Role of Valves in HAZOP Analysis, Safety and Environmental Risk Assessments

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March 10, 2016

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Topics

1. **HAZOP Methodology**
    1) What is HAZOP?
    2) Why to conduct HAZOP during EPC?
    3) When to do it?
    4) Who is responsible and who to participate HAZOP?
    5) Where to host the HAZOP meeting?
    6) How the HAZOP is conducted?
    7) After the HAZOP study
2. **Role of Valves in HAZOP Analysis**
3. **Role of Valves in Human Factors Engineering**
4. **Role of Valves in Safety and Environmental Risk Assessments**
5. **Summary**
6. **Take Away**
7. **Further Studies**
8. **Questions and Answers**

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Acronym and Definitions

Acronym

FEED	Front End Engineering Design
HAZOP	Hazard and Operability Study
HSE	Health Safety and Environment
LOPA	Layers Of Protection Analysis
OSHA	Occupational Safety and Health Administration
PHA	Process Hazard Analysis
P&ID	Piping and Instrumentation Diagram
PSM	Process Safety Management

Definitions

Catastrophic Release: A major uncontrolled emission, fire, or explosion, involving one or more highly hazardous chemicals that presents serious danger to employees in the workplace.

Risk: Measure of potential human injury, environmental damage, or economic loss in terms of both event likelihood and consequence severity.
(Risk = Likelihood x Consequence Severity)

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1. What is HAZOP?

– One of the Many Process Hazard Analysis (PHA) Methodologies

1. A systematic hazard identification methodology to identify hazardous events that could occur during operation of the facility caused by deviations from design intent.
2. The potential causes and consequences are identified, and a judgment is made as to whether additional design features should be incorporated to safeguard against the identified scenarios.
3. HAZOP serves as the final safety review in engineering design phase prior to the Pre-Startup Safety Review (PSSR)
4. Qualitative analysis
5. The focus is on operating facilities involving hazardous chemicals, such as using, storing, refining, petrochemicals, manufacturing, moving, handling, etc.

- A lot discussions on valves!

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Why to Conduct HAZOP in EPC?

- **United States federal government regulations requirement:**
  - US OSHA 29 CFR1910.119: Process Safety Management (PSM) of Highly Hazardous Chemicals, excerpt:
  - (e) Process Hazard Analysis (PHA):
    - (1) The employer SHALL perform an initial process hazard analysis (hazard evaluation) on processes covered by this standard…….
    - (2) The employer SHALL use one or more of following methodologies (next slide) to determine and evaluate the hazards of the process being analyzed.
    - (3) to (7) ….
- **To identify and evaluate potential hazards and risks in safety, health and environment**
- **To identify corrective measures that will improve safety**

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When to Conduct HAZOP in EPC?

Front End → **Detail Engineering** → **Pre-Startup**

HAZID
What-If

HAZOP, other methodologies:
- **What-If**
- **What-If Checklist**
- **FMEA Failure Modes and Effects Analysis**
- **FTA Fault Tree Analysis**
- **ETA Event Tree Analysis**
- **Cause- Consequence & Bow-Tie**

Normally after the detail design is completed, 30-40% of Engineering completion, P&IDs need to be issued for design.

IFD → **IFH** → **IFC**

resolve HAZOP findings/ recommendations per Risk Ranking

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Who is Responsible? and Who to Participate in HAZOP?

1. Facility owner is responsible to perform & manage HAZOP.
2. US OSHA 29 CFR 1910.119: Process Safety Management (PSM) of Highly Hazardous Chemicals, excerpt:
   - (e) Process Hazard Analysis (PHA):
     - (4) The PHA SHALL be performed by a TEAM with expertise in engineering and operation……

2.1 Required Core Members:

Independent Facilitator: methodology,

Scribe: technical recorder

Operator: experience and knowledge of the facility

Process Engineer: process design, including vendors

Control/Instrumentation/Electrical Engineer: instrument design, including vendors

2.2 Others: HSE, Mechanical, Maintenance, Piping, etc.

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Where the HAZOP is Conducted?

Facility's owner decision

- Can be at the Site
- Or at the EPC office locations

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How the HAZOP is Conducted?

In a group setting, with facilitated team discussions, a team of design engineers and operators will evaluate the design and identify:

1. what could go wrong? the potential causes?
2. initiating events, any previous incidents, etc.
3. what are the resulted consequences in safety & environment? Risk ranking?
4. what safe guards are already in place, what safe guards must to be implemented to prevent the incidence, etc. (implement Layers of Protection Analysis (LOPA))
5. Systematic and structured review on selected operation or system (node), on Potential Process Parameter Deviations by using Guidewords. HAZOP Work sheets
6. HAZOP Report
7. Software: PHA Pro, PHA Works

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How the HAZOP is Conducted? - cont.

- Potential Process Parameter Deviations, Guidewords

Examples of

Process Parameter Deviations	and	Guidewords:
Flow (Flow Control Valves)		No, Less, More, Misdirected
Pressure (Pressure Control Valves)		High, Low, Vacuum
Temperature		High, Low
Level		High, Low, Zero
Viscosity		High, Low
Impurity		More, Less, Unexpected
Change in composition		More of, Less of
Change in concentration		More of, Less of
Reactions		More of, Less of
Start-up, Shut down		
Maintenance, Service		
Human Factors		

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2. Role of Valves in HAZOP - IMPORTANT

Valves are discussed a lot in HAZOP, Examples

- Under "Initiating Causes":
  - FCV-xxx Fails open when require to be closed
  - FCV-xxx Fails close when require to be open
  - PCV-xxx inadvertently close
  - PCV-xxx inadvertently open
  - Manual Valves inadvertently left open (e.g. after maintenance)
  - Manual Valves inadvertently left close (e.g. after maintenance)
- Under "Safe Guards":
  - Pressure Relief Valves (PSV)
  - Blowdown Valves
  - Emergency Shutdown Valves
  - Check valves

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Supplemental Questions related with valves maybe asked

"Guidelines for Hazard Evaluation Procedures", 3rd Edition, excerpt:

1. Can bypass valves (for control valves or other components) by quickly opened by operators?
   - What hazards may result if the bypass is opened (e.g. reverse flow, high, or low level?)
   - What by pass valves are routinely opened to increase flow, and will properly sized control valves be installed?
2. How are the positions of critical valves (block valves beneath relief devices, equipment isolation valves, dike drain valve, etc.) controlled? (car seals, locks, periodic checks, etc.)?
3. Are critical isolation valve actuator powerful enough to close the valves under worst case differential pressure conditions (including backflow) in the event of rupture?
4. Are chain-operators for valves adequately supported and sized to minimize the likelihood of valve stem breakage?

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Supplemental Questions related with valves maybe asked

"Guidelines for Hazard Evaluation Procedures", 3rd Edition, excerpt: - cont. for info

5. How are the positions of critical valves (e.g. emergency isolation valves, dump valves) indicated to operators? Is the position of all nonrising stem valves readily apparent to the operators? Do control room display directly indicate the valve position, or do they really indicate some other parameter, such as actuator position or torque, application of power to the actuator, or initiation of a control signal to the actuator?
6. Are block valves or double block and bleed valve required:
   - because of high process temperature?
   - because of high process pressure?
   - because the process material is likely to erode or damage valve internals?
   - because the process material is likely to collect on the valve seat?
   - for worker protection during maintenance?

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Supplemental Questions related with valves maybe asked

"Guidelines for Hazard Evaluation Procedures", 3rd Edition, excerpt: - cont. for info

7. How will control valves react to loss of control medium or signal? Do the control valves:
   - Reduce heat input (cut firing, reboiling, etc.)?
   - Increase heat removal (increase reflux, quench, cooling water flow, etc.)?
   - Reduce pressure (open vents, reduce speed of turbines, etc.)?
   - Maintain or increase furnace tube flow?
   - Ensure adequate flow at compressors or pumps?
   - Reduce or stop input of reactants?
   - Reduce or stop makeup to recirculation system?
   - Isolate the unit?
   - Avoid overpressuring of upstream or downstream equipment (e.g. by maintaining level to avoid gas blowby)?
   - Avoid overcooling (below minimum desired temperature)?

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Supplemental Questions related with valves maybe asked

"Guidelines for Hazard Evaluation Procedures", 3rd Edition, excerpt: - cont. for info

8. **Will control valves malfunction result in exceeding the design limits of equipment or piping:**
   - Are upstream vessels between a pressure source and the control valve designed for the maximum pressure when the control valve close?
   - Some piping's class decreases after the control valves. Is this piping suitable if the control valve is open and the downstream block valve close? Is other equipment in the same circuit?
   - Is there any equipment whose material selection makes it subject to rapid deterioration or failure if any specific misoperation or failure of the control valve occurs (overheating, over cooling, rapid corrosion, etc.)?
   - Will the reactor temperature run away?
   - Is the three-way valve used in the pressure-relieving path the equivalent of a fully open port in all valve positions?

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Supplemental Questions related with valves maybe asked

"Guidelines for Hazard Evaluation Procedures", 3rd Edition, excerpt: - cont. for info

9. Is there provision in the design for a single control valve to fail:
   - in the worst possible position (usually opposite the fail-safe position)?
   - With the bypass valve open?
10. Upon a plant-wide or unit-wide loss of control medium or signal, which valves should fail to a position that is different from their normal failure position? How were the conflict resolved?
11. Can the safety function of each automatically controlled valve be tested while the unit is operating? Will an alarm sound if the sensing-signal-control loop fails or is deactivated? Should any bypass valves be car-sealed or locked closed?
12. Are battery limit block valves easily accessible in an emergency?
13. Are controllers and control valves readily accessible for maintenance?

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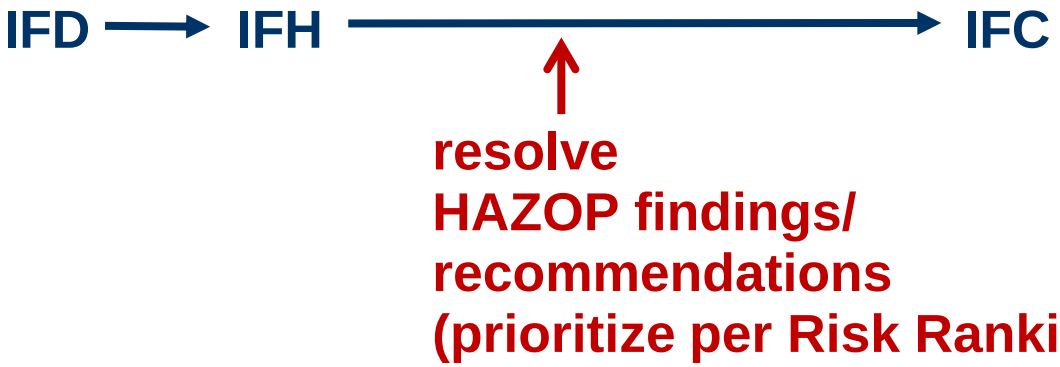
After the HAZOP Review Meeting

- HAZOP and LOPA Reports
- Resolution of the identified findings/recommendations, as required by US OSHA 29 CFR 1910.119 Process Safety Management (PSM), (e) PHA, (5)
- Need to resolve all findings/recommendations prior to P&IDs to be Issued for Construction (IFC).



- Compliance audits per US OSHA 29CFR1910.119 PSM, (o)

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3. Role of Valves in Human Factors Engineering

- Valve Criticality as information

- **Please understand the valve placement, orientation and location is owners' responsibility.**
  - Same requirements for vendor skids

ASTM F1166 – 07 "Standard Practice for Human Engineering Design for Marine Systems, Equipments, and Facilities"

- **Provides ergonomic design criteria from a human-machine perspective for the design and construction of maritime vessels and structures and for equipment, systems, and subsystems contained therein, including vendor-purchased hardware and software.**
- **Section 12 "Valve Placement, Orientation and Location" provided Valve Criticality information for variety valves, this information helps to recognize the importance and criticality of valves.**

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3. Role of Valves in Human Factors Engineering
- Valve Criticality as information

Category 1 –

- **Critical and essential for normal or emergency operations, safety and environmental**
- **Used frequently (at least once in a six month period)**
- **Have a high likelihood of failure, the consequence of failure or lack of quick access would be serious,**
- **Valve with handwheels or handles greater than 610 mm (24 in.) in diameter or length.**
- **Examples:**
  - Control valves, their bypass, isolation valves
  - Relief and depressuring valves, emergency shut down
  - Trip and anti-surge valves
  - Liquid cargo transfer valves (HC)

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3. Role of Valves in Human Factors Engineering
- Valve Criticality as information

Category 2 – NOT critical for normal operations but required for routine operations and maintenance

- **Used frequently (at least once in a six month period)**
- **Examples:**
  - Sewage treatment valves
  - Condensate drain valves
  - Service oil valves
  - Potable water valves
  - Ship service air valves
  - Hydraulic service
  - Defrost gas valve
  - Manual valves for normal startup /shutdown
  - Drains and vents (1 in.) or less with flange and cap end.

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3. Role of Valves in Human Factors Engineering
- Valve Criticality as information

Category 3 – Normally Non- operating valves that are used in particular circumstances on an infrequent basis

- **Examples:**
  - Valves used in drydock only
  - For initial vessel or structure commissioning
  - For Decommissioning
  - Only during start-ups after extended shutdowns
  - During extended shutdowns
  - To isolate pressure vessels, tanks, etc. for inspections
  - Tie-in valves
  - For pressure test

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4. Role of Valves in Safety & Environmental Risk Assessments

- **Emphasized on isolation and emergency valves**
  - In quantitative risk analysis, the resulted consequence is normally calculated and based on inventory, chemical and physical properties of the released hazardous material.
  - To reduce leaking inventories
- **Fire Hazard Analysis per API RP 2218 Fireproofing**
  - If the emergency valves (including actuators) are within Fire Scenario Envelope (exposed to fire)
  - Fireproof power and signal lines, motor operator per Sec.5.1.9

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5. Summary

- HAZOP Methodology
  a. HAZOP is one of the many Process Hazards Analysis (PHA) methodologies
  b. PHA is required by US OSHA 29 CFR 1910.119: Process Safety Management (PSM) of Highly Hazardous Chemicals
  c. Owners responsibility
  d. Qualitative analysis, wide used in EPC
  e. Facilitated group discussion using guidewords technique with experienced engineers and operators
  f. Findings and recommendations need to be resolved before P&IDs to be Issued For Construction (IFC)

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6. Take Away…..Role of Valves in HAZOP, Safety and Environmental Risk Assessments

1. All types of valves play important roles in facility's safety and environmental compliance, the risks are prevented or mitigated through engineering and valve design, selection, sizing, placement, etc.
   a. Early hazards identification at Detail Engineering phases can offer great opportunities for various engineering disciplines to apply inherent safer design (ISD) principles or risk tolerable solutions to prevent or mitigate the potential safety and environmental hazards.
   b. Correct placement and selection of valves can reduce the size of spills and prevent or hinder potential catastrophic losses
2. In quantitative risk analysis, the resulted consequence is normally calculated and based on inventory, chemical and physical properties of the released hazardous material. Emergency Isolation Valves also play important roles on calculating isolable inventory and total potential leak quantities.

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7. Further Study on HAZOP and other Process Hazards Analysis (PHA) Methodologies

1. US OSHA 29 CFR 1910.119: Process Safety Management (PSM) of Highly Hazardous Chemicals
2. US EPA 40 CFR 68: Risk Management Program
3. "Guidelines for Hazard Evaluation Procedures", 3rd Edition
   By CCPS for AICHE, 2008. Section 5.3, 7 and 15 HAZOP
4. Attend 3-day or 5-day courses on HAZOP/LOPA and PHA e.g. AICHE Academy, etc.
5. http://www.aiche.org/ and click tabs on CCPS, SBE, CEI, ifS
6. Master Degree for Process Safety Management
7. API RP 2218 Fireproofing Practices in Petroleum and Petrochemical Processing Plants
8. API RP 553 Refinery Valves and Accessories for Control and Safety Instrumented Systems
9. API STD 521 Pressure Relieving and Depressuring Systems
10. API RP 520 Part I&II Sizing, Selection, and Installation of Pressure-relieving Devices

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7. Further Study – other Countries' Standards and Guidelines

- IEC 61882. "Hazard and operability studies (HAZOP studies) – Application guide". International Electrotechnical Commission, Geneva
- "HAZOP: Guide to best practice. Guidelines to best practice for the process and chemical industries". Crawley, F., M. Preston, and B. Tyler. European Process Safety Centre and Institution of Chemical Engineers, 2000
- "HAZOP - Comprehensive Guide to HAZOP in CSIRO", Kyriakdis, I. CSIRO Minerals, National Safety Council of Australia, 2003

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8. Q & A

Questions?

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