Human Factors in the Capital Investment Management Process: The HF Model for small and large projects in the process industry

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Human Factors in the Capital Investment Management Process: The HF Model for small and large projects in the process industry

**Agenda**

I. Objectives of the Model
II. Why the need for Human Factors in Projects
III. Human Factors Influence on Manufacturing and SHE Performance Indices
IV. Model Overview
V. Tools overview
I. Objective of the HF Project Model

This Model = Human Factors Enhancements to your existing Project Management System
II. Needs for Human Factors in Project Engineering

1. To design and build a facility whose operation:
   • reduces the potential for human error
   • minimizes the number and severity of injuries, illnesses and loss incidents
   • meets Safety Management Systems and regulatory requirements
   • implements the best practices currently available (e.g. internal Design Standards)
   • optimizes manning and operator training
   • improves production efficiency

2. To reduce the cost of design, construction and rework by minimizing costly changes late in the design process or post start-up

3. To accommodate the site user population
III. Human Factors Influence on Manufacturing and SHE Performance indices

**Areas are the focus of core safety engineering**

- Workplace Design
- Equipment Design
- Work Environment
- Physical Activity
- Job Design
- Information Transfer
- Personal Factors

**Manufacturing Performance Index**
- T/A Average Availability
- Capacity Availability
- Mechanical Reliability
- Right First Time (RFT)
- Incident reduction
- Person-hours Worked
- SHE Performance Index

**Human Effectiveness**
- Process Effectiveness
- Equipment Effectiveness
- Systems Effectiveness

**Manufacturing Performance Index**
IV: Project Development Model Overview

Planning

Development (DBM/ FEL /PDS)

Detailed Design

Construction and Start-up

HF Tracking Database

HF Review (VPS)

ISHE Review

QA/QC Review Process (Includes Critical Task Design Review)

HAZOP/P&ID Review

Critical Task Identification & Analysis

LINK Analysis

Critical Procedure Development

Skill Training (including HF)

HF Design Practices

HF Awareness for Construction Workers

Post Project Review

Project Start-up SHE Review (PSSR)
IV: Project Development Model Overview

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- Construction and Start-up
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  - Post Project Review

- Skill Training (including HF)

- HF Design Practices

Risk, Reliability and Safety Engineering
2. VPS, Critical Task Analysis Triggers

Are there tasks associated with the venture that:

- require a complex thought process?

- have the potential for high SHE consequence?
  - planned SHE-critical tasks e.g. proof testing
  - production-critical tasks with SHE implications e.g. response to loss of feed
  - risk of physical injury e.g. repetitive physical tasks

- involve interaction with several other persons?

- require PPE beyond the basic?

- be difficult to recover from a mistake
  - unplanned and/or time-critical/complex tasks?
Case Study: Use of SHE process to detect HF Issues-- **Reactor Catalyst Change**

**Specifications**

1. Four identical reactors
2. 1.7m diameter
3. 500 tubes to hold catalyst
4. Operate at 400°C
5. Catalyst changeout every 8 weeks
6. Catalyst handling at the top of the reactor
Three views of a 95th percentile, South China Male operator inside the dome of the reactor.

**Dimer Reactor Dome**

- Diameter = 1460 mm
- Height to top of dome = 1220 mm
- Height to top of manway = 1650 mm

**Mannikin: 95th percentile, South China Male**

- 610 mm
- 1220 mm
- 1650 mm

Top of reactor tubes
Figure shows the reactor designed so the entire dome is removed.

The figure also illustrates:

- Reactor Dome raised for access
- Operator can reach center of reactor while leaning in from the outside
- Operator works in ambient light at platform temperature without breathing air
- Top of reactor tubes

With this configuration, two or more operators could be working on the reactor catalyst tubes at the same time to reduce turnaround time.
## IV: Project Development Model Overview

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**Risk, Reliability and Safety Engineering**
5. Some Background on the development of the HAZOP, Human Factors Tool

HF Tools in use before the introduction of this tool:

- Unit walkthroughs
- Control room visits
- P&ID Checklists
Observations on the use of HF during a project HAZOP

1. The HAZOP is not being conducted solely to identify Human Factors issues. The HAZOP is being conducted to identify HAZARDS; especially those that affect loss of containment in the process.

2. Unit walkthroughs and control room visits are not possible for a new unit.

3. Most team members did not have good knowledge of Human Factors.

4. P&ID checklist is not as targeted or as systematic as it could be. + process to identify issues is time-consuming, or ambiguous e.g. “potential human errors introduced by maintenance or on-stream equipment have been considered.”
Proposed Alternative

- Utilizes Human Factors in a very targeted manner and is based on the application of the HF-Design Standards

- Determines the difference between HF relevant and HF irrelevant systems quickly so the team can move through the P&ID in a timely fashion

- Considers only the pieces of equipment that have a Human Factors interface beyond the Engineering Design Standards

- Focuses on the operations/tasks that can be hazardous to the technician/process
Proposed Alternative (cont’d)

- Identifies/confirms critical tasks and their follow-up

- Allows the team to use the process with little previous knowledge and minimal practice with the tool.

  After a short exposure to the tool and its use, the team will be able to make distinction between relevant and irrelevant systems and quickly pinpoint the HF concerns with the relevant systems.
Objective of the HAZOP, Human Factors Tool

- Assist the HAZOP team to identify Human Factors concerns associated with a particular piece of equipment
- Quickly target the major items of HF concern
- Be user friendly
- Require minimal training to use the tool
Approach to the use of HF in HAZOPS

- Include experienced HF practitioner on the team
  - ensure that the practitioner understands the HAZOP process
- Practitioner provides the HAZOP team with an introduction:
  - to HF, and
  - to the HF process that will be used
- Develop a set of “targeted” materials for use by the team
  - Concept of “reminder lists” or “Screening Questions”
- Record HF issues that are identified on a standard HAZOP Worksheet
Design and use of Reminder Lists in HAZOPs

1. “Screening questions” developed for 13 categories of equipment
   - Valves
   - Sample points
   - Blinds/blanks
   - Field displays
   - Field Instruments: Transmitters, Flow meters, Thermocouples
   - Alarms
   - Pumps and compressors
   - Furnaces
   - Filters
   - Reactors
   - Exchangers
   - Vessels
   - Fire fighting and deluge systems

2. Lists are referenced at each node of the P&ID
   - check for equipment category
   - refer to applicable screening list

Example Screening Questions
Valves – SCREENING QUESTIONS

Thorough HF follow-up is required for this valve if any of the following HF Issues are checked

- The valve is operated manually in an emergency. So the operator must be able to get at it quickly and operate it easily without mistakes

- The valve is operated sequentially and its position and operation must be considered in relation to other valves

- The incorrect operation of this valve will exceed safe operating envelope and no apparent mitigation strategy has been implemented into the Design.

- The valve is operated remotely from a field location, so the design of the control panel is important to consider
Valves

Potential Issues

- Valve is important, e.g. Battery Limit Valve, Pump Suction, Pump discharge, but is not located where it is accessible
- Valves that are operated sequentially such as in a manifold or compressor are not located where the sequence is obvious
- The incorrect operation of the valve, such as the switch valve on a coker will cause the process to exceed safe operating limits
- Valve panels for MOVs/EBVs are confusing
- Valves are located too close together making access difficult
- Manual operation of the valve exceeds human capability
Valves

Example Issue: *Battery Limit Valves must be accessible*
Valves

Example Issue: Reaching a compressor discharge valve requires operator to stand on a line
Valves

Example Issue: *Layout of MOV switches on Delayed Coker Panel is confusing*

Potential solutions: Using Mimics instead of traditional layouts where feasible

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**Traditional Rack-mounted Design**

**Mimic Panel Design**
Valves

Issue
Valve handles are too close together

• Turning valve wheels has the risk of pinching fingers

How can this be rectified?

• Move valve further apart *(very expensive fix in this case)*

• *(Preferred)* Stagger the heights of valve wheels (extend the valve stem of every other valve about 8 inches)
Valves

Issue: *Awkward posture required to access valves can increase risk of injury*

**Posture**
- Wrist deviations
- Stooped access
- Kneeling access
- Arms elevated and away from the body

**Decreases strength capability**

**Can strain the joints**

**Affected by:**
- Wheel location (height, reach and angle)
- Obstructions
- Clearance
Valves

Issue: Manual Operation exceeds Human Capability

**Repetition**: Turns required to close and open valves

**Force**: High Force required to turn valve wheel

**Temperature**: Extreme

**Together**
+ High force increases risk of injury
+ Repetition and temperature substantially increase risk of energy expended
By-pass valves are not reachable.
Potential Design Solutions
Human Factors Follow-up

- HAZOP team agrees on a sound solution based on the team’s knowledge. The improvement recommendation is recorded on the HAZOP worksheet for follow-up.

- The team recommends a thorough examination of the HUMAN-MACHINE Interface design. The team recognizes the need to examine the HF concern outside of the HAZOP proceedings to ensure that the issue is addressed thoroughly.

- The team recommends that a Critical Task Analysis is conducted to assess the HF concern in a rigorous (formal-systematic-critical) way.
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HF Design Practices

Risk, Reliability and Safety Engineering
6. Identify and analyze “Critical Tasks”

The objective of the CTA:

- To provide a structured, systematic approach for process and equipment designers to identify and analyze the tasks performed on a unit that are critical to the safe operations of the process.

When in the project?

- Identified during the Planning and Design phases and tracked
- Conducted during PDS and/or detailed engineering Items addressed in detailed design are verified by standard QA/QC Approach
Case Study: The use of a Human Factors Evaluation in Project Design

Objective: To evaluate the Human Factors issues in the design of a reactor project

Background: The purpose of the facility is to mix and additive with raw catalyst to develop a finished catalyst for sale externally

Cost: The estimated cost of the initial design was about $15M
Case Study: The use of a Human Factors Evaluation in Project Design

Method:
A team comprised of the project engineer, design engineers, operations and maintenance personnel and a Human Factors specialist, reviewed a 3D CAD model of the facility.

The review, which lasted about 2-hours consisted of:
1. Describing the purpose of the facility to all present
2. Analyzing the operator’s task. The task analysis consists of
   • recording the sequential activities performed by the operator and
   • identifying the Human Factors issues associated with each activity
Summary Narrative
The operators activities consist of:

1. Transferring raw catalyst from the Portable Catalyst Tank (PT) to the Conical Screw Blender (CSB)
2. Transporting a 4-pack of cylinders containing additive to a hoist
3. Raising the 4-pack to the third level and storing it before emptying each of the cylinders into the CSB
4. Transferring the additive from the cylinders into the CSB one at a time
5. Operation can be conducted at any time of the day
Human Factors Issues

1. Connection to the hoist is awkward and time-consuming with opportunity for error

2. Load is allowed to swing freely and turn as it lifts or lowers

3. At the top, operator is expected to steady load with one hand and operate lift control with the other

4. Operator must have two lift control stations, one at the bottom and one at the top. Question of control interlocks becomes complicated
Human Factors Issues

5. At the top, operator is expected to work under a live load as he guides 4-pack on monorail around to storage area.

6. Note that 4-pack must clear the CSB as it is being moved to storage.
7. An articulating hoist was specified for the operator to transfer each cylinder from its storage location to the CSB.

8. Each cylinder would be grabbed, rotated upside down then mated with a connector on top of the CSB. Operation required precise motor movements.

9. Once cylinders were empty, they were returned to the pallet.

10. How does operator reach the full cylinders at the back of the pallet?
New Design
As a result of the HF review of the initial 3D model, the unit was drastically redesigned.

1. Additive cylinders were discarded.
2. Additive would now be delivered in a PT.
   In the same way as the raw catalyst.
3. Additive would be blown to a weigh pot.
4. Then blown from the weigh pot to the CSB.
5. Most of the operation takes place at grade. Operator hooks up hoses, turns valves and controls the transfer from a control panel.
6. Only one trip per operation is made to the CSB on the third level.
10. Contractor HF Awareness Training: “Doing it right the first time”

Project Objective:

- To build our projects safely, and
- To ensure this unit’s facilities are safe and efficient for the Owner to operate and maintain
- How do we do this?
  - Work safely, so you or others don’t get hurt during construction
  - Refer to the 3-D model to avoid engineered facilities & pipe
  - Learn how mechanical and electrical field-run facilities should be installed and help us identify equipment that is not designed or installed properly so that future users don’t get hurt operating or maintaining the unit
Construction Safety
You must ensure that you and your colleagues are working safely at all times

Think about how heavy the equipment is that you are assembling. Should you be assembling at waist height??

You should be using a step stool or a ladder NOT climbing on pipes.
Construction Safety
You must ensure that you and your colleagues are working safely at all times

Remote control of pickers can be dangerous

Can you see around the vehicle? Can you see where the cage is going??
Designing for Safe Operations and Maintenance

Conduit should not be installed where it interferes with the operation and maintenance of equipment.

Note how conduit is routed along the bottom of the pad.
Services and utilities should be installed so they are *ACCESSIBLE* but not *IN THE WAY* when they are not being used. Power and utilities are located to be easily accessible but not in the way. These utility lines had to be extended since they were initially installed too high to reach.
Designing for Safe Operations and Maintenance

Locate drain valves with enough end clearance so they can be connected to temporary hoses.

These drains do NOT have the required 6” clearance; cannot connect future hoses.
Designing for Safe Operations and Maintenance

Don’t install Insulation where it will interfere with future maintenance access needs

Good spacing

Insulation doesn’t allow for future bolt removal
Designing for Safe Operations and Maintenance

Keep access ways as clear and open as possible

Steam manifold is tucked in next to the column and out of the access way.

Steam manifold extends into the access way, restricting traffic.
The HF Model for small and large projects in the process industry

Summary

The model:

- Is designed to enhance your existing project management system
- Should be integrated into an existing component of your management system, e.g. SHE
- Will reduce the design, construction and rework by minimizing costly changes late in the design process or post Start-up
- The cost of Human Factors in Major Capital Projects typically in the range of 0.5% of the cost of the project. So, for a $100M project, the typical cost for plant and contractor effort is $50K. This cost varies between 0.3% to 0.75%. The percentage cost typically increases as the value of the project decreases.
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Questions?