure B was one of them, but uncertain whether the other was A or C. He informed Mr Richard of this and the latter acknowledged. He believed, but was not sure, that by this time Mr Vernon had gone. He estimated the timing as some 5 minutes after the initial pump trip and 5 minutes before the initial explosion.

6.13 There also occurred a low level gas alarm in C Module. The alarm was on C centrifugal compressor (zone C3); Mr Bollands was quite sure of that. He did not go round the back of the panel to check which of the individual detectors it was, but contacted Mr Richard, who acknowledged. Mr Bollands stated that he was able to talk to Mr Richard about this alarm. Mr Bollands did express some uncertainty as to whether the 2 compressor trips or the low gas alarm occurred first; he said he tended

to get mixed up about the order. At one point he had a feeling that the low gas alarm came first. However, in his statements both to Occidental and to the Crown he stated that the compressor trips came first, and this was also the burden of his evidence.

6.14 With the loss of the condensate injection pump and of the 2 compressors the situation had become more serious; as Mr Bollands put it, the gas plant was just about lost and they were 90% into a shutdown. However, in his 8 or 9 years he had experienced this situation perhaps a dozen, even 20, times; he was unsure if he had met it in phase 1 operation before, though he thought it probable. He had confidence in the operators and felt the situation was under control. He could not recollect a total shutdown due to such a situation and did not consider initiating a shutdown.

6.15 Then, as Mr Bollands described it, things happened very quickly. The third centrifugal compressor tripped. He accepted the alarm. There passed through his mind the desirability of carrying out a manual changeover of the main generators from fuel gas to diesel, to avert any failure of the automatic changeover to diesel which would be initiated if the gas supply were lost completely. He had no time to take action, however, before a further set of gas alarms then came up, 3 low gas and 1 high gas. The 3 low gas alarms were for C Module East (zone C2) and for A and B centrifugal compressors (zones C5 and C4); the high gas alarm was for one of the centrifugal compressors, but he did not know which. These alarms came up in such rapid succession that he was unsure of the order; he never had time to silence the audible alarm. He made contact with Mr Richard again by radio but conversation was impossible due to the noise of the alarm. He was still trying to speak to Mr Richard, the alarm was still sounding and he had his hand out to silence it when the initial explosion occurred. Mr Bollands said that he did not know whether Mr Richard had reached C Module; though he did at one point say Mr Richard identified the first gas alarm as C centrifugal compressor.

6.16 The other person in the Control Room was Mr Clark. He said that he was unaware of the 2 centrifugal compressors tripping but he did experience the first low gas alarm. He could not say if this alarm came up before he had signed the tags or just after; everything seemed to happen at once. He put the time at 22.00 hours or just after. Mr Bollands accepted the alarm and radioed Mr Richard and asked him to check it out. Mr Clark said that this low gas alarm was for C Module East. He did not see this himself on the F & G matrix and appeared to rely on his recollection that Mr Bollands had said "C Module East" in his message to Mr Richard. Then just as he was about to leave the Control Room a further gas alarm came up, Mr Bollands went to accept it and the initial explosion occurred.

6.17 Mr Bollands was questioned on a number of aspects of the gas alarms. With regard to timing, he gave various estimates of the time intervals after the first gas alarm. He put the interval between that alarm and the final group of alarms as a minute or so. The final group came up within seconds of each other. He described the first gas alarm as occurring within the last couple of minutes before the explosion. He estimated the interval between the first gas alarm and the explosion as a couple of minutes, but this was not an exact time, it could have been more. As for the pattern of gas alarms, he believed the fact that several centrifugal compressor zone gas alarms came up indicated that the leak was outside the compartment of any single compressor. It was put to him that the pattern was consistent with a leak from the site of PSV 504, but he was non-committal.

Noises immediately before initial explosion

6.18 I now turn to consider the further evidence on the leak which gave rise to the gas alarms, starting with the noises heard just prior to the initial explosion, which were described in Chapter 5. As there mentioned, these noises were analysed in a report by Mr A H Middleton of Anthony Best Dynamics Ltd. Mr Middleton was of the view that all the noises except those heard in the Mechanical and Instrument

Workshops were explicable as noises from the flare or its pipework. For the analysis of the noises heard in these workshops he used a variety of information, which included details of the workshop construction, a noise survey of Piper, recordings of air starter motors made onshore and on Claymore, of human screams and of flange leak tests. He was discouraged from interviewing survivors. For the Mechanical Workshops he estimated that the background level of noise was about 62 dBA and that for a sound to be described as very loud it would need to be 15-20 dBA in excess of this, in other words at least 77 dBA in the workshop. He also estimated the noise attenuation between C Module and the workshop as about 27 dBA, so that the source would need to be at least 104 dBA.

6.19 Mr Middleton discussed the quality of the noise heard. He explained the term quality as a combination of the pitch, or frequency of the fundamental note, plus the levels of any harmonics. The noise was described variously as like an air starter motor or a human scream. He stated that analysis of these 2 types of noise showed them to have frequency spectra which compared fairly well. He believed that the noise would have comprised a harmonic series of tones within the 6-500 kHz range. As far as concerns the noise from a leak of high pressure fluid, he explained that the loudness, or sound power, of the noise would depend on the mass flow. But the noise heard was evidently not just a broad band noise; it contained strong tones. He stated that most leaks of fluid would give a noise like a hiss rather than a scream. For strong tones to be generated something more complex than a simple hole would be required. An edge tone might be generated by a hole with complex geometry or a tone might be generated by a mechanical oscillator. He also stated that there would be greater variations in individuals' perception of tones than of broad band noise.

6.20 Mr Middleton played to the Inquiry a tape of the Newsco leak tests, described below (paras 6.122-123). The noises produced by most of these tests did not correspond with the descriptions given by the witnesses in the workshops nor with the frequency analysis of air starters and human screams. There was, however, one test which did have a particular degree of correspondence. This was a test in which a Metaflex gasket was used. Mr Middleton stated that he observed this test on video and postulated that oscillation of the gasket might be the cause of the tone, but he also said that such oscillation was only one of many possibilities. He was of the view, however, that there were a variety of geometries which might produce tones and that it was immaterial that one particular test reproduced tone generation whilst others did not.

6.21 With regard to the noise heard in the workshops, Mr Middleton listed 3 most likely sources of noise: metal-to-metal grinding; pressure letdown across a control valve; and leak of a high pressure fluid. Metal-to-metal grinding could produce tones, but tended to be very short-lived, and was unlikely to be the source. For pressure letdown across a control valve, he eliminated all possibilities except PCV 501, but considered that this was unlikely to produce a noise with scream-like quality. He judged the most likely source to be a high pressure leak. Given the right geometry such a leak could produce a high noise level with pure tones or a harmonic series of tones. He stressed that his judgement was based on the descriptions of the noise as being like an air starter or a human scream; however, he ruled out these specific events as the source of the noise. He believed that the noise heard by the 4 survivors from the tea room of the Mechanical Workshop and Mr Cassidy in the Instrument Workshop was a fluid leak as was the noise heard by Mr Young. He could find no reason why Mr Lamb should not have heard the noise. For the duration of the noise, he preferred the estimate of some 30 seconds on the basis that this was the most common figure. Mr Cassidy estimated the duration of the noise, which he found frightening, as 3-4 minutes. Mr Middleton believed this must be an over-estimate, since he would expect the hearer not to wait so long before taking action. Asked whether the noise described was consistent with a leak of fluid diminishing in pressure, Mr Middleton replied that he believed it was. Gradual reduction in pressure would cause the pitch to fall, but the noise might still be like a scream. He put the probable location of the source of

the noise in C Module. He had not investigated the possibility that it was in B Module, but considered that if it were, it must have been very loud.

6.22 I think it likely that the noise heard in the workshops was from the leak. The principal thing which I take from this evidence about the noise is that the leak lasted for some 30 seconds. Also the evidence lends some support to the view that the release was a high pressure leak from a flange.

Formation of flammable gas cloud

6.23 The evidence on the initial explosion described in Chapter 5 pointed to a leak in the south-east quadrant of C Module of a size sufficient to cause the formation of a large cloud of flammable gas containing within the flammable limits some 30-80 kg of fuel. It was not clear, however, whether this could be reconciled with the evidence of Mr Bolland on the pattern of gas alarms. It was difficult to envisage how a leak of sufficient size could occur in this quadrant without first setting off gas alarms on the nearby gas detectors, G101/1 and G101/2, both in zone C2 and without setting off the second group of gas alarms more rapidly. In other words, there was a problem of both sequence and timing of the gas alarms. The Inquiry therefore decided to commission wind tunnel tests to explore the types of gas leak which might give rise to the observed pattern of alarms. In view of the pattern of gas alarms, the events and activities at the condensate injection pumps and the information that PSV 504 had been removed and not replaced, the possibility of a leak from the site of PSV 504 was one of the principal scenarios under consideration and such a leak was one of the main cases explored in the tests. The wind tunnel tests were performed by BMT Fluid Mechanics Ltd at their wind tunnel site at Teddington and were spoken to by Dr M E Davies, Managing Director. An account of this work is given here and further details are given in Appendix G.

Wind tunnel tests: first set

6.24 Two sets of experiments were carried out, each consisting of a number of runs; each run was termed a 'series' since a given run was often repeated. The first set of experiments investigated a number of different leaks, with emphasis on leaks from the area of PSV 504. The second set was concerned with leaks of neutrally buoyant gas. The aim of the first, and main, set of tests was to study the dispersion characteristics of different leaks, principally leaks of condensate near PSV 504, not so much to replicate any particular leak scenario but to explore the sequence and timing of alarms and the formation of the flammable gas cloud. Another feature of interest was the possible effect of ingestion of air into the centrifugal compressor turbines and of exhaust from these machines.

6.25 The set of tests conducted is shown in Table G.2. The 2 gases simulated were propane at -42°C and a cold methane, propane and ethane mixture modelled as neutrally buoyant. The latter was used only in the last series, series 44. The locations of the leaks investigated are denoted as positions 1-3 in Fig J.10, position 1 being the site of PSV 504 and therefore of particular interest. Series 10-42 simulated a leak at position 1. The leak rates ranged from 1 kg/min in series 38 up to 100 kg/min in series 42. Various leak configurations were covered. In series 10-11, 16-26 and 41 the leak was a jet. The jet was a hole in a horizontal pipe running in the north-south direction with the jet directed downwards and towards the east (at the 5 o'clock position looking towards the north). In series 27 it was a jet impinging on a flat plate at 1m distance, the plate simulating the scaffolding platform. In series 29-33, 35, 36, 38-40 and 42 it was a partial circumferential leak with one 120 sector open; in series 28 a similar partial circumferential leak but with 2 sectors open; and in series 12-15 and 34 a full circumferential leak with all 3 sectors open. Series 43 simulated a leak from position 2 with a 1-sector partial circumferential aperture and series 44 a leak from position 3 with a full circumferential aperture and with neutrally buoyant gas. Results presented included for the concentrations seen by the gas detectors the steady-state concentrations, the times to low level alarm and the times to high level alarm. A selection of

the results is given in Table G.3. Results for series 43 and 44, which are for locations other than position 1, are included in Table G.4.

6.26 The concentrations and, to a lesser extent, the cloud development times, were affected mainly by changes in leak rates. They were not greatly influenced by detailed source configuration. Within the range tested the cloud concentrations and development times were relatively insensitive to compressor/turbine ingestion rates. A range of leak scenarios at PSV 504 produced a low cloud beneath sensor G101/1. For such leaks zone C3 generally saw the highest gas concentrations and gave the earliest low and high level alarms. However, whether the first low level alarm occurred in C3 or C2 depended on the configuration of the leak. Where the release was a jet or partial fan oriented generally downwards or towards the east, the first low level alarm occurred in C3 rather than C2. This is illustrated by series 16, 19, 26, 32, 35 and 42. Where the release was a full circumferential leak or a jet impinging on a plate that alarm occurred in the C2. This is illustrated by series 15 and 27. In particular, series 26 and 27 are directly comparable. Increasing leak rate decreased the time to alarm, but made much less difference to the sequence of alarms. This is illustrated in series 35 and 42 which were for identical conditions except that the leak rates were 10 and 100 kg/min, respectively. For any significant release the time delay between the low level alarms in C3 and C4 was less than 20 seconds. As far as concerns small leaks, a leak of 4 kg/min, series 36, gave an alarm in C3 followed 35 seconds later by an alarm in C2 and a further 15 seconds later an alarm in C4, but no alarm in C5 and no high alarm. Still smaller leaks, say less than 2 kg/min, gave a low level alarm only in C3. For the leak of condensate on the north side (position 2) the first low level alarm was in zone C2.

6.27 It became apparent that only the larger leaks could give a flammable gas cloud containing the quantity of fuel evidently necessary to cause the observed explosion effects. Interest centred therefore particularly on series 42, which was the only test at a leak rate of 100 kg/min. In this test the low level alarms occurred first for C3 in 5 seconds, then for C2, C4 and C5 in 15, 20 and 25 seconds, respectively. A high level alarm occurred first at C3 in 10 seconds. Thus the alarm levels in most areas occurred rapidly. This leak gave a gas cloud containing 30 kg of fuel within the flammable limits in 30 seconds and 45 kg within 120 seconds.

Wind tunnel tests: second set

6.28 The second set of tests is shown in Table G.2. The neutrally buoyant gas mixture was used in all series in this set and 4 different locations, positions 1-4, shown in Fig J.10, were used. Also considered here are the last 2 tests of the first set, series 43 and 44, which were for positions other than position 1. Series 43 was for propane and series 44 for neutrally buoyant gas. Series 45-48 simulated a leak of 100 kg/min from a jet at different locations and series 49-51 a leak of 1 kg/min from different locations. Series 52 simulated a release from a 3½ inch diameter pipe directed horizontally towards the south wall at position 1. Results presented were similar to those for the first set of tests. A selection of the results is given in Table G.4. The tests showed that the 1 kg/min leaks of series 49-51 gave steady-state gas concentrations which did not exceed 0.4% and did not set off even the low level alarms. A 100 kg/min leak near PSV 504, series 45, rapidly activated low level alarms with the C2 alarm being last. It did not, however, trigger any high level alarm. The other 100 kg/min leaks, series 46-48, activated low level alarms but with larger time intervals and with the C2 alarm being first. They also set off high level alarms, notably in the C2 area. The 100 kg/min release from the pipe, series 52, gave rise to both low and high level alarms with the C2 alarm the first to be activated. With the exception of the pipe release, the size of the flammable clouds formed from the 100 kg/min leaks tended to be smaller than that produced by a similar release of propane. Differences in the flammability limits of the 2 gases appeared to be more important in producing this effect than differences in the concentrations. The possibility was raised that there might have been a massive, near-instantaneous release, say 100 kg/s, from the open

pipe at position 1. Dr Davies felt that such a 60-fold increase was outside the range of values for which extrapolation could sensibly be attempted.

Shape and size of flammable cloud

6.29 The detailed development of the flammable gas cloud for the 100 kg/min leak in series 42 is shown in Fig 6.1. Figs 6.1(a)-(c) give the contours of the LEL of the cloud at low, medium and high levels, respectively, at times 15, 30, 45 and 100 seconds and Fig 6.1(d) the LEL contours at different heights at 30 seconds. The floor level LEL contour at 100 seconds was close to the final steady-state contour. Information on the mass of fuel within the flammable part of the cloud for different leak rates was presented in 2 ways. Fig 6.2 shows the growth of the mass of fuel, both total mass and mass within the flammable region, as a function of time for series 15, 42 and 45. For the first 2 cases a steady state is reached after about 100 seconds, and for the third after about 140 seconds. For the 100 kg/min leak of series 42 the mass within the flammable region is some 30 kg at 30 seconds, 40 kg at 60 seconds and 45 kg at steady-state at about 100 seconds. Fig 6.3 shows the effect of increasing leak rate on the mass of fuel within the flammable limits, based on series 15 and 42. The graph shows that after 30 seconds as the leak rate increases the mass of fuel reaches 30 kg at a leak rate of 100 kg/min, 45 kg at a leak rate of 110 kg/min and thereafter rises rapidly and that at steady-state the mass of fuel reaches 30 kg at 85 kg/min, 45 kg at 100 kg/min and thereafter rises rapidly.

2-stage leak hypothesis

6.30 From his results Dr Davies concluded that if the time interval between the initial alarm in C3 and the final set of alarms was as long as Mr Bolland's believed, this could be explained only on the hypothesis of a 2-stage leak or of 2 independent leaks. He thought the latter highly improbable. The 2-stage leak would be a leak initially at a low rate, say 1-2 kg/min, which then became a leak at a much larger rate or perhaps a large but non-continuous release.

6.31 As discussed in Appendix G the wind tunnel tests were subject to certain limitations and uncertainties, both in respect of the experiments and of the data furnished for the Piper conditions. They illustrate trends rather than give absolute values.

Observations on wind tunnel tests

6.32 The estimate of the mass of fuel within the flammable limits of the gas cloud required to cause the initial explosion was given in Chapter 5 as some 30-80 kg. The results of the explosion simulation described below (paras 6.38-43) indicate that a cloud containing much less than 45 kg of fuel would not give a sufficiently large explosion. It follows that at least in its final stages the leak was some 110 kg/min or more. The figures of 45 kg and 110 kg/min derive from test series 42 and it is convenient to use them as a basis for discussion, but they probably lie towards the lower limit of the true values. Attention is therefore concentrated primarily on those tests at the higher leak rates.

6.33 What the wind tunnel tests show is that at these higher leak rates the times to, and time intervals between, the low level alarms are very short. In none of the large leak tests is the interval between the first and second low level alarms more than 10-15 seconds. The gap between such a time interval and the interval between the first alarm and final group of alarms described by Mr Bolland's appears unbridgeable. The conclusion that the leak occurred in 2 stages, or rather that there was an increase, gradual or sudden, in the size of the leak, seems inescapable.

6.34 The tests point to the later, larger leak as being one of propane from position 1, from a downward pointing jet or partial fan. The 2 sets of test results given taken

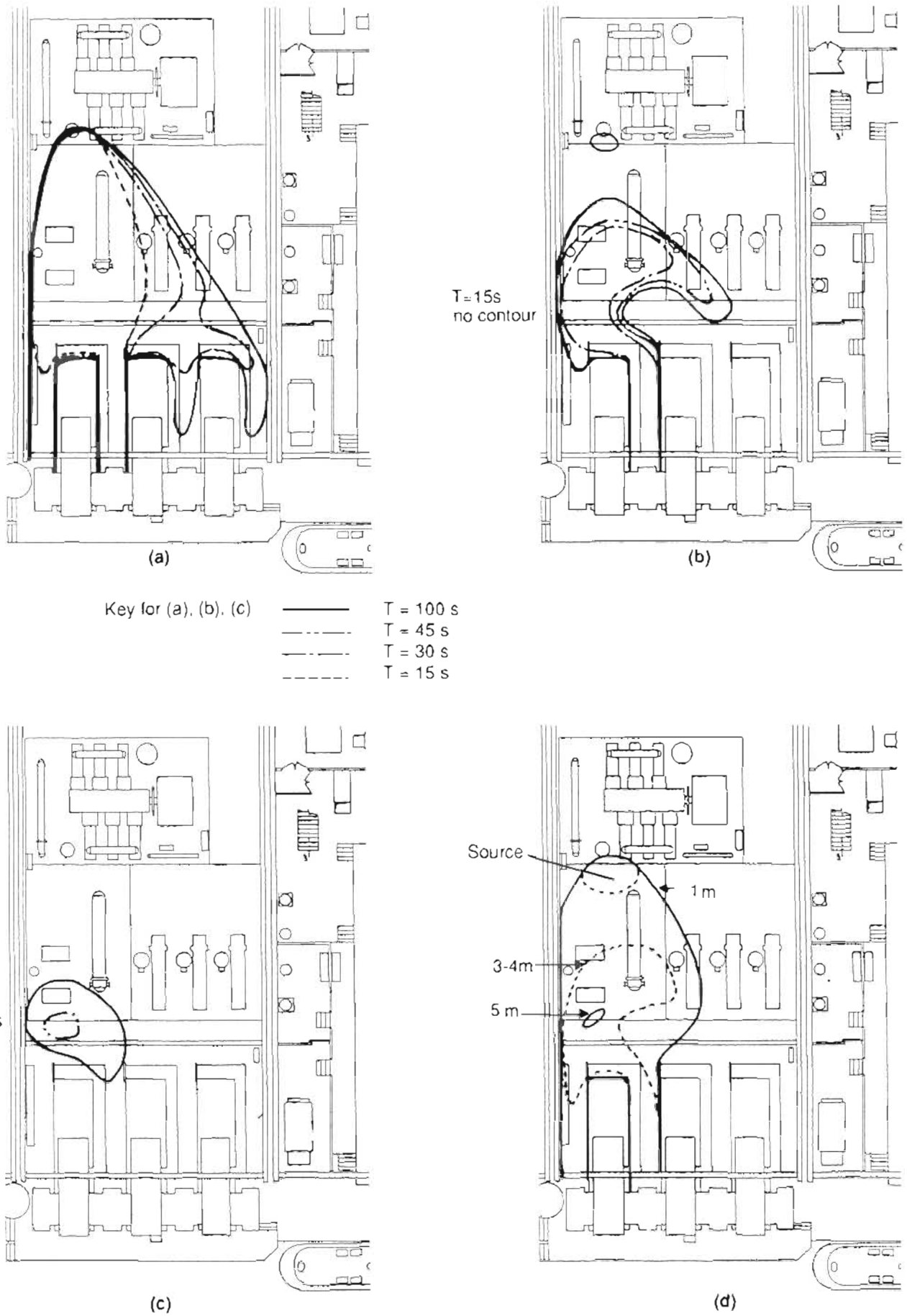


Fig. 6.1 Growth of the flammable gas cloud for leak of 100 kg/min (Series 42) in the BMT wind tunnel tests: (a) LEL contours at low level ($< 1.7\text{m}$); (b) LEL contours at intermediate level (ca. 3.5m); (c) LEL contours at high level (ca. 5.5m); and (d) LEL contours at 30 seconds.

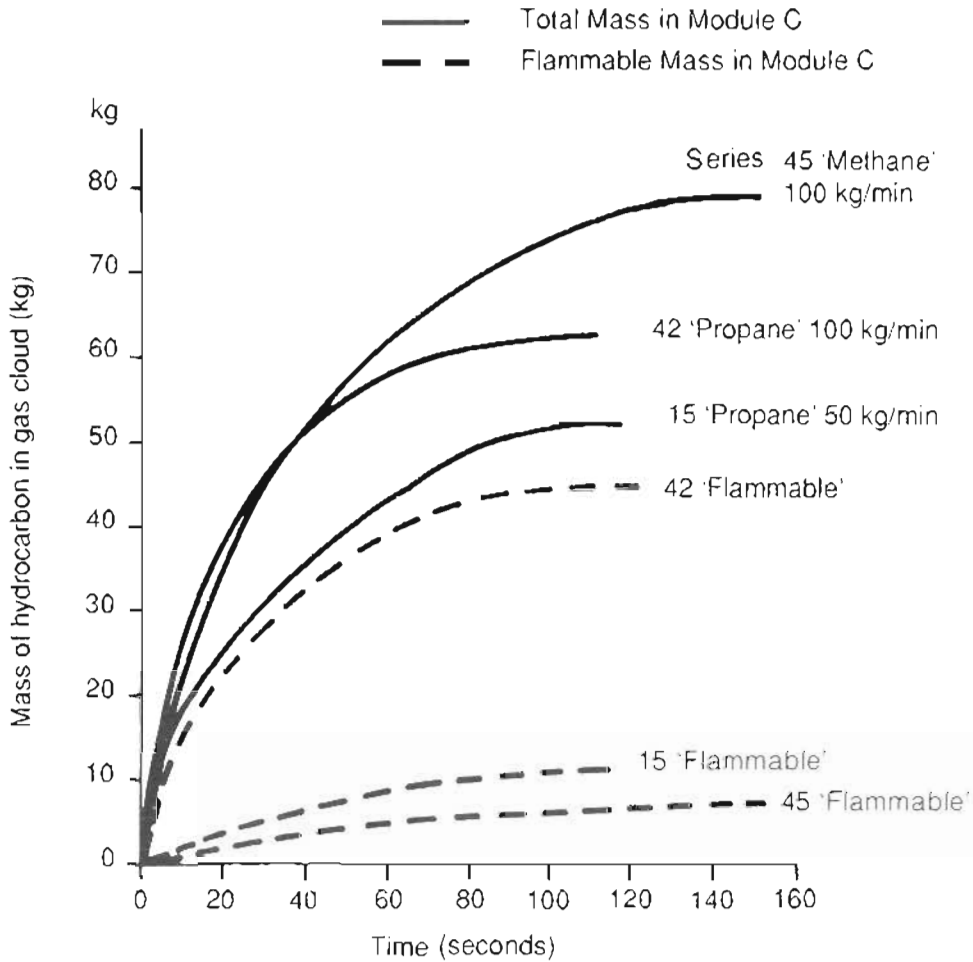


Fig. 6.2 Mass of fuel in the flammable gas cloud in BMT wind tunnel tests (total mass and mass within flammable range): variation with time.

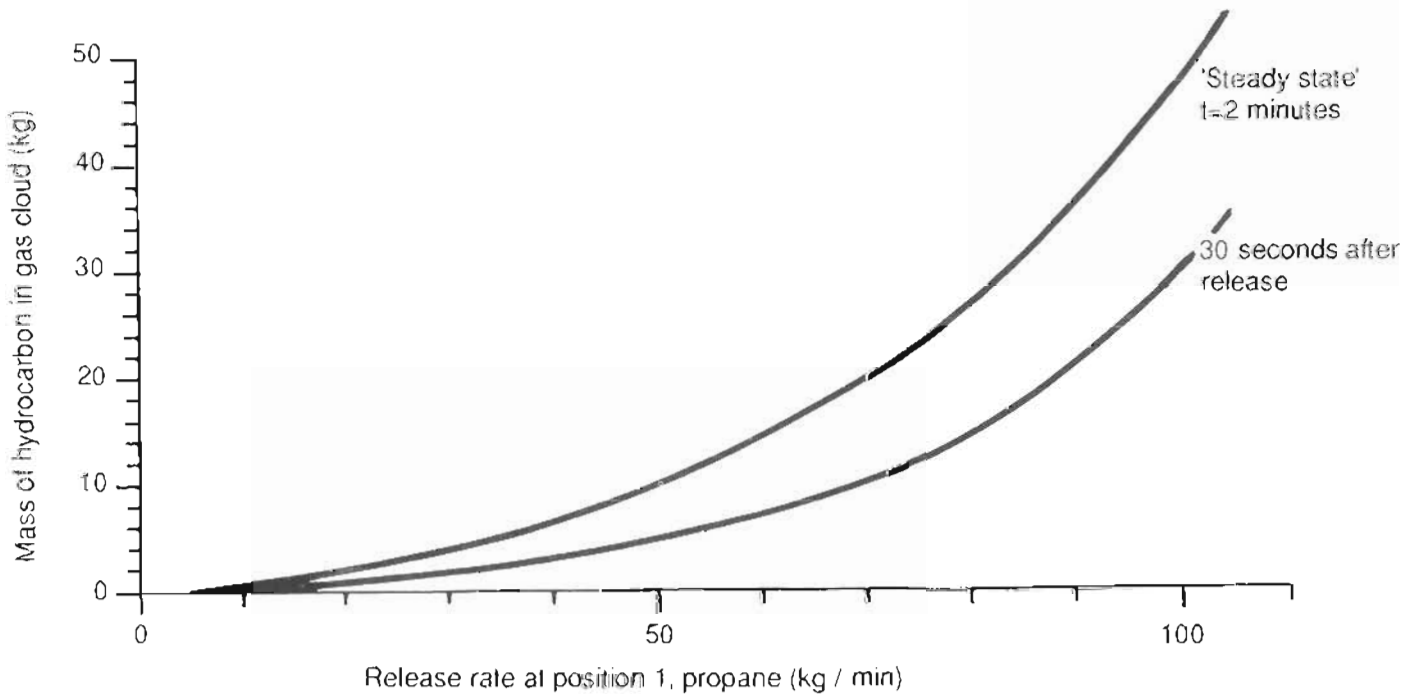


Fig. 6.3 Mass of fuel in the flammable gas cloud in the BMT wind tunnel tests (mass within flammable range): variation with leak rate.

together show that the C3 low level alarm came up first only in tests with these features. Tests involving a leak of neutrally buoyant gas in any of the 4 leak positions gave the C2 rather than the C3 low level alarm first. Moreover, these tests tended to give a much smaller gas cloud, which again tells heavily against them; the exception was the release of neutrally buoyant gas from the horizontal pipe at position 1, for which the flammable cloud was larger.

6.35 Turning to the duration of the larger leak, the relevant features are the time to the first low level alarm triggered by this leak and the time interval between this alarm and the last alarm in the final group, which consisted of the other low level alarms and one high level alarm. In attempting to determine these times, it has to be borne in mind that the postulated initial, smaller leak set off one low level alarm, so that the first low level alarm in the final group would have to be that for a different zone. The delay between the start of the leak and the first low level alarm in the final group would depend on whether this was in C2 or in C4 or C5. In the first case it would occur within seconds; in the second case, given the air speed of some 0.5m/s through the module, it could take some 15 seconds. The final group of alarms was spread over perhaps 5-10 seconds. To these times must be added the time lag of the gas detectors, which was at least 10 seconds. On this basis the duration of the final, large leak would be some 25-35, say 30, seconds. As for the leak rate of the larger leak, from Fig 6.3 the leak rate required to give a 45 kg mass of fuel in the flammable part of the gas cloud within 30 seconds is about 110 kg/min. The tests do not in themselves appear to rule out the alternative possibility that the larger leak was a massive, near-instantaneous release of propane from an open pipe at position 1, since this was simply beyond the range of sensible extrapolation.

6.36 With regard to the postulated initial, smaller leak it is virtually certain that this would resemble the later, larger leak in all but leak rate. Then taking the gas as propane and the source as position 1, as for the later, larger leak, a leak as small as 4 kg/min would give a steady state concentration well in excess of the low level alarm and would trigger a low level alarm in C3 first. It may be noted that this earlier, smaller leak would result in a build-up of a background concentration of flammable gas which would increase the concentrations resulting from the later, larger leak.

6.37 Since position 1 is close both to PSV 504 and PSV 505, the tests are equally consistent with a leak at the site of either valve.

Explosion of flammable gas cloud

6.38 The next stage of the investigation was to determine the effects which would result from the explosion of the flammable gas cloud. In particular, there was some doubt whether a cloud small enough to give the observed pattern of gas alarms would give an explosion strong enough to give the observed explosion effects. As explained in Chapter 5, prior to the Inquiry, work on explosion simulation using the FLACS computer code had been commissioned from CMI both by Technica and by the DEN. Following the wind tunnel tests, the Inquiry commissioned a further run. The work for the DEN was presented by Dr Bakke of CMI, as already described. Dr Bakke later returned to present the further work commissioned by the Inquiry. An account of this work is given here and further details are given in Appendix G.

Simulation of a gas cloud containing some 45 kg of fuel

6.39 The wind tunnel tests suggested that a plausible scenario for the flammable gas cloud was a cloud consisting of condensate, containing within the flammable range some 45 kg of fuel, filling about 12% of the module, located in the south-east quadrant and, being condensate, in the lower, or floor level, half of that quadrant. A further simulation was therefore commissioned of this case. The mass of gas actually used in the simulation was 46.1 kg. The ignition source was arbitrarily located at the centre of the cloud. The cloud simulated, the ignition source location and the pressure points

are shown in Figs 6.4 and 6.5. The firewall failure pressures used were revised values based on the evidence of Dr Cox, namely for the B/C firewall 0.10 bar and for the C/D firewall 0.12 bar. Wall porosities used were again for the B/C firewall 20%, and for the C/D firewall 40%. The results obtained are shown in Table 6.2 as case 6. For comparison the table also shows as cases 1-5 the results of the earlier runs for the DEn.

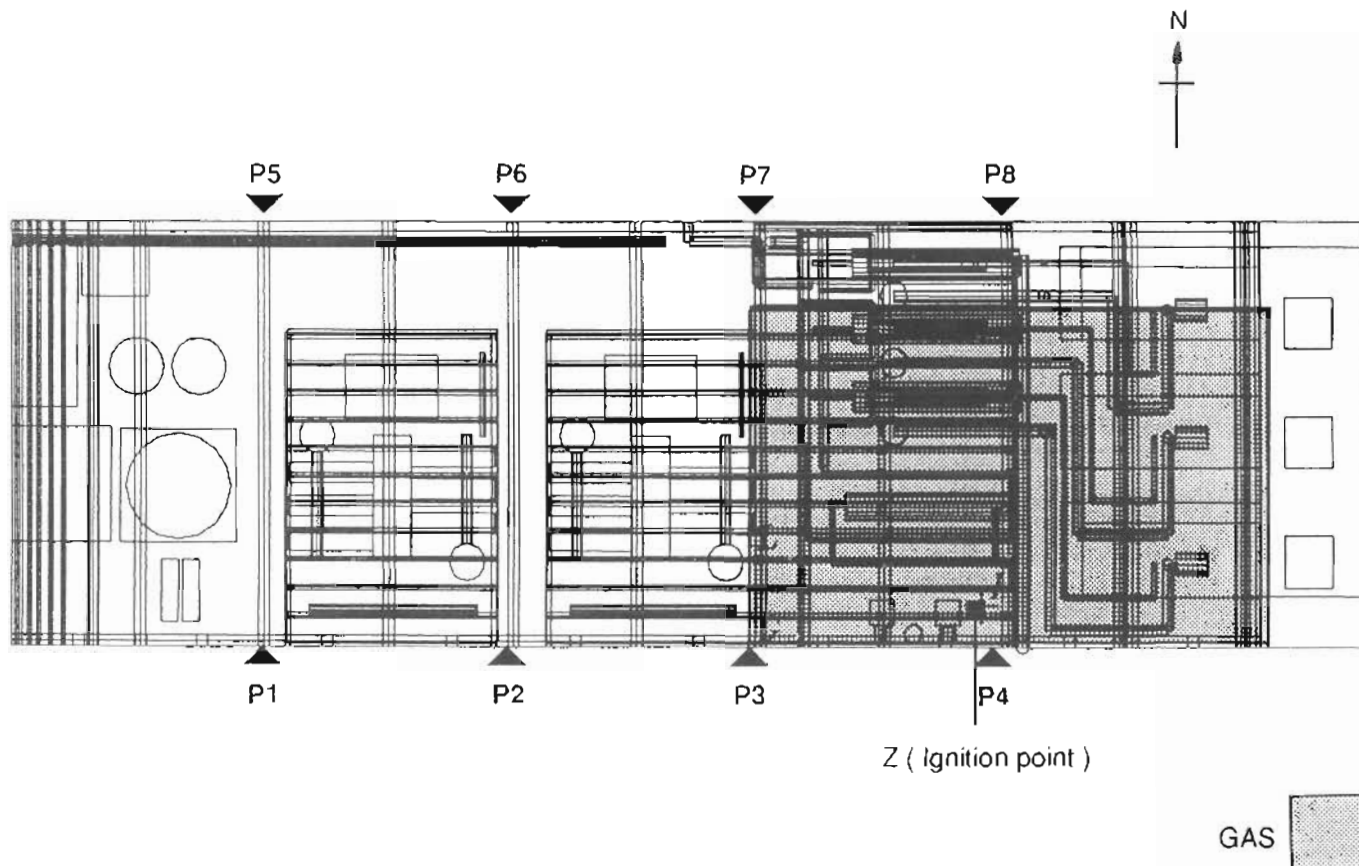


Fig. 6.4 Plan view of C Module showing pressure points P1-P8, 12% fill gas cloud and ignition source Z used in the final CMI explosion simulation.

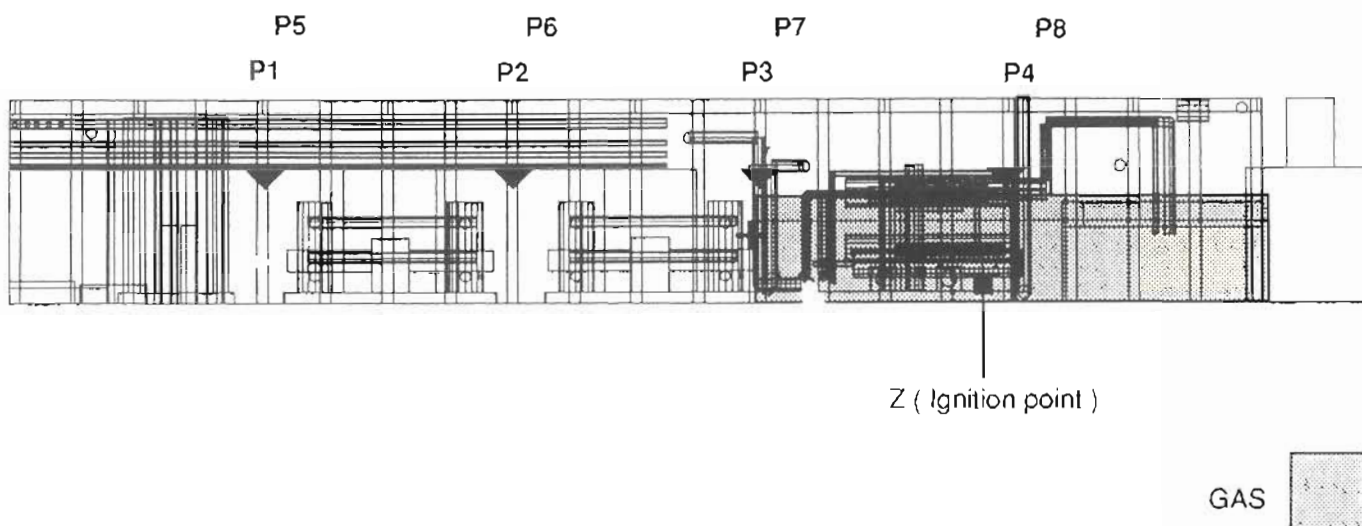


Fig. 6.5 Elevation view of C Module looking north, showing pressure points P1-P8, 12% fill gas cloud and ignition source Z used in the final CMI explosion simulation.

6.40 The simulation for case 6 showed that the B/C and C/D firewalls would fail along most of their length. However, although the pressures experienced at point 5 are sufficient to cause failure of the north wall at that point, the pressure plots indicated that there was a short section at the west end of that wall which did not see pressures high enough to cause failure. The mass of fuel in the flammable gas cloud in the case 6 simulation was judged by Dr Bakke to be close to the lower limit for a cloud capable of causing substantial failure of the firewalls.

6.41 Another relevant matter is the effect on the Control Room and its occupants. Graphs were presented which showed that the peak pressure at point 5, the location of the Control Room, occurs at about 0.9 seconds. The pressure then falls and this over-pressure is followed by a negative pressure, or under-pressure, which is most pronounced at about 0.95 seconds. The effect of these pressure changes is to cause a reversal of gas velocity first in to and then from the Control Room. Plots of the hot combustion products showed that this flow reversal occurs before the hot gases reach that point, so that the occupants would experience first an inrush of cold air from C Module, then an inrush of cold air being drawn through into that module. For purposes of comparison case 3, which was that of a gas cloud of condensate filling 50% of the module, was re-run. The results showed that this case was more likely to give an inrush of hot gas into the Control Room and flames issuing out the west side of the module.

6.42 The limitations of, and uncertainties in, the work are reviewed in Appendix G. As far as concerns the model, Dr Bakke stated that simulations tended to give peak over-pressures within some plus or minus 30% of those obtained in experimental module explosions. Another area of uncertainty was the extent of venting due to firewall failure in the course of the explosion. In view of these uncertainties both in the explosion model itself and in the data furnished for the Piper explosion, the results of the simulation cannot be regarded as highly accurate. Rather they should be regarded as illustrating trends.

Observations on explosion simulations

6.43 What the explosion simulations show is that the gas cloud explosion simulated, that of a cloud located at the east end of and filling some 12% of the module, containing some 45 kg of fuel within the flammable range and with an ignition source at its centre, has the characteristics sought in terms of its effects on the 2 firewalls and on the Control Room occupants. Given the known variation between computer simulations and experimental results and the variability of experiments themselves, the minimum mass of fuel may be estimated as perhaps about 35 kg. The only information on the upper limit is given by the re-run of case 3 with a fuel mass of 186 kg, for which the simulation suggests that there would have been an inrush of hot gas into the Control Room, but though the mass of fuel is likely to have been somewhere between these 2 figures it is likely to have been much closer to the lower one. In estimating its value it is necessary to take into account not only the explosion simulations but the wind tunnel tests. It is taken in subsequent discussion to have been of the order of 45 kg. The mass of fuel required to give an explosion of a particular strength would vary with the location of the ignition source.

Source of ignition

6.44 Another possible pointer to the nature of the cloud which caused the explosion was the source of ignition, since an ignition source inside the module would tend to give a stronger explosion than one at the eastern edge as would a strong rather than a weak ignition source. Such evidence as there was on this from witnesses was described in Chapter 5. A review of sources of ignition was given by Dr J G Marshall, a consultant, originally instructed by Allison Gas Turbine, but led by the Crown. His evidence is considered here only in so far as it bears on the explosion and the leak. Since much effort is devoted by engineers to the elimination of sources of ignition and

the question is of concern in its own right, further details of his evidence are given in Appendix G.

6.45 Ignition sources considered by Dr Marshall included electric arcs and sparks, static electricity, flames and hot gases, hot surfaces, hot particles and chemical energy. One possibility was an electrostatic spark. A release of liquid condensate under pressure would give a jet of vapour containing liquid droplets. If such a jet impinged on a body which was a conductor but was insulated from earth, an electrostatic charge could build up and in due course discharge to earth. Something as simple as a spanner lying on a rag would constitute such a conductor. The possibility that the hot surface of the centrifugal compressor gas turbines might have acted as the source of ignition was explored in some depth, but no way in which this might have occurred was identified and if it had the explosion would have initiated in the compressor enclosure, which was not borne out by the witness evidence.

6.46 I have not been able to come to any conclusion about the source of ignition, either as to what the source was or where it was located, though I consider that an electrostatic spark from the jet itself must be a real possibility.

Observations on the leak

6.47 I now give the conclusions which I have reached from this evidence about the leak. The gas cloud gave rise to a number of gas alarms, as described by Mr Bolland. I consider his account sufficiently reliable and credible that I have looked to see whether other evidence is consistent with it. I have already stated my conclusions that the gas cloud was one of condensate and that it was in the south-east quadrant of C Module. The wind tunnel tests indicate that of the necessarily limited range of tests conducted only a leak of condensate from the area of PSV 504 or 505, provided it is 2-stage, could give a cloud with sufficient fuel, say some 45 kg, within the flammable range while still giving the gas alarm pattern observed. The explosion simulations confirm that explosion of the gas cloud from such a leak would have the effects reported; in particular it would destroy the 2 firewalls in the module and would cause the occupants of the Control Room to be knocked over and experience a rush of cold air, but not hot gas. The leak pattern which I have settled on, as approximating to the middle of a range of similar cases, is a gas cloud containing some 45 kg of hydrocarbon within the flammable range, arising from a 2-stage leak, in the second stage some 110 kg/min lasting some 30 seconds and in the first stage perhaps some 4 kg/min. Virtually complete vapourisation to vapour and spray is assumed.

Scenarios for the leak

6.48 I now move to the consideration of the cause of the leak. I start from the features of the leak which I have just described and use them both to narrow the field of search to those scenarios which could give such a leak and to define the parameters by which I shall assess those scenarios. The leak was one of condensate in the south-east quadrant of C Module. The only equipment containing condensate in that area was the relief lines and the PSVs from the 2 condensate injection pumps. The leak occurred just before 22.00 hours. Therefore the characteristics of the leak itself have led me to look to see if there was anything unusual at the condensate injection pumps in the period just before 22.00 hours.

6.49 In fact at that time it was at these pumps that the initial trip occurred and around them that the activities of the operators centred. There was extensive exploration in the Inquiry of the event which caused condensate injection pump B to trip and events consequent upon its tripping, including events associated with attempts to start up the condensate pumps such as admission of condensate to A pump or attempts to restart B pump and events associated with inability to pump condensate away from the JT flash drum such as back-up into the reciprocating compressors. There emerged from this the following hypotheses, or scenarios:

1. Leak from the site of PSV 504 through a blind flange assembly which was not leak-tight.
2. Leak from the site of PSV 504 caused by some phenomenon due to admission of condensate, particularly autoignition.
3. Leak at or near PSV 505 due to hydrate blockage.
4. Leak at the reciprocating compressors due to ingestion of hydrocarbon liquid.

6.50 The first scenario is that admission of condensate into condensate injection pump A led to a leak from the site of PSV 504 through a blind flange assembly which was not leak-tight (paras 6.55-130). It arose from evidence that PSV 504 had been removed that day for recertification. In examination of this scenario I describe the actions of the operators at A pump and the state of that pump (paras 6.55-74); outline the removal of PSV 504 and the fitting of a blind flange to the end of the relief pipework (paras 6.75-100); consider the probable state of knowledge of the operators (paras 6.101-109); review the evidence bearing on the probable state of the blind flange assembly (paras 6.110-121); describe leak tests on blind flange assemblies which showed the extent to which they might leak given different degrees of tightness (paras 6.122-125); and consider the ways in which admission of condensate could give rise to a leak with the characteristics sought (paras 6.126-130).

6.51 The second scenario is a variant of the first. It is to the effect that even if the blind flange had been leak-tight, there might have been some effect consequent on the admission of condensate to the relief line on condensate injection pump A which caused rupture of that line (paras 6.131-140). The effects considered were autoignition, shock loading, brittle fracture and over-pressurisation by methanol injection.

6.52 The third scenario is that hydrates caused a blockage on the discharge side of condensate injection pump B and that this led to over-pressurisation and rupture of the relief line (paras 6.141-163). It arose from evidence that there had been an interruption of the methanol supply to the JT valve that day.

6.53 The fourth scenario is that when the only working condensate injection pump, B pump, tripped, condensate liquid started to fill the JT flash drum and backed up into a reciprocating compressor, causing it to rupture (paras 6.164-170). It arose from the evidence that B pump had tripped and that the JT flash drum level had started to rise.

6.54 I end the chapter by considering some additional scenarios described by Mr R Sylvester-Evans and Dr K E Bett (paras 6.171-176) and by giving my conclusions on the cause of the leak and my observations on the PTW system, the shift handover and the methanol injection (paras 6.177-197).

Admission of condensate to condensate injection pump A

6.55 The first scenario involving a leak at the site of PSV 504 is that following the trip of B pump Mr Vernon took steps to bring A pump back on line, that as a result condensate was admitted to the relief line and that a leak occurred from a blind flange assembly on that line which was not leak-tight. The first step in assessing this scenario is to consider whether condensate was admitted to the relief line.

Actions of operators

6.56 Evidence on activities at the condensate injection pumps was given by Mr Grieve and Mr Young. Mr Grieve knew that it was B pump which had been operating. He had no idea of the state of A pump and believed that it was in the normal standby mode. He did not know it was shut down for maintenance. He was unaware that PSV 504 had been removed; he learnt this only when he was in hospital after the disaster. Mr Grieve was uncertain exactly when he overheard Mr Bolland's first call to

Mr Richard. He was also unsure how much time elapsed before he went down; his estimates ranged up to 10 minutes. He may have arrived at the condensate pumps some 2-3 minutes before the initial explosion. He came down the staircase on the extreme east of the plate skimmer platform, walked past the plate skimmer, the JT flash drum and the pump main control panel (see Fig J.6). He described Mr Vernon's position when he first saw him variously as in the area of the GOVs on A pump, as between the 2 pumps and as at the push-pull button for the GOVs on A pump. Mr Grieve also stated that Mr Vernon was not stationary but was moving between one area and another.

6.57 In a statement to Occidental on 29 July 1988 he stated:

“As I said I had just arrived there, just sort of walked down and they were busy trying to get the GOVs open, reset them get ready for another start at the pump. I just sort of walked up beside B pump and they gave me a nod to push the button.”

The exchange continued:

Q. “Do you think they tried “A” as well?”

A. “I would have thought so the way that they were going around down there.”

Earlier in the statement there occurred the following exchange:

Q. “Did you have time to speak to anyone at the condensate pumps?”

A. “No. As I said I spoke to Bob Vernon and said ‘What’s the score?’ and he said more or less that they couldn’t get the pumps to work and that was about it.”

Q. “Can you remember whether he said pump or pumps?”

A. “I would say pumps, because they were at the stage of trying to open the GOVs on both of them then.”

Q. “They were actually opening the GOVs on both then?”

A. “Aye, they were just sort of picking whichever one they could get away.”

and earlier still in the exchange:

Q. “Did you have a go at starting both of them?”

A. “Well I don’t know. When I went in there they’d just had a go at starting one of them. But I take it they’d been starting to try another one before I got there. It had been a good 5 minutes or so before I got there.”

Similarly, in a statement to the DEn Mr Grieve stated “When I initially arrived in the DSF I observed Vernon at the GOVs. I believe that he was lining up the GOVs on both A and B injection pumps.” “Lining up” was the term used by the operators to describe the process of opening the GOVs prior to pump startup.

Further Mr Grieve stated in evidence that if the A pump had been on standby, then lining up its GOVs and trying to start it would have been the obvious thing to do in the circumstances.

6.58 However, when he learnt what effect the activities at the 2 pumps may have had, Mr Grieve became more cautious. As he said: “I realised you could only say what you actually saw. You were not allowed to assume what could have happened.” His evidence on any actions taken to line up the GOVs on A pump was guarded. He was unaware of any action to line up the GOVs on A pump before he arrived. When he did arrive, nothing was said about A pump. He could not honestly say that either operator opened the GOVs on A pump or even touched the GOVs or the pump. He was not aware of any attempt to start up A pump or of any instructions by Mr Vernon to this effect. He was clear that while he was there no one pressed the start button on A pump. Mr Vernon did not start the pump. Mr Grieve himself did nothing to the pump. At one point in the evidence Mr Grieve confirmed that although he was not prepared to state positively that any action was taken on A pump, the statement he

gave to the DEN to the effect that Mr Vernon was lining up the GOVs on both pumps was still his recollection. Later he said concerning this statement "I was probably going on what I thought he could have been doing at the time. I would never say for definite. I never saw him open the GOVs on A pump at all. He opened the GOVs on B pump for me before I started it. That is the only action I can recall him taking."

6.59 As described above, it was indicated to Mr Grieve on his arrival that he should assist Mr Vernon and Mr Richard in restarting B pump. Mr Richard was apparently to go to the pump main control panel JCP057 to reset the system and Mr Vernon was at the B pump push-pull button while Mr Grieve himself went to the local pump panel to push the start button. Before the actual attempt to restart B pump Mr Richard was called away; he did not participate in the restart. It is not clear from Mr Grieve's evidence whether Mr Richard had time to effect the reset or whether Mr Vernon had to do it. Mr Grieve said that he thought Mr Richard did the reset but shortly before he stated that Mr Vernon went to the control panel. The attempt to restart B pump failed. In Mr Grieve's words "The electric motor kicked in and turned a few revolutions and then stopped." Mr Grieve then set off to reopen the GOVs on the B pump. At this stage he lost track of Mr Vernon and was unable to say what the latter was doing. Asked whether Mr Vernon might then have attempted to start A pump on his own, Mr Grieve described the actions which he would have had to take. These were to go to the main control panel JPC057 and reset the system; to open the push-pull button on the pump GOVs; to adjust the pump speed controller setting; and then to go to the local pump panel to push the start button. Mr Grieve was clear that Mr Vernon did not push the start button of A pump, but agreed that there was certainly plenty of time for Mr Vernon to have pressurised the discharge of A pump by "jagging", the term used by the operators to describe the action of repeated, brief opening of the GOV. The route taken by Mr Grieve after this abortive attempt to restart B pump passed along the north side of B pump. He was making his way when the initial explosion occurred.

6.60 The other witness of events at the 68 ft level was Mr Young. There is some conflict of evidence between Mr Grieve and Mr Young as to who arrived last. Mr Grieve believed Mr Young had arrived first. At any rate, he remembered him being in the area and did not see him arrive so assumed he got there first. Mr Young on the other hand was firm that Mr Grieve was there when he arrived. Mr Young came down the stairs from C Module at the north-west corner of B pump. Mr Vernon and Mr Grieve were there, but he never saw Mr Richard at all. Mr Grieve was coming away from the local pump panel on B pump. He saw Mr Vernon at the edge of A pump, walking away from it. Mr Young stated that before he had a chance to speak to either of them, he heard a loud rushing noise and then the dull bang of the initial explosion. I should add that when he recovered from the explosion Mr Young started to make his way up the staircase to C Module and met 2 men coming down, who told him to get back because the place was filling up with black smoke. The men, who went off towards the east, were never identified, though Mr Young said they were not Occidental employees, since they were not wearing the distinctive company flash.

6.61 In the submission of Score there is no direct evidence that any action was taken to admit condensate to the discharge side of A pump nor can it be inferred from the actions of the operators. Score argued that Mr Vernon must have known PSV 504 had been removed. By way of illustration Score gave 5 possibilities for Mr Vernon's actions on return to the pumps. These may be summarised as follows: (i) that he did nothing to A pump but attempted to restart B pump; (ii) that he started on A pump, found the pneumatic supply disconnected, remembered that PSV 504 had been removed and desisted; (iii) that he was dissuaded by Mr Richard from starting on A pump; (iv) that he found A pump spaded; and (v) that he did reconnect the pneumatic supply on the A pump GOVs and opened them. I agree that there is no direct evidence that Mr Vernon admitted condensate to A pump. The evidence does, however, support the view that he had the intention and opportunity to do so. Any inference that he did is a matter to be considered in the light of the whole of the evidence.

Status of condensate injection pump A

6.62 Before turning to Mr Vernon's intentions, it is necessary to consider the status of condensate injection pump A. Evidence on this was given by Mr T A Henderson, a lead operator, and Mr A C B Todd, the maintenance superintendent. On 4 July condensate injection pump A was on standby for 18 hours. At 18.00 hours this pump was started up and pump B was shut down for repair to the LP suction pressure switch. This work was completed on 5 July and by 21.50 hours the pump had been test run and put on standby. Pump A then ran overnight until it was taken out for the maintenance work on the morning of 6 July. By the evening pump A was still out for maintenance, but the work to be done on it had changed.

6.63 According to Mr Henderson, there had been a problem of noise on the Voith coupling on the pump for quite some time. The problem had been highlighted in a vibration survey. The pump was also due in August to have a preventive maintenance overhaul which was done every 24 months - the 24 month PM. The unhealthy state of the coupling was discussed at the Monday morning meeting between maintenance and the beach on 4 July and it was decided to bring forward the 24 month PM and to do the coupling at the same time. Arrangements were made for the spares necessary for the PM to be sent out to the platform. They were due to arrive with the supply boat on the night of Tuesday 5 July. This was the situation when Mr Henderson left the platform at 11.00 hours on 5 July; he was not able to say whether the spares arrived that night. He expected the work to take some 2 weeks. The essentials of this account were confirmed by Mr Todd, who stated that the supply boat would be expected to arrive at the field on the Wednesday morning and to be unloaded by mid-day. He said that personally if he knew the spares were in the field on the boat he would start to strip down the pump, but not otherwise.

6.64 Mr R H Seddon, the senior maintenance superintendent, stated that he was aware that there was an intention to bring forward the PM work on A pump. He spoke to Mr White at about 16.50 hours on 6 July and told him that "he should possibly only do the torque converter work". Mr Seddon said that he did expect that his recommendation would be carried out. His reason for putting off the PM was that his team were fully committed and that although the overhaul itself was of known duration, the running in time was an unknown quantity. It could take up to 5 days and he did not wish to embark on the unknown. He had had the thought of deferring the PM some time before but had not got round to communicating this to anyone else. As far as others on the platform were concerned, therefore, until about 17.00 hours on 6 July the plan was to carry out a 24 month PM on A pump.

6.65 At 07.00 hours on 6 July, Mr J Lynch, the first day-shift lead production operator, was asked by Mr B Curtis, the acting operations superintendent, to take A pump off, put B pump on and release A pump to maintenance. Mr W H Smith, the night-shift lead maintenance hand, brought the PTW, a pink hot work permit, for the PM about 07.45 hours. It was for a 24 month instrument, electrical and mechanical PM. The PTW was not signed on when Mr Lynch left because the pump was not ready. It would have been handled by Mr H E G Flook, the day-shift lead production operator who took over from Mr Lynch. The general rule was that PTWs should not be issued until the work was to be started, but this was a planned job and the PTW might be made out in advance. The pump had to be isolated and depressurised and there was therefore a good deal of work for the operators to do first.

6.66 Mr Clark said he understood when he came on shift on the evening of 6 July that the PTW for the Voith coupling had been written, but had not actually been taken out. The electrical isolation had been done. Mr Smith had told him in the handover that the PTW was in the Safety Office; it would remain there until it was taken out and signed on.

6.67 The general procedure for mechanical isolation of equipment was described by Mr Lockwood. The usual method was to close isolation valves and chain them off.

The valves were not necessarily tagged. It depended largely on the size of the job; tags would be used on valves for the isolation of the phase 2 plant but not on a small job with just 2 valves. There was nothing on this in the written procedures. All operators carried keys to the locks. Mr Bolland's stated that if an item of equipment was being worked on there would not necessarily be anything on the mimic panel to indicate this. It is also relevant to note that for full mechanical isolation the preferred procedure given in the Occidental General Safety Procedures Manual was to remove a piece of the pipework, or spool piece, and to blank off only the live end of the pipework.

6.68 The methods of isolation of a condensate injection pump were described in a second appearance by Mr Henderson. Different procedures would apply for a 24 month PM, a coupling repair and removal of the PSV. For a 24 month PM the procedure would be to effect electrical isolation, disconnect the air line to the GOV and to spade off the pump; this spading would be done by maintenance. For removal of the PSV the valves on the pump would be locked off and the air line disconnected but he himself would not isolate electrically. For work on the Voith coupling the pump would be electrically isolated but not depressurised. It is not known how pump A was isolated that day. There was evidence, however, that it was electrically isolated and that it was valve isolations which were checked by the operator prior to the removal of PSV 504. No witness said it was spaded off.

Electrical isolation of GOVs

6.69 The evidence described earlier is that condensate injection pump A had been electrically isolated. The air supply to its GOVs would be disconnected. In order to be able to move the GOV using the push-pull button, or plunger, all that was required was to reconnect the air supply, a simple task which could be done by an operator; the GOV would then remain open as long as the button was held. It is not known whether electrical isolation of A pump had been effected by locking off or racking out. Mr P Lloyd, a Senior Electrical Engineer, stated that in his time on the platform up to 1980 both methods were used but that he had been told that since then racking out was the normal method. Mr Bolland's also stated isolation was by racking out and that when a pump was electrically isolated there was no amber light on the mimic panel. If isolation was done by racking out, the GOV could be kept open only by holding on to the push-pull button, whereas if it was done by locking off, the GOV would stay open when the button was pulled and would close only if it was deliberately pushed back again.

6.70 The evidence on whether or not A pump was electrically de-isolated was conflicting. Mr Clark was unsure if he signed the red tags before or after the first gas alarm. There was a period of some minutes which he could not account for and there may well have been a lapse of some time between his signing the tags off and the initial explosion. His evidence was that it was his intention to get the de-isolation done by one of the electricians on the night-shift. Mr Bolland's stated that he heard Mr Clark speaking on the telephone first to Mr Savage and then to one of the night-shift electricians. Mr Clark stated that the final set of gas alarms came up just as he was leaving the Control Room, evidently to give the red tags to the electricians. What is not clear is whether these electricians had taken any action to de-isolate A pump before receipt of the red tags. This would not be normal practice, but there was a degree of urgency.

6.71 Mr Bolland's stated that the amber light for A pump on the mimic panel had been off that evening. It came on at some time but was not continuous. It was on some time before Mr Vernon first left the Control Room. Mr Bolland's was non-committal as to whether it was on in the minutes preceding the initial explosion. Mr Clark in several of his original statements stated that the amber light on A pump was on at the time of the explosion, but told the Inquiry that he must have been mistaken; A pump was electrically isolated. When Mr Vernon returned for the A pump PTW,

he told Mr Bollands that the A pump was electrically isolated, that an instrument PM was going on and that he wanted the pump reinstated. Mr Bollands also stated that Mr Vernon told him instrument technicians were working on the pump and that he knew Mr Young had a PTW for work on the pump; he assumed that this was the reason for the amber light. It was Mr R F Carey's evidence that he was not aware of any action which he, as an instrument technician, could take while working on the electrically isolated pump which would bring up the amber light.

6.72 I consider this evidence is inconclusive as to the state of the electrical isolation of A pump just before the initial explosion. However, there was reason to effect prompt de-isolation and there appears to have been sufficient time to do so. I conclude that A pump had been electrically isolated, almost certainly by racking out, and that it could well have been de-isolated some time in the last few minutes before the initial explosion.

Intentions of operators

6.73 It is clear from Mr Bollands' evidence that when Mr Vernon returned to the Control Room it was his intention to bring A pump back into service. Possible explanations of Mr Vernon's intent are that:

1. He did not know that PSV 504 was off, because
 - (a) he did not know it had been taken off, or
 - (b) he knew of this, but believed the valve had been put back on.
2. He knew the valve was off but
 - (a) he believed there was another duplicate valve on,
 - (b) he forgot the valve was off, at least initially,
 - (c) he went ahead knowingly.

6.74 It would be bad practice to start up A pump without the protection of a relief valve. Witnesses were agreed that Mr Vernon was an experienced and conscientious man who would not do so. I regard it as highly unlikely that he would have attempted to start the pump knowing that it had no PSV on. Moreover, Mr Clark was involved in the decision and Mr Richard in the activities at the pumps. Both might have been expected to oppose such an action. Evidence was given that the pressure relief protection arrangements on the condensate injection pumps differed from other systems on the plant in having only one PSV on each pump. It is conceivable, though unlikely, that Mr Vernon knew that PSV 504 was off, but believed that the pump was still protected by another duplicate valve or that he simply forgot that the PSV was off. In both cases it is necessary to assume that neither Mr Clark nor Mr Richard intervened. Mr Clark knew of the plan to start up A pump; he had discussed it on the telephone. Mr Richard was at the condensate injection pumps both before and after Mr Vernon's visit to the Control Room to get the permits signed off and it is highly unlikely that he did not know Mr Vernon's intention. These arguments point to the alternative that neither Mr Vernon nor Mr Clark nor Mr Richard knew that PSV 504 was off at 21.45 hours that evening, that this information was not transmitted through the handover and PTW systems, and that the status of A pump was a contributory factor in this.

Work on Pressure Safety Valve PSV 504

6.75 In order to take further the question of the state of knowledge of the operators it is necessary to give an account of the recertification work done on 6 July on PSV 504 and the information which was communicated about this work. The account includes the background to the contract and touches on the availability of suitable blind flanges, which bears on the question of the leak-tightness of the blind flange assembly, but consideration of the latter is deferred until later.

6.76 As already indicated, on 6 July condensate injection pump A was out of service to allow maintenance work to be done on it. Its pressure safety valve, PSV 504, was removed for recertification. Evidence on the PSV recertification programme was given by Mr Seddon and Mr D Whalley, a supervisor of Score (UK) Ltd, the specialist company doing the valve recertification work; on the work on PSV 504 itself on 6 July, and the associated PTW, by Mr A D Rankin, the supervisor of the 2-man Score team and other witnesses; and on handovers between shifts by Mr Clark and Mr Bollands.

PSV recertification programme

6.77 According to Mr Seddon, there were on Piper some 300 pressure safety valves and they were recertified at an interval of approximately 18 months. This was a fairly large workload and it was contracted out to specialist contractors. Towards the end of 1987 the contract was awarded to Score (UK) Ltd. Mr Seddon was involved in the negotiation of the contract and had a number of meetings with Mr C B Ritchie, Managing Director of Score, and with other Score personnel, Mr Whalley and Mr Wood. Occidental put the contract out to competitive tender with 6 contractors and carried out an appraisal of the bidders. A collection of documents on this contract was produced at the Inquiry. The appraisal would involve visits to Score's premises and review of its quality assurance (QA) procedures and quality manual; Mr Seddon was unsure whether training procedures would be checked. There were favourable assessments of management, facilities and the PSV workshop, and the stores, the offshore containers, curriculum vitae of personnel and QA procedures were acceptable. The safety organisation was noted. Score was given a rating of 8 on a scale of 1 to 10, where 1 is poor and 10 very good. The Score bid was not the cheapest received, but the engineering side held out for award of the contract to Score which they rated more highly from the technical point of view; a special meeting was held and the contract went to Score.

6.78 Score was provided with the Occidental Safety Procedures Manual, the 'Red Book'. This manual gave details of the isolation and PTW procedures. The question was raised whether this version of the manual, dating from 1982, was that actually current on 6 July. A new manual, General Safety Procedures Offshore Operations, was issued as a working draft in September 1987. Mr Seddon stated that in his meetings Score personnel were made aware of Occidental's PTW system, that work permits would be required for removal of PSVs and that the PTW was described in the Safety Procedures Manual. In any event personnel from such a company would be expected to be familiar with PTW systems in general. The requirements for blind flanges were also discussed between Mr Seddon and Score personnel.

6.79 Mr Whalley stated that he and Mr Wood had a meeting onshore with Mr Seddon about the work and that in December 1987 he and Mr J Tait paid a familiarisation visit to Piper. They were shown the areas where work on PSVs was required. Mr Whalley said that he was told by Mr Seddon that blind flanges were to be fitted on removal of PSVs. One of the reasons for the visit was to check that there was a sufficient supply of blind flanges. He was given to understand that there were sufficient blind flanges available on the platform. He investigated the blind flanges available on the platform. On the 68 ft level he found a stock of blind flanges painted blue. There were blind flanges in other areas dedicated to those areas. He found that not all the blind flanges required were available and that it would be necessary for Score to supply some. Following this visit Mr Whalley had a further meeting with Mr Seddon, with blind flanges as the main topic. The discussion centred on the lack of smaller size blind flanges on Piper. It was decided that Score should supply those which were deficient. Two delivery notes were produced dated 19 and 21 January 1988 for the delivery to Piper of blind flanges; Mr Whalley stated that these were only part of the blind flanges supplied by Score.

6.80 Work on the recertification programme began in January 1988 with a 4-man team from Score. The Score supervisor was responsible to the Occidental maintenance

superintendent. The release of particular PSVs for recertification was discussed on a daily basis with the lead operator. On an average day the team would do 3-4 valves. By the middle of March a large proportion of the work had been done and it was decided to reduce the Score team to 2. On 11 April the team was demobilised, because the remaining valves could not be made available until the June/July shutdown. During May Mr Whalley was asked by Occidental to attend at their Aberdeen offices to assist in a review of the recertification test certificates. A programme for the remaining work was drawn up and a 2-man Score team returned to the platform on 13 June. The Score container, which had been taken away in April, was brought back to the platform. On 27 June the Score personnel who went out were Mr Rankin and Mr T J Sutton, with the former as supervisor.

6.81 This was Mr Rankin's first tour offshore as a supervisor. Evidence on the training which he received for this, particularly on the responsibility of the supervisor in relation to the PTW system, was given by Score personnel and by Mr Rankin himself. Mr Ritchie stated that the company safety officer, Mr A Buchan, gave both Mr Rankin and Mr Sutton instruction on the Safety Procedures Manual and the PTW system of Occidental. There was no specific training for supervisors. Mr Whalley said that he himself had had a 15-30 minute meeting with Mr Rankin before the latter went offshore and was sure that the PTW system was part of it. He had no doubt Mr Rankin knew how the system worked. He also believed that the Occidental maintenance superintendent would have gone through the PTW system with Score. The training of supervisors was "on the job". Mr Rankin himself said that he was first made a supervisor just before going offshore on 27 June and that this was therefore the first platform where he had been a supervisor offshore and had been concerned with the PTW system. The only instruction which he received was from a Score director, Mr J Scott, to the effect that he should adhere to the Occidental PTW system. He did not recall being instructed in the Occidental procedure before going offshore; he could not recollect any briefing by Mr Buchan. He had instructions about the PTW system on his previous trip on the platform from Mr Whalley and there was a notice about the system pinned up on the wall of the Score container. Mr Rankin said that he knew that he had to go to the maintenance lead hand to obtain a permit and to the operations superintendent to get it approved and that he knew the Designated Authority was the "Control Room lead hand", whom he understood to be the lead operator in the Control Room. He said he knew how to validate and suspend a permit. He had not, however, suspended a permit before. Mr Todd, the Occidental maintenance superintendent, said that Mr Rankin came to his office on 28 June. He was new to Mr Todd as a supervisor so Mr Todd asked him if he knew the PTW system. Mr Rankin said he was happy with it and knew how to work it. Mr Todd did not question Mr Rankin further on this.

Removal of, work on and permit for PSV 504

6.82 The removal of and work on PSV 504 were described by Mr Rankin. This valve was the last which needed to be done and only this work kept Mr Rankin and his colleague, Mr Sutton, on the platform. On 5 July Mr Rankin inspected the job site in C Module. On 6 July he came on shift at 06.00 hours. He met Mr Smith who told him that pump A had been shut down for work to be done on it and hence that PSV 504 would be available some time that day.

6.83 Mr Rankin went with Mr Sutton to the site of PSV 504 to check the need for scaffolding and rigging and to check the blind flanges and tools needed. Then at about 07.00 hours or a bit later they got the PTW and took it along to the maintenance office where Mr White signed it and, Mr Rankin believed, wrote in the tag number, PSV 504, and the location, C Module; Mr Rankin had not put these details on the permit. At about 07.40 hours Mr Rankin took the PTW to the production office where it was signed by Mr Curtis. One copy of this permit, No 23434, signed by Mr White and Mr Curtis was recovered from the accommodation module at Flotta and was produced to the Inquiry. On the permit under "Work to be done and equipment to be used"

was the entry "PSV refurbishment injection pump discharge condensate" and under "Additional precautions" the entry "Open pipework to be fitted with blind flanges. Liaise with lead operator. Operator to isolate as required." The entry under "Tag No" was "PSV 504" and that under "Location", "C Module".

6.84 From there Mr Rankin went straight to the Control Room, arriving sometime before 08.00 hours, to inform the lead operator and get the PTW signed (Visit 1). He went to the desk where the lead operator usually sat and asked for his PTW to be signed and said he would need scaffolding but was unsure about rigging; he had no recollection of discussing isolation. He could not say who this person was or if he had ever seen him before and he did not ask him if he was the lead operator, but the man did not demur at being asked to sign the PTW. He left the PTW in the Control Room. He was unsure how long the visit lasted.

6.85 Mr Rankin and Mr Sutton then had a break while the scaffolding was put up and the isolation effected. In the container they made their preparations, Mr Sutton getting ready the blind flanges and tools and Mr Rankin the test equipment. Some time before lunch the latter went down to the site but the scaffolding had not been started; he understood the scaffolders had another job. Between 13.00 hours and 14.00 hours Mr Rankin and Mr Sutton went for lunch. At some time after 14.00 hours the scaffolding was ready with the Safety Department green tag on it.

6.86 Mr Rankin went alone to the Control Room (Visit 2) to retrieve the PTW. He saw the "lead operator", who filled in the PTW, which he did without consulting Mr Rankin. Mr Rankin could not say who this person was or whether it was the same man as on his first visit. He had little recollection of the precautions specified; he believed mechanical isolation was by locking off valves but had no recollection of the electrical isolation or of any red tags and none of any gas test. The operator telephoned Mr P Grant, the phase 1 operator; Mr Rankin presumed this was to ask for the isolation to be done. The visit lasted about a minute.

6.87 Mr Rankin then went down to the job site. Mr Sutton and Mr Grant were already there. He showed Mr Grant the PTW. The latter then attended to the isolations. Mr Rankin thought that he was checking rather than performing them; he did not see him close a valve. Mr Grant went down to the level below and also checked an isolation valve in C Module; Mr Rankin observed from the floor of the module. Mr Rankin was at the site while the flanges were opened up. Then, with the valve still in position, he returned to the Control Room (Visit 3), where he again saw the "lead operator". Mr Rankin could not say who this person was and was unsure if he took action to obtain a rigger. However, when he got back to the job site he found that a rigger was there, that PSV 504 was on the module floor and the crane was available. The valve was taken through the module on a push-barrow and lifted up by the crane to the container. Mr Rankin estimated he had been away from the site perhaps 10 minutes.

6.88 Mr Rankin then began work on the PSV in the container. Once the valve was in the container Mr Sutton took the blind flanges down to the job site. He would have carried them individually. Somewhat less than an hour later Mr Sutton returned to the container and confirmed that he had fitted the blind flanges. Mr Rankin did not check this at the job site; it was not his normal practice to do so. Mr Sutton then assisted Mr Rankin with the testing of the PSV. There was a lapse of some 2 or 3 hours between the arrival of the valve in the container and the witnessing of the test certificate by Mr N McLeod, the Occidental QA representative, at 17.40 hours.

6.89 At about 18.00 hours Mr Rankin went alone to the Control Room to arrange a crane to lift the valve back down (Visit 4). There was only one person there. He did not know who this man was, though he believed that he was not the same person as he had spoken to earlier and that he was the "oncoming lead operator". Mr Rankin told him that the PSV was ready to be restored. The operator told him that the crane

was not available; he knew this already without having to check by telephone. It was mutually agreed that the PTW should be suspended. The operator retrieved the other 2 copies of the PTW, making 3, and gave them to Mr Rankin. Mr Rankin then suspended the permit. There was no place on the permit for suspension and it was normal practice on the platform to effect suspension by signing 'SUSP' in the gas test column. Mr Rankin said that this is what he did. He had never suspended a permit before and could not remember how he came to know about this procedure. Mr Rankin gave the operator the permit to sign, or perhaps just placed it on the desk. He could not recollect whether the operator signed it. According to normal procedure, Mr Rankin should have checked the job site prior to suspension of the permit, but did not do so. He confirmed to the Inquiry that he considered that he had left the equipment in a safe condition and had complied with the requirements of the Clearance Certificate.

6.90 Mr Rankin then returned direct to the container. There he found Mr Sutton and other persons. Mr Rankin stated that it had been his intention, for his own peace of mind, to inform Mr Smith of the state of the PSV. He and Mr Sutton knocked off and went to the accommodation. They had a wash and then, by chance, in the recreation area, ran into Mr Smith, who had finished his shift; the time would have been between 18.00 and 18.30 hours. Mr Rankin told him, in Mr Sutton's presence, that there was no crane available and the valve was still off. Mr Smith asked if blind flanges had been fitted and Mr Rankin confirmed that this was so.

6.91 There was some conflict between the evidence of Mr Rankin and that of other witnesses. Mr Lynch stated that Mr Rankin's first visit to the Control Room was about 08.30 hours or 08.45 hours. He knew Mr Rankin was the Score foreman and had issued permits to him. There was no possibility of his confusing Mr Rankin with anyone else; he believed he had his name on his cap. Mr Lynch was equally certain that Mr Rankin knew he was the lead production operator and expected to be addressed by him by name, particularly as he had "Joe Lynch" on his overalls. Mr Rankin said he knew A pump was to be given to maintenance and asked if he could have PSV 504. He made this request to Mr Lynch, as lead operator, but Mr Flook was party to the conversation. Mr Lynch was satisfied that Mr Flook knew that Mr Rankin wanted PSV 504 and that if a permit had been issued later, it would have been by Mr Flook. Mr Rankin did not ask Mr Lynch about scaffolding and would not need to, since he could obtain it on request to the scaffolding foreman, who would have a PTW for the whole of C Module. On this visit Mr Rankin did not have a PTW for the PSV 504 overhaul and Mr Lynch sent him to Mr Smith to get one. When shown the recovered PTW signed by Mr Curtis at 07.40 hours, Mr Lynch agreed it was surprising that Mr Rankin did not have it with him; he surmised that the permit might have been in Mr Curtis' desk without Mr Rankin knowing about it. Mr Lynch also stated that Mr Rankin knew that there was other work to be done on A pump.

6.92 Evidence on the removal of PSV 504 was also given by 2 of the riggers involved, Mr J M McDonald and Mr J Rutherford. Mr McDonald stated that he was working in the GCM with Mr Rutherford when about 09.00 hours Mr Sutton came to them and asked for assistance in removing a PSV in C Module. Mr Rutherford went down and he himself followed some time between 10.30 hours and 11.00 hours. When he got there the valve was already on the floor. He assisted Mr Rutherford in taking the PSV along the module to the crane, which took some 20 minutes. By this time the crane was unavailable since the crane driver took his dinner from 11.00 hours to 12.00 hours. They had theirs from 12.00 hours to 13.00 hours. He had no further dealings with the valve. It could have been lifted without riggers by the crane driver any time after 12.00 hours. About 16.00 hours he went down and cleared away a chain block in C Module. Some time about 17.15 hours to 17.30 hours he was told, either by Mr Rutherford or Mr Sutton, that Mr Smith had said the valve was not to go down until the morning, but there was no mention of the crane. It was not uncommon for Mr Smith to terminate work at 18.00 hours to avoid contractor overtime working. He

himself had a conversation with Mr Smith about 18.00 hours but no mention was made of the PSV.

6.93 Mr Rutherford, who was on his second trip on the platform, said that he had done a good deal of work in the GCM before becoming involved with PSV 504. He thought in fact that it was afternoon, about 14.00 hours, when he assisted in taking the valve down, though he may have gone and had a look at the site in the morning. He rigged up a sling to take the weight of the valve. The flanges were opened by one fitter working alone. Mr Rutherford lowered the valve first on to the scaffolding and then to the ground. At this point Mr McDonald arrived and moved the valve to the end of the module using the push-barrow, while he took the rigging down.

Handovers concerning removal of PSV 504

6.94 Mr Bolland's evidence shows clearly that Mr Vernon had the intention of starting up condensate injection pump A. Yet Mr Vernon should have been aware that PSV 504 was off. He should have been made aware of this by means of the PTW and this aspect has just been described. He should also have been made aware of it, as should the phase 1 operator, Mr Richard, by the handovers between shifts. As shown in Table 6.1, Mr Smith handed over as maintenance lead hand to Mr Clark. Mr Lynch, lead production operator, handed over to Mr Flook who handed over to Mr Vernon. Mr Grant, phase 1 operator, handed over to Mr Richard. Mr Slaymaker, Control Room operator, handed over to someone unknown, who handed over to Mr Price, who handed over to Mr Bolland. Direct evidence on handovers on 6 July is confined to that of Mr Clark and Mr Bolland. According to Mr Clark, handover between maintenance lead hands normally took place in the maintenance office at about 17.30 hours and was based on a diary of work written up at the end of the shift, together with an A4 pad of notes, a sort of priority list of work, on-going in and planned for the forthcoming shift. Immediately after handover the maintenance lead hand would go to the Control Room and draw out all the PTWs in his name. Mr Clark said he never went through the suspended PTWs, which were held in the Safety Office.

6.95 On 6 July Mr Smith and Mr Clark held their handover meeting at 17.30 hours. Mr Smith spent some time outlining the work planned for the Voith coupling on condensate injection pump A, explaining that the pump was shut down and electrically isolated but that no work had started on it and that the PTW for this work was in the Safety Office. Mr Clark was clear that Mr Smith did not tell him anything about the work on, or PTW for, PSV 504 and that it was not noted in the diary or the A4 pad. It would be normal for the Score supervisor to tell Mr Smith he was taking out a PTW and Mr Clark believed that if Mr Smith had been aware of the PSV overhaul he would certainly have mentioned it in the handover and recorded it on the A4 pad, it being normal practice to record which PSVs contractors were working on. He agreed that if a PSV overhaul had been completed and the valve returned to service during the day-shift, there would be no need to tell the night-shift maintenance lead hand; the important thing was whether the valve had been replaced. He accepted that, with the handover starting at 17.30 hours, Mr Smith could not know about a PTW suspended towards 18.00 hours and, that if he believed the valve overhaul would be complete within the shift, he might not include it in his handover. Mr Clark was categorical that if he had known that PSV 504 was off, he would not have contemplated starting up A pump and that the first he heard of this was in a telephone conversation with the DEN some time after 16 July 1988; he was surprised and shocked to learn this.

6.96 According to Mr Lockwood and Mr Bolland, handover between lead production operators normally took place in the Control Room, commencing about 17.15 hours and lasting some 20-25 minutes. The operators kept notes, not a log, on an A4 pad, and used this as an aide-memoire in the handover discussions. They would also refer to the Control Room operator's log and sometimes, but not always, to the phase 1

operator's log. After handover, at about 17.40 hours, the oncoming lead operator would walk round the platform. About 18.00 hours the lead operator would return and start going through the PTWs. The 2 lead operators did not go through the PTWs together as part of the handover. Before 17.00 hours the PTWs coming in were signed by the outgoing lead operator. If he was not there the PTW could be left on his desk, as described below. After 17.00 hours all incoming PTWs would be handled by the oncoming lead operator. If he was present, he might sign such a permit there and then. He would not start to process the other PTWs until 18.00 hours. A Performing Authority returning a PTW for completion or suspension after 17.00 hours and finding the lead operator unavailable could sign his copy of the PTW, match it up with the other 2 copies and leave them on the desk of the lead operator for him to process.

6.97 According to Mr Bollands, on 6 July Mr Flook and Mr Vernon commenced their handover at 17.10 hours. He stated that he would have expected Mr Flook to know PSV 504 was off and to tell Mr Vernon, but also that Mr Vernon could not have known that the PSV was off because he would have said so and would not have attempted to start up A pump without its PSV. Mr Vernon would have signed off any PTW suspended after 17.15 hours, particularly one suspended at 18.00 hours. Mr Clark stated that Mr Vernon would have told him the PSV was off and tried something else. He knew Mr Vernon well; he was a competent and experienced man and a stickler for detail. Mr Lynch considered that Mr Flook would inform Mr Vernon of the state of the PM work on A pump.

6.98 Mr Bollands also described the normal handover between the phase 1 operators. This would start about 17.15 hours in the Control Room, but at the back of the panels, out of sight both of the lead production operators and the Control Room operators. The basis of the handover was the phase 1 operator's log, which covered only the gas plant. Mr Bollands believed that on 6 July the phase 1 operator's log would have recorded the fact that A pump had been depressurised for maintenance. He was sure Mr Richard knew that he had only one pump available, as evidenced by his prompt reaction when told of the trip on B pump around 21.45 hours. He was also certain that the overhaul of PSV 504 would be recorded in the log and that Mr Grant would tell this to Mr Richard. Mr Grant, who kept a good log, would enter the PSV overhaul, even if the valve was finished and replaced prior to the end of the shift, as the log would record the time when the pump was shut down and the time when it was repressurised. Mr Bollands believed, however, that Mr Richard did not know PSV 504 had not been reinstated as he could not imagine him wanting to restart the pump without its PSV.

6.99 The Control Room operators' handover, described by Mr Bollands, normally began about 17.15 hours in the Control Room and lasted some 15-20 minutes. The basis of the discussion was a log, in triplicate, kept by the Control Room operator, which covered the oil, water injection and produced water plants together with the diesel pumps and the JB turbines. The gas plant was covered not in that log but in that of the phase 1 operator. The oncoming Control Room operator did not read the latter log or have any discussion with the phase 1 operator. Nor did he read the extant PTWs except, when alerted by the lead production operator, those for hot work, since the latter affected the status of the F & G panel. On 6 July Mr Bollands' handover from Mr Price started about 17.10 hours and took about 5-10 minutes. Mr Bollands was not told at handover, nor did he see in the log, anything about maintenance work on, or PTWs for, A pump. In particular, he was not told of the plan to work on the Voith coupling or of the removal for overhaul of PSV 504. In the course of the evening he became aware that A pump was with maintenance, but believed it was for an instrument PM. He said that he would not expect to be told and would not expect that the Control Room operators' log would record the overhaul of a PSV such as PSV 504, and agreed that the system as practised did not allow for such information to be recorded in such a way that the Control Room operator would know. He did not read the phase 1 operator's log that evening.

6.100 Mr Bolland knew Mr Rankin as a Score technician by sight but not by name. He could not remember seeing him in the Control Room between coming on shift and just after 18.00 hours. However, having a PTW signed off or suspended was not a long job and Mr Rankin could have returned the PTW without his noticing.

State of knowledge of the operators

6.101 Against this background, I return to the state of knowledge of the operators. Mr Smith had brought the PTW for the PM to the Control Room just before 08.00 hours that morning. Operations changed over from A pump to B pump and would have set about making the valve isolations and depressurising the pump, preparatory to spading off by maintenance. Mr Rankin stated that Mr Grant seemed to be checking rather than making valve isolations. Mr Seddon did not communicate his intention to defer the PM and proceed only with the Voith coupling work to Mr White until 16.50 hours. Almost certainly the outgoing operators, Mr Flook and Mr Grant, handed over believing that the PM was still on.

6.102 It was the practice for the phase 1 operator's log and handover to include information about PSVs. However, it can clearly be inferred that Mr Richard was not informed by Mr Grant of the state of PSV 504. The fact that the pump was with maintenance may have been a factor in this.

6.103 The handover between Mr Smith and Mr Clark concentrated on the Voith coupling work. It is not clear whether Mr Smith already knew of the decision to abandon the PM or whether he was treating the coupling work as a priority job within the PM. In any event Mr Clark stated that Mr Smith did not tell him PSV 504 was off. Mr Clark agreed that if Mr Smith expected the PSV to be restored on the day-shift, he might well not mention it. The handover occurred before the time when Mr Rankin said he went to the Control Room to suspend the PTW.

6.104 If Mr Vernon was unaware that PSV 504 was off at 21.45 hours, it must have been either because he had no knowledge of the work at all or because he believed the valve had been put back. The persons from whom Mr Vernon could have learnt about the PSV were Mr Flook and Mr Rankin.

6.105 Crucial to this issue is Mr Rankin's last visit to the Control Room, for which I have only his evidence. Mr Rankin stated that the "lead operator", whom he could not identify, told him there was no crane available to lift the PSV. This is difficult to understand, since it was not the function of the lead production operator to deal with the crane. The operator made no telephone call, so that he evidently knew already that the PSV was not to be replaced. Mr Rankin also stated that he suspended the permit by writing "SUSP" in the gas test column, which was the usual practice on the platform. He had never suspended a PTW before and appeared quite unsure how he knew that this was the procedure.

6.106 I am not satisfied that I can rely on Mr Rankin's evidence on this last visit to the Control Room. I have to consider whether he may not have gone back at all. If he did not, and therefore did not return the PTW, Mr Vernon should have detected the absence of the outstanding permit and should have had the work site checked.

6.107 I also have to consider whether if he had dealings with a lead operator it was Mr Flook not Mr Vernon. This would require both that Mr Flook stayed on later than usual and that Mr Rankin's visit was earlier than he thought. According to Mr Rankin, the lead operator seemed to be aware already that the PSV was not to be replaced that night. A natural explanation of this is that, given that he had no confirmation of restoration of the PSV by the time of his own handover, Mr Smith advised the lead operator that if the job was not completed on the day-shift, it should be left to the next day. He was known to be opposed to overtime working by contractors. If it was Mr Flook who dealt with the matter, it was his responsibility to

make arrangements to have the work site checked out. Since he himself was going off shift, the simplest way to do this was to advise Mr Vernon.

6.108 I think it much more likely, however, that Mr Rankin did return to the Control Room and that any dealings which he had with a lead operator were with Mr Vernon. His account suggests to me that either he had only minimal communication about the PTW with the lead operator or, more probably, he simply left the permit on the desk. I am not satisfied that the way in which he had filled in the PTW would convey to Mr Vernon that the job was suspended. However, whether the permit showed the job as suspended or completed, it fell to Mr Vernon as the incoming lead operator to have the work site checked. The practice had developed that the lead operator would sometimes sign the permit, whether completed or suspended, before having the work site checked. I infer that by 21.45 hours he had still not had the site checked; with the pump down for maintenance, he could have viewed it as a low priority.

6.109 I conclude that it is probable that the fact that PSV 504 was off was not known to Mr Clark, Mr Vernon, or Mr Richard and that this was due to failures of the handover and in the execution of the PTW systems, which were aggravated by the status of A pump.

Blind flange assembly at site of PSV 504

6.110 Admission of condensate to A pump would cause a leak from the relief line at the site of PSV 504 only if the blind flange assembly at that point was not leak-tight. The flange was a ring type joint (RTJ) flange with a groove on each flange face into which fitted a soft iron ring. A good deal of evidence was heard on this point. Possibilities explored included failure to fit a blind flange at all, inadequate tightening of the bolts, and damage to, or deterioration of the flange, the ring or the bolts. Another possibility considered, arising from uncertainty as to the sizing of the flange, was the fitting of a mismatched blind flange. A possible factor was the physical difficulty of handling these heavy flanges.

Pressure safety valve PSV 504

6.111 Pressure safety valve PSV 504 was supplied as part of the condensate injection pump package by Thyssen Maschinenbau Ruhrpumpen. It was of unconventional design, in that the inlet and outlet connection flanges were not part of the valve body itself but were welded to adapters, which were in turn bolted to the valve body. The valve was recorded in some documents as 4 inch 900 RTJ x 4 inch 600 RTJ, meaning that it was a valve to fit a 4 inch diameter pipe with a 900 lb flange upstream and a 600 lb flange downstream, both flanges having a ring type joint; in other documents it was recorded as 4 inch 1500 RTJ x 4 inch 600 RTJ, meaning that the upstream flange was 1500 lb, the other features being the same. The valve was Class 900 rated to 2160 psi. A full scale model of the valve configuration is shown in Plate 24(a) and a blind flange and ring in Plate 24(b).

6.112 The most recent operating set pressure of the valve was 1750 psi. The operating set pressure had been changed from its original value of 1400 psi, once in 1985 to 1550 psi and again in 1986 to 1750 psi; one reason suggested was to accommodate the higher pressures involved in injection of condensate into the wells.

Flange rating on PSV 504 pipework

6.113 The rating of the flange became an issue initially in that one explanation advanced for a leak at the site of PSV 504 was the fitting of an incorrectly sized blind flange. Subsequently, the rating of this flange also became an issue in relation to the possibility that the blind flange might have been disturbed by an internal explosion caused by compression and autoignition. The evidence on the rating of the flange is given in Appendix G. I have come to no conclusion on the matter. It does not

materially affect my views on the possibility of a leak from a less than leak-tight blind flange at the site of PSV 504. The only other matter to which it is relevant is that it leaves open the possibility of rupture if autoignition occurred.

Blind flange practices

6.114 A number of witnesses gave evidence on practice in the fitting of a blind flange. The practice of Score was described by Mr Ritchie and Mr Whalley and by 2 other supervisors, Mr J Tait and Mr A Watt. Other evidence was given by Mr J Pirie, a service engineer with Wood Group Valves and Engineering Services Ltd, Mr R W Barclay, formerly a valve technician with the same company, and Mr A C Bruce, formerly a valve technician with Score. Mr Ritchie gave as reasons for fitting blind flanges: to obtain access to the item concerned; to protect the faces of the pipe flange; to prevent condensation in the pipework; to prevent residual hydrocarbons coming out; and to prevent a leak from the pipework in the event of inadvertent admission of hydrocarbons. Mr Whalley gave the additional reason of keeping debris out but seemed reluctant to acknowledge the function of containing high pressure to which it might be inadvertently exposed. Mr Ritchie said that it would be bad practice and highly unlikely that hydrocarbon would be admitted to the pipework closed by the blind flange. There should be block valves chained shut to prevent passage of fluid and any leak should be very small. If hydrocarbon at pressure were admitted, the blind flange would be expected to withstand a gradual build-up to the static pressure; it would not necessarily withstand a sudden pressure transient, or water hammer. There was always the possibility that a block valve might pass fluid and in this case the pressure between the valve and the blind flange could build up to the line static pressure. This is one of the reasons why the blind flange should be able to withstand that pressure. Mr Ritchie said that the fitting of a blind flange to open pipework was normal practice in the North Sea, and it was the practice of Occidental and of Score. When a PSV was taken out it was Score's invariable practice to fit a blind flange. The blind flange was fitted as soon as possible after taking out a PSV. The exception was where there was a complete shutdown, when often blind flanges were not used. There were no circumstances in which, if a blind flange was fitted, it would not be flogged up. He stated that it was the company's invariable practice that a blind flange should be flogged up. He rejected the suggestion that combination spanners might be used on a flange of the size of that on PSV 504. He agreed, however, that for smaller flanges a combination spanner might be used.

6.115 A demonstration was given by Mr Whalley of the fitting of a blind flange on the PSV 504 rig at the Inquiry (Model E) shown in Plate 24(a). The rig was fitted with a 900 lb RTJ flange on the valve inlet side and a 600 lb RTJ flange on the outlet side. Mr Whalley performed the fitting on the 900 lb pipe flange of a correct 900 lb blind flange and an incorrect 1500 lb blind flange.

6.116 A flange may in principle be tightened by the use of the fingers, or a combination spanner or a flogging spanner and hammer. The tightnesses so achieved are referred to as finger tight, hand tight and flogged up, respectively. Witnesses agreed that a blind flange would not be tightened by fingers alone. There were several who stated, however, that they tended to use combination spanners rather than to flog up or that it was a matter of personal choice. For example, Mr Pirie stated that for joints of 1500 lb or less he used a combination spanner, both for a blind flange and in making up the flange on the valve; this was his personal choice. Witnesses who addressed the question were agreed that a blind flange should not be exposed to high pressure hydrocarbons without a prior pressure test. Evidence was given that in fitting a blind flange the old bolts and the old ring would be used. The possibility was explored of damage to flanges or rings which might lead to a leak. Mr Watt stated that damage to the grooves on flanges did occur and that repair of such flanges was one of the jobs done in the company's workshops. Mr Clark stated that one could not simply look at an old ring and say it was all right and that his expectation that a blind flange would hold system pressure depended on the use of a new ring.

6.117 Mr Grieve gave evidence that on one occasion on Piper, late in 1987 or early in 1988, he had found a blind flange which was loose. This was at the site of one of the discharge PSVs on the first stage of B reciprocating compressor; the valve had been removed for recertification. The blind flange was not incorrectly fitted; it was just lying on top of the pipe flange, with the bolts loose though with nuts on. He went to the container of the contractors, Score, and spoke to them about it. They told him that they had just finished recertification and were going to reinstate the valve. In the course of conversation they also said that it was not common practice in the North Sea to fit blind flanges when removing PSVs. He did not mention it to anyone else.

State of flange on PSV 504 pipework on 6 July

6.118 Mr Rankin stated that it was both standard practice and a Score requirement to fit a blind flange and to flog it up; it could have been an Occidental requirement also. The reasons he gave for fitting a blind flange were the same as those stated by Mr Whalley. He was clear that a blind flange had been fitted to the inlet pipe of PSV 504, although he did not see it fitted and did not inspect it afterwards. He stated that before lunch Mr Sutton prepared the blind flanges and tools, obtaining these items from the container. The tools were combination spanners, flogging spanners and hammer and, he believed, wedges. Mr Sutton did not mention being short of any blind flanges but, if he had been, he would have obtained them from the Occidental flange store on the 68 ft level. After lunch the scaffolding was up and Mr Sutton took the tools down to the job site, making more than one journey; he had no recollection of assisting Mr Sutton. Following his second visit to the Control Room, Mr Rankin went down to the job site and assisted Mr Sutton to break the flanges on the valve. He then went back to the Control Room to arrange the crane, returned to find that the valve was already on the floor and went back up to the container. Once the valve was in the container Mr Rankin busied himself with the valve. Mr Sutton took the blind flanges down to fit them; he would have had to carry them individually. Mr Rankin did not visit the job site again that day. Mr Rankin essentially left it to Mr Sutton to take the blind flanges down and fit them. He did not at the time consider the difficulty of carrying the heavy blind flanges down and lifting them on to the scaffolding. He considered that one man was capable of fitting the blind flanges, though Mr Sutton might have got assistance from a rigger.

6.119 With regard to the size of the upstream flange, Mr Rankin was confident that the blind flanges used were 1500 and 600 lb. He was sure that flanges of this size were in the container. Mr Sutton prepared the blind flanges and tools before the scaffolding was put up. He would know the flange size because he had done PSV 505 and they had available a previous test report indicating flange size. Mr Rankin did not check how many blind flanges Mr Sutton took and did not himself examine the ratings. If a blind flange had been wrongly sized, it would have been obvious and he would have been informed by Mr Sutton who would not have fitted a wrong flange. As far as concerned the tightening up of the blind flange, Mr Rankin regarded the use of combination spanners or flogging up as an individual matter. His own practice was to flog up, which was equally easy, but he could only speak for himself. He had seen Mr Sutton fit blind flanges on Piper before but he could not remember if he flogged them up. As far as concerns 6 July, it was put to him that his second statement of 19 April 1989 included the passage "We were using big combination spanners which would give sufficient torque but there was a flogging spanner on the site and he might have used that also." It was suggested to Mr Rankin that Mr Sutton could well have realised that the work on the PSV would not take long. He may have returned for a blind flange and found the valve in a reasonable condition. He might not have gone to the length of flogging up the bolts. If things went as expected, he would have to start undoing them very soon after. It was also suggested that Mr Sutton might not have put a blind flange on at all, but Mr Rankin rejected this. Mr Rankin had worked with Mr Sutton at least 18 months and regarded him as a competent and experienced workman, which was the reason that he did not go down to inspect his work. In any event, he would have assisted Mr Sutton in putting the PSV back in. A poorly fitted

blind flange would be obvious to him. It was not something Score would tolerate. Further testimony on Mr Sutton's competence and conscientiousness was given by Mr Ritchie.

6.120 The other witnesses of the work at the site of PSV 504 were the 2 riggers, Mr McDonald and Mr Rutherford. Mr McDonald's involvement was minimal; he did not go up the scaffolding and he saw neither the fitting nor the state of any blind flanges. Mr Rutherford stated that it was he who did the rigging to remove the valve. There was only one fitter there and he opened the flanges alone, though possibly the bolts might already have been slackened off. He had no recollection of seeing any blind flanges or being asked to assist with them in any way.

6.121 The evidence on whether fitting a 1500 lb flange was a one-man job was to some extent conflicting, but may perhaps be summarised by saying that whilst ideally it would be done by 2 men it could be done by one. Mr Bruce, the Score fitter, had worked with Mr Sutton. He confirmed that he was quite efficient at fitting a blind flange alone, that he would not fit a mismatched flange and that he always flogged blind flanges up; he never cut corners. He agreed that a mismatched flange or finger tight bolts would be detectable and would be severely dealt with. Mr Rutherford was requested to lift the 1500 lb blind flange, shown in Plate 24(b). He was then asked whether he personally would carry such a flange down 50 ft of stairs and replied that he would not, unless there was no alternative, and doubted whether a fitter would; he would call for a rigger.

Leak tests on blind flange assemblies

6.122 The size of leak which might be expected from a blind flange which was not completely leak-tight was explored by experimental leak tests on blind flange assemblies. Assemblies tested included not only assemblies with varying degrees of tightness, but also assemblies with mismatched fixed and blind flanges.

6.123 Two sets of experimental tests on leaks from blind flange assemblies were presented. Mr R Standen, Senior Physicist with Nowsco Well Services Ltd, described tests commissioned by Occidental and conducted by his company. The tests reported were a sample of those conducted, selected on the advice of the Assessors. They were carried out in a marquee on a rig with a fixed flange of 900 lb rating and using both 900 lb and 1500 lb blind flanges. The fluids used were nitrogen (or nitrogen/helium mixture), water and carbon dioxide, the latter being a surrogate for condensate. The pressure aimed for, and achieved in most tests, was 650 psi. The main variables investigated were the fluid, the blind flange rating, the number of bolts, the ring and the degree of tightness. The degrees of tightness were finger tight, hand tight and flogged up. A video of the tests was shown and a still from this video is reproduced in Plate 26(b); the video included sound recordings. The tests showed that with a properly matched blind flange and ring hand tight or flogged up there was no leak and that even with a mismatched 1500 lb flange, with 4 bolts rather than 8, or with the ring missing, the leak flow with bolts hand tight or flogged up was negligible. Leaks were obtained, however, with flanges which were finger tight or slack. Some of the leaks were partial circumferential leaks, and thus oriented in a particular direction. Asked to explain this, Mr Standen referred to tests involving a 1500 lb blind flange on the 900 lb fixed flange. In such tests the fitter had tended to hang the blind flange on and fasten the 2 top bolts first, so that these bolts were perhaps tighter than the others. He was asked whether he would expect a properly matched flange finger tight to show a directed leak. It was his feeling that finger tightening might give a flange which was not uniformly tight. A set of measurements of bolt stretch was also presented. Using a torque-indicating wrench 8 bolts were tightened first from finger tight to hand tight and then from finger tight to flogged up, the torques being 250 ft lb and 430-440 ft lb, respectively, and measured on just 2 bolts in each case. The increase in bolt length was measured for the 8 bolts, numbered 1-8, starting at the 11 o'clock position and going anti-clockwise. For hand tight the increases were 0.06, 0.14,

0.08, 0.02, 0.08, 0.04, 0 and 0.38 mm respectively, and for flogged up 0.16, 0.14, 0.10, 0.44, 0.24, 0.24, 0.08 and 0.22 mm respectively. In these results, therefore, the hand tight bolts were less tight on the underside and there was considerable variability of tightnesses. Attempts were made to produce leaks which gave strong sounds, particularly tones. Sounds started at low pressures, tens of psi, and varied with the pressure. A sound of 121 dBA with a 7500 Hz tone, an almost pure whistle, was produced by a leak of 400 scfm of nitrogen from a 900 lb blind flange with 8 bolts finger tight. A test conducted with a Metaflex gasket, not included in the report but done with the express purpose of inducing a noise, gave a squealing sound.

6.124 Mr R A Davie, Senior Consultant with YARD Ltd, Consulting Engineers, spoke to tests commissioned by the Contractors' Interest conducted by the National Engineering Laboratory (NEL) and witnessed by YARD. These tests were conducted in 2 phases, the first conducted by NEL at the Wood Group facilities at Peterhead and the second by NEL at their own laboratories at East Kilbride. They were carried out on a rig with a 1500 lb fixed flange using a 1500 lb blind flange. The fluids used were air and water and the pressure up to 670 psi. The main variables investigated were the fluid, the number of bolts, the ring and the degree of tightness; no tests were done on mismatched flanges. Again a video of the tests was shown. The degrees of tightness were finger tight and flogged up, which corresponded to measured torques in the ranges 1.7-9.1 Nm and 274-656, respectively, and arbitrary intermediate values of 109 and 347 Nm. The torque corresponding to the enhanced finger tightness obtained by applying a spanner lightly and casually corresponded to a torque of about 50 Nm. These tests too showed that with a matched blind flange flogged up there was no significant leak even with 4 or 2 bolts rather than 8 or with the ring missing. In fact there was no significant leak in any tests where the bolt torque was more than 50 Nm. Leaks were obtained, however, with finger tight bolts. At a pressure of about 450 psi the leak flow of water with a ring and 8 bolts finger tight was about 65 kg/min and that with a ring and 4 bolts with a torque of 50 Nm about 4 kg/min. Measurements were made of the displacement of the blind flange as a function of applied pressure of air for different ring and bolt configurations and bolt tightnesses. At a pressure of 670 psi with a ring and 4 bolts finger tight the displacement was about 0.43 mm and with 8 bolts it was 0.22 mm. The equipment used in the tests was new. Mr Davie was questioned on the possible effects of equipment which had suffered deterioration, but he tended to discount this. He did not think there would be any significant difference between an old and a new ring, though he had not studied that aspect. Mr Davie also pointed out that there are 2 types of ring used in an RTJ, an octagonal ring and an oval one. That used in his work was the octagonal ring, as specified for the flange on Piper. These air and water leak tests were analysed by Dr D A McNeil, Senior Scientific Officer at NEL, for the cases with and without a ring, to obtain estimates of the equivalent hole diameters and associated leak flows at a pressure of 46.3 bara, for the finger tight condition only. With the ring and with bolts finger tight he made the estimates shown in Table 6.3.

6.125 What I principally take from this evidence is that a blind flange which is hand tight or flogged up will not give a leak of the size sought, short of gross damage or deterioration, but that one which is finger tight could do so.

Scenario of leak at site of PSV 504 through a blind flange assembly which was not leak-tight

Nature of the 2-stage leak

6.126 Continuing with my first scenario of a leak at the site of PSV 504 through a blind flange assembly which was not leak-tight, I now turn to the sequence of actions which might have caused a leak. I remind the reader that the leak pattern which I am considering is a gas cloud containing some 45 kg of hydrocarbon within the flammable range, arising from a 2-stage leak, in the second stage some 110 kg/min lasting some 30 seconds and in the first stage perhaps some 4 kg/min. I note, however, that in the

first stage a leak as low as 1 kg/min would be sufficient to give a C3 alarm in 30 seconds.

Scenarios for the 2-stage leak

6.127 The fourth and sixth reports presented by Drs Richardson and Saville dealt with the leak rates obtainable at A pump for different GOV states, given suitable orifices in the blind flange. These were spoken to by Dr Saville and Dr Richardson, respectively. The most straightforward way in which a leak might occur is for the GOV to be opened, thus admitting condensate to the delivery pipework, and to remain open. The size of the assumed orifice may be defined in terms of its equivalent diameter, the leak flow being proportional to the square of the diameter. At the condensate pressure of 46.2 bara the large, second stage leak sought, a leak with a leak rate of 110 kg/min, would be given by an orifice 8 mm (actually 7.8 mm) equivalent diameter.

6.128 For the initial small leak a semi-continuous gas leak of 4 kg/min would be given by a variety of combinations of orifice diameter and gas pressure. These include an orifice of 10 mm orifice and 5.3 bara; one of 8 mm and 8.3 bara; and one of 3.4 mm and 46.2 bara. The jaggging times to give these pressures are some 0.4, 0.6 and, by extrapolation, about 2.6 seconds, respectively.

6.129 A 2-stage leak could have arisen from various permutations of actions at the GOVs of A pump. One such pattern of actions is that perhaps 2 minutes before the initial explosion the GOV was opened by jaggging and then closed before the relief line had filled with liquid, giving a small leak, and that some 30 seconds before the explosion it was opened and stayed open, filling the relief line with liquid and giving a larger leak. The order of leak envisaged is in the second stage some 110 kg/min from an orifice of about 8 mm equivalent diameter and in the first stage one of some 4 kg/min. If the orifice were 8 mm in this first stage also, the pressure required would be 8 bar, but in fact the final 8 mm orifice would be the result of the full pressure of 46.2 bara, so that in the first stage the orifice would be smaller and the pressure greater, though it is difficult to quantify this. The evidence on the actions of the operators at the pumps has already been described. Mr Grieve did not observe Mr Vernon work the push-pull button on A pump. However, either Mr Vernon or Mr Richard could well have jaggged the GOV before Mr Grieve arrived. Having reconnected the air line to the GOV, it would be a natural action to give a short pull to confirm movement of the valve. If the electrical de-isolation of A pump had then been effected, the second opening could have been completed in a few seconds and the valve would have remained open. It is worthy of note that when Mr Grieve first arrived at the 68 ft level, Mr Vernon was beside the A pump GOVs. When Mr Young first arrived, Mr Vernon was again beside these GOVs.

Observations on this scenario

6.130 The scenario under consideration is that of a leak at the site of PSV 504 through a blind flange assembly which was not leak-tight. I have already given my views on a number of aspects of this scenario and can be brief at this point. I find the scenario thus far entirely credible. Mr Vernon had the intention and the opportunity to admit condensate to A pump. A natural sequence of actions to effect this admission would give rise to a 2-stage leak. The scenario does require, however, that the blind flange assembly was not leak-tight, for which there is no direct evidence. On this aspect of the credibility of the scenario I defer further discussion until I have considered the other scenarios.

Scenario of leak at site of PSV 504 due to autoignition or other effects consequent on admission of condensate

6.131 Several other scenarios which might account for a leak from the site of PSV 504 were also explored. There were 3 which were postulated on the admission of condensate, namely:

1. Autoignition
2. Shock loading
3. Brittle fracture

whilst the 4th was:

4. Over-pressurisation by methanol injection.

All 4 scenarios were considered by Drs Richardson and Saville in their fifth and third reports. The fifth report dealt with the above 4 scenarios and was spoken to by Dr Saville. It concluded that all but autoignition could be dismissed. The third report, presented by Dr Richardson, addressed further the question of autoignition. In this work frequent use was made of 2 computer programs, PREPROP and BLOWDOWN. The first was used to calculate thermophysical properties of mixtures by an extension of the principle of corresponding states, the second to simulate the depressurisation of a vessel.

Admission of condensate

6.132 In their fifth report, Drs Richardson and Saville gave estimates of the conditions which would occur in the pump system, initially at atmospheric pressure, if condensate at 46.2 bara were admitted through the suction valve GOV 5005. Opening of GOV 5005 would give an initial flow velocity of 133 m/s. If this valve was opened without the interruption inherent in jaggging, pressurisation would be essentially complete after some 2 seconds, with the valve still only about 30% open. The BLOWDOWN code was used to determine the temperatures in the gas phase after compression. For the case of compression of air under adiabatic conditions the temperature in the gas space would attain a value of about 500°C. Dr Saville stated that this temperature would be much reduced if the gas space contained a large proportion of hydrocarbon or if conditions were not adiabatic so that there was appreciable heat transfer to the wall. He said that each of these features could reduce the temperature increase by a factor of roughly 2. Assuming that the pump system was initially filled with air, the authors calculated for this case the temperatures shown in Fig 6.6. Compression of the air would lead to a rise in temperature, which would reach almost 270°C (520°F) at the end of pressurisation. The effect of the pressure letdown would be to cause the condensate to flash off, forming vapour and liquid, with the liquid temperature falling to provide the latent heat of vaporisation of the vapour. For a letdown from an upstream pressure of 46.2 bara to atmospheric pressure in the pump system there would be a temperature drop to about -26°C (-15°F), but this would bottom out at about 0.12 seconds, as shown in Fig 6.6. If instead the GOV was jaggged, the temperature reached by the gas would depend on the period of the jag. It was estimated that for jags of 0.5, 0.75 and 1.0 seconds duration, the maximum temperatures attained by the air would be 203, 220 and 240°C, respectively. In all cases except the first the maximum temperature would be reached on the first jag.

Autoignition

6.133 If a flammable mixture had accumulated in the relief line from the pump, sudden admission of condensate would cause compression of this mixture and could possibly result in ignition. Such autoignition would be similar to that which occurs in a diesel engine, where ignition is effected not by a spark plug but by compression, although the temperatures attained would be much lower. For ignition to occur, there would have to be a flammable mixture in the system. In other words, there would need to be ingress of air, which would depend on the extent of any openings to atmosphere. The evidence was that the flange at PSV 504 had been open for about an hour. There were also other possibilities. For example, if the valve used to vent the pump to flare had been left open, condensate vapour, being denser than air, would continue to stream out of this valve, drawing air in at the top through the flange at the site of PSV 504. It was not known how long the pump vent valve might have been open nor whether this coincided with the period when the flange was open. As far as

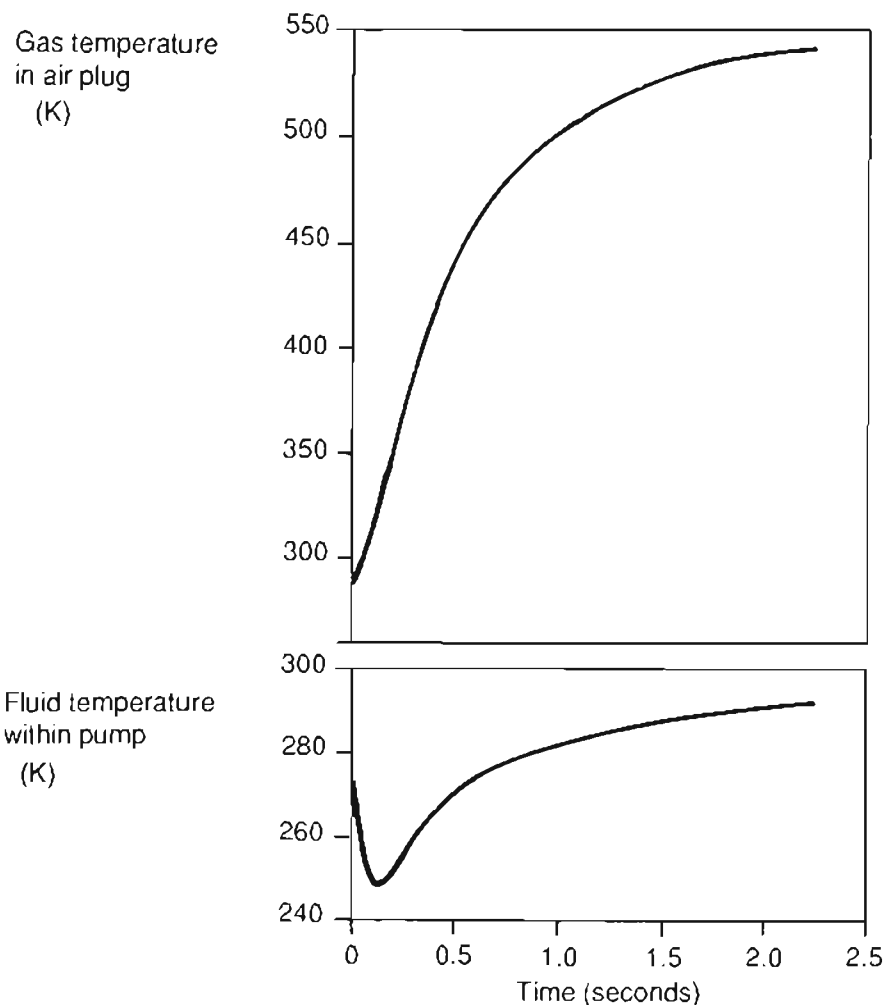


Fig. 6.6 Estimated temperatures of gas (air) and liquid on admission of condensate through GOV 5005 into condensate injection pump A system.

concerned entry of air into the open flange, there was an 11 inch horizontal section from which condensate vapour would readily flow out. If the penetration of air were then by molecular diffusion, it would be very slow, about 1 m/h, but any disturbance, whether of wind velocity or temperature or something else, would increase the rate of diffusion. It was put to Dr Saville, and he agreed, that the vapour from condensate would be rich in methane and so that the gas in the pipe would be buoyant and that air might be drawn in this way. The report considered a mixture of condensate vapour and air with the air content 95%, as a worst case in the sense that the gas temperature after compression would be high and more favourable to autoignition. It was estimated that for pressurisation by jugging the temperatures of the air in the relief line would be in the range 200–270°C. This range of temperatures was compared with published data on autoignition temperatures for the paraffin series of hydrocarbons, showing that those of pentane and above lie in or below this range. Dr Saville pointed out that the scenario envisioned involved a multi-component mixture and also that it differed from the situation in which the published data would probably have been determined, in respect of factors such as vessel geometry and pressure. The conclusion in this report, therefore, was that it was an open question whether autoignition could occur. The authors were not able to say what effect autoignition would have. Dr Saville was asked whether an autoignition scenario could explain a leak giving gas alarms some time before the initial explosion as well as the latter, but he was unable to help. He was asked whether he would expect the flame from an autoignition to pass through the rupture, thus giving on the outside an ignited leak, but he was unsure. It was put

to him that if autoignition occurred such as to rupture the pipework, it would be expected that someone in the area would hear it, and he agreed. The objection was raised that there did not seem to be a history of autoignition incidents. Dr Saville replied that compression ignition incidents were really quite common, though not necessarily offshore, and perhaps more often in the past. He pointed out that it would be normal practice to purge with nitrogen. The third report by Drs Richardson and Saville, concerned exclusively with autoignition, was presented by Dr Richardson. This dealt in greater detail with the probability of autoignition and with its effects. The report acknowledged the assistance received by the authors from Dr J F Griffiths, of the School of Chemistry at the University of Leeds, and Mr I A Smith, a consultant. The process of combustion is a complex one and is influenced by a large number of factors. It is convenient for practical purposes to characterise it by features such as autoignition temperatures (AITs) and to treat these as if they were properties, but this is an oversimplification. AITs give a ranking of the reactivity of the substance with oxygen and this ranking is relatively insensitive to the conditions, but the absolute value of the AIT is sensitive. Factors affecting the temperature at which compression ignition may occur, which were discussed in the report, were fuel composition; fuel-air ratio; container volume and geometry; initial pressure; fluid motion; and wall temperature. Some of these factors tend to lower and others to raise the AIT. As far as concerns the specific scenario considered, the high pressure would be a factor tending strongly to decrease the AIT and the fluid motion a factor tending to increase it, but to an unknown degree. Dr Richardson thought the latter effect would be in tens rather than hundreds of degrees. The report concluded that it was not possible to predict whether, for the scenario postulated, autoignition would have occurred. The situation was too complex and experimental work would be required. Asked about air ingress, Dr Richardson said he had little problem in envisaging that sufficient air might have entered to give a flammable mixture.

6.134 Although they were unsure whether autoignition would occur, the authors nevertheless investigated the explosion pressure which would occur if it did. There was some doubt about the composition of the vapour which would exist in the pipe. One possibility was that it would be close to that of condensate. Another was that there might be left in the pump a pool of heavy ends which would slowly evaporate. Two vapour mixtures were therefore investigated, condensate and a heavy end mixture. The authors used the PREPROP code to determine the pressure resulting from an explosion. They calculated that if ignition did occur, then assuming an adiabatic explosion of a stoichiometric mixture, containing some 3-4% of hydrocarbon, initially at 46.2 bara in the fixed volume of the system, the resultant pressure would be 293 bara for a condensate mixture and 297 for a heavy end mixture, or in round figures 300 bara.

6.135 Next the report addressed the question of the effect of such an explosion on the relief line. It considered the effect on the pipe and, for a blind flange, on the flange itself and on the bolts and ring. The detailed results of this analysis are given in Appendix G. They show, assuming a worst case explosion pressure of 300 bara, that a properly made up 1500 lb blind flange assembly would not fail, that a properly made up 900 lb blind flange assembly might possibly fail by failure of the flange itself, that it was possible to find a number of modes of improper assembly which could lead to failure, and that the flame would only propagate to the outside if the hole were relatively large. It was also concluded that an improperly made up blind flange assembly might fail if it had rather fewer than 8 bolts fitted loosely; many fewer than 8 bolts fitted tightly; grossly undersized bolts; or mismatching flanges. The authors drew attention to the effect of pipe whip due to an explosion, but stated that analysis of this was outside their expertise. Dr Richardson agreed that such analysis would require detailed knowledge of how the pipework was restrained.

Shock loading

6.136 The fifth report by Drs Richardson and Saville also dealt with other ways in which failure of the condensate injection pump system might occur. Sudden admission

of condensate into the relief line might possibly lead to a shock loading severe enough to cause rupture. If the delivery valve, GOV 5006, was open and the suction valve, GOV 5005, was opened so as to admit condensate into the pump system, a mass of condensate would travel through the system until stopped. The maximum possible pressure on a blind flange at the site of PSV 504 may be determined by assuming that it received the full force of the plug of condensate. Taking the initial flow velocity of 133 m/s obtained by opening of GOV 5005 and a condensate density of 300 kg/m³, the pressure on the flange caused by this impulse would be 53 bar, which added to the existing system pressure of 46.2 bara would give a total pressure on the flange of about 100 bara.

6.137 In practice the pressure exerted on the flange would be less than this because it would be most unlikely that the fluid would maintain this flow rate through the pump and line and because the first fluid to contact the flange would be gas moving ahead of the liquid and being compressed by it. It was Dr Saville's judgement that by the time the condensate reached the flange it would have little momentum left. The maximum allowable pressure for a 900 lb flange assembly was 150 bar (2160 psig) and for a 1500 lb assembly 250 bar (3600 psig). The conclusion reached was that given a properly made up flange shock loading could not have led to a leak. Dr Saville agreed, however, that if the bolts had not been properly tightened, the flange might have been dislodged sufficiently to permit some degree of leakage. Another possibility considered was a rupture due to unrestrained movement of the relief line. The effect was compared by one counsel with the whip effect when water is admitted into a fire hose. Dr Saville had not studied this, but he re-emphasised that there would be a change in flow as the condensate passed through the pump, referring to an order of magnitude reduction; he was not prepared, however, to rule out the possibility of pipe whip.

Brittle fracture

6.138 The chilling effect consequent on the sudden admission of condensate might conceivably give a temperature low enough to result in brittle fracture of the relief line. For a pressure letdown from an upstream pressure of 46.2 bara to atmospheric pressure in the pump system the instantaneous temperature drop would be to about -26°C (-15°F), as shown in Fig 6.6. This temperature would last, however, for less than a second, too short a time to cause any significant fall in the temperature of the metal. This temperature was compared with the safe lower operating temperature of most carbon steels of -20°F. It was concluded that the temperature drop attendant on admission of condensate could not have led to a leak caused by brittle fracture.

Over-pressurisation by methanol injection

6.139 The last of these scenarios was over-pressurisation of the relief line by methanol injection. The methanol supply was from one head of the methanol injection pump and the methanol would be delivered at a pressure of 230 bara (3320 psig) and a flow of 0.5 litre/min (8 US gal/h). There was some doubt as to the location of the methanol injection point on the condensate injection pumps. It was shown on a drawing as on the delivery line, but Mr J Drysdale, an operator, remembered it as on the suction line. Following pressurisation of the condensate injection pump A it would have been normal, to prevent hydrate formation, to begin methanol injection in the pump before starting it up. It was assumed that GOV 5005 and GOV 5006, the suction and discharge valves, would be closed during this operation. The worst case would be where the pump, its inlet and outlet lines and its pulsation dampeners, unprecharged, were full of condensate at 46.2 bara (670 psi) and 286 K (55.9°F). The volume of the system was estimated as 0.4m³ and the mass of condensate as 200 kg. The rise in pressure resulting from methanol injection was predicted using the PREPROP code. The 2 extreme cases for heat transfer between the condensate liquid and the metal walls were considered, namely no heat transfer (adiabatic conditions) and perfect heat transfer (isothermal conditions). The results showed that the methanol delivery

pressure of 230 bara would be reached after 37 and 52 minutes for the adiabatic and isothermal cases, respectively. Given this fairly long time, Dr Saville said that he would expect the system to approximate more closely to the isothermal case. The maximum allowable pressures of a 900 lb flange assembly would be reached within between 23 and 32 minutes and that of a 1500 lb assembly within between 40 and 54 minutes. If the pulsation dampeners had been precharged to their mid-position prior to methanol injection, the remaining halves of the 2 dampeners would give a volume to be filled of 76 litres and pressurisation would take of the order of 2½ hours. It was concluded that assuming methanol injection began between 21.45 hours and 21.50 hours, there was insufficient time for over-pressurisation to take place and that it was most unlikely that this was the cause of the leak.

Observations on autoignition and other variants

6.140 Of the mechanisms considered for rupture of the blind flange assembly on the relief line or the line itself, only autoignition emerges as a possibility and that only if the flange was 900 lb rating. The occurrence of autoignition is necessarily postulated on the admission of condensate to the relief pipe by jacking the suction GOV so that the liquid completely fills the pipe. A 2-stage leak might occur if an initial jag of the GOV led to autoignition and rupture of the blind flange assembly to give a hole and the GOV were then closed after this initial jag and later opened so that it remained open. In the first stage the leak rate would initially be comparable to that in the second stage. Then, depending on the precharge pressure of the pulsation dampeners, it would on the figures given by Drs Richardson and Saville subside within some 6-25 seconds. The wind tunnel tests do not give sufficient information to decide whether an orifice large enough to give the required leak rate in the second stage would give only a single low gas alarm in this first stage.

Hydrate formation and methanol injection

6.141 At various parts of the plant there was potential for the formation of, and blockage by, hydrates. In accordance with standard practice methanol was injected at selected points to prevent this, as shown in Fig J.8. The quantities of methanol required in phase 1 operation were an order of magnitude greater than in phase 2 and the platform was advised accordingly. It emerged in the course of the evidence that conditions, ie methanol concentration and temperature, at the JT valve, PCV 721, were of particular significance.

Experience of hydrates on plant

6.142 Hydrate problems were sometimes experienced on Piper and evidence on this was heard from several witnesses. Mr Grieve remembered a problem occurring on a single occasion perhaps a couple of years earlier when the molecular sieve driers had become saturated with water. This lasted 2 or 3 days and affected the condensate injection pump 2 or 3 times. The pump did not trip but either ran rather noisily or did not pump anything at all. In his statement to Occidental he described this type of situation in the following terms:

“There is no visible sign that the hydrate is there; it’s just by the pump itself; you get a sort of knocking noise from the pistons themselves. It’s very difficult to tell, it’s the sort of thing that somebody decides that that’s what they reckon it is. They shut the pump down, they zero vent it, leaving lying to zero vent for 5-10 minutes, shut it again and give it a start, it’ll run away with no problems at all.”

Mr Henderson stated that hydrate problems on the condensate injection pumps were few and far between. Generally the blockage occurred on the suction rather than the discharge side. The usual symptom was that the pump would tend to speed up and there could be a knocking of the valve chest. The remedy was to shutdown, vent off and recommission. Mr Clark said that the pumps might run well for a period and then there would be a number of trips. He agreed that when this occurred it would tend

to be due to process conditions. He could not think of anything other than hydrates which would cause such repeated trips. Mr Carey stated that they did not have much damage to equipment from hydrates; it was normally blockages in pipes. He referred in his statement to Occidental to blockages on PCV 723A, B. Mr J E Cotter, the phase 1 operator on nights until 4-5 July, stated that he had had no trouble with hydrates on his last tour.

Methanol injection

6.143 Operation in the phase 1 mode required that different quantities of methanol be injected. Calculations to determine these quantities were made by Mrs E A Paterson, a young chemical engineer in the Facilities Engineering Department. On 23 March 1988 Mrs Paterson, then using her maiden name, Mortimer, sent an internal memo to Mr J Bryce and Mr P J Cosgrove, specifying the quantities of methanol to be injected. This memo stated that areas where hydrate formation was most likely were the JT valve, the JT flash drum inlet, the condensate pumps and the second stage reciprocating compressor suction scrubbers, and specified methanol injection rates of 26, 23, 8 and 3 US gal/h, respectively, at these points. These quantities were determined using the method of Campbell given in *Gas Conditioning and Processing* and included a 5°F safety factor. The memo noted that according to the Occidental Production Chemical Treatment Handbook the maximum injection capacity of the main methanol pump to the JT valve was 23 US gal/h and thus less than the recommended rate. It proposed that additional methanol capacity should be provided at the JT valve and that there should be a back-up injection system at this point. The use of the Williams pumps was suggested, though the wording implies their use for the former rather than the latter purpose. On 6 July heads D and F of the main methanol pump were both connected up to supply methanol to the JT valve. Although both operators and management were examined at some length on the methanol supply to the JT valve and JT flash drum, there was no suggestion that the Williams pumps had been brought into use. The amount of methanol required for phase 1 operation was much greater than for operation in the phase 2 mode; 1300 as opposed to 100 US gal/day. Mr Grieve stated that the operators were fully aware of the need for these higher injection rates; he himself had seen a copy of the 23 March memo. If anything, the operators were going in for overkill.

6.144 According to Mr Grieve, early in the evening of 5 July a leak developed on the seal on head D of the methanol pump; the leak was small but liable to get larger and a repair was carried out. The whole pump was shut down for some 5 minutes. Head D was shutdown for a rather longer period, but Mr Grieve's evidence on this was variable, ranging from an hour in his statement to Occidental to 15-20 minutes. In this statement Mr Grieve estimated that about 100 gallons of "injection rate" would have been lost, but he was unable to explain this figure. A further interruption to the methanol supply occurred on the afternoon of 6 July. Evidence on this was given by the fitter involved, Mr J B Russell. At about 14.00 hours that day he was working on the system renewing a drain valve on the methanol storage tank; this job was covered by a PTW which was recovered. He noticed that head F was leaking and informed the maintenance department. At 16.00 hours the leaking head was shut down for repair. It was not handed back to production until about 20.00 hours, so that it was down for 4 hours. According to Mr Russell, the pump head was checked by Mr Grieve and put back into operation. Mention was also made in evidence of work on a non-return valve on one of the methanol lines. Mr Grieve believed that an NRV was fitted on the hose from the methanol pump to the JT valve during the day. He stated that on 6 July he came on duty at 17.30 hours and was made aware of the work on the pump; he believed there was an entry in the log. He did not, however, have a clear recollection of the events. He could not remember reinstating the head after repair. He was reluctant to accept that the pump head was off for as long as 4 hours or that the work extended into the evening. Asked about the possible effect of a loss of methanol supply to the JT valve, Mr Grieve was unable to say how long it would take for such an effect to show up - whether it was a matter of minutes, hours or days.

6.145 Evidence on the pumping capacity of the individual heads on the main methanol pump, which was recovered and stored at Peterhead, was given by Mr R Williamson, an engineer from the pump manufacturers, Bran and Leubbe (UK) Ltd. The stroke position indicators on the pump were plastic and had been destroyed by heat. After some initial difficulties due to seizure of the main drive motor, it proved possible to free the system sufficiently to rotate the drive shaft and observe the full forward and reverse stroke cycle of each pump head. The stroke lengths were then determined and the corresponding theoretical liquid volumetric flows were determined. These were 21.8, 7.6, 0, 19.9, 7.3 and 18.0 US gal/h for heads A-F, respectively. Thus interruption of the methanol supply from head F would cut off 18.0 US gal/h and leave only the supply of 19.9 US gal/h to the JT valve.

Temperature at JT valve

6.146 The temperature of the JT flash drum in phase 1 operation given in Fig 4.12 of the Petrie Report was 40°F. In the initial process quantities flowsheet (PSK-A1-1229-0) for phase 1 operation on 6 July produced by Occidental after the disaster the temperature of stream 200 downstream of the JT valve was shown as 49.7°F (9.9°C). A revised quantities flowsheet (PSK-A1-1229-1), given in Table J.1, spoken to by Mr M R Clark, Chief Process Engineer of Occidental, gave this stream temperature as 52.5°F (11.4°C) and that of stream 210 entering the JT flash drum as 55.6°F (13.1°C). The temperature of this latter stream, which would also be that in the drum itself, was higher because of the addition of the warmer condensate in stream 320 from the condensate suction vessel. Mr Clark explained that the figure of 55.6°F was based on the last entry in the Fiscal Metering Log Sheet for 5 July, but acknowledged that that entry referred to the temperature at the outlet of the condensate injection pumps and that since there was a rise in temperature between the drum and the outlet of these pumps, the temperature in the JT flash drum would have been lower, but he considered that the temperature rise of 4.5°F shown on the flowsheet might have been estimated on the high side. Assuming it to be correct, however, on the basis of the log the temperature in the JT flash drum would be some 51°F (10.6°C) and that at the JT valve some 48°F (8.9°C). Evidence was also given of the temperatures at the JT valve actually observed on the plant. The log for 5 July stated that the JT flash drum temperature was 40°F and had been down to 28°F. Later entries in the log showed a rise in temperature. Mr Henderson that day noted that the JT flash drum temperature was 48°F. This, however, was before the startup of the third centrifugal compressor. Mr Clark believed that bringing in the third compressor would have tended to raise the JT flash drum temperature. According to Mr Bolland, the plant conditions should have remained steady on 6 July after this compressor had been returned to service on the evening of 5 July.

Hydrate formation at JT valve

6.147 This evidence indicates that on 6 July there almost certainly was an interruption of the methanol supply from head F to the JT valve between 16.00 hours and 20.00 hours and that the temperature downstream of the JT valve could well have been no more than 50°F (10°C) on that evening, thus creating conditions favourable to hydrate formation. Evidence on whether hydrate would in fact form under such conditions was given by Drs Richardson and Saville in their first and eighth reports, presented by Dr Richardson and Dr Saville respectively. Drs Richardson and Saville calculated that at a temperature of 50°F the methanol in the aqueous phase required to prevent hydrate formation was 15% w/w. This corresponded to a methanol injection rate at the JT valve of 19.9 US gal/h. This flow equalled that to the valve during the interruption of methanol supply.

6.148 Additional evidence on the equilibrium conditions for hydrate formation, on the rate of formation and on the behaviour of hydrates was given in work commissioned by the Inquiry and spoken to by Dr H K Johnsen, Managing Director of Petreco, Stjordal, Norway. Dr Johnsen carried out a number of experiments on hydrate

formation and behaviour under conditions typical of those on Piper. All the tests were done using a wheel-shaped flow simulator. Condensate was formed in the wheel by admitting a suitable mix of gases and was then brought to equilibrium at the required pressure and temperature by rotating the wheel. Water was then admitted and the behaviour of any hydrates formed was observed. The first series of tests investigated hydrate formation under conditions representative of downstream of the JT valve, downstream of the JT flash drum, and within the condensate injection pump. The third series dealt with hydrate formation due to decrease in temperature. The second and fourth series were concerned with hydrate dissolution by increase in temperature and by methanol addition, respectively. Three tests in the first series were concerned with conditions downstream of the JT valve. In particular one test simulated the conditions which may have occurred at the JT valve on partial loss of methanol on 6 July. In this test with 15% w/w methanol in the aqueous phase at 50°F (10°C) and 639 psia (43.5 bara) hydrates formed rapidly at the valve, about a quarter of the water being converted to hydrates. After 40 minutes all the water had converted to a hydrate slurry. Dr Johnsen considered that the conditions at the JT valve, with water being sprayed into an atmosphere of hydrocarbons, was a close to ideal situation for hydrate formation. On the basis of this work Dr Johnsen estimated that some one third to one half of the water at the JT valve would be converted to hydrate during the period of reduced methanol supply. He also estimated that the flow rate of water at the JT valve was about 130 litres/h, making some 500 litres over a 4 hour period, and that this would yield some 250 kg or more of hydrate. In a test in the fourth series, involving the effect of raising the methanol concentration, at 34°F (6.1°C) and 604 psia (41.1 bara) with 10% w/w methanol sticky hydrates formed. When water with 20% w/w methanol was injected the hydrates formed a slurry which flowed.

Hydrate behaviour in condensate system

6.149 Dr Johnsen thought it probable that hydrate formed at the JT valve would adhere loosely to the JT flash drum and along the pipework leading to and from the condensate booster pumps. This pipework was 10 inch on the suction and 8 inch on the discharge side of these pumps; the pressure rise across them was only 35 psi, from 635 to 670 psia. He expected water and hydrates to accumulate in parts of the pipework which were not horizontal and in particular he expected such accumulation in an upward pointing bend after the booster pumps. It was his expectation that on resumption of the full methanol supply to the JT valve the hydrates formed would become more mobile. He envisaged that they would begin to move from the JT flash drum and that they would pass relatively freely through the condensate booster pumps. The hydrates would then enter condensate injection pump B in which they would be raised from 670 to 1100 psia. Since water is relatively incompressible, the temperature rise would be small compared to the pressure rise so that the conditions at the pump discharge would be much more favourable to hydrate formation. He envisaged that a compacted hydrate would form at the discharge of the pumps and would block the discharge line. He thought that the timescale over which this movement of hydrate might occur could well correspond to the period which elapsed between the resumption of full methanol flow to the JT valve and the trip of B pump at about 21.45 hours. On the basis of these studies, Dr Johnsen postulated a scenario in which the trip of B pump at that time was caused by hydrate blockage, the relief valve opened but also blocked with hydrate, the pump over-ran and generated a high pressure and the relief valve ruptured.

6.150 Dr Johnsen was asked what experience there was in the offshore industry of hydrocarbon leaks caused by hydrates. He stated that he had never read anything in the literature on such cases; it was the sort of thing which was not publicised. He said that he had heard of instances of rupture due to dislodging of hydrate plugs in large bore pipes; he later referred to maybe a couple of cases, but could not put a date to them. He had not heard of cases of rupture due to dislodging of plugs in small bore pipes or due to over-pressure behind a hydrate blockage. The Inquiry was the first

time he had assisted an investigation of an incident which may have been caused by hydrates.

Scenario of leak at or near PSV 505 due to hydrate blockage

6.151 The basic scenario is that condensate injection pump B delivery line was blocked by hydrates, that the relief line also became blocked by hydrates, and that the latter line was over-pressurised and ruptured. The scenario was put forward by Mr Sylvester-Evans, but its detailed development was due to Dr Johnsen. A further account of the Johnsen scenario was given by the Crown and a version of it was favoured by Score. The versions of this scenario actually advanced by Dr Johnsen are not as clear as they might be. However, he appeared to hypothesise that the rupture occurred either at the initial trip or during an attempt to re-start the pump. The version favoured by Score was that the rupture occurred during an attempt, but not the final attempt, to re-start the pump. There are therefore 2 cases to consider, rupture at the initial trip or rupture at a re-start. It is common to both versions that hydrate formed at the JT flash drum and was carried forward. It passed through the condensate booster pumps and through B pump but blocked on the delivery side. This blockage occurred first on the pipe to the MOL, which is the pipe where there is flow. The delivery pressure rose, PSV 505 opened and condensate flow occurred in the relief line.

Rupture at initial pump trip

6.152 In the first version, case 1, the relief line too became blocked by hydrates at the PSV during the initial trip. The pump over-run was enough to cause over-pressure and rupture at the valve. The rupture orifice plugged with hydrate, which then slowly melted, giving first the initial alarm and then, as the final melting occurred and the hole grew rapidly larger, the final group of alarms. Mr Vernon evidently made at least one attempt to re-start B pump before coming up to the Control Room to get A pump reinstated. Mr Grieve took part in a further attempt to re-start B pump. It is not known how many attempts Mr Vernon made before Mr Grieve arrived, so there may have been some additional efforts between the first and last attempts at re-start. In this version these attempts at re-start are of secondary importance. At most they may have created high pressures again in the relief line and aggravated the leak. In particular, the last re-start attempt may have finally dislodged the last bit of hydrate.

Rupture on pump re-start

6.153 In the alternative version of this scenario, case 2, at the initial trip, flow but no blockage occurred in the relief line. However, during an attempt, but not the final attempt, to re-start the pump the discharge was over-pressurised and again PSV 505 opened. This time the hydrates plugged the PSV and rupture occurred. The rupture orifice itself plugged with hydrate, which then slowly melted, giving first the initial alarm and then, as the final melting or dislodgement occurred and the hole grew rapidly larger, the final group of alarms. It was suggested by Score that this final increase in leak size occurred as a result of (i) the admission of suction pressure due to the opening of the GOVs during the final attempt to re-start the pump; (ii) the generation of discharge pressure due to the actual attempt to re-start the pump; (iii) melting of the hydrate plug; or (iv) a combination of these. These explanations of the final, increased leak seem equally applicable to the first version (case 1).

Relief line

6.154 The tenth report by Drs Richardson and Saville, spoken to by Dr Saville, addressed the burst pressures of the B pump relief line and of PSV 505 itself, shown in Fig J.9. They found that the weakest point was the flanged joint on the body of PSV 505 and that the failure pressure of this joint was 250 bar.

Pump trips

6.155 No mention has been made so far of the trips on the pump. Those which appear most relevant are those for high pressure, pump overload, lube oil system and pump vibration. The pump overload trip needed to be re-set at a point away from the 68 ft level. It is not known what caused the initial trip on B pump, but Mr Bollands said that Mr Vernon seemed to think it might be the high pressure trip, though the latter also mentioned something about oil, perhaps lube oil, near the pump. Whatever the trip was, it was evidently not such as to inhibit attempts to re-start B pump. This seems to argue against pump overload. Dr Johnsen hypothesised it was the HP trip activated by high discharge pressure due to hydrate blockage.

6.156 As far as concerns over-pressurisation of the pump, there were 2 trips which should have prevented this, the HP trip and the pump overload trip. However, the pump overload trip may have been set at a relatively high value. According to Dr Johnsen, the pump motor was likely to have been drawing some 70-80 kW of its total capacity of 368 kW and he understood that it was likely that the overload setting would be close to the latter rating. In this case it is conceivable that even with the pump pumping against a discharge pressure rising to 250 bar instead of its normal discharge pressure of 75.8 bara the overload trip might not operate immediately. The HP trip should have operated to shut the pump down on high discharge pressure before the PSV opened. It was set 50 psi below the PSV set pressure. Given a gradual rise in discharge pressure and accurate setting of both devices, this should have been enough to shut the pump down before the PSV opened. But with a sudden blockage and very rapid pressure rise it is possible that the PSV would lift before the pump was fully stopped. This would be the more likely if there were errors in the setting of the HP trip or PSV, or both, which brought the setting of the HP trip above that of the PSV. PSVs had lifted to relieve pressure on a number of occasions. The assumption made by Dr Johnsen was that on the occasion when the over-pressure causing rupture occurred, the HP trip blocked with hydrate and so could not prevent the rise in pressure, which led to the opening of the PSV, the flow of condensate in the relief line, and the blockage in, and rupture of, the line. Score, on the other hand, assumed that the HP trip operated correctly, but not fast enough to prevent the above effects.

Pump power train

6.157 For this scenario to be valid, therefore, it must have been possible for the pump to continue pumping for a sufficient period to cause the discharge pressure to rise to at least 250 bar. Dr Johnsen stated that the pump weighed about 3.3 tonnes and he estimated that the rotating part would weigh perhaps 2 tonnes. It would therefore have an appreciable inertia. The volume of the relief pipework from the discharge of the pump to the PSV was some 160 litres and the volume displaced per revolution of the pump some 10 litres. Dr Johnsen was sure that even 2 revolutions of the pump would create a very high discharge pressure.

6.158 The pressures which might have been attained if pump over-run occurred were estimated in the ninth report by Drs Richardson and Saville, spoken to by Dr Saville. Fig 6.7 gives the pump discharge pressures as a function of the number of revolutions of the pump and shows that a pressure of 250 bar would have occurred after less than 1 revolution of the pump. At the normal pump speed of 100 rpm, this pressure would have been reached in about 0.6 seconds, or at the minimum speed of 40 rpm in 1.5 seconds. The pressures estimated assume that nothing happens to prevent such pressure rise. Dr Saville mentioned as points to consider whether the pump pistons or valves would withstand the pressures or the drive fracture. He agreed that it would also be necessary for the hydrate plug to hold, but stated that he had experience of plugs of particulate matter withstanding 2000 bar, albeit in different sized pipe.

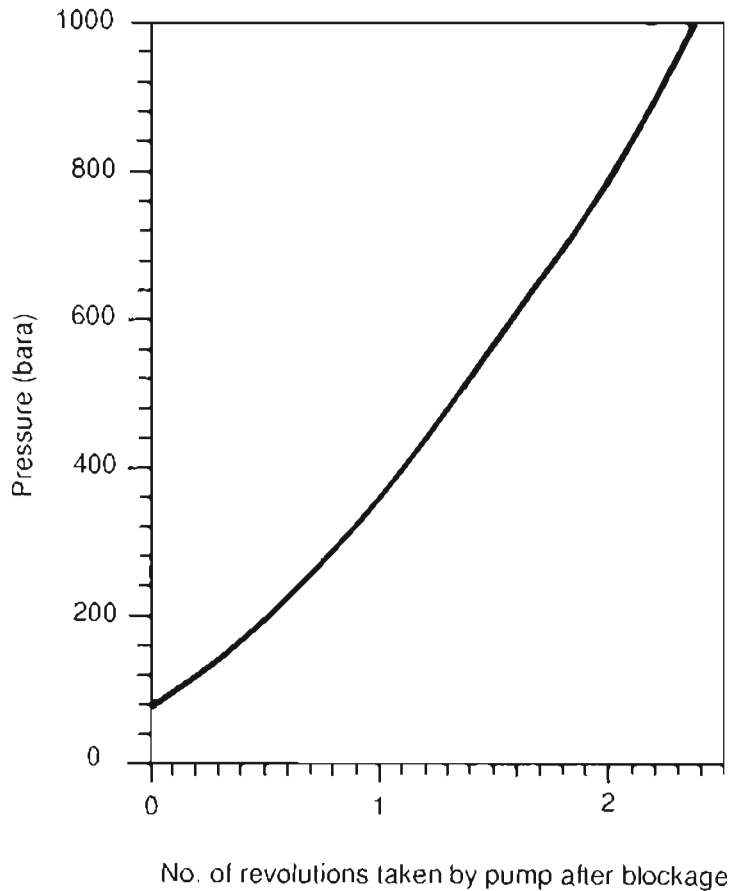


Fig. 6.7 Estimated pressure rise in condensate injection pump B discharge pressure with no pressure relief.

6.159 The possibility of pump over-pressure was addressed by Mr Skidmore. He considered what would happen in the following 4 cases if the pump delivery and relief lines were blocked: (i) case 1, pump re-start with torque converter healthy and a minimum pump speed of 40 rpm; (ii) case 2, pump re-start with converter locked; (iii) case 3, pump running and converter healthy; and (iv) case 4, pump over-running after a stop signal and converter healthy. He argued that in the first case the converter would stall and that in the second the motor would trip on overload. The third implied failure of protection by both the HP trip and the PSV. The upper bound of the torque, with the converter vanes fully open, corresponded to a pump discharge pressure of 356 barg (5160 psig). He agreed that a high JT flash drum level would imply a higher than normal converter vane setting. In the fourth case he believed the torque transmitted would fall away very rapidly.

Observations on this scenario

6.160 I now give my observations on the scenario of a leak in the relief line to or at PSV 505, confining myself at this point to the question of whether it is credible. There is clear evidence that there was an interruption of the supply of methanol to the JT valve, of the order of 4 hours, starting about 16.00 hours and ending about 20.00 hours. The temperature of stream 200 at the JT valve could well have been 50°F or below. At this temperature the loss of methanol would almost certainly have resulted in the formation of large amounts of hydrate at the JT flash drum. The passage of this hydrate through to the condensate pumps could well have been delayed so that

it manifested itself towards 21.45 hours that evening. The hydrates could have passed through the condensate booster pumps and condensate injection pump B and then blocked first the delivery line to the MOL. If the HP trip did not operate first, PSV 505 would have opened and condensate would have flowed through the relief line. The HP trip might have failed to operate first because it was blocked by hydrate but it seems at least equally likely that the setting of the HP trip and PSV 505 might have been sufficiently in error for the relief valve to lift first. It is clear, however, that B pump did trip eventually and that Mr Vernon was uncertain of the cause of the trip. It is probable that it was the HP trip which activated. It is less likely that the trip was on pump overload, since this would have inhibited further re-starts until cleared at a point away from the 68 ft level.

6.161 Either on this occasion or on a subsequent attempt to re-start B pump the opening of the PSV and flow of condensate through the relief line could have carried forward hydrate which then blocked the line. The likely point of blockage would then be PSV 505, both because this seems to have been the point most likely to block and because, given the hypothesis of a leak, it was the weakest point. When this blockage occurred the pump would trip. However, it would continue to rotate for a period of uncertain though very short duration. Given that both delivery and relief lines were blocked, the discharge pressure would rise very rapidly and 1 or 2 revolutions would be sufficient to cause the PSV to rupture. The occasion on which the pump motor and pump would unarguably have high rotational speeds is the initial trip. Moreover, the vane setting of the torque converter might well have permitted the transmission of power to the pump, especially given a high level in the JT flash drum. It is less certain what speeds would be attained in the subsequent attempts to re-start the pump, and converter stall is more probable.

6.162 A leak pattern consistent with the gas alarms observed by Mr Bolland, with the noises heard in the workshop and with the sudden departure of Mr Richard could be generated by a leak which was initially small but which increased in size so that by the last 30 seconds it was substantial. Such an increase might be caused by melting of the hydrate plug, or during the final attempt to re-start the pump, by admission of suction pressure through the GOVs or by the pressing of the start button.

6.163 There is no direct evidence that there was hydrate blockage and over-pressure at PSV 505, but there is evidence that conditions could well have been conducive to hydrate blockage. Such blockage might explain the behaviour of the pump system and a rupture consequent on pump operation. I cannot rule out on the available evidence that one or other of the sequences of events which the versions of this scenario require took place.

Scenario of leak at reciprocating compressors

6.164 The other leak scenario proposed in the Petrie Report was carryover of liquid into the reciprocating compressors resulting in damage and a leak (Scenario B). A meeting of technical experts chaired by the Assessors was held to clarify the issues and a report was presented by Mr C D Plummer, Chief Engineer of Atkins Oil and Gas Engineering Ltd. The scope of the work was to explore the possibility of ingestion of liquid into the compressors; it did not address the consequences if this had happened. The report tackled the problem from 3 angles:

1. The back-up of liquid in the time available.
2. The physical possibility of ingestion.
3. The probability of failure of the devices which should have prevented ingestion.

The equipment which would fill with condensate on cessation of pumping from the JT flash drum was taken as the drum itself, the second stage suction scrubbers and the interconnecting pipework. The condensate suction vessel was excluded because it was controlled at a higher pressure than the JT flash drum and even back-up of the

liquid in the latter would not overcome this pressure differential. The total volume of the JT flash drum was 18.05m³ and the volumes at normal operating level and at high level alarm were 3.02m³ and 6.14m³, respectively. Those of the 2 suction scrubbers were 1.1m³ each and that of the pipework was 2.58m³. Following the evidence given, the state of the plant was taken to be normal phase 1 operation up to 21.40 hours (case 1), then operation with the reciprocating compressors unloaded and on recycle (case 2), then as this last case but with only one centrifugal compressor running (case 3). In the last 2 cases the flow of lift gas would stop and the gas would be flared.

6.165 Process flowsheet simulations were done using a computer package and reasonable agreement was obtained for the base case given in the original process quantities flowsheet (PSK-A1-1229-0). For this base case of normal operation (case 1) the total condensate production rate was taken as 8,800 bbl/d with the contribution from the condensate suction vessel being 4,218 bbl/d, or 0.482 m³/min, and the rest coming through the JT valve. For case 2 the total condensate production was 3,146 bbl/d, or 0.381 m³/min, this being the reduced rate from the condensate suction vessel with no contribution from the JT valve, after the last of the lift gas had worked through the system. For case 3 the total condensate production was 2,185 bbl/d, or 0.265 m³/min. The average total condensate production during transition from case 1 to case 2 was 3,682 bbl/d, or 0.432 m³/min, and that during transition from case 2 to case 3, 2,558 bbl/d, or 0.30 m³/min.

6.166 Starting with the JT flash drum at its normal level, the times to fill the JT flash drum, suction scrubber and interconnected pipework were calculated as 19.7 min, 52.1 min and 74.7 min for cases 1-3 respectively. Two further cases were also investigated, based on the evidence of events on the night. In the first, case 4, it was assumed that the condensate injection pump tripped at 21.50 hours, that the reciprocating compressors were unloaded and recycled at 21.54 hours, that 2 centrifugal compressors tripped at 21.55 hours and that the initial explosion occurred at 22.00 hours. In the second, case 5, these events were assumed to occur at 21.45 hours, 21.50 hours, 21.55 hours and 22.00 hours, respectively. In both cases 4 and 5 the unloading and recycling of the compressors was assumed to occur after the JT flash drum had reached its high level alarm. Utilising the condensate flows from cases 1-3 for the appropriate periods gave the volume of condensate in the JT flash drum at 22.00 hours as 8.97m³, 50% full, for case 4 and 11.7m³, 65% full, for case 5. The use of the revised quantities flowsheet (PSK-A1-1229-1), which included the water contents of the streams, was investigated; its effect was to reduce the total condensate production rates, that for normal operation being 7,500 bbl/d, and thus to increase the times to fill the drum. The conclusion from this work was that there was insufficient time for liquid back-up to occur. This agreed with Mr Grieve's evidence that just before the initial explosion the level reading for the JT flash drum was somewhere around the 90% mark; it had not reached 100% (a full-scale, or 100%, reading on the level indicator was reached well before the drum was full). Mr Plummer stated that these timings were taken on instruction. He agreed that on timing the crucial issue was the time which elapsed between the trip of the condensate injection pump and the unloading and recycling of the reciprocating compressors. The possibilities of passage of liquid from the JT flash drum before it was full due to droplet carryover or foaming were investigated but discounted. The gas flow with the reciprocating compressors on recycle would be low and not conducive to carryover. It would be normal for fine liquid droplets to pass into the compressors and they would cope with this throughout their working life. The possibility of preferential filling of suction scrubber A due to the pipework arrangement was also considered, but discounted.

6.167 Another argument advanced was that the conditions at the reciprocating compressors when on recycle were such as to make it physically impossible for liquid to pass into them. A computer simulation was carried out to predict the suction and discharge pressures and temperature of the compressors when on recycle, recycle being through GOVs 903 and 905, but not PCV 746. The analysis indicated that the recycle would occur in a system which was effectively closed. The suction pressure

would have risen from about 635 psia to about 730 psia and the discharge pressure fallen from about 1735 psia to about 750 psia. The rise in pressure on the suction side would cause the NRV on the line from the JT flash drum to close, while on the discharge side both the NRV to the gas lift well and PCV 945 would close as the pressure fell. Compression of the gas in this closed system would cause its discharge temperature to rise until the machine tripped on high discharge gas temperature.

6.168 With liquid backing up the gas space in the JT flash drum would be compressed and with continued inflow of gas the pressure would rise within about 10 minutes to 670 psia, equalling that in the condensate suction vessel. This pressure rise would be countered, however, by the action of DPCV 723 which would open to relieve the pressure, thus preventing the pressure from rising above the suction pressure of the compressors. If liquid backed up so that it entered the line to DPCV 723, the valve would open and discharge condensate to flare; there were several mechanisms by which this might occur, but they all had this effect. Failure of this valve was possible, but given that its action had been checked that day and that it would be open just before the compressors were unloaded, coincident failure was unlikely.

6.169 There were devices which should have functioned to prevent liquid being ingested into the compressors even if it had backed up. There was a level control valve on each of the suction scrubbers, though the offtake line was only one inch. More significantly, there was on each scrubber a high level trip which would trip the compressor.

6.170 Mr Plummer concluded that ingestion of liquid into the reciprocating compressors would not have been possible. Counsel to the Inquiry indicated that in view of this evidence and of the fact that it had not been challenged at the meeting of technical experts, further evidence on this scenario would not be led.

Other leak scenarios

Scenarios reviewed by Mr Sylvester-Evans

6.171 Difficulties perceived in the scenarios of a leak at the PSVs led in the early stages of the Inquiry to an exploration of other possible leak sources. This work was described by Mr R Sylvester-Evans of Cremer and Warner. He did not deal with the 2 scenarios put forward in the Petrie Interim Report (Scenarios A and B), but did address other scenarios given in the Petrie Final Report. He outlined 8 other scenarios, C-J, broken down into some 30 sub-scenarios, summarised in Table 6.4. He illustrated the scenarios by reference to Figs J.8 and 3.4. The aim of the work was to produce a fairly comprehensive list of scenarios. The scenarios were not purely theoretical but had some link with the information available at the time, which included a hazop study, past equipment failures and process conditions that night. The evidence was confined to a review of the scenarios and of the underlying assumptions. It did not deal with their likelihood and did not attempt to rehearse previous evidence.

6.172 The account which I give here of the scenarios is necessarily a simplified one. In general terms, scenarios were favoured which fitted a low lying leak of condensate at the east end of C Module and the gas alarm sequence, with the first alarm in zone C3. The genesis of scenario C was evidence on hydrate blockages in the recycle lines of the centrifugal compressors and on failure of a differential pressure tapping on these machines together with the fact that off-loading of the reciprocating compressors and tripping of the centrifugal compressors would place a load on the various pressure control and depressurising valves. Evidence that there had been leaks on the centrifugal compressor suction and discharge scrubbers underlay scenario D. Failures of pipework had occurred on the reciprocating compressors due to vibration and fatigue and gave rise to scenario E. The origin of scenario F was evidence that there had been a failure of a flexible hose on the fuel gas line in the turbine compartment of a centrifugal compressor on 16 May 1988 and of a tapping on the pipework of compressor A on 13

June 1988, as well as repeated gas alarms on the compressors. Scenario G was suggested by evidence that in phase 1 operation the gas pipeline to Claymore was being topped up using high pressure gas from Tartan and on maintenance activities on PSV 524/1,2. Scenario H was concerned principally with leaks downstream of condensate injection pump B arising from the evidence on the activity at this pump just before the initial explosion. The possibility of low temperature brittle fracture of the JT flash drum resulting from sudden depressurisation was identified in a hazop study carried out in 1986 by Occidental and gave rise to scenario I. The various leak scenarios associated with maintenance activities in the GCM were comprehended in Scenario J.

6.173 Some of the sub-scenarios involved blockage of a pipe by ice or hydrate or isolation by closing a valve, followed by exposure of the upstream section to a high pressure which the pipe was not designed to withstand; these included C1, C2, D3, E2, H5, and I2. Others involved the dislodging of an ice or hydrate plug and consequent mechanical damage to the downstream pipework; C1, E1, E3, E4, G2, H2, H3 and I4 were of this type. One version of one of these sub-scenarios, scenario H2, is the third scenario which I considered above. Formation of ice or hydrates at some of the points envisaged in Scenarios C-J was addressed in the 7th report of Drs Richardson and Saville, spoken to by Dr Saville. They assumed methanol addition at the prescribed rates, but commented on the effects of loss of methanol. They also considered the potential for low temperature brittle fracture in the sense that pipework might fall to -20°F . They found that there was potential for formation of ice or hydrates downstream of PSV 1000A and downstream of DPCV 723A,B, unless there was sufficient methanol in the vapour to suppress it, which could not be assessed; downstream of the centrifugal compressor recycle valves 201A, 202B, 203C, probably, and downstream of the first stage reciprocating compressor recycle valves GOV 902, 904; and downstream of the drain valves on the lines on the centrifugal compressor discharge scrubbers and on the second stage reciprocating compressor suction scrubbers, with potential for brittle fracture in both cases. Another set of sub-scenarios involved the existence of an inherent defect and its activation by the events leading up to the initial explosion; C3, D2, E1, F2, F3, and G3 fell into this category.

6.174 Common difficulties with these scenarios were that they tended to involve a number of assumptions, such as presumed failure of instruments or actions of operators, and that the associated leak did not fit well in respect of its location, its timing or the gas alarm pattern.

Scenarios involving reciprocating compressors

6.175 A report on possible leaks from the reciprocating compressors was given by Dr K E Bett of Imperial College. One possibility was a fatigue failure of the pipework on one of the compressors. There had been one fatigue leak and one fatigue crack on the compressor systems in the first half of 1988. Whilst he could not discount entirely a leak prior to the unloading and recycling of these machines, he considered it highly unlikely. It might be argued that vibration could be worse when the compressors were unloaded and recycled, but there was no evidence for this and on the basis both of his experience and of theoretical considerations, he would not expect it.

6.176 Dr Bett also considered the possibility of stud bolt failure. 7 failed stud bolts were discovered on No 1 cylinder yoke/frame extension flange on A machine in February 1988 and 5 failed stud bolts at a similar location on No 3 cylinder of B machine in June 1988. These were fatigue failures. On each occasion all the stud bolts at the flange where the failures occurred were replaced. All other bolts were retorqued to establish that they had not cracked or lost their pre-tension. When the failures occurred on A machine, no check was made on B machine. Dr Bett considered the condition a serious one and failure to check the other machine a serious omission. However, he thought it highly unlikely that such stud bolt failure was the cause of the leak on 6 July.

Conclusions as to the cause of the leak

6.177 The evidence before me at the Inquiry explored a large number of possible scenarios. I have to consider whether or not I am satisfied that a particular one was the explanation for the leak and hence for the initial explosion. For that purpose I apply the ordinary standard of proof in civil cases - proof on a balance of probabilities. In the present case there is no direct evidence as to what happened. Accordingly proof is dependent upon inference from the evidence; and the inference must be a natural and reasonable one. This involves among other things that I have to consider whether a particular scenario is or is not consistent with the evidence; whether it provides a credible explanation for the observed events; and whether there is enough factual evidence from which to draw the inference that it was the explanation, as opposed to being a mere possibility or a matter for conjecture.

6.178 The scenarios which were described by Mr Sylvester-Evans of Cremer and Warner explored a wide range of explanations for my consideration. I will put to one side for the moment the explanation based on hydrates in the relief line on B pump and deal with the rest. Many of those scenarios were devised by adopting an assumption that what had occurred in a previous incident had happened again; and to that extent each had a credible element. However, each posed a difficulty in the way of acceptance partly because of the number of assumptions which required to be made as to the failure of equipment or the actions of operators before a leak was produced; or because it was inconsistent with evidence as to matters such as the location of the leak and the pattern of the gas alarms. Even more fundamentally none of these scenarios had its origin sufficiently founded in the events on the evening of 6 July. For these reasons after considering the whole evidence I regard them as no more than theoretical possibilities. I make the same observations in regard to the scenarios considered by Dr Bett.

6.179 Coming to the events of 6 July I accept the evidence that ingestion of condensate liquid into a reciprocating compressor did not occur. Accordingly I rule out the scenario which was based on this having happened.

6.180 I consider next the scenario of a leak from a blind flange at the site of PSV 504. This scenario involves quite a short series of events, namely the admission of condensate to A pump, followed by a leak from the blind flange.

6.181 As regards the first of these events there is no direct evidence that Mr Vernon took this action. However, he showed a clear intention to start A pump. He had a strong reason for doing so. He had sufficient time and was in the correct place to do so. His actions at the pump were consistent with his attempting to start A pump. There was probably no physical impediment in the way of mechanical or electrical isolation which would have prevented him from doing so.

6.182 In regard to the leak, there is no direct evidence as to how it was brought about. However there are a number of important considerations:

- (i) The evidence of the wind tunnel tests and explosion simulation pointed to a leak in the region in which PSV 504 and PSV 505 were situated.
- (ii) My conclusion, based on the evidence as to the gas alarms and the wind tunnel tests, that there was a 2-stage leak might appear to introduce a complication. However, I have come to the conclusion that it provides support rather than a difficulty for the scenario. It seems to me quite likely that an operator having re-connected the air line to the GOV would try it out by giving the GOV a short jag. This would account for the initial stage of the leak. The second stage would be due to subsequent and longer opening of the GOV. Further the timing of the 2 stages of the leak fits reasonably well with the evidence which points to Mr Vernon's opportunity to open the GOV for A pump.
- (iii) In the light of the evidence of Drs Richardson and Saville the flow rates of

escaping condensate which would be required to account for the explosion would be consistent with the results of the GOV being open for a period of about 30 seconds, given a hole size at the site of PSV 504 of equivalent diameter of some 8 mm. The evidence of the leak tests showed that a blind flange which was only finger tight could give the required flow rate and would be consistent with a hole of that size. Further a finger tight configuration appears to be one of those most likely to give rise to the noises which were heard shortly before the initial explosion.

6.183 At this point it is necessary for me to consider on the other hand the evidence given by Mr Rankin that Mr Sutton told him that he had fitted blind flanges - which was in accordance with the PTW - and the evidence given by Mr Rankin that he would have expected Mr Sutton to make a leak-tight joint. However, as I have noted earlier in this chapter, I found Mr Rankin's evidence to be unsatisfactory on a number of points; and on one it is in conflict with that of Mr Lynch, the lead production operator. Mr Rankin appeared to have total recall of all his actions in regard to the PTW, including the procedure for its suspension, but no recall as to the persons with whom he dealt. I am doubtful as to the reliability of his evidence as to what he expected Mr Sutton to do and what Mr Sutton said to him. I bear in mind that Mr Rankin did not check the work site before suspending the PTW, as was required by the PTW system. Accordingly he did not see what Mr Sutton had done.

6.184 Earlier in this chapter I have recounted the evidence on normal practice in fitting a blind flange. However, the circumstances on 6 July were somewhat unusual. From the time when the PTW was issued until nearly the end of the day-shift a pump was to be the subject of a full planned maintenance. If the pump, having been shut down and vented, was to be isolated for that purpose it might well be thought that it was unnecessary to replace PSV 504 immediately and that the blind flange on the pump side of the site of PSV 504 need not be made leak-tight. (I note in passing the preferred method of isolation for a planned maintenance was to drop out a spool piece and fit only the live end of pipework with a fully tightened blind flange.) A number of witnesses gave evidence without contradiction that Mr Sutton was a competent and careful fitter. If he had left the blind flange on the pump side of the site of PSV 504 only finger tight when it should have been flogged up, the difference would have been easily discoverable; on the evidence it might well have led to his dismissal. If therefore Mr Sutton left a blind flange only finger tight it is likely that this was for a particular reason. It may be that he was given to understand that it was unnecessary to make up the joint fully but that evidence of this has been lost as a result of the death of a number of the personnel who were on the day-shift. I may add that for him to fit the blind flange finger tight would still serve a useful purpose in that it would prevent dirt from entering the relief line. In these circumstances I do not regard the hypothesis of a finger tight blind flange as improbable.

6.185 I have examined an alternative type of explanation, which is that the blind flange assembly at the site of PSV 504 ruptured following the admission of condensate due to events such as autoignition, shock loading, brittle fracture or over-pressurisation by methanol injection. I have rejected all of these except autoignition. This cannot be ruled out but I regard it as unlikely. It depends upon the fulfilment of a series of assumptions for which there is no direct evidence. Further the assumed explosion was not heard by any witness.

6.186 So far as concerns the scenario of a leak from the relief line at or near PSV 505, there is clear evidence of a considerable loss of methanol supply on the evening of 6 July. The JT valve had experienced a low temperature on the previous day. Accordingly process conditions on the night of 6 July might well have been conducive to formation of hydrates which passed into condensate injection pump B and caused blockages on the discharge side. Over-pressure of this pump could well have occurred on the initial trip given the particular converter vane setting which seems quite likely and a failure of the high pressure trip which could have occurred from several causes

including trip setting or hydrates. This scenario requires that the melting of hydrates at the rupture point was gradual and did not give rise to a gas alarm until some 10 minutes later. Converter stall appears to present a greater difficulty for other versions of this scenario. All versions depend upon a complex train of events and involve a number of assumptions which cannot be substantiated in evidence. On the evidence I do not rule out this scenario but consider it to be unlikely.

6.187 In the whole circumstances I have come to the conclusion that on a balance of probabilities the leakage of condensate was from a blind flange assembly at the site of PSV 504 which was not leak-tight.

Observations in regard to the permit to work system and the shift handover

6.188 It is clear in my opinion that Mr Vernon would not have attempted to start condensate injection pump A if he, or for that matter Mr Clark, had known that PSV 504 was not in place. From the evidence I conclude that this was due to a failure in the transmission of information under the permit to work system and at shift handover.

6.189 Information as to the removal and non-replacement of PSV 504 should have been included in the handover between Mr Smith and Mr Clark both for the effective prosecution of the work on the platform and as a matter of good safe practice. Mr Smith did not mention the PSV work to Mr Clark and had not recorded it in the maintenance diary or on the A4 pad, as he should have. Mr Smith knew that the overhaul of PSV 504 was under way. He had had no contact with Mr Rankin during the day. He should have assumed that the work was incomplete and so informed Mr Clark. Mr Clark was in general critical of the PTW and handover systems. In his own words: "It was a surprise when you found out some things which were going on."

6.190 The handover to Mr Vernon himself was not deficient even if it contained no information on the overhaul of PSV 504. Mr Vernon knew that A pump was with maintenance and had been electrically isolated for the planned maintenance or for the repair of the coupling. The overhaul of PSV 504 was information which it was reasonable to expect him to be informed of by his operators if events required him to know. It is evident that he did not learn this from Mr Richard, the phase 1 operator. It was the practice to record the overhauls of PSVs in the phase 1 operator's log. The handover between phase 1 operators was based on going through that log. I infer that Mr Grant failed to inform Mr Richard that the PSV had been removed and not yet replaced, which he should have done, notwithstanding the fact that the pump was with maintenance.

6.191 In any event it is necessary to examine why Mr Vernon failed to become aware of the work on PSV 504 from his involvement with the permit to work system. According to Mr Rankin, when he suspended the permit at 18.00 hours, he spoke to the lead operator. At that time the lead operator could only have been Mr Vernon. I have already expressed my views on Mr Rankin's reliability. I am not satisfied that a conversation between Mr Rankin and Mr Vernon about the suspension of the permit took place. In any event, even without a discussion with Mr Rankin, Mr Vernon should have known of the overhaul of PSV 504 because at the end of the day-shift the permit should have been suspended as the work was incomplete. This should have involved Mr Vernon signing the permit and having the job site checked by one of his operators. It is evident Mr Vernon failed to have the job site checked and accordingly failed to ensure that the site of PSV 504 was left in a safe condition over-night.

6.192 I should add for the sake of completeness that I do not consider that the handover to Mr Bolland was deficient. By 21.45 hours he knew that A pump was with maintenance. It was not necessary for him to know the details of any maintenance work which was being undertaken.

6.193 As I have stated earlier, prior to signing and leaving the PTW for the PSV work for suspension Mr Rankin should have inspected the job site which on his own

evidence he did not. That would be sensible and safe practice in any PTW procedure. However, before acting as a Performing Authority Mr Rankin had received no training in the detailed operation of the PTW system on Piper either from Occidental or from Score.

6.194 I consider that it is of some importance to know whether these failures were merely isolated instances or form part of a wider pattern of deficiencies in the permit to work system and in handovers between shifts. As part of the background to the disaster I examine these matters further in Chapter 11.

Observations on methanol injection

6.195 Although I have concluded that the failure of methanol supply and the possible consequent formation of hydrates was not the cause of the leak, it is clear that the maintenance of adequate methanol injection was important to the safety of the platform and that it was not achieved. It was recognised by Mr J L MacAllan, the Production and Pipelines Manager, and Mr J Bryce, the Production and Pipelines Superintendent, that when the platform's operation was changed from phase 2 to phase 1 the only operational problems which might ensue would result from the gas stream being wet rather than completely dry as in phase 2 production. It is clear from Mr MacAllan's evidence that it was realised that this had implications for safety on the platform. To offset this and the known consequent potential to form hydrates they decided that methanol needed to be injected at various points in the process, and in particular prior to the pressure letdown over the JT valve. They commissioned a study of the rates of injection required at different points. This was carried out by Mrs E A Paterson (then Ms Mortimer) of the Facilities Engineering Department. In a memorandum setting out her results she stressed the importance of methanol injection being continuous and suggested that a back-up injection system should be made available. In the result the former was not achieved and the latter was not provided. The memorandum did not contain any guidance as to what should be done if the injection failed as such an operational problem was beyond her experience.

6.196 While Mr MacAllan could not recall seeing the memorandum, it is clear that it was sent to the management of the platform and that the process operators who were responsible for the methanol injection system received a copy. There was no evidence to indicate that the operators were given any instructions as to any special action to be taken if the methanol injection failed. Mr MacAllan's evidence was that it would be a matter of concern if methanol was not injected for several hours at the critical point upstream of the JT valve and that in such an event, while there was a lot of methanol being injected elsewhere, he would expect to shutdown part of the process operation.

6.197 It is clear that continuous injection of methanol was critical not only to the smooth operation of the platform but more importantly to its safe operation. The fact that this was not achieved was due, in my view, to the inadequate instructions to the operating staff who should have been given clear guidance as to what to do in the event of the failure of any part of the injection system. Such guidance could have set out the action to be taken, even a simple instruction to report immediately any failure to the platform management would have guarded against the dangers inherent in hydrate choking. I consider that there was no fault on the part of the operators and leading hands involved as they did not have the technical background to assess the risks consequent on a failure in the methanol injection, particularly as their previous experience was that hydrate chokes could be cleared easily. However, it seems to me that those who were responsible for the management of the platform, both onshore and offshore, failed to give adequate instructions to guard against an eventuality which had safety as well as production implications.

Table 6.1 - Some Piper production and maintenance personnel on shift on night of 5 July and on 6 July 1988

	Night (5/6)	Day	Night (6/7)
A—Production			
Lead production operator	C Lockwood ^(a)	J Lynch/ ^(b) H E G Flook	R A Vernon
Control Room operator	G Bollands	J M Slaymaker/ ^(c) A N Other/ R L Price	G Bollands
Phase 1 operator	-(^d)	P J Grant	R M Richard
Phase 2 operator	E C Grieve	M J Groves	E C Grieve
Oil water operator	-	J B Kirby	A R C Bremner
	-	D A McWhinnie	G M Rennie
B—Maintenance			
Maintenance lead hand	A G Clark	W H Smith	A G Clark

Notes:

- (a) Mr Lockwood left the platform on 6 July.
- (b) Mr Lynch was relieved by Mr Flook about 10.00 hours and then left the platform.
- (c) Mr Slaymaker was relieved about 10.00 hours by someone unknown and then left the platform. Mr Bollands did not know who this person was; he believed it would have been one of the operating team but probably not the lead operator. This unknown person was relieved by Mr Price about midday.
- (d) Dash indicates that no evidence was taken.

Table 6.2 - Details and results of FLACS code simulations

Case	1	2	3	4	5	6
Type of fuel	NG	NG	C	NG	C	C
Mass of fuel (kg)	173	173	186	80	186	46
Location of ignition source	X	Y	Y	X	Y	Z
Proportion of module filled by flammable mixture (%)	50	50	50	30	50	ca.12
Wall behaviour	FL	FL	FL	FL	FX	FL
Over-pressures (barg)						
P1	0.43	0.55	0.69	0.11	1.54	0.196
P2	0.43	0.63	0.76	0.15	1.70	0.251
P3	0.39	0.63	0.77	0.19	1.58	0.295
P4	0.34	0.67	0.77	0.19	1.48	0.234
P5	0.37	0.51	0.62	0.10	1.89	0.176
P6	0.37	0.60	0.70	0.15	1.88	0.235
P7	0.35	0.70	0.72	0.17	1.60	0.255
P8	0.37	0.72	0.84	0.19	1.62	0.257

Notes:

- (a) See Figs 5.1, 6.4 and 6.5
- (b) NG = Natural gas; C = condensate
- (c) FL = wall fails; FX = wall fixed, does not move
- (d) In cases 1-5 the firewall failure pressures were taken as for the B/C firewall 0.138 bar and for the C/D firewall 0.25 bar. For case 6 the corresponding pressures were taken as 0.10 and 0.12. A version of case 6 was also run with the former set of wall failure pressures. For this latter case the pressures P1-P8 were, respectively:-
0.219; 0.269; 0.314; 0.261; 0.23; 0.302; 0.31; 0.288.

Table 6.3 - Estimated gap size, orifice diameter and condensate flow for certain conditions of blind flange assembly on PSV 504

No of bolts	Gap size (mm)	Equivalent orifice diameter (mm)	Estimated flow (kg/s) ^(a)
8	0.072	6.79	1.46
4	0.11	8.39	2.22
2	0.188	11.0	3.82

Note:

(a) Flow of condensate at a pressure of 46.3 bara.

Table 6.4 - Summary of leak scenarios reviewed by Mr Sylvester-Evans

No.	Description of scenario
A } B }	see note (a) below
C	Release from failures of piping associated with pressure control valves or centrifugal compressor recycle or depressurising valves in C Module
C1	Hydrate or ice plug in various pipework locations
C2	Blockage and over-pressure of vent header
C3	Inherent defect in centrifugal compressor pipework
D	Failure of condensate piping or centrifugal compressor discharge scrubbers located at east end of C Module
D1	Low temperature brittle fracture of centrifugal compressor discharge scrubber boot or pipework
D2	Inherent defect in condensate pipework triggered by tripping of compressors
D3	Over-pressure of or mechanical damage to drain line to oily water system
E	Release from failures of pipework associated with reciprocating compressors, due to causes other than liquid carryover from the suction scrubber
E1	Inherent defect in small bore pipework on reciprocating compressors
E2	Over-pressure of or mechanical damage to drain pipework of reciprocating compressor suction scrubbers
E3	Dislodging of ice or hydrate plug in condensate pipework from second stage reciprocating compressor suction scrubbers to condensate knockout drum
E4	Dislodging of ice or hydrate plug downstream of reciprocating compressor recycle GOVs 902 and 904
F	Releases within enclosures of centrifugal compressors and turbines
F1	Failure of seal oil system
F2	Failure of tapping or flange
F3	Failure of fuel gas flexible coupling
G	Release from Claymore pipeline system located in west end of C Module
G1	Liquid slugging at PSV 524 or in downstream pipework
G2	Dislodging of hydrate plug downstream of PCV 501
G3	Inherent defect in pipework
G4	Isolation and over-pressure of flare header downstream of PSV 524
H	Release from failures of condensate piping in C Module other than those associated with condensate injection pump A
H1	Liquid slugging downstream of PSV 505
H2	Over-pressure or mechanical damage to pipework downstream of PSV 505
H3	Dislodging of hydrate plug downstream of condensate injection pump B
H4	Over-pressure of PSV 505 or downstream pipework due to methanol injection
H5	Isolation or blockage by ice or hydrate plug and over-pressure of vent or drain pipework
H6	Dislodging of hydrate plug downstream of LCV 724
I	Release from failure of condensate or relief piping associated with JT flash drum or relief piping associated with condensate suction vessel
I1	Depressurisation and rapid repressurisation of JT flash drum leading to low temperature brittle fracture
I2	Over-pressurisation or dislodging of ice or hydrate plug or liquid slugging downstream of DPCV 723A and B
I3	Inherent defect in transmitter tapping of DPCV 723A and B
I4	Dislodging of ice or hydrate plug downstream of PSV 503A and B.
J	Release into C Module associated with maintenance activities ongoing in GCM
J1	Leak from passing isolation valve ignited by hot work, causing explosion which then caused larger leak
J2	Release from vessel or pipework not fully freed of hydrocarbons
J3	Repressurisation of section of pipework between Valves 1 and 2 which had been opened to form a double block and bleed arrangement

Notes:

- (a) Scenarios A and B, which were not considered by Mr Sylvester-Evans, are the 2 scenarios given in the Petrie Report:
A - A gas release from condensate injection pump A system
B - Liquid carryover in to the reciprocating compressors causing damage and a gas release
- (b) For GOVs 902, 904; PSV 524; PCV 501; DPCV 723 see Fig J.8. LCV 724 was the level control valve on the line from the condensate suction vessel to the condensate knockout drum. PSV 503 was the pressure safety valve on the condensate suction vessel.

Chapter 7

The Escalation of the Disaster

Introduction

7.1 In this chapter I will consider the physical events and actions which followed the initial explosion and may have had a bearing on the series of fires and explosions which led to the destruction of Piper Alpha. I will also discuss the effect of events on the platform systems. While this study will draw on the evidence given by eye-witnesses and others, the description of what happened to personnel on the platform is postponed to Chapter 8. A discussion of the effectiveness of external fire-fighting is included in Chapter 9. The present chapter will also discuss the response on other installations to what was happening on Piper.

From the initial explosion to the rupture of the Tartan riser at 22.20 hours

Evidence given by eye-witnesses

7.2 The evidence given by eye-witnesses on the initial explosion was described in Chapter 5. Captain Clegg on the *Lowland Cavalier* and Mr Flaws, Mr Murray and Mr Miller on the *Tharos* all saw the flames associated with this explosion. As already described, within a matter of seconds Mr Miller also began to take photographs, the first being that shown in Plate 14(a). Mr Miller estimated that he took this photograph some 5-10 seconds after the initial explosion, although the smoke plume shown in it is already well developed, which suggests a rather longer time lapse of the order of perhaps 15 seconds. The photograph shows a fireball coming out of the west face of B Module at a time when there was already a fire there. Although he was unaware of it at the time, it also shows what appears to be flaming at the north face of the platform. Thereafter Mr Miller took a series of photographs over a short period in quick succession. In the following 3 photographs (Plates 14(b), 15(a) and (b)) the fireball is shown as subsiding. Flames appeared temporarily below the 84 ft level. Those and subsequent photographs (Plates 16(a) and (b), 17(b) and 18(a)) taken by him show that the fire in B Module developed rapidly and strongly. In some of them flames could be seen in C Module. Some show flames apparently south of the line of the firewall between A and B Modules and behind the heat shield. Flaming at the north face of the platform was shown until the 13th photograph when the view was obscured by smoke. On close examination it appears that the flaming was at the 121 ft level. The fire does not appear to have taken hold at the 68 ft level until the 19th photograph (Plate 18(a)) when flames become clearly visible below the west side of B Module. From the time when the fire started in B Module thick black smoke streamed northwards from B Module progressively engulfing the upper parts of the platform which lay in this direction. The timing of the photographs taken by Mr Miller is discussed below.

7.3 A number of survivors who were on the dive skid below the 68 ft level observed oil running down the MOL immediately after the initial explosion. Mr MacLeod, the diving superintendent, described this increasing to the point where there was "a vast amount of oil" dropping down and the dive skid was "an inferno".

7.4 About 22.15 hours the jib of the west crane fell into a lowered position resting on the heat shield.

7.5 In connection with what happened in this period it is important to note that photographic and other evidence shows that the fire in B Module was still burning strongly at about 22.50 hours.

The outbreak of fire in B Module

7.6 It is clear from the evidence, such as that provided by Mr Miller, that the initial explosion was followed without apparent delay by a fire in B Module. This was a significant fire before the fireball occurred and for the first 20 minutes it was the principal fire on the installation. The expert evidence which I describe below makes it clear that missiles generated by disintegration of the firewall would have had more than enough energy to rupture small pipework on the oil system in the module.

7.7 Dr D D Drysdale, a Lecturer in the Fire Safety Engineering Unit of the University of Edinburgh, gave evidence as to his interpretation of these conditions in the light of the evidence of eye-witnesses and the available photographs. It is clear that the fuel for the fire in B Module must have been crude oil. According to Dr Drysdale stabilised crude oil on Piper contained about 7% of light ends. An ignited leak of this oil would give flames both from the flashing vapour (for which he used a round figure of 10%) and from the resulting pool of oil. He suggested that the fire might have been due to a rupture in the 4 inch condensate line in B Module before it joined the MOL, the rupture being either upstream or downstream of the non-return valve (see Fig J.8). In the latter case the rupture would release condensate in the normal direction of flow and also crude oil from the MOL in the reverse direction. In the former case oil would not be released from the condensate line unless the non-return valve had failed to function properly. He said that such malfunction was not uncommon. I accept his evidence that rupture of the condensate line at either place could explain the subsequent fire.

7.8 The explanation put forward by Dr Drysdale gains support from the evidence given by Dr R A Cox, then of Technica Ltd. He considered the damage which could have been caused by projectiles generated by the disintegration of the firewall between B and C Modules in the event of an explosion in C Module. He estimated the energy requirement to cause pipe collapse as 164 kJ for the 20 inch MOL. The 4 inch condensate line had 2 sections of different strengths:- (i) the short piece between the non-return valve and the MOL and (ii) the piece which comprised the remainder of the pipe and which had thicker walls. Dr Cox estimated the pipe collapse energies for these 2 sections as 2.9 kJ and 5.79 kJ, respectively. He gave the energy required to break off small bore pipework as of the order of 0.05 kJ. He obtained the kinetic energy of the projectiles from their velocity as estimated from the dynamic pressure pulse derived from the TNT equivalent explosion model. Although he also gave results using other models, which tended to yield higher kinetic energies, this method, which he called the gas velocity method, was his preferred approach. He considered the range of possible projectiles, including panel bolts, small and large panel frames or portions of these and the door in the firewall; and 3 explosion scenarios namely (i) case 1, 100% fill of natural gas and edge ignition; (ii) case 2, 25% fill with natural gas and edge ignition; and (iii) case 3, 50% fill with propane and central ignition (see the 2 Technica cases, T1 and T2, and the DEN case 3 in Table 5.1). The kinetic energies obtained for the large fragments were in the range of 18-40 kJ, 3.3-8.5 kJ and 77-161 kJ for cases 1-3 respectively. Making an allowance for the efficiency of energy transfer from the fragment to the target to take into account factors such as the orientation and relative stiffness of the projectile, Dr Cox proceeded on the assumption that if the ratio of the fragment energy to pipe collapse energy exceeded 5, the pipe collapse was probable. He concluded that bolt projectiles would not cause pipework failure in B Module; that the smaller fragments would not cause failure of the 20 inch MOL and were unlikely to cause failure of the 4 inch condensate line; that the larger projectiles were unlikely to cause failure of the MOL; that, depending on the case considered, these larger projectiles might cause the 4 inch condensate line to fail; and that all of the panel and door projectiles were capable of breaking off small bore pipework. He thought failure of the 4 inch condensate line was to be expected for cases 1 and 3. For case 2 it was possible but not probable. I note from the above figures that the fragment kinetic energies in case 3 were higher than those in case 1, that in the former the gas was propane and ignition was central and that these factors

more than compensate for the smaller module fill. I expect that there would be a similar effect as between case 2 and the scenario considered in the explosion simulation with 12% fill propane and central ignition which has been described in Chapter 6.

7.9 A detailed analysis of failure modes for the 4 inch condensate pipe was given by Dr A C Palmer of Andrew Palmer and Associates Ltd, Consulting Engineers, who described 10 possible modes of pipe deformation and the energy required in each case to rupture the pipe. In his opinion the most likely mode was denting by an edge, or formation of a deepish dent by impact with a very sharp knuckle at the end of the dent. Another quite likely mode would be dynamic puncturing, or a gouge penetrating the wall to such a depth that, with the aid of the internal pressure, it created a crack. He calculated the energies required to give these 2 failure modes of the pipe as 26 and 7 kJ, respectively. The latter, being a dynamic mode, also required a higher velocity of at least 40m/s. He did not himself make estimates of the velocity or kinetic energy of the firewall fragments but compared the values which he had estimated for the various failure modes with those given in the Technica study. He thought that pipe rupture was probable with the kinetic energies given for cases 1 and 3 above, and possible but less probable for case 2. He accepted that the velocities given in the Technica study were maximum velocities and that projectiles striking the pipe close to the firewall were less likely to have reached their maximum velocity than those striking it further away. With regard to the efficiency of energy transfer he emphasised that this was highly variable and described circumstances where the energy available to rupture the pipe might be half the kinetic energy of the fragment. One potential projectile which received greater emphasis in Dr Palmer's study was the door in the firewall. He calculated that with an applied force equivalent to 0.4 bar over-pressure and at a distance of 1.5m, which was that from the wall to the section of pipe parallel to it, the velocity of the door would be some 40m/s and its kinetic energy some 150 kJ, the latter initially increasing linearly with distance. Dr Palmer did not suggest a particular part of the 4 inch condensate line as being especially likely to suffer rupture. He did believe, however, that the probability of a fragment striking the pipe was quite high. He said "We are talking about a large wall with a pipe very close to it and the wall becoming fragments of different sizes, some of them perhaps quite large with the pipe only 5 feet away. My judgement is that in that situation impact would be quite likely. It is not to be thought of like throwing balls at a coconut-shy. It is something much closer in than that."

The occurrence of the fireball

7.10 The first matter to be considered is the timing of the fireball which depends upon the timing of the photograph in Plate 14(a). Mr Miller believed that he took that photograph within 5-10 seconds of the initial explosion and, though pressed, he held to that view. Various attempts were made to use the length of the plume of smoke to determine the time which must have elapsed before the photograph was taken. However this is complicated by uncertainty as to whether the whole plume is in the photograph and by the fact that the wind at the time would blow the plume not due north but approximately north-east. From the evidence I estimate that the photograph was probably taken some 15 seconds after the initial explosion.

7.11 Dr Drysdale estimated that the fireball shown in the photograph had a vertical dimension of 33m and a horizontal dimension of 23m. Using a standard model relating the diameter of a fireball to the mass of the fuel and taking a diameter of 28m he obtained for the mass of fuel a figure of 112 kg. He advanced the hypothesis that the fireball was consistent with a full-bore rupture of the condensate line either upstream or downstream of the non-return valve already mentioned. In the event of such a rupture the contents of the line between PCV 511 and the point of rupture would have been released. The total amount of condensate in the line between PCV 511 and the MOL was about 125 kg. The initial discharge rate would be about 500 kg/s. The flash fraction in this instance would be about 40%, which would give a rapid evolution of vapour resulting in the ejection of virtually the whole of the contents of the section

of the line concerned within 1-2 seconds. The eruption of the fireball would have been accompanied by some over-pressure, although this would have been very much less than that associated with the initial explosion. As stated above, the fireball was shown to decay in the second, third and fourth photographs taken by Mr Miller which he said he took at intervals of about 2-3 seconds.

7.12 It is obviously necessary to consider why the fireball did not appear at the same time as the fire in B Module. This raises the question whether there were 2 separate releases or not. Dr Drysdale dismissed the possibility that the rupture of the condensate line was caused by over-heating of the line due to fire in B Module on the ground that there was not enough time for this to occur. He looked instead for any non-normal events which might be taking place at this time and identified the closing of ESV 208 on the MOL and the run-down of the MOL pumps. ESV 208 was a 20 inch valve and on the rule of thumb that such a large valve closes at a rate of about 1 inch per second its closure time would be about 20 seconds. In the light of the events described it appears to me to be likely that the condensate line was damaged by a missile sufficiently to leak a significant amount of oil. Dr Drysdale put forward as one possible failure mechanism initial damage to the line, causing a partial rupture, with subsequent full-bore rupture on closure of ESV 208 and/or as the MOL pumps ran down. Factors which might have contributed to the total rupture were heating of the line, perhaps from a jet flame from the leaking oil, and vibration resulting perhaps from the state of the pipework after the initial explosion. The fireball, which I have estimated to have occurred about some 15 seconds after the initial explosion, would then have been the result of this rupture. I accept this sequence of events as a credible explanation.

7.13 Dr Drysdale explained that the running of oil down the MOL may have resulted from oil being sprayed on to the MOL during the time when the fireball was occurring. Alternatively it was due to a leak from above ESV 208 which decreased when the valve closed. Dr Drysdale also stated that the fireball would have caused burning gases to spread from the existing fire in B Module. The flames which appeared temporarily on the 68 ft level at the time of the fireball appear to have been forced down to that level by over-pressure in B Module.

The extent and duration of the fire in B Module

7.14 Dr Drysdale was of opinion that the weight of evidence was against flaming in C Module immediately after the initial explosion. If Mr Flaws was correct in his evidence that he saw flames to the left of the west crane, this may have been a jet fire at the site of the initial leak, but assuming that the inventory was limited the leak and the jet flame would be diminishing. Some of the later photographs taken by Mr Miller show flames in C Module (eg Plate 18(a)). In Dr Drysdale's view these almost certainly emanated from the fire in B Module through a breach in the firewall. If there had been a separate fire in C Module, flames would have issued from the module merging with those in B Module to give a continuous "wall" of flame. What appeared to be flames at the base of the derrick above A Module were interpreted by Dr Drysdale as reflection, perhaps from the flare, rather than flames as there was no indication at that point of flame through the heat shield immediately below. He also expressed the opinion that the flames on the north face were an extension of the fire in B Module. The phenomenon of flame extension is well known in buildings where fire gases which are rich in products of partial combustion such as carbon monoxide emerge from a fully developed room fire, pass along the ceiling of a corridor and on meeting a stairwell or an opening to atmosphere burst into flame. In the present case the gas stream would also be rich in volatile hydrocarbons. Dr Drysdale discounted the alternative possibility that the fire was at the diesel tanks above the 121 ft level since both the storage site and the quantities stored made that improbable. His hypothesis was that the hot gases passed from B Module through a breach in the firewall into C Module and thence to the north face. He had some difficulty in identifying the precise path taken beyond C

Module. However, he noted that fire damage had occurred to the cabins at the north-west corner of the ERQ, which was consistent with there having been a prolonged external fire at that point. Further the area of the north wall of the ERQ which was to the west of the air intake duct had been exposed to temperatures in excess of 900°C. The hot gases would be driven by buoyancy, wind and any over-pressure in B Module. They would tend to be channelled by the I-beams in the roof of B and C Modules. During their passage through C Module they would undergo some rather inefficient combustion with the air beneath. The photographs taken by Mr Miller show that the west end of C Module was masked by smoke apparently within tens of seconds of the initial explosion. This would have obscured the view of any hot gases passing through C Module. It was suggested that any hot gases passing into C Module might well find outlets to atmosphere other than on the north face, on reaching which they would burst into flame. This might explain other flaming observed at the periphery of the platform. Dr Drysdale also expressed the view that the extension of the fire to the 68 ft level which was shown in the 19th photograph taken by Mr Miller might indicate that oil leaking on to the deck of the 84 ft level had started to spill over the collar of the deck penetration where the MOL came up from the 68 ft level. The continuing overflow would have allowed a pool to be established on the deck in parts of the 68 ft level exposing the Tartan riser to intense heating for at least 10 minutes. Survivors had also described a fire at the drums of rigwash stored near the riser. If the 2 fires were initially distinct, it is probable that they soon merged.

7.15 Following the fireball, the fire in B Module would have been fed by oil issuing from the system and spreading out over the deck of the module, giving rise to a pool fire. Estimates of the burning or regression rate of the fuel on the pool surface were given by Dr Drysdale. For pools in the open the burning rate depended on the pool diameter and approached a limiting value asymptotically. He quoted a value of 0.08 kg/m² per second for this limiting burning rate. For small confined pools increases in burning rate had been recorded which exceeded those for similar pools in the open by factors of 5 or 6 but for the large pool envisaged in the present case this factor would probably be much less. With a confined pool the burning rate was increased by radiation of heat back to the pool from the enclosure. In the case of B Module conduction of heat through the deck would also tend to increase the heat received by the pool. On the other hand the effect of the grating in the module would be to reduce the amount of radiation received by the pool surface. Taking such features into account he gave an estimate for the burning rate of 0.16 kg/m² per second. The main source of fuel in the process plant was in the separators, which he estimated at 50-55 tonnes. At the above burning rate and assuming that the pool contained some 50 tonnes and that some 5 tonnes of oil did not enter the pool but went down the drains, pool areas extending to 50, 100, 150 and 200m² would burn for 104, 52, 35 and 26 minutes, respectively, neglecting any fraction flashing off immediately on release, or 94, 47, 32 and 23 minutes, respectively, after allowing for a flash fraction of 10%. There was thus enough oil in the separators to maintain a fire in B Module up to 22.50 hours provided that the pool area did not exceed about 100m². He considered, however, that the pool was larger than that. Making the assumptions that the deck plates were sloped from a high ridge at the centre of the module towards the open drains under the MOL pumps and that the eastern limit would be defined by the penetration of the MOL through the deck plates, he estimated a minimum pool area of 150m² (10m x 15m) and making the assumptions that there was a collar 5 cm high to prevent normal spillages running down the MOL and that the deck plates were sloped at an angle of one degree, he obtained an estimate of 200m² for the maximum pool area. He adopted the value of 150m² for the probable area of the pool. These considerations led Dr Drysdale to postulate that the pool fire in B Module was also fed from another source. Possible sources were the wellheads and the MOL. Accepting the evidence of an Occidental investigation of the wellhead valve which showed that the valve had closed, he concluded that it was probable that ESV 208 did not achieve a tight shutoff and that oil leaked back from the MOL. He drew attention to photographic evidence of an intense fire near the location of the MOL. An alternative explanation was that the fire caused over-heating and at least partial fracture of the MOL. As will be seen from

what follows the Tartan riser is believed to have ruptured after being subjected to an oil pool fire for some 10-15 minutes. I should add that once the Tartan riser had ruptured, the jet flame from that riser would have enhanced the heat input to, and the burning rate of, the pool fire, a point which strengthens Dr Drysdale's contention that the pool was not fed from the separators alone.

7.16 The available data on the oil pipelines in the network between Piper, Claymore and Flotta were examined by Scientific Software - Intercomp (UK) Ltd in Annex 9 of the Petrie Final Report, spoken to by Mr I R Ellul. It is clear that due to the limited amount of information and uncertainty as to its accuracy it is difficult to draw a clear conclusion. With the aid of a computer model Mr Ellul simulated for each pipeline what might occur in the event of - (i) no leak; (ii) a 10% leak; and (iii) a 20% leak in the MOL at Piper. The predicted results were then compared with the graphs of the measured pressures in the oil lines between 21.00 hours on 6 July and 06.00 hours on 7 July. Mr Ellul stated that the comparison of the predicted results with the readings for the Tartan oil line suggested no leak. The comparison with the readings for the Claymore line suggested a 10% leak. Nothing could be taken from the comparison in the case of the Flotta readings due to the low pressure in the oil line which allowed gas to be liberated from the oil and made the readings unreliable. Mr Ellul concluded that the results suggested a low probability of a significant leak of oil from the oil export line at Piper until at least 23.15 hours when Claymore shut down and depressurisation of the line commenced at Flotta. A "significant" leak meant a leak of about 10%. He explained that he was only able to say that there was a low probability of such a leak as he considered that the validity of the Claymore readings was undermined by the way in which the graph fell away sharply at 23.30 hours, which on one view fitted a "no leak" better. However at such low pressures his programme was not necessarily accurate. He agreed that if the pressure on the Claymore model had not fallen away so sharply at 23.30 hours he would have had no reason for coming to any other view than that the Claymore readings suggested a 10% leak at Piper, and he agreed that further inaccuracies in the computer predictions might be produced due to the scarcity of information for 23.30 hours. He accepted that his findings were consistent with a leak having occurred as a matter of probability.

7.17 In the light of the evidence I draw the following general conclusions:-

- (i) The fire in B Module which followed immediately after the initial explosion was fuelled by crude oil which was released as a result of the 4 inch condensate line in B Module being ruptured by projectiles generated by the disintegration of the B/C firewall which was due to the initial explosion.
- (ii) The fireball which came from the west face of B Module did so about 15 seconds after the initial explosion and was due to the rupture becoming full bore as a result of the pressure of crude oil.
- (iii) The fire in B Module extended through a breach in the B/C firewall into C Module and thereafter appeared on the north face of the platform. As a result of the spillage of crude oil from the pool which was providing fuel for the fire in B Module, the fire was extended to the 68 ft level.
- (iv) The crude oil came not only from the inventory on the platform but also from the MOL as a result of ESV 208 not achieving a tight shutoff.

The rupture of the Tartan riser at 22.20 hours

7.18 It is clear from the evidence of survivors and photographs that at 22.20 hours there was a second major explosion which engulfed the platform in a sudden and massive intensification of the fire. Its effects were immediately felt on vessels several hundred metres away as well as by personnel at the base of the platform. It is clear that this was due to the rupture of the Tartan riser.

7.19 The riser came up from the seabed between legs B5 and B4. Just below the 68 ft level it bent over to a horizontal run in a southerly direction where it was suspended

from 3 pipe hangers. Between legs B3 and B2 it entered a right-angled bend towards the east and thereafter inclined upwards, penetrating the 68 ft level deck plating and connecting into the main pipeline shutdown valve ESV 6 upstream of the pig receiver. The riser had a diameter of 18 inches and a wall thickness of 1 inch. The steel grade was API 5LX-X60. Its coating was paint. Its flanges were RTJ A105.

7.20 Dr Richardson, who has been referred to in Chapter 6, gave evidence as to the analysis of flows in the gas lines between Tartan and Piper, MCP-01 and Piper, and Claymore and Piper. In his second report with Dr Saville he calculated the gas inventories in the various lines prior to the initial explosion and with the assistance of computer models attempted to predict the likely rate of depressurisation of each line, based on the start time and capability of each facility which would match the resulting pressures measured in the lines. From their calculations they were able to conclude that at least one of the Tartan gas import or MCP-01 gas export valves on Piper appeared to have shut at about 22.00 hours. Indeed, the data available to them were consistent with all Tartan gas import and MCP-01 gas export valves on Piper having shut at about that time, although he could not say whether they had shut tightly or not. It appeared that until 22.20 hours all the lines were intact. At that point it appeared likely that the Tartan to Piper line ruptured at Piper. The line then had an inventory which he estimated at 18 MMSCF. All the information of which he was aware implied a full bore rupture. Over about one minute 7% by mass of the gas would have left the line; in a further 23 minutes about 80%. The time for depressurisation to essentially atmospheric pressure was about 60 minutes, although the mass flow may have been rather higher. Pressure measurements at Tartan seemed to him to indicate that depressurisation was in fact completed in 55 minutes after 22.20 hours. This was subject to any small amounts taken off by Tartan itself.

7.21 Mr M R Clark, Chief Process Engineer of Occidental, prepared an estimated inventory of hydrocarbons as at 22.00 hours, which included the residual hydrocarbon content in C Module when depressurised in an emergency shutdown of phase 1 operation. The time taken for the major flows of hydrocarbons to reach the flare would be 5 minutes, after which there would be a slow boil-off of the small amounts of heavier hydrocarbons. This period was based on experience on Piper that neither the reciprocating nor the centrifugal compressors retained significant pressure for periods beyond that time. After blowdown the largest inventory of hydrocarbons would be the 1200 barrels of diesel in the diesel storage tanks.

7.22 Dr Cox undertook an investigation of the failure times of the Tartan riser due to varying heat loads. He calculated the rate of heating of the riser under different conditions and estimated the time at which the critical failure temperature would be reached. His best estimate of the likely range of heat fluxes was 100-200 kW/m². He considered a number of failure mechanisms, out of which the governing mode of failure was likely to be high temperature reducing the pipe steel strength to below the hoop stress induced by internal pressure. That failure would probably occur within the temperature range of 580-700°C. A number of heat transfer mechanisms were considered, of which the significant ones were heat gain due to radiation and convection from the fire; heat loss to surroundings by radiation; and heat loss to stagnant gas within the pipe. The critical section of the pipe for heat transfer was that immediately upstream of ESV 6 where the fire burned most fiercely and a pool of burning oil could have collected underneath. At a typical heat flux level of 150 kW/m² the exposure time to failure of the riser would be of the order of 7-18 minutes. This would be consistent with the timing of the observation of the large eruption of fire. Dr Drysdale also gave evidence that the most likely mode of failure of the Tartan riser was failure under hoop stress due to internal pressure caused by over-heating. He described the fire resulting from the rupture of the riser as an impinging jet fire. The question was raised as to why the MCP-01 riser did not rupture about the same time as the Tartan riser. Dr Drysdale was not able to offer an explanation for this other than the fact that the former was slightly further to the north than the latter.

7.23 Dr Cox was aware of the practicability of applying fireproofing to pipework. He agreed that this type of coating could have made a difference to the time during which the pipe retained its integrity, depending on the thickness of the coating. He said that he was fairly sure that “one could extend the survival time of a pipe of this sort by something of the order of a small number of hours perhaps, or one hour, two hours, three hours but only of that very very approximate sort of figure”. If the pipe had been protected by a deluge which itself survived the fire, it could have survived indefinitely so long as the deluge continued. I should add that, as was stated in Chapter 3, the automatic operation of the deluge system on the 68 ft level had been switched off before the disaster because of the carrying out of welding work in connection with the Chanter riser. In any event the deluge system was disabled by the initial explosion (see para 7.65). The existing deluge system in the area of the 2 risers was a foam system, which suggests that it was primarily suitable for extinction of fires rather than cooling of equipment. There was no evidence as to whether if the system had come into operation at the time of the initial explosion, it would have been able to provide the protection for the Tartan riser which was envisaged by Dr Cox.

7.24 In the light of the evidence I draw the following general conclusions:-

- (i) The major explosion at 22.20 hours was caused by a full-bore rupture of the Tartan riser immediately upstream of ESV 6 as a result of the high temperature created by a pool fire beneath it.
- (ii) The rupture gave rise to an impinging jet fire and to the depressurising of the Tartan gas pipeline in 55-60 minutes.
- (iii) Rupture of the riser could have been delayed by fireproofing for a substantial period, perhaps 1-3 hours, and by a cooling deluge system which came into operation after the initial explosion for an indefinite period. In the light of evidence which I heard in Part 2 of the Inquiry and which I discuss in Chapter 19, I recognise that there are certain disadvantages in fireproofing.

Subsequent explosions and the disintegration of the platform

7.25 At about 22.50 hours there was a further violent explosion, the vibration of which was felt 1 mile away. Debris was projected 800m from the platform. The men who were on the helideck of the platform were forced to jump off and the FRC from the *Sandhaven* was destroyed and 2 of its crew killed while engaged in the rescue of personnel from the platform. This is likely to have been due to the rupture of the MCP-01 gas line at Piper on the downstream side of its emergency shutdown valve. The pig launcher for that line was a short distance to the north of the pig receiver for the Tartan line. From there the MCP-01 line went west, running under the 68 ft level, then turning north and then eastwards towards the A3 leg, where it turned north again and ran towards the A4 leg, where it took a vertical turn down towards sea level. From his examination of the records Dr Richardson expressed the view that the gas line to MCP-01 appears to have been intact until 22.50 hours when it started to be depressurised, apparently as a result of a full-bore rupture at Piper. At that time the inventory in the line was 51 MMSCF. Depressurisation was complete within about 5 hours. Support for the interpretation of a rupture at 22.50 hours is provided by the recording at MCP-01 of the pressure in the line. After 22.50 hours there was a sharp tail-off in pressure. By 24.00 hours one half of the pressure had been lost. This could not be accounted for by flaring alone but must have been largely due to a rupture.

7.26 Following the explosion at 22.50 hours the collapse of the structure of the platform started at the 68 ft level below B Module. About 23.15 hours the western crane collapsed from its turret. It is probable that the jib and cab fell into the sea. This was as a result of the continued deterioration of the area around B Module due to riser fires. Shortly thereafter there was a major structural collapse in the centre of the platform. The deteriorating condition in the area of B Module caused the drilling derrick to collapse towards the north-west corner, the top section falling across the

pipe deck. The structure of the platform had already taken a slight tilt to the east. This was followed by a sudden collapse of the pipe deck. According to Mr Letty, the master of the *Tharos*, shortly after beginning to pull back from the platform at about 23.18 hours, there was “an enormous explosion on the platform”, which he believed to be “the biggest of the night”. This was probably caused by the failure of the Claymore gas riser. Some witnesses said that the collapse of the pipe deck was associated with an explosion while others did not distinguish it in this way. The collapse was much more serious than the first and was to the west. Both this and the first tilt caused equipment to fall and injure or trap men in the White House. It caused the structure of the White House and the OPG workshop (both of which were on the pipe deck) to fail and force many of the men out, although some were trapped or engulfed by flames at this point. When the men came out, they discovered the pipe deck had collapsed to the west at an angle of up to 45° and was split from east to west along the line of the south face of the SPEE Module. The collapse also caused structural failure in the support of the ERQ which tipped to the west. It is also probable that it then crushed and destroyed the LQW. This conclusion was advanced by Mr D M Tucker, a Fire and Loss Consultant of Tucker Robinson, Consulting Scientists, who examined the ERQ at Flotta after its recovery from the seabed. He indicated that slide marks in the kitchen of the ERQ could be explained by a tip to the west which could only occur if this tip destroyed the LQW or if the LQW had already gone. There was no evidence of any prior collapse which would have destroyed the LQW. Although the LQW was made of more combustible materials than the other modules, the explanation that it had been destroyed by fire could be discounted because of the amount of unburnt wreckage from it. Accordingly it appears correct to conclude that the LQW was destroyed when the ERQ tipped to the west in the same structural collapse that caused the derrick to fall and the pipe deck to collapse. This would account for the fact that survivors saw wreckage from the LQW in the water. Mr Tucker also concluded that the ERQ would have fallen into the water at about this time. The basis for this view was the lack of fire damage to the west and south faces of the ERQ, which suggested that they were shielded from fire and smoke until the ERQ fell (see Plate 22(b)). In addition smoke ingress into the ERQ through doorways from the LQW was more consistent with small fires in the LQW and not with the LQW being fully ablaze or absent.

7.27 In the light of this evidence I consider that it is more likely that the rupture of the Claymore riser contributed to the structural failure of the centre of the platform rather than having been caused by it. The Claymore pig launcher was situated at the 68 ft level in the north-west corner of the platform. From the pig launcher the riser turned vertically downwards in the western half of the north face and maintained that direction to sea level. Dr Richardson noted that there had been an apparent depressurisation of the Claymore pipeline at 23.00 hours. At that time the inventory in the pipeline was about 10 MMSCF. According to evidence given by personnel on Claymore depressurisation of the pipeline started at Claymore at 23.00 hours through FCV 970, which was a choke valve of 6.25 inches diameter. This evidence was not available to Dr Richardson. Accordingly he was unable on the information available to him to determine whether the depressurisation had begun at Piper or at Claymore. However, he did say that he would have expected the pressure at Claymore to have dropped more rapidly than was shown in Fig 9.5 of the Petrie Report (Fig 7.3) if depressurisation at Claymore accounted for the total effect.

7.28 The explosion which took place when the Claymore riser ruptured contributed to the accelerating deterioration in the condition of the platform which followed. Mr Letty said that by 00.15 hours the north end of the platform had disappeared completely. However, the log of the *Tharos* stated that at 00.45 hours “The Piper accommodation module over-turned into the sea.” This was probably the AAW, the only module remaining on the north end of the platform at that time. Mr Tucker found that the AAW (see Plate 23) had suffered much more extensive fire attack than the ERQ with heating predominantly from the south. He also said that it had tipped over on to its north face and remained there for a period of time. It could not have

tipped over to the north until the LQW had gone. Eye-witness accounts indicate that the north end of the platform collapsed slowly. Once the centre had fallen out of the platform the AAW would have been subjected to extreme heating on its south face, certainly from around 23.30 hours. The description of the AAW bending over towards the sea could have been due to its falling over into the space left by the LQW before sliding into the sea at the north-west corner of the platform. Mr Letty also confirmed that by 00.15 hours the fire was mainly from the surface of the sea, a highly pressurised fire, like a Bunsen burner. This indicates that burning gas, under pressure, was coming from one or all 3 of the gas risers which by then had been severed by falling equipment and structural debris from the modules and the north end of the platform. Plate 21 shows the broken end of one of the risers ablaze the next morning. Mr Letty also described a pool of burning oil, about 100 ft across, in the vicinity of the MOL riser.

Extended flaring

7.29 Photographic and other evidence shows that there was significant flaring and venting on Piper after the initial explosion. In particular the high pressure flare, shown just before the initial explosion in Plate 13, continued to burn with a clean, constant flame until the explosion at about 22.50 hours. If the shutdown systems had worked correctly, then depressurisation of the production facilities would have been expected to occur long before this time. The low pressure flare was extinguished about 10 minutes after the initial explosion but after several minutes it began to emit a strong vapour plume. About 10 minutes after the initial explosion a vapour plume was also seen coming from an atmospheric vent on the east flare boom. This plume lasted beyond 22.20 hours but disappeared before either the high pressure flare or the low pressure plume ceased.

7.30 An interpretation of the photographs of the flaring was provided by Mr P C A Watts, Chief Process Engineer, Kaldair Limited, who were the suppliers of the flare tips. On his interpretation the flow of gas through the high pressure flare prior to the disaster was about 20 MMSCFD. During the blowdown the rate was 60 MMSCFD through the high pressure flare and 4 MMSCFD through the low pressure flare. Photographic evidence showed a rise to a peak of 240, falling to 160 MMSCFD. Thereafter there was a rapid reduction in the high pressure flare, with some dark smoke, which would be induced by the carryover of liquid droplets or an increase in the molecular weight of the gas or a combination of both. This was followed by a steady period of flaring for about 45 minutes at 60 MMSCFD until the explosion at 22.50 hours. At some time during this period the low pressure flare went out and was replaced by a steamy plume. The high pressure flare showed the burning of clean gas free from liquid or heavy ends. The flare would be smoky only if there was a low gas pressure and flow combined with either gas of molecular weight greater than 60 or with liquid carryover in excess of about 50% w/w.

7.31 Mr R J Smyllie, Senior Engineer, Cremer and Warner, estimated that 200-300,000 SCF had flared off in a period of 3 minutes after the initial explosion. This excluded gas coming from the source of the continuous background flaring of 60 MMSCFD over that period, which was equivalent to 125,000 SCF. He said that after the flare subsided the smoke might have been due to the burning of gas with a significant increase in heavy ends or even a hydrocarbon liquid carryover. The source was most likely to be the JT drum and the production separators. He said that a large proportion of the gaseous inventory on the platform (220,000 SCF plus 25-30,000 SCF from the centrifugal compressors) must have been consumed very shortly after the first explosion in order to fuel the observed 240 MMSCFD peak flow. In fact the volume of hydrocarbons estimated to have flared off in the first 3 minutes was consistent with the gaseous and flash gas inventories that existed on the platform at the time of the explosion. The remaining oil and condensate inventories left after depressurising were not sufficient to supply the high pressure flare for a prolonged period. Further had these been a major contributor a smoky flame would have been expected. However, the remaining hydrocarbon inventories could have produced a small continuous flow

by way of the fail-open PCVs if fires in the vicinity generated sufficient heat to drive off gases. The high pressure flare could be expected to reduce to a minimum flow within a relatively short time of an ESD.

7.32 As regards off-platform sources Mr Smyllie said that the probability of a combination of valve failures allowing gas to come from a well was small. Moreover, such a source would give a smoky flame. He ruled out gas lift since the isolation valves were found to be closed. Turning to the gas pipelines, the lack of change in the flare before and after the event which affected the Tartan pipeline at 22.20 hours indicated that that line was not the source. He considered that the mass balance carried out by Drs Richardson and Saville showed that there was no major leak at ESV 956 on the MCP-01 pipeline. Thus by process of elimination he was drawn to the conclusion that the source of the gas was the Claymore pipeline. This pipeline contained Tartan gas which would not give a smoky flame. For the Claymore line to be the source the gas would have had to pass through the ESVs at the pig trap; then through one of a number of intermediate routes; and finally through a PCV or PSV to flare. He considered a path through ESV 501, PCV 501 bypass and PCV 945.

7.33 I consider each of these routes in turn. PCV 945 was a fail-open valve. Dr Cox expected that this valve and the other PCVs to the flare would have gone to the open position due to action of the PESD. With regard to the path through the PCV 501 valve set Mr Smyllie's preferred route was through the bypass. However, although the PCV itself was near reciprocating compressor B the bypass was at some height up and fairly inaccessible. Evidence of normal practice was that on loss of 1 or 2 centrifugal compressors the phase 1 operator would open the manual block valves on either side of PCV 501 but that until the third compressor was lost no action would be taken to open the PCV itself. Mr Bolland said that Mr Richard would know what to do but he would have had no time after the tripping of the third centrifugal compressor to open the PCV. However, PCV 501 was a fail-open valve and Dr Cox stated that he could envisage that damage caused by the accident might cause such a valve to open. I think it probable that the block valves were opened and regard it as more probable that the PCV opened as a result of the explosion than that the bypass was already open. As far as concerns the path at the pig trap, MOV 502 and ESV 503 were normally closed and are unlikely to have been the route. It is much more probable that ESV 501 failed to close fully. The ways in which this might have happened were explored with both Mr Smyllie and Dr Cox. Mr Bolland stated that he did not press the buttons to close the gas pipeline ESVs. According to Dr Cox ESV 501 would therefore only have closed if there was a loss of the 120V AC supply. As described below, he believed that the D Module 120V AC supply was lost. Even if it had not been lost, the cable for ESV 501, which was separate from that for ESV 6 and ESV 956, might have been damaged even if the UPS was intact, thus effecting the closure of ESV 501. However, if local damage to the valve occurred it might not have closed fully. As regards the low pressure flare Mr Smyllie's interpretation was that it was due to the blowdown from the third centrifugal compressor and the deoxygenating towers. The vapour plume was thought to be the result of steam generated within a number of vessels as a result of fires burning in their locality. As regards the atmospheric vent, his interpretation was that the plume was most likely to have come from the 3 inch diameter centrifugal compressor skid blowdown line, possibly due to a fracture or a passing valve. I should add that the Claymore gas pipeline could be "topped up" with Tartan gas through the "Gas to Claymore" (GTC) valve and that during phase 1 operation the dry Tartan gas was being used in preference to the wet Piper gas for topping up the line. Such a topping-up operation could have been going on at the time of the initial explosion. However, Mr Smyllie's argument against Tartan gas being the source for the extended flaring still stands. Moreover, the record at Tartan of the Tartan line gas pressure showed that ESV 6 on that line at Piper closed when that platform shut down at 22.00 hours.

The response of other installations

7.34 It has been shown earlier in this chapter that the amount of crude oil which fuelled the fire in B Module could not be wholly accounted for by the inventory of crude oil on Piper at the time of the initial explosion; and accordingly must have come partly from the MOL, either by reason of the failure of ESV 208 to close completely or by reason of a fracture of the MOL itself. The MOL at Piper formed part of a system into which 2 other installations, Claymore and Tartan, normally pumped crude oil; and in which the onshore terminal at Flotta normally maintained a back pressure (see Fig 3.1). It was therefore appropriate to discover whether anything could have been done at any of these other installations which would have had the effect of reducing the amount of crude oil discharging at Piper and so reducing the consequences which flowed from that. It has also been shown earlier in this chapter that the disaster at Piper was hastened by the successive rupturing of the gas pipelines connecting Piper with Tartan, MCP-01 and Claymore. Accordingly it was appropriate to discover whether anything could have been done elsewhere to prevent or defer such events taking place.

Stopping the production of oil

7.35 Claymore continued the production of oil until about 23.10 hours. About 10 minutes earlier steps were begun in order to carry out a controlled shutdown. This type of shutdown was chosen in order to avoid problems with the compressors at Claymore. An emergency shutdown would have taken immediate effect. At Tartan between 22.30 and 22.45 hours steps were begun to shut down oil production. Wells were shut down in stages between 22.55 and 23.23 hours. The last step was the closing of the main export valve at 23.52 hours. Once again this was a controlled shutdown. The reasons given in evidence were the risk of generators not automatically switching over to diesel so that the operators would be faced with a "black start" situation; and the containment of full pressure in vessels and flow lines from satellite fields. An emergency shutdown would have taken immediate effect. Before oil production was shut down on Claymore the terminal at Flotta had shut down a stabilising train and a gas plant as a result of indications that Piper had shut down production and information from Claymore that an explosion had taken place at Piper and that personnel were being evacuated. Between about 23.15 and 23.25 hours Flotta was instructed by Occidental to effect the depressurisation of the pipeline from Piper. This was carried out after Flotta had verified that Claymore and Tartan had both ceased production. The normal back-pressure of 220 psi, which was equivalent to 16 bar, had been reduced to 6 bar at 00.20 hours and 0.7 bar at 07.00 hours.

Depressurisation of the gas pipelines

7.36 The depressurisation of the gas pipeline from Tartan to Piper was instructed on Tartan between 22.30 and 22.45 hours. This took until 23.20 hours to set up, the last step being the opening of the export gas valve ECV 54. As will be explained below, it was then found that the pipeline contained virtually no gas pressure which was capable of being measured at Tartan. The depressurisation of the gas pipeline from Piper to MCP-01 was carried out at MCP-01 starting just after 23.00 hours. This pipeline normally contained about 60 MMSCF. The flaring capacity at MCP-01 was 2.6 MMSCFD. The depressurisation of the gas pipeline between Piper and Claymore was instructed on Claymore about 23.00 hours and took about 5 minutes to set up. Depressurisation was carried out through FCV 970. In addition after 24.00 hours gas was taken through the separators to the low pressure flare. It is uncertain how quickly this pipeline lost pressure. According to Mr J Davidson, Operating Superintendent on Claymore, a pressure of 400 psi was reached in about 4 hours, whereas the trend record for this line given in the Petrie Report, which was based apparently on readings taken on Claymore, showed that this pressure was reached after about 45 minutes. The pressure records for all 3 gas pipelines are given in Figs 9.1, 9.3 and 9.5 of the Petrie Report and are here reproduced in Figs 7.1-3.

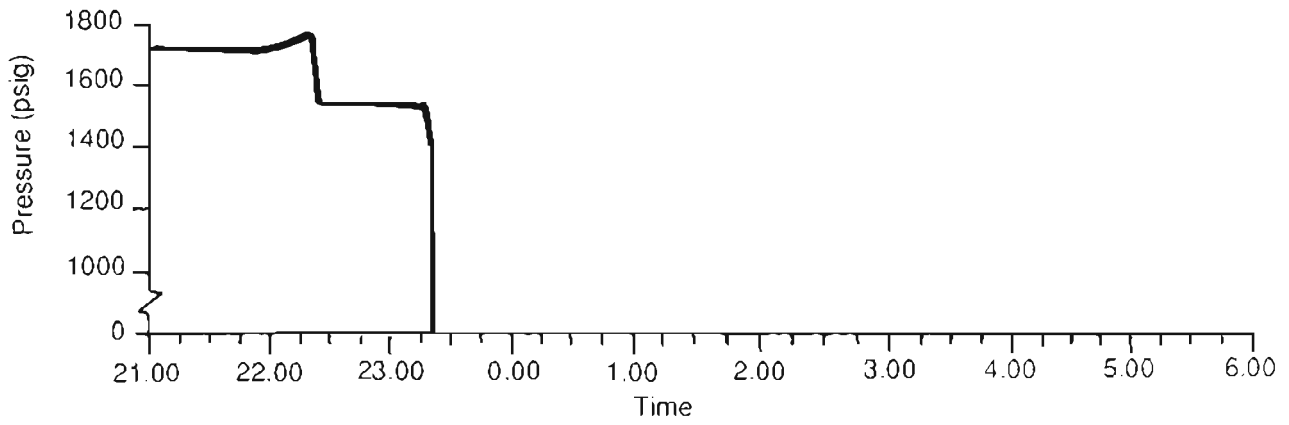


Fig. 7.1 Trend record of the Tartan gas export pipeline pressure on 6/7 July.

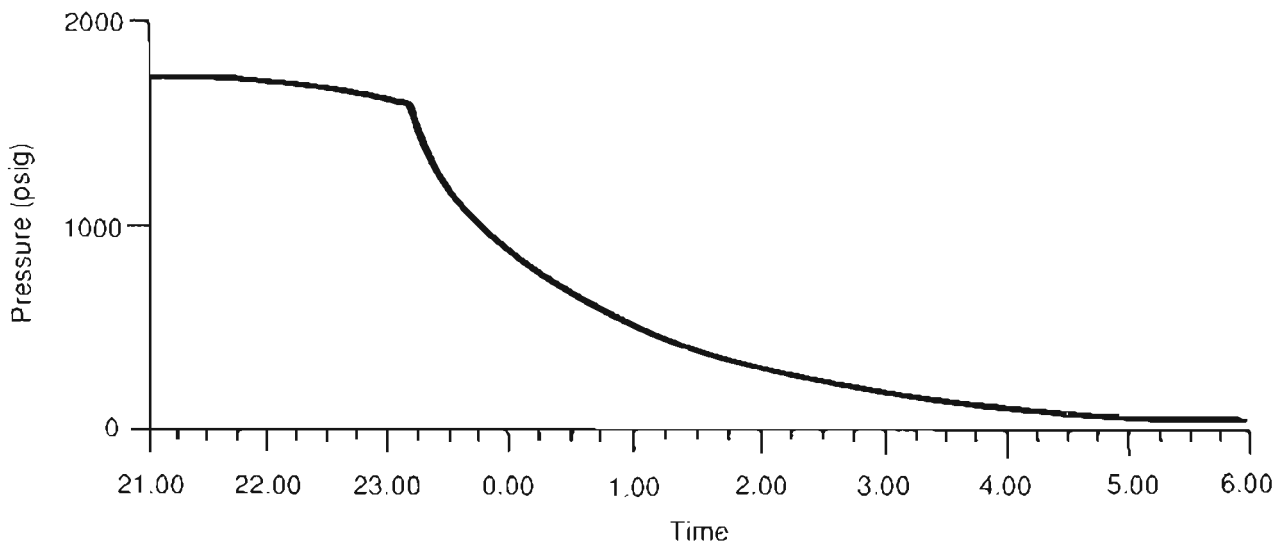


Fig. 7.2 Trend record of the MCP-01 gas import pipeline pressure on 6/7 July.

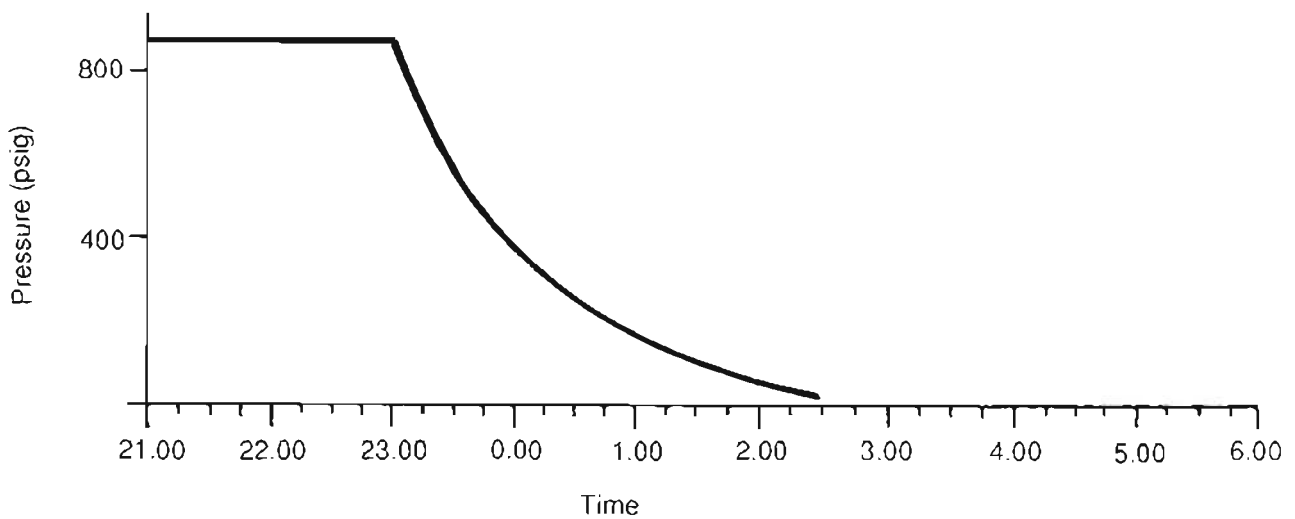


Fig. 7.3 Trend record of the Piper-Claymore gas pipeline pressure on 6/7 July.

The response on Claymore

7.37 Shortly after 22.00 hours the OIM on Claymore, Mr S B Sandlin, was told that there had been a mayday due to fire and explosion on Piper. At that time Piper could not be seen from Claymore. The OIM said in evidence that he treated the matter as a major emergency but thought that it could be controlled on Piper. He and Mr Davidson tried to telephone Piper but without success. The OIM said that he had not been unduly concerned about this as platforms such as Piper had the ability to isolate themselves and to control communications through the OIM in the event of an emergency. After hearing of a second mayday the OIM instructed the standby vessel of Claymore, the *Nautica*, to proceed to Piper. He also telephoned Mr J Bryce, Production and Pipeline Superintendent, who was his immediate superior, in order to report what he knew. There was very heavy traffic on radio channels. The information available on it was unclear and confusing. The most reliable source of information was the *Tharos*. Mr Davidson was told by the *Tharos* on VHF that there had been an explosion on Piper and that there was a fire on its west side, with a large volume of black smoke blowing over the helideck from the east side. This was about 22.15 hours. Mr Davidson told the OIM of this and said that he wanted to shut down the MOL because of the risk of oil being released on Piper in the area of the fire as a result of heat failure. It was known by then that Piper had shut down production of oil. Having found that the pressures in the pipelines were stable, the OIM decided that production should be continued.

7.38 Arrangements were made for the pressures in the pipelines to be monitored and any change reported. It was then discovered that the telemetry system providing information from other installations had failed. As a result operators had to note what was shown on the pressure gauges for the gas pipeline and look at the chart recorder in respect of the oil pipeline. At 22.20 hours the telephone system failed when the OIM was attempting to telephone Occidental's Emergency Control Centre. At 22.20 and 22.30 hours Mr Davidson again raised the shutting down of production with the OIM. At the latter time he had heard from the *Tharos* of fire spreading and people being in the water. From the helideck he could then see a glow coming from the direction of Piper. The OIM continued to maintain production as he did not think the position on Piper would be beyond the control of its fire pumps.

7.39 Following the failure of the telephone system at 22.20 hours the OIM spent a considerable number of minutes trying to get in touch with Occidental's Emergency Control Centre by means of the satellite system. There is disagreement among the witnesses as to when this communication was established. According to Mr Davidson it was between 22.50 and 22.55 hours, whereas Mr A G McDonald, Occidental's Head of Telecommunications in the North Sea, gave the time of 22.38-22.40 hours, which he said he had logged at the time. The OIM himself said that he spoke first to Mr Bryce and then to Mr Bryce's superior, Mr J L MacAllan, Production and Pipeline Manager. It appears likely that the latter conversation took place at about the time period mentioned by Mr Davidson. By the time of this conversation Mr Davidson had on 2 further occasions suggested to the OIM that production be shut down. Throughout the time since monitoring of the pipeline pressures had begun no report had reached the OIM of any drop in those pressures. The OIM said that he spoke to Mr Bryce in order to establish a communication link; and to Mr MacAllan "for mutual information". Mr Davidson said in evidence that when the OIM was in conversation with Mr MacAllan he (Mr Davidson) got a further report from the *Tharos* of a massive explosion in which Piper was enveloped in flames. (This is plainly a reference to the explosion at 22.50 hours.) He said that at this he shouted across the radio room to the OIM to get him to ask Mr MacAllan if Claymore should be shut down. It seemed to him that the OIM was asking Mr MacAllan for instructions or advice. The OIM's account was that he was not consciously consulting Mr MacAllan or anyone else; it was for himself to decide when to shut down. When Mr Davidson shouted about a major deterioration at Piper, he realised that the situation was uncontrollable and he decided to shut down production. Mr MacAllan said that he asked the OIM about

the position with regard to production and the pipelines. When the OIM told him that Claymore was still on line he instructed him to shut down production, blow down the gas line to Piper, and get in touch with Tartan by way of VHF in order that Tartan should shut down production and start blowing down the gas pipeline between Tartan and Piper. His reaction to hearing that Claymore was still on line was “a certain degree of anger”, which he explained as a reaction of impotent frustration. He himself called Texaco, the operator of Tartan, to impress on them the urgency of having the gas line to Piper blown down as quickly as possible. He also made arrangements for Flotta to depressurise the oil pipeline and for Total to blow down the gas line to MCP-01. These courses of action were followed. From the evidence it appeared that this was the first time at which Claymore had been in touch with Tartan since 22.00 hours. According to Mr McDonald, there was no technical reason to prevent Claymore calling Tartan earlier, ie by means other than the omnibus telephone system.

7.40 The OIM explained that his decision to continue production was based on the maintenance of pipeline pressure and on a limited knowledge of the situation on Piper “albeit appearing to get worse but still not indicating to me that a major disaster was in the making”. He relied on his own judgement and knowledge of what was written down. He was referred to para B.4.4.1 of Occidental’s Pipeline Operating and Emergency Procedures Manual, which states:- “If it is immediately clear that a major problem exists such as the rupture of the pipeline or a serious incident at the platform, shutdown of the platform or the whole system will be initiated by the affected platform. Each location can only initiate automatic shutdown of its own systems so it is vital to inform the other locations of the situation and of the need for action so that they can initiate their own shutdown actions. The objective will be to reduce pressure in the pipeline as quickly as possible and to halt the outflow of product from the pipeline in the event of a rupture ...”. He knew that in the event of a pipeline rupture the amount of oil or gas would be such as to provide a very considerable source of fuel for the fire on Piper. He would have shut down and vented if he had received word from Piper to do so or if he had known the situation to be as extreme as it was. He was also referred to para B.4.4 which states “... in relation to the pipeline and pipeline contents the priority is to reduce pressure and stop flow into the pipeline by stopping gas compression and closing the main line valves. This may be to reduce pressure acting on damage (sic) sections or to minimise the quantity of gas escaping if the pipeline is ruptured.” He said that at the time he had no indication that there was any gas escaping from the Claymore pipeline. The indications were that that pipeline was secure and pressure was reducing gradually through normal usage. The OIM had not required to shut down Claymore at the time of the emergency on Piper in 1984. He also said that if Mr Davidson or anyone junior to him had felt that the platform should have been shut down, they could very easily have done so without any fear of repercussion from himself or Occidental. However, he agreed that Mr Davidson had indicated that he was deferring to him. “He gave his reasons for wanting to and with my experience and knowledge and information at hand my choice was to continue production.”

Tartan

7.41 After hearing about the mayday the OIM, Mr J Leeming, looked in the direction of Piper, some 12 miles distant, and saw “a red envelope of flame” projecting from its north side just below the modules. He realised that something serious had happened. Mr M D Moreton, the Production Supervisor, was instructed to monitor pressure on the gas pipeline to Piper. The OIM spoke on the telephone to his superior in Aberdeen. Between 22.10 and 22.20 hours Mr Moreton discovered that the telemetry system had frozen as from 22.00 hours, with the result that only information from Tartan was updated on the VDU display. He tried without success to call Piper and Claymore on the omnibus system. Production was maintained in the belief that Piper was also doing so. However, over a period of 10-15 minutes he noticed an increase in the pressure of the gas pipeline to Piper which indicated to him that the import valve on Piper had

shut. At about 22.15 hours he decided, in accordance with instructions from the OIM, to shut down the export compressors and close ECV 54. He did so for the purpose of stopping a rise of pressure in the gas pipeline. If he had not done so, the gas compressor would have tripped in due course. The closure of ECV 54 is in accordance with the procedure to be followed in the event of a serious emergency on Piper. Mr Moreton did not at that stage consider depressurisation of the gas pipeline. After the closure of ECV 54, which was recorded as being at 22.25 hours, Mr Moreton was told of a large explosion on Piper. He looked in the direction of Piper and saw a fireball. He then noticed that there had been a sharp drop in the pressure of the gas pipeline between 22.20 and 22.25 hours. He thought this odd, discussed it with someone else but could not explain it. He did not associate it with the large explosion on Piper although "it is apparent now". It should be added that the OIM was unable to explain why, if the decision to close ECV 54 was taken prior to the explosion on Piper at 22.20 hours, it took as long as until 22.25 hours for ECV 54 to be closed.

7.42 The pressure chart for the gas pipeline to Piper showed a horizontal line after 22.25 hours. Neither the OIM nor Mr Moreton nor Mr K Roberts, the Facilities Engineer on Tartan, were aware that the sensor for the chart was upstream of ECV 54 and that accordingly the chart was presenting a false picture as to the pressure in the gas pipeline. There was a pressure gauge downstream of ECV 54 but this was not normally monitored. Later on the OIM instructed Mr Moreton to depressurise the gas pipeline to Piper. The last step in this process was the re-opening of ECV 54 at 23.20 hours. According to Mr Moreton the process was started about 22.45 hours. Until then "everyone was to some extent in some degree of shock as to what had happened over there, and trying to find out what was happening and what had happened". According to the OIM the process took over 45 minutes. "On this particular night I think personnel were suffering from shock, so they would be additionally cautious in what they did, so maybe it took a little longer than expected". While the process was going on, a message was received from Claymore asking Tartan to depressurise the gas line. This refers, of course, to a result of the conversation between Mr MacAllan and the OIM on Claymore. As stated above when ECV 54 was opened, it was found that the pipeline had already depressurised. On Tartan depressurisation had been designed to supply fuel and sweet gas for operations. A heat exchanger and a 2 inch pipe restricted the flare discharge to 10 MMSCFD. The gas in the gas pipeline was 20 MMSCF. Accordingly total depressurisation of the pipeline would normally have taken at least 2 days. Initial venting would have been at the rate of 500,000 SCF per hour. There was no way in which depressurisation could have been speeded up beyond this rate.

7.43 The OIM also instructed Mr Moreton to shut down oil production. He said he did so because of the escalating situation at Piper. It is not clear when this instruction was given. According to Mr Moreton it was given at the same time as he instructed depressurisation. According to the OIM it was in the region of 22.30-22.40 hours. The last step in this process was the closing of the main export valve at 23.52 hours. During this process a further message was received from Claymore asking Tartan to shut down oil production. It appeared from the evidence that due to problems with VHF radio transmissions Tartan had been unable to initiate contact with Claymore at any earlier stage of the disaster.

7.44 Mr Moreton said that his general approach had been to estimate the seriousness of the incident. He had assumed Piper's fire-fighting equipment was working and that the incident was being tackled. It did not occur to him that the closing off of crude oil production could affect the fire on Piper. He agreed that as regards gas, the major threat to Piper was not Tartan's production but the pent-up capacity of the gas pipeline. He said that at no time had his employers pointed out that fact to him or discussed it in management meetings or the like. The OIM's general approach was that he had hoped that the situation on Piper could be contained. He had not thought that Tartan crude oil was fuelling the fire. He had considered that there might be some sort of check valve to prevent oil back-flowing to Piper, since Claymore had not

stopped production. Until ECV 54 was opened he was not aware of gas from the Tartan line escaping and fuelling the fire on Piper. The pipeline contained about 20 MMSCF as compared with a production rate of about 30 MMSCFD of gas. Accordingly the amount which would be put into the pipeline during an hour would be relatively small compared with that which was already contained within the pipeline. Asked whether at the stage when ECV 54 was closed he thought that the gas in the pipeline might escape and fuel the fire on Piper, he said "I cannot recollect that consideration specifically, but yes, I suspect I had considered that". He thought that being aware of the potential catastrophe of a rupture at either end of the pipeline "was not something that perhaps you would think about. Maybe, if you had a morbid mind you may dwell on that subject". However, he said he thought that the production staff including Mr Moreton would certainly have been aware of the potential reservoir within the pipeline and the effects of a rupture. An increase in the depressurising rate at Tartan had been discussed in the past "but not really gainfully". The blowdown rate of 500,000 SCF per hour was to evacuate any contaminated gas near Tartan. A fast rate of blowdown was not necessary for that purpose. He did not believe that depressurisation of the pipeline was ever considered for emergency purposes.

7.45 During the evidence there was some discussion of para 5.2 of the Emergency Procedures Manual for Texaco Submarine Pipelines, which refers to a "serious incident on Piper or Claymore platform (no Tartan oil or gas line damage)". One of the steps stated is that "Piper closes valve on incoming riser from Tartan causing gas process shutdown at Tartan". Corresponding to this is the step "Claymore closes valve on incoming riser from Tartan causing process shutdown at Tartan". The manual is inaccurate in respect that owing to the compressibility of gas a closure at Piper would not cause an immediate gas process shutdown at Tartan. It would take over an hour for a closure to have this effect. As regards Claymore the procedure described was unknown to either Mr Davidson or the OIM of Claymore. Further Mr Davidson said that Claymore would not close the valve on the incoming riser from Tartan until Tartan had said that they had shut down. What was stated was contrary to practice and not sensible. The OIM said that he would rather have not closed the valve without reference to Tartan in the first instance.

MCP-01

7.46 Shortly after 22.00 hours Mr J Burns, the Shift Supervisor, was called to the Control Room after the mayday had been received. He found that it was possible to telephone the shore. However the telephone links to Tartan and Piper did not work, nor did the telemetry from them. It was decided that in the absence of any indication that the flow from Tartan or Piper had been interrupted MCP-01 should continue as it had been. Pipeline pressures were monitored. No noticeable change in pressures was seen until 22.50 hours when there was a sharp drop. Since the pressure of the gas arriving from Piper required to be slightly higher than the gas which was compressed at MCP-01, MCP-01 would have required to shut down the line from Piper in such circumstances. However they received a telephone call from Occidental to blow down the line from Piper. This process began shortly after 23.00 hours. By 24.00 hours the gas pipeline from Piper had lost about half its original pressure. This loss could not be accounted for merely by flaring but must have been largely due to rupture at Piper. The blowdown facility at MCP-01 was not designed to blow down the line from Piper but could be used to do so. The flaring capacity was 2.6 MMSCFD, whereas the pipeline from Piper contained 60 MMSCF. At a later stage the shore provided MCP-01 with the working frequency of Tartan on VHF and contact was made between MCP-01 and Tartan at 01.30 hours.

Observations

7.47 As regards shutting down oil production, there was no physical reason why it could not have been done earlier than it was done at Claymore and Tartan as part of a controlled shutdown. This would have caused an almost immediate reduction in the

flow of oil which was fuelling the fire in the centre of the platform. In so far as the fire on the 68 ft level was fed by an overflow of oil from the 84 ft level any reduction might well have had a significant effect on the fire threatening the Tartan riser. If oil production had been shut down before 22.20 hours, this would probably have delayed the rupture of the Tartan riser. It is not possible to say that it would have prevented it.

7.48 It is more problematic what shutdown would have achieved after 22.20 hours and in particular what its effect might have been on the timing of the rupture of the MCP-01 and Claymore risers, since by then the intense heat of the burning gas from the Tartan riser was added to the fire. On that particular point I am not able to reach a conclusion. However, any delay in shutdown contributed to the amount of smoke and heat which was generated by pool fires.

7.49 The OIM on Claymore had full authority to shut down oil production and was under no constraint from management in this respect. His suggestion that Mr Davidson or his juniors might have shut down production had they felt that this should be done was unrealistic. Mr Davidson repeatedly made his point of view clear to the OIM but clearly deferred to him for his decision. The OIM was well aware of the serious consequences of oil discharging at Piper near the seat of any fire. His attitude at the time was that there was an insufficient basis for him taking the step of shutting down oil production. Making all allowances for the benefit of hindsight, I consider that he should have shut down earlier than he did, at the latest after the rupture of the Tartan riser at 22.20 hours. By then and despite difficulties in regard to radio messages he had received first-hand information of a major fire on Piper which could then be seen to be ablaze. At the same time the telephone system had failed, presumably as a result of the major explosion at 22.20 hours. At that stage any confidence or hope which he had previously entertained that the fire on Piper was controllable should have been severely shaken. It seems to me that it was not enough for him to rely on lack of evidence of actual rupture of a pipeline. The risk of rupture was too serious in its consequences. The OIM appears to have persisted after 22.20 hours in attempts to exchange information with the Occidental Emergency Control Centre. From the evidence I conclude he was reluctant to take the responsibility for shutting down oil production. The shutting down of oil production at Claymore was a direct result of instructions which Mr MacAllan gave to the OIM.

7.50 As regards Tartan, I am surprised that it did not occur to Mr Moreton or the OIM that the continued production of oil by Tartan could affect the fire on Piper; and that the OIM could only speculate as to the existence of a check valve which would prevent oil back-flowing to Piper.

7.51 As regards the depressurisation of the gas pipelines between Piper and Claymore and Tartan it is clear that even if this had been undertaken at an earlier stage than it was it could not have had any material effect on the fire at Piper, having regard to the fact that the capacity of each platform to flare off gas was extremely small compared with the enormous quantity of gas contained within the length of pipeline in each case.

7.52 The strong impression with which I was left after hearing the evidence as to the response of Claymore and Tartan was that the type of emergency with which the senior personnel of each platform was confronted was something for which they had not been prepared. Both Mr Moreton and Mr Leeming said that they had not undertaken any pipeline exercises for anything on the scale of Piper. Occidental witnesses provided confirmation of this in the case of Piper and Claymore. Mr G Richards, one of the OIMs of Piper, said that a scenario in which it was assumed that one of the platforms was knocked out had never been considered by him or discussed by the OIMs. Mr A Bodie, the Offshore Safety Superintendent, said that he had never been involved in joint procedures between the different platforms. Mr R M Gordon, Manager of the Loss Prevention Department, said that the Department had never

been involved in discussions with other platforms as to the collation of procedures. Mr A D McReynolds, Vice-President of Operations, said that he had never been involved in a scenario which involved the knocking out of one of the platforms. In my view if there had been adequate and regular practising of the type of response which should be undertaken in the event of a major emergency involving fire or explosion on one of the three platforms, much of the misunderstanding, delay and indecision on Claymore and Tartan would have been avoided. In this way safety in a wide range of possible scenarios would have been enhanced. Much of the existing procedures for Claymore and Tartan seems to have been based upon the assumption that the means of communication between the platforms would remain capable of being used. For example, in para B.4.3.1 of the Pipeline Operating and Emergency Procedures Manual which applied to Claymore it was stated "in all cases rapid communication and notification of actions to the four Control Rooms is essential so that the necessary actions can be taken quickly to minimise the consequences". Mr Davidson stated that he had not taken part in any exercises for rapid communication and notification in the case of an emergency. In any event if exercises had been undertaken in which it was assumed that the ability to communicate was wholly or partly affected, this would have provided a clearer basis for decision-making. Mr Davidson and other Occidental witnesses such as Mr Bodie and Mr MacAllan did not realise that a failure on Piper might affect the omnibus telephone link to the other platforms, although this was appreciated by Mr McDonald, Occidental's Head of Telecommunications.

Effect on platform systems

7.53 A number of eye-witnesses provided evidence of their own observations from which it was possible to determine to what extent the platform systems had been affected by the initial explosion. In addition evidence was given by Dr Cox on this subject in the light of the evidence of eye-witnesses and an understanding as to layout and operation of the platform systems. Subject to my comments below I accept the conclusions at which Dr Cox arrived. His study proceeded upon the assumption that the initial explosion took place in C Module. An air-hydrocarbon gas cloud expanded on combustion by a factor of about 7. Given that the gas cloud before ignition was towards the east end of the module the explosion pressure would be higher at that end. It was probable that the firewalls were severely damaged at the centre of the module and at its eastern end. With the destruction of the firewalls between C Module and B and D Modules along most, if not all, of their length much of the movement of gas would be into those modules, where it was reasonable to expect heat effects and projectile impacts. His overall conclusion was that all the critical systems either suffered considerable direct damage or were rendered inoperable due to loss of power. This was only to be expected where there was no design for blast resistance. However, there could be cases where equipment was robust enough to withstand the effects of an explosion. Disablement of equipment might have been avoided due to a variety of reasons such as distance from the centre of the explosion, the existence of a back-up battery power supply or the operation of fail-safe systems.

Electrical power

7.54 There was a considerable body of evidence as to the immediate or early loss of electric light. At the time of the initial explosion the lights went out at once in the diving area, the Mud Module, the oil laboratory and the GCM. In all these areas except possibly the last the emergency lighting came on. Witnesses spoke of the loss of power to machinery in the first 2 areas. The lights also went out in the Control Room and the Mechanical Workshop, which remained in darkness. The Control Room was severely damaged and the ceiling of the Mechanical Workshop fell in so that the lighting in both may have been completely disabled. On the other hand some time after the initial explosion light and power were still available in the drilling area. In the accommodation the normal lighting stayed on for a period and then failed. The emergency lighting came on for some 10-15 minutes and then itself failed, leaving lighting only in areas where a back-up from battery packs existed. As regards the

process alarms in the Control Room and the platform general alarm system the evidence was conflicting as to whether or not they were disabled.

7.55 It was Dr Cox's view that the initial explosion probably resulted in immediate loss of electrical power from both the normal and emergency 440V switchboards, although it was not certain which elements in these systems had failed. However, he believed that the drilling 440V switchboard had continued to supply power for some minutes. The main generators might have been lost due to damage to the machines themselves, to their diesel supply, to trips caused by damage to the switchboards or to vibration trips. A cable to the 13.8 kV switchboard and a cable to and a transformer for the 4.16 kV switchboard, both at the east end of D Module mezzanine level, were probably damaged. Likewise a cable to and a transformer for the main 440V switchboard, located just to the west of the 4.16 kV switchboard, probably suffered damage. He considered that it was very probable that the emergency 440V switchboard, which was located next to the C/D firewall, would have been severely damaged. The emergency generator itself was unlikely to have been damaged given its location in the north-west corner of D Module. However, its diesel fuel supply, which ran from the 107 ft level through C Module, could well have been. Moreover, the damage to the emergency 440V switchboard could have caused the emergency generator to trip out. Probably the drilling generators in the diesel module escaped damage at this stage. Loss of the emergency switchboard would cut off the normal 125V DC and 120V AC supplies. As for the D Module UPSs Dr Cox considered that the evidence pointed strongly to the conclusion that the 120V AC UPS was damaged, but he believed that the 125V DC UPS survived for some time. The latter was in the DC room at the north-west corner of D Module mezzanine level. The former was in the same room but on the south wall and 10 ft nearer the C/D firewall. He adduced as evidence of the loss of the 120V AC UPS the absence of process alarms. As evidence of the survival of the 125V DC UPS he pointed to the operation of emergency lighting. On this assessment, accordingly, the 125V DC UPS was the only power supply in D Module which was not disabled. He considered that due to their position the 125V DC and 120V AC supplies in the Utility Module were unlikely to have been damaged. There was no evidence of changeover to the Utility Module UPS supplies.

Process alarms

7.56 There was conflicting evidence as to whether there was a supply of electrical power to the process alarms in the Control Room. Mr Bollands said he was fairly sure that the mimic panel was still intact but he could not be sure if there were lights on. The JB generator panels seemed to be all right. Mr Ferguson, who entered the Control Room after the initial explosion, said that the control panels were still in place but he could not remember any lights on them. On the other hand Mr R F Carey, an instrument technician, said that when he entered the Control Room there was definitely an alarm light with a sound on the far side of the room.

7.57 Dr Cox pointed out that the power for the main control panel annunciators was from 125V DC and 120V AC supplies in the DC room. These annunciators were relatively near the C/D firewall. On the basis of the evidence of Mr Bollands and Mr Ferguson he concluded that the process alarms were not functioning. This could have been due to damage to the panels themselves or to the 120V AC UPS or cabling. His conclusion was that it was unlikely that the process alarm panel was functioning after the initial explosion. This is the only conclusion to which Dr Cox came about which I have any doubt, in view of the evidence of Mr Carey.

Public address and general alarm systems

7.58 A number of survivors spoke of hearing an alarm. This was anything between 10 and 40 minutes after the initial explosion, according to their differing accounts. Some of them described it as sounding like an alarm for the abandonment of the platform. On any view it did not last for more than about 30 seconds. Mr Jennings

said that when he was in the Radio Room some 10-15 minutes after the initial explosion he heard an alarm coming from a loud speaker in the Radio Room. He thought that it must have been on the UPS system as otherwise he would not have been able to hear it. This speaker had a microphone by which a message of abandonment could be broadcast throughout the platform. However, Mr Kinrade, the Radio Operator, was not able to say if this tannoy was working after the initial explosion. Mr Bolland described a survivor trying to activate an alarm on the west side of the platform but to no effect. The UPS should have provided power for this to sound.

7.59 Dr Cox said that in view of the conflicting eye-witness evidence the status of these systems could not be confirmed. What was heard was not definitely identified. The sound could have been due to telephones or other alarms and perhaps from such things as the operation of the halon system. The main amplifiers in the Communications Room and main reception could have survived, as well as the microphone in the Radio Room and the main reception. The microphone in the Control Room was near enough to the C/D firewall to have a significant probability of damage. Loudspeakers in some parts of the platform may have been damaged. The power supply was from the D Module 120V AC UPS with back-up from the Utility Module 120V AC UPS, changeover being manual. The former UPS and cable may well have been damaged and there was no evidence that manual changeover was effected. If on the other hand electrical supply was available the various alarms heard could have been alarms initiated by actuation of, or damage to, manual alarm points or other field equipment. Dr Cox took the view that probably the 120V AC UPS failed. His general conclusion was that the public address and general alarm systems were most likely to have been not operative due to loss of power supplies.

Communication systems

7.60 Some of the internal telephones on the platform were still working after the initial explosion. For example, Mr B C Barber, the diving superintendent, was able to telephone the Radio Room from the dive module. A number of witnesses described a telephone call received at the drill floor from the Bawden workshop on the 107 ft level, some 10 minutes after the initial explosion. A call was received in the Radio Room from the Occidental Materials Office in Submodule D about 5 minutes after the initial explosion. One of the survivors described the OIM making a telephone call to the Radio Room from the accommodation. Radio communication in the platform was still possible by means of hand-held radios. As regards radio communication between the platform and elsewhere Mr Kinrade, the Radio Officer, was not able to say to what extent the radios in the Radio Room were damaged by the initial explosion. He was able to send out a mayday a few minutes after that explosion, then a 2-tone alarm and an abandon platform message, all on 2182 kHz (which was not audible on the platform). Mr Jennings described the standby Radio Room as being inaccessible due to smoke and heat. When he reached the Radio Room 10-15 minutes after the initial explosion he found the room deserted and very hot. Over the SOLAS radio, which was battery powered, he heard the *Tharos* relaying the mayday. This radio was not linked to the tannoy. Communications to and by other platforms have been described earlier in this chapter. On the day of the disaster MCP-01 was "host" to the tropospheric services. From the evidence it is clear that the whole telemetry system failed at the time of the initial explosion. The omnibus telephone system also failed at that time, but the 3 line of sight systems continued to operate. Until about 22.20 hours both Claymore and Tartan had telephone contact with the shore by the line of sight systems via Piper into the MCP-01 tropospheric link. However, Tartan could not establish telephone contact with Claymore, whilst Claymore made no attempt to contact Tartan. After 22.20 hours Claymore and Tartan lost this link with shore. Sometime later Claymore established a telephone link with shore via satellite. When MCP-01 came to use the telephone links with Tartan and Claymore it found them dead. Later in the evening radio links were established. Claymore's call to Tartan about 23.00 hours was by VHF radio. MCP-01 also made contact with Tartan by VHF after obtaining the Tartan radio frequency from shore. At no point was any

platform able to contact Piper. Flotra found the land line dead; MCP-01 obtained only a burring sound; and Claymore apparently got through but heard the telephones ringing unanswered. Mr McDonald attributed the “dropping” of the telemetry system just after 22.00 hours to damage in the Control Room, where the telemetry equipment was situated.

7.61 Dr Cox pointed out that the platform telephone exchange was powered by the D Module 120V AC UPS but had its own internal battery UPS. The radio systems were supplied from the normal and emergency 440V switchboards with battery back-up for the HF ship-to-shore radio. Since the normal and emergency 440V supplies and probably the 120V AC UPS (all in D Module) were lost at the initial explosion only those communications systems with battery back-up would have been available, namely the telephone systems, line of sight systems, the HF ship-to-shore radio and hand-held radios. He referred to the evidence of survivors that there was a partial availability of the main telephone and sound powered systems but also that some extensions were not working. The line of sight systems between Piper and Tartan and between Piper and MCP-01 were still operating at that time. The ending of the telemetry links at the initial explosion was probably due to damage to the telemetry equipment in the Control Room. His conclusion therefore was that after the initial explosion communications were probably confined to elements of the telephone system, the line of sight systems, the HF ship-to-shore radio and hand-held radios.

Emergency shutdown and depressurisation systems

7.62 According to the evidence Mr Bollands pressed the PESD button shortly after the initial explosion. He said that it appeared to him to be intact. In any event he expected the system to have shut down before he pressed it. A number of survivors were aware of a silence after the initial explosion which they associated with a platform shutdown. At the same time some survivors noticed an increase in flaring which would have been consistent with the blowdown of pressure vessels and process pipework.

7.63 Dr Cox considered that the ESD system was activated. The use of the PESD button in the Control Room opened the pneumatic loop directly and was not dependent on electrical power. Further it was probable that the pneumatic ESD loop, which passed through several process areas with high potential for damage, was in fact damaged sufficiently to depressurise it. Due to its location in A Module the wellhead hydraulic ESD system should not have been damaged. The PESD would result in shutdown of all the wells, the separators and their inlet valves, ESVs 37, 38 and 39, the gas processing equipment and the oil pumps. The gas processing plant was probably depressurised by way of compressor shutdown and loss of instrument air to the relevant pressure control valves. The pipeline ESVs not part of the ESD system probably closed due to loss of the 120V AC UPS power supply. It was also possible that the cables were damaged. The cable to ESV 501 and that to ESV 6 and ESV 956 were separate but both were vulnerable to damage. However, it was possible that local damage to pipeline ESVs occurred through damage to the valve, the actuator or the small bore pipes supplying the actuator, thus preventing full closure. I have already considered this aspect in my earlier discussion of the extended flaring.

Fire detection and protection systems

7.64 As regards gas alarms it has been recounted above that Mr Carey said that when he was in the Control Room there was definitely an alarm light on with a sound on the far side of the Control Room. On the other hand Mr Bollands said that he could not see the fire and gas panels because of smoke. As regards the fire-water system it is clear that it never came into operation. A mere trickle came out of the sprinklers at the dive module and the gondola, which was slung under the 68 ft level. Apart from this no water came out of sprinklers or the deluge or water hoses. Mr R A Vernon, lead production operator, and Mr R Carroll, safety operator, put on breathing apparatus sets and endeavoured to reach the fire pumps in D Module in order to start them manually. However, due to the fire they could not get near them.

7.65 Dr Cox stated that the fire and gas panels, which were near the firewall between C and D Modules, could easily have been damaged by the initial explosion. Power supplies could also have been damaged. The water pumps were near the same firewall and therefore might be likely to have been damaged, especially in view of the likelihood that there was greater damage at the east side rather than the west side of D Module. It was also probable that no power was available for the electrically operated pumps. The fire main on the production deck ran along C and D Modules near the firewall between them and also near the firewall between A and B Modules. The energy required to crush the fire main, which was 16 inches in diameter, was much less than the estimated kinetic energy of some of the larger debris from the firewalls. The smaller branches could be broken even more easily. The fact that Mr Vernon and Mr Carroll were unable to reach the fire pumps due to heat and smoke, along with the considerable damage to the Control Room, suggested that the fire pumps had been damaged. The main was unlikely to be intact even if the pumps could have been started. His general conclusion was that it was very likely that the fire pumps and the smaller fire main branches were severely damaged by the initial explosion so that fire-water was not available. Moreover, there was probably no capability to distribute it.

7.66 While I have no difficulty in accepting the conclusion that the initial explosion had these effects on the fire-water system, it was also clear from the evidence that at the time of the initial explosion the diesel fire pumps, which formed an important part of the fire-water system, were not on automatic but on manual mode, with the result that even if these pumps had not been rendered inoperable by the initial explosion, they would not have come into operation automatically but would have required manual intervention. Accordingly there would have been the risk that these pumps were not started at all or started after some delay. Moreover, the evidence also raised questions as to whether the deluge system in C Module would have functioned fully, in view of evidence as to a long-standing problem of blockages in the nozzles of that system. These matters were explored further in evidence. They are discussed below in Chapter 12.

7.67 In conclusion it is convenient to note a submission by the Trade Union Group that there had been a breach of Reg 9(2) of the Fire Fighting Equipment Regulations in respect that the fire pumps were not "situated in different parts of the installation". This submission was not well founded. The written guidance provided by the DEN, which is consistent with Reg 9(2), clearly took the line that what mattered was separation for the purposes of fire protection. Thus it was stated that there should be "a minimum of 2 pump units so arranged that a fire in any part of the installation will not put both pump units out of action." The arrangements in regard to the fire pumps on Piper, which are described in Chapter 3, could not unreasonably be regarded as satisfying that objective, and were apparently approved by the DEN or its agents for that purpose. What neither the regulation nor the DEN nor Occidental took into account was the risk of wholesale disablement by explosion. It was also submitted that it was arguable that there had been a breach of Reg 9(3) in respect that, having regard to the limit of endurance of their protection against fire, the pumps were not each "capable, once activated, of operating automatically for 12 hours". This submission was misconceived. The provision in question is concerned with operating capability as opposed to protection.

Chapter 8

The Effects of Events on Personnel

Introduction

8.1 In this chapter I will set out a description of the events on the platform as they affected the personnel on board. I will also compare the intended procedure for a major emergency with what happened on the evening of 6 July; and consider whether despite the fire and explosions more might have been done to save lives. My description of events is of necessity based on fragmentary evidence owing to the large loss of life. The description of what happened to survivors will continue to the point where they left the installation; their rescue will be described in Chapter 9. As regards the cause and circumstances of the deaths of the deceased, the present chapter should be read along with Chapter 10.

Personnel on board at 22.00 hours on 6 July

8.2 At 22.00 hours there were 226 personnel on board the installation (see Fig 3.11). 62 persons were on night-shift duty.

8.3 The remaining 164 persons were off duty. It appears correct to infer that by far the greatest number of them were in the living quarters at 22.00 hours. However, it is known that a few were working in the offices or were about to return from finishing overtime. Further, although they were officially off duty, 10 of the personnel were on 24 hour call. These were the OIM; the safety supervisor and the medic; the acting maintenance superintendent; the offshore projects superintendent and the offshore contracts supervisor; the drilling supervisor and the drilling platform superintendent; and the acting operations superintendent and the acting deputy operations superintendent.

Occidental's system for control of a major emergency

8.4 The system is set out in Occidental's Emergency Procedures Manual and was described in evidence by Mr G Richards, the back-to-back OIM, and other witnesses. Under that system a major emergency is defined as one requiring the mobilisation of the response teams and key personnel and possibly external support. An example of such an emergency is the occurrence of a fire or explosion which involves the need to evacuate the installation. Under the system it was the duty of personnel at the site of an incident to activate the general emergency alarm or telephone the Control Room or the Radio Room. The operator in either of these rooms then notified the OIM and personnel are sent to investigate and report back.

8.5 The OIM was expected to proceed to the Radio Room and exercise control from there. On his instructions the Duty Communications Operator at the Occidental Emergency Control Centre in Aberdeen and other agencies would be informed. The OIM was to remain in charge of the platform throughout the emergency. He was responsible for ensuring the shutdown of the process and drilling operations, the direction of fire-fighting and damage control, the evacuation of non-essential personnel, and the evacuation of diving personnel. He was to discharge these responsibilities by co-ordinating the work of key personnel from the Radio Room. He was also to maintain liaison with the Onshore Emergency Controller and his team.

8.6 The OIM was the person who had the ultimate responsibility for deciding whether the platform should be abandoned and if so by what method. In the event of a major emergency the first objective was to ensure that non-essential personnel were taken off the installation before conditions deteriorated. If it appeared that evacuation

might be necessary the OIM was responsible for alerting Occidental's Communication Operator in Aberdeen. He was to ensure that contact was made with the Duty Doctor if medical assistance was required. He was to consult with or advise the Onshore Emergency Controller on the evacuation of non-essential personnel. He was to contact the standby vessel and call other installations, shipping and helicopters in the area for assistance if that was necessary; and advise the coastal radio and Coastguard that evacuation was taking place. Following an emergency on the installation on 24 March 1984 Occidental reviewed and modified their emergency procedures. One of the changes which was made was the institution of an Emergency Evacuation Controller (EEC) and his team which included the helicopter landing officer and the lifeboat coxswains. Their function was the evacuation of non-essential personnel. They assembled at the reception area where the EEC directed the arrangements for evacuation in consultation with the OIM. If the OIM summoned helicopter transport, which was the preferred method of evacuation, the EEC was to ensure that the helideck was operational and that groups of personnel were called up from the lifeboat muster stations where they had assembled. (It may be noted that as the result of drills on the installation personnel were familiar with the practice of proceeding to their lifeboat stations from which one lifeboat complement at a time was called to the reception area as if for evacuation by helicopter.) Information on the state of evacuation was to be broadcast under the instructions of the OIM. If as a last resort evacuation by lifeboats was essential, the OIM was to give the instruction 3 times on the public address system. If the evacuation was to be total, the OIM had to ensure the complete shutdown of the platform; and the standby vessel and Occidental's emergency control centre were to be informed before transmissions were closed down. The lifeboat coxswains were responsible to the OIM and the EEC for all operations concerning the lifeboat stations and were to await instructions from the OIM on the public address system before allowing personnel to board the lifeboats.

8.7 Also according to Occidental's system the Operations Superintendent was to go to the Control Room to assess the extent of the emergency and determine priorities. He was to co-ordinate plant shutdown to a safe status and fire and damage control in production areas. It was his responsibility to maintain contact with the emergency teams and keep the OIM informed as to plant status and emergency action. He was also required to ensure that the other pipeline users were kept informed of the situation. The "assigned mechanic and electrician", whose names were shown on a notice board, were required to report to the electrical workshop and start up and run the emergency diesel pumps (for pumping fire-water) and SOLAR generator "as required" (in accordance with para 6.2.7 of Occidental's Emergency Procedures Manual). The safety supervisor was to co-ordinate fire and damage control with the superintendents, advise emergency teams and keep in touch with the Radio and Control Rooms. Safety operators were assigned to each of the emergency teams. These emergency teams were 3 in number and each normally had 6 members. An Occidental team was made up of personnel from the Maintenance Department with a leading hand in charge. A second team was made up of personnel employed by Bawden International with a toolpusher in charge. A third team was made up of personnel employed by companies in the Wood Group with a supervisor in charge. The Bawden team was to muster at the White House on the pipe deck. The other two teams were to muster at the Electrical and Mechanical Workshops in D Module. These teams were to remain on the installation to deal with any fires, depending on the extent and location, until there was no further hope of control. The Drilling Superintendent was responsible for closing down the wells.

The response to the emergency

8.8 In the event the system was almost entirely inoperative and little command or control was exercised over the movements of personnel.

8.9 Mr D H Kinrade, the Radio Operator, stated in evidence that the OIM came into the Radio Room which was situated above D Deck of the ERQ a few minutes

after the initial explosion. He was wearing a survival suit. Mr Kinrade did not think that he had a portable radio with him. The OIM instructed him to send out a mayday call because of the explosion and fire. Mr Kinrade then sent out a mayday call asking for assistance. He used the international distress frequency of 2182 kHz. This was about 3-5 minutes after the initial explosion. At that stage the OIM had said nothing to him about evacuation. He did not seek to use the public address system on the installation or instruct Mr Kinrade to use it. Mr Kinrade did press the button and blow into the microphone for the public address system but found it difficult to tell whether it was still working. Public address could also be achieved by means of the use of the internal telephone system but Mr Kinrade did not establish whether this was working. The normal procedure would be for the radio operator to establish whether the radio equipment was damaged and to await instructions from the OIM. Depending on those instructions he would have established a telephone circuit with the Occidental office in Aberdeen; established contact with the standby vessel and the *Tharos* by VHF radio; and used the public address system to instruct personnel on board the installation. However, the OIM left the Radio Room without giving any further instructions or stating what were his intentions. (I should add that Mr Kinrade said that the telephone for communication with the Occidental office had come off the bulkhead, but he did not know if it was still operable.) The OIM had been gone "a matter of seconds when he came running back" in what appeared to Mr Kinrade to be a state of panic. He told Mr Kinrade that the access to the Radio Room was on fire and full of smoke. Mr Kinrade told him that in that case they had to get out and could use an escape hatch for the purpose. Mr Kinrade took out 3 life-jackets, one for the OIM, one for himself and one for a telecommunications engineer who was also in the Radio Room at the time. The OIM instructed Mr Kinrade to broadcast a message on the same frequency as before that the platform was being abandoned. He did not say what kind of abandonment. Mr Kinrade set off a 2-tone alarm signal in order to discourage other radio traffic on the frequency and broadcast that the platform was going to be abandoned. He said that he himself was panicking and the message was haphazard. The OIM made no specific attempt to call in helicopters from the *Tharos* or elsewhere; or to communicate with vessels around the installation; or with the shore or other installations; or with personnel on Piper. As stated above it appeared that the OIM did not have a portable radio with which to communicate with senior personnel who had such radios. It would not have been possible for him by using facilities in the Radio Room to make contact with such radios. Mr Kinrade added that while he was in the Radio Room a telephone call was received on the FILO's telephone from Mr E Duncan in the Materials Office to the effect that he was trapped there because of fire and asking if the other radio operator could go with keys to enable him to get out of that room into the adjoining telecom room at the west end of Sub Module D. This was possibly about 5 minutes after the initial explosion. After broadcasting the second message Mr Kinrade along with the OIM and the engineer left the Radio Room. By this stage flames could be seen coming up the east side of the platform and coming out of the east crane.

8.10 There is reason to think that the evidence given by Mr Kinrade as to the messages sent out by him was not entirely accurate. According to the record of messages picked up by Wick radio from Piper on 2182 kHz, which I accept as being an accurate record, the following messages were heard:-

At 22.04½ hours: "Mayday (repeated) explosion and fire on the oil rig on the platform and we'll (sic) abandoning abandoning the rig". The record notes that radio interference was being experienced at this time. This message was acknowledged at 22.05 hours.

22.06 hours: "Mayday (repeated) we require any assistance available any assistance available we've had an explosion and er a very bad explosion and fire er the Radio Room is badly damaged".

22.08 hours: "Mayday (repeated) we're abandoning the Radio Room we're abandoning the Radio Room we can't talk any more we're on fire."

There are a number of possible explanations for these inconsistencies and in particular in regard to whether Mr Kinrade broadcast at the outset that the installation was being abandoned. Apart from the obvious explanation that Mr Kinrade's memory has become confused, one possibility is that he broadcast a message that was not picked up by Wick radio. However Mr Kinrade said clearly that he had sent out no mayday before sending out one 3-5 minutes after the initial explosion. Another is that the first message picked up by Wick radio was in fact 2 messages that appeared to run into one because of interference. The third is that Mr Kinrade was still in the process of sending out the first mayday when the OIM returned to the Radio Room and told him to send out a message about abandonment of the installation. It is unnecessary for me to choose which of these explanations is the correct one. While I accept that the record kept by Wick radio as the reliable account of the messages sent out I have no difficulty in accepting the substance of the rest of Mr Kinrade's evidence.

8.11 Mr M H G Jennings, the FILO, who had been in the cinema at the time of the initial explosion went to the dining-room on D Deck of the ERQ and telephoned the Radio Room. He spoke to the telecommunications engineer who told him that Mr Kinrade was putting out a mayday call. He suggested that Mr Jennings check the Standby Radio Room which was in the AAW. Mr Jennings found that that room was inaccessible on account of smoke and heat. When he reached the Radio Room about 10-15 minutes after the explosion it was deserted and very hot. Over the SOLAS radio, which was battery powered, he heard the *Tharos* relaying the mayday. From a loudspeaker he heard an alarm.

8.12 From the evidence it is possible to gain some insight into the limited extent to which there was an organised response to the events that had so suddenly and so quickly overwhelmed the installation. The EEC, who was Mr J Heggie, and at least part of his team assembled at the reception area. Both Mr Heggie and Mr N McLeod, who was second in command, had portable radios. Mr A H Mochan, who was another member of the team gave evidence that Mr McLeod and another volunteered to put on breathing apparatus and look for a way of escape out of the doors from the reception area to the helideck (see Fig J.7(d)). They returned in about 10 minutes saying that things were "pretty desperate". It was known that Mr R Carroll was in the area of the Control Room and in touch with Mr Heggie by portable radio. He and Mr Vernon, lead production operator, put on breathing apparatus and made an unsuccessful attempt to reach the fire-water pumps in order to start them. However they found that they could not approach them owing to the smoke and flames. Owing to the conditions the emergency response teams were unable to reach their respective muster points. However it appears that a number of small groups of men, wearing fire-fighting clothing and breathing apparatus, made a series of excursions out of the upper levels of the ERQ in order to see whether there was any safe route available. These may well have been members of one or other of the emergency response teams. The safety supervisor, Mr A Wicks, was also seen wearing breathing apparatus and apparently looking for a way out. In the event none of these brave efforts led to anything. At no time was there any organised exodus from the accommodation. Access to the lifeboat muster stations was at all times out of the question because of the presence of smoke and flames. Likewise the smoke and flames would have made it impossible for any helicopter to land on the helideck. Persons such as Mr Mochan spent a considerable amount of time searching for a means of getting out of the accommodation. There were no facilities in the ERQ to assist the OIM or other senior personnel to assess the situation outside; or determine the status or action of any of the emergency systems.

8.13 I have set out above a brief account of whatever traces there may have been of the coming into operation of any system for coping with a major emergency on the evening of 6 July. Later in this chapter I will come to the situation which developed in the living quarters and the way in which a number of survivors made their escape from it. However in attempting to set out the whole picture it is appropriate at this point to turn to the various groups of personnel who were at work at 22.00 hours. As will be seen a number of them never reached the accommodation but were able to

make their escape from the installation. Others reached the accommodation; and from that point onwards the story of their escape is bound up with the larger number of personnel who had been in the living quarters when the initial explosion occurred.

Personnel working on the 68 ft level and below; and in D Module

8.14 At the time of the initial explosion 7 divers were on or near the dive skid below the 68 ft level and one was working underwater at -50 ft depth. The diving supervisor was in the gondola at the 58 ft level and 6 other diving personnel, including Mr S R MacLeod, the diving superintendent, and Mr B Barber the Occidental diving representative, were working in or near the dive complex on the 68 ft level (see Fig J.6). Immediately after the initial explosion these levels were progressively affected by fire and the dropping of oil and debris from above. The smoke which at first was light rapidly became dense. These personnel were efficiently and intelligently led and their orderly evacuation owes a lot to the presence of mind of Mr MacLeod and Mr Barber, the latter of whom perished later when making his escape to the sea. In accordance with normal procedure the diving personnel assembled at the dive complex. Steps were taken to recover the diver who was submerged. After a brief period in a decompression chamber he joined the rest of the personnel in making their way to the north-west corner of the platform on the 68 ft level. It had been intended that they should muster at their lifeboat station on the 107 ft level but the smoke was so dense that they were unable to reach a higher level than the 68 ft level. Before the diving personnel set out from the dive complex the Radio Room had been unable to give any advice to them as to which route they could take. By the time that the last of them, including Mr MacLeod, left the dive complex the dive skid was, in his words, "like an inferno". Accordingly by the time this group reached the north-west corner it was impossible for them to retreat to the area from which they had come. Dense black smoke was being blown along the platform in a north-easterly direction. The north side of the platform was wholly enveloped in smoke. Their only means of escape was to go down to sea level. It was impossible by then for them to use the internal stairways from the 68 ft to the 20 ft level. They reached the 20 ft level by means of a knotted rope attached to the 68 ft level which was reached by use of the navigation platform located a short distance below that level. They were joined in this means of escape by 4 riggers who had been working on the 68 ft and the 20 ft levels; by 7 personnel from the Mechanical, Instrument and Electrical Workshops in D Module; by Mr Clark and Mr Bolland from the Control Room; and by Mr Young from the 68 ft level. Two of these personnel fell off the rope into the sea on their way down to the 20 ft level. The explosion at 22.20 hours forced one of them to jump off the navigation platform into the sea and others to jump off the 20 ft level. Apart from these personnel a further rigger who had been working on the 40 ft level jumped off the 68 ft level into the sea. Mr Grieve who had been on the 68 ft level in the area of the condensate pump jumped off the same navigation platform. It remains to mention the chemist, Mr M R Khan, who was working alone in the oil lab on the 68 ft level. He walked directly to the 20 ft level by means of a stairway at the southern end of the platform.

Personnel working elsewhere

8.15 As was shown in the earlier chapters the initial explosion took place in C Module and was followed rapidly by a crude oil fire in B Module. The survivors included no one who had been present in A, B or C Modules at the time of the initial explosion. Apart from the obvious conclusion which can be drawn from the initial explosion and the subsequent fire and explosion no specific account can be given of what happened to such of the personnel on duty as were working in any of these modules at 22.00 hours.

8.16 As regards the other working areas, 10 of the personnel who had been working there survived the disaster. Of these 10, 6 were employees of Bawden International. The initial actions of the shift drilling crew indicated a well organised response to the initial explosion. Having ensured that the drilling equipment had been secured the

Bawden employees from the drill floor crossed the pipe deck as a group and formed around the entrance to the Bawden offices on B Deck under the instructions of the toolpusher, Mr J L Gutteridge. The main body of drilling personnel then made their way to the galley on D Deck in order to muster there (see Fig J.7). Mr Gutteridge stated in evidence that it was decided that this should be done because it was already apparent to him that he could not muster the Bawden emergency response team at the White House on the pipe deck because of the smoke. However, 2 of the Bawden personnel having talked together decided that it was not worth while for them to wait in the smoke at the accommodation and made their way back to the drill floor where the air was clear. They then decided that their best course of action was to get down to the 68 ft level at the south-west corner of the platform, from which they jumped at the time of the rupture of the Tartan riser at 22.20 hours. Meanwhile Mr Gutteridge and others checked the Bawden living quarters for any men who were off duty and investigated to see if any of the exits from the accommodation were passable before going to the galley. The remaining 4 personnel consisted of Mr Mochan and Mr Kinrade, who have been mentioned already, and 2 personnel who had been engaged on work on the GCM and made their way to the accommodation.

The accommodation

8.17 The remaining 20 survivors were in the ERQ at the time of the initial explosion. 7 were in the cinema on C Deck. One was in the television room next to the cinema. 12 were in cabins (1 on A Deck; 7 on B Deck; 3 on C Deck; and 1 on D Deck). As has been mentioned already, after the initial explosion there was no announcement of any kind made by the public address system and no alarm, whether a general or an abandon platform alarm, was sounded. However, from the time of the initial explosion none of the survivors had been in any doubt that a major emergency had occurred and that the platform would require to be evacuated. Along with others in the living quarters they made their way to the higher levels of the accommodation (see Fig J.7). A large number of them began to assemble in the galley. There was no evidence that this was the result of any positive actions on the part of anyone in a position of authority. Varying estimates of their numbers were given in evidence. One witness estimated their number as being in the region of 100. Mr Mochan said that the EEC's team were advised by those who were outside the accommodation to keep people as calm as possible until a way out could be found for them. At first conditions were not too bad. There was still emergency lighting and the smoke in the atmosphere was light. It is clear that personnel were waiting in the galley for a helicopter to arrive to take them off. However after the emergency lights went out panic set in. The smoke was becoming much worse and beginning to affect the personnel. It seemed that the opening of doors was the main source of the increasing smoke. The deteriorating conditions forced the men to crawl along the floor at low level in order to escape the worst and use wet towels as make-shift face masks. The smoke was gradually incapacitating its victims both physically and in their thought processes. Some hoped that the *Tharos* might be able to take them off. At 22.33 hours the following message on channel 9 VHF was received by the *Tharos*: "People majority in galley area. *Tharos* come. Gangway/hoses. Getting bad."

8.18 From the evidence it is clear that the personnel in the galley received no further instruction than to wait for a helicopter to take them off. There were no instructions as to what to do or where to go. A number of survivors said that in the galley no one was in charge or giving instructions or advice; and that there was confusion. Mr Jennings said that he was carried by the crowd into the dining-room where he could see flames coming up the north face of the platform. The OIM was trying to calm everyone, saying that the mayday had been put out and that the whole world knew they were having problems. It was already obvious to the witness (who was a FILO) that a helicopter could not land safely on the platform. Another survivor described the OIM trying to make a telephone call in the galley. After the call the OIM said that he had made a distress call to all shipping and helicopters in the area. The OIM did not give any other instruction or guidance. One survivor said that at one stage

people were shouting at the OIM and asking what was going on and what procedure to follow. He did not know whether the OIM was in shock or not but he did not seem able to come up with any answer. The witness thought that it was a safety officer who said that a mayday had been sent out and that a helicopter would be there in an hour. Nobody was giving any orders. Another survivor said that the OIM came into the galley and just generally asked if there was contact with the Control Room. He was told "no, no contact". After a further explosion quite a few started to panic, screaming for someone to make a decision. It was fairly obvious that there was not much of a decision to be made ie he had to get out of there. Another survivor said that when there was panic and shouting, no one seemed to be taking charge. Another survivor described the OIM as standing on a table in the centre of the galley. He supposed that he was trying to assume some kind of command. This was virtually impossible due to panic, commotion and heckling. The witness said to the OIM that he was in charge and to get them out of there. The OIM told him to calm down. He told him that 4 men were outside with breathing apparatus trying to find an escape exit. The OIM spoke 4 times into a radio in order to make contact with the men but got no answer. People were now crouching down in the dining-room in order to avoid the smoke as far as possible.

8.19 Following the rupture of the Tartan riser at 22.20 hours a number of personnel in the accommodation and especially those on D Deck reached a point where they decided individually or in groups that they had to find a way out. In a few cases they had a particular destination in mind but in most cases the main aim was to get out of the accommodation. Some left the galley because there was no point in staying there. Others realised that if they did not get out they were going to die there. Others took the view that they had nothing to lose by at least attempting to save themselves. A particularly graphic account was given by Mr J M McDonald, a rigger. He asked the Occidental lead production operator, Mr A Carter, for instructions but found that he was delirious. He then said in evidence:

"I just said to myself 'get yourself off'. I got my pal Francis, and I got him as far as the reception, but he would not go down the stairs because he says 'We have done our muster job; they'll send choppers in'. I said to Francis 'I've tried to speak to Alan Carter; Alan Carter cannot talk to me, Francis. There's something drastically wrong on this rig. We'll have to get off'. Francis would not go, and he just slumped down. Anybody that knows the rig and the reception next to the bond, he slumped down there. That was as far as I could get him."

A large number of people apparently made no attempt to leave the accommodation. From the evidence it appears that there were a number of reasons for this. Some waited in the hope of a helicopter coming. Some stayed because they had been told to wait there and had received no other instruction. Some would not have remained there if they had known the full gravity of the situation which threatened the platform. Others remained because they simply did not know what else to do. There was no systematic attempt to lead men to a means of escape from the accommodation.

Escape from the accommodation

8.20 While conditions were deteriorating in the accommodation and in particular in the galley area on D Deck of the ERQ small groups of personnel were searching for a safe way of getting out of the accommodation. A number of drillers were aiming to reach the drill floor. Most had no objective other than getting out of the accommodation and in doing so they took whatever opportunities presented themselves. There was no organised escape. If leadership occurred in these escapes, it arose by individuals joining those who seemed to know their way around. A number of the survivors said that it was only their familiarity with the platform which saved them. One of these was Mr McDonald to whom I referred in para 8.19. Making use of advice which he had heard on a training course he used his initiative and found out that the wind was blowing from the south after he had got out of the accommodation. He used his knowledge of the platform to make his way to the drill floor and from there to the south-west

navigation platform from which he descended by means of a hose before dropping into the sea. It is impossible to state the total number of personnel who were able to leave the accommodation. Of those who did 28 survived. They left behind them at least 81 personnel in the accommodation. Many of them were not familiar with the platform outside the accommodation. This was the total number of bodies which were later recovered from the accommodation, as will be explained in Chapter 10.

8.21 Personnel found that they could escape from the accommodation at a number of levels and exits (see Fig J.7). On D Deck they escaped through the door which led from reception to the helideck; through the double doors in the storeroom adjacent to the kitchen; and through the double doors on the east side of the dining-room. From this level a number of them made their way down to the pipe deck, whereas others climbed up on to the level of the helideck (see Fig J.5). 10 survivors escaped from D Deck and made their way in one or other of these directions. 7 of them reached the level of the helideck. When they were there, 4 of them were forced to jump into the sea by the explosion at 22.50 hours. The distance from the helideck to sea level was approximately 175 ft. The remaining 3 then made their way down the outside of the south face of the accommodation to the pipe deck. 7 of the survivors escaped at C Deck from the accommodation, using the double doors of the recreation room which were adjacent to the construction and drilling tea huts. One of them, Mr Kinrade, made his way up to the level of the helideck where he too was forced to jump into the sea. The remainder made their way downwards towards the pipe deck. 11 survivors escaped by the door on B Deck which was adjacent to the Bawden Office. These included Mr Gutteridge and 4 other drillers who were familiar with the means of access to the accommodation at that point. From this door these survivors and others made their way to the pipe deck. Having reached the pipe deck a number of survivors who were mainly drillers made their way to the drill floor and across it to the navigation platform at the south-west corner of the 68 ft level where they climbed down a hose from which they dropped 15-20 ft into the sea and swam to leg B1 at the south-west corner of the platform. 2 survivors made their way to the drill floor and down to the oil lab on the 68 ft level where, after throwing a life raft overboard, "which failed to inflate" they climbed down a rope and entered the sea. One survivor headed for the south-east corner of the platform and used a rope in order to descend from the navigation platform at the 68 ft level. At that corner he reached the base of leg A1 where he stood until he was forced off it by the explosion at 22.50 hours. Another survivor crossed to the drilling derrick and climbed on to a roof beside it and facing south. He remained there until he was forced to jump off as a result of the same explosion. The remaining survivors who had reached the pipe deck sheltered for a time in the White House, which was the drill store, and the OPG Fabrication Workshop on the north side of that deck. At the time of or shortly after the damage to that deck which occurred as a result of a series of explosions (described in para 7.26) they attempted to get off the platform by jumping from the level of the pipe deck which was approximately 133 ft above sea level. 15 survivors made their escape from the platform in this way and through intense heat. 13 made their way along pipes on the collapsed slope of the west side of the pipe deck and jumped off. One went along a beam beside the SPEE Module on the north side of the gap which had opened in the pipe deck; and one ran along a cat-walk, probably on the east side of the platform, and jumped off.

8.22 A number of the survivors who jumped off the platform from a great height commented that they had been led to believe that it was very likely to prove fatal. In that connection the Emergency Response Handbook provided by Robert Gordon Institute of Technology (RGIT) to those undertaking training in survival has, since the disaster, highlighted the advice that it is recommended that persons seeking to escape should get down if possible to a height of 10m before going into the water: but that if a person is in a "no alternative" situation at whatever height and is forced to step off, he will have to do so. It was also noteworthy that when jumping into the water survivors followed their training by holding their nose with one hand; and holding down their life-jackets with the other arm in order to minimise the risk of

breaking their necks when they hit the water. Some also adopted the expedient of curling themselves into a ball in order to minimise impact injury.

Summary of escape from the platform

8.23 Since the bodies of 30 of the personnel from Piper have not been recovered it is not possible to determine how many of the personnel from Piper escaped alive from the platform. As regards those whose bodies have been recovered, it will be seen from para 10.19 that in 14 cases the deceased died during or after an escape from the platform. A total of 61 of the personnel from Piper survived the event. Their evidence was heard at the Inquiry. In the light of the account which I have given in the preceding paragraphs and which is based on that evidence it can be seen that they escaped from the platform in the following ways:-

27 descended by rope from a navigation platform below the 68 ft level to the 20 ft level.

1 walked down by stairways to the 20 ft level.

7 climbed down a rope or hose from the 68 ft level or a navigation platform below it and dropped into the sea.

5 jumped off the 68 ft level or a navigation platform below it.

1 jumped off a roof beside the derrick.

15 jumped off at the level of the pipe deck (133 ft).

5 jumped off at the level of the helideck (175 ft).

8.24 Of the 61 survivors, 39 (including 34 contractors' personnel) had been on night-shift duty. The remaining 22 (including 21 contractors' personnel) had been off duty. These numbers may be broken down by categories of work as follows:-

<i>Category</i>	<i>On duty</i>	<i>Contractors</i>	<i>Off duty</i>	<i>Contractors</i>
Operations	3	1	—	—
Drilling	6	6	4	4
Maintenance	8	5	5	4
Marine & Underwater	19	19	—	—
Offshore Projects	2	2	12	12
Inspectorate UK	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>
	<u>39</u>	<u>34</u>	<u>22</u>	<u>21</u>

This may be compared with the table of the total complement (Table 3.2) and the breakdown of the numbers of the deceased in para 10.20. It may be noted that 63% of those who had been on night-shift duty survived the disaster; whereas only 13% of those who had been off duty did so.

Life rafts

8.25 The capsules in which the life rafts were contained were situated on the 68 ft level (see Plate 12(b)). It was intended that they should be launched overboard after the pin which secured the straps holding the capsule in place had been removed. One end of a painter line was attached to the platform at the point of launch and the other end was attached to a mechanism inside the capsule for operating a gas cylinder. When the capsule was launched, its fall caused a length of the painter line to be pulled out of the capsule. Once the capsule had reached the sea a further length of the painter line required to be pulled out of the capsule until the end of the line was reached. At that point a further pull or tug would cause gas to discharge from the cylinder and the life raft to inflate. The length of painter line which was used on Piper was twice the distance between the 68 ft level and sea level. This length was in accordance with the length prescribed by the SOLAS convention. However, while the convention applies to ships and mobile installations, it does not apply to fixed installations. Accordingly it would have been open to Occidental to arrange for any length of painter line so long as it was of appropriate length, ie long enough to allow for the distance between the 68 ft level and sea level together with a nominal margin and an allowance

for tidal effect. The length of painter which required to be pulled out was marked on each capsule. However it was not shown on a pictogram which was displayed at the launching point for the guidance of those intending to put a life raft into operation.

8.26 A number of the survivors who had assembled at the north-west corner of the 68 ft level kicked a life raft capsule overboard but were unable to inflate the life raft. One witness said that the painter line had been pulled out "to the bitter end". It was, he said, "a ridiculous long amount to pull". Several witnesses said that the painter line was pulled out to the extent that it was taut and the life raft was being pulled out of the water. Following these efforts the life raft drifted under the jacket and the line became wrapped around a leg of the platform. The attempt to inflate the life raft was then abandoned. Mr P G Jeffery, Consultant Engineer, of Plessey Assessment Services, carried out an examination on 31 January 1989 of a number of life rafts which had been recovered after the disaster, including the life raft to which I have referred above. It had been recovered partially inflated. At the time of his examination it had been deflated. He found that the valve head of the cylinder showed that the cylinder had been operated. This was confirmed by removing the operating head cover and examining the mechanism. There was no evidence of malfunctioning on any of the operating heads. Mr Jeffery also found that there was no sign of fire damage or oil contamination on the life raft. The survival packs were complete and the sea anchors secured. There was a tear in the boarding ramp consistent with fouling after inflation. The container had a split and some signs of charring and oil residue. He said that it appeared that wave action had caused the life raft to inflate. The pull required for this purpose would have been between 12 and 30 lb. He had carried out a functional test of a life raft which had been recovered from Piper still in its capsule. In this case it had been found that the painter which was considerably frayed was fully extended although inflation had not taken place. Only a sharp tug was required to cause this life raft to inflate. It did not fully deploy, apparently because the survival equipment container had become displaced in the life raft chamber, probably during recovery, and as a result the cord securing the container had become snagged around the buoyancy chambers. It could have been deployed manually. As regards the evidence given by the survivors Mr Jeffery suggested that there was confusion as to what was happening at the time. The witnesses were not clear as to what had to be pulled out of the capsule. As the painter line was pulled out of the capsule it would appear taut. Wave action could give the impression that the life raft was being lifted out of the water. He suggested that either the painter had not been fully extended or that it had not been pulled hard enough. However, if anyone could lift the life raft, which weighed 400 lb, out of the sea it would be expected to inflate. As regards the maintenance of the life rafts, the Merchant Shipping (Life-saving Appliances) Regulations require that inflatable life rafts be serviced annually at an approved service station. Records of the servicing of all the life rafts on Piper had been provided and checked against the serial numbers noted in the last survey of life rafts by the DoT in February 1988. The installation records and servicing certificates accorded with the survey certificate. In those circumstances Mr Jeffery found no evidence of any general failure in maintenance which might throw light on the incident. In that state of the evidence I am not able to come to any definite conclusion as to the cause of the non-inflation of the life raft from the north-west corner of the 68 ft level. Despite the fact that survivors described the life raft in graphic terms as being lifted out of the water I am inclined to think that in the circumstances of the emergency confronting them they may, quite understandably, have thought that they had reached the point at which they had done everything to inflate the life raft when in fact this was not so. The fact that the painter line was twice the length of the distance between the 68 ft level and sea level might well have made it more difficult for them to cause inflation.

8.27 It was clear that a number of those who assembled at the north-west corner of the 68 ft level had never been shown the location of the life rafts nor how to launch and inflate them. Some survivors did not know how long was the painter line which required to be pulled out of the capsule after it had landed in the sea. Others thought

it was considerably shorter than it was. I will return to the matter of safety inductions in Chapter 13.

8.28 In the course of making their escape from the platform 2 of the survivors had kicked a life raft capsule at the south-west corner of the platform but had made no attempt at inflating it as it was seen to be moving under the platform. (It may be noted that this life raft was at the time obscured by scaffolding boards. Mr B M Goodwin, one of the 2 survivors, said that he would not have known of its presence if he had not carried out maintenance on it before the disaster.) This life raft was also recovered after it had inflated of its own accord. It was covered in oil, badly burned and damaged apart from the underside of the floor. This was consistent with it having drifted under a spray of hot or burning oil. There was no evidence that any attempt had been made to use any other life raft on the platform.

8.29 Mr Goodwin also gave evidence that some months before the disaster and shortly before an inspection - which may have been the DoT inspection in February 1988 - he had found that the lever which was intended to be used to make the capsule drop into the sea was seized as a result of salt spray. The same applied to most of such levers at that time. It did not, however, prevent the capsules from being kicked overboard. He had managed to loosen the lever and had reported their state to the safety department. Mr G G Robertson, safety supervisor, said that 2 levers on the west side of the platform had been reported as seized but were found to be operable after maintenance had been carried out. He said that the life rafts were checked monthly by the safety department. There was no evidence before the Inquiry that at the time of the disaster any of the levers were seized or that their maintenance was deficient.

Life-jackets

8.30 The life-jackets used on Piper were of the standard non-inflatable type which was passed over the head and had flotation compartments at the front and back. They were fitted with a whistle and had reflective strips to make them visible. Each person on board was allocated one for his own use which was kept in his cabin. Supplementary life-jackets were kept at lifeboat muster stations but these were fewer in number than those kept in the cabins. A number of life-jackets kept in reserve in a box at the north-west corner of the platform proved insufficient to meet the demand from the survivors who had arrived there. They had, of course, been unable to return to the accommodation to collect their own life-jackets. A number of survivors criticised the type of life-jacket. It was said that they were too bulky for narrow spaces, for wearing with breathing apparatus, for climbing down knotted ropes and for wearing while swimming. It was said that they could get water-logged and did not always keep the face of the wearer out of the water. Some bodies had been seen dressed in survival suits and wearing life-jackets but face downwards in the water. It was also pointed out that orange was an unsatisfactory colour for life-jackets since many other objects likely to be seen in the sea were of the same colour.

The later examination of the accommodation

8.31 In November 1988 the ERQ and the AAW were recovered from the bed of the sea adjacent to the remains of the platform jacket and transported to Flotta. Mr D M Tucker, Fire and Loss Consultant, gave evidence as to his findings following an examination of these parts in the accommodation in November 1988 at Flotta. His evidence throws further light on what happened inside these modules during the course of the events which I have attempted to describe above from the point of view of the personnel who were there.

8.32 As regards the ERQ he found that there was evidence of severe external attack by fire on its east and north sides (see Plate 22(a)). There was little evidence of attack by fire elsewhere save at the north-west corner where windows on the north face had

broken and there had been some limited spread of fire into the end cabins on the lower 3 decks. The west and south elevations had been protected by adjoining and adjacent structures (see Plate 22(b)). The underside of the ERQ appeared to have suffered relatively little fire attack. Paint on the helideck was increasingly damaged towards its south-eastern corner. In general the fabric had been fairly successful in withstanding the effect of heat. On the other hand, he found that smoke, hot gases and some flame had spread into the reception area on D Deck through a door-way from the LQW and the door on the south side which gave access to the helideck. It was not possible to say which was the more important route. This was consistent with prolonged exposure to a layer of very hot smoke spreading in from these directions. He said that conditions in this area would not have been survivable for long. However, closed doors leading off from the reception area had protected the rooms beyond. Smoke and gases had been able to spread to rooms which were near the reception area and the kitchen storeroom by way of voids in the ceiling. On the other hand walls and other barriers had prevented them spreading by this route to the plant room, stair enclosure and dining-room. There was no evidence that the ventilation system had been a major route. The ventilation air intake dampers were found to be closed. They were designed to be activated by high temperature but not by smoke so that closure must have been due to heat from the fire. The ventilation fans would have stopped on loss of power so that air was no longer drawn in. (It appears therefore to have been the fortuitous loss of power which prevented smoke being drawn in by way of the ventilation system, at least until the inlet dampers closed on account of the heat.) He found that a fire-resisting door between the reception area and the staircase had been held open by a hook. (This was apparently because the reception area was both a general thoroughfare and an emergency control centre.) As a result hot, dense smoke had spread into the passage between the reception area and the dining-room and stairwell. The door from the passage to the dining-room had been open briefly from time to time. There was no major route of smoke ingress to the dining-room but it could reach that area through gaps around the door, when the door was opened and through the kitchen and ventilation system. Some smoke could have entered the kitchen from the storeroom by way of ceiling voids or extract trunking. The kitchen and the dining-room showed moderate smoke damage but no heat damage. He thought that judging by smoke deposits conditions there would have been survivable in the short term. There would have been enough oxygen in the ERQ as it was not totally enveloped in flames, especially on its south side. Accordingly in the light of his examination of the ERQ it was possible that some of the deceased might still have been alive in those rooms when the ERQ fell into the sea. Mr Tucker noted that the ERQ was more substantial and more insulated than the AAW. Its sprinkler system was intact and would have operated if it had been activated. Its operation would have washed out some of the particles and possibly some of the toxic products from the smoke and so prolonged the conditions in which personnel could have survived. To minimise smoke ingress and prolong survival the fire doors should have been kept shut. The closing of the door between the reception area and the stairs, which was a self-closing door would have reduced the ingress of smoke to the dining area possibly by a significant amount. As regards the other levels he found that smoke conditions would have been in general survivable in the cabins. On C Deck he found that its north corridor had been affected by a spread of smoke and hot gases from the LQW. Smoke damage to cabins had occurred where their doors had been open. In A and B Decks there was only slight smoke damage. As regards both C and B Decks there was no significant evidence of the spread of smoke from the AAE.

8.33 As regards the AAW Mr Tucker found that there had been severe heating of its external faces and roof (see Plate 23). This module had been subjected to considerably more fire than the ERQ and possibly for longer. However, it was less able to withstand a given level of fire. The external copper piping of the sprinkler mains especially on the south side, had melted. This probably would not have happened if water had been flowing through it. As regards internal damage this was more severe than in the case of the ERQ. He took the view that it was unlikely that anyone who had been trapped in it would have survived even before this module fell into the sea.

Heat conducted through the external walls had damaged most of its rooms. Fire and hot gases had come through the external doors. Hot gases and smoke had also entered it through the ventilation trunking and some of the extract trunking. All of the sprinkler heads appeared to have been activated by heat. Mr Tucker said that the AAW did not have true fire dampers. However the later evidence of Mr G H Bagnall, a lead maintenance technician with Occidental, satisfied me that it had 4 fire dampers. Only one of them was found to have been fully closed. The remainder varied between fully and partially open.

8.34 The above evidence of Mr Tucker satisfied me that unlike the AAW the ERQ would have been able to provide within the galley area on D Deck and in cabins on its lower levels a survivable atmosphere for some time after the initial explosion. As far as the ERQ is concerned it is clear that the fire dampers operated successfully and that the ventilation system was not a major cause of the ingress of smoke. That ingress was due primarily to the temporary or permanent opening of doors in the path of the smoke which accelerated the deterioration of conditions to the point where personnel were overcome by its effects. It is also clear that if greater discipline over the opening of doors had been exercised and in particular if the fire-resistant door had not been pinned back this would have prolonged the conditions in which personnel were able to survive in the galley area. It is probable that that door was hooked back to ease the movement of personnel. That was the interpretation which was given by the back-to-back OIM, Mr Richards.

The actions of the OIM

8.35 After reviewing the evidence which I set out in this chapter it is necessary for me to consider what view I should take of the conduct of the OIM. He was the person who was primarily responsible for the taking of decisions for the safety of those on board the installation. He must have known that the conditions of fire and smoke were such that access to the lifeboats and access to a helicopter were out of the question. Further, I cannot see how he could have taken the view that there was any prospect of either form of access becoming practicable. After the initial explosion the fire which broke out in B Module spread rapidly and extensively. He must have known that virtually every emergency system on the installation had been rendered ineffective and that Occidental's system for response to emergencies on board was crippled from the start. Conditions in the galley were initially tolerable but within about a quarter of an hour after the initial explosion were deteriorating to the point where personnel were being overcome. In face of all this it is unfortunately clear that the OIM took no initiative in an attempt to save life, even if it was that the personnel should choose the lesser of two evils by getting out of the accommodation as quickly as possible. It is clear that a considerable number of those who had been in the accommodation realised that there was no point in staying to die. It was better to get out of the accommodation whatever lay beyond that. Meanwhile those who remained in the accommodation in expectation or obedience succumbed to the effects of smoke and gases which came from the extensive crude oil fire on the production deck and below. There was only one way in which those who were in the accommodation could escape certain death there and that was to get down to sea level by whatever means were available. It is, of course, impossible to say how many would have survived in this way. The risks of death were considerable. However, in my view the death toll of those who died in the accommodation was substantially greater than it would have been if such an initiative had been taken, even allowing for the speed and voracity of the disaster which was engulfing the platform.

Chapter 9

Rescue

Introduction

9.1 In this chapter I will describe the offshore and onshore response to the disaster and the way in which the survivors were rescued. Following a general account I will explore in more detail a number of aspects which caused difficulties or led to criticism.

Vessels in the area of Piper Alpha

9.2 The Emergency Procedures Regulations require that within 5 nautical miles of every offshore installation when it is manned there is to be present a standby vessel ready to give assistance in the event of an emergency on or near the installation. On the evening of the disaster Piper was attended by the *Silver Pit*, a converted trawler, as its standby vessel (SBV) (see Plate 11(b)). She was on close standby about 400m north-west of the platform, with a fast rescue craft (FRC) swung out ready to be launched. The FRC was an HT 24, diesel-driven water-jet boat, capable of accommodating 3 crew and 12 survivors. It was capable of a speed of 25-30 knots. It had no fixed radio on board. The *Silver Pit* was certified as having space available for 250 survivors, with a minimum manning of 9 persons. In addition to the FRC, the *Silver Pit* also carried a smaller inflatable craft for the use of the crew in accordance with the requirements of the DoT, called a DOTI boat. For 300 survivors she would have required to have 2 FRCs; and would then have been exempt from the requirement to carry a DOTI boat.

9.3 About 550m off the west face of Piper and with her stern square on to the platform was the *Tharos*, which was owned by the Occidental Group (see Plate 11(a)). The *Tharos* was a semi-submersible vessel which was designed to have a number of functions including that of a fire intervention vessel. She carried equipment for fire-fighting and well killing; a hospital with emergency facilities for 22 persons; accommodation for 224 men and crew; and a gangway for access to installations. She had on board a fast rescue craft which was jet driven and could be launched by crane and accommodate 18 men. She also had a helicopter which could take 12 passengers, but was not equipped with a winch for rescue purposes. The *Tharos* was designated as the support vessel for major emergencies in the sector of the North Sea in which Piper was situated. However on the day of the disaster she was at Piper in connection with work on the installation at Piper of a pipeline which was to carry hydrocarbons to Piper from the satellite Chanter field. At the time of the initial explosion she was holding her position by means of 3 anchors set to the south and west and was ballasted at a draught of 15m.

9.4 The *Maersk Cutter*, a supply vessel, which was acting as an anchor handler for the *Tharos* was about 1 mile off the north-east corner of Piper. This vessel was fitted with fire monitors and was able to act as a rapid intervention vessel (RIV). She was capable of discharging 10,000 tons of water per hour with a range of up to 140m.

9.5 The *Lowland Cavalier* lay 25m off the south-west corner of the platform and with her stern facing it. She was engaged in trenching operations for the pipeline between Chanter and Piper. At the time the trenching equipment was on the seabed and over the pipeline track.

9.6 In response to the mayday a number of vessels involved in offshore work came to the scene in order to assist. I do not intend to give a description of the part played by each of them. But at this stage I would mention the following vessels which figure in the narrative which follows. The *Sandhaven* was on standby duty at the Santa Fe mobile drilling installation which was 4½ miles from Piper. She was a converted supply

vessel, and was more manoeuvrable than a converted trawler such as the *Silver Pit*. She had a crew of 8. Her FRC was an Atlantic 21, which had a petrol-driven engine. It had a crew of 3 and was capable of a speed of 30 knots, 3 times that of the parent vessel. The *Sandhaven* also carried a DOTI boat. At the time of the mayday the *Loch Shuna* was sailing with supplies for the Kingsnorth UK installation. It diverted from this journey, arriving on the scene at about 22.50 hours. It had an FRC of the Atlantic 21 type (see Plate 12(a)). The *Loch Carron*, a supply vessel, was heading for the Marathon Brae installation. It also was diverted, arriving on the scene at 03.00 hours on 7 July. Her FRC was a petrol-driven Fletcher type in which the fuel was stored under the deck. Part of the hull was hard and there was a flotation collar.

9.7 During the disaster a large number of FRCs which had been launched from different vessels, took part in the search for and recovery of survivors and the dead. (Plate 12(a) shows a FRC of the Atlantic 21 type.) According to information collected by Mr A D M Letty, master of the *Tharos*, 11 FRCs were involved, so far as had been recorded.

9.8 The Piper platform was located at 58° 28'01" North, 00° 15'36" East. It was 120 miles north-east of Aberdeen. According to the log of the *Tharos* the following weather conditions were noted as at midnight on 6/7 July: Wind 160-170°, 10-15 knots. Maximum wave height 3m. Visibility 10+ miles.

Maritime search and rescue

9.9 The responsibility for initiating and co-ordinating civil maritime search and rescue in the United Kingdom part of the continental shelf (UKCS) rests with HM Coastguard on behalf of the DoT. The co-ordination of search and rescue operations is achieved through a number of maritime rescue co-ordination centres (MRCCs), including one at Aberdeen which is responsible for a region within which Piper was situated. The MRCC at Aberdeen was fitted with a comprehensive telecommunications system which included a 24 hour radio watch on the international distress frequency, channel 16 (VHF). The International distress frequency of 2182 kHz was manned on their behalf by British Telecom International which had permanent liaison arrangements with the MRCC. For the purposes of search or rescue offshore the coastguard relied on the facilities provided by Ministry of Defence helicopters through rescue co-ordination centres (RCCs), one of which is situated at Pitreavie near Edinburgh; the DoT search and rescue helicopter at Sumburgh and other facilities such as Nimrods and warships that may be available. The MRCC at Aberdeen has private telephone lines to most oil companies and to the RCC with which it has close operational links. The RCC is not responsible for co-ordinating the rescue effort but for supporting the coastguard with airborne assistance. The RCC at Pitreavie controls the movements of search and rescue aircraft at 7 bases which have at least 1 unit on permanent standby. At night Wessex helicopters are on 1 hour standby, whereas the Sea King helicopters are on 45 minutes standby, with the exception of those at HMS Gannet at Prestwick where the period is 90 minutes. Nimrod aircraft, which are maintained at Kinloss, are on 1 hour standby.

9.10 It is well recognised that, as part of an efficient system of search and rescue at sea, it is essential that there should be an on-scene commander (OSC) to monitor and co-ordinate developments in detail. According to the *Offshore Emergencies Handbook* prepared by the DEN and circulated to all operating companies and agencies which may be called upon to deal with major emergencies involving offshore installations:

“The OSC will normally remain the OIM of the stricken installation, or the master of the vessel in distress, unless the seriousness of the emergency or loss of communication demands otherwise. As soon as a decision is made to abandon an installation/vessel the role of OSC must be devolved to another. Depending on circumstances, this may be the OIM of a nearby platform, the master of a safety, supply or specialised vessel, or the captain of a suitably equipped aircraft. Hard and

fast rules cannot be laid down and a decision must be based on the nature and scope of the emergency and the type of facilities and expertise immediately available. As time is critical the master of a standby vessel, for example, could assume OSC initially before relinquishing to the master of a more sophisticated vessel with better communication and equipment as soon as one becomes available ...” (Annex A, paras 8.3-5).

The Handbook also states that the MRCC, after consultation with the operator, may designate another vessel or aircraft to assume the role of OSC. The functions of the OSC may be summarised, according to the Handbook, as executing the plans of the search and rescue mission co-ordinator, which may be the MRCC; modifying those plans as required to cope with changing on-scene conditions; assuming operational co-ordination of all units assigned by the co-ordinator; establishing and maintaining communications with the co-ordinator; submitting situation reports at regular intervals to the co-ordinator for action; establishing and maintaining communication with all facilities performing search, rescue or similar operations; providing initial briefing and search instructions to such facilities; receiving and evaluating sighting reports from them; co-ordinating and diverting surface facilities or helicopters and aircraft to evaluate sightings; and obtaining the results of search as each facility departs the scene. It is also envisaged that as the process of search and rescue progresses any surface vessels may join in the search for survivors. The most suitable may be appointed to be the co-ordinator surface search (CSS), for which the Merchant Ship Search and Rescue Manual (MERSAR) provides an outline of duties and details procedures and techniques. The Handbook also emphasises the importance of liaison between the MRCC and the operator. It states that:

“In a major incident effective rescue action will demand the integration of facilities directly or immediately available to the operator with those made available to, and under the co-ordination of the MRCC. Regardless of whether search and rescue mission co-ordination rests with MRCC or the operator, during any search and rescue incident offshore it is vital that close liaison is maintained between the MRCC and the emergency control organisation of the operator ...” (paras 5.1-2).

The provisions made by the Handbook for the co-ordination of search and rescue are broadly similar to those issued by the International Maritime Organisation (IMO) and embodied in MERSAR to which I have referred above.

General narrative of search and rescue

9.11 In immediate response to the initial explosion the FRC of the *Silver Pit* was manned and launched at about 22.02 hours. Two minutes is the normal time for manning and launching. The FRC went in towards the north-west side of the platform, with the *Silver Pit* following. At about 22.05 hours the FRC crew had picked up the first survivor from the platform, who had walked down stairways to the 20 ft level. The FRC thus began a number of trips between the platform and its parent vessel.

9.12 At about 22.02 hours the *Lowland Cavalier* broadcast a mayday. She moved back to about 60m from the platform in order to allow her work-boat to be launched. It was launched about 22.14 hours. Later in the evening the *Lowland Cavalier* also launched one of her lifeboats.

9.13 In response to the initial explosion the crew of the *Tharos* manned their emergency stations and her master took charge of the movement of the vessel. Generators for the fire pumps were started as additional engines were brought on line. The *Tharos* started moving towards the platform at about 22.05 hours. This process involved paying out her anchor cables in a controlled manner. It took about half an hour for the vessel to reach a close range from the platform. The process was made longer by the fact that the vessel’s thrusters cut out from time to time due to an overload on the supply of power. At 22.11 hours her helicopter was airborne. Two minutes later the pilot reported to the vessel that Piper’s helideck was obscured by

smoke. No flames were visible on the east side of the platform. As from 22.03 hours the *Tharos* was in communication by satellite with Occidental in Aberdeen.

9.14 By the time of the rupture of the Tartan riser at 22.20 hours the FRC of the *Silver Pit* had picked up 2 additional loads of men from the north-west corner of the platform near B4 leg and was making its way towards the *Silver Pit*. The heat of this explosion blistered the paintwork of the *Silver Pit* and damaged her DOTI boat. The work-boat of the *Lowland Cavalier* picked up 2 men who had fallen into the sea from the rope at that corner. When this boat was heading towards the south-west corner to pick up more men a fireball forced its crew to get into the water for shelter. After it had passed, the men to whom the boat was heading were no longer to be seen. By 22.20 hours about 22 survivors had left the platform. Thereafter most, if not all, of the survivors reached safety by being picked up in the sea, either by an FRC or by one of the larger vessels.

9.15 The master of the *Tharos* did not make any announcement that he had assumed the role of OSC but effectively acted in this role from the outset. He expected that the coastguard would know of his vessel's capabilities. At 22.18 hours he instructed vessels in the vicinity to launch their FRCs. At that time the *Tharos* launched her own. At 22.15 hours the jacking out of the fire boom which supported the gangway had started. The crane was being racked in order to fit the fire monitor which operated from it.

9.16 The mayday which had been broadcast by the *Lowland Cavalier* was picked up by Wick radio, after which the MRCC alerted the RCC. At 22.19 hours the RCC instructed RAF Kinloss to scramble a Nimrod. This Nimrod became Rescue 01. Its main use was as a flying communications platform, handling the signals from the helicopters and reporting back to the RCC on HF transmission. It could remain on station for 8 hours. At 22.20 hours the RCC was told about the messages from Piper that the platform was being abandoned. At 22.22 and 22.28 hours Sea King helicopters, R137 and R131, took off from Lossiemouth and Boulmer respectively. The first of these helicopters had been recalled from going to participate in a mountain rescue.

9.17 At about this time the RCC was in discussion with MRCC and the Royal Navy as to the possibility of support being given by the Standing Naval Force Atlantic (STANAVFORLANT) which at this time was at 50° north 3° east. Maritime HQ advised that this force, including helicopters, was available if required. The MRCC took the view that this would be a valuable asset and asked the RCC to request that it proceed to Piper with all speed. There was some conflict in the evidence as to when the MRCC expressed this wish to the RCC but it was not later than 22.35 hours. It then lay with the Royal Navy to make contact with the naval force with a view to diverting it to Piper. It appears that radio communications with the force took some time to be achieved.

9.18 The *Maersk Cutter* had been made ready for fire-fighting within about 3 minutes of the initial explosion. The master estimated that her fire monitors were being deployed on to the platform after about 10 minutes. The vessel was then about 150-160 ft off the south-east corner of the platform. The monitors were being aimed at the level of the drill floor. By about 22.30 hours 3 of her 4 monitors were in use, discharging at the rate of 7500 tons of water per hour. She continued to discharge water at this rate until about 00.15 hours. She did not launch her FRC as it was decided that she should concentrate on her primary function of fire-fighting. She also used her searchlight to point out survivors in the water.

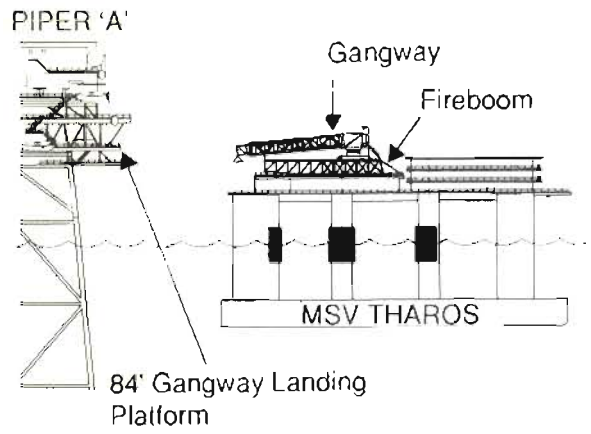
9.19 The FRCs were continuing to pick up survivors (see frontispiece); the last of those who were to reach the *Silver Pit* were more seriously injured than those who had reached her earlier. Her FRC picked up a number of more seriously injured survivors who were holding on to an upturned lifeboat. They were taken to the *Silver*

Pit with the exception of one man who was so injured that he required to be taken on to the *Loch Shuna*.

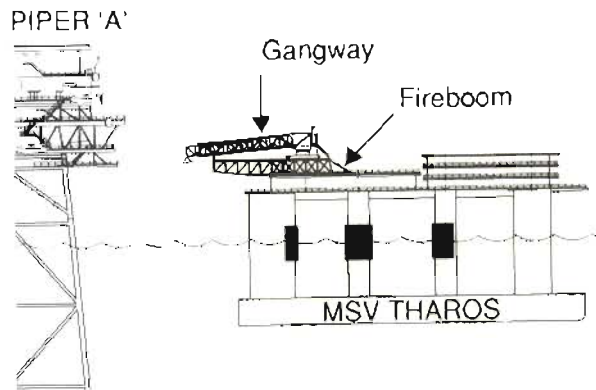
9.20 In the meantime preparations had been made for the *Tharos* to open her fire-fighting monitors. The master's intention was to deploy them in such a way as to create a cascade of water on to the platform rather than jets. The latter would have run the risk of causing injury to survivors. The intention was to open the monitors in sequence. However the opening of the first discharge valve of a fire pump did not occur until 22.31 hours when 6 fire monitors began to deliver water under the correct pressure. This was some 14 minutes after that pump had started. Normally it would have taken about 2 minutes from the starting of a fire pump to the opening of its discharge valve. The reason for the difference was that too many monitors had been opened shortly after the starting of that pump, with the result that there was insufficient pressure for the discharge valve to be opened. Fire-water did discharge briefly and weakly from the monitors which had been opened. Instructions were given that all the monitors were to be shut except for one which was used in order to bleed off air. The discharge valves of the other fire pumps were opened at 22.35, 22.39 and 22.52 hours. Although there was a substantial delay in the cascade coming into operation, which can be put at approximately 12 minutes, it does not appear that this made any practical difference to conditions on the platform. I accept the master's evidence that at 22.31 hours the cascade was not yet close enough to reach the platform. However, I must point out that the cascade proved to be of assistance not merely to those on the platform but also to the rescue vessels and those in the water. At 22.41 hours the spray which provided a heat shield to the *Tharos* was put on. By 22.45 hours the *Tharos* was 60-70m off the west face of the platform and the monitors were being deployed on to it. The master's intention had been to deploy the gangway on to a landing on the west face of the 83 ft level of the platform (see Fig 9.1). The fire boom supporting it could only be extended slowly. It would take 5 minutes to be extended 2 ft and 75 minutes to reach a minimum usable length of 30m. At 22.33 hours the *Tharos* received the radio message from Piper: "People majority in galley area. *Tharos* come. Gangway. Hoses. Getting bad." By 22.50 hours the *Tharos* was about 50m from the platform. By that stage a number of survivors on the platform were feeling the benefit of the spray from her monitors, in particular in giving some alleviation of the intense heat and dense smoke. This was particularly the case for those who reached the pipe deck and the helideck. The spray was also giving some cooling to fast rescue craft, such as that of the *Silver Pit*, which were continuing to penetrate extreme conditions of heat in their search for survivors in the water. However at this stage the landing position where the master intended to place the gangway was completely obscured by smoke and flames. The tremendous roaring made by the ignition of gas from the Tartan riser made communications difficult. In those circumstances the *Tharos* was unable to land her gangway on the platform. However lines and baskets together with life-buoys had been deployed over her aft end. One of the survivors was successful in swimming from the platform to the *Tharos* which he reached at 22.40 hours. He climbed up a fixed ladder on one of her stabilising columns.

9.21 At about this time a number of additional search and rescue aircraft became airborne. At 22.45 hours the Shetland coastguard helicopter (R117) took off. At 22.51 hours a second Sea King (R138) took off from Lossiemouth. At 22.55 hours the Nimrod, Rescue 01, took off from Kinloss.

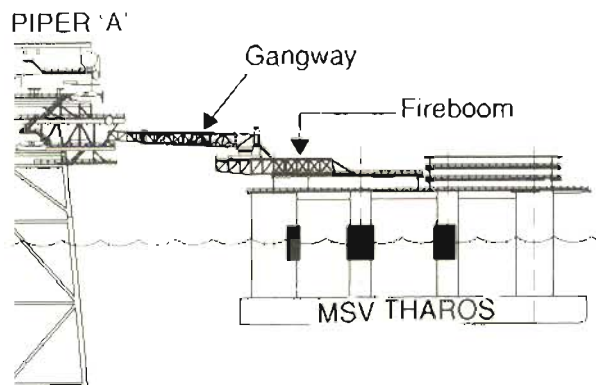
9.22 By the time of the rupture of the MCP-01 riser at 22.50 hours approximately 39 survivors had left the platform. Shortly before it occurred the FRC of the *Sandhaven* had picked up 4 men from the south-west corner of the platform and had turned back to pick up 2 additional men. All of them had probably reached that corner by descending from the drill floor. At the moment of the explosion the FRC was entangled with ropes which had been used in the escape. The explosion destroyed the FRC and killed all its occupants with the exception of the crewman Mr I Letham. The fireball associated with the explosion partially engulfed the *Tharos*, and her master gave orders



(a)



(b)



GANGWAY = 21.5 m

(c)

Fig. 9.1 The *Tharos* gangway: (a) gangway fully retracted; (b) gangway partially extended; and (c) gangway fully extended.

that the vessel move back to a distance of 100m from the platform so that the position could be assessed. I should add that at a later stage in the evening a further explosion damaged the hull and engine of the FRC of the *Silver Pit*. However it was able to rescue a further 5 persons before it lost power and stayed barely afloat. Its occupants were later rescued by the *Maersk Cutter* after it had ceased fire-fighting.

9.23 At 22.56 hours MRCC made direct contact with the Occidental Emergency Control Centre. At 23.06 hours a direct radio link was created between MRCC and the *Tharos*, which had commenced moving back towards the platform at 23.05 hours. MRCC formally requested the master of the *Tharos* to assume the role of OSC. Mr Letty instructed the *Loch Shuna*, which had pulled up to the west of the platform, to co-ordinate the surface search and rescue. As OSC he thereafter made periodic reports on the situation to MRCC.

9.24 At 23.13 hours the *Silver Pit* was alongside the *Tharos* so that 3 of the more seriously injured survivors could be transferred to her. At 23.18 hours the *Tharos* was advised by MRCC or Occidental to pull back from Piper due to the possibility of hazard from the presence of hydrogen sulphide. Her master ordered that the vessel move back about 200m. Other vessels in the vicinity received similar advice. At this stage men who had jumped off the level of the helideck and the pipe deck were being picked up by FRCs, such as those of the *Silver Pit* and the *Loch Shuna*; and also by larger vessels such as the *Silver Pit* and the *Maersk Logger*. Vessels were instructed to bring survivors to the *Tharos* in view of its hospital facilities. They were brought aboard mainly by the use of a crane and basket.

9.25 At 23.27 hours the Nimrod aircraft reached the area of Piper, having already assumed the functions described above. Three minutes later the first search and rescue helicopter, R137, reached the *Tharos*, where the *Maersk Leader* was unloading survivors. This was followed by the arrival of helicopters R117, R138 and R131 at 23.44, 23.48 and 23.53 hours. Arrangements were made for helicopters to be refuelled at the Claymore platform. The first helicopters on the scene were used to evacuate non-essential personnel from the *Tharos* to other platforms from which additional medics were brought back. This process started at 23.38 hours. The worst casualties were brought to the *Tharos* by helicopter from the *Silver Pit*. Other helicopters took part in the search for survivors. Casualties continued to be brought to the *Tharos* at least until about 00.26 hours. The seriously injured were accommodated in the sick-bay, and the others in the helicopter hanger. The master of the *Tharos* explained in evidence that, apart from the risk of hydrogen sulphide, there were a number of additional reasons for his pulling the *Tharos* back to the extent that the platform was no longer within the range of her monitors. Soon after his moving back there was little left of the platform. Further he wanted to pull back sufficiently far to ensure that helicopter operations were not compromised by the heat of the fires on the platform.

9.26 At 00.40 hours the *Tharos* pulled back a couple of hundred metres and turned off the heat shield. At 00.43 hours command of the surface search and rescue was passed from the *Loch Shuna* to the *Lowland Cavalier*. By 01.19 hours there were 21 injured men in the sick-bay of the *Tharos*. By then a team from Aberdeen Industrial Doctors had arrived at the *Tharos* and were at work there. At 02.00 hours the Offshore Specialist Team from Aberdeen Royal Infirmary arrived at the *Tharos* with a considerable amount of medical equipment. It was found that the injuries sustained by the survivors were in general external and internal burns, carbon monoxide poisoning, bruises and some fractures. The efforts of the medical team were directed to stabilising the condition of those who had been seriously injured pending their being taken to hospital in Aberdeen. At 01.13 hours the Nimrod advised that no further helicopters were required to give assistance. At 02.02 hours all fire-fighting was stopped, and all ships were instructed to participate in the current search of the area around the platform.

9.27 At 02.26 hours the first helicopter left the *Tharos* for the shore with casualties and medics on board. All the casualties were to be taken to the Aberdeen Royal

Infirmary. This helicopter arrived at the infirmary at 03.30 hours. Medical care was provided on most of the flights to Aberdeen, apart from one which carried the walking casualties. At 04.00 hours the *Tharos* resumed control of surface search and rescue from the *Lowland Cavalier*. Her deputy OIM set up a search and rescue pattern with the use of MERSAR. By this stage 45 vessels or more were in the vicinity of the remains of the platform. At 07.29 hours the *USS Hayler* arrived at the scene, her commander (who was the Commodore of the NATO force) having become OSC.

9.28 By 08.15 hours 63 personnel (including the surviving member of the crew of the FRC of the *Sandhaven* and one survivor from Piper who subsequently died) had been landed on shore. Aircraft were used to search the area of the platform until the afternoon of 7 July. The search by vessels continued until 22.45 hours on that day.

The method of rescue of the survivors

9.29 Of the 61 survivors from Piper a total of 37 survivors reached the *Silver Pit*, 29 of them having been picked up by her FRC and the remaining 8 by the vessel directly. Nine men who had been picked up by FRCs were taken to the *Tharos*. Seven were taken to other vessels. Seven survivors were picked up directly by other vessels, in particular by the *Maersk Logger*. As stated above one survivor reached the *Tharos* by swimming out to it.

The co-ordination of search and rescue

9.30 It is clear that from the outset this was threatened by poor communications and a failure in the procedures which were intended to secure a prompt, well-informed and efficient response. Mr J P A Wynn, who was Search and Rescue Mission Co-ordinator at MRCC until relieved by the Deputy Regional Controller, stated that for almost an hour after the initial explosion all that they knew was that there had been an explosion on Piper. They needed to know the nature of the incident, the number of persons on board, the intentions of the OIM, the weather on scene, the communication facilities, the available life-saving facilities, the vessels available in the area and other information. Without that information they had to assume the worst, that all had abandoned the platform by whatever means. Reference was made to Sec 3 of the Offshore Emergencies Handbook with which the witness was familiar. This sets out the information which the "OIM/shore base" should report to, *inter alia*, the MRCC "in the event of a fire becoming, or in danger of becoming, uncontrollable". He assented to the description of the first hour as "an hour of chaos". Mr Wynn explained that the international frequency of 2182 kHz, which was the only frequency available for direct contact with Piper, was controlled by Wick radio station "so we could not interrupt it willy-nilly". MRCC concentrated on seeking information from Occidental and asking the coastal radio station to try to establish communications with either the *Tharos* or the *Lowland Cavalier* which could provide MRCC with more information as to what exactly was happening. However the distress frequency was cluttered with traffic. Mr Wynn commented that:

"In the North Sea with its many rigs, platforms, support vessels, aircraft and fishing vessels and so on, the response to a distress message is often out of all proportion to the assistance required. The relay via the coast radio station is unwieldy and inefficient. Vessels offered assistance on a continuous basis and inhibited us gaining vital information from on scene. Queries and suggestions received by the coast radio station are really destined for the Search and Rescue Mission Co-ordinator at the Coastguard Rescue Centre. However, the coast radio station operator had little time to consult with Aberdeen MRCC and we think could be therefore pressurised into making decisions which are not really his responsibility."

He advocated communications by VHF as the ideal method for controlling search and rescue operations. The Aberdeen Search and Rescue region was unique among those in the United Kingdom in respect of the much higher activity from 100 to 150 miles from the coast. This was an area of high disaster potential because of the existence of

large numbers of drilling rigs, fixed installations and associated vessels and aircraft employing many thousands of men.

“Without the benefit of VHF coverage offshore and because of our limited facilities regarding medium frequency equipment, and the present procedures whereby the coast radio station controls the distress frequency, Aberdeen MRCC was put at a severe disadvantage and we were not able fully to co-ordinate the initial rescue phase effectively and provide on-scene the executive authority that is required. I am talking of the first hour or hour and a half or so of the incident.”

According to the witness it was not until 22.56 hours that the Occidental Emergency Control Centre was fully manned and the MRCC was able to obtain information from that source as to what was involved in the incident at Piper. MRCC was then told that the approximate number of persons on board Piper was 220; that the platform could not be completely evacuated at the time; some persons were in the water; that all communications to Claymore and Piper had been lost; and that there was one satellite link to the *Tharos* which Occidental wished to maintain and did not want to put through to anywhere else. The use of the satellite link would have provided earlier knowledge of the scale of the disaster. However, the witness clearly stated that this would not have affected the way in which MRCC in fact responded to the emergency. According to the witness the radio link between MRCC and the *Tharos* was eventually established by Wick radio. MRCC would have designated the master of the *Tharos* as OSC at an earlier stage had they been able to make contact. Liaison officers from Grampian Police and Occidental eventually arrived at MRCC, the latter after MRCC had made a second request for attendance. The witness was questioned about exercises carried out with oil companies in order to test emergency procedures. These were usually on the basis of a slow build-up. A scenario on the scale of Piper had not been considered. For the future the initial reaction of MRCC to an incident would remain unchanged, namely mobilising the rescue services until they got more information.

9.31 Mr E R Kerr, a Radio Officer who was in charge of radio telephones at Wick radio station, which was part of the maritime section of British Telecom International, gave evidence as to the receipt of the mayday from the *Lowland Cavalier* and the series of wireless messages received on 2182 kHz from Piper. The mayday was telexed to the coastguard, RCC and Lloyd's between 22.12 and 22.17 hours; but owing to the number of calls from vessels offering assistance he was unable to broadcast a relay until 22.26 hours. His first contact with the *Tharos* was at 22.13 hours when the vessel sent a message that it was 500m off the west face of Piper and that a helicopter was on the way. He passed that information to the coastguard. Contrary to the evidence given by Mr Wynn, Mr Kerr said that as far as he recollected Wick radio had not been involved in setting up any direct link between MRCC and the *Tharos*. Further there was no entry in any of the logs to this effect. He suggested that the link was through Stonehaven radio which dealt with day-to-day communications with the *Tharos*. If the coastguard had wanted a direct link Wick radio would have called the *Tharos* on 2182 kHz and asked the vessel to transfer to a working frequency so that the vessel could communicate with the coastguard. He did not recollect any particular difficulty in communicating with the *Tharos* that night apart from possibly later on when there may have been occasions when the radio operator on the *Tharos* did not respond immediately, perhaps because he was busy with other communications.

9.32 Squadron Leader G D Roberts of the RCC stated that very little information had been received by the RCC during the first hour after the initial explosion. The first indication of the extent of its seriousness came from the Nimrod aircraft at 23.27 hours. When the first helicopter took off it had no information as to how significant the incident was or what it would be required to do when it reached the scene. As regards the naval force it seemed to be surprising that it took as long as it did for them to arrive on the scene. However, it did not appear that life had been endangered by this lapse of time. In the circumstances I decided not to pursue further enquiries into it.

9.33 As stated earlier in this chapter from an early stage after the initial explosion the master of the *Tharos* carried out the work of an OSC; he said in evidence that he supposed that it was at the back of his mind that he was in fact in command of the emergency. The master of the *Silver Pit* said that he had assumed that the *Tharos* would provide the OSC as his vessel was directly involved in rescue work. However, it does not appear that Mr Letty, let alone Occidental, informed the coastguard that he had assumed this role. He was not familiar with the Offshore Emergencies Handbook, but he considered that most merchant mariners would be familiar with MERSAR. He took the view that the main importance of the *Tharos* on the night of the disaster was as an operations control centre. She was in radio communication by VHF with all the vessels and aircraft in the area, as well as with Occidental and in due course the coastguard. However in the area of instructions and communications a number of criticisms were expressed in the Inquiry. The diving superintendent, Mr S R MacLeod, who assisted the rescue effort after he had reached the *Silver Pit* stated that the *Silver Pit* managed to make radio contact with the *Tharos* informing them that there were 7 seriously injured people there needing immediate medical attention. He was told to stand by but nothing happened for an hour. Contact was then made by the *Silver Pit* directly with a helicopter which removed the worst cases. *Tharos* had been contacted 3 times and on each occasion the *Silver Pit* was told to stand by. The radio channels were busy and chaotic but those on the *Silver Pit* felt that they were being ignored. Another witness from the diving team, Mr J Barr, said that there were no clear instructions for the *Silver Pit* until the Nimrod aircraft came on the scene. The master of the *Loch Carron* advanced a number of trenchant criticisms which were not otherwise borne out in the evidence. He said that as his vessel was proceeding to Piper his crew were aware of a great deal of radio traffic without proper co-ordination. He was familiar with the concept of on-scene command but there appeared to be no effective command at that time. By the time that the vessel arrived on the scene there was some form of command but it was difficult to get proper instructions as to what part they could play in the rescue. The ships were too far apart and there was no real communication with whoever was organising the search. He said that it did not show good foresight to be transferring survivors between vessels before taking them to the *Tharos*. He expressed the view that it was not practicable for the master of a standby vessel or a supply vessel to act as OSC as there was far too much for the crew of each of them to do.

The recovery of survivors from the platform and the sea

9.34 The events on the night of the disaster proved beyond any doubt the importance of FRCs in a case in which men are forced by a major emergency to take to the sea to save their lives. The work for which they are normally used in conjunction with a standby vessel is the recovery of men who have fallen overboard from the platform. For that type of rescue speed of response is essential. On the night of the disaster the FRCs showed also how they could be used to get close to the platform even when the fire was raging. Conspicuous bravery was shown by the crews of these FRCs who repeatedly exposed themselves to danger. I would mention in particular the crew of the fast rescue craft of the *Silver Pit*, under their coxswain Mr J P McNeill, who showed an extraordinary example of cool courage in the face of extreme hazard; and the crew of the fast rescue craft of the *Sandhaven*, all of whom but Mr I Letham perished at the time of the rupture of the MCP-01 riser as I have described above. Through the efforts of the various FRCs 45 of the 62 survivors were directly recovered, either from the platform or from the sea immediately around it.

9.35 The weather conditions for the use of rescue craft in the recovery of survivors were fortunately favourable during the evening of 6 July. However the Inquiry heard that it is practicable for FRCs to be used for the recovery of survivors in wind speeds up to 35 knots, and that such craft can be used in a force 9 gale. The real limitation lies in whether the craft can be safely launched from or recovered by the parent vessel. It was said that the launching of the FRC of the *Tharos* would not have been hazardous for the crew until the wind reached force 8; whereas the Captain of the *Loch Carron*

said that launching was difficult in winds of more than force 5. His view was that launching and recovery procedures were inadequate.

9.36 The Inquiry heard some criticism to the effect that more FRCs could and should have been put into use. A particular instance was the FRC on the *Maersk Logger*, the crew of which, it was said, appeared to be too busy dealing with survivors to launch it. I do not consider that the evidence at the Inquiry bears out this criticism. I have already recorded that at about 22.18 hours the master of the *Tharos* instructed vessels in the vicinity of the platform to launch their FRCs. There was also evidence from the master of the *Silver Pit* that sometime within the first half hour after the initial explosion he sent a message on the radio for shipping to put out their rescue boats. Subject to the instructions received from the vessel in charge of the search and rescue operations, it was for the master of each vessel to use his facilities to the best advantage. I do not consider that there was any evidence of failure in this respect. The master of the *Loch Carron* also referred to difficulties experienced in communications between FRCs and the parent vessel and advocated the adoption of a helmet containing a radio, such as is used by the RNLI. Other evidence supported the installing of fixed radios in the FRCs.

9.37 Some witnesses said that FRCs should be better protected against explosion either by being diesel powered or by having the fuel tanks located under the deck. However it is clear that neither of these things would have made any difference to the fate of the FRC of the *Sandhaven*. Other evidence suggested that the crew should be better protected against fire and debris.

9.38 The method for recovering survivors and for transferring them to other vessels was not ideal. In the circumstances survivors had to be dragged into the FRCs as quickly as possible. It was said that it was difficult to put men aboard a vessel from an FRC in seas over 4 ft. While these factors did not cause any problems at the outset when the survivors were relatively uninjured, they caused distress when the more seriously injured survivors were being handled.

9.39 A number of FRCs broke down during the course of the evening. At one point the FRC of the *Tharos* appeared to lose power and headed back to the parent vessel where it was lifted out of the water for attention to the fuel supply. The FRC of the *Sandhaven* moved in to take its place. Had this problem not occurred the FRC would probably have remained at the platform picking up survivors. It was subsequently used to transfer survivors from the *Silver Pit*. The coxswain of the FRC of the *Loch Shuna* gave evidence that for some time its engines had not been working well, although attempts had been made to rectify this. During the evening the crew found that the engines were not fully operable.

9.40 During the evidence as to the recovery operation the Inquiry heard that problems were caused by vessels having to investigate orange-coloured objects in the sea in mistake for life-jackets. The use of a specific colour for life-jackets was advocated.

The Silver Pit

9.41 According to her master the allocation of a particular vessel for standby duties was a matter for agreement between her owners and operator. The deployment of the vessel was decided by the OIM of the installation, with whom the master had no more than radio contact. Until the time of the disaster he had seen the role of his vessel in terms of ordinary evacuation procedures or the rescue of men who had met with an accident.

The conduct of the master and crew

9.42 At an early stage in the evidence given by the survivors there were a number of criticisms which I must examine at this point. The navigation of the vessel in its

approach to survivors in the water was criticised. It was said that the master found it hard to approach the survivors while taking care not to let the propeller come close to them. The wind and tide often made the vessel drift away. Although the vessel appeared to be trying to stop up-wind of the survivors and drift down-wind towards them it was never actually coming alongside them. In my view these comments arose out of the lack of manoeuvrability of the vessel both in itself and in the condition in which it was on the night. I am satisfied that the master was doing his best in what were difficult circumstances. A number of witnesses complained of a lack of co-ordination or leadership on board the *Silver Pit*. The master appeared to be over-worked and needed someone to back him up. The demands on the crew were more than they could meet. Much of the organisation, initial assistance, care and transfer of the injured was undertaken by the diving team among the survivors who were more familiar with the sea than the others. It was also said that those who endeavoured to operate the VHF radio did not appear to know the correct procedure. In considering these complaints it is only right to bear in mind that the crew of the *Silver Pit* consisted of 9 persons; consisting of the master, mate, chief engineer, second engineer, cook and 4 deckhands. The master was constantly on the bridge. The chief engineer was in the engine room. The second engineer was acting as medic and was in the sick-bay. The cook was supplying hot soup and tea for survivors. The mate was giving help where he could; and the deckhands formed the crew of the FRC. The master and crew of the *Silver Pit* found themselves confronted with a situation in which on the one hand the vessel required to take part in the rescue of survivors and supporting its FRC for that purpose; and on the other hand to deal with 37 survivors, a substantial number of which were seriously injured. I agree with the view which a number of survivors and others expressed that the crew showed great courage in maintaining a position close to the platform and that they did their best to cope with the handling of the survivors. On the other hand it is clear that for the actual job which they had that night the crew were seriously under-manned. Further, I consider that the crew should have been better trained in order to have the technical and practical skills required for responding to an emergency situation, and in particular one involving large numbers of survivors for which their vessel was theoretically able to provide accommodation. In saying that I do not place any responsibility for those deficiencies on the master.

Inherent capability for the rescue of survivors

9.43 The difficulty in the manoeuvring of the *Silver Pit* was due mainly to her inherent characteristics. Converted trawlers have good sea-keeping qualities with low freeboard, open deck space and large internal space. Against that, they are old and of limited manoeuvrability because of having single screw propulsion. If thrusters have been added, as in the case of the *Silver Pit*, they tend to be under-powered and of use mainly in the harbour. Their restricted visibility and high windage makes it necessary to approach survivors drifting down-wind, beam on, which is a slow process. The master is the only person on the bridge. Hand steering is normal. The *Silver Pit* was a typical converted trawler. Its weak bow thruster did not prove very effective when turning up to the wind. At the time of the disaster it worked in any event for only 5 minutes before breaking down. Unfavourable comparisons were made between converted trawlers such as the *Silver Pit* and larger and more modern vessels, such as supply vessels, which are used for the purpose of standby duties. These would have been preferable because of their larger size, greater manoeuvrability with the assistance of thrusters and better behaviour in rough weather. Vessels such as the *Silver Pit* were described by some witnesses in evidence as being no more than "a token gesture" by operators, "a necessary evil" in order to satisfy the legal requirement for a standby vessel. I am entirely satisfied that in the above respects the *Silver Pit* was essentially unsuitable for the purpose of effecting the rescue of survivors. I am also satisfied that this led in a number of instances to distress and delay in the process of recovering survivors.

The state of the vessel

9.44 In a number of significant respects the state of repair of the *Silver Pit* left much to be desired:

- (i) The searchlight was not working. There were no searchlight bulbs on the vessel and the master believed that the wiring might also have been defective. The master had discovered this after the vessel had sailed. He had had 2-3 hours notice of sailing and clearly relied on the owners as regards the state of maintenance of the vessel. The normal procedure for the reporting of an item was to put it on a list before the vessel came into port. The master said that there was a lot of repair work on those vessels. "They are old ships and they do tend to have a lot of breakdowns". In place of the searchlight the crew used an Aldis lamp to try to locate persons in the sea. The lighting could not in any event cover the full 360° around the vessel.
- (ii) As stated above the bow thruster ceased to function about 5 minutes after the initial explosion.
- (iii) When an attempt was made to open a gate in the side of the vessel the gate fell off.
- (iv) An unsuccessful attempt was made to start the DOTI boat. This boat had no facilities to start it and was unserviceable. In any event there were no davits for launching it. (However it should be pointed out that in evidence the master and mate said that they did not consider that this inflatable boat was suitable for launching even if it could have been started. Its vulnerability would create additional risks to those who are picked up. The heat from the fire on the platform had caused blisters on the flotation sections which could be punctured so causing the boat to sink.)

Facilities for the reception and treatment of survivors

9.45 Difficulties were encountered in getting survivors, especially those who had been badly burned, on board. Scramble nets had been placed on the sides of the vessel but they were not properly secured and sagged into the water. Although there was adequate assistance from those on the vessel it was an agonising experience for the injured to clamber up the nets. The ropes attached to the life-rings were of unsuitable length and diameter for rescuing survivors in the water. There was only one boat-hook available. The movement of injured men on the vessel also caused difficulty and distress. In particular it was difficult to get injured men past some of the bulkheads and into the forecastle where there were mattresses. It was also difficult to get stretchers up and down stairs to the aft deck for evacuation by helicopter. Some of the men were in agony when they were moved. From this evidence it was plain that the layout of this converted vessel was by no means satisfactory for the reception and handling of the injured.

9.46 The second engineer who was acting as medic on the night of the disaster had undergone a 2-day certification course of first-aid approved by the DoT. He had also attended a course on the care of survivors which was approved by the DoT. It should be added that at least 2 other members of the crew had undergone the first-aid course. The medic was continuously at work attending to the injured. His performance won well-deserved praise. He was assisted by members of the dive team who helped in moving the injured and attending to those in shock and with severe burns. The medical supplies on board were in accordance with the requirements of the DoT. However, the medic found that they were not adequate in respect of supplies for the treatment of burns such as bandages. There was no saline drip. Further the sole pain-killers on board were a personal supply of paracetamol which the medic had with him. In the master's cabin in a locked box was a supply of morphine. However there was only enough for a few injections. Only the master could administer it and he could not leave the bridge. As a result the morphine was not used. One survivor explained that

in view of his injuries the FRC which held him had been lifted out of the water and on board. He was then taken below on a stretcher which tilted on the way. Although he had a crushed vertebra and a broken leg the only pain-killers he could be given were the paracetamol tablets. He was taken by helicopter to the *Tharos* and given medical treatment there. It was also found that there were insufficient warm clothes, blankets and hot drinks. Problems and distress were encountered in the movement of men by stretchers to the *Tharos*. The medic did not know that a more suitable type of stretcher for this purpose was stowed at the forward end of the vessel. The most seriously injured men had been put in cabins and it was extremely difficult to manoeuvre them in and out.

The inspection of the Silver Pit by the Department of Transport on 21 December 1987

9.47 The *Silver Pit* was inspected by Mr E Hutchison, a Nautical Surveyor in the Marine Directorate of the DoT, on 21 December 1987 under the Merchant Shipping Act 1970. At that time the *Silver Pit* had been granted a certificate for operation as a SBV until 11 May 1988 but the Chief Surveyor had information that the vessel was not in a position to fulfil that role. At the time of his inspection the vessel no longer had a launching davit on the starboard side for the FRC, which was not on board, and difficulty was being experienced with the hydraulic mechanism for the operation of the port davit. This had led to the vessel returning to port. The reason for the collapse of the starboard davit had been two separate weld failures. Mr Hutchison also found that 4 types of lights on the vessel were absent or inoperative. The master and the company's representative were informed that it was proposed to recommend withdrawing the certificate of suitability. Some of the deficiencies were rectified on the day of inspection and a letter of compliance was issued with some of the deficiencies outstanding.

9.48 Mr Hutchison said that the deficiencies in the vessel which were said to be present on the night of the disaster were not present at the time of his inspection. He would have expected to pick them up. For example at the time of his inspection the searchlight was working. He confirmed that the vessel should have had a working searchlight and that the DOTI boat should have been maintained in a condition so that it could be launched immediately.

The Tharos

9.49 The presence of the *Tharos* on the evening of the disaster was fortuitous. So too was that of the anchor haulers such as the *Maersk Cutter*. There was no legal requirement for the availability of a vessel for fire-fighting, let alone rapid intervention for that purpose. The *Tharos* and the *Maersk Cutter* were unable to arrest the development or reduce the intensity of the fire on Piper. It was abundantly clear from the evidence that fire-fighting with water has no effect on a fire which is fed by gas escaping under high pressure from a riser. The master of the *Tharos* also said in evidence that when it came to the well-kill operation in the aftermath of the disaster he was personally surprised by the lack of effect which the fire monitors had on the wellhead fires which were relatively small in comparison to the fires on the night of the disaster. Following discussion with 'Red' Adair they agreed that the only effective method of extinguishing large hydrocarbon fires was to remove the source of combustion. On the other hand numerous survivors spoke of the beneficial effect of the spray from the *Tharos* monitors in providing some cooling and keeping down smoke. One of the survivors said that had it not been for the *Tharos* spray he did not think that he would have been able to get out on to the pipe deck and hence escape from the platform. The *Tharos* also had a valuable role as a communications centre and as a place for the reception and treatment of survivors. However during the survivors' evidence a number of criticisms of the *Tharos* were advanced and to these I must now turn.

Criticisms of the Tharos

9.50 It was said that the *Tharos* should have been brought into action more quickly. To increase its speed its anchor cables should have been cut. In any event her dynamic positioning system should have been used in conjunction with 2 of her anchors in order to enable the vessel to be manoeuvred close to the platform. It was also pointed out that initially the spray from her monitors fell a long way short of the platform and then died down. Her heat shield should have allowed her to come in close to the platform where the gangway should have been deployed for rescuing personnel from the platform. She did not stay close to the platform for long enough to fight the fire, and moved away when men needed to be picked up from the water. If she was unable to rescue men directly from the platform they should have been told to get off. Instead some waited for her to come in; while others vainly attempted to attract her attention by waving towels. One of the survivors said "If they had said they could not get in to help us some of the guys in the accommodation would have found their own way out."

9.51 In connection with this evidence I was reminded of the radio message received by the *Tharos* at 22.33 hours: "People majority in galley area. Tharos come. Gangway. Hoses. Getting bad." My attention was also drawn to a number of statements about the capability of the *Tharos* in *Oxy Today*, No 15, which was issued by the Occidental Petroleum Corporation in 1981. This publication contains a number of statements about the *Tharos* including the following:

"Like a semi-submersible rig, the *Tharos* has great stability in rough seas. Sophisticated dynamic positioning permits it, by virtue of a computer link to 4 motors, to remain on station, perhaps over a damaged pipeline section while maintenance is being carried out, or beside an oil production platform during an emergency. Primarily the vessel is designed to fight fires, kill wild oil wells and provide support and hospital facilities during any offshore emergency. Its water cannon can throw 40,000 US gallons of water per minute over a horizontal distance of 240 ft. A 62 ft bridge enables personnel to walk on to a stricken installation to work on a fire or blow-out. About 20,000 gallons of water a minute can be piped to a platform to assist any fire-fighting teams which are still aboard in the event the platform's own water pumps happen to be shut down In the event of a platform evacuation, communications with the shore, standby vessels, helicopters and HM Coastguard would be sustained from a protected communications center which carries radio, telephone, telex and computer links."

In the same publication 'Red' Adair, who is described as having helped in the design of the *Tharos*, is quoted as saying that for fighting offshore fires "the *Tharos* is the best solution to date. Second to having a stable platform, powerful water cannon are needed to keep a flaming platform cool and protect the platform from literally melting away." The editor of the *Oil and Gas Journal* was quoted as saying that "the people on the Claymore and Piper fields can certainly now sleep a little bit more safely at night." A number of survivors said that the *Tharos* could not do what it was claimed it had been designed to do. The vessel was referred to as "the most expensive white elephant in the North Sea".

The capability of the Tharos

9.52 It is clear that the *Tharos* was designed to fulfil a number of functions, one of which was that of a fire intervention vessel. The others, as described in his evidence by Mr K R Wottge, Occidental's Facilities Engineering Manager, were the functions of a diving inspection/construction vessel, an intermediate lift crane barge, a construction support floatel, a first-aid/hospital vessel and a well-kill/plugging support vessel. The master of the *Tharos* said in evidence that she had never been designed to be a rapid intervention vessel, which normally was a supply vessel with a fairly high speed and fitted with fire monitors. Her intervention would be expected to take place after the initial evacuation of personnel by lifeboats, helicopters or a standby vessel. He pointed

out in that connection that the high volume of water which the vessel was capable of delivering could not be used when personnel were still on the platform because of the risk of causing injury to them as well as structural damage to the platform. During the course of the evidence it was also pointed out that the gangway, which had been fitted to the fire boom after the 1984 incident, was made of aluminium and accordingly was unsuitable for deployment in close proximity to an intense hydrocarbon fire.

9.53 While I have no difficulty in accepting the evidence which I have referred to in the last paragraph as reflecting the real sense in which the *Tharos* was able to act as a fire intervention vessel, I am left with a clear impression that there was misunderstanding as to what it was capable of doing in the face of an outbreak of a major hydrocarbon fire no more than 500m away from it. This was reflected in the evidence of survivors and in the evidence as to the radio message received by the *Tharos* at 22.33 hours. The master rightly decided not to persist in his attempt to land the gangway on the platform. He said in evidence that he did not hear of the message received from Piper at 22.33 hours until about 1-1½ hours later, but it is clear that this did not influence his decision. I doubt whether it would have been practicable for the *Tharos* to have sent a message which was capable of being received by those who were in the accommodation after that time. However the OIM on Piper should have known what was the true position and disabused those who waited of their mistaken hopes.

The movement of the Tharos

9.54 The response of the *Tharos* to the initial explosion was immediate. Control was switched from the forward to the aft control room. The chief engineer went to start the fire pumps; and the positioning operator was instructed to commence moving the vessel towards the platform. As stated earlier, she started moving at about 22.05 hours. Having regard to the way in which she was anchored and the depth to which she was ballasted her potential speed was much less than her normal transit speed and amounted to about 2½ knots. However this was not attainable in the comparatively short distance through which the vessel travelled towards the platform. The automatic positioning system kept the vessel heading square on to the west face. Manual adjustments were made to port and starboard to allow for the effects of wind, tide and anchors. One of the first mates had the responsibility of keeping the correct tension on the winches which were paying out the anchor cables. As stated earlier, thruster phase-out was occurring from time to time as the maximum power generated was not quite sufficient to keep all systems functioning. This reduced the speed of the vessel from time to time but did not affect the pumps or winches. The vessel proved difficult to manoeuvre near the platform because of the effect of the anchor cables, the bad visibility caused by the spray and the smoke blowing over the platform. The master had considered jettisoning the anchors but decided that this would take too long, although precautions had already been taken to provide equipment ready to cut the cables if required. Likewise there was not enough time to set up the dynamic positioning in the way suggested by one of the survivors. Taking into account the inherent characteristics of the vessel I am satisfied that there was no fault as regards the speed with which the vessel approached the platform. Further I do not consider that there is any good ground for criticism of the master for his decision, in the exercise of his responsibility for the vessel, to pull back from the platform in face of the explosion at 22.50 hours.

Fire-fighting from the Tharos

9.55 It was clear to me from the evidence that the crew immediately responded to the initial explosion by making preparations to fight the fire. All the pump motors were lined up by 22.05 hours. There was however a delay of about 12 minutes in the cascade coming into operation, for the reason set out earlier in para 9.20. While this made no difference to the time at which the cascade was brought to bear on the platform and the personnel who were still on it, this must have reduced the relief and protection given to the rescue vessels and those in the water between the *Tharos* and the platform. This appears to have arisen from an over-enthusiastic attempt to bring

the monitors into operation. It was stated in evidence that the monitors were tested every month. However proper training in the procedures should have ensured that the monitors were not allowed to discharge prematurely. This is a matter which could have been, and no doubt since the disaster has been, put right. I should add for the sake of completeness that difficulty was encountered with the starting of one of the fire pumps. However I accept the evidence which was given that this of itself played no part in either delaying or reducing the amount which the *Tharos* was able to cascade.

9.56 The Inquiry heard that from the stage when the *Tharos* was able to bring her cascade to bear upon the platform the crew had difficulty in judging where the spray was landing to the extent that another vessel was asked to report to the *Tharos* where the spray was landing. It was suggested that this evidence suggested of itself lack of training in the use of the monitors. However I interpret it as indicating the difficulty was caused by the obscuring effect of the fire and smoke on the platform. I see no grounds to find fault with the manner in which the cascade was used.

9.57 It was also suggested that a rapid intervention vessel (RIV) should have been on the scene. This ignores the fact that the *Maersk Cutter*, although it was in attendance as an anchor handler for the *Tharos*, was immediately involved in the use of its monitors on the east side of the platform. In any event her fire-fighting capability made no difference to the intensity or escalation of the fire. Accordingly in the case of the Piper Alpha disaster the presence or absence of an RIV was irrelevant.

The care and treatment of the injured

9.58 The Inquiry heard certain criticisms relating to the transfer of the injured to the *Tharos*. It was said that it was a long time before the injured who required medical attention were taken there; and that the basket and crane method of transfer from vessels to the *Tharos* was not suitable for those who were injured. On board there was, according to Dr Strachan, Director of Aberdeen Industrial Doctors, a degree of confusion in the sick-bay, with almost as many helpers as there were casualties. Mr A Matheson, Senior Consultant in the Accident and Emergency Department of Aberdeen Royal Infirmary, who headed the Offshore Specialist Team, said that though there had been a degree of confusion, the medical arrangements had gone as smoothly as could reasonably have been expected. I accept that this was so.

Occidental and Grampian Police

9.59 At 22.03 hours the *Tharos* informed Occidental in Aberdeen that there had been an explosion on the platform. This information was received by the Occidental Communications Officer who initiated a cascade call-out system in accordance with the laid down procedure. He also initiated a lesser call-out which was carried out by security guards at the security lodge. For this purpose the information given to the guards was that a major emergency had occurred offshore. At that time it was the practice that no further detail should be given to or issued by them. This series of calls was completed between about 22.12 and 22.21 hours. The first call in this was to police headquarters. The call was made on a dedicated direct exchange line between the security lodge and the police. The call was received by the police at 22.08 hours. The security guard who made the call followed the normal procedure by informing the police that a major emergency had occurred offshore. The police officer concerned then used the same line to telephone back to Occidental to authenticate the first call. This was a standard procedure in order to eliminate the risk of a hoax call.

9.60 In response to the cascade call-out senior Occidental personnel arrived at headquarters and manned an Emergency Control Centre there. Mr J L MacAllan, the Production and Pipeline Manager, was the first to arrive at 22.21 hours. Mr J B Coffee, as Vice-President Operations was the Onshore Emergency Controller. However as he had only recently been appointed to take responsibility for operations in the North

Sea he had to rely on the advice of senior personnel in co-ordinating the response. He was supported by the Vice-President Engineering, and the managers of the Production and Pipeline, Transport, Marine Operations, Loss Prevention and Drilling Departments. Mr MacAllan made a series of attempts to make contact with Piper and Claymore without success. He was eventually able to speak to the OIM of Claymore by the satellite system and had a conversation with him, as I stated in para 7.39. A plan was devised to send a team to the *Tharos* to assist in fire-fighting and rescue. The team, which included members of Grampian Fire Brigade, was flown out to the *Tharos* at 04.40 hours on 7 July but when they arrived they found that there was little left of the platform. In the light of the evidence which I heard I have no reason to consider that there was any material failure in Occidental's procedures for calling out senior personnel: or that Mr Coffee's lack of experience affected the security of emergency facilities.

9.61 The next step which the police were to take in carrying out contingency plans for emergencies was to send an inspector as a liaison officer to the emergency control centre of the operator. However it appears that this was delayed as a result of a desire to obtain more information as to the nature of the emergency. According to the evidence of Chief Inspector I Gordon who was concerned on a full-time basis with offshore emergency procedures and the contingency plans of the police and operators, the police tried to telephone Occidental 2 or 3 times between 22.20 and 22.40 hours but found that there was either no answer or the line appeared to be engaged. However, according to Occidental's Head of Telecommunications in the North Sea, Mr A G McDonald, the dedicated line to the security lodge was manned by a guard during this period. Numerous other telephone lines passed through the public exchange, but these had all been monitored and in every case but one the call had been answered. There was one additional dedicated line but that was in an office at the Occidental headquarters which was for the use of the police liaison officer when he arrived. Between 22.20 and 22.40 hours no attempted calls to Occidental headquarters were recorded in the police log. They would have been recorded in the police teltag system but a print-out was not available to the Inquiry as evidence since the records were destroyed some 6 months after the disaster. In these circumstances I am not satisfied that the police used the dedicated line or that there was any neglect on the part of Occidental in responding to any call from them at this stage.

9.62 In the meantime the police received telephone calls from the media asking them for confirmation of reports of an explosion on Piper and saying that the coastguard had informed them that they were not able to take press calls at that time. According to the contingency plan the coastguard should inform the police of an incident immediately and the police should be informed as to the installation involved, the nature of the incident and the casualties. It is obviously important that the police should have such information at an early stage. The police called the coastguard on a direct line and were told that the coastguard was busy and would call back in a few minutes. When the coastguard did not do so the police called the coastguard again. This was about 22.40 hours. At that stage the police were advised by the coastguard that they had received reports of an explosion on Piper. There were no reports of fire or casualties but it was said that a Nimrod and at least 6 helicopters had been scrambled in an effort to evacuate personnel from the platform. At this stage Mr Gordon became involved and a sergeant of Grampian Police, who was more readily available, was sent to Occidental headquarters to provide liaison with Occidental and establish the facts. At the same time another police officer was sent to the coastguard as a liaison officer.

9.63 At about 22.55 hours the police set up a major incident room for casualty enquiries, which was served by 12, later 24, telephone lines. The state of confusion as to what had happened prevailed even after 23.00 hours. At 23.10 hours when Chief Inspector Gordon spoke to Mr D A Miller, Occidental's Security Manager, who was then with the sergeant serving as the liaison officer, Mr Miller advised him that he had been told that "it was a diving accident", in response to which Chief Inspector Gordon said that he was rather surprised if this was the case as the police had been

told by the coastguard that a Nimrod and at least 6 helicopters had been scrambled. At 23.20 hours the coastguard provided more information about the disaster to the police, as a result of which the police called out trained casualty documentation teams. At 23.47 hours the first information on casualties reached the police. After midnight the Occidental liaison representative arrived at police headquarters. At 00.45 hours the police received from Occidental a list of the persons who had been on board Piper. This was not entirely accurate as it included 7 persons who had moved from Piper to the *Tharos* some hours before the disaster. Further, the list was not in a form which was entirely helpful in respect that the names were arranged alphabetically within the companies represented on the installation. The significance of these points can be appreciated when it is understood that one of the tasks of the police was to advise the next of kin of any person who has died and to advise if a person has been injured. In the course of the night the police required to deal with numerous enquiries from relatives. Police officers were sent to Aberdeen airport and the helipad at Aberdeen Royal Infirmary where the uninjured and the injured, respectively, were landed by helicopter. Details of the passengers and their medical condition were relayed to the incident room at police headquarters. Police officers from the Grampian and other forces were sent out to advise the next of kin of the deceased. This was done within 24 hours of the incident. The tasks undertaken by the police were considerable. The Inquiry heard that 174 officers of Grampian Police were involved in work arising out of the disaster during the first 24 hours after it began.

9.64 Since the disaster the police and operators have given further consideration to emergency communications and procedures. This has resulted in a booklet prepared by the police and approved by the United Kingdom Offshore Operators Association Ltd (UKOOA) in July 1989. In accordance with that procedure the police will send a liaison officer to the operator on being informed of a "major offshore emergency". However in the light of the reasons set out in the booklet as to why the police require to be told of the nature and location of incidents it is hoped by the police that in future operators would give more information than that.

Chapter 10

The Causes of Loss of and Danger to Life

Introduction

10.1 In this chapter I will describe and comment on the recovery and examination of bodies of the deceased. I will give my findings as to the medical causes of death where these are ascertainable. I will also set out my conclusions as to factors which contributed to the deaths of the deceased and the risks to which the survivors were exposed in the disaster.

The recovery of bodies of the deceased

10.2 Late on 6 July rescuers recovered an injured person from Piper who later died from his injuries in hospital on 19 July. On 7 July the bodies of 15 deceased persons from Piper were recovered by various vessels from the surface of the sea at and around the remains of the platform; and the bodies of 2 members of the fast rescue craft of the *Sandhaven*.

10.3 In the period after 7 July the Marine Department of Occidental was responsible for the location and recovery of bodies, in addition to the examination of the platform jacket and the identification of debris on the seabed. At the time of the disaster the *British Magnus* was on its way to carry out underwater survey work, including the use of remotely operated vehicles (ROVs), for which it was then fully equipped. As a result of the co-operation of BP, Occidental were successful in obtaining the services of this vessel for the initial survey and recovery work. A series of side scan sonar sweeps and ROV excursions around the platform were carried out. Surveys were carried out in grids of 10m², with the intention of attempting to cover each square twice. As a result of this work between 10 and 29 July a further 27 bodies from Piper were recovered from the seabed.

10.4 On 4 August the *British Magnus* was demobilised in order to proceed to her original work for BP. On 8 August the *Seaway Condor*, a diving support vessel, took up the survey work which had previously been done by the *British Magnus*. As from 10 November 2 fishing vessels, the *Heather Sprig* and the *Janeen*, were used to trawl in a wider area for debris and any human remains which had not been located previously. Arising out of this work 4 bodies were recovered between 15 August and 17 October; and a further 6 between 31 October and 22 November 1988.

10.5 The last body to be recovered from the seabed was found on 2 June 1989.

10.6 Early on in the survey work the ERQ and the AAW of the platform's accommodation had been located in the seabed. The ERQ was resting upside down. It was also found that the LQW was in a disintegrated condition on the seabed. It was found that the ERQ contained a considerable number of bodies. In September 1988 7 bodies were recovered by divers from its galley. Preparations were made for the lifting of the ERQ and the AAW from the seabed. This involved a difficult operation and called for considerable resources of equipment and manpower. On 10 and 15 October 1988 the AAW and the ERQ were raised from the seabed. Thereafter they were taken to the Occidental terminal at Flotta for examination. Later in October and in November 1988 a total of 74 further bodies were recovered from the ERQ, 70 from D Deck and 4 from A, B and C Decks. No bodies were found in the AAW.

10.7 From the above it will be seen that 16 of the deceased from Piper were recovered from the surface of the sea; 38 were recovered from the seabed; and 81 were recovered from the ERQ. 30 persons from Piper remain missing and should be presumed to have died on 6 July as a result of the disaster.

10.8 Appendix H to this report contains a schedule of information relating to the deceased, including the 2 members of the crew of the fast rescue craft of the *Sandhaven*. That schedule sets out information as to the recovery of the body of the deceased where this was achieved. In the case of those missing and those recovered from elsewhere than the wreckage of the accommodation it sets out the last known whereabouts of the deceased in the period from about 22.00 hours on 6 July in the light of the evidence available to the Inquiry.

10.9 It was found that of the 135 bodies from Piper which were recovered, 66 were wearing survival suits; and of the 81 recovered from the accommodation 42 were wearing them. As regards life-jackets, the position is unknown in regard to the bodies which were recovered on 7 July, apart from one case in which a life-jacket is known to have been worn. As regards the remaining bodies it was found that a life-jacket was worn in 19 cases.

10.10 In his closing submissions Senior Counsel for the Trade Union Group criticised Occidental's effort with regard to the recovery of bodies in a number of respects. His remarks were directed to the evidence given by Mr D J M May, Senior Engineer for Pipelines and Structures in Occidental's Marine Department. He submitted that when the *British Magnus* was demobilised on 4 August 1988 the search was not complete because during the 4 weeks since the disaster there were, in the words of Mr May, "too many things to do and not enough things to do them with". The *British Magnus* was not replaced with a comparable vessel but with the *Seaway Condor* which was not only a less well equipped vessel for such a search but was required in any event to assist in the recovery of the accommodation quarters. This created, in the words of Mr May, "a conflict of goals". Accordingly the *Seaway Condor* could not be released to concentrate on the search for bodies. Counsel submitted that his criticisms were supported by the fact that only a few bodies were recovered between the demobilisation of the *British Magnus* and the start of the trawling operations and by the fact that the results of the trawling operations demonstrated that there were further bodies which could be recovered. He went so far as to suggest that it was possible that more bodies would have been recovered "had the search been continued with the same concentration, expertise and facilities as was provided in the first 4 weeks". However, the evidence shows that the *Seaway Condor* continued the type of search in which the *British Magnus* had been involved. Mr May gave evidence that Occidental had equipped that vessel to standards which were practically equivalent to those of the *British Magnus*. The reference by Mr May to "too many things to do and not enough things to do them with" was in the context of the practical difficulties which had been experienced in carrying out surveys with the ROVs, which initially required to be done on an *ad hoc* basis. His reference to a "conflict of goals" arose from the fact that at the time Occidental wanted to recover the ERQ as they knew that it contained bodies which they could not otherwise recover. They also suspected that there were bodies in the AAW. He also pointed out that the work required to recover the ERQ precluded survey work in the area of the ERQ and a large area around it. This meant that Occidental could not survey the most important area on the seabed which the *British Magnus* had not surveyed. It is also reasonably clear from the evidence that as a result of the combined work of the *British Magnus* and the *Seaway Condor* a large area surrounding the platform was surveyed, and in most instances twice. At the time when the trawlers were put into operation there was no obvious deficiency in the scale of the work which had been done with a view to the recovery of bodies. That was not inconsistent with their realisation that it was possible that further bodies might be recovered in the trawling operation which was to cover a still wider area. In my view the criticism of Occidental in these respects was misconceived. I do not consider that Occidental failed to take any steps which they should reasonably have taken in the light of the information available to them and the whole work of survey and recovery in which they were involved.

The Post-mortem Examination of Bodies

10.11 Appendix H sets out the principal cause of death, where that has been ascertained, of those whose bodies were recovered. In paras 10.11-10.18 they are

identified by the numbers shown against the names in that Appendix. The deceased from Piper and the *Sandhaven's* fast rescue craft were examined by a team of pathologists under Dr W T Hendry, then Head of the Department of Forensic Medicine in the University of Aberdeen, with the exception of the deceased (No 14) who was recovered alive on 6 July but died later from extensive burns; and the deceased (No 84) whose remains were recovered on 2 June 1989.

10.12 As regards the bodies recovered at sea on 7 July 1988 the post-mortem findings were as follows. The 2 members of the crew of the FRC (Nos 10 and 146) were found to have died by drowning. They also showed patchy superficial burning of the face. As regards the 15 deceased who had come from Piper, 8 of them had apparently died during an attempt to escape from the platform. Of that group 5 (Nos 28, 53, 64, 99 and 109) had died by drowning, showing also superficial burns of the face, possibly sustained by contact with burning oil in the water. The remaining 3 (Nos 40, 95 and 131) had died by chest injury, essentially fractures of the ribcage combined in varying degrees with injury to the lungs, heart and liver. In Dr Hendry's opinion, those injuries were typical of the result of impact with water after a descent from a considerable height when the victim struck the water in other than a feet-first attitude. The remaining 7 deceased had apparently died on board from the effects of the fire. Of this group 6 (Nos 4, 22, 27, 49, 122 and 156) had died from the inhalation of smoke and gas. This finding was based on the presence of a sooty deposit in the airways and confirmed by analysis of blood samples for the presence of carbon monoxide which is the most important toxic gas produced in fires. In these cases the carbon monoxide content varied from 71% to 89% saturation of the blood. In the case of fire victims it is usually accepted that a level of 50% or greater indicates that death was essentially the result of the inhalation of smoke and gas. In 4 cases there were varying degrees of post-mortem heat injury, 3 showing major post-mortem injury. In the seventh case (No 67) there was evidence of both significant inhalation of smoke and gas and a necessarily fatal open abdominal injury along with post-mortem heat damage. The injury in that case was consistent with the victim striking, or being struck by, a penetrating object.

10.13 Of the 27 deceased whose bodies were recovered from the seabed between 10 and 29 July, 4 of them (Nos 33, 43, 73 and 141) had apparently died during an attempt to escape from the platform. In each case it was considered that they had drowned. This diagnosis was not based upon positive evidence to that effect because the bodies had been exposed to pressure at depth. It was presumed in the absence of injury and heat damage, together with a low blood level of carbon monoxide. The remaining 23 deceased had died apparently on board the platform. 14 of this group (Nos 26, 66, 68, 98, 105, 114, 127, 134, 140, 144, 145, 157, 161 and 163) had died from inhalation of smoke and gas, the levels of carbon monoxide in the blood varying from 63% to 93%. Several of them showed minor heat damage and some degree of injury. 2 of the deceased (Nos 162 and 164) presented severe damage by heat and were regarded as having died in the fire. 3 (Nos 19, 44 and 152) had a blood level of carbon monoxide varying from 43% to 47% and were regarded as having died from inhalation of smoke and gas. The remaining 4 deceased (Nos 45, 56, 75 and 160) were found to have suffered major visceral injuries involving the heart or a main vessel, 3 showing signs of the inhalation of carbon monoxide, in one case at a level of 48%. These injuries suggested that the victims had sustained impact following motion as in a fall or projection by blast.

10.14 Of the 4 bodies recovered between 15 August and 17 October the first 2 presented difficulty of interpretation due to greater post-mortem change. As the samples of blood which were taken from them were seen to be decomposed it proved necessary for them to be sent to the Department of Forensic Medicine and Science, Glasgow University, where more sophisticated laboratory equipment was available. As a result of analysis by that equipment it was found that in one case (No 104) there was a 72% concentration of carbon monoxide which confirmed death had occurred by inhalation of smoke and gas. In the other case (No 39) a result could not be

obtained. Accordingly all that could be said was that the latter victim died in a fire since the remains showed only post-mortem heat damage and no injury. The third body (No 72) which was found showed no evidence of primary injury or heat damage. The carbon monoxide level was later found to be 86%, which confirmed death by inhalation of smoke and gas. The fourth body (No 154) was the subject of a presumptive diagnosis of death by drowning because there was no evidence of heat damage to the body or injury and the carbon monoxide level was only 17%.

10.15 As regards the 6 bodies recovered between 31 October and 22 November 1988, death was ascribed in 4 cases (Nos 42, 121, 130 and 133) to the inhalation of smoke and gas, the blood carbon monoxide levels varying from 21% to 84%. There was no evidence of injury. In the fifth case (No 7) there was no evidence of burning or injury and it was considered that death had been due to drowning. In the last case (No 38) there was insufficient material on which to base an opinion.

10.16 In the case of the body which was recovered on 2 June 1989 (No 84) it was found that there was insufficient material on which to base an opinion as to the cause of death.

10.17 All of the bodies which were recovered from the galley of the ERQ in September 1988 showed post-mortem change but no sign of injury or heat damage. The diagnosis of the cause of death depended almost entirely on the results of the blood analyses which were later received from Glasgow University. In 3 cases (Nos 54, 107 and 126) the relevant levels varied from 39% to 69%. It was considered that death in these cases was due to the inhalation of smoke and gas. In a further 2 cases (Nos 15 and 86) the levels were 22% and 21%. It was interpreted that they also had most probably died from inhalation of smoke and gas. In the remaining 2 cases (Nos 91 and 147) the cause of death was not ascertained because the relevant level was reported as being only 13%.

10.18 As stated earlier 70 bodies were recovered from D Deck of the ERQ at Flotta (Nos 1, 2, 3, 5, 8, 11, 16, 17, 18, 20, 21, 23, 25, 31, 32, 34, 35, 36, 37, 46, 47, 48, 50, 51, 52, 57, 63, 69, 70, 71, 76, 77, 78, 79, 81, 82, 85, 87, 88, 89, 90, 92, 94, 97, 100, 101, 102, 103, 106, 110, 111, 112, 116, 117, 119, 120, 123, 128, 129, 132, 135, 137, 138, 142, 148, 151, 155, 159, 165 and 166). It was found that in general they were remarkably intact and well preserved in comparison with those recovered from the seabed, despite the long post-mortem interval. Evidence of fire damage was seen in only 10 cases and this was limited to localised post-mortem lesions. There were minor post-mortem fractures in 10 cases. A single body (No 151) had sustained major crush injuries after death. In almost every case there was evidence that the victim had inhaled smoke and gas. Analyses of samples of blood and muscle at Glasgow University showed the presence of carbon monoxide in each case, the level in the blood in 56 cases varying from 24% to 93% and the level in the muscle varying in 19 cases from 24% to 83%. In 45 cases a level of 50% saturation or more was obtained. In only 7 cases was the carbon monoxide level less than 30%. Dr Hendry expressed the opinion that the variation in the carbon monoxide blood levels might be explained in some cases by the possible loss of carbon monoxide over a period of time in decomposing or stored blood. On the other hand he said that it had been recorded that carbon monoxide might be formed in the tissues of a submerged body but that this was only minimal in the case of blood specimens. Those considerations apart, he said that it was a well recognised fact that in fatal fires some of the victims were found to have low levels of carbon monoxide in the blood. Those deaths were usually attributed to a deficiency of oxygen or an excess of carbon monoxide in the atmosphere or to a rapid rise in body temperature in a very hot environment. Other toxic gases such as hydrogen cyanide might have been implicated but they could not be detected after any delay. Taking into account all those factors his belief was that it was reasonable to conclude that all the victims in the ERQ died in an irrespirable atmosphere, just as two thirds of them undoubtedly did. It was quite clear that not one of them died by burning. In November 1988 the remaining 4 bodies which had been taken from

Decks A (Nos 41 and 139), B (No 59) and C (No 113) of the ERQ were examined. The findings in these cases were similar to those in the case of the deceased recovered from D Deck. The levels of carbon monoxide in the blood varied from 30% to 65%. No injuries were found but in one case localised post-mortem heat damage had occurred.

10.19 In the light of these findings, which I accept in their entirety, it can be seen that the cause of death was ascertained in the case of 131 out of the 135 bodies from Piper which were recovered. The principal causes of death may be summarised as follows:-

11 of the deceased died by drowning

11 of the deceased died from injuries, including burns

109 of the deceased died from the inhalation of smoke and gas (79 of them having been recovered from the ERQ)

It may be noted that in a total of 14 cases (11 drowning, 3 injuries) the deceased died apparently during or after an attempt to escape from the platform. In all other cases the deceased died on, or apparently on, the platform. Death was caused by burn injuries in only 4 cases.

The deceased from Piper

10.20 Of the total of 165 deceased persons from Piper 23 (including 17 contractors' personnel) were on night-shift duty on the evening of 6 July. The remaining 142 (including 116 contractors' personnel) were off duty. The latter number includes 10 who were on 24 hour call (see para 8.3). These numbers may be broken down by categories of work as follows:-

<i>Category</i>	<i>On duty</i>	<i>Contractors</i>	<i>Off duty</i>	<i>Contractors</i>
OIM	—	—	1	—
Safety	1	1	4	1
Operations	4	2	12	3
Drilling	11	11	27	26
Maintenance	5	3	22	12
Marine & Underwater	1	—	9	9
Offshore Projects	—	—	43	42
Materials	1	—	1	—
Inspectorate UK	—	—	2	2
British Telecom	—	—	3	3
Kelvin Catering	—	—	18	18
	<u>23</u>	<u>17</u>	<u>142</u>	<u>116</u>

It may be noted that 37% of those who had been on night-shift duty died in the disaster; whereas 87% of those who had been off duty did so.

Summary of conclusions

10.21 In the light of the evidence which I have considered in this and the previous chapters I am able to state my conclusions in summary as follows:-

- (i) All those named in Appendix H died as a result of the disaster. They died on 6 July 1988, with the exception of No 14 who died on 19 July 1988.
- (ii) In the case of 133 out of the 135 bodies of personnel from Piper which were recovered it was possible to ascertain the principal cause of death, which was as set out in Appendix H.
- (iii) In the light of the findings as to the principal cause of death it should be inferred that in 14 cases the deceased died during or after an attempt to escape from the platform; and that in all other cases the deceased died on, or apparently on, the platform.

- (iv) The disaster was the result of a series of events which were set in train by an initial explosion in C Module. In paras 6.177-187 I set out my conclusions as to the cause of that explosion. In paras 6.188-192 I made observations as to failures which led to this. This is subject to my further observations in Chapter 14 as to the management of safety.
- (v) The series of events included (a) a crude oil fire which generated heat and dense black smoke which engulfed the accommodation from the outset; (b) a series of explosions; and (c) massive and prolonged fires fuelled by gas under high pressure following the ruptures of the Tartan and MCP-01 risers.
- (vi) The development of the crude oil fire and the damage caused by it were greatly assisted by the fact that the initial explosion had destroyed or disabled the active fire protection system.
- (vii) The size and duration of the crude oil fire and the heat and smoke generated by it were exacerbated by the fact that the Claymore and Tartan platforms did not shutdown production sooner than they did.
- (viii) The ruptures of the Tartan and MCP-01 risers were on the upstream and downstream sides of the respective emergency shutdown valves, thus rendering these valves ineffective for the purpose of isolating the platform from the inventories of the pipelines.
- (ix) The death toll among those in the accommodation was greater than it would have been if the OIM had given instructions that personnel should abandon the accommodation and attempt to escape from the platform by whatever means they could.

SECTION THREE: BACKGROUND TO THE DISASTER

Chapter 11

The Permit to Work System and Shift Handovers

Introduction

11.1 Chapter 6 of this report has already examined the working of the permit to work system and the handover from the day to the night-shift on 6 July. The exploration of these matters led to the revelation of a number of serious deficiencies of which those on 6 July were merely specific instances. In this chapter I will set out some of the more salient shortcomings, together with a brief account of an earlier fatality which is relevant to the discussion. In Chapter 14 I will examine the way in which Occidental management discharged their safety responsibilities in regard to the permit to work system and handovers.

The permit to work system

11.2 A permit to work system is a formal written system which is used to control certain types of work which are potentially dangerous. Within that system the permit is a formal written means of making sure that potentially dangerous jobs are approached and carried out with the use of appropriate safety procedures. It is an essential part of a procedure to ensure that the work is done safely. Safety in this context means the safety not only of those carrying out the work but also of those who may be affected by the carrying out of that work. An examination of the system as it prevailed on Piper for a substantial period up to the time of the disaster raised a number of general questions. It is convenient to set out the results of that examination by reference to the questions which follow below.

Was the Occidental procedure complied with?

11.3 In order to ensure that an effective permit to work system is achieved in practice it is essential that operating staff work exactly to the written procedure which has been developed by the management of the company. The Occidental written procedure was contained in their Safety Procedures Manual, which was a working draft issued in September 1987 in replacement of an earlier manual. So far as the permit to work procedure was concerned the same content but in a slightly different format appeared in a Work Permit Booklet which was produced in 1985 as an up-date of the earlier procedure. However, the evidence at the Inquiry demonstrated that in a number of significant respects this procedure was habitually or frequently departed from. From the evidence a number of examples may be given as follows:-

- (i) The procedure required by section 3.2 that the Performing Authority take the permit to the Approving Authority in person, but this was often not done in practice.
- (ii) An examination of a number of permits to work, which appeared to be typical of recent practice, showed numerous errors in completion of various details which are required under the procedure, such as errors in regard to signatories, the description of work, the carrying out of gas tests, the effecting of electrical isolation and the affixing of red tags, the insertion of dates and times, the completion of declarations and certificates, the deletion of inapplicable alternatives and the details of extensions, suspensions and safety precautions.

It may be noted at this point that Reg 3(3) of the Operational Safety, Health and Welfare Regulations requires that a permit to work should specify "The work to be carried out, the precautions which have been taken to ensure that the work is carried out safely, any particular procedures to be followed or particular equipment to be used or worn, the period for which the permit is to continue in force and the name of the person to whom it is issued."

- (iii) Occidental procedure required by section 3.1 that the precise nature of the task should be set out on the permit by the Performing Authority. It will be recalled from Chapter 6 that when Mr White, the maintenance superintendent, signed the permit for PSV 504 he entered the number and location of the valve on the permit. This necessary information had not been included by Mr Rankin, the Performing Authority.
- (iv) Section D10 of the permit form asked "Is there any other work which may effect (sic) this work?" (see Fig 3.9). This section was seldom used. At most it might be ticked but no detail supplied as to the work or its effect.
- (v) Section 3.3 of the procedure provided that the Designated Authority was to mark section E of the form showing the protective equipment required, stating "These are not suggestions, they are demands to ensure the personal safety of the people performing the work ...". On the other hand at a safety meeting on Piper in September 1987 those who were present were reminded that the responsibility for completing that section was that of the Performing Authority. However this was not brought to the attention of Mr C Lockwood, an experienced lead production operator, who explained the working of the permit to work system at an early stage in the Inquiry.
- (vi) Contrary to the written procedure multiple jobs were undertaken on a single permit. A particular example of this was provided by the permit issued in March 1988 in respect of the refurbishment of both PSV 504 and 505 which were attached to the pipework of different condensate injection pumps.
- (vii) Contrary to the written procedure the Performing Authority's copy of the permit was frequently not displayed at the job site. It was not uncommon for the Performing Authority to keep it in his pocket, as Mr Rankin did.
- (viii) When Performing Authorities returned permits to the Control Room shortly before the end of the day-shift they would sign off all copies of the permit and leave them on the desk of the lead production operator for his subsequent attention. This was contrary to Occidental procedure which required the Performing Authority and the Designated Authority to meet. This deficient practice had developed because the lead production operators were engaged in their handover at this time. It will also be recalled from Chapter 6 that the evidence of Mr Rankin was that before returning to the Control Room to suspend the permit at 18.00 hours he did not inspect the work site. This also was contrary to the Occidental procedure. It was, of course, contrary to good practice in that as supervisor he failed to ensure that the work was in a safe condition to be left overnight.
- (ix) Designated Authorities would regularly but not always sign off permits both for completion and for suspension prior to having the job site inspected. This was contrary to Occidental procedure at section 3.5. Mr Lockwood agreed that this was an example of a number of fairly casual aspects to the permit to work procedure. According to Mr Rankin's evidence the lead operator accepted the permit for suspension without first inspecting the job site and satisfying himself that it was in a safe condition.
- (x) Suspended permits were filed in the Safety Office overnight. However, Occidental procedure by section 3.6 required Designated Authorities to retain the suspended permits. It followed that unless he was involved himself in suspending a permit a night-shift lead production operator would not know

which permits had been suspended and accordingly what equipment had been isolated for maintenance purposes.

These examples serve to demonstrate that the operating staff had no commitment to working to the written procedure; and that the procedure was knowingly and flagrantly disregarded.

Were practices in the permit to work system unsafe?

11.4 It is not unreasonable to proceed upon the basis that the specific provisions of the Occidental procedure were devised with the intention of achieving the safety objective to which a good permit to work system should be directed. Accordingly each of the above departures from the written procedure represented a departure from safe practice. In any event it does not take much imagination to appreciate that they had in them the potential for causing accidents. However the unsafe aspects of the system can be further demonstrated by the following examples:-

- (i) Apart from the case where it had been planned to carry out a major shutdown, there was no consistently used system for affixing a tag to an isolation valve which had been closed as part of the isolation of equipment for maintenance where the tag warned that the valve should not be opened. Unlike the practice of locking-off for electrical isolation, there was no consistent practice of physically locking-off isolation valves which had been closed in order to prevent their being opened inadvertently. Even where equipment had been locked-off, there was nothing to tell an operator what was the reason.
- (ii) Where the work under one permit could affect the work under another there was no cross-referencing of the two permits. Reliance was placed on the memory of the Designated Authority. As stated above section D10 of the permit might be ticked but no further detail was supplied. Further, the system of filing active permits in the Control Room according to the location of the equipment meant that work affecting associated equipment on different levels would not be filed together.
- (iii) At shift changeover lead production operators would not review or discuss the active or suspended permits. Accordingly there was a gap in the system of communication.
- (iv) Suspended permits were not kept in the Control Room but in the Safety Office, apparently on the ground that there was not enough room in the Control Room to display them there. A lead production operator could be aware of a suspended permit if it was one of those permits which came to him for suspension during the period of three quarters of an hour before he officially came on shift. But it could be unknown to him if it had been suspended days before or earlier on the same day before he arrived in the Control Room for the handover. Mr Lockwood stated that he would not look at the suspended permits in the Safety Office when he came on shift; and there is no evidence of such a practice. On the other hand Mr A G Clark, a maintenance lead hand, said that he would check suspended permits. The correlation of suspended with active permits was made more difficult by the fact that in the Safety Office suspended permits were not filed according to location but according to the trade involved. This made it difficult for any supervisor to check readily which equipment was isolated for maintenance.
- (v) For significant periods there were large numbers of suspended permits in the Safety Office, some of which had been suspended for months. In February 1988 it was found that 124 permits to work were outstanding. The safety staff accepted the need to reduce this number and to police the system but no procedure was instituted to bring about any improvement.
- (vi) There appeared to be no system for ensuring that fire and gas panels were reactivated as soon as the need for locking them off had ceased. The reactivation

depended upon whether action was taken by either the Control Room operator or the Designated Authority and in either case whether he knew that the work for which the fire and gas panels had been locked off was either completed or suspended.

Faced in cross-examination with the proposition that in many ways merely lip service was paid to the permit to work system and that in reality communication was relied upon either by word of mouth or by habit Mr Lockwood replied "That is correct. The communication was very good. That is the only thing I can say in defence of the system. Communication between the people working on the operations and the maintenance was very good." Whether that was generally the case I am unable to judge, as this would go far beyond the province of this Inquiry. However in my view such an approach put too high a premium on informal communications. On 6 July the permit to work system failed to prevent the night-shift staff from embarking on the recommissioning of the A condensate injection pump while its PSV was missing from the system. Such a failure can well be understood against the background of the informal and unsafe practices which I have outlined above.

Was there adequate training in the system?

11.5 In order to have an effective permit to work system it is essential that the personnel who are required to operate the system are thoroughly trained in all its aspects. This applies particularly to those who are to act as Designated Authorities and as Performing Authorities since the safe execution of maintenance work is their responsibility.

11.6 As regards Occidental personnel who were to act as Designated Authorities it is clear that Occidental provided no formal training in the permit to work system. Thus Mr Lockwood required to pick up the practice from watching others carrying out the function of Designated Authority. This also applied to other personnel on the platform. While training "on the job" no doubt has a part to play in the full training of personnel in positions of responsibility for safety, I consider that it should not be the sole or primary means of training. It suffers from the crucial weakness of perpetuating or accumulating errors.

11.7 The contractors who worked on Piper could be divided into 3 groups:- (i) long-term contractors, such as heating and ventilation technicians; (ii) specialist contractors, such as Score (UK) Ltd; and (iii) short-term contractors, such as those working for a few weeks on major overhauls. Personnel from the first and second of these groups were in practice expected to operate the permit to work system as Performing Authorities. It will be recalled from Chapter 6 that on 6 July 1988 Mr Rankin was acting as Performing Authority in relation to the permit to work for the overhaul and recertification of PSV 504. It is clear that to a large extent Occidental placed the responsibility of ensuring that contractors' employees were familiar with the permit to work system on the contractors themselves. According to Mr A C B Todd, maintenance superintendent, under whose authority maintenance contractors work, Occidental organised no training for contractors' employees in regard to the permit to work system. In his view the long-term contractors would be familiar with the system. As I stated in para 6.81, he said that when Mr Rankin came to his office on 28 June he asked him if he knew the PTW system. Mr Rankin said he was happy with it and knew how to work it. Mr Todd did not probe to determine whether this was the case.

11.8 In para 13.5 I will refer to the safety induction at which the permit to work system was "explained". However, in the light of Mr Patience's evidence, this appeared to be no more than a reference to the existence of a permit to work system; and a statement of the types of work for which the different kinds of permit were intended. "Newcomers" to Piper were provided at the heliport with copies of a small Safety Handbook prepared by Occidental for Piper and Claymore in May 1987. This

contained information on 3 pages relating to the permit to work system. However a comparison between its statements and the system as it was in fact operated on Piper demonstrated a number of significant differences, some of which could have important implications for safety. The Safety Handbook stated incorrectly that:- (i) there were 4 different types of permit; (ii) that written application for a permit to work was submitted to the OIM (this was the case on Claymore); (iii) that on receipt of a permit the person responsible for carrying out the work was to personally inspect the work site (whereas in practice he was expected to do so before obtaining the permit, in order to ensure that there was no problem in proceeding with the work); (iv) that on completion of the work or at the expiry of the time written on the permit the person responsible for carrying out the work was to state when returning the permit that "normal operations may safely be resumed at the work site" (whereas no such statement was contained in the "clearance certification" on the permit to work form or was a necessary implication of the returning of the work permit). In these respects the handbook was dangerously misleading. At this point I note that in giving evidence on behalf of the Wood Group, Mr W H Carr, a Director of the John Wood Group PLC and Wood Group (Engineering) Ltd, stated that their clear understanding from Occidental was that the permit to work system was fully dealt with in the platform induction procedure and the Safety Handbook. The only other written guidance as to training in the permit to work system was contained in a set of notes issued by the OIM and safety supervisor on Piper to the discipline supervisors and charge-hands in or about 1987, a copy of which was produced at the Inquiry. This included a section on permits to work. After providing some guidance as to the work for which, and the procedure by which, a permit was obtained it stated "Prior to commencing any task, supervisors are to ensure that all conditions of the permit are strictly adhered to. On completion and/or suspension of the permit, the job site is to be cleared and made safe." This fell a long way short of what should have been provided, namely a systematic and consistent set of training notes explaining in relation to the permit form the full and exact responsibilities of the Performing Authority and the safety implications of full compliance with laid down procedure.

11.9 In the result I consider that the training required to ensure an effective permit to work system was operated in practice was not provided.

Was the operation of the system adequately monitored?

11.10 An essential aspect of any permit to work system is the monitoring and auditing of the operation of the system in practice. By the former I mean checking on a routine basis by platform personnel. By the latter I mean the planned examination of the system at infrequent intervals by personnel who are not responsible for the operation of the system. I will leave over auditing to Chapter 14.

11.11 The monitoring of the permit to work system on Piper was carried out almost entirely by the safety organisation. The lead safety operator considered that it was one of his duties to check whether the formal permit to work procedure was being complied with. This was confirmed by the platform safety supervisor, who personally joined in this activity although there was no laid down procedure as to how it should be done. The faults which he personally found were limited in number and importance and he said that he had no concerns about the system. Mr Todd said that he had taken no action to monitor the permit to work system in the 12 months prior to the disaster. Mr R G Sneddon, an operations superintendent, considered that compliance with the procedure was an important aspect of safety but said that the system was being operated in a proper manner in 1988 and that he was not aware of any problems. Mr A Bodie, the Safety Superintendent who was based on the shore, did not investigate the working of the system or discuss it with the lead operator. His department, the Loss Prevention Department, did not help personnel on Piper to be acquainted with the permit to work procedure. He had no feedback about problems with permits to work.

The written procedure

11.12 A number of comments can be made on the adequacy of the written procedure itself, but I should not be taken as indicating that in all other respects the procedure was satisfactory. The points which I would mention are as follows:-

- (i) The procedure makes no reference to methods of isolation and in particular does not set out a system of tagging and locking-off of isolation valves which have been closed or opened as part of making equipment safe to work upon. While Occidental's general approach to the isolation of equipment for maintenance is set out in another section of their General Safety Procedures Manual there is no mention of either tagging or locking-off. Without these added precautions there is a real risk of inadvertent operation of a valve which is critical to safe isolation.
- (ii) The procedure does not mention the need to cross-reference permits where one piece of work may affect another. Without this there is a danger that on completion of one task isolations which are critical to another piece of work may be removed.
- (iii) The procedure does not draw attention to the danger which is involved in the recommissioning of suspended maintenance work.
- (iv) Reg 3(4) of the Operational Safety, Health and Welfare Regulations provides that:-
 - “It shall be the duty of the person to whom any work permit has been issued, on the work to which it relates being completed or ceasing to be carried on by him:-
 - (a) to sign thereon a declaration that the work which he has carried out has been properly performed and either completed or ceased to be carried on and that the equipment affected by the work has been left in a safe condition; and
 - (b) to deliver the work permit to a responsible person.”

The form of permit used by Occidental included a “clearance certification” which was to be signed by the Performing Authority, making a declaration in the following terms:

“I declare that the work for which this permit was issued is now completed/suspended, that all men have been withdrawn: and that all tools have been removed and that obstructing objects do not remain.”

It does not appear that the permit contained a declaration by the Performing Authority which satisfied para (4). In particular it did not contain a declaration that the equipment affected by the work had been left in a safe condition.

End of shift handovers

11.13 In Chapter 6 I found that the handovers between phase 1 operators and maintenance lead hands on the evening of 6 July 1988 were materially deficient in that they failed to include communication of the fact that PSV 504 had been removed for overhaul and had not been replaced. Was this an isolated case of the failure to transmit evidence as to maintenance which had a critical bearing upon whether it was safe to operate equipment which was part of the gas plant? It should be noted that there were no written procedures for handovers. Mr Lockwood had never experienced problems as a result of inadequate handover and considered communications between process and maintenance staff to be very good. What was written on the lead production operator's pad and communications at handover was left to his discretion but this did not present problems. Mr Lockwood's own practice, which he thought others followed, was to look at the operators' logs to check what was going on. Maintenance work was not always set out in the logs which were kept by operators. It was only if it affected an important piece of machinery so that it would not be available to be operated.

11.14 However, this evidence should be taken in conjunction with that of Mr Clark, who had worked on Piper since 1977. On the one hand he agreed that the whole plant and platform was run in a professional manner. He felt that those who were employed on the platform did their utmost and took a pride in what they did. Safety was improving continually. There were quite a few meetings at which complaints were put forward and, if it was practicable, the complaint was dealt with. On the other hand it was his view that there should be a written procedure as to the amount of information which should be transmitted between personnel as to the work that was being done. "There were always times when it was a surprise when you found out some things that were going on." At a seminar held at the head office of Occidental in Aberdeen in early 1988 he had criticised the way in which the permit to work system was applied. "I thought it was high time it was upgraded and more specific." He had also criticised the lack of communication of information. "I just said that it was totally inadequate and it left a great need for rewriting." He said that nothing had really come from this seminar by 6 July. Asked whether he had felt this in the years leading up to 1988 he said "We had made an issue of it and we had discussed what we felt we wanted between the people on the platform. We had approached the OIM about getting something done with the permit system. We discussed it with him for quite some time and the permit system was altered but, again, when it came, it was not what we wanted." Right from the beginning he had also been critical of the method of communication. He could not see any reason why his suggestions could not have been carried out. As far as the permit to work system was concerned it was open to interpretation. "Everybody had their own idea of how the permit system should be applied and it sort of changed week to week and crew to crew." He criticised the way in which a permit was extended. "At the end of the day-shift, when it was cancelled, the night-shift would take it back out and just put "extension" on the back of it, which was not the way it was supposed to work." What annoyed him more than anything was permits not being properly carried through. "With permits, there was such a great difference between them and that should never have been." The majority of the maintenance department and also contractors were critical both of the communication methods and the permit to work system on Piper. These comments, which I have no reason to think were other than well-founded, underline the grave shortcomings in Occidental's approach to potentially dangerous jobs.

The Sutherland fatality

11.15 On 7 September 1987 Mr F Sutherland, a rigger employed by an offshore contractor was killed in an accident in A Module. This accident and what arose out of it has a significant bearing on the discussion of the adequacy of Occidental's attention to the quality of its permit to work system and handover procedure.

11.16 On the day of the accident a damaged bearing required to be replaced in a pump on the east side of A Module. It was found that it was impossible to remove the bearing without lifting the motor. For that purpose Occidental's lead maintenance hand on the day-shift obtained the assistance of riggers before handing over to his night-shift counterpart. Occidental's mechanical technicians on the night-shift decided to depart from the method of lifting which had been proposed by the day-shift and decided that clamps should be attached to overhead beams for the purpose of assisting in the lift. This was not discussed with the night-shift lead maintenance hand. In order to attach a shackle and sling to the beams Mr Sutherland climbed on to a panel which formed part of a canopy over the pump. The panel shifted from its support on one side and Mr Sutherland fell off sustaining injuries from which he later died. A number of points should be noted for present purposes:-

- (i) According to a note made by Mr R D Jenkins, a DEN Inspector, whose work will be referred to in more detail in Chapter 15, the one and only permit which had been issued in respect of the work was to "check and repair the thrust bearing". The lifting of the motor and the replacement of the bearing were not mentioned. One of the conclusions of the Occidental Board of Inquiry into this accident was that "The expansion of the original scope of the work to the

extent that it required the raising of the motor did not alert the supervisor to the additional measures that might have been taken to ensure the safe conduct of the new workscope.” In those circumstances it might reasonably be said that if a further permit to work had been applied for this would have ensured that attention was given to the precautions to be stated on the fresh permit and taken at the time when the work was being carried out. Following the fatality Occidental were prosecuted under secs 3(1) and 33(1)(a) of the HSWA for failing to conduct their undertaking in such a way as to ensure, so far as was reasonably practicable, that persons not in their employment who might be affected thereby were not thereby exposed to risks to their health and safety. The complaint, to which they pleaded guilty on 17 March 1987, set out a specification of the manner in which they had failed to supervise the job including “No new permit was taken out to cover the installation of said lifting gear and other necessary work”. Mr G Richards, the back-to-back OIM, agreed in evidence that the permit to work should have been extended but took the position that this did not contribute to the accident. This was not identified as a problem at the time. He agreed that if work had been restricted the crew would not have reached the stage where the accident happened. But, according to him, an additional permit would not have played a key part. A permit stated precautions, not the method of carrying out the work. While I appreciate that distinction it does not in my view follow that the absence of a further application for a permit to work had no bearing on this accident. Once again, it seems to me that the Occidental approach left too much to be settled as the work went along.

- (ii) The complaint to which Occidental pleaded guilty also specified “inadequate communication of information from the preceding day-shift to the night-shift”. A number of witnesses from the production and maintenance sides on Piper said in evidence to the Inquiry that no changes were made to handover practice after the fatality or Occidental’s plea of guilty. There was no awareness of any weakness in or criticism of communication at handover. Mr Bodie, who was a member of Occidental’s Board of Inquiry into the Sutherland fatality, was not made aware of the terms of the complaint to which Occidental had pleaded guilty or asked to reconsider the report of the Board in the light of those terms. The report was a production before the Inquiry and contains no examination of the adequacy or quality of the handover between the maintenance lead hands. Nonetheless, Mr Bodie said that he concluded that there was no contribution from the handover.
- (iii) The fatality to Mr Sutherland had a number of sequels, one of which was the issuing of a memorandum by Mr J L MacAllan, Occidental’s Production and Pipeline Manager, to all OIMs dated 24 September 1987. In this memorandum he emphasised, *inter alia*, that persons filling out permits should be encouraged to be more specific and detailed in the job description. As an example he said that it would not be sufficient to state “change gas head”. The permit should read “erect scaffold, change gas head, dismantle scaffold”. This advice reinforces the terms of the Occidental written procedure for permits to work. However, it was apparent that this advice was not followed. One example of this was provided by the permit which related to the refurbishment and recertification of PSV 504 and 505 in March 1988. The instruction “isolate as required” was inadequate.
- (iv) Another sequel to the fatality was the issuing of a memorandum dated 21 October 1987 to rigging and other supervisors. This referred to the assessment of the job by the rigging foreman and the raising of permits for certain categories of lift. However the evidence given by riggers at the Inquiry was that they would give assistance without their foreman being involved. Mr Richards said that he had checked with the rigging foreman that “everything was going to him”. He was unaware that personnel who needed rigging would simply approach a rigger, as apparently happened at the time when preparations

were made for the removal of PSV 504 on 6 July 1988. Once again it appears that although action was taken in a certain respect after the Sutherland fatality it did not have a lasting effect on practice.

Chapter 12

The Operability of the Fire-Fighting System

Introduction

12.1 In para 7.66 I accepted the conclusion that the failure of the fire-water deluge system was likely to have been caused by the effect of the initial explosion on the fire pumps and at least the smaller branches of the fire-water main. In this chapter I am concerned with considering the importance of the fire-water system and the extent to which it would have been operable on Piper even if the initial explosion had not had either of the effects. In para 13.18 *et seq* of the next chapter I will discuss training for fire-fighting and other duties.

The importance of the fire-water deluge system

12.2 In a memorandum dated 24 May 1985 to Mr P G Clayson, then Occidental's Safety Superintendent, Mr K R Wottge, Occidental's Facilities Engineering Manager, made the statement that:

“We certainly concur with you that the fire-water system is critical to platform safety and must be maintained in a peak operating state at all times.”

In this he was entirely correct. The basis of Occidental's approach to fire protection was that fire could be controlled on Piper before heat damage occurred to pipework, pressure vessels or structural members. Mr Wottge explained in evidence that in B Module Occidental anticipated primarily an oil fire. It was recognised that they could have difficulty in closing off any oil leakage. The deluge was therefore designed to deliver foam, sealing in the flames and knocking down the fire. In C Module it was assumed that the gas inventory could be shut down and vented to flare in a short period of time. The removal of the fuel source would prevent the fire continuing for long enough to cause any structural damage. He agreed that the isolation of the fuel source and the deluge system were the critical aspects of fire-fighting capacity on Piper. Apart from its effect in sealing in the flames and knocking down the fire it provided cooling to pipework, pressure vessels and structural members, so preventing escalation. The deluge was effective to control a fire in C Module because pressure was significantly reduced after the first minute of blowdown to flare and was virtually depleted after 5 minutes. The fire would be controlled by a combination of the deluge, monitors at each end of the module and the use of fire-hoses. Piper had not been originally designed in order to provide cooling for structural members, apart from the effect which the water curtain should have had on the firewalls. However the overall effect of the deluge would be to decrease the intensity of heat. As regards the removal of the hydrocarbon inventory to flare in the case of a gas fire in C Module Mr Wottge appreciated that it was essential that this take place as quickly as possible. This was underlined by a passage in his memorandum dated 18 March 1988 to Mr J L MacAllan, Occidental's Production and Pipeline Manager, in which he said:

“This is especially critical on Piper since we have no structural fireproofing as on Claymore and all structural members are highly stressed. Structural integrity could be lost within 10-15 minutes if a fire was fed from a large pressurised hydrocarbon inventory.”

Mr Wottge observed that it was very difficult to fight or put out a high pressure fire with any kind of water system. In any event, as Mr Clayson and Mr J S Henderson, the Commandant of the Offshore Fire Training Centre at Montrose, observed, the extinguishing of a large gas release may exacerbate the situation by allowing a gas cloud to grow and then find another source of ignition with devastating results. In the case of a gas fire the fire-water is used to cool the surrounding area until the fuel can be cut off. The need to ensure that the fire-water system was maintained in a peak operating state at all times was, if anything, increased by the fact that on Piper unlike

Claymore there was no structural fireproofing, and in particular fireproofing of the structural members associated with the production modules, such as the diagonal trusses, the upper and lower chords and the deck beams connecting the modules to each other. The fireproofing material which had been used on Claymore was mandolite, a cement-like material.

The operability of the diesel fire pumps

12.3 On the evening of 6 July the diesel fire pumps had been switched from automatic to manual mode in accordance with the practice followed on Piper during any shift in which diving was to take place beneath the platform. I will examine the practice below. I will first examine the implications of this for the fire-fighting capacity and what would have been involved in any attempt to start those pumps.

The implications for fire-fighting capacity

12.4 Until such time as the diesel fire pumps had been started the fire-water system on Piper would have had to depend on the output of the 2 electric pumps. These pumps were kept in continuous operation, even during an emergency shutdown. According to Mr A Bodie, Occidental's Safety Superintendent, these pumps could feed at least one module and a couple of monitors. However, the amount of deluge required depended upon the areas from which there was a demand for fire-water. It is clear that in a substantial emergency the fire-fighting capacity on Piper was severely handicapped if the diesel fire pumps were out of action.

Starting the diesel fire pumps

12.5 Under the arrangements for the starting of the diesel fire pumps which had prevailed at least from 1983-84 it was possible for the Control Room operator to start the pumps when they were in the automatic mode by operating a switch in the Control Room. Accordingly if one of the pumps did not come into operation automatically when it should have done so the operator could ensure that it was started. If on the other hand the diesel fire pumps were switched to the manual mode there was an alarm light for each pump in the Control Room showing that the pump was in that mode. However, in order to start the pumps when they were in the manual mode it was necessary for someone to go to the control panel which was adjacent to each pump in D Module in order to operate a switch to start the pump. The process of starting would have taken 1-3 minutes. Mr Bodie pointed out that in accordance with Occidental's Emergency Procedures Manual at 6.2.7 there were an assigned mechanic and an assigned electrician whose duties in the event of an alarm included the starting up and running of the diesel fire pumps. He informed the Inquiry that their names were shown on lists which were posted in the Control Room, the Mechanical Workshop, the Electrical Workshop and provided to the operations superintendent. However, at the beginning of an emergency they could be anywhere on the platform and might take some minutes to reach the pumps, assuming that their route was not impeded by the emergency itself. Further, there was no procedure by which the Control Room operator might ascertain whether they were on their way or had reached the pumps. In theory it was possible for the Control Room operator to go and switch on the pumps. It would take him about 1 minute to reach them. However, as Mr Bollands quite properly pointed out, a Control Room operator would not leave the Control Room unattended and would only go if he could find someone to whom he could delegate his duties. In any event the fact that it was necessary to go to the pumps themselves in order to start them when they were in the manual mode created the danger that the emergency itself might impede access. This was what happened on the night of the disaster when Mr Vernon and Mr Carroll donned breathing apparatus and attempted without success to reach the control panels of the diesel fire pumps in order to turn them on. If, on the other hand, there had been a switch in the Control Room by means of which these pumps could have been switched on when they were in the manual mode this could have made a vital difference to fire-fighting capability

so long as the fire-fighting system was not disabled. From the evidence there appeared to be no technical reason why such a switch could not have been provided in the Control Room.

The practice on Piper in regard to the diesel fire pumps

12.6 The practice that the diesel fire pumps were on manual mode during any shift in which diving work under the platform was taking place had been followed during at least 2 or 3 diving seasons during which divers were down for extended periods mainly on the night-shift. In practice, according to Mr Wottge, they were in the water 20-30% of the time in the diving season. Accordingly during the summer period the diesel fire pumps were regularly on manual mode from 18.00 hours until 06.00 hours on the following morning. The Inquiry heard differing evidence as to how the practice had arisen. According to Mr Richards the divers had requested this arrangement. The decision had been made on the platform and been accepted by the beach. On the other hand Mr C J Rowan, Senior Diving Supervisor of Stena Offshore, gave evidence as to a meeting on Piper on 16 April 1988 at which Mr C Seaton, the deceased OIM, had ruled that the practice on Piper was that the diesel fire pumps were to be on manual mode during the whole time that divers were in the water and rejected Mr Rowan's proposal that Piper should follow the same practice as on Claymore, where each of the pumps was left on automatic mode unless a diver was working near its intake.

12.7 In accordance with the practice adopted on Piper a pump status sheet was prepared in respect of each shift. A copy of it was posted in the Control Room and another copy was handed to the diving co-ordinator before the beginning of the shift. The divers would keep in close contact with the Control Room throughout the day. After the pump status sheet had been handed over the Control Room operator was not to alter the status of the pumps without the permission of the diving superintendent, after which the pump status sheet was changed. It was up to the Control Room to decide whether pumps were to be on or off. If a pump was already on manual mode the divers would be warned by a telephone call from the Control Room or by the sounding of an alarm. The divers informed the Control Room, usually by telephone, when they had finished their diving work. At the end of the shift it was up to the Control Room operator to put the diesel pumps back on to automatic mode. Mr Richards said that he had not made it his practice to ensure that this was done.

12.8 A number of witnesses with diving experience gave evidence as to the risk which formed the reason for following the practice on Piper. Mr S R MacLeod, the diving superintendent, described the difficulties which divers could experience through the effects of disorientation, currents and poor visibility. There was the possibility of a problem if a diver was working at the -120 ft level, which was just above the level of the open end of the stilling columns of the pumps. There would be in his view an equal problem whether the pumps were on already or were started up while the diver was working at that level. However a diver should be all right if he kept 20 ft away from an intake. If a diver was working at -50 ft he saw no problem. The diver would be in radio contact with his supervisor and could say when he had finished working in a hazardous area. The supervisor would have a good idea of the state of visibility. As far as he was concerned there were some dives on which there would be no risk posed by the intakes. Mr E T R Punchard, the diving inspection controller, drew attention to an accident on Piper a few years before the disaster in which a diver was injured as a result of being sucked into a pump intake. He would not be happy about working "adjacent to an unprotected intake which was switched to automatic". On the other hand Mr J Barr, the diving supervisor, said that a diver would be aware before diving of the pumps that would be in use. He could safely work on the same level as the pump intakes so long as he was aware of them and could take precautions. If a pump was switched on unexpectedly there would be some risk if the diver was within 15 ft of the intake. However he would know to ensure that his umbilical was nowhere near an intake. About 10-15 ft away from an intake a diver would probably

be able to notice the flow. Given the cages around the pump intakes there should be no undue danger. He would not expect disorientation at Piper as the water was quite clear and there was seldom a large reduction in visibility. If there was, this would be readily apparent to those on the surface. A diver should not change levels unexpectedly. He would require to adjust for the difference in the pressure with depth. In the dive control he would know by looking at a gauge what depth the diver was at and he would also check the depth by speaking to the diver. Although, as I have stated above, Mr Rowan sought to establish the same procedure at Piper as at Claymore he appreciated that it was safer for the divers that the diesel pumps should be on manual mode. He was aware of the previous accident at Piper. He felt that a safe distance for divers from the intakes was 10-15 ft.

12.9 The practice of keeping the diesel pumps on manual mode during the time when diving was taking place was noted in June 1983 at the time of a fire protection and safety audit on Piper. At that time the audit personnel, who included Mr Wottge, noted a recommendation that a procedure be adopted to ensure that those pumps were set to the automatic mode when diving was not being carried out near the intakes of those pumps. It appears that despite this recommendation it was left to the OIM to determine the practice which should be followed. Mr Wottge informed the Inquiry that it was only when he heard the evidence at the Inquiry that he realised that the practice of putting the pumps on manual mode whenever divers were in the water had continued to the time of the disaster. Mr Bodie said that he had no problem with the practice followed on Piper, given that fire-water was fed from the utility water main.

The practice on Claymore

12.10 On Claymore there were 2 inlets for pumps at -160 ft, and 20 ft apart, with mesh screen protection below the intakes. A switch in the Control Room could be used to start each pump, whether it was in the automatic or in the manual mode. In practice the pumps were left on automatic except when work was being done near a particular pump intake. In that event only that pump was switched to manual, and for the duration of that work.

Should changes have been made in the practice or intakes at Piper?

12.11 I can appreciate that there were significant differences in the existing configuration of the pump intakes at Piper and Claymore. The intakes at the latter platform were spaced much further apart and accordingly could be separately considered if it proved necessary for the manual mode to be used. At Piper on the other hand it was not unreasonable for both of the diesel pumps to be treated in the same way. On the other hand in the light of the evidence given by Mr Wottge there appeared to be no technical reason why the intakes of one or more of the pumps could not have been moved in a horizontal or vertical position so that they could be separately treated. However, this apparently had not been considered by Occidental. Turning to the period for which in practice the diesel fire pumps were kept on manual mode, it is understandable that an OIM would be attracted to a practice which was simple and did not rely on the exercise of judgement. In my view, however, the practice of keeping the pumps on manual mode throughout shifts in which any diving was taking place inhibited the operability of the pumps in an unnecessary and dangerous way. I was not convinced in the light of the evidence that there was any good reason why the recommendation made by the auditors in 1983 was not followed, so that pumps were set to the manual mode only when diving work was being done in the area of their intakes. The effect of the practice on Piper may be illustrated by reference to the events of the evening of the disaster. Diving operations started at about 18.00 hours after which 3 divers dived to work at the -120 ft level. The last of these divers left the water about 21.00 hours. After an interruption Mr G P Parrydavies dived at about 21.20 hours in order to carry out work at -50 ft. He was working there at the time of the initial explosion and was recovered by the diving personnel. If the diesel pumps had been put back on to automatic mode shortly after 21.00 hours and had been in

that mode at the time when Mr Parrydavies was carrying out his work I do not consider that this would have caused any risk of the diver or his equipment being sucked against the intake at the -120 ft level.

The fire-water deluge system

12.12 It is clear that the operability of the deluge system was at least one of the critical elements in ensuring adequate fire protection on Piper. In the light of evidence which emerged at the Inquiry I considered it proper to enquire whether as at 6 July 1988 the deluge system, and in particular C Module, was capable of fulfilling that role.

The operability of the deluge in C Module

12.13 The deluge system was normally tested every 3 months as part of regular maintenance and under the supervision of the safety department. Work on the system was carried out by the maintenance department, unless it involved clearing out or replacement which would be undertaken by the Offshore Projects Group (OPG). Any problems with the system were reported to management through either the Production Department or the Facilities Engineering Department. A routine test in C Module on 14 May 1988 disclosed that 50% of the deluge nozzles were blocked. These comprised 15 in area C1 and 17 in area C2. It proved impossible to improve the situation by removing deluge heads and flushing through the system. The deluge pipework required to be disconnected and cleared by rodding. The state of the nozzle heads was due to the fact that the galvanised carbon steel from which the deluge distribution pipework had been fabricated had been affected by salt water with the result that scale from internal corrosion had caused plugging. The findings on 14 May were immediately reported to the Facilities Engineering Department and it was decided that the distribution pipework in C Module was to be replaced as a matter of high priority. An Authorisation for Expenditure (AFE) was issued for approval on 17 May and approved on 1 June 1988. The engineering package was scheduled for completion on 23 June, following the issuing of a preliminary bill of material to the OPG on 24 May. The disaster came before this planned replacement could be carried out.

12.14 As will be seen below the plugging of nozzle heads with scale was no new problem on Piper. So far as 1988 was concerned the Inquiry heard evidence from a number of other sources as to the state of these heads in the period up to the disaster. The previous routine testing of the deluge system in C Module showed that on 14 February 1988 several heads were blocked in C1 and on 16 February there were at least 25 blocked heads in area C2. At this time the blockages were cleared relatively easily. Mr J S Meanen, a scaffolder, gave evidence that 1 or 2 days before the disaster he had removed bags which had been attached to the heads of the deluge in C Module in order to catch water which was discharged when the system was tested. He found that out of the 10 or 12 bags which he took down 3 or 4 were dry when they should have had water in them. When Mr G G Robertson, safety supervisor on Piper, reported the findings on 14 May to Mr Bodie he pointed out that even if rodding was successful "it is only going to be temporary as the amount of internal corrosion in the system is extensive". When Mr Wottge was asked about the deluge as at 6 July 1988 he said that there would have been plugging and that it was likely or possible that the fixed distribution system did not provide "full coverage". That is an under-statement. In the light of the evidence I consider that it is likely that if the deluge had been activated on 6 July 1988 a substantial number of the deluge heads would have been blocked by scale with the result that they would not have discharged.

12.15 The vulnerability of deluge heads in C Module to blockage was not detected by the Department of Transport (DoT) in the course of the last biennial inspection before the disaster which was concerned, *inter alia*, with the functioning of the fire-fighting equipment of the installation. Mr W P Wood, a ship surveyor in the Surveyor General's Organisation of the Marine Directorate of the DoT visited Piper on 1 and

2 February 1988. He said in evidence that he usually tested “an agreed selection” of the deluges. He asked for certain systems to be tested but did not force his selection as there might be reasons why a particular part of the system could not be tested at the time. On this visit he tested the deluge system in A Module and in the area of the pig launchers for the Tartan and MCP-01 gas lines. He found even distribution and no shadow effect. Two heads were found to be blocked. He understood that they were cleaned out later in the day. There was no apparent corrosion. He chose those areas principally because they were ones which had no pumps or significant control equipment. This could have caused a problem in B and C Modules. Another reason which he had for testing in A Module was that it contained the greatest danger. He had not been to Piper before and had no means of knowing whether the systems which he tested were the same as those which were tested during the last visit by a DoT surveyor. He did not inspect any records as to the testing of the deluge system. At the time of his visit he was not aware of any problem with the deluge system. He did not expect an operator to tell the surveyor about any problems. He expected the operator to rectify any defects. He would not necessarily pick up even “severe problems” in a biennial survey. The system could have been flushed out immediately before the visit or it could have been covered by planned maintenance. If he had found that the deluge system was not operating satisfactorily he would have asked for something to be done about it and would have asked for all the deluges to be tested. If he had found that 10% or more of the system was inoperative he would have discussed the matter with the OIM. If there had not been a quick solution he would have discussed the matter with his office in Aberdeen. If as much as 50% was inoperative he would have wanted the platform to be shut down, although he was unsure of what power he had to insist on this. In the light of what was found by Occidental in May 1988 no fresh certificate would have been issued until matters had been put right. Mr Wood also said that at the time of his visit he was not personally aware that any alterations had been made to the deluge system in the preceding 2 years, although there was documentary evidence before the Inquiry of correspondence between Occidental and the DoT in regard to the changing of heads and the replacement of pipework. The latest part of that correspondence was in March 1987. Since the disaster surveys by DoT inspectors are preceded by a telex to the operator informing them of the visit and giving them ample time to protect equipment against the operation of the deluge.

The previous history of Occidental's actions

12.16 The problem caused by scale plugging the deluge heads was identified by Occidental at least as early as 1984. At that stage Occidental were in no doubt as to the cause of the scale. Their first action was to replace the existing nozzles with ones which had larger orifices. This was begun on a trial basis late in that year. It was, however, appreciated that it might well prove necessary to replace the distribution pipework itself. The memorandum from Mr Wottge to Mr Clayson dated 24 May 1985, to which I have referred earlier in this chapter, demonstrated the extent of the problem at that time. Up to 40-50% of the original type of nozzles had been found to be blocked when the deluge system had been recently tested. The new type of nozzles had shown a definite decrease in plugging. However, Mr Wottge proposed that a specification for the replacement of the deluge pipework should be developed and stated that replacement might need to be done in the longer term if the short-term results were not successful. Preparations were made in July 1985 for the replacement of the distribution pipework in B Module but that project was suspended pending the results of greater experience with the new type of nozzles. By mid-1986 it had become clear that this would not provide a long term solution and the Facilities Engineering Department turned to the replacement of the distribution pipework on a systematic basis. It should be pointed out at this stage that Occidental were encountering no problems with blockage on the 68 ft level as the Kunifer material from which the distribution pipework on that level was made was not affected in the same way.

12.17 On 25 June 1986 an AFE was approved for the replacement of the distribution pipework in B Module with “duplex” quality stainless steel piping. In October 1985

Occidental's partners had given budgetary approval to improvements to the deluge system to prevent further corrosion. In support of the AFE the Facilities Engineering Department had stated on 6 June 1986 that:

“... the original deluge distribution pipework is fabricated in galvanised carbon steel and over the years in service salt water has virtually destroyed the galvanising protection of the steel. The resultant internal corrosion scale from the pipework has been causing serious problems of plugging in the deluge nozzle heads during deluge flow tests. This has entailed removal of the heads for cleaning out during the tests but leaves a serious question on how many deluge nozzles could block during an emergency situation. This problem has been getting worse over the last few years and shorter periods between deluge testing is in operation to reduce the amount of corrosion scale that can collect between tests. Larger diameter nozzles have also been installed and tested over an extensive trial period. These larger nozzles have reduced the amount of plugging considerably although not completely eliminating it”.

In evidence Mr Wottge said that he could not say that the statement that the problem had been getting worse over the last few years was incorrect “but whenever we do AFEs we write a justification: we like to dramatise it a little bit to make it easier for people up the line to approve it”. The approach adopted by the Facilities Engineering Department was to complete one module before starting work on the others so that anything learnt in the installation of the first could be designed into the replacements in the other modules. B Module was selected since it contained the highest hydrocarbon inventory. As far as Mr Wottge was aware the problem in B Module was approximately the same as the problem in C Module. The total replacement of the distribution pipework was further supported by a memorandum from Mr Bodie to Mr G F Foldes of the Facilities Engineering Department dated 18 August 1986, which enclosed test results for B and C Modules for the previous 18 months. Mr Bodie stated “These show a consistent pattern of head blockages. I therefore recommend that the replacement of the deluge pipework be carried out to alleviate this problem.” In evidence Mr Bodie said that the frequency of testing had been increased in 1985 to every 6 weeks in order to obtain data to justify replacement of the whole distribution pipework. However it was found that this set up a vicious circle as more flushing meant more corrosion. The tests went back to the quarterly basis.

12.18 The carrying out of the replacement of the distribution pipework in B Module was affected by a number of delays. In the first place what was said to be a shortage of draftsmen held up the issuing of the engineering package to the OPG. Mr Wottge said that it was possible that a delay of no more than 4 weeks resulted but he was not sure. The draftsmen were engaged by Occidental on contract and it seems surprising that this situation was not avoided especially as the project was, according to Mr Wottge, accorded “high priority”. Mr Wottge also said that there could have been a delay of several months while the stainless steel was being procured. The Facilities Engineering Department forecast that the work of replacement in B Module would be carried out within January 1987; and following installation experience with B Module planned to issue an AFE for the replacement of the pipework in A and C Modules during 1987. In the event, the work in B Module having started in January took until about August 1987 to be completed, although the work was done in parts which in total amounted to a period of the order of 2 months. It should, of course, be pointed out that the work was designed to be done in such a way that only a small amount of the deluge system in B Module was out of action at any given time.

12.19 In the meantime a further AFE was raised and approved for a similar replacement in A Module. When asked in evidence why it was decided simply to replace in A and not in C Module Mr Wottge said “We do not want to be working on half of the deluge system on the platform. You cannot adequately control that. When you replace a deluge system you have to have fire watches, you have to have people out there and our policy has been to de-activate only a small portion of the system at a time.” He denied that the fact that the work was done in sequence was

related to the question of manpower and expense. "One of the main reasons I had for my recommendations is that in these projects of replacing systems just about every job we do is in a very congested area. It does not always go to plan. We learn by doing the work and we like to incorporate what we learn into a following similar project." He explained that A Module had been chosen on the basis that it had the next highest risk level in an extended hydrocarbon-fed fire which could be fed by a well accident. He said that he did not believe that because an AFE had been written only for A Module that the timing of the replacement in C Module necessarily suffered. "You are looking at a major system in A Module. You cannot just tear down piping in several modules." From mid-1987 his department had worked on the drawings for the replacement in both A and C Modules. He agreed that C Module would still be at risk but maintained that the fire monitors at each end of C Module could supplement the deluge if there were some blocked nozzles. He added "At that time we did not experience massive deluge head blockages. The system was OK for practical purposes." His evidence was that on routine tests "They would find the odd nozzle plugged". This was broadly in line with the evidence of Mr Bodie who added: "The blockages we were experiencing were on the ends of pipe-runs. Deluge systems are not the be-all and end-all. They are a tremendous first-hit system. If deluge systems worked perfectly, there would be no need for firemen. We could see some blockages in the heads and we were taking action to do it, but it was in the ends of heads over at the edges of the modules head blockage over the side of the module does not cause me such great concern as a head blockage in the centre runs. We have other systems to back this up, of course - the fire monitors, and then we go in and fight it by hand." He said he felt confident that the deluge system would work in an emergency. His staff were carrying out the tests and would also have to head the fire teams. They would certainly not let the system slip into a state where it would not work at all, as was proved by the immediate reporting of the difficulties in the following May.

12.20 Progress towards the replacement of distribution pipework in both A and C Modules was also delayed. Problems with the delivery of stainless steel caused the work on A Module to be deferred initially to early 1988. However, in about November 1987 the corporate auditors advised Occidental to consider adding direct spray protection on to structural members as part of the project. Mr Wottge put the replacement of the distribution system in A and C Modules "on hold" and commissioned a study of the viability of incorporating such cooling. Mr Wottge perceived that his main problem, as he put it in a letter to the auditors dated 23 February 1988, was that:

"Essentially all members on Piper are highly stressed and to assure adequate cooling of these would require an extensive fixed deluge distribution network which would also consume incremental high water rates. If you are aware of any novel structural cooling deluge distribution system, we would welcome information on these or any ideas that you may have. The basic problem that I see is that to provide thorough coverage via fixed nozzles at near ceiling level will require a very extensive costly distribution network."

12.21 This was the state of matters against which the finding of blockages in February and May 1988 should be viewed. It should be noted that what was found in February was not immediately reported by the platform to either Mr Bodie or to Mr Wottge, although the former read later in a report for the month of March that the blockages were "now cleared". Both of them stated in evidence that if they had known of the blockages at the time their reactions would have been the same as they were in May, namely to recommend immediate replacement of the distribution pipework in C Module.

12.22 At the time when hasty preparations were made in May for the replacement of the pipework in C Module it was also planned to proceed with A Module after replacement in C Module had been completed. It also should be noted that Occidental had obtained full budgetary approval from their partners in the previous year for the

replacement of pipework in both modules. When the replacement of the pipework in C Module was authorised for expenditure on 1 June 1988 it was noted that a further AFE might follow to cover the cost of any additional steel work cooling that might arise.

12.23 In the Inquiry Occidental were criticised for having deliberately decided to defer replacement in C Module, first in order to give preference to B Module and secondly in order to give preference to A Module. The problem of blockage was no worse in these other modules than in C Module. It was suggested that the piecemeal ordering of deferral of work was due to a desire to save or spread cost. Further the process of replacement was unnecessarily extended by various delays. In the meantime there were no grounds for confidence that the deluge system in C Module would work properly. This is a subject to which I will return in Chapter 14 (at paras 14.47 *et seq*) in the light of the evidence of management witnesses. However at this point I should say that I do not consider that it was unreasonable for Occidental to proceed by taking the replacement of pipework in one module at a time in order to gain experience from the installation. Further, it was reasonable for them to proceed in such a way as to avoid putting the whole of the deluge system in a single module out of operation at any given time. On the other hand the total period from the point at which replacement in B Module was sanctioned to the point where it was completed amounted to approximately 2 years. Should the progress of the design work have been held up by lack of manpower if the project had, and deservedly, a high priority? After the work on B Module was finished shortly after the middle of 1987 should Occidental not have been able to move rapidly into the work of replacing in the other modules? By then they would have known the problems which would be encountered in the course of installation. It would be normal practice for early orders to be placed for the necessary material. Should further work on replacement in A and C Modules have been placed on hold in the light of the auditors' report? The latter did not prevent hasty steps being taken in May 1988 for replacement in C Module. I am also sceptical of the evidence that the actual experience on the testing of the deluge system in C Module prior to February 1988 showed only a few blocked heads. In the light of the long history of the problem which the larger size of nozzles had failed to remove and the statements which were made as to the state of the pipework in June 1986 and in May 1988 I find it hard to believe that in 1988 there had been an unexpected deterioration in the performance of the deluge system.

Chapter 13

Training for Emergencies

Introduction

13.1 During the course of the Inquiry evidence was heard on a number of aspects of emergency training. In this chapter I will be concerned mainly with training which was specific to Piper. What I learnt in the course of the evidence gave cause for concern on a number of points, as will be seen below.

13.2 It was Occidental's policy that personnel who came to work on Piper should have attended the combined fire-fighting and survival course provided by RGIT or an equivalent course provided by another of the 6 centres in the United Kingdom. At the heliport there was a check that such personnel were in possession of the certificates of attendance. Deficiencies were reported by Occidental to the relevant contractors by monthly report. Occasionally someone worked on the platform even although he had not completed the course. For example, 3 of the Wood Group personnel on Piper at the time of the disaster had not taken the course. Supervisory personnel of contractors such as Bawden International required to have completed separate survival and fire-fighting courses, on the basis of their responsibility for the safety of others. Personnel were expected to undertake refresher training 3-4 years after the original training. However to a significant extent this was not the case. Thus of the 14 Wood Group employees who survived the disaster 8 had not received the refresher training which they should have. One cause of this was the waiting list for such training, which has been somewhat eased by the opening of an additional centre in Dundee.

Safety induction

13.3 It was Occidental's intention that "newcomers" to Piper should receive a safety induction briefing on their arrival at the platform. Whether a person was to receive an induction was determined at the heliport from which a telex message was sent to Piper and passed on to the safety personnel there. The period since a person's last visit to Piper which was long enough to make him a "newcomer" for this purpose was apparently 6 months. However it was surprising that a number of the Occidental safety personnel who gave evidence were either mistaken or uncertain as to what the period was. Mr J A Patience, a lead safety operator, could not recall any set period. Mr G G Robertson, who had been a safety supervisor on Piper until shortly before the disaster, thought that the period was a year. Mr R M Gordon, the Manager of the Loss Prevention Department, could not recall whether the period was 6 or 12 months, but believed that it was the latter. This state of the evidence should be considered in conjunction with the evidence of survivors to which I will refer below.

13.4 As I have stated in Chapter 11, "newcomers" to Piper were provided at the heliport with copies of a small Safety Handbook for Piper and Claymore, the current edition of which was issued as from May 1987. This handbook contained the injunction that the possessor should "study it well - it may be your passport to survival"; and at the induction on the platform personnel were told that it was their duty to read it. However it should be noted that the handbook depicted a method of throwing life raft capsules over the rail which did not apply to Piper. It also stated, but in very small print, that there was perhaps 80 ft of line which required to be pulled out before inflation would begin. It also advised "Should the need arise for you to use a life raft, try to board it via scrambling nets, knotted ropes or lower walkways keeping as dry as possible", whereas scrambling nets had been removed from both Piper and Claymore in the early 1980s.

13.5 On arrival at the platform personnel who were to receive an induction were collected by safety personnel after they had been given the number of their cabin and

the number of their lifeboat. A lead safety operator, such as Mr Patience, would normally give the induction after obtaining details from the “newcomers” of their names, job titles, employers and courses attended. It did not appear that any particular format was laid down for safety personnel to follow in giving the induction. Instead they appear to have developed a common practice which was described in evidence by Mr Patience and illustrated by a letter dated 5 April 1987 from Mr Robertson to his immediate superior, Mr A Bodie, who was the shore-based Safety Superintendent. The letter contained a list of 11 subjects stated to be included in the induction. In brief the list comprised helicopter safety procedures; prohibited areas; protective clothing requirements, cleanliness and hygiene of personnel; no smoking areas/smoking permit areas; emergency procedures and required action of personnel during emergency situations (including alarm systems, lifeboat allocation, helicopter evacuation and emergency telephones); explanation of permit to work system, housekeeping and common sense; reporting of incidents/accidents/potential hazards/near misses; fire-fighting equipment; lifting gear; low specific activity (LSA) (ie radioactive materials); and scaffolding. Mr Patience said in evidence, and the letter also indicated, that what was said at the induction was tailored to some extent to the work which the audience had come to perform. Thus for drillers there would be an indication of the type of hazards associated with their work. Further guidance would be given by their supervisor on the job. Anybody who had not been on the combined course “would obviously be given a little bit of additional detail”. Mr Patience also explained that he would ask his audience to confirm that they had been assigned to a lifeboat; and would explain where the lifeboats were located. He would explain that on a platform general alarm personnel were to go to the muster station associated with their lifeboat and report to the coxswain there. In the event of a real or simulated evacuation by helicopter they would proceed in accordance with the coxswain’s instructions to a secondary muster area in the accommodation. If they could not get to their lifeboat station they should go to another lifeboat station, which failing to the life rafts. The number and location of the life rafts were described. They were told to familiarise themselves with stairways and passages through the plant. In the event that it was not possible to reach either lifeboats or life rafts they would be instructed to proceed to the accommodation. No guidance was given against the event that evacuation by helicopter was also impossible. Personnel were told about the means of reaching sea level by stairways and knotted ropes. It was generally indicated that it was inadvisable for personnel to jump off the platform. As regards fire-fighting equipment the induction was confined to what was available for the purposes of extinguishing fires. It did not extend to instruction in the method of operation. In practice safety operators would give instructions for specific tasks such as fire-watching duties as required.

13.6 Mr Patience went on to state that following the briefing in the accommodation the personnel were taken to their respective lifeboat stations, where he would make sure that they knew how to strap themselves in. He would enter the lifeboat with them and point out the items of equipment and the lowering and release mechanisms. Those who were new to the offshore environment were shown how to put on a life-jacket. Once that had been done they were generally shown the location of the life rafts on the 68 ft level, at which point the induction came to an end. Personnel were, however, advised to make themselves familiar with direction signs and with alternative routes to lifeboats, life rafts and life-saving appliances. (I should add that Mr Bodie, who had been a safety operator and lead safety operator between 1976 and 1983, stated that it was his recollection that when he gave safety inductions he would state that 140 ft of line required to be pulled out of the life raft capsule.)

13.7 According to Mr Patience the whole induction could last about three quarters of an hour, including about 15 minutes for the visit to the lifeboat and life raft locations. The shortest time for the briefing which he could envisage was about 20 minutes. On the other hand a note of a seminar attended by supervisory staff on 7 May 1987 recorded that Occidental’s induction took up to one hour offshore, whereas it took up to 2 hours at Flotta. According to Occidental’s records in 1987 455 “newcomers” arrived at Piper; and 320 man-hours were devoted to giving induction.

Evidence given by survivors

13.8 The evidence of a significant number of the survivors, which I have no reason to consider to be unreliable, disclosed a different picture from that portrayed by Mr Patience. 26 of the survivors (all contractors' personnel) were asked whether they had received a safety induction. Six of them said that they had never done so. One thought that he had not; and one could not recall. The remaining 18 said that they had received an induction. But 4 said that it had lasted for 5-10 minutes. These included Mr D M Thompson who had arrived at Piper 2 days before the disaster. When he was asked about his briefing he replied: "He asked if we had been on the Piper before. I said 'No'. He said 'Have you worked offshore before?', and I said 'Yes'. He said 'Well, you will know what the score is then'. That was much about what it was." He was told the number of his lifeboat but he had to look for it himself. Four others also said that they had not been shown their lifeboats. Of the 18 to whom I have referred 9 had visited Piper for the first time prior to 1988. Three had received no repeat of the induction since their initial one. These included Mr W P Barron who had returned to Piper in late 1987. He said: "When I went on this rig I was asked if I had worked on an offshore rig before, and I said 'Yes', that I had been on two, that I had been on Piper in 1982 and also the Claymore in 1985. This was at the safety induction, so he said 'Well, nothing has changed'." This was the sum total of the induction. As I have stated earlier in para 8.27 a number of the survivors who assembled at the north-west corner of the 68 ft level after the initial explosion had never been shown the location of the life rafts nor how to launch and inflate them. Some did not know how long was the painter line which required to be pulled out; others thought that it was considerably shorter than it was.

The monitoring of safety inductions

13.9 The safety personnel on the platform and their superiors onshore were in no doubt as to the importance of the systematic giving of induction training at the earliest opportunity when a "newcomer" arrived at the platform. Mr F McGeogh who had been Safety Training Co-ordinator with Occidental since February 1988 said that he had received favourable comments from supervisors as to the quality of the induction provided by Occidental. Mr Robertson said that checks were made about every 2 months to ensure that induction was being properly carried out. By this he meant making enquiries of the medic who was responsible for passing the information on the telex to safety personnel. He also said that he had checked with safety personnel that they were going to the lifeboats and the life rafts with the "newcomers". However he had not checked on the extent to which the inductions were being completed and he had not asked the "newcomers" what they had received.

Changes in Occidental's approach to inductions prior to the disaster

13.10 Mr McGeogh was given the task of considering whether the provision by Occidental for training and safety awareness should be improved. He took the view that induction "could be made slicker" for the large number of contract personnel who were travelling offshore, as was normal in the industry. In June 1988 he had instituted a system of onshore induction for 5 or more personnel in order to supplement the offshore induction which they would receive when they reached the platform. The onshore induction lasted half a day and ended with the attendance of various members of the senior staff of Occidental. Guidance notes giving a safety training and awareness plan had been produced. At these inductions he explained that the one thing he could not do in the classroom was to orientate contractors' personnel. When they arrived offshore they would still have an induction and be shown to their lifeboats. Thereafter they would be introduced to their supervisor, part of whose function was to help them to be orientated on the platform. Nevertheless he emphasised that they should also take time themselves to walk round the platform and help to familiarise themselves with it. He had planned to go offshore in August 1988 for 2 weeks in order to canvass ideas for the safety training programme.

13.11 Mr McGeogh also said that he believed that the existing offshore induction of about 30 minutes should be extended by the showing of a video for those spending longer time offshore. This should be followed up by a guided tour of the platform in the company of someone who was in the same department as the “newcomer”. Finally there should be a feedback session. A record should be kept of the attendances at, and the extent of, the induction given.

Observations on inductions

13.12 Occidental were right to emphasise the importance of induction training at the earliest opportunity when a “newcomer” arrived at the platform. This applied especially in the case of contractors’ employees who might be on the platform for a comparatively short period but might need to face an emergency at a moment’s notice. Occidental were also right to plan that personnel should receive a repeat of induction training. However, I am not satisfied that the system as operated on Piper came close to achieving the necessary understanding on the part of all personnel as to how to react in the event of an emergency. The lack of an exact format or content for the induction training; the brevity of the time devoted to it; the almost cursory assessment of whether an individual required to attend the training; the uncertainty on the part of safety personnel as to the time interval before a repeat of the induction training was required; the failure to ensure that each person was shown the location of his lifeboat; and the errors in the safety handbook all point to a failure to ensure that all were properly informed on matters critical to their safety in an emergency.

Drills, exercises and training in emergency duties

13.13 Occidental’s manual on general safety procedures made provision for the drills, exercises and training for emergencies which were to be followed on its offshore installations. These followed the general statement that:

“Each person present on an offshore installation shall receive sufficient and appropriate emergency safety training to ensure his own personal safety and to enable him to perform all duties expected of him efficiently.” (4.18.1.1).

The responsibility for ensuring compliance with these requirements lay with line management, and in particular the OIM, in accordance with Occidental’s policy. Records of what was carried out were kept in the OIM’s log and were summarised in Monthly Activities Reports which were sent from the platform safety supervisor to Mr Bodie. It was Mr Bodie’s responsibility to assess the adequacy of what had been done. On the other hand it fell to the safety personnel on the platform to attend to the safety content in these activities.

Evacuation drills

13.14 According to the Occidental manual on General Safety Procedures offshore drills were to be held at intervals not exceeding 12 days; drills involving alternative evacuation routes were to be carried out at least once in every 3 tours of duty; and exercises should be as realistic as possible, including full-scale emergency scenarios assessed by qualified personnel external to the installation.

13.15 Mr G Richards, the back-to-back OIM, said that it was the aim on Piper to have evacuation drills once a week, if that was possible, and that these were pre-arranged to take place at 21.00 hours on Saturdays in order to minimise disruption. However, a study of the Monthly Activities Reports for the first half of 1988 showed that 2 lifeboat drills had been held in January, March and June, 3 in February and April and one in May, a total of 13. This pattern was in accordance with the evidence of various survivors as to their recollection over a longer period prior to the disaster. Mr Richards agreed that this was an unsatisfactory situation but attributed the shortfall to cancellations due to bad weather. He said that there was “not much you can do against the weather” and that it was too disturbing on the platform to have evacuation

drills at different times. In this he was supported by Mr Bodie who said “My experience of having these drills on the platforms is that it is a very traumatic business for everybody to get up at the accommodation, break their work cycles and have them coming to the lifeboats and carrying out a drill. It is a 24 hour operation. There are some people going to bed, some people getting up, some people have to stay up late to go to these drills.”

13.16 Mr Robertson said that at each evacuation drill life-jackets were worn by the participants. The coxswains and some of the complement boarded each lifeboat. The lowering of a lifeboat was done occasionally. The last time was 2-3 months before the disaster. At least 1 in 3 of the drills included a simulated helicopter evacuation in which personnel were summoned from their lifeboat stations to reception. The drills never included taking personnel to the 20 ft level. It was quite properly considered that this would involve too great a danger to them. However, no particular attention was drawn to the means of getting from the accommodation to that level. Of the normal complement about 80 persons did not normally go to muster stations as they had specific duties to perform in designated areas on the platform. However, apart from 20 who were entirely exempt, they were occasionally sent to their muster stations at lifeboats 4 and 5. The evidence as to whether, and how frequently, the drills involved alternative evacuation routes was unclear. Mr Patience could recall only one occasion in which a route was treated as blocked off; whereas Mr Robertson said that perhaps every 2 or 3 muster drills used alternative routes.

13.17 As regards full-scale emergency scenarios, no such exercise had taken place in the 3 years before the disaster, let alone been “assessed by qualified personnel external to the installation”. No total shutdown emergency scenario had taken place in the 3 years prior to the disaster. One had been planned for 1986 but was overtaken by an oil spillage. Another had been planned for June 1988 but was delayed until October because production was not being fully shut down. The object of such an exercise was to seek out deficiencies in the procedures and communications and would have taken place unannounced.

Training of personnel with specialist duties

13.18 The Occidental manual on General Safety Procedures states that:-

“The following personnel may be called upon to perform specialist duties in an emergency:

- helicopter landing officer
- fire team members
- fire team leaders
- helideck fire crews
- lifeboat coxswains
- first-aiders

These personnel must have had appropriate instruction/training prior to taking up their specialist duties.

The following drills, involving specially appointed personnel, should be carried out at weekly intervals:

- fire-fighting
- breathing apparatus
- emergency equipment handling
- casualty handling
- first-aid
- man overboard.”

13.19 It is reasonably clear that drills in the 6 subjects mentioned above were not carried out at weekly intervals or anything approaching that. Thus the Monthly

Activities Reports for the first half of 1988 show only 3 occasions on which there were breathing apparatus drills, although Mr Robertson claimed that they could have been done along with casualty handling as part of the fire-fighting drills undertaken by the emergency response teams. The Monthly Activities Report for April 1988 does not show that drills were carried out in any of the 6 subjects, although Mr Robertson said that it was likely that they were incorporated with the 3 lifeboat drills which had taken place during that month. The Monthly Activities Report for May 1988 shows only that there were 3 man overboard drills and nothing in regard to the other 5 subjects. The Monthly Activities Report for June 1988 shows 3 drills in fire-fighting; one drill in breathing apparatus; and one man overboard drill. Mr Robertson agreed that even if the drills carried out were not adequately recorded in the Monthly Activities Reports the fact remained that drills in these subjects were not being carried out with the regularity specified in the manual, although attempts were being made to improve the situation. According to him they were obtaining better results but not what they had hoped to achieve. The OIMs were attempting to make changes and encourage regular safety training at week-ends. Mr Richards claimed that on most Saturday and Sunday afternoons there was training of fire teams and first-aiders. Mr Bodie said that he had discussed the frequency of training with Mr C Seaton, the deceased OIM, after the manual had been produced at the end of 1987. He said that Mr Seaton had felt that the intended frequency was "a bit ambitious" as did Mr A Wicks, the safety supervisor. Mr Bodie added "What we were doing was saying 'let's try and get to this level of training and see how it works out and then we can take it from there'". These difficulties did not appear to be known to Mr G E Grogan, Vice-President Engineering, who was responsible for the Loss Prevention Department. He said that on the basis of the reports which were sent from the platform to Mr Bodie (which he did not monitor) he considered that the drills and exercises which the emergency response teams carried out were adequate.

13.20 In 1988 Occidental introduced modular training as additional training for coxswains, members of the emergency response teams and personnel with responsibilities for giving first-aid. According to Mr Bodie the bulk of the first-aid training was completed and the training for coxswains was on-going at the time of the disaster. As regards training in fire-fighting for the emergency response teams Mr Robertson stated that it comprised 5 modules with about 12 parts in each module. At the time of the disaster the first module of which one part was the introduction to fire-fighting had been introduced. There had been 4 or 5 training sessions. Reference to the minutes of the supervisors' safety meeting dated 28 May 1988 shows that these sessions began sometime after the end of April 1988. It was and is obvious that the completion of the modular training for fire-fighting would have taken a considerable time. There appeared to be no plan or target as to the period within which this modular training was to be completed; nor any definite view as to what improvement in progress should be made, however that was to be achieved.

13.21 On 29 May 1988 Mr Richards wrote to Mr Gordon complaining of a shortage of safety personnel offshore following the non-replacement of safety operators who had been promoted to the position of safety supervisors. According to the letter one thing that suffered as a result of this shortage of manpower was "the regular 'emergency' training that is required to ensure the competency of our offshore emergency teams, as they only receive infrequent basic training. A lot of time has been spent in putting together a modular training package for first-aiders, coxswains and emergency fire teams. We are unable to implement this fully due to other work commitment. Other 'safety awareness' training has suffered due to the necessary commitment to the modular training previously mentioned." The letter concluded by proposing the addition of one safety operator per crew, stating "this would enable us to meet all our commitments to Occidental's health and safety policy." Mr Gordon said that Mr Richards' representations were to have been put to the Management Safety Committee in August 1988. In evidence Mr Richards said that the only reason which he had for requiring additional safety personnel was because of the need to implement the additional modular training. At some stage which he was unable to specify the safety

personnel had been made up to the original strength by means of a contractor. However the need for additional personnel in order to meet the modular training remained at the time of the disaster. However he was emphatic that the safety of the platform was not impaired at all. Mr Bodie pointed out that on Piper Occidental was trying to get to “a very high level of training for the offshore staff”. He had to agree with Mr Richards that at times when the safety department went down to the minimum manning level approved by the company the first thing that would suffer would probably be the safety training. At the time of the disaster he had not collated the figures in order to reach a view as to whether the safety department on Piper required additional staff in order to implement the modular training scheme. Meanwhile he had been pushing his safety supervisors to maintain as much training as they possibly could. Mr Patience agreed that it was very likely that the fact that the modular scheme was not fully implemented was due to other work commitments on the part of the safety personnel. As regards training generally both he and Mr Robertson indicated that one reason why training was not being carried out with the frequency which had been intended was because line management did not make personnel available for the training. Mr Robertson said that he had taken up this point. Mr Bodie said that the OIMs had agreed to do their best to release personnel; and that he had heard from the supervisors of a favourable response to this. Mr Richards said that the production department had been asked to co-operate in making personnel available, but agreed that at times the safety department were being held back by the production department, depending on the workload. On the other hand Mr Gordon was not aware of any failure on the part of the production department to release personnel. He would have expected to hear about it if it had been a problem.

Onshore training

13.22 I have noted above that according to the Occidental manual on General Safety Procedures personnel who may be called upon to perform certain specialist duties “must have had appropriate instruction/training prior to taking up their specialist duties”. The manual also provides that “personnel with specialist skills should receive refresher training at intervals determined by the company”.

13.23 The members of the Occidental emergency response team in addition to having attended the combined fire-fighting and survival course of the type provided by RGIT had also attended a 4-day fire-fighting course of the type provided by the Offshore Fire Training Centre at Montrose. The leader of that team had also attended a fire leader’s course. In addition the safety supervisor attached to that team attended a fire control course which was offered for those responsible for organising overall control of offshore fires. On the other hand Occidental did not require or arrange that the members of the contractors’ emergency response teams, apart from their leaders, should attend the 4-day fire-fighting course or an equivalent course. This was unsatisfactory, as Mr Richards and Mr Gordon appeared to accept. Mr J L Gutteridge, the toolpusher, who was the leader of the Bawden emergency response team, said in evidence that he had undertaken the 4-day course at Montrose, which had been paid for by Occidental. Apart from him there was only one other member of the Bawden team who had been on such a course. He said that the lack of basic training in fire-fighting of the persons in his team had been brought up on many occasions at safety meetings but without result. According to Mr Robertson it was an established practice in regard to the Bawden team that when a Bawden employee reached a certain rank he automatically became a member of the team without regard to whether he had had any training in fire-fighting. He agreed that this was unsatisfactory and said that he had mentioned to others that he thought the teams would benefit by additional training. On the other hand Mr McGeogh did not appear to be troubled by the fact that members of the Bawden team would require to have their fire-fighting training wholly on the platform. He said “One of the things I was very much aware of compared to other operations I had seen was that there was a very very high level of activity of training on the platform, not only in response training, fire team training, first-aid and

so forth, but in the general occupational health subjects and technical matters. In fact it was different from anything I had seen elsewhere.”

13.24 In a memorandum to Mr T Rogers, OPG Superintendent, dated 3 January 1988 Mr T J Scanlon, the Wood Group Offshore Supervisor, reported that the view of Wood Group personnel was that on-platform training in fire-fighting was inadequate and that platform safety and fire team performance would be enhanced if personnel attended an onshore fire-fighting course. The Wood Group had made a similar request when they were first requested to supply a team for fire-fighting. At a supervisors’ safety meeting on 20 March 1988 it was recorded that the Occidental management had indicated that they would not fund onshore fire training and that accordingly in-house offshore fire training would continue as planned. This had been decided by Mr J L MacAllan, Production and Pipeline Manager, on the ground that personnel who had been trained might go to other work so that the cost of the training would not be of benefit to Occidental. However at the conclusion of his evidence he said that after further discussion it had been decided that there would be training onshore.

Observations on training

13.25 The evidence to which I have referred above demonstrates that none of the drills required for practising evacuation procedures for the platform personnel or for the training of persons who had specific duties to perform in an emergency were carried out to the frequency predetermined by Occidental management. The responsibility for this failure lay with the platform management and the OIMs in particular. In my view they did not demonstrate the necessary determination to ensure that regularity was achieved or dissatisfaction expressed with the inadequate results. The lack of a determined commitment to emergency training on the platform meant that the platform personnel were not as prepared for the disaster as they should have been. While the platform management did not exhibit the leadership required in this important area of training, the onshore safety staff did not operate an effective monitoring system with regard to emergency training. Where strong critical comment was called for they were ineffective.

Certificates of attendance at onshore courses

13.26 In the course of the Inquiry a number of unsatisfactory aspects of certificates of attendance at courses were the subject of evidence. It has been known for some time that false certificates were being used to mislead employers and operators. Mr J H Cross, Managing Director of RGIT, informed the Inquiry that his organisation had changed their certificates 3 times in order to overcome forgery and had asked companies not to accept photocopies. They now employed a member of staff to answer queries from the companies about the credentials of individuals who had offered certificates. Mr J S Henderson, Commandant of the Offshore Fire Training Centre at Montrose, said that the centre had been asked to assist in the investigation of allegedly forged certificates of attendance at their courses. The problem had been dealt with recently by embossing their certificates, so rendering them incapable of being reproduced by photocopying. In the case of personnel from Piper who were either deceased or missing an investigation by Grampian Police disclosed the existence of 3 apparently false certificates. Two of these purported to be from RGIT in respect of the combined survival and fire-fighting course. The third purported to have been issued by Petans Ltd, Lowestoft, in respect of a survival refresher course. In 2 cases there was no record of attendance of the persons named in the certificate of which a photocopy was held. In the third case the certificate had been issued to a person with the same name as, but a different address and date of birth from, the person in respect of whom it was held. The police enquiries also showed that apart from these 3 cases 18 of those who were deceased or missing after the disaster held no certificate. The general practice appeared to be that employers were prepared to accept photocopies of certificates and made no check on whether the person tendering the certificate had

attended the relevant course. However, the experience of the police in making enquiries into the false certificates indicated that it would not take long for employers to obtain the information which would be necessary in order to enable them to treat certificates or their photocopies as valid.

Chapter 14

Occidental's Management of Safety

Introduction

14.1 In the light of the matters discussed earlier, I considered that it was appropriate for me to seek evidence as to management's knowledge of, and attitude to, them. This chapter relates to that examination and the conclusions which I was able to form about the quality of Occidental's management of safety in these respects. After describing Occidental's safety policy and system (paras 14.3-11) and their approach to the risk of, and hazards involved in, a major platform emergency (paras 14.12-24), I will consider the quality of their management of safety in regard to the prevention of incidents (paras 14.25-43); and the mitigation of incidents (paras 14.44-51). I conclude with my general observations (para 14.52).

14.2 The sources of evidence from management to which I will be referring consisted of the following witnesses:-

- (i) Mr G Richards, the back-to-back OIM of Piper since 1984, who had been with Occidental since entering their employment in 1975 as an utilities operator and who had served on Piper for all but 11 months of that period.
- (ii) Mr J L MacAllan, Production and Pipeline Manager since 1987, who had previously been an OIM on Claymore and Production and Pipeline Superintendent.
- (iii) Mr A D McReynolds, Vice-President Operations from 1982 until May 1988, who had previously been Production and Pipeline Manager and Offshore Operations Manager.
- (iv) Mr R M Gordon, Loss Prevention Department Manager since 1985, having previously been Head of Safety for Shell Expro.
- (v) Mr G E Grogan, Vice-President Engineering since 1987, having become Manager of Engineering in 1983.

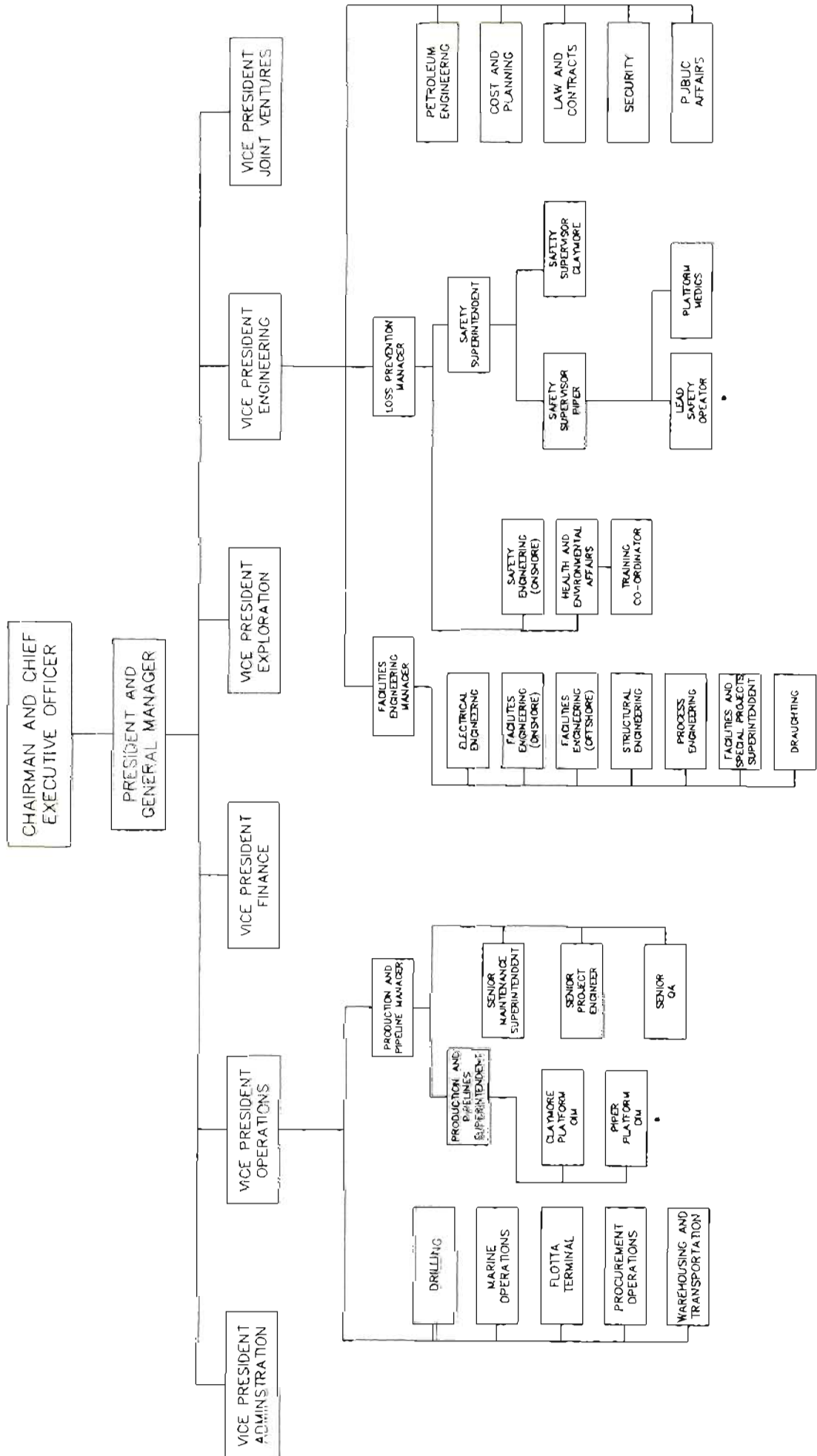
In view of the fact that Mr J B Coffee had succeeded Mr McReynolds only shortly before the disaster I did not consider that it would be of assistance to have his evidence also. Fig 14.1 shows the organisational structure of Occidental.

Occidental's policy and system for the management of safety

14.3 Occidental's statement of general policy under Sec 2(3) of the Health and Safety at Work etc Act 1974 (HSWA) stated, *inter alia*: "The promotion of health and safety is an integral part of the duties of line management and should be afforded the same priority as other key responsibilities." This statement was commonly interpreted on Piper as meaning that the safety of personnel came first at all times, according to Mr Richards. It followed from this statement that the responsibility for safety and ensuring that all safety procedures were adhered to lay with line management. Accordingly responsibility for safety on Piper rested, in terms of the structure of onshore management, with the Production and Pipeline Department which reported to the Vice-President Operations. This included operations, maintenance, offshore projects and quality assurance.

14.4 On the platform safety was one of the responsibilities of the OIM. He kept abreast of what was going on in a number of ways including a daily meeting with the heads of departments on the platform and receiving copies of outgoing reports and incoming job packs for those departments. He had a daily meeting with the safety supervisor in the morning. In order to provide information and obtain advice he took part in a morning conference call with the beach, which was updated by a call to the

OCCIDENTAL PETROLEUM (CALEDONIA) LTD



• PLATFORM ORGANISATION CHART APPLIES

Fig. 14.1 Organisational structure of Occidental Petroleum (Caledonia) Ltd.

Production and Pipeline Superintendent in the afternoon. He usually called the onshore Safety Superintendent during the day. About every 5 weeks each department on the platform had a safety meeting, followed by the supervisors' safety meeting, which was chaired by the OIM. There was an established system for the reporting of accidents and incidents including "near misses" and significant leaks so that management were in a position to observe trends and take action. This system included informing contractors where their employees were involved. Since October 1987 there was also a system by which employees could submit safety-related work requests to management. The OIMs had a monthly meeting onshore with the Production Department and the group leaders of other departments, at which matters of safety were discussed.

14.5 On the shore the Production and Pipeline Department received daily reports from the platform and held regular meetings, some jointly with the Engineering Department. Mr MacAllan said that he was regularly in daily contact with the onshore Safety Superintendent. He also said that he went offshore from time to time to make presentations in which he stressed that "safety was first". The departmental managers, along with the safety training co-ordinator, took part in a monthly Safety Co-ordination Meeting, which was chaired by the Vice-President Engineering, at which the current safety record and possible safety initiatives were discussed. Senior management attended quarterly management safety meetings, which were chaired by the President & General Manager.

14.6 The principal activities of the Loss Prevention Department were:

- (i) Providing specialist advice and assistance on occupational health, safety and environmental matters to other departments. Examples given in evidence ranged from their input in regard to engineering work to making available literature on health and safety to the whole workforce.
- (ii) Developing and revising company loss prevention policies and procedures in consultation with line departments and monitoring the effectiveness of these policies and procedures. Under this heading the department was responsible for compiling amendments to the manuals and setting out safety and emergency procedures in the light of incidents, information from other operators and notices from the DEN.
- (iii) Reviewing the overall effectiveness of the company safety performance. This included routine and *ad hoc* safety inspections.
- (iv) Co-ordinating and facilitating in-house and external loss prevention reviews, assessments and audits.

14.7 On the platform, safety personnel were responsible for, *inter alia*, gas testing for "hot work"; daily monitoring of the operation of the PTW system, including inspections of work sites; the regular testing of safety and emergency equipment; the organisation of training for emergencies; and the provision of guidance and advice on health and safety to the workforce. The safety supervisor was on the one hand responsible on a day to day basis to the OIM. On the other hand he had a separate reporting line to the onshore Safety Superintendent. Reporting was carried out on a daily, weekly and monthly basis, covering information as to incidents, the results of testing, survey reports and certificates relating to equipment which had been tested. This reporting line which had been set up in order to secure independence from the Production Department led to the Loss Prevention Department for which the Vice-President Engineering was responsible as well as for the Engineering Department itself. The Loss Prevention Department organised safety training sessions onshore for supervisors, including contractors' personnel, which were conducted by external trainers and included discussions with representatives of management.

14.8 It was stated in evidence that safety was monitored by, *inter alia*, project briefings, the supervisors' meetings, the reviewing of incident reports, the safety co-ordination meetings, daily safety inspections and safety reviews. It was emphasised

that employees were encouraged to report incidents and matters of safety concern to Occidental.

14.9 Occidental operated a comprehensive system of audits, which included the following:

- (i) Regular "in-depth technical audits" carried out over extended periods on equipment, systems or procedures by line personnel and specialists co-ordinated by a senior engineer from the Loss Prevention Department.
- (ii) Corporate audits, carried out by personnel from the American parent organisation. These involved 2-3 days of work offshore.
- (iii) Fire and gas audits, carried out by consultants as a condition of insurance on an annual basis.
- (iv) Partners' audits every 3 years. These involved 3 days of work offshore.

The audits were followed by exit meetings. Following the issue of a final report there was a system of checking to see whether the findings of the audit had been attended to.

14.10 The system which I have outlined above enabled line management, with the support of the Loss Prevention Department, to carry out its safety responsibility. It provided a system which should have been adequate for the purposes of securing that appropriate safety and emergency equipment and procedures were in place and working as they should. I do not fault Occidental's policy or organisation in relation to matters of safety. However, in previous chapters I have had to consider a number of shortcomings in what existed or took place on Piper. This calls in question the quality of Occidental's management of safety, and in particular whether the systems which they had for implementing the company policy on safety were being operated in an effective manner.

14.11 Before coming to the management evidence in regard to these shortcomings it is necessary for me to examine the evidence as to a number of events within a few years of the disaster which came to the attention of the Inquiry and appear to me to have an important bearing on this chapter.

Evacuation in a major emergency

14.12 On 24 March 1984 there was an equipment failure, explosion and release of gas on Piper, followed by a fire in the GCM. The alarms and deluge functioned on demand. The fire pumps came on line and continued to operate. The supply of fuel to the fire was cut off. The fire was put out by fire-fighters in just over 2 hours. It was essentially always under control. Platform personnel were evacuated by a number of helicopters which were in the area. By this means 179 persons were evacuated within about 50 minutes.

14.13 This incident was the subject of an Occidental board of inquiry and arising out of it a number of changes were made in the evacuation procedures. These included procedures for evacuation by helicopter which clearly was or had become the favoured method of evacuation. Occidental continued to employ a FILO on the platform to monitor in-field and passing helicopter traffic so that in an emergency their services could be called for and co-ordinated. Occidental also set up the EEC team and increased the Emergency Response Teams (see paras 8.6-7). Mr McReynolds pointed out that if the emergency happened at night-time Occidental could have scrambled 3 or 4 large helicopters from the shore. Mr Richards said that in such circumstances the longest time which the platform would require to wait for a helicopter was 2½ hours until the first personnel left the platform. I should say in passing that this seemed to me to be unrealistic as a means of delivering personnel from the hazard posed by an emergency. Long before the end of such a period the emergency would

either have been brought under control or gravely imperilled those on the platform. Following the incident there was an improvement in the radio communications from Piper, including the installation of a satellite system. However, as I have noted in para 7.52 it was not fully appreciated that in the event of communications with Piper being knocked out the establishing of communications between the other platforms and the shore would prove difficult.

14.14 In May 1984 Captain P G Clayson, then the onshore Safety Superintendent, sent a memorandum to Mr G F Foldes, who was a member of the Facilities Engineering Department and took part in the board of inquiry into the incident. This memorandum was entitled "How it was vs How it could have been". In it Captain Clayson pointed out that the successful evacuation was made possible by a number of favourable conditions. These included that the helideck was operational throughout and was not affected by explosion, fire or smoke. Unimpaired ground to air communications had been maintained. It was daylight and weather conditions were conducive to helicopter operations. Enough helicopters happened to be in the area, available and capable of responding to the emergency call. The *Tharos* was close by with less than 500 ft between the helidecks. There were no problems in refuelling the helicopters. However, he postulated a situation in which the incident might have taken place at 01.30 hours on a Sunday morning; the wind north-westerly, a sea and swell of 50-70 ft and the temperature below freezing; the standby vessel 4 miles to the south-west; the RIV 8 miles to the west, roughly half way between Piper and Claymore; and the *Tharos* not available. If evacuation by helicopter was impossible (and it did not matter why this was so), it was his opinion that injuries and risk of loss of life would be "reasonably high". As regards the lifeboats there would be little opportunity or point in attempting to launch the 4 which were on the north face. If they did get into the water and unhooked "that would be the end of them as a means of evacuation and a form of life support". He suggested that in wind velocities of force 6 and above lifeboats launched beam-on to the sea would never clear the platform before being smashed against the structure and destroyed. As regards the life rafts he said: "Just how they could be even partially loaded in bad weather boggles the mind. A fit young man would have problems and maybe fail. Many of the unfit, over-weight personnel would have no chance at all." He went on to say: "We would be very lucky indeed to get anyone aboard any of the 7 rafts. I will go further, and say we would be lucky to get anybody on any of the rafts in a 50-70 ft sea condition." Experience with ships had shown that the chances of survival were infinitely greater if personnel could stay with the ship rather than take a chance in a lifeboat. He did not challenge the philosophy of getting as many off as possible if it was safe and practical to do so. "What I am saying is, we should look at being as safe, and as comfortable as possible, in the event that we cannot go *anywhere* immediately." He suggested the following points for consideration: "(i) recognise that evacuation by sea in bad weather is not practical (many people do already but just will not admit it); (ii) shift the bias of training for mustering and drills towards evacuation by air; (iii) consider provision of offshore-based helicopter and secondary helideck provision; and (iv) re-appraise practicality and usefulness of RIV boats in realistic terms." Mr Foldes passed this memorandum to Mr Grogan along with a memorandum of his own dated 17 May 1984 in which he expressed his full agreement with the points raised and recommended that arrangements should be made to have standby helicopters available round the clock for emergency evacuation purposes. These papers came before Mr Grogan in the middle of June at a point when the Occidental board of inquiry had submitted its report. Captain Clayson was not aware of any response to his memorandum but both Mr McReynolds and Mr Grogan considered and discussed it. It may be noted that Mr Richards could not remember having seen it before the disaster; and neither Mr Gordon nor Mr Bodie knew of its existence. However Mr Bodie had discussed what would be the means of evacuation in the event that evacuation by helicopter or lifeboat or both was precluded. He said: "I still seriously thought up until the event that we could hang on to the platform with the systems we had. Given that the helicopter evacuation was unviable and lifeboat evacuation was unviable, then we would fight the fire or the

emergency on the platform with the platform capability ... until such time as we could effect a rescue by whatever means.”

14.15 Mr McReynolds said that after the incident the philosophy was reviewed in recognition of the fact that evacuation by sea in bad weather may not always be practical and account needed to be taken of the alternative of evacuation by helicopter. However as lifeboats would always be available but helicopters might not be, the bias of training was not shifted from mustering and drills at lifeboats. He felt that Captain Clayson’s scenario was “painting the worst case situation”. However he was not aware whether Occidental had attempted by means of risk analysis to assess the probability of this situation coming about. His view was that “our approach against these risks or worst case scenarios is to try and make sure that the platform itself is self-sufficient to address the scenarios whereby the people do not have to evacuate the platform.” “We relied on the on-board system to safeguard people on the platform; the system was designed to be self-sufficient; it would cater for any type of emergency that we could envisage.” Occidental had considered on several occasions how to upgrade the evacuation system. He pointed out that Captain Clayson himself had admitted that it was difficult for him to know what to suggest. Consideration had been given to re-siting the lifeboats but they were felt to be at the safest end of the platform as drilling involved the greatest area of concern. Additionally the probability of having to use the lifeboats was not high as it was expected that it would be possible to contain any fire-related emergency situation on board the platform. Occidental had decided that all coxswains should be Occidental staff and had upgraded their training, but on safety grounds had not increased the frequency of drills in which lifeboats were actually launched. The re-siting of an alternative helideck had been considered but this was not practical as the only alternative would have been at the south end of the platform which would be too close to the flares and the cranes. An in-field helicopter had been rejected as it would have been too small to be effective in evacuating personnel before land-based helicopters arrived. He posed the theoretical situation of an in-field helicopter with a pay load of about 10 persons taking 400-600 minutes to evacuate 200 personnel. This, of course, assumed that such a helicopter was the only one available for use.

14.16 Mr Grogan did not accept that the wind blew more frequently from the north. The pattern of wind direction around Piper was almost evenly distributed. Captain Clayson’s scenario was considered to be very unlikely. If the wind was from the north smoke and flames would be blown away from the helideck; the accommodation would provide a safe haven until helicopters arrived; and it would still be possible to launch at least the lifeboats from the east and west faces of the platform. The problem of lifeboat orientation and of getting away from the platform was one faced by the industry. Occidental had joined in the study by a working group of UKOOA of various methods but no good solution had emerged. For a number of reasons Occidental had decided that the lifeboats were best left where they were, which was similar to that found on most platforms in the North Sea. They had also rejected the suggestion of additional lifeboats as there were no good options. Occidental had also rejected an in-field helicopter and the re-siting of the alternative helideck for a number of reasons which he gave. The location of a FILO on Piper put Occidental in a better position than most operators to obtain the assistance of helicopters. His view was that Occidental “had considered all the things we felt necessary to remove the men from the platform. If they could not be evacuated by lifeboats, if they could not be evacuated by helicopter, there is only one thing left for them to do and that is for them to get into the life rafts.” He said that Captain Clayson had been asked to examine the life raft situation but he could not recall what was done as a consequence of that examination; and it did not appear that he had followed that matter up with him.

14.17 The Inquiry heard evidence as to the limits within which helicopters can land and take off from a platform. Mr I L Griffiths, who was the pilot of the *Tharos* helicopter, a Sikorski S76, at the time of the disaster said that the limits for that aircraft were a 200 ft cloud base and three quarters of a mile visibility. The turbulence

due to wind could also be a limiting factor. Flight Lieutenant S A Hodgson, who was the captain and pilot of a Sea King helicopter from Lossiemouth (R137) said that what was most likely to present a problem would be strong wind and very low cloud or fog. The top limit for the wind would be in the region of probably 75-80 knots. He also agreed that a fire on the platform could also give problems of turbulence.

14.18 The evidence to which I have referred in the last 6 paragraphs serves to demonstrate that there may well be situations in which evacuation by helicopters is not possible, at any rate in time to avert danger from personnel on the platform. Evacuation by lifeboats of the conventional type, and even more so escape by life raft, can be both difficult and dangerous. Neither Captain Clayson nor Occidental, in common with the industry at that time, were able to suggest any significant improvement on the methods of evacuation which already could be used on Piper. In my view the difficulties which faced Occidental were real ones and made it all the more imperative that both incident prevention and the means of fighting any fire should have been of the highest standard.

The risk of a prolonged high pressure gas fire

14.19 Occidental management can have been in no doubt as to the grave consequences for the platform and its personnel in the event of a prolonged high pressure gas fire. In para 12.2 I have referred to Mr Wottge's memorandum dated 18 March 1988 in which he stated that structural integrity could be lost within 10-15 minutes if a fire was fed from a large pressurised hydrocarbon inventory. In their property loss prevention report to Occidental dated 14 October 1986 Elmslie Consultancy Services Inc commented on the pipelines to and from the platform. They said:

“These pipelines, especially the gas pipelines, would take hours to depressurise because of their capacity. This could result in a high pressure gas fire on the cellar deck that would be virtually impossible to fight and the protection systems would not be effective in providing the cooling needed for the duration of the depressurisation.”

In 1987 the Marine Department commissioned from the Loss Prevention Department of Occidental a report in connection with their consideration of the need to continue with the hire of an RIV. Mr I Saldana prepared a preliminary report which was considered at a meeting on 16 June 1987 which was attended by Mr Gordon, Mr McReynolds, Mr Grogan and others. In his report Mr Saldana described various scenarios which could weaken the platform's structural steel support members and the means of fire-fighting in each case. One of these was an oil/gas riser rupture. In the case of a rupture on the pipeline side of the emergency shutdown valve no direct action could be taken on the platform to stem the flow of hydrocarbon. Even when the line was depressurised at the other end the flow could go on for many hours, depending upon line size, line length and system pressure. The most serious situation was a jet flame impinging on a part of the platform support structure. A detailed examination offshore was necessary to identify any such location. However, he went on to say:

“It is likely that an aerial deflagration from escaping gas or a fire on the sea from the escaping oil represents a more serious hazard to personnel and to platform abandonment plans than to the integrity of the structure itself and this may become the major concern in such an incident.”

These passages could be used to describe what happened in the disaster.

14.20 Occidental's approach to the hazard was to rely on a number of safety measures. These were:

- (i) The provision of ESVs on the risers, in order to achieve isolation of the fuel source. The Tartan and MCP-01 risers had hydraulically actuated valves with nitrogen back-up. The MOL and the Claymore riser had an electrically

operated valve with pneumatic back-up, to which a further nitrogen back-up had been retrofitted in early 1988. According to Mr Grogan subsea isolation valves (SSIVs) had been discussed in the light of a guideline from the Institute of Petroleum which suggested that they should be considered on pipelines of a certain type. However, the Elmslie report said that "the lack of subsea valves on the pipelines is an inherent hazard to the platform that is impractical to resolve at this point of platform life." Mr Richards thought SSIVs were still impractical.

- (ii) The provision of a system for rapid blowdown to reduce pressure as quickly as possible. Mr McReynolds said that in 1986 Occidental had carried out a hazard and operability study on the blowdown and flare system. Mr Wottge stated that in December 1987 his department started a safety review of the gas lift system, part of which involved a review of the hydrocarbon inventory in C Module. He had written as he did in his memorandum dated 18 March 1988 because he had been led to believe that in a platform ESD the reciprocating compressors would not automatically depressurise. This was incorrect; and it was found that following an emergency blowdown the remaining process inventory would be only about 5 barrels.
- (iii) Taking steps to ensure the integrity of the pipeline on the other side of the ESV from the platform. Mr Richards and Mr McReynolds described work which had been done some years before the disaster to ensure that there were no fittings on that side. On the Claymore line they had removed a pressure indicator. The risers were examined every year but no area of weakness had been identified.
- (iv) The provision of a deluge and other means of fire-fighting. The significance of fire-water in the case of a gas fire would lie in its use to cool the surrounding area until the fuel could be cut off. As far as the risers were concerned Mr Grogan said that the deluge covered the pig trap area; and that nearby there were monitors which could be directed at any part of the riser. However there was no other part of the deluge system which was specifically directed to the riser "because if anything fell on the riser it would fall on to the sea, to the surface of the sea".

As regards the possibility of providing fireproofing for the structure of Piper Mr Gordon said that Occidental relied very largely on the expertise of Elmslie. Mr Grogan said that it was considered impracticable because of the complexity of the operation on a platform which was fully laden with equipment; and because the additional weight would not have been supported by the structure.

14.21 As regards Mr Saldana's report Mr Gordon, Mr McReynolds and Mr Grogan all gave evidence that at the meeting it was considered that no further action was required in view of the arrangements which had already been made to prevent a catastrophe. In the light of figures obtained by the engineer from other sources Mr Gordon said that the probability of the event "was so low that it was considered that it would not happen". He added that the scenario of a platform fire burning out of control to the destruction of the metal support work had been considered in a number of studies done by Elmslie and others. "It was not considered that in the lifetime of the platform there would be a situation where all the systems failed and that such a scenario would indeed occur." He also said that Mr Wottge had assured the meeting that all reasonably practicable steps had been taken to upgrade the platform fire-fighting systems, although he accepted that at the time there were continuing problems with the deluge systems in A and C Modules and that the replacement of distribution pipework had not then started. Mr Grogan said that he and Mr Wottge had "many times considered and talked about the situation of a riser rupture because that is one of the things that we should be concerned about". "We always knew that a major riser rupture was an event which needed to be avoided. In that light we had considered that kind of situation would be one which we would not want to encounter". However it did not appear from the evidence of these 3 witnesses that the hazard posed by an

aerial deflagration to which Mr Saldana had pointed was specifically considered at the meeting. Mr McReynolds in particular said that the paragraph did not impact on him when he read the report. Both Mr McReynolds and Mr Grogan made comments on Mr Saldana's state of knowledge. Mr McReynolds said that while he was a good young engineer he was not aware of the various studies that had been done previously as he had not worked on Piper. Mr Grogan said he regarded him as not particularly familiar with the offshore scene nor aware of all the actions which had been taken and were being taken with regard to the matters which he had raised in his report.

14.22 Although the Loss Prevention Department provided advice on qualitative and quantitative risk analysis (QRA) for the auditing of the blowdown and relief system Mr Gordon could not recall that this report had considered the impossibility of blowing down the inventory of the pipelines in any reasonable time. The type of scenario that happened in the disaster in which the inventories of pipelines vented on Piper had never been considered by his department. They had not used their expertise to determine the probability of failure in circumstances specific to Piper. It was pointed out by Mr McReynolds that in his report Mr Saldana had shown the frequency for the rupture of an oil/gas riser as 10^{-4} /year. The witness commented: "I think this assessment in Appendix B was recognised to be a general assessment of industry statistics not related to Piper or Claymore. If anything these statistics would probably have given us some comfort, quite frankly, because I think our risers were designed very competently." He confirmed that no member of the management team considering the report had sought to apply the same type of analysis to the particular circumstances of Piper or Claymore. Mr Grogan also questioned the validity of Mr Saldana's frequency, pointing out that it was derived from all offshore incidents including those arising out of collision and corrosion. No consideration was given to fireproofing the risers.

14.23 I have 2 main observations to make about the evidence which I have endeavoured to summarise in the last 2 paragraphs. The first is related to the attitude of the management witnesses to the hazard posed by a prolonged high pressure gas fire. I do not think that Mr Saldana provided them with any insight into the magnitude of the hazard which they would not otherwise have appreciated. If the fuel source were not isolated, the danger to the structure and to personnel would be very great. Further, management had reasonable grounds for confidence in the measures which had been taken to prevent such an eventuality, so far as these measures went. I can also appreciate that Mr Saldana may well have appeared to be over-enthusiastic and over-ambitious in the scope of his report. However, the attitude of the management witnesses to the assessment of risk was, in my view, unsatisfactory. No doubt holes could be picked in the frequency which Mr Saldana had mentioned in his report but the witnesses' reliance on merely a qualitative opinion showed, in my view, a dangerously superficial approach to a major hazard. This was all the more pointed in the case of Piper where, unlike Claymore, there was no fireproofing of structural members; the fireproofing of risers had not been considered; and the deluge protection to the risers was apparently limited to what Mr Grogan described. I must make every effort to avoid being influenced by hindsight, but making all allowances for that I consider that management were remiss in not enquiring further into the risks of a rupture of one of the gas risers and in such an event the risk of structural damage and injury to personnel.

14.24 Quite apart from the considerations which I have discussed in the previous paragraph, the major hazard involved in the risk of a high pressure gas fire, whether prolonged or not, underlined once more the need for the highest standards in incident prevention and the means of fire-fighting.

The prevention of incidents

14.25 The quality of the management of safety in regard to the prevention of incidents depends upon what management achieve in a number of areas, including (i) the

reviewing and monitoring of safety procedures; (ii) the investigation of past incidents and equipment failures and applying the lessons of those investigations; and (iii) the examination of the safety implications of changes in equipment and activities. The evidence given in the Inquiry enabled me to consider management performance in regard to these matters. In particular I heard evidence as to their approach to reviewing, monitoring and auditing the PTW system; their response to the Sutherland fatality; their response to the discovery of stud bolt failure on a reciprocating compressor; and their decision to maintain production in the period leading up to the day of the disaster. I will deal with these subjects in turn.

The permit to work system

14.26 In Chapter 11 I examined a number of deficiencies in the PTW system. Mr Richards recognised that as a line manager one of his duties was to maintain adequate procedures for the safe control of work and to monitor their effectiveness. Accordingly he was concerned to see that the PTW system worked properly and that its efficiency was kept under review. He had no formal procedures for reviewing the system. But he said: "When an accident occurred, the permit was part and parcel of the investigation which was checked and reviewed. Occasionally I monitored, by looking at permits and I went around the site. Invariably at the time I visited the site there was no work going on because it was usually in the evening. Line supervision monitored the permits. They were checked and we never found anything seriously wrong with the permits." Minor deficiencies in the operation of the system were brought to his attention from time to time in safety meetings. His approach seemed to be, in his own words, "surely that is all you are concerned with about the permit system ... If the system is working and no problems are identified ... then you should be reasonably happy with it, surely?" He was aware that suspended permits were kept in the Safety Office. This had been the practice for years. Prior to the disaster he had paid no attention to it; but he now realised with hindsight that it was unsatisfactory. He had been surprised at the number of deficiencies in the operation of the permit system which had been revealed in the Inquiry. He had checked this out and found it to be true. He had asked himself how those deficiencies could exist without his knowledge. His conclusion was that a proper audit system should be set up. Mr MacAllan said he knew that the system was monitored on a daily basis by safety personnel. By the lack of feedback he "knew that things were going all right and there was no indication that we had any significant permit to work problems". From his own experience of 10 years offshore on Piper and Claymore he felt he knew how the crew worked and was comfortable with it. He was satisfied that the discipline necessary to operate the pressure system including the permit system existed as there were many experienced personnel on Piper. On his visits to the platform about 6 times a year he made a point of checking permits by looking at job descriptions and safety precautions. The only deficiency he had noticed was that the permit was sometimes not displayed at the job site. In such a case he would tell the man concerned to put it on display. During his time on Piper Performing Authorities did not leave suspended permits on the lead production operator's desk. His own practice had been to interrupt the handover in order to suspend the permit. Mr McReynolds explained that the permit system had been developed originally by the Loss Prevention Department, and thereafter reviewed and, if necessary, revised on a regular basis. The last review in 1985 had been prompted by an audit in 1984 which observed that the procedure was being administered somewhat differently as between Piper and Claymore. He had commissioned Mr J Barnes, an experienced OIM, to review and re-write the procedure so that it would "fulfil its purpose for controlling work and find acceptance from as many people as possible so that it would be administered in the same way". The resulting procedure was very little different from its predecessor but the witness felt that the re-writing had "tightened up the system and we were not seeing permit-related accidents". The witness accepted that it was his responsibility to see that the system was monitored. From the outset safety staff had a specific responsibility to make sure that they were satisfied with the details of the permit including the precautions to be followed and to check whether they were being followed. A similar message was given to both Occidental and contractors'

supervisors in safety seminars. On his own visits to a platform he would take notice of the work going on and whether permits were being displayed at the job site. Overall he did not get any feedback from anyone in the Operations Department that the permit system was not being operated as it should have been. In the absence of that he assumed that the system was working properly. The only points of concern about the system which he could recall were the administrative differences between Piper and Claymore and a question relating to the number of hot permits out at any one time. He was not aware of the DEN ever criticising the permit system. "From many general conversations I had a good feeling that people felt well about the permit system being able to control the work and people were reasonably happy with the system."

14.27 Mr Gordon said that monitoring was achieved by the daily checking by safety personnel on the platform. If the system was not being followed on a regular basis he would have expected to hear about it. He "had no feeling that there were deficiencies with the system". He could offer no explanation as to why none of the audits in which his department were involved revealed what had emerged at the Inquiry. A corporate audit in the last quarter of 1987 had looked at hundreds of permits which had been sent in from Piper and had not reported any deficiency to Mr Grogan. This was confirmed by Mr Grogan himself.

14.28 The quality of the laid down permit procedure was the acknowledged responsibility of management, and Mr McReynolds in particular. Although that procedure was revised as recently as 1985 there appears to have been no attempt to assess whether it stood comparison with the systems of other operators or satisfied the guidelines available to the industry as a whole. In view of the wealth of experience available within Occidental it is hard to understand how there were critical and obvious omissions in the PTW system, such as a method of locking off isolation valves to prevent inadvertent de-isolation (to which I have referred in para 11.4). The managers who had responsibility for the correct operation of the PTW system were all aware that the safety personnel on the platform were expected to monitor the daily operation of the system. All of them assumed that because they received no reports of failings the system was working properly. However none of them checked the quality of that monitoring nor did they carry out more than the most cursory examination of permits when they had occasion to visit Piper. The lack of any critical reference to the PTW system in the audits which had been carried out on Piper reinforced the assumption that all was well. However it is difficult to understand how it came about that this auditing did not identify the deficiencies which so quickly became apparent in the course of evidence at the Inquiry. Mr Richards was evidently correct when he said that his conclusion was "that a proper audit system should be set up".

14.29 Earlier in this report I reached the conclusion that a failure in the PTW system had occurred on the evening of the disaster and that if this had not occurred Mr Vernon would not have attempted to re-start condensate injection pump A and thus unwittingly caused a leak of condensate from the site of PSV 504 (see paras 6.188 and 6.191). The evidence which I considered in Chapter 11 showed that this failure was not an isolated mistake but that in a number of respects the PTW system was being operated routinely in a casual and unsafe manner. That evidence along with the evidence to which I have referred earlier in this chapter shows, in my view, the operation of the PTW system was not being adequately monitored or audited. These were failures for which management were responsible. If there had been adequate monitoring and auditing it is likely that these deficiencies in the PTW system would have been corrected.

Occidental's response to the Sutherland fatality

14.30 As I have already stated in para 11.16 the report of the Occidental board of inquiry contains no examination of the adequacy or quality of the handover between the maintenance lead hands. Nor did it examine the implications of the expansion of the scope of the work beyond what had been covered by the PTW. However, the

complaint to which they had pleaded guilty specified that there had been a failure of supervision in both these areas. In my view the work of the board of inquiry was superficial in respect that it did not examine either of these areas, at the latest after the stage at which Occidental had tendered their plea of guilty on 17 March 1987. *Prima facie* if there had been an adequate handover or if the work had been limited to the scope and conditions of one or more permits to work the fatality could have been prevented.

14.31 Mr Richards, who disagreed with the suggestion that there had been a failure in handover or that any deficiency in the operation of the permit system had any bearing on the fatality, said that no changes were made either to handover procedure or the permit system. He considered it important that each person coming on shift was properly informed of what was going on. He said that he would expect all handovers to comprise both a written log and a discussion lasting 10-30 minutes. It was his belief that handover procedures were good and he saw no reason to change them. Handovers were not formally monitored. He did not personally check on their quality but would keep his eye on them. No problems with them had been identified. Mr MacAllan's immediate assessment was that the fatality was due to a structure being used for access and as a walkway when it had not been designed for those purposes. From his experience of working on Piper he was familiar with the routine adopted for handover. He had not checked on handovers during his visits to the platform but "essentially there was a good handover period". Mr McReynolds agreed that the failure to take out a new permit for the change in lifting arrangements was a serious infraction. He said that he had given instructions that separate permits were to be taken out for the rigging component in maintenance jobs. As far as he was aware everyone was content with the handover system although there was no formal procedure covering it. The information which was passed on seemed adequate and no problems had been identified. He had no concerns about the handover system, but he was not aware that the DEN had criticised the shift handover in the case of the Sutherland fatality. Mr Grogan agreed that the change in the scope of the work was a contributory factor to the fatality and that this should not have taken place without the supervisor being informed. He treated this as an aberration of a good system, although there was nothing in the report to support that interpretation. Mr Gordon believed that the complaint related to the handover was ill-founded, but the basis for this was Mr Bodie's assurance that the handover had been well done. His department had not considered handover practice despite the findings of the DEN and Occidental's plea of guilty. The report had highlighted that supervisors must approve any change in the scope of the job. However, this had not alerted him to question the scope of what was covered by the permit in that case.

14.32 It is clear that following the Sutherland fatality Occidental personnel took a number of steps in reaction to what had happened. Two of them I have already mentioned in para. 11.16. Further it is clear that as a result of a request by the President of Occidental, Mr J F Snape, at a meeting of the management safety committee on 3 March 1988, Mr J Letham of the Loss Prevention Department prepared a memorandum dated 13 May 1988 which set out the extent to which the fatality had been followed up. However the approach adopted by management to the contents of the report of the board of inquiry was such that the result of the investigation was not passed on to senior onshore personnel, let alone senior personnel on the platform. Mr Gordon told the Inquiry that copies of the report itself were issued only to senior management, the Legal Department and himself. Accordingly Mr Richards, who had been the OIM at the time of the fatality, did not receive a copy of the report. Apart from hearing some of them "on the grapevine" he was not told what were the conclusions of the report. Mr MacAllan did not see a copy of the report but saw a photocopy of part of the recommendations which Mr McReynolds showed to him. This appeared to be in line with the policy described in a memorandum which had been submitted to Mr Grogan dated 29 March 1984 by a member of the Legal Department in connection with the incident which had occurred a few days earlier on Piper. The relevant passage of the memorandum was as follows:

“I would confirm that there is significant exposure here and that prosecution is possible. I would therefore respectfully suggest that we proceed with care, particularly in our dealings with the Department of Energy. I would also suggest that staff be reminded not to discuss the detail of the incident itself or follow-up investigation.”

I may say at this point that safety personnel appear to have been in a similar situation. Mr G G Robertson, who was then the safety supervisor on Piper, did not know what the management team had decided to do about the deficiencies which had been shown up by the fatality. Mr Bodie, the onshore Safety Superintendent, was aware of the practice whereby the discussion of any accident such as the fatality was discouraged. He said that he had to concur with that policy, which was still in force at the time of the disaster. When he was asked whether he had made representations against it he replied: “We certainly had discussions. It really is a problem, having found out what had happened in any particular incident, then to have to disguise your writing and send out memos without any mention of that particular incident but try to get action taken.” When asked whether that militated against the proper feedback which ought to have arisen he replied: “No, we managed to get the messages across to the personnel, in a lot of cases verbally, and, as I said, by very cleverly worded memos.”

14.33 The evidence given by senior management, on the other hand, rejected any suggestion that discussion was inhibited by company policy. Mr McReynolds was asked:

“Q. Was there any policy known to you whereby, in the event that an accident happened on an Occidental installation, discussion of the circumstances of the accident and lessons to be learnt, would be discouraged for fear of potential prosecution?”

A. Absolutely not. We discussed every accident in detail. We discussed the recommendations. The only thing we did not do was to duplicate that report and give it wide distribution.”

Asked whether he wished to modify that answer in the light of the passage in the memorandum to which I have referred above he replied:

“No, I do not. I would say, without doubt, that every incident of this nature was always fully discussed amongst management and amongst our subordinates. I see what the man said but that was invariably done.”

Mr Grogan’s version of the policy was as follows: “The directive from the President was one which said we want to pass the information down that is necessary for people to take action on, but we do not want to distribute reports which may have extraneous information which other people did not require to know.”

14.34 Earlier in this report I concluded that there had been a failure to communicate information as to the removal of PSV 504 in the handovers to Mr Clark and Mr Richard and that if that information had been given to them Mr Vernon would not have attempted to re-start condensate injection pump A, with the consequences which I have described earlier (see paras 6.189-192). Turning to the evidence which I have summarised above, Occidental management should not, in my view, have acted as they did by dismissing from further consideration the possible shortcomings in the PTW system and the handover practice which the prosecution in the Sutherland fatality had called in question. As regards handovers, there was, as I have pointed out in Chapter 11, some dissatisfaction as to the amount of information which was transmitted. There was no laid down procedure for carrying them out and little, if any, monitoring of them. If the practice had been adequately investigated it appears to me to be likely that failures of the type which occurred on the evening of the disaster would have been detected. As regards the results of investigation into incidents such as the Sutherland fatality, while the attitude of senior management may have been as stated by Mr McReynolds and Mr Grogan, I am far from satisfied that this took effect at lower levels. In the result I consider that whether by direction or by inaction Occidental management failed to use the circumstances of particular incidents to drive

home the lessons of the investigation of those incidents to those who were immediately responsible for safety on Piper on a day to day basis.

The response to the discovery of stud bolt failures

14.35 As I stated in para 6.176 it was discovered in February 1988 that 7 of the stud bolts on the yoke/frame extension flange on No 1 cylinder of reciprocating compressor A had failed. These were fatigue failures. All the stud bolts at the flange were replaced; and the bolts on the other cylinders were retorqued to establish that they had not cracked or lost their pre-tension. However when these failures were discovered no check was made on similar bolts on reciprocating compressor B. This was not done until May 1988. Mr MacAllan, who recalled the discovery, agreed that proper practice would have been to check the latter compressor forthwith. The fact that this was not done until May 1988 he put down to an oversight on the part of himself and the maintenance superintendents when they discussed the original problem. Mr McReynolds was aware of the original discovery but was not involved personally and did not ask why failure had occurred. He agreed that good practice would have been to inspect the latter compressor immediately. The fact that this was not done he put down to an oversight on the part of those who were dealing with the problem. Mr Gordon recalled the discovery as it was important enough to be discussed at the monthly safety co-ordination meeting. The problem was handled by the Facilities Engineering Manager and the Production and Pipeline Manager. While he knew that there was a similar compressor he could not recall whether it was discussed at that meeting but imagined that it would have been. He was surprised that several months had passed before it was examined but he was not aware of that at the time.

14.36 The failure to check the latter compressor was an extremely serious error which could have had disastrous consequences. However, in the light of the evidence I treat it as a failure on the part of those who were directly involved rather than indicating a deficiency in Occidental's general approach to such matters.

The decision to maintain production prior to the day of the disaster

14.37 Earlier in this report I described the unusually high level of work which was proceeding on Piper in the period leading up to the time of the disaster. This included major construction work, additional maintenance work, the changeout of the GCM and the associated changeover from phase 2 to phase 1 operation (see paras 3.111-117). The maintenance work included the tailend of the programme of recertification of PSVs which had taken longer than expected (para 6.80). In addition from the morning of 4 July until about 17.00 hours on 6 July it was intended to include the 24 month preventive maintenance of condensate injection pump A (paras 6.62-64).

14.38 As a result of the abnormally high level of work the number of personnel working on Piper was unusually high. A substantial number of contractors' personnel required to be accommodated on the *Tharos*.

14.39 During the period leading up to the day of the disaster there were a number of gas leaks (see para 3.120). The volume of gas being flared was unusually high, being on average 30 MMSCFD, as compared with 1-5 MMSCFD in phase 2 operation, and was subject to considerable surging. The heat generated by flaring was so great that it was necessary to protect equipment and materials. Abnormal icing was also found on the flare line passing through the dive area (para 3.125). The water cut of the processed oil was about 10% on the evening of 6 July, as opposed to a normal figure of about 2%. This was attributed to operational upset in the production separators. Mr Bolland, the Control Room operator, could not recall such a level but considered that action would have been required to reduce it (para 3.131).

14.40 The changeout of the GCM was required in order to replace the dessicant in the molecular sieve dryers. The GCM was installed in December 1980. The first

replacement of dessicant was in 1984. Thereafter it required to be at 2-yearly intervals. During the changeout in 1984 the platform was operated in the phase 1 mode for 2 months. In 1986 the platform was totally shut down during the changeout and the carrying out of other maintenance work. In these circumstances since December 1980 the only period in which the platform had previously been operated in the phase 1 mode was for the 2 months in 1984. Phase 1 operations entailed that pipework and pressure vessels were to be subjected to higher pressures and in some instances used for a different purpose from that which they served during phase 2 operation.

14.41 In regard to 1988 it is clear that it was originally contemplated that the platform would be totally shut down in June while the GCM changeout and other work was carried out. However, Mr MacAllan, Occidental's Production and Pipelines Manager, decided that production should continue during this work on the basis of phase 1 operation. In these circumstances production was maintained until the time of the disaster at the level which it had reached in the month before the additional work was started. Mr MacAllan explained that his decision was based on the view that the only part of the work for which a total shutdown was considered necessary was the planned maintenance of electrical switchgear. This particular work had been deferred to 1989. The safety implications of phase 1 operation had been considered with the Facilities Engineering Department, which was mainly concerned with the suppression of hydrates by additional methanol injection. Mr MacAllan said that he had considered that the other work which was to be done at the same time as the changeout would be achieved under control. Mr A Carter who had been responsible for working out the detailed changes required for phase 1 operation in 1984 had carried out the same responsibility in 1988. Mr MacAllan said that while he had taken the decision on the basis that this was within the authority which was delegated to him he had kept Mr Coffee informed of progress.

14.42 Mr MacAllan agreed that there was room for mistakes to occur more readily at the time of the disaster than in normal circumstances. However he was sure that the programme had been adequately planned and that contractors' personnel were familiar with the operation and were adequate from a safety point of view. He was emphatic that the OIMs and superintendents on the platform were familiar with what was going to happen. If they had had any qualms at all they would have said so. They were encouraged to do so by senior personnel. If they had thought that there was too much work to be done without a total shutdown, all that they had to do was simply to say so. "There was no pressure put on them to have too much work. They had the authority to approve and to disapprove work." I noted, however, that Mr Richards, the back-to-back OIM, said that he had not been personally involved in the decision to continue production under phase 1 operation. He was apparently unable himself to explain the reason for the decision. As regards the future, Mr MacAllan said that, although Claymore was very different from Piper, Occidental would be considering a total shutdown during the time that major works were carried out.

14.43 The decision to continue production on Piper and at the prevailing rate while carrying out a substantial and diverse programme of construction and maintenance works is puzzling. If this course was to be followed, it should have required strengthened management and supervision on the platform. In the event 2 senior posts, lead safety operator and deputy maintenance superintendent, were vacant and 3 posts, maintenance superintendent, operations superintendent and deputy operations superintendent, were filled by personnel who had been temporarily upgraded. The abnormal mode of operation and any upset conditions should have put platform management on the alert for any sign of impending problems. In the event on the evening of the disaster any decision as to whether to shut down production was left to the judgement of the lead production operator. He would have learnt how to cope with such a decision by an experienced lead operator working with him initially "to show him the ropes". There were no exercises or scenarios to give practice in dealing with this type of situation. Usually there was no time for him to refer the question of a partial or total shutdown to the OIM. Invariably he would have to make the decision

himself and he would inform not the OIM but the operations superintendent first. At least in the unusual conditions in which the platform was being operated prior to the disaster this seems to me to have imposed an excessive burden on the lead production operator and compounded the risk of something going wrong. I find it surprising that management did not consider that it was their responsibility to provide the lead production operator with greater support or guidance for this period during which process upsets were more likely and could call for the shutting down of production.

The mitigation of the effects of incidents

14.44 In realistic terms the fighting of fire on Piper depended essentially on the platform's own capability to do so. As far as external fire-fighting was concerned, the usefulness of an RIV was limited in 2 ways. In the first place, as Occidental management well knew, it would be of little or no effect against a prolonged fire fed from a ruptured gas riser, as was shown at the time of the disaster. In the second place, although Occidental elected to continue using an RIV, despite the comments which Captain Clayson had made, it was retained only as a back-up and might be 4-8 hours away from the platform, according to Mr McReynolds. Accordingly an RIV would not be at Piper unless there was a particular reason for having it there.

14.45 As regards the diesel fire pumps, Mr Richards felt no great concern that they were put on manual mode when the divers were in the water as the electric fire pumps kept the fire main primed and could supply the deluge system. The diesel pumps could be started up in less than 30 seconds. Mr McReynolds believed that the diesel pumps were kept on manual mode only when divers were working in the vicinity of the intakes. This had been the system when he had been the Production and Pipelines Superintendent in the early 1980s. When asked whether he considered that the automatic start facilities on the diesel pumps were a necessary part of platform safety he said "I thought it was a nice enhancement to the platform safety; yes." A switch in the Control Room to start the diesel pumps similar to that on Claymore had not been considered. Mr Gordon's position was that he had not been aware of the practice of putting the diesel pumps into the manual mode when divers were in the water. However he said that he would not have necessarily objected to it.

14.46 The practice which was followed on Piper of keeping the diesel pumps on manual mode whenever divers were in the water was directly due to the decision of the OIM. I have already expressed the view in para 12.11 that this inhibited the operability of the diesel pumps in an unnecessary and dangerous way. It happened despite the audit recommendation to which I have referred in para 12.9 and which was apparently not followed up by management. The absence of a switch in the Control Room by means of which they could be returned immediately to automatic mode was an obvious deficiency which ought to have been picked up during one of the many safety audits which were carried out on Piper and for which management were directly responsible.

14.47 As regards the deluge system I return to the discussion at the point where I left it in para 12.23. Evidence was given in regard to it by Mr McReynolds, Mr Grogan and Mr Gordon.

14.48 Mr McReynolds expressed the view that while the deluge system was a very important feature it was not a critical one in the sense of "the one and only thing we hang our hat on". There was more than one system which was used for fire-fighting. There were fire monitors and hose reel stations. He was familiar with the past problems of the deluge system but he said that he was satisfied that between 1986 and 1988 the deluge system would operate efficiently in the event of an emergency. There was ample water capacity as there was quite a bit of redundancy built into the system due to the uprating of the fire pumps in 1983. The problems were properly monitored. He understood that on routine testing 4-6 nozzles per part of a module were found to be blocked. He had not perceived any change by the time when he left in May 1988.

This would not prejudice the density of the spray. He also pointed out that the nozzles that tended to block were those on the outer extremities of the laterals of the pipework whereas most of the equipment was located in the centre of the modules. He said that he would have been informed if anything was found to have changed as a result of routine testing. He had told his staff in 1986 that if anything changed he would take another look at what required to be done. As he had heard nothing after 1986 he assumed that conditions had not changed. He also relied on the insurance auditors but he could not recall any comments on the deluge system in their reports. (It may be noted that whereas the audit reports in 1984 and 1985 refer to the problem of blockage, the reports in 1986 and 1987 make no reference to that problem or to the testing of the deluge system.) He was aware of the delay in the replacement of pipework in A and C Modules. He said that that was requested by the insurance auditors "who wanted to re-look at the system before we replaced it and make sure there was not something we were missing".

14.49 Mr Grogan said that he had been assured by production, safety and engineering staff that the deluge system would operate efficiently in an emergency. He was satisfied from reports of routine testing and insurance audits that the problems were not critical, although he could not recall reading that in any audit report. He said that the issue was frequently discussed by senior management but could not recall whether it had been on the agenda at the quarterly management safety meetings. (It was not recorded in the minutes of those meetings between June 1986 and May 1988.) He had no part in the decision to delay replacement of pipework in A and C Modules but he agreed with it as there were no particular problems in A Module and the problems in C Module were being controlled by regular maintenance. His information was that throughout 1987 there was a low percentage of blockage at the end of pipe runs in A Module and 10-20% blocking in the same areas in C Module. He was unaware of what was found on routine testing of C Module in February 1988. The final decision was to put not fireproofing but cooling water on the structural members. The deluge covered the pig trap area. In the area below that there were fire monitors which could be directed at any point on the riser. Apart from the pig trap area there was no deluge specifically directed to the riser "because if anything fell on the riser, it would fall on to the sea, to the surface of the sea". He felt sure that he would have discussed with Mr Wortge the problem created by the shortage of contract draftsmen, but he could not recall doing so or taking any specific action to expedite the work. At no stage did he ask for a check as to whether the system could still meet the requirements of the Fire Fighting Equipment Regulations but he assumed that it did. He visited Piper twice a year but had not asked to witness a test on the deluge system to see for himself the problems which were being experienced.

14.50 Mr Gordon who had supported the plan to phase the replacement and to start with B Module which had the highest hydrocarbon inventory, had agreed with the delay in the replacement of A and C Modules. This was on the advice of Elmslie that Occidental should look at the water protection of the structure. Mr Gordon agreed that the deluge system was very important for the safety of the platform. He said: "Our department made checks on the system at regular intervals, and we were keeping a constant watch on the position." He himself did not receive specific reports but relied on Mr Bodie to keep him informed. The position of his department was that the deluge system was operating satisfactorily although not to capacity. He was assured by the Facilities Engineering Department that the water capacity was still sufficient to address any fire situation within the modules. The system would perform if required and was acceptable in the short term, despite the statement by that department on 6 June 1986 that there was "a serious question on how many deluge nozzles could block during an emergency situation. This problem has been getting worse over the last few years ...". Mr Gordon did not call for any testing of the deluge system other than was carried out under safety personnel on the platform. He relied on the insurance audit as an independent check. That system had not been commented on in the audit reports for 1986 and 1987. Therefore he inferred that the situation was satisfactory to the auditors.

14.51 In contrast with onshore plants where a local fire service and expert fire crews can be called up within minutes an offshore platform such as Piper requires to be self-sufficient in fighting a fire. On Piper the main systems of active fire-fighting were the deluge system and the fire monitors. It was essential that these systems along with the facility to blow down the hydrocarbon inventory were maintained in first class working condition. It was reasonable for Occidental to attempt to cure the difficulties which had come to light by fitting larger nozzles and carrying out regular cleaning, before embarking on a complete replacement of the distribution system in non-corrosive material. As I said in para 12.22 it was not unreasonable for them to proceed by taking the replacement of pipework in one module at a time and to do the work in such a way as to avoid putting the whole of the system in one module out of operation at any given time. However, having regard to the very great, if not critical, importance of the deluge system it was in my view unacceptable that the process of rectification should be still only one third complete 4 years after the problem had been clearly identified. Even if it was reasonable for the initial replacement in B Module to take as long as 2 years Occidental should have been able to draw on their experience by following on rapidly with replacement in the other modules. They could and should have eliminated delay caused by the lack of enough contract draftsmen. The prolonged process appears to me to have stemmed from the failure of senior management to manage the rectification with the urgency that such a vital safety system warranted. No senior manager appeared to me to "own" the problem and pursue it to an early and satisfactory conclusion. None of the management who gave evidence took the step of witnessing deluge tests for himself. They too readily accepted the advice of more junior staff that the system would still be effective in handling an emergency; whereas in reality by at least February 1988 it was clear that it would not.

General observations

14.52 The evidence which I have considered in this chapter should be considered along with my observations in Chapters 11-13. It appears to me that there were significant flaws in the quality of Occidental's management of safety which affected the circumstances of the events of the disaster. Senior management were too easily satisfied that the PTW system was being operated correctly, relying on the absence of any feedback of problems as indicating that all was well. They failed to provide the training required to ensure that an effective PTW system was operated in practice. In the face of a known problem with the deluge system they did not become personally involved in probing the extent of the problem and what should be done to resolve it as soon as possible. They adopted a superficial response when issues of safety were raised by others, as for example at the time of Mr Saldana's report and the Sutherland prosecution. They failed to ensure that emergency training was being provided as they intended. Platform personnel and management were not prepared for a major emergency as they should have been.

Chapter 15

Piper Alpha and the Department of Energy

Introduction

15.1 In this chapter I will examine the involvement of the Department of Energy (DEn) with safety on Piper from June 1987 until the disaster; and consider how it was that this did not reveal deficiencies which I have set out in preceding chapters.

15.2 The statutory background to the roles of the DEn and other bodies is set out in the following chapter. For the present it is sufficient to state that a large number of specific duties are placed upon operators and OIMs by the Mineral Workings (Offshore Installations) Act 1971 (MWA) and numerous regulations made under that Act. In addition the Health and Safety at Work etc Act 1974 (HSWA) imposes wide-ranging general duties on employers to ensure, so far as is reasonably practicable, the health and safety of their employees and those who may be affected by the conduct of their undertakings. The Government has no direct legal responsibility for safety. On the other hand it is responsible for developing, administering and enforcing the statutory framework. It also seeks in various ways to assist those who are directly responsible for safety to meet their responsibilities and seeks to promote progressive improvement in safety standards. Much of this work is carried out by the Safety Directorate which forms part of the Petroleum Engineering Division (PED) of the DEn. Under an agency agreement with the Health and Safety Commission (HSC) the Secretary of State for Energy undertook responsibility for the enforcement of the HSWA and the regulations made under that Act. The enforcement of the legislation is sought to be achieved mainly through inspections and investigations carried out by inspectors from PED. However the adequacy of fire-fighting equipment, life-saving appliances and navigational aids is sought to be achieved by means of biannual examinations by surveyors of the Department of Transport (DoT) on behalf of the Secretary of State for Energy. In addition, offshore installations require to be certified as fit for various purposes affecting safety. In that connection during their working life they are subject to periodic survey by a certifying authority, such as Lloyd's Register of Shipping.

Inspections and investigations by the Department of Energy

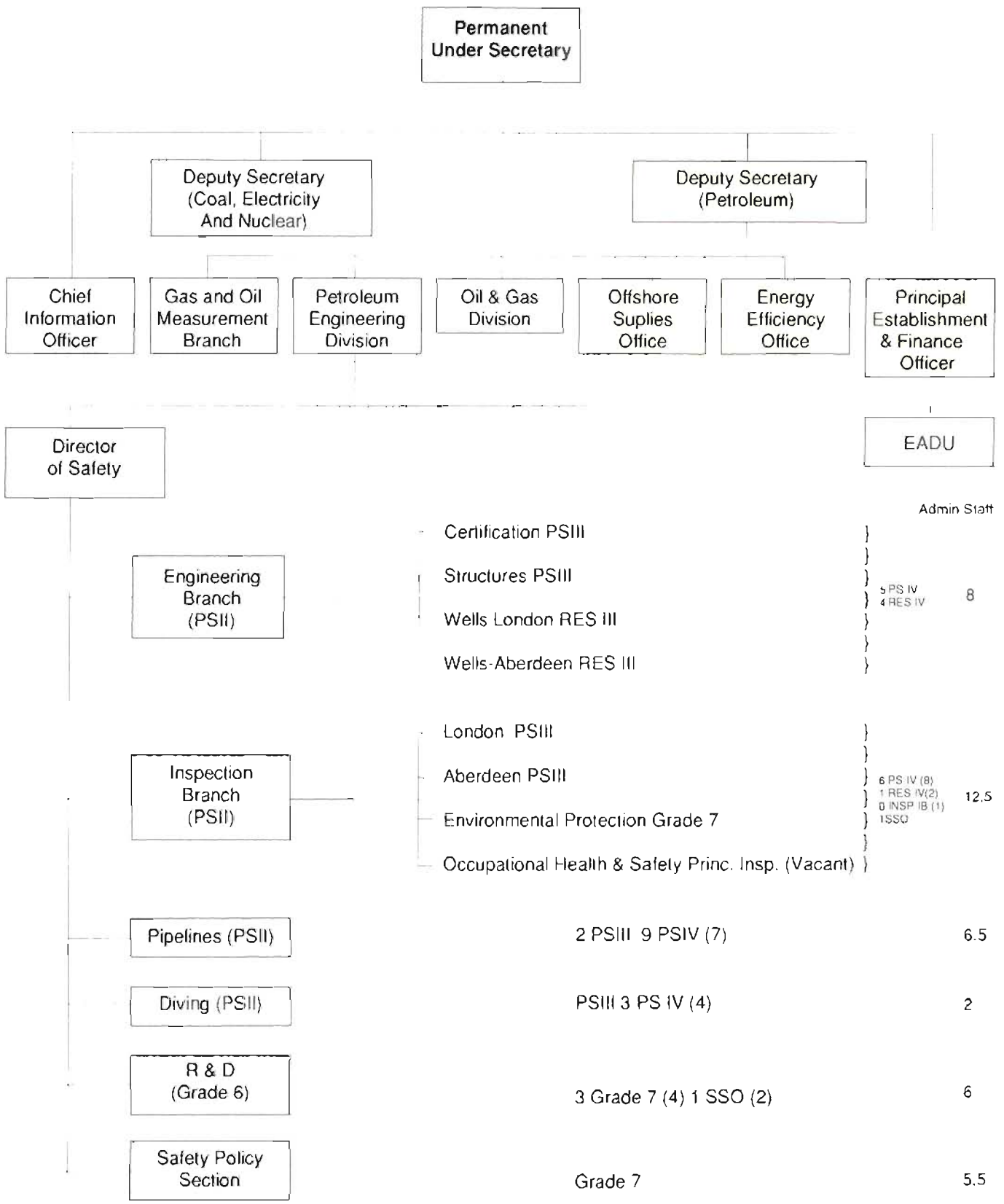
15.3 The Inquiry heard the evidence of Mr J R Petrie, who has been the Director of Safety since 1987; Mr R J Priddle, Deputy Secretary of the DEn since September 1989; and Mr R D Jenkins, one of the Senior Inspectors of PED who carried out inspections of Piper in June 1987 and June 1988, along with the investigation of the Sutherland fatality to which I have already referred in para 11.15 *et seq.* This evidence enabled me to consider the inspections and the investigation against the background of the system of which they formed part, and examine the extent to which that system was effective to secure its stated objectives. Fig 15.1 shows the organisational structure of the DEn and of the Safety Directorate.

Inspections

15.4 According to Mr Petrie in giving evidence from a prepared statement the primary objectives of inspections carried out by the DEn are to:

“(a) monitor compliance with the legislation; (b) secure compliance where necessary; and (c) promote safety, health and welfare, in particular by disseminating relevant information to industry and keeping abreast of developments.”

The type of inspection practised by the DEn plainly calls for the exercise of judgement on the part of the inspector. As is put in a document describing the offshore regime and produced by the DEn at the Inquiry,



Key:

PS - Petroleum Specialist
 RES - Reservoir Evaluation Specialist
 INSP - Factories Inspector
 SSO - Senior Scientific Officer

Fig. 15.1 Organisational structure of the Department of Energy and of the Safety Directorate. Figures show staff in post on 11/8/89, excluding consultants. Staff complement, where different, is shown in brackets.

“The purpose of inspection is not exclusively to seek out cases of non-compliance with the regulations, but more to assess the adequacy of the safety of the installation as a whole. This is an essentially selective procedure. Neither in this, or in any other area of industrial safety, would it be possible or right to provide total supervision of the operator’s activity, which he carries out in pursuance of his own primary responsibility for safety. The purpose of inspection, supported as necessary by enforcement, is to provide stimulus and support to that eventual activity and to ensure that standards are maintained.”

15.5 At the time of the disaster there were 59 fixed installations and 42 active mobile installations in the northern waters of the North Sea within the UKCS. At July 1989 there were 139 fixed installations and 76 active mobile installations in the whole of the UKCS. An annual programme of inspection is drawn up and agreed with the HSC. The frequency with which an installation is inspected is determined by the use of a rating system, which was revised in early 1988. According to this system, which is operated with the use of a computer program, points are added in proportion to the lapse of time since the last inspection; and a rating is given by an inspector at the time of an inspection, based on the type of operation, the effectiveness of management to maintain acceptable standards, the complement on board and a general view of all aspects of safety, health and welfare including training, maintenance and emergency procedures and equipment. The higher the total of the marks, the sooner the installation will be visited again. The number of visits to an installation varies from 3 or 4 per year during the construction phase to less than one every 2 years for unmanned installations. The average period between inspections is in the region of 12-18 months. The rating system reflects the fact that greater emphasis is placed on installations which are perceived to be “at greater risk”. The Principal Inspector assigns the inspectors who are to inspect particular installations. Inspectors of different disciplines are frequently assigned to successive inspections of an installation. Mr Priddle pointed out that although there were advantages in an inspector becoming familiar with a platform it was undesirable for too close a relationship to develop between him and an OIM. According to Mr Jenkins the target set for inspectors is a total of 35 offshore visits per year, inclusive of both inspections and investigations.

15.6 Mr Petrie described the inspection as:

“essentially a sampling exercise. The inspector samples and audits the state of equipment and working and management procedures. He talks to personnel and seeks to obtain an over-all picture of how well the installation is being operated, maintained and managed. An inspector must exercise his professional judgement in determining the scope and depth of the inspection and is selected, trained and supervised by line management to this end. He is not given a fixed list of procedures, equipment and items which he must tick off in the form of a check list. This could create considerable difficulties given the variety of operations, working procedures and installations involved. In addition it would lead to operators anticipating those areas which an inspector always checked.”

He distinguished inspections from surveys - such as carried out by certifying authorities. “They are required to report positively in that they must indicate what they have actually checked; on our inspections we report what actually catches our eye at the time of the inspection.” It was for the inspector to decide what were the areas in which his time could be most fruitfully spent. In focusing his attention on the areas which were most in need he could give a better quality of inspection.

15.7 Inspections are planned in advance. This preparation takes on average about one day’s work. Its scope depends on the size, type and activities of the installation, and the results of previous inspections and investigations. Apart from looking at the relevant documents the inspector may seek information from colleagues who are skilled in other disciplines. The inspector should amend his plan in the light of any problems encountered on the platform which require special attention. Mr Petrie also said that special visits may be made concentrating on one aspect or checking on some particular

deficiency. The reports of investigations were previously held in London and sent to Aberdeen only on request. They are now held in Aberdeen. Mr Jenkins said that he had not been given any written guidance in how to go about preparing for an inspection but in the 3 or 4 months after he had joined the PED in March 1987 he had picked up the method from other inspectors in the first inspections which he had attended. He selected the areas in which he would carry out his sampling process on the basis of a reading of the inspection reports for the previous 2 or 3 years.

15.8 During an inspection an inspector often will check fire-fighting equipment and life-saving appliances. He may require all or part of a drill to be carried out. His main concern would be the effectiveness of the maintenance and the emergency procedures. If he found defects in any equipment which was relevant to the work of the surveyors he would discuss this matter with the Principal Inspector, who might raise the matter locally or take it up on an inter-departmental basis.

15.9 Transport to installations is by means of helicopter on charter to the licensee or operator. The Inquiry heard evidence as to the practicability of inspectors making surprise visits; and as to the possible advantages and disadvantages of such a practice. Mr Petrie pointed out that in view of the need for advance booking of passengers into a flight it was not possible to keep a visit secret. Generally 3 days' notice was required. If a helicopter were to be chartered or obtained at very short notice the filing of flight plans and normal communications would mean that there could be no question of a surprise visit. In any event clearance to land would be required from that installation. This might not be possible for a variety of reasons such as the use of explosives in drilling activities at the time of arrival. The opportunity to make a surprise visit had occasionally arisen and been taken. More recently an arrangement had been made whereby helicopter operators were authorised to make seats available on particular flights even if it meant that someone else required to miss the flight. It was recognised that this might cause problems of accommodation on the installation. It had been used occasionally, allowing the inspector to arrive with only a few hours' notice. On the other hand both Mr Petrie and Mr Jenkins pointed out that there were certain advantages in advance notice of an inspector's visit. A higher profile for the visit was created. There was no excuse for any failures in the operation or house-keeping of the installation. Personnel knew when they would be able to approach an inspector with any points which they wished to raise. Mr Jenkins also made the point that advance notice "usually means that the installation is cleaned up and an inspector can concentrate on more fundamental and important matters".

15.10 In the northern waters inspections typically take 2 days, including the time for travelling to and from the installation. According to the evidence, inspections might cover any aspect of an installation, its systems and practices. The inspector might decide to concentrate on a particular topic and extend the visit. If he saw anything requiring immediate correction he would direct the necessary action. If the problem was in an area of expertise where his own knowledge was not sufficient he would discuss it with colleagues and might pass it on to another inspector of the appropriate discipline if this was agreed by the Principal Inspector. During the inspection the inspector would ensure that he was available to discuss any points which personnel wished to raise with him. Mr Petrie said that the value of feed-back from personnel was that "the inspector will gain direct from the workforce their concerns, their worries and how they do their job, which are valuable matters to him in deciding on the thrust of his inspection and matters that he may wish to take up with the manager or onshore management". Notices were posted on installations giving contact numbers of the DEN. Anyone might complain by letter, telephone or by personal appearance. He said that a worker would often wish to maintain anonymity. This created difficulties from time to time. It could be difficult to carry out investigations offshore in such a manner as to hide the identity of the complainer. Prior to the disaster there were not many complaints. "There have been quite a lot since." Mr Jenkins pointed out that there was a further point of contact with the workforce, namely by meeting elected safety representatives. Many companies had had a voluntary

system of elected safety representatives and committees. However on Piper the safety representatives who met on the safety committee were supervisors from various departments and not independently elected individuals. Accordingly a formal meeting was not held with them.

15.11 After the inspection the inspector would discuss any matters of concern with the OIM and give him a note of them. These points were later included in a letter to the company. If a satisfactory reply was received the inspector might take the matter no further. If he remained dissatisfied he would discuss the matter with the Principal Inspector and perhaps carry out a check visit. The actions open to him were:- (i) to indicate the improvements to be made; (ii) to enforce these by use of improvement or prohibition notices under the HSWA; or (iii) to recommend prosecution. The inspector also had powers under the Inspectors and Casualties Regulations to require operators and OIMs to “do or refrain from doing any act as appears necessary” to avert any casualty, immediate or otherwise, or to minimise the consequences of a casualty. The use of such powers could result in the temporary shutdown of an installation. Under Reg 7 of the Operational Safety, Health and Welfare Regulations the inspector could require the operator to amend written instructions so as to make adequate provision for the safe use of equipment and safety in the carrying out of operations on an installation. In exceptional cases Mr Petrie might intervene by writing to the senior management of the operator. He said that this had been found to produce prompt corrective action. Although in principle the licence could be revoked, this has not so far been considered necessary.

15.12 Following his inspection an inspector would prepare a report of the inspection. This is submitted to the Principal Inspector and then passed on to the higher levels within the Safety Directorate. According to Mr Petrie the report is intended to indicate to PED management and the next visiting inspector what has been attended to and any matters of concern. It should contain a reasonably comprehensive description of what the inspector has done. According to Mr Jenkins a report is normally expected to be 2-3 pages long. This was set by the Principal Inspector as the ideal target. He did not set out to note everything that went through his mind on an inspection. He put in the items which he considered to be most relevant on the visit.

15.13 The operator is not sent a copy of the rating form or of the inspector’s report.

Investigations

15.14 The investigation of accidents and dangerous occurrences is clearly recognised as an important aspect of the work of the Safety Directorate since it can point to lessons which can be learnt. Under the Inspectors and Casualties Regulations operators are required “in the most expeditious manner practicable” to report to the DEN any “casualty”, which means for practical purposes any fatal or dangerous accident. According to the informal guidance given by the DEN, the reporting requirement covers (i) fatalities and cases of serious bodily injury; (ii) accidents involving the integrity of the structure; and (iii) accidents which could have directly caused serious bodily injury and which fall under one of the following 6 heads:- (a) a blowout from a well or emission of noxious vapours e.g. hydrogen sulphide; (b) bursting of high pressure hoses, pipes, pressure vessels or boilers; (c) structural failure of any plant, machinery, equipment or material; (d) explosion or fire; (e) collapse or failure of a crane or part of a crane or crane rope or chain or other equipment used in the lifting of loads; and (f) any other form of accident that could have had similar serious results. In the passing it may be noted that a leak of hydrocarbon is not specifically mentioned. Accordingly it would only come within the reporting requirement if it fell under one of the above heads. According to Mr Jenkins a leak would qualify for reporting if there was sufficient gas to cause a significant explosion if it was ignited.

15.15 An immediate offshore investigation is carried out in every case in which the accident has proved or is likely to prove fatal. Apart from these cases it is for the duty

inspector, or for the Principal Inspector on the next working day to determine whether such an investigation should take place. The decision as to whether there should be an offshore investigation depends largely on the view taken of the severity of the result of the accident and the information that may be learnt from it. Mr Petrie agreed that learning came from a study of the causes of accidents as opposed to their results but said that the results usually gave some indication of the original causation. Further, part of the reporting procedure was that the person reporting stated what was understood to have gone wrong. Investigations were initiated either immediately or at any rate within a few days of the receipt of the report. All the reports were read. In some instances the investigation was onshore only. Mr Jenkins explained that the Principal Inspector decided whether there was to be an onshore investigation or none at all. Pending the visit of an inspector operators were required to "freeze" the area of the casualty for 3 days.

15.16 As regards the number of reports which were investigated, Mr Petrie said that all fatalities and accidents involving extensive injuries, if there were any major lessons to be learnt, were investigated. So also were the larger explosions and any "near misses", having regard to their potential severity. Overall, 40% of the total of fatal and serious accidents reported to the Department were investigated, either by an offshore or an onshore investigation. Mr Petrie regarded this level of investigation as acceptable, and indeed quite high. Limitations on manpower prevented the Department from investigating all accidents. Further, he did not know of any industry in which this was practised. It would be practicable for the Department to call on the Health and Safety Executive (HSE) for additional manpower, but the HSE have their own staffing problems and any inspector who was seconded from the HSE would require to work under a DEN inspector who alone had the statutory powers through which the legislation could be enforced. However, he had arranged for assistance, from the Technology Division and Research Laboratory of the HSE. Help could also be obtained through contracts with consultants such as The Robert Gordon Institute of Technology.

15.17 In connection with casualties inspectors have open to them the various courses of action which I have set out above in connection with inspections.

The inspection of Piper in June 1987

15.18 Mr Jenkins carried out an inspection on Piper on 3-4 June 1987. This was his first visit to Piper and the first inspection which he had carried out on his own since becoming an inspector in the Safety Directorate in March 1987. He said that he found the platform was well run. He was quite impressed by the quality and confidence of the personnel. The methods of working were not necessarily committed to writing. Although they were often based on custom and habit they appeared to be satisfactory. Housekeeping appeared to be good; the log books, maintenance records, lists of personnel on board, and records of musters and drill frequencies were in order. He was aware that the platform equipment was getting old and that the Occidental personnel had served there for a long time. In his report he stated "There are indications that the staff are looking over their shoulders and cannot see any fresh developments from Occidental in the North Sea. This is an operator where morale and job interest could drop as the years progress." In his report he also noted that a number of areas on the platform had been refurbished and commented that it would be necessary for this effort to continue. He noted that the Control Room was an alarm and indicating station in which a small number of automatic controls could be performed by conventional pneumatic controllers; and that the remaining actions required to be carried out by operators at the plant itself. He said that he favoured the use of small intermediate control rooms in the various areas of the plant.

15.19 Following his inspection Mr Jenkins discussed a number of comparatively trivial points with the OIM which he put in writing on 12 June 1987. On 10 July Occidental replied stating how the various points had been attended to. This response

was regarded as satisfactory. As nothing dangerous or life-threatening was found during his inspection no immediate follow-up was necessary.

The investigation of the Sutherland Fatality

15.20 The death of Mr F Sutherland on 7 September 1987 was investigated by Mr Jenkins who visited Piper on the following day and submitted his report on 29 September 1987. He found that the handover between the day-shift and night-shift was unco-ordinated. The supervisors handed over in one location. The tradesmen did so simultaneously in another place. The night-shift supervisor did not subsequently visit the site or discuss the job with the men before the accident. The procedure for handling the canopy was not clear. The day-shift supervisor had delayed deciding how he would handle the canopy until after the cover was removed. The night-shift supervisor did not grasp this problem and the job continued without adequate supervision. The personnel on the night-shift changed the procedure without informing the supervisors. It was Mr Jenkins' view that the fatality was due to poor handover procedure and inadequate supervision. The original task had been to inspect the pump bearing and repair it if possible. A permit to work had been issued for this work. The job then developed into replacing the bearing. A new permit to work was not taken out to cover the enlarged scope of the work. "It was a case where people were too lazy to take the permit out". He agreed that if the work had been confined to what was covered by the permit Mr Sutherland would not have died. However, he said that in his investigation he had concentrated on areas other than the permit.

15.21 As I have stated earlier in para 11.16 Occidental were prosecuted for a breach of Secs 3(1) and 33(1)(a) of the HSWA. In the complaint to which they pleaded guilty on 17 March 1988 it was charged:

"And you did fail to supervise said job in the following respects, viz (1) there was inadequate communication of information from the preceding day-shift to the night-shift during which said accident occurred; (2) no new permit was taken out to cover the installation of said lifting gear and other necessary work; (3) the said deceased had been allowed to select his own method of performing the job without discussion with the supervisor; (4) suitable access to the working area had not been provided nor had safety equipment such as harness and lines; and (5) said canopy was not bolted down and was being used as a working platform."

The inspection of Piper in June 1988

15.22 Following Occidental's plea of guilty on 17 March 1988 Mr Jenkins was asked by Mr D Bainbridge, the Principal Inspector in Aberdeen, to examine changes in Occidental's work procedures and at their offices and then carry out a "check visit" to Piper in April or May 1988. On 25 March he attended a meeting at Occidental's office in Aberdeen and was given a description of job task analysis which Occidental proposed to introduce. As they were in the throes of introducing this he did not go into the new work procedures in detail. He considered that new procedures would develop from job task analysis but that it would take a long time to set up the latter. At the meeting there was also discussion of Occidental's award of a 3 year contract to the Wood Group for the provision of all-trade services. This was intended to minimise the disruption caused by the changing of short-term contractors and improve supervision of tradesmen.

15.23 In the event Mr Jenkins' third visit to Piper was delayed until 26 June 1988. This visit was intended to combine the "check visit" with a routine inspection of the platform. The length of this visit is of some significance. Mr Jenkins arrived at Piper in the middle of the morning and worked there until 22.00 hours. The normal routine would have been to continue the inspection on the following day until it was time to depart for the shore. However, on this occasion he was due to be transferred by shuttle helicopter to the *Tharos*. He rose early and carried out an inspection on the *Tharos* in

regard to its accommodation role until lunch time. After that he met the OIM and caught the crew-change helicopter back to the shore. In the result he was able to devote only about 10 hours to the inspection of Piper. During that time he took "a comprehensive walk" round all the production and drilling areas and the 68 ft level. His walk took most of the afternoon. The areas which he concentrated upon were those in which there was construction work in progress.

15.24 In his report on this inspection dated 4 July 1988 Mr Jenkins stated "With respect to the Sutherland fatality, the following improvements in working practices were noted: (a) handovers between shifts have been tidied up; (b) Occidental are looking at the more formal methods of undertaking jobs through the job task analysis scheme ...". As regards the "tidying up", Mr Jenkins said that he was informed during his inspection that Occidental had arranged that "supervisors did handover to the incoming supervisor at the workshops where they sat in on the tradesmens' handover. This ensured continuity between handovers. In other words, all relevant personnel were at the same location for the handover." He had discussed the method of handover with Mr A G Clark, maintenance lead hand, who indicated that Occidental had taken it in hand and that they then had a satisfactory method of handing over, so that there was no need for him to make a recommendation. Mr Clark had described the method of handover and he was satisfied with it. However, Mr Jenkins did not witness an actual handover as he did not have time to do so. Nor did he check what Mr Clark had said to him. He said in evidence that if he had known that Mr Clark was not satisfied that the handover procedure was watertight he would have been dissatisfied. As regards job task analysis Mr Jenkins was aware that this involved the preparation of written procedures, including details of the methods to be followed, the type of persons to be employed, the tools and materials required and the safety isolation steps. It was usual to employ consultants to set this up initially. "I wondered how busy personnel were doing their usual work before touching any job task analysis, and I questioned if they had the manpower or the impetus to carry it through. For the system to work it does require that the management onshore are fully behind it, and that they in turn enforce on the lower-level management the requirement to see that it is put into effect."

15.25 As regards the permit to work system, Mr Jenkins examined about half of the 20-30 permits in the Control Room. In the case of 6 of them he checked to see whether the precautions at the work site matched those stated in the permit and were suitable for the job. He asked to see permits which were being used by contractors and endeavoured to find out whether they understood what was on the permit. During these checks nothing abnormal was found. He had also asked personnel in the Control Room if permits were being filled in properly. Since the permit to work was not regarded as a key factor in the Sutherland fatality he did not concentrate on the permit to work system. No attempt was made to assess the overall quality of the permit to work system in the light of that fatality.

15.26 Mr Jenkins concluded his report by stating: "There appears to be a new air of confidence in Occidental with appraisal drilling and well testing both on fixed platforms and from a number of semi-submersibles round about. Lessons appear to have been learnt from the Sutherland fatal accident. A routine inspection in one year's time is appropriate." He provided a short list of points for the OIM. There were no points of major concern. Following the visit he had a meeting on 4 July with Mr R M Gordon, Occidental's Loss Prevention Manager, at which there was some discussion of the fatality and the progress made since then in the quality of supervision and procedures. However, the main subject of that meeting was a routine inspection of Claymore where for commercial reasons a production separator had been welded in a hazardous area without a complete platform shutdown.

Comments on the inspections

15.27 The findings made by Mr Jenkins in his inspection in June 1988 bear a striking contrast to what was revealed by the evidence in the Inquiry. A number of examples may be taken.

15.28 As regards the permit to work system Mr Jenkins said in evidence that the practice of having work permits relating to the same plant in both the Control Room and the Safety Office was not conducive to the correct functioning of the permit to work system. This imposed an even greater need for cross-referencing. Permits should not be separated on the basis that the jobs to which they related were on different levels. If there were many suspended permits this suggested that forward planning might not have been good. He wondered how contractors' employees would necessarily know about the practice of placing suspended permits in the Safety Office, for which no provision was made in the General Safety Procedures Manual. He also commented on the time which would elapse if the checking of work sites was left until after work was suspended or cancelled. Had these points come to his attention he would have brought them to the notice of the OIM. He said that he had not known that suspended permits were kept in the Safety Office. He also expressed concern about the implication in the evidence that gas testing was carried out on Piper on a fairly regular basis. This suggested that there were a large number of hot work permits issued. On many installations, he said, it would not be the norm for hot work permits to be granted unless it was impracticable to do otherwise. Many installations endeavour to save hot work for shutdown for safety reasons. In this connection he referred back to the welding on the production separator discussed at the meeting on 4 July with Mr Gordon. In that case it appeared to him that Occidental had considered production more important than safety. In addition the practice they carried out on that occasion led to a loss of production which would have been little different from that which would have been suffered if they had completely shut down before carrying out the necessary repair. Mr Jenkins said that he had accepted the form of the permit to work as reasonable for the nature of the installation. As far as he was concerned it conformed in spirit with Reg 3 of the Operational Safety, Health and Welfare Regulations.

15.29 Mr Jenkins' attention was drawn to the "Guide to the Principles and Operation of Permit-to-work Procedures as Applied in the UK Oil Industry" which was prepared by the OIAC. This contains amongst other things a checklist, consisting of a series of questions, to enable permit to work procedures to be assessed in order to determine whether they cover all the essential points. Mr Jenkins knew of this document but was not familiar with the checklist. The inspectors had not been provided with any checklist on which to base an assessment of a permit to work system. He said that to carry out a detailed, comprehensive check on the permit to work system on Piper would require a study over a period of days, ideally by persons with specialised knowledge. He had never prepared, reviewed or brought into operation a permit to work procedure. He did not look at Occidental's Operating Procedures Manual in connection with the permit to work procedure on Piper because he did not have time to perform a full audit which, as he said, would take 2 or 3 days.

"It would involve reviewing the procedures, which is such an exercise that it would probably be done onshore; it would involve seeing the planning exercise that went on in a specific number of jobs; it would involve watching the permits being taken out for these jobs; it would involve watching the jobs being undertaken; it would involve observing the precautions that were being taken to initiate these jobs; it would involve observing the permits being suspended at the end of the day and seeing them being taken out again the following day and eventually being cancelled at the end of the job. Typically, even a short-term job can take 2 or 3 days, and I do not have that sort of time during my inspections."

He agreed, however, that with the knowledge he now had of what did take place on the platform, so far as the permit to work procedure was concerned, such an exercise would have been very revealing.

15.30 In regard to handovers at the end of shifts Mr Jenkins agreed, as I have stated above, that had he been told the full story he would have been dissatisfied and would have brought matters to the attention of the OIM.

15.31 As regards the fire-fighting system, Mr Jenkins was totally unaware of the practice of switching the diesel fire pumps to manual mode during the shifts in which

there was diving. He did not inspect the deluge system. He might have asked whether the platform were having any problems with the system but could not recall doing so. He could not remember whether there was anything wrong. However, he was sure that during both inspections he examined the certificate issued by the DoT surveyors. If there had been something wrong with the deluge system he would have expected the certificate to tell him so.

15.32 As regards lifeboat drills Mr Jenkins said that he frequently but not invariably checked the records of these drills. Even if he did so he did not necessarily put it in his report. Apart from the target length for the report, he put in the items which he considered to be most relevant on the visit. As regards drills "it depends on whether they catch the eye during the visit or not".

15.33 Mr Petrie was asked to comment on the fact that Mr Jenkins' reports made no mention of (i) weaknesses in the permit to work system; (ii) maintenance problems with the deluge system; (iii) holding of diesel fire pumps on manual mode; (iv) the frequency of drills; and (v) difficulties in release of personnel for training and drills. He could not explain why neither inspection had disclosed any of those deficiencies. He said "I think within the context of carrying out an inspection and the very wide-ranging Inquiry that is going on here there is a total difference in approach. All I can say is that if the inspector had come across anything in those items I would have expected him to comment upon it." However he maintained the view that the sampling system worked. He had not, as a result of the disaster, looked personally at the quality of the work which the DEN had done in regard to Piper.

The quality of the Department of Energy's inspections and investigations

15.34 In the light of the evidence which is reflected in the preceding paragraphs of this chapter I turn next to consider a number of factors which were the subject of evidence and which may have a bearing on the quality of the DEN's inspections and investigations and their failure to detect a number of significant weaknesses and deficiencies on Piper which had serious safety implications.

The qualifications and training of inspectors

15.35 The basic qualification for an inspector is that he should be a chartered or graduate engineer with at least 5 years' background experience. The range of acceptable backgrounds includes structural, mechanical, electrical and process engineering, naval architecture and drilling. The DEN have been unable to recruit process or chemical engineers. However, according to Mr Petrie, "I have people who are aware of process control and can look at the process system from the point of view of safety." One of the inspectors is a former OIM. All inspectors became "Senior Inspectors" upon recruitment. A new recruit during his first months would attend internal seminars or he would probably go to the OPITB course for OIMs. An attempt would be made to get him on to the first available legal course provided by the HSE as part of the 22 week course for its intake. His attendance at other modules in that course would be a question of management control and assessment of the needs of the individual recruit. However, Mr Petrie stressed the difference in background and experience between recruits to the DEN and recruits to the HSE. Efforts are made to ensure that DEN inspectors do not concentrate attention on the disciplines with which they were already familiar. During the course of their work they gain additional skills. They do not carry out inspections on their own until they have been working for 3-6 months. Their appointment is subject to confirmation at the end of 2 years. When Mr Jenkins joined the Inspectorate as a Senior Inspector in March 1987 he had no past experience in process or chemical engineering. He is an electrical engineer. Prior to the disaster he had attended the course for OIMs and courses on law enforcement and drilling. It had been his intention to attend a course on production in the autumn of 1988 but the disaster intervened. As I have stated above, his visit to Piper in June 1987 was his first unaccompanied inspection as well as his first visit to Piper.

15.36 Mr Petrie agreed that his inspectors had no expertise in the scrutiny of hazard and operability studies, whereas this expertise existed within the HSE. He explained that one of his Principal Inspectors was consulting with the HSE and others in connection with the Department's proposals for safety assessment. However he saw no need to seek advice from the HSE in regard to their approach to general inspection work. One inspector remained on secondment from the HSE to the Safety Directorate. His function was to keep in touch with current practice in the HSE and also to provide additional expertise in occupational health and safety. There were difficulties in employing HSE factory inspectors for general inspection work offshore because of their different qualifications and experience. Mr Petrie said that he regarded his inspectors as being more like Mines and Quarries inspectors, who form a separate group within the HSE, requiring special qualifications and experience of the industry with which they are involved. Mr Priddle gave a number of examples of external training which DEn inspectors had undertaken during 1989. These included risk assessment, drilling and workover, noise mitigation and the problems associated with high pressure wells. There was, however, no internal training course which was aimed at how to carry out an inspection and make the judgements which it required. Training was predominantly "on the job". He shared a concern with Mr Petrie about the need to develop more effective training of inspectors.

The guidance given to inspectors

15.37 The Inquiry was provided with a copy of instructions to inspectors for inspections and investigations and for the application of the DEn's enforcement policy, which have been in preparation since July 1987 and were issued as a working document on 31 July 1989. According to the evidence of Mr Petrie these:

"set out the organisational framework within which the inspectors operate and the procedures they should adopt in the exercise of their professional judgement. They do not seek to define the technical and safety management system standards inspectors should secure. Inspectors will in the first instance rely on the standards prescribed by regulations. Where standards are not set out in regulations they will be guided by authoritative codes and standards such as the guidance notes published by the Department. These and safety notices which bring recent developments to the attention of the industry and inspectors alike, provide a bench-mark of reasonable practicability."

These instructions were reviewed in the light of 3 months' operational experience. No changes of substance were made save that inspectors were instructed to meet the safety representatives both at the beginning and end of their inspection. These instructions were prepared following the report on the Inquiry into the fire at the Bradford Football Ground. The instructions cover, *inter alia*, the following subjects:- (i) preparation for the visit; (ii) the sampling of working systems, maintenance procedures and documentation; and (iii) the appropriate follow-up actions. They are not intended to operate as a detailed checklist. It is clear from the evidence that these instructions to a large extent set out existing practice so that it may be followed in a consistent fashion. Thus as far as Mr Jenkins was concerned the document did not make any substantial changes to what was already done.

15.38 In regard to inspections para 1.6 states:

"... Inspection involves assessing the extent to which operators and others meet their legal obligations for the overall safety of the installation and the personnel on board. Inspection therefore includes the installation and its equipment and working practices, procedures and arrangement on the installation at all levels."

Para 1.8 states:

"... It is impracticable for inspectors to attempt a detailed inspection of every part of an installation and its equipment as well as current activities and procedures. The approach must therefore be to sample and audit various aspects with the

objective of gaining an overall impression of how well the installation is being operated, maintained and managed.”

When he was referred to these passages Mr Jenkins said: “What I said to the Inquiry is that we do sample and we do audit working practices and working procedures, but we have never conducted full audits in any area, so we have no experience of having conducted full audits which we could then correlate back to improving the sampling technique.” However, he claimed that he had the expertise to carry out an audit of the permit to work procedure, based on an understanding of how installations are managed, what is required of permit to work systems and an understanding of the regulations. Such an audit would be impossible within the time currently available.

15.39 Para 2.2 of the instructions states:

“An inspection should monitor, *inter alia*, the duty of the operator, the owner and employees to provide a safe place of work and safe working practices (i.e. the overall management, operation and control). The inspector must not be seen to usurp the responsibility of these persons or the OIM for safety.”

When he was referred to this passage Mr Jenkins stated: “My assessment of the management does include the overall management of the company.” He explained that he normally had a meeting onshore with management where he found that personnel on the installation were not receiving support from that direction. He said: “I believe that the purpose of the inspections is to target on the offshore installation. It is not to target on the onshore office, and the only time when the onshore office comes into the picture is when they are found not to be supporting the offshore installation or carrying out changes which are required as a result of the findings of the inspection.” If the instructions meant that the overall management required to be monitored “someone will have to instruct me how we would go about doing that”. He later said: “What I was saying is that the way I am encouraged to go about my work is that I require to find the problems offshore, which then takes me onshore. An inspector is not encouraged to go to the door of somebody like Occidental, knock on the door, walk in and perform an audit of the management of that company.” However he said that he did not believe that he had any difficulty in coming to a view about the general management performance when he was on the platform and then knowing what action to take. In his evidence Mr Petrie said that it was essential that the quality of the management of safety was assessed and found to be adequate. One way in which this was done was through inspections. The inspections fulfilled an auditing function. Any failure on the part of management which was apparent should be pursued by inspectors back through the management chain as occasion arose. He also pointed out that, while it was not done as a matter of routine, it was not unusual for an inspector to require the operator to produce the safety policy statement (under Sec 2(3) of the HSWA) and other safety documents for his consideration, including if necessary at the inspector’s office onshore.

15.40 Para 11.3 of the instructions states:

“As a minimum the inspection report should describe the extent of the inspection. It should record the nature of the inspections undertaken e.g. observation of working practices, tests of equipment, discussions, examinations of records, witness of musters and drills etc. The report should record those areas found to be satisfactory as well as the unsatisfactory ones ...”

Mr Jenkins’ comment on this passage was: “I believe that whoever wrote this will have to provide me with more information on what they are looking for ... I believe that a report of that nature would take a considerable number of pages ... It will increase the time that is required to conduct an inspection ... It may be that someone will have to allocate more time to me to conduct an inspection.”

15.41 It appeared from the evidence of Mr Jenkins that he had not been given specific guidance on a number of aspects of inspection including: (i) the use of the

checklist on the permit to work system to which I have referred above; (ii) the completion of the form for rating installations for future inspection; and (iii) the monitoring of the overall management as expressed in the instructions to which I have referred above. Mr Petrie had never spoken to him about how he was getting on with his work.

The monitoring of the work of inspectors

15.42 Mr Petrie said that the monitoring of the quality of inspections was in the first instance a matter for the Principal Inspector. He would discuss such matters with the Principal Inspectors from time to time. On occasions he saw reports of inspectors and discussed the overall philosophy and results with the Principal Inspector who was the head of the branch. Additionally he would visit the office in Aberdeen and talk to the Principal Inspector. Each year there was an annual performance review in which the performance of individual inspectors was set against the objectives which had been set for them. This involved overall assessment covering about 15 areas. The quality of inspections was not one of these areas but the reporting officer would inevitably cover that in his overall assessment of the inspector's performance during the year. The Principal Inspector, who was the reporting officer, would in the ordinary course of his work see every report which the inspector produced. Part of his job was to go offshore with an inspector probably about once a year in order to measure his performance in the actual undertaking of the inspection.

The manning of the Inspectorate

15.43 In 1980 the Burgoyne Committee, to which further reference will be made in Chapter 16, recommended that the DEN should continue its policy to employ an Inspectorate consisting of well-qualified and industrially experienced individuals, capable of a broad but authoritative approach to the monitoring and enforcement functions (6.7). The Committee pointed out that the current Inspectorate was to a certain extent under-staffed. This together with extensions of role suggested in the Committee's report entailed the need for further recruitment (4.14).

15.44 In the event there has been a persistent shortfall in the required complement of inspectors for the purposes of carrying out inspections of the type described earlier in this chapter. At the time of the disaster the Aberdeen office, which was concerned with the northern waters (extending northwards from the Solway Firth on the west and the 56° parallel on the east) comprised 1 Principal Inspector and 3 inspectors, as against a complement (fixed by a management board of the DEN) of 1 Principal Inspector and 5 inspectors. This shortfall had existed for about 2 years. At the same time the London office which was concerned with southern waters comprised 1 Principal Inspector and 2 inspectors, as against a complement of 1 Principal Inspector and 5 inspectors. Accordingly at that time there was a shortfall of inspectors of 50%. By August 1989 there had been a net increase of 1 inspector in Aberdeen and 1 inspector in London, leaving a shortfall of 1 in Aberdeen and 2 in London.

15.45 The recruitment of personnel in the Safety Directorate is carried out by the Civil Service Commission through the Establishment and Finance Division of the DEN. Mr Petrie said that there had been considerable publicity and advertising in an attempt to make up the shortfall. The Department was able to recruit on a continuous basis. However, despite these efforts it had not been possible to make up the shortfall. The HSC had also been aware that as a result of the shortfall there had been a reduction in the frequency of inspections. They had expressed concern and there had been correspondence between them and the Minister. The Minister had replied that all efforts were being made. Mr Petrie also said that he had had discussions with the HSE with a view to additional assistance. One inspector had been seconded to the DEN on a permanent basis as a result of one of the recommendations of the Burgoyne Committee in order to provide assistance with occupational health and safety, such as in regard to working practices and procedures and the use of equipment. However,

posts such as that held by Mr Jenkins, were not so interchangeable. The holders of these posts were classified as petroleum specialists, having regard to the experience and expertise for which the Department were looking. He said that it would be appropriate to consider the needs of PED as similar in this respect to those of the Mines Inspectorate which formed a separate group within the HSE. Mr Priddle said that when he took up office in September 1989 he saw it of immediate importance that the resources of PED matched its requirements. It was clearly not satisfactory that the inspectorate was at half strength at the time of the disaster. He found that the Department had reviewed the salary scales (see para 15.46 below) and had tried to make recruitment more attractive. He had encouraged the launching of a further recruitment exercise which was to be announced in early 1990. He had spoken to the Minister about this matter. Priority was being given to the inspection team. He believed that this initiative would be successful. If it was not he would devise new initiatives in recruitment. He also pointed out: "There are attractions about work in the Department. There are responsibilities there which cannot be matched outside. There is a breadth of experience here which has a real value and there is a public service element which has a real value, so we have a number of positive things going for us when we seek to project our recruitment efforts." Mr Petrie and Mr Priddle said that consideration had been given to creating a lower grade of inspectors, similar to general inspectors of the HSE, but regarded this as very much a longer term exercise.

15.46 As regards the possible reasons for the Department's past lack of success in achieving its complement, Mr Petrie said that he was satisfied that the right persons existed and in the right numbers for these jobs. However, it had been found that applicants had little experience which was relevant to the job which would be expected of them even with the amount of training and instruction which they would receive. Some clearly misunderstood what the job entailed. There was no easy answer to the question of how to attract the right people. He agreed that the level of remuneration inevitably played some part. However, similar salaries were offered in industry. He agreed that industry provided opportunities for higher salaries and promotion, along with other attractions such as foreign travel. Within the PED the prospects of career development were limited for inspectors because of the departmental grading which they were in and because of the comparatively small size of the PED. They would not be expected, nor perhaps have the ability, to move into the administrative stream. The loss of inspectors to industry was not an annual event but it was not infrequent. Mr Priddle pointed out that over 1988 and 1989 PED had been able to recruit 5 inspectors with the loss of 1 otherwise than by retirement. Since about 1980 petroleum specialists have been treated as a specialist grade within the DEN. Accordingly the negotiations for the fixing of salary levels have been outside the normal salary negotiations for general grades in the Civil Service. Their salary level was very close to that of factory inspectors. An increase in the salary scale was made early in 1989. This provided a higher percentage increase for the recruitment grade i.e. Senior Inspectors, than for the higher grades. This involved an increase in the maximum for the recruitment grade from £27,005 to £30,332 *per annum*. According to Mr Priddle the objective of such salary levels was to be competitive with those on offer in the private sector. The salary scale was not brought into effect until late in 1989 and the recruitment exercise in early 1990 was to be based on those figures. As at January 1990 a post as inspector had been offered to one applicant, whose response was at that time unknown. By way of comparison it may be noted that as part of the same alteration in salary levels the maximum payable to a reservoir evaluation specialist at the inspectorate level was increased from a little under £30,000 to a little over £35,000. Mr Petrie said that this was an entirely different grading from that of the petroleum specialists for which candidates came from different sources.

15.47 As I stated above the shortfall in manpower for inspections was met by a change in the frequency of inspection. However, as regards Piper Mr Petrie adopted the position that even if there had been more senior inspectors in the Aberdeen office there would not have been any greater frequency of inspection than there was in 1987

and 1988. Speaking more generally Mr Petrie said that if there were the full complement of senior inspectors they would largely be devoted to the same type of work. He said that in the meantime “the quality will not be sacrificed. The frequency is not a real measure in so far as the inspections are targeted at the areas most in need. We do not say that every installation must be inspected in x months or years. The criterion is the rating system which attempts to put on to the installation an overall assessment of safety or risk in a positive manner based on an inspector’s rating system, time lapsed and any other factors. The number of inspections that are carried out are, I believe, still sufficient for the purpose of the inspection programme, and that is to monitor the industry and their compliance with the requirements.” He agreed that “inevitably with additional resources there is a potential to cover more things, and more installations”. He disagreed with the suggestion that the shortfall affected the extent of what was inspected. He said: “Not the extent because an inspector during every inspection should look at all parts of the installation to some extent ... When I said look at all parts of the installation, it was within the context that an inspection is a sampling technique.” However he appeared to agree that with increased manpower the depth of his inspection would inevitably be able to be increased. From his viewpoint Mr Jenkins said in evidence that if the positions in the Aberdeen office were filled “there would be less pressure to make the same number of inspections and there would be more time to meet people from the industry onshore.” He thought that inspections would take approximately the same time but that certain installations might be inspected more frequently.

Observations on the inspection system

15.48 Even after making allowances for the fact that the inspection in June 1988 proceeded on the basis of sampling it is clear to me that it was superficial to the point of being of little use as a test of safety on the platform. It did not reveal any one of a number of clear-cut and readily ascertainable deficiencies. The visit failed to follow up the investigation into the Sutherland fatality in an effective way, in that Mr Jenkins failed to grasp the importance of the weakness in the permit to work system and misunderstood the position in regard to the procedure for handovers.

15.49 It would be easy to place responsibility for these criticisms on Mr Jenkins but I do not consider that this would be fair, having regard to his relative inexperience and the limited guidance which he was given. Further this would not address the shortcomings in the inspection system itself. In my view the inspectors were and are inadequately trained, guided and led. Persistent under-manning has affected not only the frequency but also the depth of their inspections. These shortcomings affected the quality of the inspections on Piper, and in particular the inspection in June 1988. Apart from any other consideration, the length of the visit at that time was manifestly inadequate having regard to the size of the installation, the activities then taking place and the recent fatality.

15.50 However, the evidence which I heard caused me to question the inspection system in a more fundamental sense. Even if the shortcomings which I have mentioned above were made good would inspections be able by their nature to achieve the objective of assessing the adequacy of the installation as a whole? In giving evidence from a prepared statement Mr Petrie said, *inter alia*:

“As responsibility for safety remains with the operator, the installation manager and other personnel, inspections do not diminish that responsibility. An inspection involves assessing the extent to which operators and others may meet their legal obligations for the overall safety of the installation and the personnel on board.”

However he accepted the latter sentence “must be read within the overall sampling techniques of an inspection.” When asked to re-state what he had said in a way that was consistent with what in fact was done he said: “I think I would re-state it along the lines of an inspection involves sampling the work and activities on the installation to an extent to have a reasonable view as to how operators and others may meet their

legal obligations.” However the limitations of sampling, especially on the basis of “what catches the eye” within a relatively short visit to an installation runs a plain risk of missing what lies deeper than a surface inspection and of failing to reach a true assessment of the installation as a whole. Further, while it is true that if an inspector finds something that is amiss he may be able to prevent it leading to an accident, the inspection is not targeted at preventing the occurrence of what was amiss. For this one would have to turn to the management of safety by the operator. It is clear from the evidence that the DEN inspectors do not become involved to any extent with the onshore management of safety except in an incidental way. These considerations led me to doubt whether the type of inspection practised by the DEN was an effective means of assessing or monitoring the management of safety by operators. This brings me to matters which were the subject of evidence in Part 2 of the Inquiry, which I will discuss below in Chapter 21.



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