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Application of Inherently Safe Principles to Projects

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What you don't have can't leak.

People who aren't there can't be killed.

- Trevor Kletz

Bhopal Disaster - 1984

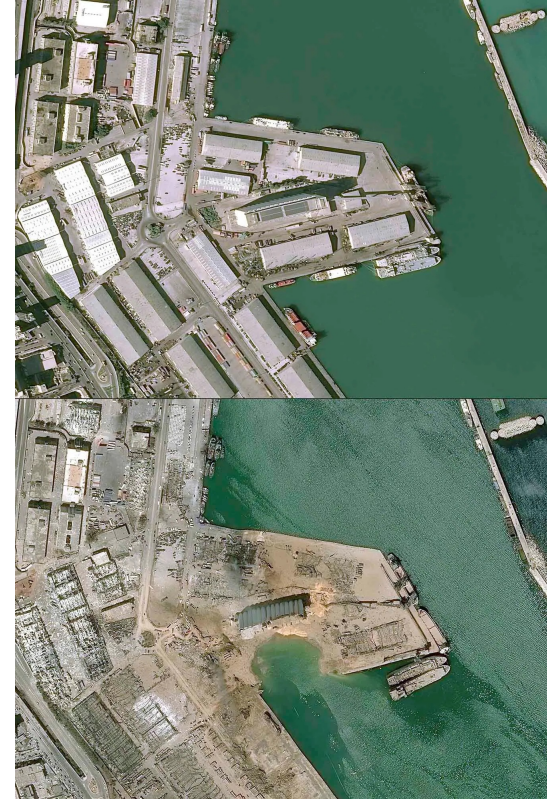
- Estimated 4k – 20k fatalities due to exposure of highly toxic gas cloud of methyl isocyanate (MIC)
 - Over 500,000 people exposed, with approximately half experiencing exposure effects
- Liquid MIC stored in three 18,000 US gal underground tanks
 - MIC used as an intermediate in production of carbaryl (pesticide)
- Introduction of water to tank (highly exothermic) resulted in large production of vapor MIC to ATM via overpressure protection devices
 - Multiple other safety devices failed to limit ATM release



Source: Wikipedia

Beirut Explosion - 2020

- At least 218 deaths from an explosion of 2750 tons of ammonia nitrate that was being stored in a port warehouse
 - Strength of explosion equivalent to ~1.1 kilotons of TNT
- Explosion was preceded by a large fire in the same warehouse
 - Ammonia nitrate becomes unstable and can explode when exposed to high heat
- Ammonia nitrate had been stored without safety precautions for 6 years after being confiscated by authorities



Source: New York Post

Aqaba Chlorine Leak - 2022

- At least 13 people killed after a 25 ton cylinder of chlorine dropped from a crane and ruptured
 - Cylinders were being transferred from dock to barge
- Wire rope sling of crane was rated for 8.5 tons
 - Failed on 5th of a planned 25 transfers
- Senior port officials had delegated critical safety tasks to untrained personnel



Source: Reuters

The public isn't responsible for the hazards!



What is Inherent Safety?

- The concept of avoiding the creation of hazards, or minimizing a hazard if its inclusion is required for a design
 - “The safest hazard is the one that doesn’t exist”
- Awareness and recognition of hazards, including fire, explosion, and other accident potentials, is critical
- Elimination or reduction of hazards is accomplished through the application of the four common Inherent Safety Principles

Inherent Safety Principles

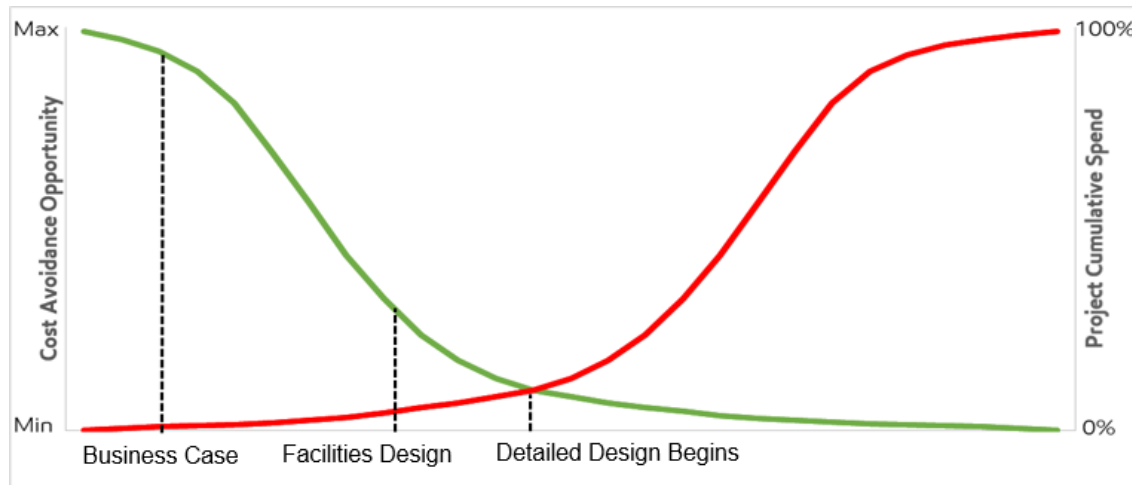
- Substitution
 - Substitute a more hazardous material with a less hazardous one, if feasible
 - Substitution can involve process raw materials or utilities
- Reduction
 - Reduce the inventory in storage and process vessels to a practical minimum
- Attenuation
 - Reduce the severity of the conditions under which hazardous materials are used
- Simplification
 - Simplify the process to reduce the potential for operator error

Inherent Safety in Projects

- Projects alter the risk profile of an operating facility by modifying or introducing new hazards
 - Project design will be modified to be consistent with endorsed risk profile of operating facility
- Inherent Safety is included in most design philosophies, but might not adequately recognize risks of new technologies/chemicals or changing risk philosophies over time
 - “But we’ve always done it this way...”
- To help ensure the Inherently Safest Design has been considered, Inherent Safety Reviews should be completed with a focus on the project’s specific hazards and proposed design
 - Layout, sources of energy, and proximity of hazards to public receptors are critical points of interest
- Inherently Safest Design has a more substantial and permanent reduction in a risk profile
 - Inherent Safety Reviews check for application of the inherent safety principles and suggest associated design modifications

Inherent Safety Review Timing

- Hazards identified later in a project's schedule, or after a facility has already been built and operational, will most likely require mechanical or procedural safeguards to reduce risk to an acceptable level to the risk owner
- Inherent safety mitigations (e.g. layout, chemical, or process changes) can be costly to implement later in schedule
- All mechanical or procedural safeguards have failure potential, so risk cannot be fully eliminated
- Mechanical safeguards require continual maintenance and testing, while procedural safeguards will require routine training



Inherent Safety Review Structure

- Formal review of design information available in early stages of project
 - Business Case Inherent Safety Reviews should focus on ‘show stopper’ hazards that would require costly critical safeguards if hazards cannot be eliminated through application of Inherently Safe principles
 - Facilities Design Inherent Safety Reviews should focus on reducing the number of designed safeguards that might be necessary to manage the project’s risk
 - Review should cover the most representative design and hazard information available at the time
- Effective review methodologies are “What-If” or Checklist Review
 - “What-if” is a fit-for-purpose brainstorming group approach where participants ask questions or voice concerns about undesired events
 - Checklist Review is a highly-versatile, experience-based approach which requires review facilitator to develop a list of project and hazard-specific checklist questions in advance of formal review

Inherent Safety Review Participants

- A highly effective Inherent Safety Review is dependent on the knowledge of the participants on the hazards inherent to the process or technology being reviewed
- Team size should be selected based upon complexity of technology or project
 - More complex technologies/projects will require a larger array of knowledgeable participants
- Potential review members
 - Process Safety Engineer – acts as facilitator; expertise in inherent process safety considerations
 - Process Technology Expert – knowledge of technical process and how hazards are historically controlled
 - Industrial Hygienist – expertise in understanding of hazards inherent to personnel exposure
 - Project Representative – expertise in project scope and basis as well as design philosophy
 - Operations/Maintenance Representative – provide commentary on hazards of existing similar processes
- *More details on Inherent Safety Reviews can be found in “CCPS: Guidelines for Hazard Evaluation Procedures”, 3rd edition*

Inherent Safety Challenges in Projects

- Even if the Inherently Safest Technology is applied early in a project cycle, they may still incur a larger overall project cost
 - Relocation of a hazard to farther from an occupied area might result in incremental facilities
 - Decreasing the size of one large storage tank to multiple smaller requires additional material and instrumentation
- Resolution of one risk can sometimes introduce another that needs further evaluation
 - Substitution of a highly hazardous chemical with a less hazardous one that will still require safeguards
- Inherently Safest Technology cannot be applied for logistical reasons
 - On limited plot areas, resolving risks by relocating equipment is not likely feasible
 - Unavailability of less hazardous material in remote locations

Inherent Safety Questions for Process Safety Events

- Inherent Safety question for Bhopal – ‘what if I get a large amount of water into my MIC tank?’
 - Was consideration given to a reduced volume of ‘intermediate’ MIC being stored at the facility?
 - Was consideration given to routing the PSVs to a closed system?
- Inherent Safety question for Beirut – ‘what if there is a large uncontrolled fire in the warehouse?’
 - Were the hazards associated with ammonia nitrate exposed to a fire not recognized?
 - Was consideration given to transferring the ammonia nitrate into smaller containers?
- Inherent Safety question for Aqaba – ‘what if one of the chlorine cylinders is dropped and breaks?’
 - Was consideration given to an alternate means of cylinder transfer?

Inherent Safety Summary

- One of the most successful ways to reduce the risk profile in a project is through the inclusion and timely review of the Inherent Safety Principles
- Application of the Inherent Safety Principles in a project can decrease the quantity of designed mechanical and procedural safeguards that are required
- The earlier in a project cycle that hazards are identified and Inherent Safety Principles applied, the less impact on a project schedule and cost
- Sometimes the Inherently Safest Technology cannot be applied, but the review is key in aiding a project in their rationale of safeguards and meeting an operating site's endorsed risk profile

Questions?

Thank you, and BOILER UP!

ExxonMobil