Process Safety Fundamentals

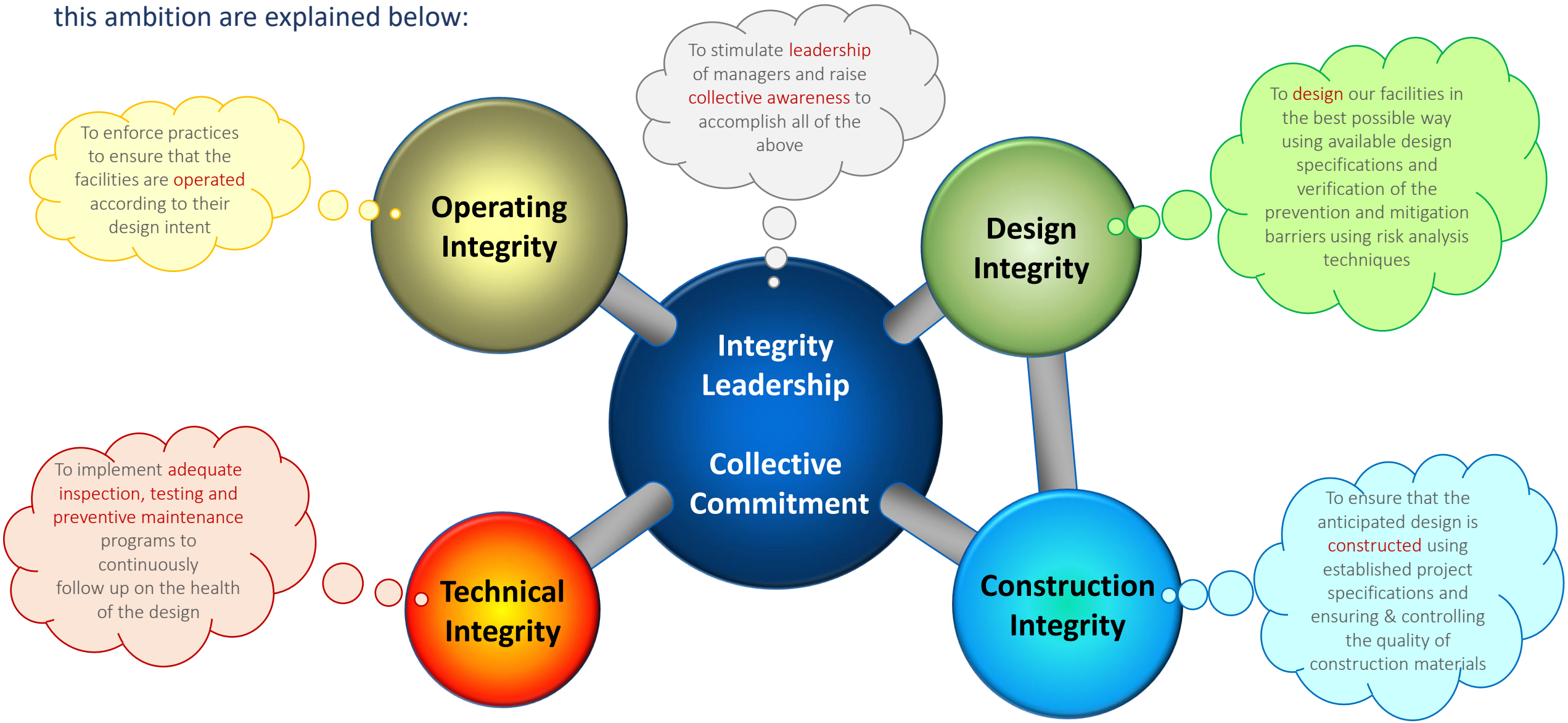
Safe Operational Principles

to avoid incidents with hazardous chemicals

EUROPEAN PROCESS
SAFETY CENTRE

Origin

Process safety and technical integrity management is about the capability to operate an asset so that it safeguards life and environment whilst meeting production objectives during the operational phase of its lifecycle. The key activities to achieve this ambition are explained below:



Origin : Shell Process Safety Fundamentals

After review of Process Safety Events by Shell, a set of safe operating principles called “Process Safety Fundamentals” was developed.

Context of Process Safety Fundamentals

- No new requirements. Formulation of operational principles.
- An upgrade in behaviors. Operational Excellence of Process Safety execution.
- Emphasis on front line critical tasks, fully understood and supported by all operational leaders.
- Understanding of the dilemmas that frontline may face to comply with Process Safety Fundamentals.
- Makes Process Safety an everyday frontline conversation with an involved leadership.
- Attention on risk normalization and substandard practices.
- Sanction management not emphasized, open culture driving Process Safety Excellence.

Process Safety Fundamentals and Safety Leadership

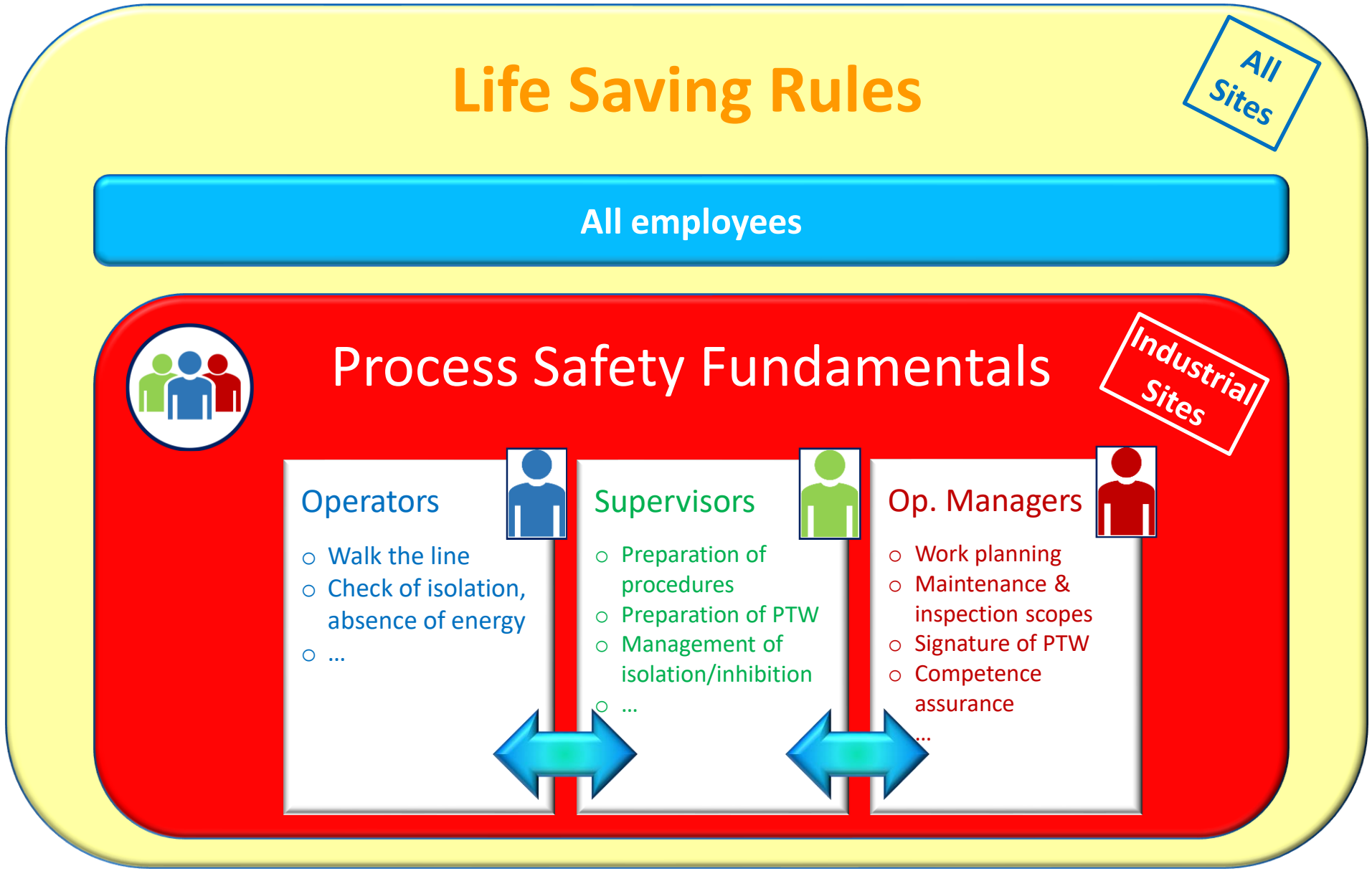
Leaders are expected to leverage the Process Safety Fundamentals as a tool to

- Drive safety from a position of care
- Be visible in the field
- Have a regular dialogue on the PSFs. Help front line staff to comfortably surface dilemmas, operational issues, and weak signals
- Show their commitment to safety. Once dilemmas are brought forward, work with the front line to resolve the issue.
- Show curiosity. Seek to understand and comply with the PSFs before allowing deviations.
- Recognize risk normalization in many of our daily activities and address it.

Process Safety Fundamentals and Life Saving Rules

Aspect	Life Saving Rules: Occupational Safety	Fundamentals: Process Safety
Objective	Reduce number of injuries/fatalities	Avoid loss of chemicals with potentially serious consequences for people, environment and Business
HSE Domain	Behaviors in occupational safety	Behaviors on operations involving hazardous chemicals
Target	All	Operation teams on hazardous sites (process operators, process engineers, maintenance technicians, operational management)
Nature and applicability	In principle simple rules that are easy to understand and apply in all circumstances	More complex principles that cannot always be fully applied (e.g. in case of design issues)
Implementation method	Non-negotiable set of requirements “Life saving Rules” or “ Golden rules”	Identify situations that are not in line with the Process Safety Fundamentals and start a discussion on how to proceed, avoiding uncontrolled initiatives “to get the job done”

Process Safety Fundamentals and Life Saving Rules



IOGP Process Safety Fundamentals

- An analysis by IOGP has shown that nearly all (91%) fatal process safety events are linked to one or more of the core set of IOGP PSFs.

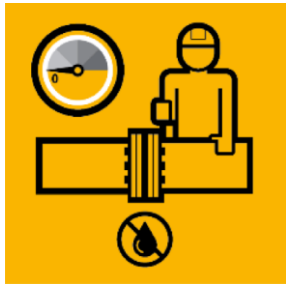
We respect hazards

We apply procedures

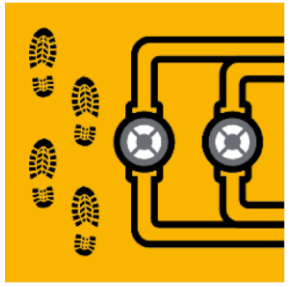
We sustain barriers

We stay within operating limits

We maintain safe isolation



We walk the line

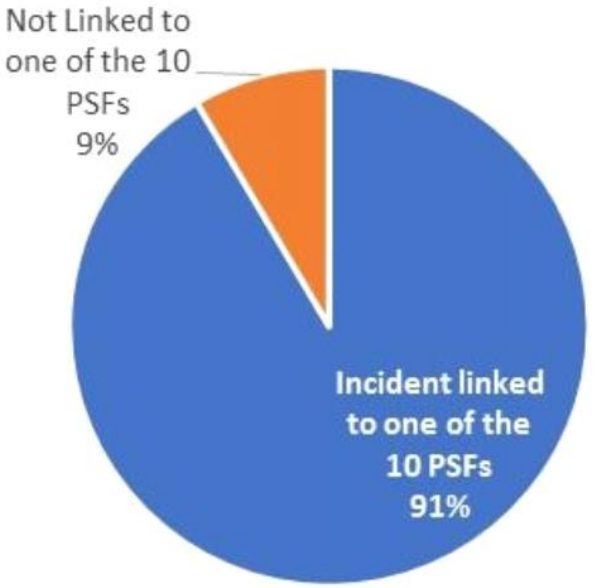


We control ignition sources

We recognize change

We stop if the unexpected occurs

We watch for weak signals



PSF Logo

Title of PSF

EPSC

Hazards:

Description of specific hazards related to this Process Safety Fundamental

When important:

Description of situations in which the application of this Process Safety Fundamental is important

Challenges in the field:

Description of possible difficulties encountered in the field when applying this Process Safety Fundamental

Options to get it right

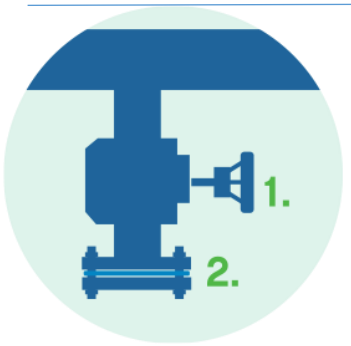
Suggestions for efficient application of this Process Safety Fundamental

Process Safety Fundamentals – 18 Titles

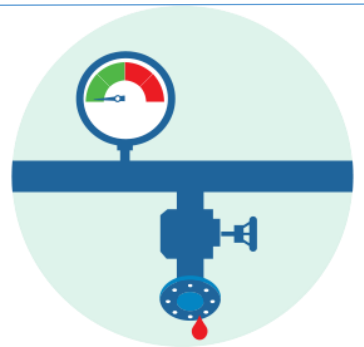
Apply Double Isolation	Control utility systems connected to a process
Empty and De-energise before line-breaking	Report deficiencies on Safety Critical Equipment
Monitor an open drain	Unplugging of equipment
Manage overrides of safety critical systems	Stay out of the Line of Fire
Walk the Line	Control (Un)loading
Verify leak tightness after maintenance work	Check atmosphere in fire box before igniting the burners
Avoid working behind a single valve	Avoid splash loading
Verify the condition of flexible hoses	Avoid run-away reaction
Operate within safe limits	Report process safety incidents

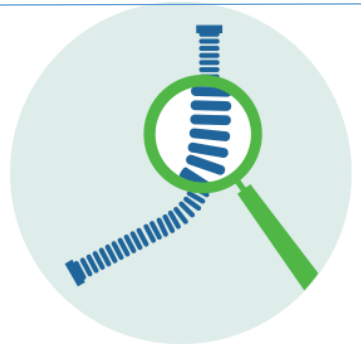
EPSC

EPSC Pictograms

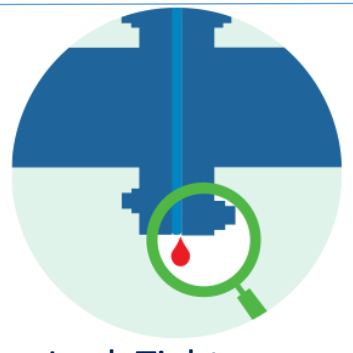


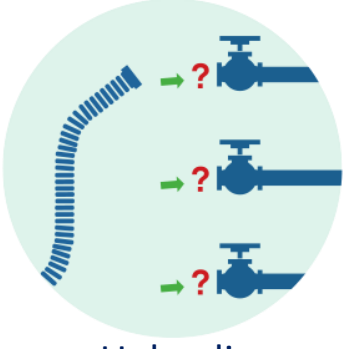
Double Isolation


First Line Break


Flexible Hoses


Furnace Burners


Leak Tightness

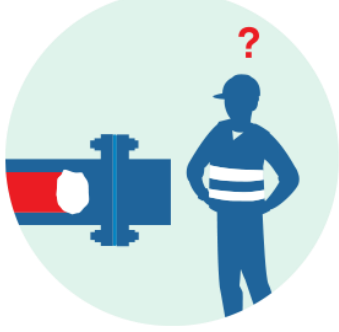


Unloading


Open Drain


Operating Limits

Overrides

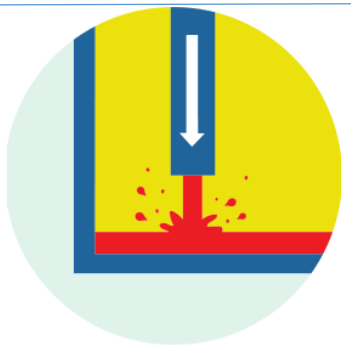


Plugged Equipment

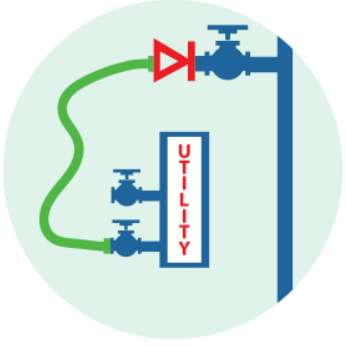

Critical Equipment


Reporting

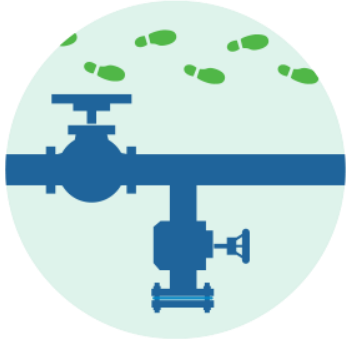

Run Away Reaction


Splash Loading

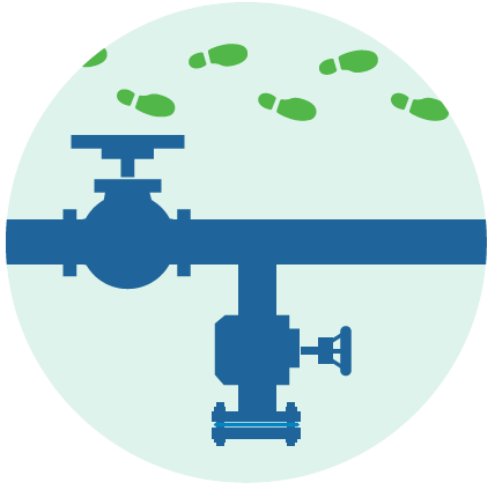

Line of Fire



Utility Connections


Walk the Line


Single valve



Walk the Line

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Hazards:

Spills or inadvertent mixing might occur when the transfer line is not ready for operation due to open ended lines or drains, wrong valve or tank line-up.

When important:

After each change in set-up of a transfer line, e.g. start-up after shut-down, isolating equipment, change of equipment, maintenance work, draining

Challenges in the field:

- Transfers occurring around shift change-over
- Long transfer lines, not fully accessible
- Distracted by other things
- Bad weather, low visibility at night
- Pipelines or valve position that are not easily to see

Options to get it right

- Validate a correct line-up (all valves, tanks, pumps), before starting the pump / transfer
- Perform a check, after pump start, to detect leaking drains, hoses, flanges or pump seals
- Use P&IDs or better isometrics during line check
- Label equipment in the field, like valves, pipelines and pumps to help with the field check
- Tag all the bleeds and drains
- Validate the transfer regularly by checking the levels of the tanks versus the calculated level from the pump flow speed. Take actions upon deviation

Video on “Walk the Line”

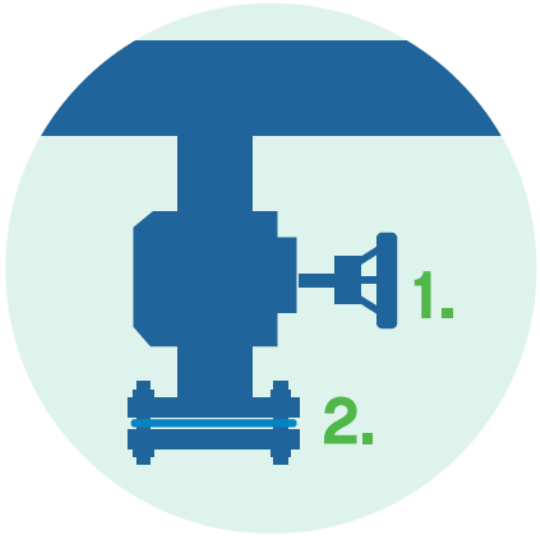
Guidance on Implementing the Process Safety Fundamentals (PSF)

- Select a limited number of PSF relevant for your operation to start. Eventually expand in next steps with additional more specific PSF.
- Use the PSF slide to start the discussion. It is the discussion that provides the understanding of where you really are and what can be improved!
- Establish clear agreement & procedures on the discussed PSF.
- The following activities can be used to initiate the Process Safety Fundamentals

Practice	Purpose
Employee orientation (all levels)	Explain PSFs and why they are important
Setting behavioral expectations	Emphasize behaviors expected in relation to the PSFs
HSE days	Communication of PSFs to workforce during themed HSE days / events
Toolbox talks	Explanation of PSFs to workforce by supervisors
Posters	Examples of types of posters used as part of a communication campaign about PSFs

- Other activities can be envisaged after launch of the PSFs (integration in existing practices and systems – auditing, reward/recognition, post-incident review,….).

To get in the positive process safety mood, feel free to use this video made by Shell: https://www.youtube.com/watch?v=l9Fu4ydckGg



Apply Double Isolation

EPSC

Hazards:

Spill of (hazardous) material can occur when a barrier (like a valve) fails and no second barrier is in place

When important:

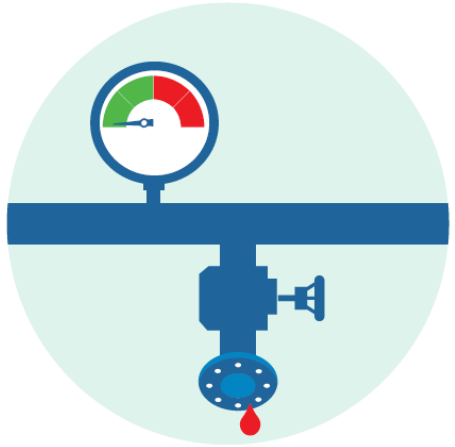
During routine and special operations: draining & sampling, (un-)loading activities, utility connections

Challenges in the field:

- Older plant design often do not provide a double barrier
- Blind flanges not put back after maintenance work
- Blind flanges not installed with bolts & missing end-caps
- Importance of “primary containment” not understood
- Valve handles that can be opened accidentally

Options to get it right:

- Do not rely on a single valve for positive isolation
- Execute regular audits to check that drains are having an end-cap (blind flange or screw cap) conform pipe-spec
- Do not accept missing blind flanges or missing bolts on blind flanges
- Report and investigate all incidents from leaking drains
- Valve handles can be locked to avoid accidentally opening



Empty and De-energize before Line-breaking

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Hazard:

Uncontrolled release of energy or a hazardous material during the opening of piping or equipment

When important:

When unbolting, unscrewing, drilling or cutting of process equipment

While working on live equipment

Challenges in the field:

- Working at the wrong location
- Complexity of piping or break points arrangements
- Double block and bleed not possible
- Plugging of vents or drains / leaking valves
- Installing blinds
- Drains at the wrong location

Options to get it right

- Have a validated isolation plan available, that indicates numbered isolation points in the right sequence on a P&ID
- Apply LOTO to avoid that equipment can be re-energised: that is providing locks and labels
- Empty and clean equipment properly
- Check the completion of the isolation plan by an independent operator, before signing the permit to work
- Wear selected PPE for residual chemicals that might not be purged or drained and provide absorbents for leaking fluids
- Perform a Last Minute Risk Assessment by the mechanic or contractor, before opening, to validate that the pressure indicator is zero, the drain is open, the system is at ambient temperature, there is no flow and assure you are at the right equipment
- Use blinds according pipe spec, that is indicated on the isolation list
- Upon changes, validate that isolation remains intact

Monitor an Open Drain

EPSC

Hazards:

Unintended product release can occur during draining from a storage tank or other equipment to atmosphere

When important:

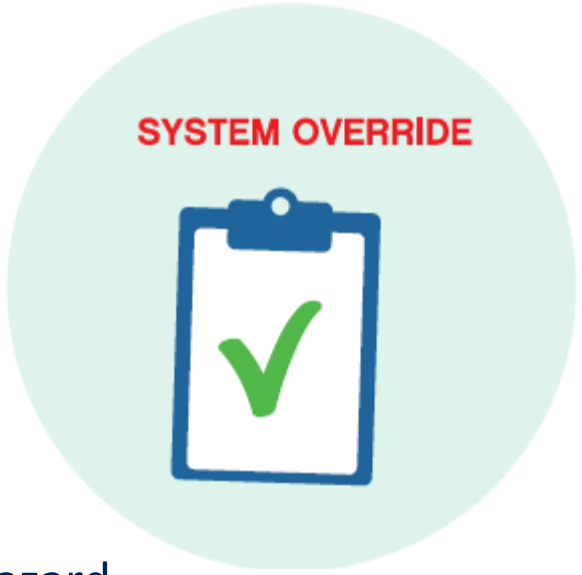
When draining water from a tank that contains hydrocarbons to a sewer.
When removing liquid from process equipment

Challenges in the field:

- Distracted by other things that need attention
- Long draining time
- Bad weather
- Under estimation of the potential consequence of the product being released
- Drain valve does not fully close

Options to get it right

- Identify the critical draining operations on site
- Limit drain size (typical to 1 inch) to limit the release rate of the hazardous chemical
- Spring Loaded valves can help to assure that an operator remains present when drain time is short
- Understand the draining time necessary when starting the draining process
- Ensure the drain-valve can be closed from a safe location
- Avoid doing something else while monitoring a draining task
- In a critical situation, first stop the draining process before leaving the drain
- Stop draining during shift handover



Manage Overrides of Safety Critical Systems

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Hazard:

Insufficient safeguards are in place when a safety critical system is not working properly or is bypassed.

When important:

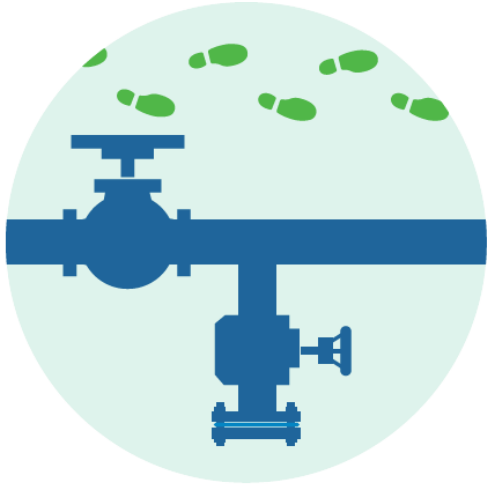
Failure of or unreliable safety systems
Testing of interlocks
Turnaround or maintenance work
Commissioning, start-up & shutdown

Challenges in the field:

- Consequences are unknown
- Safety systems that prevent start-up
- Lack of knowledge of procedure
- Absence of authorizers

Options to get things right:

- Understand the safety critical systems and identify them in the field
- Every bypass/override needs a formal authorization based on a risk assessment (a special permit to work for bypass can help)
- Define the criticality of the system to bypass like the SIL level
- Authorisation level needs to be inline with criticality
- Identify solid interim protection measures and put them in action
- The bypasses must be registered in a bypass log accessible in the control room
- Discuss active bypasses during shift handover
- Determine process units that require shutdown when safety critical systems are unavailable
- Limit bypass duration, initiate a formal MOC for long term bypasses
- Protect safety interlocks against easy bypassing in the field
- Review bypassed functions daily (typically in the morning meeting)
- Review statistics on bypassed equipment



Walk the Line

EPSC

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When important:

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Options to get it right

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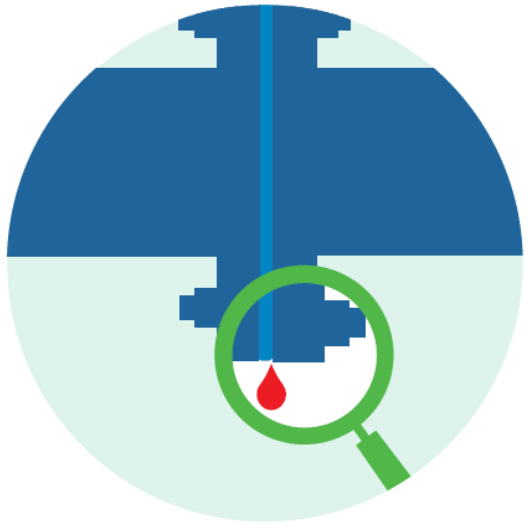

Verify Leak Tightness after Maintenance Work

EPSC

Hazard:

When a flange or other equipment is closed, it can still leak, when hazardous chemicals are introduced

When important:

After work where equipment and flanges have been opened

Temperature change can influence bolt tension and create leakages

Challenges in the field:

- Competent people when bolting
- Verification competency or procedures are missing

Options to get it right:

- Perform a leak test before introducing hazardous chemicals
- Leak test can be done
  - by introducing a less hazardous gas and perform a pressure hold test
  - put soap bubbles on all flanges that have been opened
  - Ultrasound measurements can detect leakages
- Develop criteria for acceptance of leak test results
- Develop a special procedure for the flange that was used in the leak-tightness test (the flange to be closed after the leak test)
- Verify proper torqueing
- Validate and adjust bolt tension after heating-up the equipment
- Record Leak Test results

Avoid working behind a Single Valve

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Hazard:

Single valves can leak because they are not fully closed, are fouled or just leak
During working behind a single valve the valve might be accidentally opened or start leaking, releasing chemicals

When important:

During and after line breaking due to a repair or maintenance activity
When the plant is not fully de-energized

Challenges in the field:

- Older plant design often might not provide a second barrier or full block and bleed option to isolate equipment
- Placing a blind, turning a spectacle flange

Options to get it right:

- Realize when it is not possible to work behind double isolation
- Try to remove the substance or energy in the system before start working behind a single valve
- If isolation by a single valve cannot be avoided:
  - Validate that the single valve is not leaking e.g. at a drain point downstream of the isolation, or by a pressure gauge
  - Mechanically lock the isolation valve handle to avoid accidental knocking open during the task, deactivate the actuator for automated valves after checking the valve fail-safe position
  - Mount a spade or blind flange after the single valve directly after the line break
  - Consider if emergency responders should be in place during the line break, until the blind-flange is placed
  - Wear appropriate personal protective equipment (PPE) during the task
  - Keep working time short and avoid critical process conditions during

Verify the Condition of Flexible Hoses

EPSC

Hazard:

Hazardous fluid release due to hoses failures

Wildly moving hoses at pressure release when coupling gets loose

When important:

When using flexible hoses

When disconnecting hoses that still contain pressure or toxic material

Challenges in the field:

- Connections are not properly made, requiring bended or stretched hoses
- No good storage location available

Options to get it right:

- Make sure you use the correct hose: correct material of construction and temperature & pressure rating
- Visually inspect hoses before using them and check for defects like corrosion, wear or mechanical damage
- Hoses (including the connections) with hazardous fluids should be inspected periodically by an approved body and certified
- Avoid hoses for very toxic chemicals (like phosgene)
- Hoses should be tagged and included in the maintenance schedule
- When not in use, hoses must be properly stored, with the appropriate bend radius, hanging straight down, or laying straight
- Hoses must not be twisted or forced when connected
- Connect hoses well, follow-up on possible vibrations
- If required replace hoses preventively and remove old hoses from the site
- Check correct depressurization of hoses before disconnecting

Operate within Safe Limits

EPSC

Hazard:

Hazardous reactions and releases or equipment damage can be caused when safe operating limits are exceeded

When important:

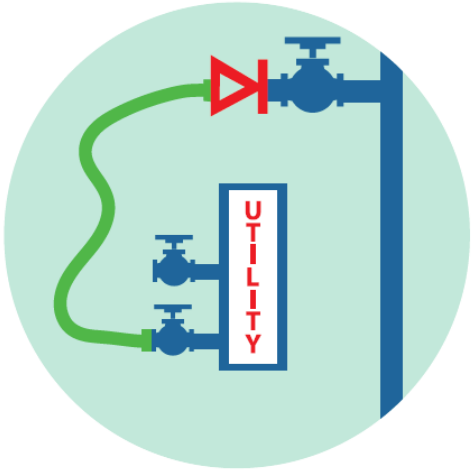
Deviations from normal operation
Transient operations, batch process , start-up / shut-down
At design changes

Challenges in the field:

- Limits not well known or identified
- MOC process not followed
- Pushing production

Options to get it right :

- Establish safe operating limits for key process variables and for all operating phases, and make them visible for operators
- Validate that instruments are working well
- Understand the critical process parameters that can result in equipment damage and loss of containment due to deviations
- Install alarms and interlocks for critical process variables
- Define actions to bring the process variable back within the operation limit
- Report and discuss the cause when operating limits are exceeded
- Understand the chemical hazards at non-standard conditions and have a chemical compatibility matrix available



Control Utility Systems connected to a Process

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Hazard:

When utility systems are temporarily connected with a flexible hose to a process, hazardous substances can flow back into the utility system

When important:

During inerting, cleaning and unplugging operational equipment using utilities
When taking a sample a utility is needed to purge a system

Challenges in the field:

- Lack of knowledge
- Easy availability of utility stations & hoses
- Hazard studies did not identify the hazard

Options to get it right

- Awareness of the hazard that utilities can be contaminated with process gasses or liquids
- Understand the pressures in the systems and how they can deviate during operation
- Define suitable safeguards against backflow, at least one non-return valve must be present
- Remove the utility hoses from the process directly when the task is completed
- Ensure that the hoses applied have the same pressure rating and chemical compatibility as the process when used in normal operation
- Evaluate backflow during MoC and HAZOP studies when fixed connections exist between utilities and process units

Report Deficiencies on Safety Critical Equipment

EPSC

Hazard:

Safety Critical Equipment provides a barrier to prevent or limit the effect of a major incident

When important:

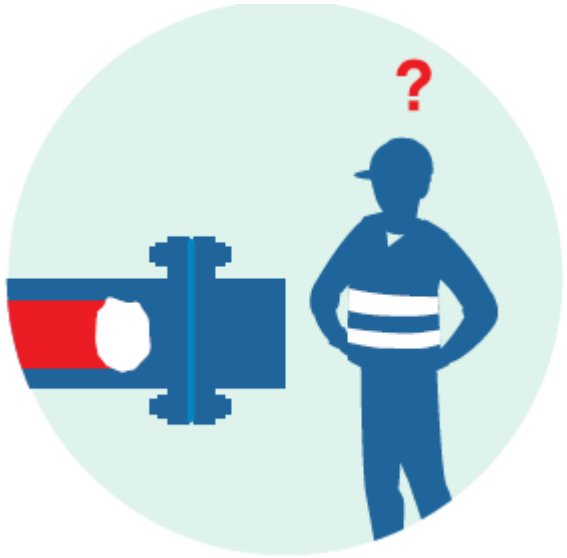
When Safety Critical Equipment is not working properly

Challenges in the field

- A shutdown might be needed to repair the broken equipment
- Not aware of the criticality
- Unawareness of the failure – no testing
- Unreadable equipment, like a fouled side glass

Options to get it right:

- Determine which equipment is safety critical
- Ensure workers know what equipment is Safety Critical, and understand the potential hazard
- Safety Critical Equipment must have a testing protocol and frequency
- Report failures or deviations on safety critical systems (also from testing)
- Decide what action is appropriate, if necessary stop the operation
- Implement interim mitigating measures that are approved, in case of continuing operation
- Repair or replace safety critical equipment with highest priority
- Analyse why equipment failed
- Keeping a log on critical equipment out of service



Unplugging of Equipment

EPSC

Hazard:

Unplugging might requires opening of installations that can unexpectedly result in a release of hazardous substances

When important:

When process equipment is blocked, eg by fouling, polymer, corrosion, objects after maintenance etc.

Challenges in the field:

- Unexpected severe flow restrictions
- No unplugging procedure or good options
- Not wanting to stop production

Options to get it right :

- Consider to stop production before unplugging
- Do not start unplugging without an approved plan that includes a hazard analysis
- Understand the source and reason of plugging
- Understand the hazards while unplugged and have a mitigation plan for unexpected releases
- Understand that instrumentation might give misreading or that safety valves do not operate properly
- Understand that opened equipment can still have pressurized hazardous material inside behind the plug
- Apply isolation and First Line Break principles in the unplugging procedure
- Do not use hazardous gas to blow out pipelines / equipment

Stay Out of the Line of Fire

EPSC

Hazard:

Exposure in case of unexpected release of energy or chemicals or unexpected movement of objects like a manhole, also vacuum can form a hazard

When important:

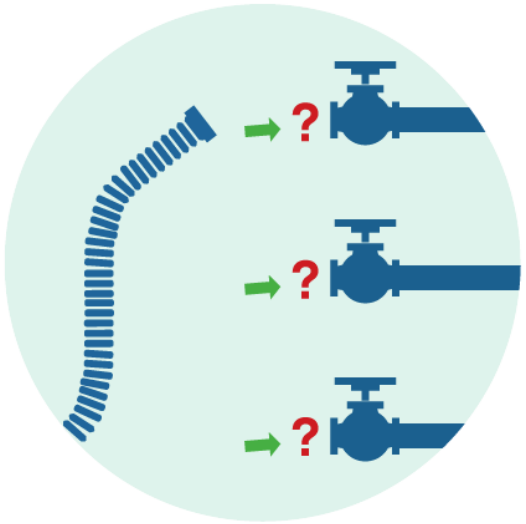
When being in processing units that do not work at ambient pressure

Challenges in the field:

- Release points not designed well: e.g. PSV release points that end in a pathway
- Manholes (or manway) that are stuck
- Heat releases from flare

Options to get it right :

- Identify hazardous location around release points or below hoisted objects in the field, e.g. by lines or colours on the floor
- Understand release locations and remove yourself from the potential energy discharge path from release points like PSV's, explosion panels and plugs under pressure
- Keep people out of the heat radiation zone around a flare
- Protect yourself (location of your body) when opening installations
- Add physical barriers to prevent people from accidentally entering the paths
- Verify that PSV's are designed to always vent to a safe location
- At flange opening, first untighten the bolts that are far away from you



Control (Un)loading

EPSC

Hazard:

Unexpected run away reaction
Formation of toxic chemicals
Overfilling or loss of containment

When important:

Receiving of chemicals at your site
Loading chemicals to a tank or reactor
Waste handling operation

Challenges in the field:

- Lack of knowledge & guidance of the contractor or operator involved
- Line up
- Chemical identification

Options to get it right :

- Validate that the right chemical is loaded by a positive identification: analysis of a sample, inline analysis (density), certificate, barcode, clear label
- Have a good procedure in place with check points
- Provide unique coupling for hazardous chemicals (e.g. Chlorine, Ammonium, Ethylene oxide) to avoid wrong line-up
- Use colour codes (or bar codes that can be scanned) on pipelines, tubing and connection point
- Use professional firms for transporting the chemicals (that are ADR, ADN & RID compliant)
- Guide contractors well that are involved in (un)loading
- Assure that receiving equipment has sufficient volume available
- Have a compatibility matrix available to understand the hazards

Check Atmosphere in Fire Box before Igniting the Burners

EPSC

Hazard:

When the firebox of a furnace or boiler has an explosive mixture by accumulation of large amounts of flammable gases, this will explode when igniting the burners

When important:

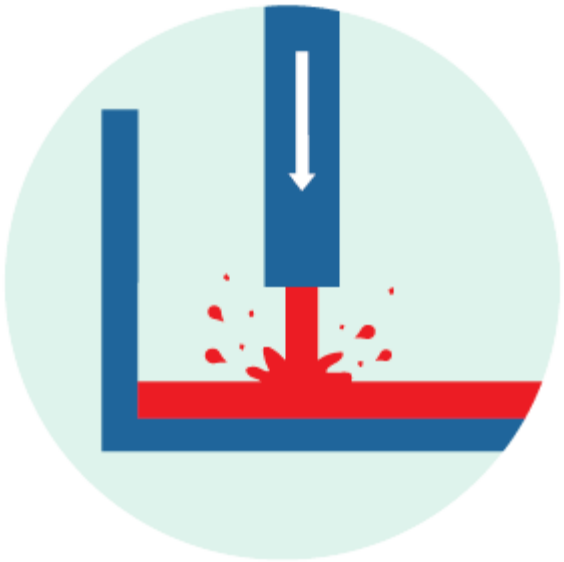
Upon start and restart
Cold start
After a furnace trip

Challenges in the field:

- Reliability of instruments
- No good procedure / practices
- Fast restart required to avoid shut down

Options to get it right :

- Furnaces/boilers need to be purged well with air to remove all gasses and to avoid an explosive atmosphere, before igniting the burners
- Procedures for start of furnaces and boilers must be available, up-to-date. Management shall undertake a periodic verification of the correct execution of these procedures.
- Report problems with fully automated systems (burner management systems) or deviation from start-up procedure immediately
- Limit the number of attempts to ignite a furnace/boiler (and keep sufficient time between attempts)
- Perform a leak test on the gas supply before igniting a furnace/boiler
- Check atmosphere in the fire box before igniting the burners with a LEL meter
- Bypassing of safety instrumentation (flame eyes, gas detection,sensors) must be managed carefully
- Limit the number of people in the vicinity when starting furnaces/boilers to those necessary for the start-up operation
- Avoid time pressure when starting or restarting furnaces or boilers



Avoid Splash Loading

EPSC

Hazard:

When loading non conductive flammable liquids, an explosive atmosphere will be created in the tank, that can ignite when electrically charged droplets generate a spark

When important:

When transferring flammable liquids
When liquids fall down and form droplets

Challenges in the field:

- Lack of knowledge
- Design issues, e.g. on pump or loading dip-pipe
- Communication (ship – shore)

Options to get it right:

- Assure that the loading speed in the drop-down pipe in the vessel is below 1 m/s when start filling! This assures droplets are only little loaded and can not form sparks.
- When loading ships this is arranged in a ship-shore agreement, that should include the pipe diameter and pump speed
- Ensure that pipelines, tanks, vessels are grounded
- When the filling pipe is submerged below the liquid level inside the vessel or tank, the risk for splashing has gone and pump speed can be increased
- Inertisation can eliminate an explosive atmosphere
- Understand which chemicals are flammable liquids with low conductivity (like benzene, kerosene, butane – heptane). These are highly hazardous as they form an explosive mixture with air and dissipate static electricity slowly

Avoid Run-Away Reaction

EPSC

Hazard:

Bhopal & Seveso incidents occurred after an exothermic exponential runaway reaction started

When important:

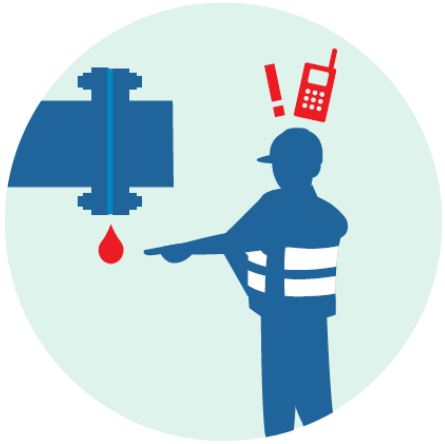
Exothermic batch reactions
Storage of reactive chemicals
Unexpected Polymerization or Decomposition

Challenges in the field:

- Chemistry at increased temperature can be different or unknown to operators
- Cooling can malfunction or might not be able to cope with the exponential increase of the reaction rate

Options to get it right :

- Understand the chemistry and side reactions at abnormal conditions like elevated temperature
- Understand the point where cooling can not cope with the exponential heat of the reaction (point of no return)
- Assure good design data is available on heat balance of all the reactions involved (like DSC curves)
- Understand the effect of malfunctioning cooling
- Have a reactivity matrix available & make sure operators know the critical combinations of chemicals to avoid
- Assure cooling is reliability and have back-up cooling available
- Validate inhibitors are present as applicable
- Have a last line of defence like Interlocks, Breaker plates, Bunkers
- Have an emergency procedure: Run away in a runaway reaction!



Report Process Safety Incidents

EPSC

Hazard:

Acceptance of small leakages, near misses or substandard practices

When important:

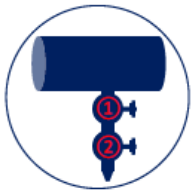
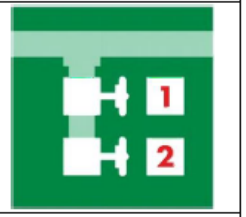
When related to Safety Critical Equipment
Small leakages & Activation of barriers

Challenges in the field:

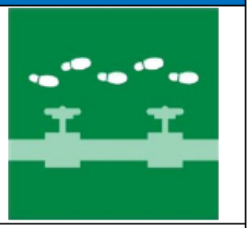
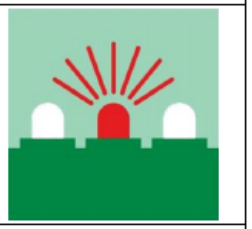
- No open learning culture that stimulates intervention by all on safety
- Production pressure
- Bad follow-up and feedback on reported items
- Difficult reporting tools

Options to get things right:

- Create a culture where reporting nasty items is considered valuable feedback to improve safety. Have time available for that
- Report all spills: have an easy database to do so
- Follow-up on reported items and provide feed-back
- Classify LOPC according to a standard and have a KPI with a target
- Ensure workers recognise and report on TIER 3 & 4 incidents, that is weak signals or leading indicators, that should include:
  - Small leakages
  - Failures of safety critical systems
  - Activation of a last line of defence like a safety interlock
  - Fires; liquid hammering; vibrations; corrosion
  - Pressure or temperature outside design: like Auto-refrigeration
  - Locked or car-sealed valves not in the right position
  - Long standing or nuisance alarms
  - Ignition sources in zoned area’s; Atex deficiencies
  - Deviation of critical procedures

Safe Operation Principle	Possibilities for Logos		
1. Provide safe isolation and perform a zero energy check with work performer before starting work.			
2. Use two barriers for hydrocarbon and chemical drains and vents.			
3. Operate with safety critical equipment in service and take mitigating measures in case of failure/maintenance/ inhibition.			
4. Verify complete leak tightness before returning equipment to service.			
5. Confirm Positive Equipment Identification, before starting maintenance work.			
6. Do not leave an open drain without monitoring.			

Refernce Pictograms as designed by others

Safe Operation Principle	Possibilities for Logos		
7. Walk the Line.			
8. Verify the condition and compatibility of flexible hoses before use.			
9. Operate within safe operating limits and respond to critical alarms.			
10. Perform a risk analysis and install backflow protection when connecting utilities to process equipment.			
11. Address anomalies and substandard situations.			
12. To prevent fires and leaks, always follow procedures.