SKF 4163 : Safety in Process Plant Design

Hazard Identification & HAZOP

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Hazard Identification is part of HIRARC

For Hazard Identification,

What are the hazards? Unsafe conditions? Unsafe act?

For Risk Assessment (or Hazard analysis),

- What can go wrong and how?

  Also known as scenario identification.

  i.e. Events that can lead to accident

- What are the chances of accident to take place?

  i.e. The probability of those events occurring

- What are the consequences?

  This could include injury/fatality, loss of production/equipment, damage building/environment etc.

Risk Control

Modification of process/operation, Installation of control measures, Emergency response etc.

Definition of Hazard

- Unsafe conditions and unsafe acts that could potentially cause accidents

Definition of Unsafe Condition

- A hazardous physical condition or circumstances which could directly permit the occurrence of an accident.

- This could be the result of an unsafe act by someone.

Examples of Unsafe Condition

- Inadequate guards or protection
- Defective tools, equipment
- Congestion, bad housekeeping
- Inadequate warning system
- Fire and explosion hazards (flammable and explosive substance)
- Hazardous atmospheric condition (exceed TLVs?)
- Excessive noise
- Inadequate illumination or ventilation

Definition of Unsafe Act

- A violation of an acceptable safe procedure which could permit the occurrence of an accident

Examples of Unsafe Act

- Operating without authority
- Operating at improper speed
- Making safety devices inoperable
- Using defective equipment
- Using equipment improperly
- Failure to use PPE
- Improper loading, placement
- Servicing equipment in motion
- Failure to warn or secure

Hazard Identification

- Observing unsafe condition and unsafe acts that could potentially cause accidents.
- Conducting walk-through surveys, audits, check-list and inspections.
- Job Safety Analysis/Review.
- Examining documents and data.

When to perform hazard identification and risk assessment*?

1. At the initial design stage.

   ASAP to enable any modifications to be easily incorporated into the final design.

2. During ongoing operation.

Note:

*Best result is obtained if hazard identification is performed together with risk assessment.

This could also prevented “gold-plated” i.e. implementing unnecessary / expensive safety equipment and procedures.

Hazard Identification Methods

1. Process Hazards Checklists

2. Hazard Survey
   a. Inventory of hazardous material
   b. Dow indexes
      Dow Fire and Explosion Index
      Dow Chemical Exposure Index

3. HAZard and OPerability studies (HAZOP)

4. Safety Review

1. Process Hazards Checklists

- Straightforward, systematic conventional checking procedure.
- List of possible problems and areas to be checked.
- The format depends on intend.
- Effectiveness depends on thoroughness of checklist preparations.
- Only for preliminary stages of a complete hazard identification
- Can also be used during design or before process operation
- Useful for checking compliance with standards etc.

Note:

Some companies have customized checklists for specific equipments

Process Design Safety Checklist

The checklist covers,

- General layout
- Buildings
- Process
- Piping
- Equipment
- Venting
- Instrument and Electrical
- Safety Equipment
- Raw Materials

2. Hazards Survey

Suitable for identifying hazards for equipment design, layout, storage etc.

Can be as simple as survey of inventory of hazardous Chemical.

Can be fairly rigorous such as Dow Fire and Explosion Index (Dow F&EI).

Requires little experience and quick result.

Dow Fire and Explosion Index (Dow F&EI)

Tailored for storage, handling and processing of explosive and flammable material in chemical processing industry.

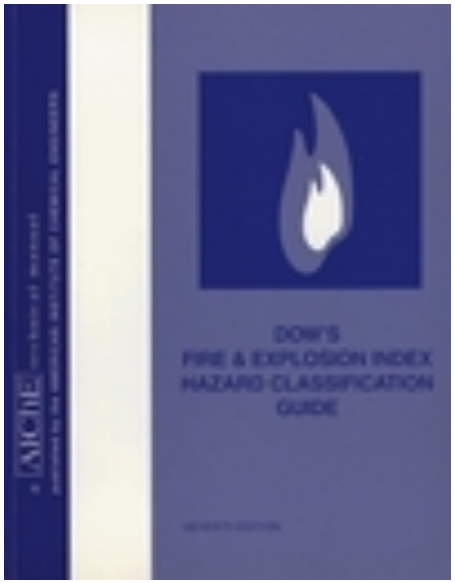
Systematic approach using rating form.

Can be used at an early stage of a project and for audit of existing plant..

Final rating number (i.e. F&EI) will provide a relative ranking of the hazard.

Could also estimate damage radius using Dow correlation.

Can also estimate dollar losses in the event of accident using consequences analysis form.



- **Dow's Fire & Explosion Index Hazard Classification Guide, 7th Edition**
  American Institute of Chemical Engineers (AIChE)
  ISBN: 0-8169-0623-8
  Pub No: T-80
  Paperback
  83 pages
  June 1994
  Purchase From Wiley

- **Description:**This popular safety best-seller is designed to help the user quantify the expected damage of potential fire and explosion incidents in realistic terms, identify the equipment….

Steps in Dow F&EI

- Divide the process into separate units.
- Select units that have highest likelihood of hazard (e.g. from process safety checklists).
- Determine material factor (MF) from a table (e.g. Table 10-1). Higher MF means higher flammability and/or more explosive.
- Determine Penalty Factor (F_1) for general process hazards.
- Determine Penalty Factor (F_2) for special process hazards.
- Calculate F&EI = (F_1 x F_2) x MF

Penalty Factor (F_1) for general process hazards

1. Exothermic reaction that might self heat.
2. Endothermic reaction that could react because of external heat source.
3. Material handling and transfer.
4. Enclosed process unit.
5. Limited access for emergency equipment.
6. Poor drainage and spill control.

Penalty Factor (F_2) for special process hazards

1. Toxic material that could impede fire fighting
2. Less than atmospheric pressure (outside air could leak into system)
3. Operation in/near flammability limit
4. Dust explosion risk
5. High pressure risk
6. Low temp operation that could lead to embrittlement
7. Quantity of flammable material
8. Corrosion and erosion of process unit structures
9. Leakage around joints and packings
10. Used of fired heater (source of ignition)
11. Hot oil HEX (source of ignition)
12. Large rotating equipment

DOW Chemical Exposure Index : DOW CEI

- A simple method of rating the relative acute health hazard potential for people (communities) in neighboring plants arising from possible chemical release incidents.

3. HAZards and OPerability Studies (HAZOP)

- A formal procedure to identify hazards in a chemical process facility.
- Systematic, comprehensive, effective, flexible and well accepted.
- Identify all the possibilities where processes and operation can go wrong.
- For large process, the studies could take months of biweekly meetings to complete.

- A team consist of cross-section of experiences:

  Process/Chem engr, Mech/elect/civil engrs, Control & instrumentation engr, Plant Manager, Plant superintendent, Safety engineers, Supervisor, Senior technician, Lab chemist, Hygiene technician, SHO etc

- Brainstorming in a controlled fashions

- Lead by a HAZOP leader (with experience in process industry and HAZOP procedures)

- Secretary (note taking/report preparation)

Advantage of HAZOP Study/Analysis

- Complete identification of hazards from operational upsets, operational procedures (SOPs) and equipment failures.
- Fewer commissioning and operational problems.
- Less down time.
- Improved product quality.
- Less waste is produced.
- Better informed personnel.
- Employees' confident in the safety of the process.
- Could be used as evidence of comprehensive thoroughness to insurers and inspectors.

Disadvantage of HAZOP study

- Tedious to apply.
- Need a team with experience judgment.
- Considerable staff time.
- Potentially identify hazards independent of the risk (as HAZOP is not a risk assessment process).

HAZOP procedures

- 1. Begin with detailed/up to date process info, PFD's, P&ID's, equipment specs, materials of construction, MSDS, M&E Balances Report and process simulation data etc.

- 2. Divide into separate units (a unit could be a reactor system, boiler house, a storage area etc.) and do the HAZOP study for each of the unit.

- 3. Choose a study node for the unit (e.g. a vessel, cooling coil, pipe line, tank, operating instruction).

Cont. HAZOP procedures

- 4. Brief description of the function/design intend of the study node (e.g. V-1 is to store the benzene feedstock and provide it on demand to the reactor).

- 5. Pick a process parameter:
  - flow, level, temperature, pressure, concentration, pH, viscosity, state (s,l,g), agitation, volume, reaction, composition, power etc.

- 6. Apply guide words/deviations (no, more, less, higher etc) to the process parameter to suggest possible deviations.

- 7. For each deviation, determine possible causes and note any protective systems.

Cont. HAZOP procedures

- 8. Evaluate the consequences of the deviation (if any)
- 9. Recommend action (what?, by whom?, by when?)
- 10. Record all information (see HAZOP form)
- 11. Repeat steps 5 through 9 until all applicable guide words have been applied the chosen process parameter.
- 12. Repeat steps 4 through 11 until all applicable process parameters have been considered for the given study node.
- 13. Repeat steps 2 through 12 until all study nodes have been considered for the given section
- 14. Proceed to the next section and repeat steps 2 through 13 until all sections have been considered for the process plant.

Basic HAZOP form

- Project name:
- Process: Reactor System
- Section: Reactor Unit
- Column 1 for Item number: e.g. 1A

  1 refers to study node, A refers to guide word
- Column 2 for name of study node: e.g. Cooling coil
- Column 3 for Process Parameters: e.g. Flow
- Column 4 is Guide Words (Deviation): e.g. No
- Column 5 for Possible Causes
- Column 6 for Possible Consequences
- Column 7 for Action Required
- Column 8, 9,10,11 are for work responsibilities and completion

The potential process modification resulting from this HAZOP study,

- Install a high-temperature alarm in the event of cooling water loss.
- Install a high-temperature shutdown system,
  - the shut-down temperature would be higher than the alarm temperature to alert the operator with the opportunity to restore the cooling.
  - auto shut-down in the event of high reactor temperature.
- Install a check valve in the cooling line to prevent reverse flow.
- Periodically inspect the cooling coil to ensure its integrity.
- Study the cooling water source to consider possible contamination and interruption of supply.
- Install cooling water flow meter and low-flow alarm (to provide immediate indication of cooling loses).
- All coolant water failures be properly reported and proper action taken if occurred repeatedly.

- Monomer feed valve must be fail closed on power failure

4. Safety Review

- Informal Safety Review

- Formal Safety Review

Informal Safety Review

- For small changes to existing process
- For small bench-scale or lab processes
- Usually involve 2-3 people
- Exchange ideas and developed safety improvement.
- Significant improvement is summarized in a memo for others to refer

Process Description

- Phosgene is fed from container through valve into a fritted glass bubbler
- The reflux condenser condenses aniline vapors and return them to reactor
- A caustic scrubber (using NaOH) is used to absorb phosgene and HCL vapors
- The whole process is contained in a hood

Results from informal safety review

- 1. Flow indicator provides visual indication of phosgene flow
- 2. Relied system is added on the phosgene line with an outlet to a scrubber (in case of fritted glass bubble plugged)
- Install a trap to catch liquid phosgene
- 3. Scrubber is replaced by a more effective bubblers
- 4. Ammonia hydroxide bubbler is added as it is more effective to absorb phosgene
- 5. A pail of caustic is placed nearby.

  The phosgene cylinder would be dumped into this pail in the event of cylinder leak.

  The caustic would absorb the phosgene
- 6. Hang phosgene indicator area in the operating area (it will turn brown when exposed to 0.1 ppm phosgene
- 7. Use safety checklist before startup
- 8. Post up-to-date process sketch near the process

Formal Safety Review

- For new process or,
- For substantial changes in existing process or,
- For process that need an updated review.
- Consist of:
  - Preparation safety review report by the appointed review team.
  - Inspection and report review by selected committee.
  - Implementation of the recommendations.
- Less tedious but requires experience committee members.

Content of Formal Safety Review Report

1. Introduction
    - Executive summary
    - Process overview
    - Reaction & Stoichiometry
    - Engineering data
2. Raw materials and products
    - Hazard and handling problems
3. Equipment setup
    - Equipment description
    - Equipment specifications
4. Procedures
    - Normal operating procedures
    - Safety procedure
        - Emergency shutdown
        - Fail-safe procedures
        - Major release procedures
    - Waste disposal procedure
    - Cleanup procedures
5. Startup Safety Checklist
6. MSDS for each hazardous material

Reference

- Crowl, Daniels A. and Louvar, Joseph F., Chemical Process Safety: Fundamentals with Applications, Prentice Hall, 1990, New Jersey, USA.
- Occupational Safety and Health Act (OSHA) and Regulations, MDC Publishers Sdn Bhd, Malaysia