Implementing Inherent Safety

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Who We Are

Since 1994, AcuTech has been the global leader providing management and technical consulting services, a world-class training institute and a new enterprise risk management software for improving risk, safety, environmental, and security performance specific to the oil and gas, petrochemical and chemical industries.

AcuTech seeks innovation with technical excellence, and fosters a collaborative, team approach to problem solving. We are committed to excellence and customer satisfaction and continuously strive to provide responsive, flexible, and cost-effective solutions that exceed expectations.

AcuTech consultants possess strong project management skills and emphasize high-quality, on-time, cost-effective performance. AcuTech has robust project experience in safety, security, and preparedness for industries handling hazardous materials.

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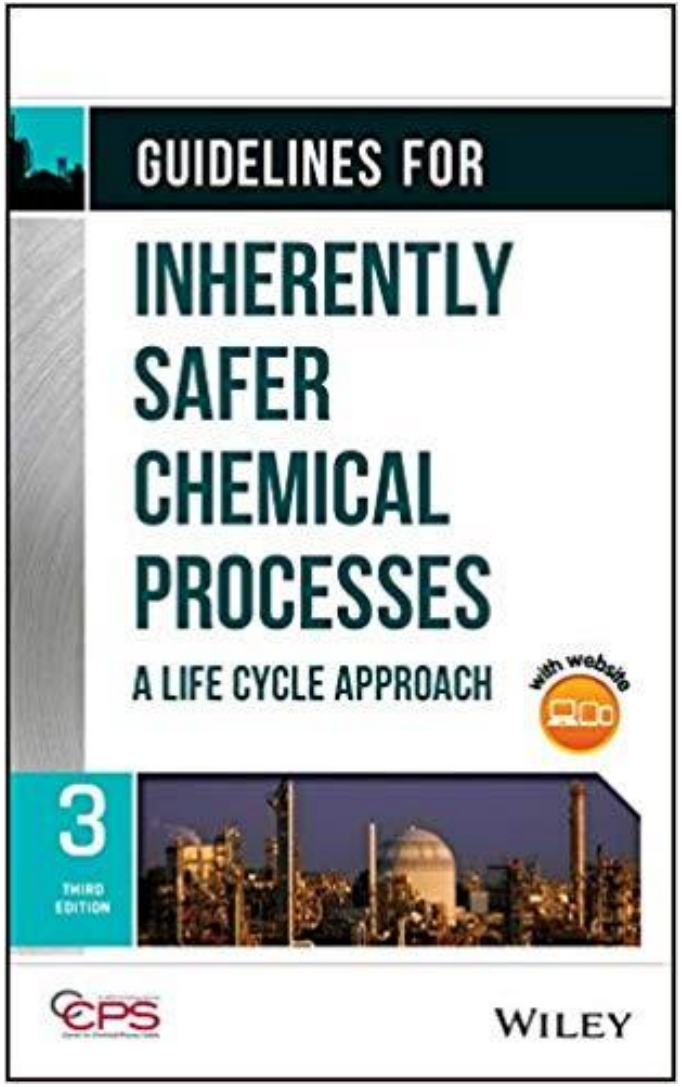
Inherently Safer Design (ISD) – State of the Practice

- ISD is a valuable process risk management technique
- Process safety professionals have embraced the concepts voluntarily for over 50 years
- It is an established method for addressing process risks, with excellent guidance available.
- The problem is – we still are not using the concept to its full potential
- Companies can to use ISD to routinely make a wide range of risk reductions at all levels and there are many opportunities to improve process safety.



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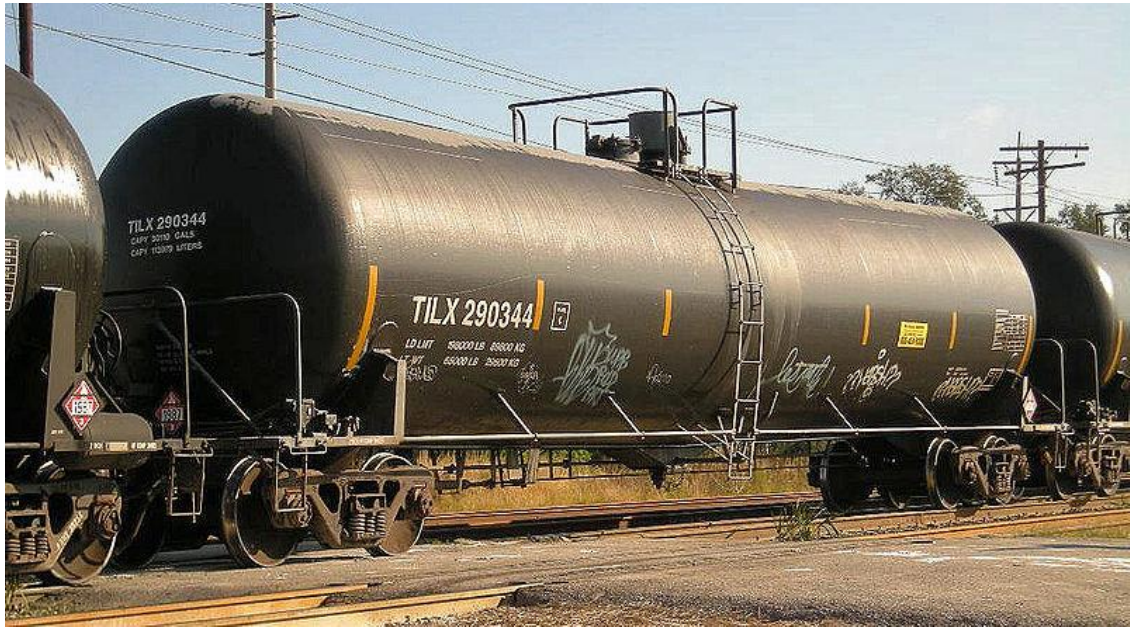
Fundamentals of ISD

- Inherently Safer Design presents a holistic approach to making the development, manufacture, and use of chemicals safer.
- Involves such practical applications as:
  - substituting more benign chemicals at the development stage,
  - minimizing risk in the transportation of chemicals,
  - using safer processing methods at the manufacturing stage,
  - and inherent safety during commissioning a manufacturing plant.
- Concept originated in UK in late 1960’s from ICI. Trevor Kletz, “What You Don’t Have Can’t Leak”



ISD is the First Level in the Hierarchy of Controls

Control	Objective
Inherent	Eliminating or reducing the hazard
Segregate	Using of distance and barriers to reduce the effects of hazards
Passive	Minimizing the hazard through process and equipment design features
Active	Using controls, alarms, and other means to minimize the likelihood of the hazard escalating or to limit the consequences
Procedural	Using policies, procedures, training, administrative checks, emergency response, and other management approaches to prevent incidents, or to minimize the effects of an incident;

Inherently Safer Design Strategies

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Strategy	Examples
Minimize	Use smaller quantities; eliminate unnecessary equipment; reduce size of equipment or volumes processed.
Substitute	Replace hazardous material with a less hazardous substance.
Moderate	Use less hazardous conditions, a less hazardous form of material or facilities which minimize the impact of a release.
Simplify	Design facilities which eliminate unnecessary complexity and make operating errors less likely.

Figure 1: Inherently Safer Approach to Analyzing & Managing Process Risks

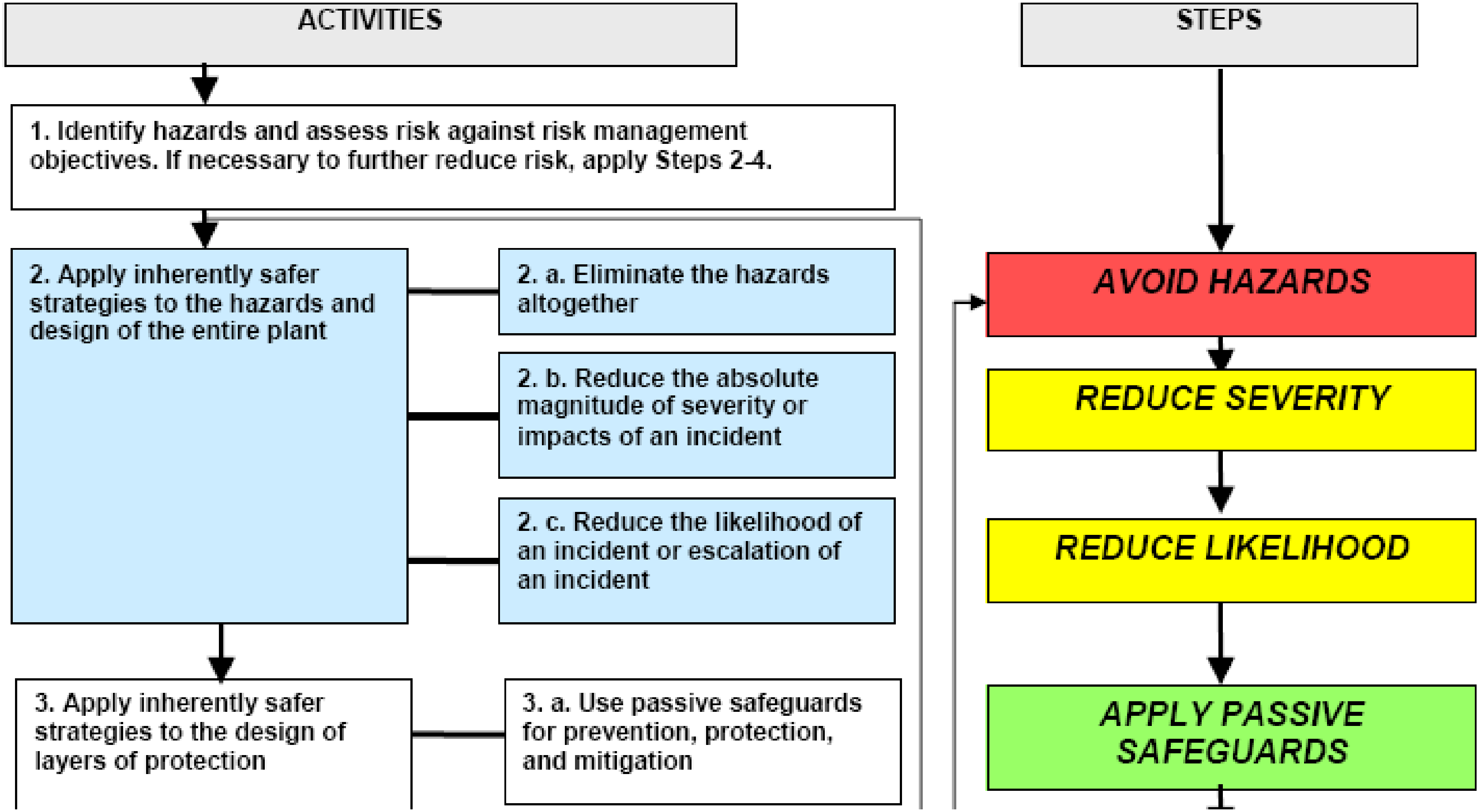
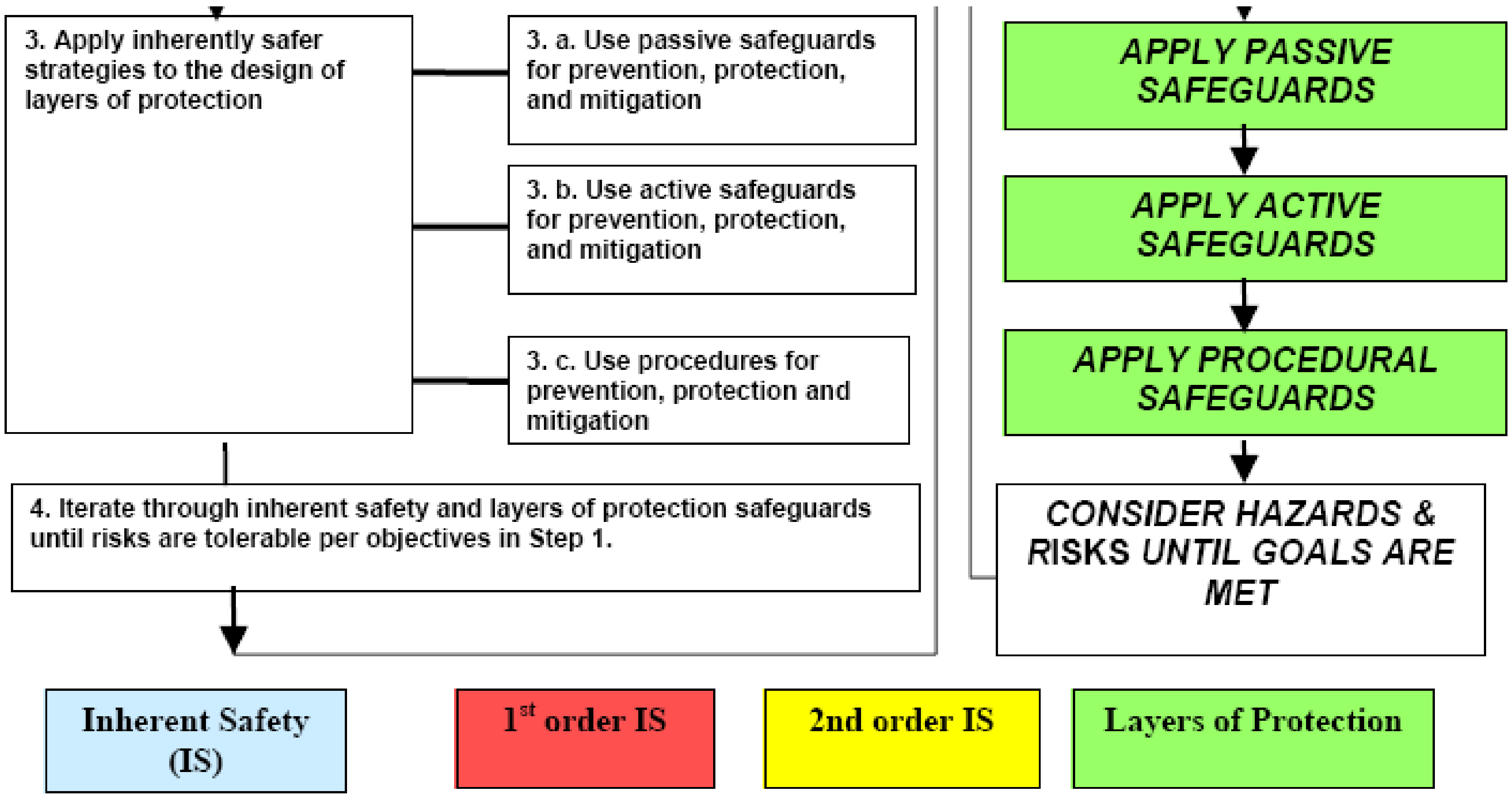
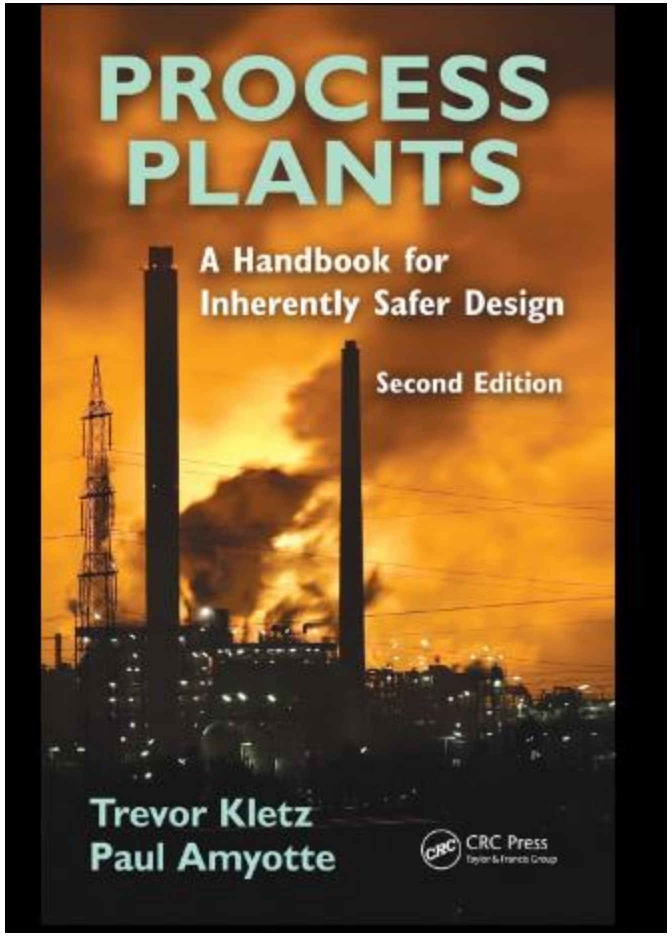


Figure 1: Inherently Safer Approach to Analyzing & Managing Process Risks



Typical Process Safety Activities
Does Not Focus on Reducing the Hazards

- PHA — Emphasis on Layers of Protection
- MOC — Checklist/PHA
- OR Review — Simple checklist



"What you don't have can't leak!" Trevor Kletz

Typical Brief PHA Approach – No Consideration of ISD

STUDY TITLE: PROCESS EXAMPLE							**SHEET: 1 of 4**		
Drawing No.:			**REV. No.:**				**DATE:** December 17, 1998		
TEAM COMPOSITION:			LB, DH, EK, NE, MG, JK				**MEETING DATE:** December 15, 1998		
PART CONSIDERED:			**Transfer line from supply tank A to reactor**						
DESIGN INTENT:			**Material:** A **Source:** Tank for A		**Activity:** Transfer continuously at a rate greater than B **Destination:** Reactor				
No.	**Guide word**	**Element**	**Deviation**	**Possible causes**	**Consequences**	**Safeguards**	**Comments**	**Actions required**	**Action allocated to**
1	NO	Material A	No Material A	Supply Tank A is empty	No flow of A into reactor Explosion	None shown	Situation not acceptable	Consider installation on tank A of a low-level alarm plus a low/low-level trip to stop pump B	MG
2	NO	Transfer A (at a rate >B)	No transfer of A takes place	Pump A stopped, line blocked	Explosion	None shown	Situation not acceptable	Measurement of flow rate for material A plus a low flow alarm and a low flow which trips pump B	JK
3	MORE	Material A	More material A: supply tank over full	Filling of tank from tanker when insufficient capacity exists	Tank will overflow into bounded area	None shown	Remark: This would have been identified during examination of the tank	Consider high-level alarm if not previously identified	EK

Typical Brief PSSR Approach – Checklist with No Consideration of ISD

Field Inspection	N/A	OK	Deficient	Comments
All open screwed connections bull plugged				
Lines, equipment, and steam tracing are identified				
No crosstie between process and utilities; dead spools and double block-bleeds in place				
Proper hose connections provided				
Adequate operating access, escape routes provided				
Operator alarm and shutdown test facilities adequate and have been tested				
Fire and safety inspection performed				
Temporary piping, hoses, tubing and gauges removed				
All primary PSV block valves are car sealed open. Spare PSV block valves are car sealed closed				
All valves designated on the P&IDs are car sealed in correct position and all valves that been blinded temporary or permanent are in the master blind list				
Operating procedures and process discussions updated				
Operator training completed				

27 November 2019 TPC Group
Port Neches, TX Butadiene

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21 March 2019 Chenjiagang Chemical Industry Park, Chenjiagang, Yancheng, Jiangsu, China 78 Fatalities and 617 Injuries

- MEM will more strongly enforce its production 'blacklist'. This exposes companies that have violated the production law and restricts them from establishing new projects, using land, as well as access to finance. Last year's blacklist named 46 companies in China.
- One industry source told Chemical Watch that the explosion "might lead to the government shutting down more chemicals companies and industry parks that have violated safety production regulations or environmental regulations. This could lead to the shortage of some raw materials and higher prices."
- The source added that it might also speed up the drafting of the new Law on the Safety of Hazardous Chemicals. This will replace parts of the country's existing overarching law on chemicals, Decree 59

Preferred Risk-Based Hazard Evaluation Process – ISD is Integrated Into the Entire Workflow

MOC

All changes are evaluated and hazards identified and focus on eliminating or reducing hazards through ISD

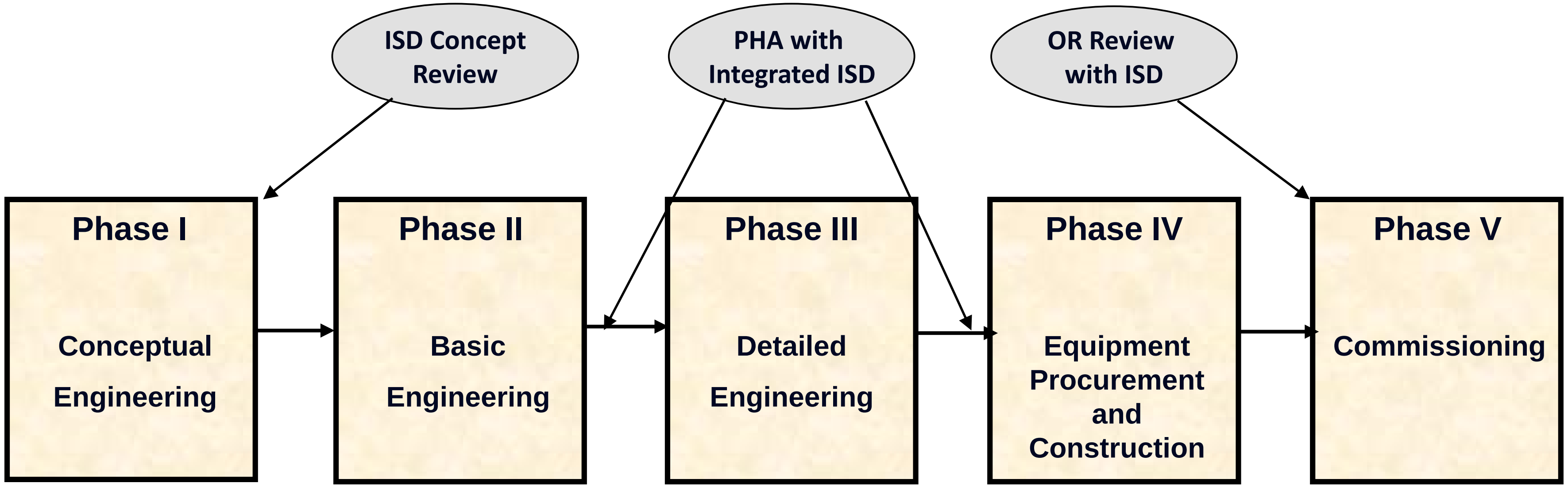
PHA

Risk-based evaluation throughout the lifecycle of the process seeking ISD opportunities

Operational Readiness Review

All changes are evaluated for readiness to initiate operations and consideration of ISD as is possible

Pre-startup Safety Reviews
Capital Project Reviews



Technical Feasibility

Economic Feasibility

Process Flow Design

Develop Construction Specifications and Drawings

Installation

Check out and Start up

Reduce Complexity and Focus on the Reduction of the Hazard

Inherently Safer Viewpoints

Viewpoint	Examples
Macro (community-based & strategic)	• Use alternative technology that has a lower operating pressure • Substitute feed stocks with less toxic substance • Substitute entire process technology
Micro (plant-based & tactical)	• Reduce the size of a particular vessel or line in a process • Use a catalyst that is less toxic • Simplify DCS controls and/or control/operating procedures

Inherently Safer Design (ISD)
First Order vs Second Order

- Use ISD "order" to set priorities for evaluation and risk control.
- **First Order**
  - A change that results in the highest degree of risk reduction possible by employing an ISD strategy
  - For example, elimination of a material from site with no need for substitution.
- **Second Order**
  - Risk reduction that is less than First Order and varies in risk reduction.
  - Substitute a less hazardous material that reduces hazard and risk levels.
  - Minimize inventory, but does not eliminate.

ISD Study Approach

- Steps to conduct an ISD study are like other PHAs but differ in that the emphasis is first on whether the process has opportunities to reduce basic hazards using inherent safety as a first strategy.
- Frequently not discussed in a typical PHA study since the team tends to focus on the basic design and determines the adequacy of the layers of protection.
- Approach:
  - Identify and understand hazards associated with a process (HAZOP, HAZID);
  - Analyze the opportunities for each of the four ISD strategies (first to second order);
  - Determine the feasibility of the potential ISD opportunity;
  - Develop recommendations to implement the ISD strategies that are feasible and justified.
  - Assess the adequacy of the layers of controls in the priority of inherent, passive, active, and administrative controls.

Reasons Why Companies May Not Be Getting Maximum Value From Inherent Safety?

- Is there is a perception that ISD is not a suitable strategy since:
  - the core technology or chemical cannot feasibly be changed?
  - opportunity was only if new process?
  - it may be threatening to the very existence of the business if forced to do so?
- *If so, these may be misconceptions holding you back*

Does Your Company Have a Written Policy and Procedure for Explicit Use of Inherent Safety?

- Can you pass this test?:
  - We have a written policy to use ISD?
  - There is a written procedure on how to evaluate ISD?
  - We formally documented ISD opportunities in PHAs?
  - We have given training on ISD and how to conduct evaluations?
  - We audit our operations for use of ISD?
- *If not, you may not be fully facilitating its use*

Inherently Safer Design – It Is For Everybody

- Premise: ISD can be widely and routinely used in any facility during any stage of the process lifecycle
- Key factors limiting use:
  - Misunderstanding of what it means
  - Lack of appreciation of potential value
  - Lack of encouragement of its use
  - Lack of knowledge of how to fully apply inherent safety

Inherently Safer Design – It Is For Everybody

- Creative ideas from the employees of the company may be keys to step changes in process safety performance and hazard reduction
- These ideas may be readily implemented
- Companies that create a culture of inherent safety will be advantaged through continuous and creative risk reduction

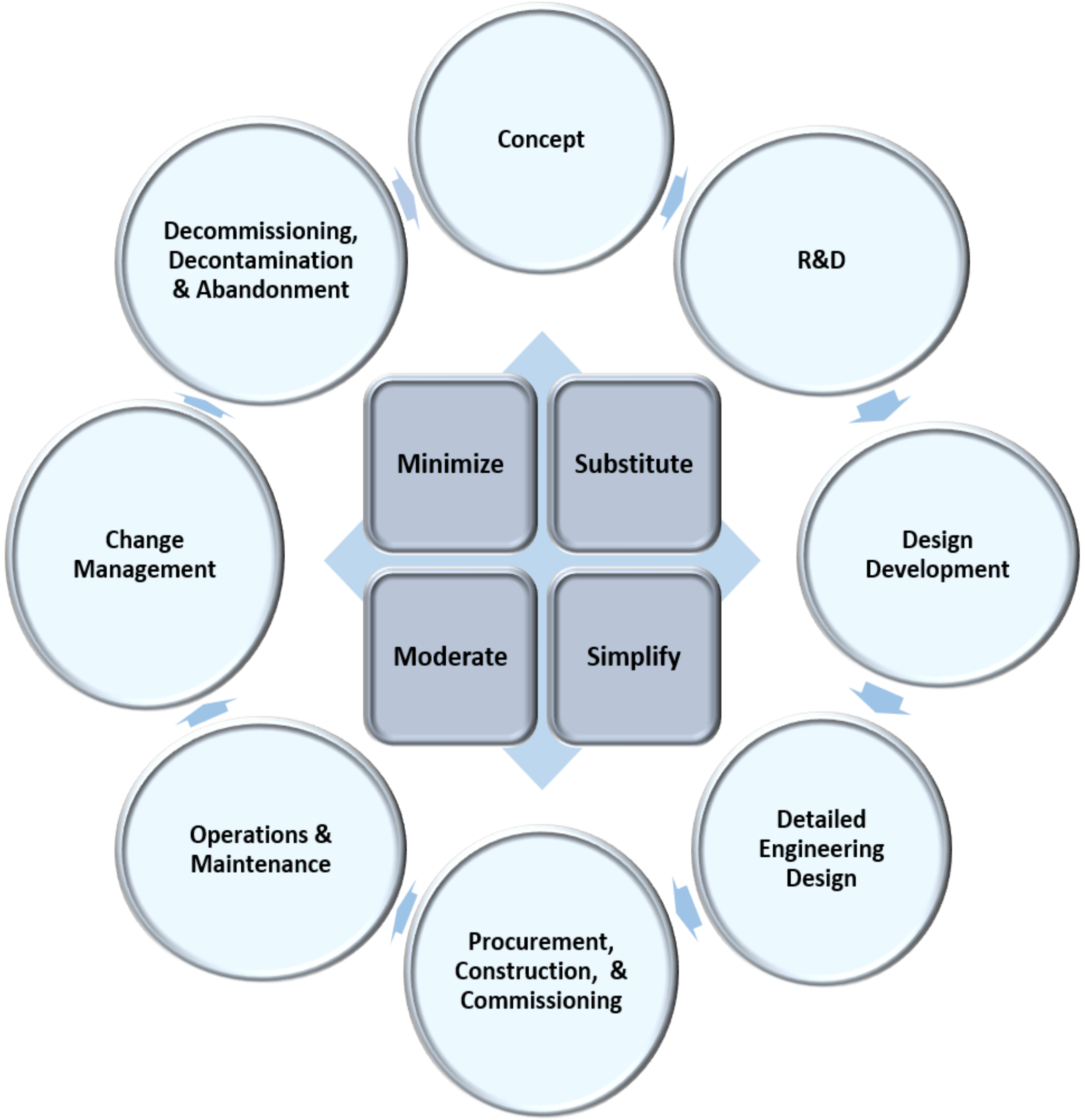
The Keys to Taking Maximum Advantage of the ISD Concept

- Understand the real potential of ISD and commit to it
- Define a plan to encourage its use
- Ensure that it is an integral part of the safety philosophy and practice of the organization

Inherent Safety Benefits and Limitations

- Inherently safer design is a fundamentally different way of thinking about the design of chemical processes and plants.
- It focuses on the elimination or reduction of the hazards, rather than on management and control.
- This approach should result in safer and more robust processes, and it is likely that these inherently safer processes will also be more economical in the long run (Kletz)
- It must be recognized, however, that applying an inherently safer concept to a plant does not necessarily mean that plant is the most safe, secure, efficient, or economical.

ISD During the Process Lifecycle



Means to Institutionalize ISD

- Implement policy and procedures
  - Management commitment and accountability
  - Policy and procedures encouraging ISD
  - Principles, goals and incentives
- Practical tools to facilitate ISD
  - Checklists and analytical methods -- independent or integrated into routine activities
  - Auditing protocols
  - Inherent Safety indices

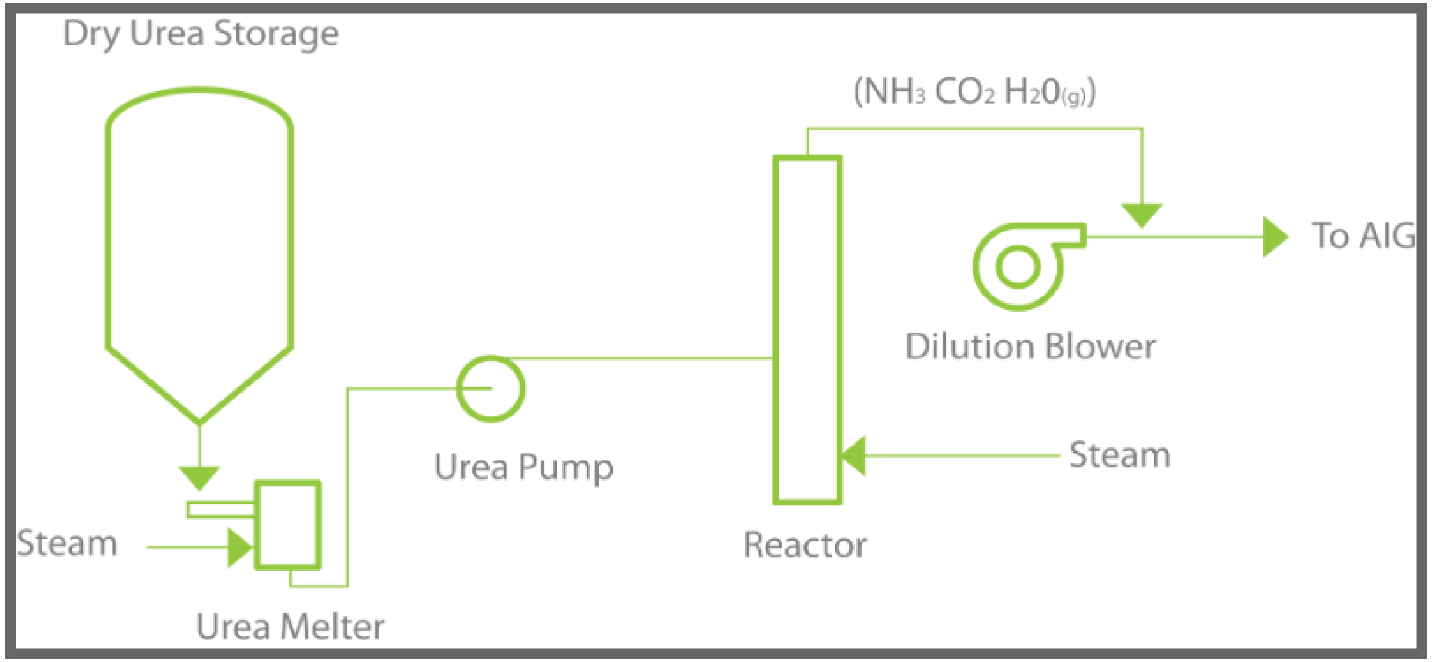
Market-Driven Inherent Safety

SafeDeNOx® Reactor System

Enviro Safe Denox®

SafeDeNOx® Urea to Ammonia

Chemithon's patented SafeDeNOx® process economicaly generates ammonia from urea for Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) of nitrous oxides (NOx). Our process is a safe alternative to shipping, handling, and storing anhydrous or aqueous ammonia (classified as toxic materials). Urea is non-hazardous and can be stored safely on site.



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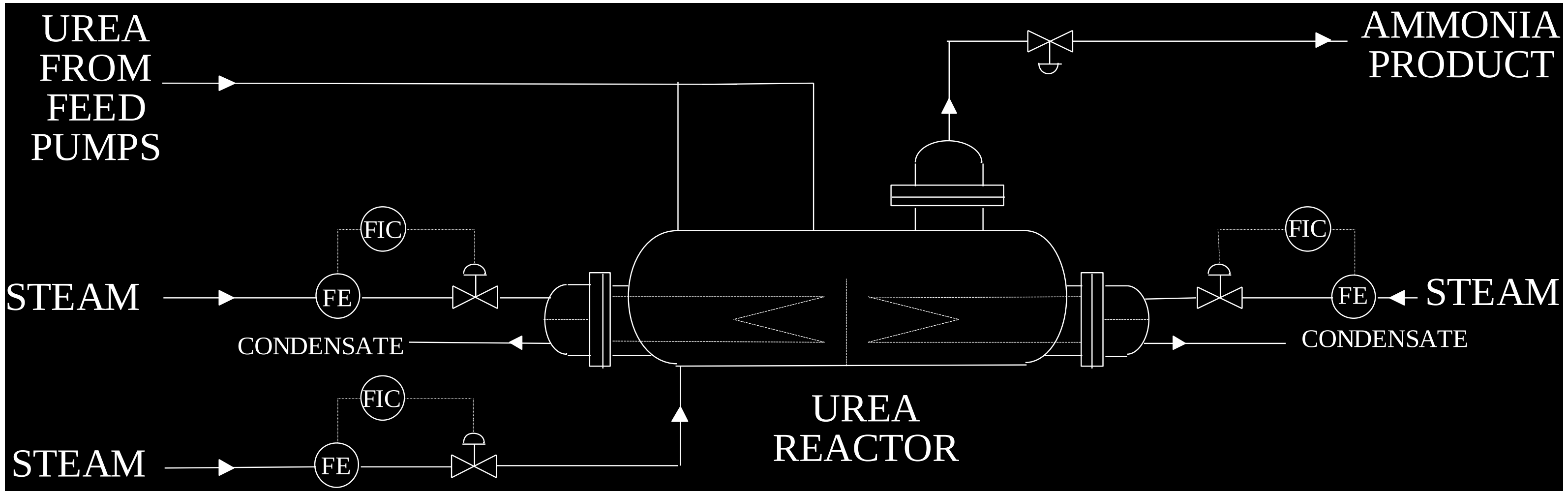
Market-Driven Inherent Safety

SafeDeNOx® Reactor System Example



Overall reaction

$(NH_2)_2CO + H2O \rightarrow CO_{2\uparrow} + 2NH_3\uparrow + H20$

Urea + water vapor (steam) carbon dioxide + ammonia + water

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Market-Driven Inherent Safety

SafeDeNOx® Reactor System

- Unlike other processes for generating ammonia, our SafeDeNOx® process involves melting granular urea rather than dissolving it in water. Our capital and operating costs are lower because less equipment and energy are required.
- The product gas is a mixture of ammonia (NH3), carbon dioxide (CO2), and water vapor. The overall reaction for converting urea to ammonia is: NH2CONH2 + H2O (steam) --> 2NH3 + CO2 + H2O
- Our unique process uses a catalyst to accelerate the reaction so the system responds quickly to changes in ammonia demand. Only a few minutes are required to reach equilibrium when feed rates change. Non-catalytic systems require about 20 times as much urea in solution for the same ammonia production rate. As a result the non-catalytic systems are larger and their process takes much longer to reach equilibrium when feed rates change.
- Because temperature and pressure are kept constant during production rate changes, our system produces a gas mixture with a constant ratio of ammonia to carbon dioxide and water vapor. So the amount of ammonia injected into the flue gas follows ammonia demand. In other systems where the temperature or pressure varies, the reaction is not at equilibrium during production rate changes. As a result, the ratio of ammonia to carbon dioxide and water vapor in the product gas varies, making control of ammonia slip very difficult.
- The SafeDeNOx® process is the most advanced and cost-effective on the market as well as a cost-effective and safe alternative to using anhydrous or aqueous ammonia for NOx reduction.

EPA RMP Final Rule (2016)
Safer Technology and Alternatives Analysis (STAA)

- "Safer technology and alternatives" refer to risk reduction strategies developed using a hierarchy of controls that are considered inherent, passive, active, and procedural. This strategy can be applied initially to all design phases and then continuously throughout a process's life cycle.
- STAA includes concepts known as inherently safer technologies (IST) or inherently safer design (ISD), which reduce or eliminate the hazards associated with materials and operations used in a process. IST, ISD, and inherent safety are interchangeable terms that are used in the literature and in the field.

EPA RMP Final Rule (2016)
Safer Technology and Alternatives Analysis (STAA)

- The four major inherently safer strategies are:
  - Minimization–using smaller quantities of hazardous substances;
  - Substitution–replacing a material with a less hazardous substance;
  - Moderation–using less hazardous conditions or a less hazardous form, or designing
  - facilities that minimize the impact of a release of hazardous material or energy; and
  - Simplification–design facilities to eliminate unnecessary complexity and make
  - operating errors less likely.
- Process Hazard Analyses (PHAs) are already part of the existing rule requirements. As part of the PHA, qualifying programs in three industry categories (paper manufacturing; coal and petroleum products manufacturing; and chemical manufacturing) are required to thoroughly evaluate safer technology and alternatives when conducting their Process Hazard Analysis, however implementation is not mandatory. These categories were selected because of highest frequency of accidents.

EPA Risk Management Program (RMP) Reconsideration Final Rule (2019)

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- On November 20, 2019, EPA Administrator Andrew Wheeler signed the Risk Management Program (RMP) Reconsideration final rule, which modifies and improves the existing rule to remove burdensome, costly, unnecessary amendments while maintaining appropriate protections and ensuring first responders have access to all of the necessary safety information. This rule also resolves important security concerns.

Why did EPA reconsider the RMP Amendments Final Rule?

- EPA reconsidered the final RMP Amendments Rule based on objections highlighted in three petitions submitted to the Agency under Clean Air Act Section 307(d)(7)(B) and based on its own review of that rule.
- The final rule addresses:
  - Potential security risks associated with new information disclosure requirements introduced in the final Amendments rule.
  - The Bureau of Alcohol, Tobacco, Firearms and Explosive's (BATF) finding that a key incident affecting US chemical safety policy, a fire and explosion in West, Texas, was caused by a criminal act (arson) rather than being the result of an accident.
  - Concerns with the costs of the Amendments rule
  - Concerns that EPA did not adequately coordinate its rulemaking with OSHA. EPA made changes to the RMP Amendments final rule to:
    - Maintain consistency of RMP accident prevention requirements with the OSHA Process Safety Management (PSM) standard; •
    - Address security concerns; •
    - Reduce unnecessary regulations and regulatory costs; •
    - Revise some compliance dates to provide necessary time for program changes.

Chemical Security and Inherent Safety

- New appreciation of intentional acts against hazardous materials
- Public concerns increased
- Cases not previously considered credible are being expected
- Pressure for regulation and action
- Some changes are reasonable and sensible, some are unreasonable

Chemical Security and Inherent Safety - What are the possibilities?

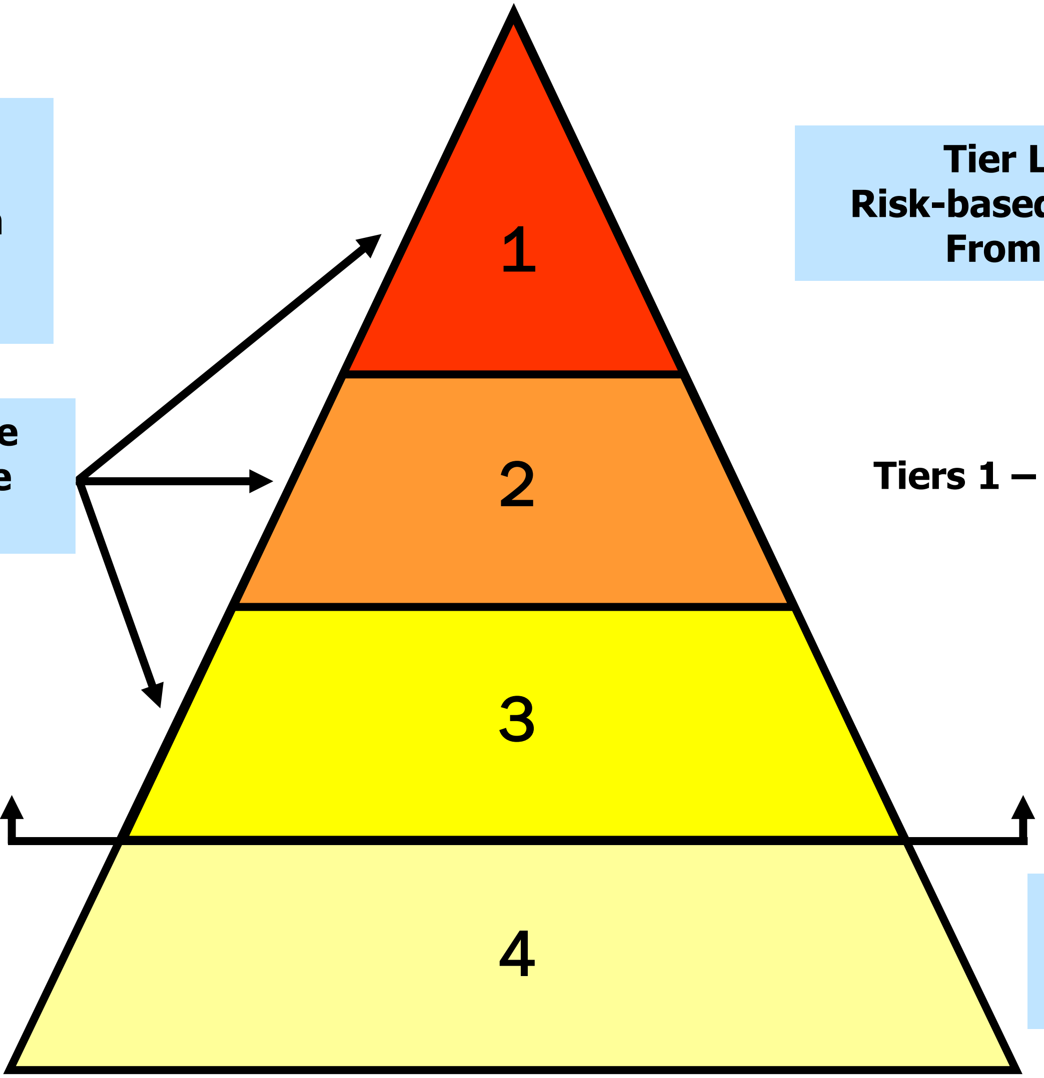
- **Security objective**:
  - Make the site less attractive to security act
  - Make the site less vulnerable to security acts by forced entry, standoff attack, or insider attack
- **Traditional security strategies:**
  - Defense in depth through multiple barriers to deter, detect, and delay and
  - Problem with this? – All security measures can be defeated
- **ISD strategies**:
  - Substituting chemicals to reduce consequences (and interest in theft, diversion, or release)
  - Reducing quantities of materials to reduce consequences
  - Less reactive chemistry to avoid sabotage by physical or cyber means
  - Simpler, less complex process to manage with lower likelihood of human error in emergencies or more likely to detect intentional discrepancies
  - Reducing usage and storage of chemicals by changing production methods and processes
  - Employing inherently safer technologies in the manufacture, transport, and use of chemicals
  - Employing inherently safer ‘technologies’ in the manufacture, transport, and use of chemicals
  - Rerouting of transported materials

CFATS Risk-Based Tiers

As of September 4, 2019, the CFATS program identified 3,321 facilities as high risk, with 167 facilities placed in Tier 1, 79 facilities in Tier 2, and the remainder in Tiers 3 and 4.

Tier Levels correspond to Risk-based Performance Standards From Low (4) to High (1)

DHS Consequence Thresholds Define Tiers



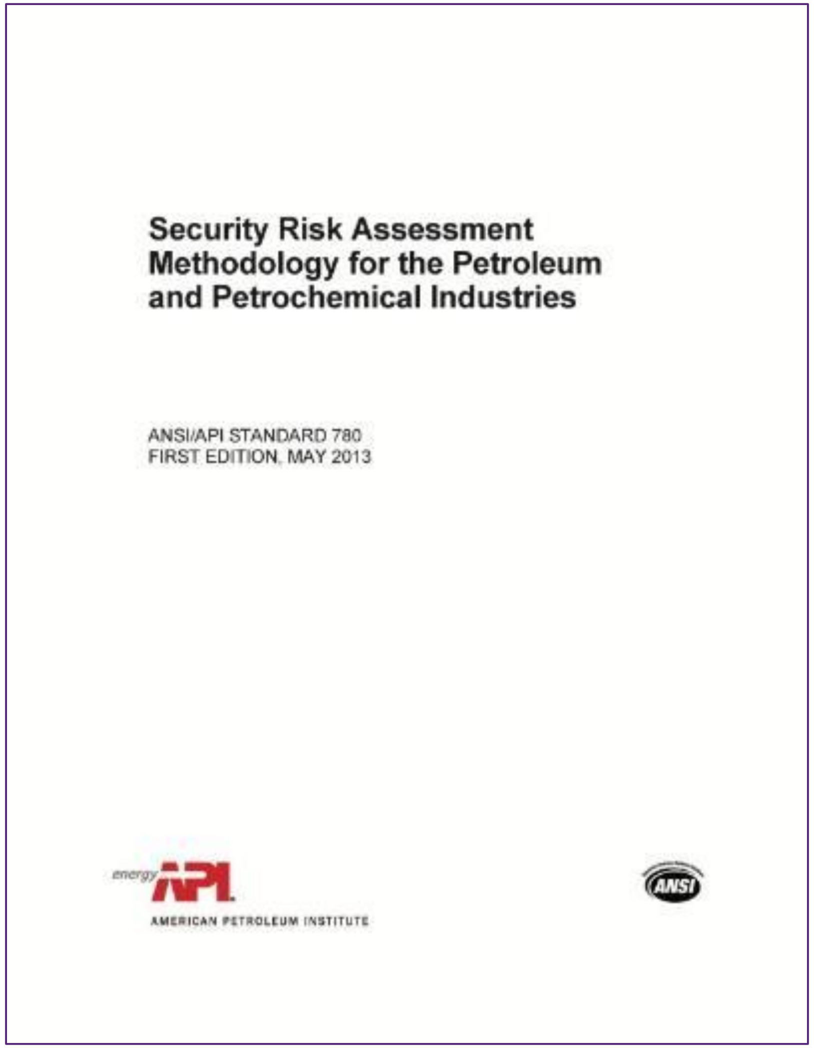
Tiers 1 – 3 use the CSAT SVA

Over 60,000 facilities initially registered and 95% screened out from the definition of High Risk

Tier 4 uses CCPS-type SVA, but also DHS Threats & Assumptions

Industry SRA Methodologies v DHS Approach

- Tier 4 facilities may submit for review and approval other methodologies so long as it is certified by CCPS as equivalent and has equivalent steps, assumptions, and outputs and sufficiently addresses the risk-based performance standards and CSAT SVA potential terrorist attack scenarios.
- Most common certified methodology is the ANSI/API Standard 780.
- This more thoroughly evaluates the specific scenarios, not only the limited number of interest to DHS, and is a more complete approach.
- Evaluating the quality of SRAs submitted is easier with a government standard online submittal but perhaps not as thorough or useful to industry.


Security Risk Assessment Methodology for the Petroleum and Petrochemical Industries

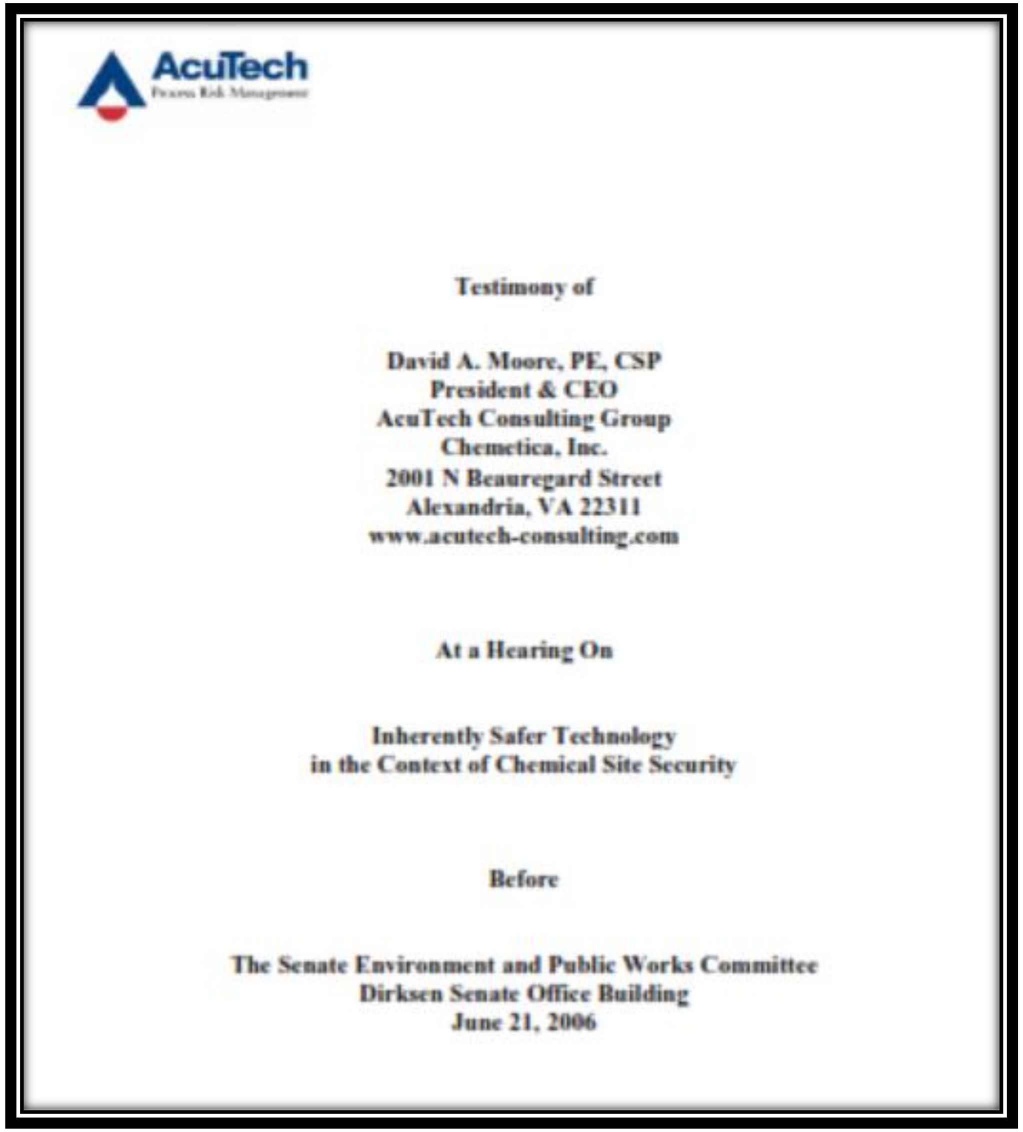
ANSI/API STANDARD 780
FIRST EDITION, MAY 2013

energy API
AMERICAN PETROLEUM INSTITUTE

ANSI

Problems with Regulating Inherent Safety

- Disruptive to businesses when may not be the only security solution
- May involve eliminating certain chemicals in the sector or shutting down certain operations
- Difficult to do for large scale existing facilities without high expense
- Unclear how secure is secure enough
- Eliminating one hazard may create another – example: more transports of hazardous material when a supply tank is removed onsite)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At a Hearing On

Inherently Safer Technology
in the Context of Chemical Site Security

Before

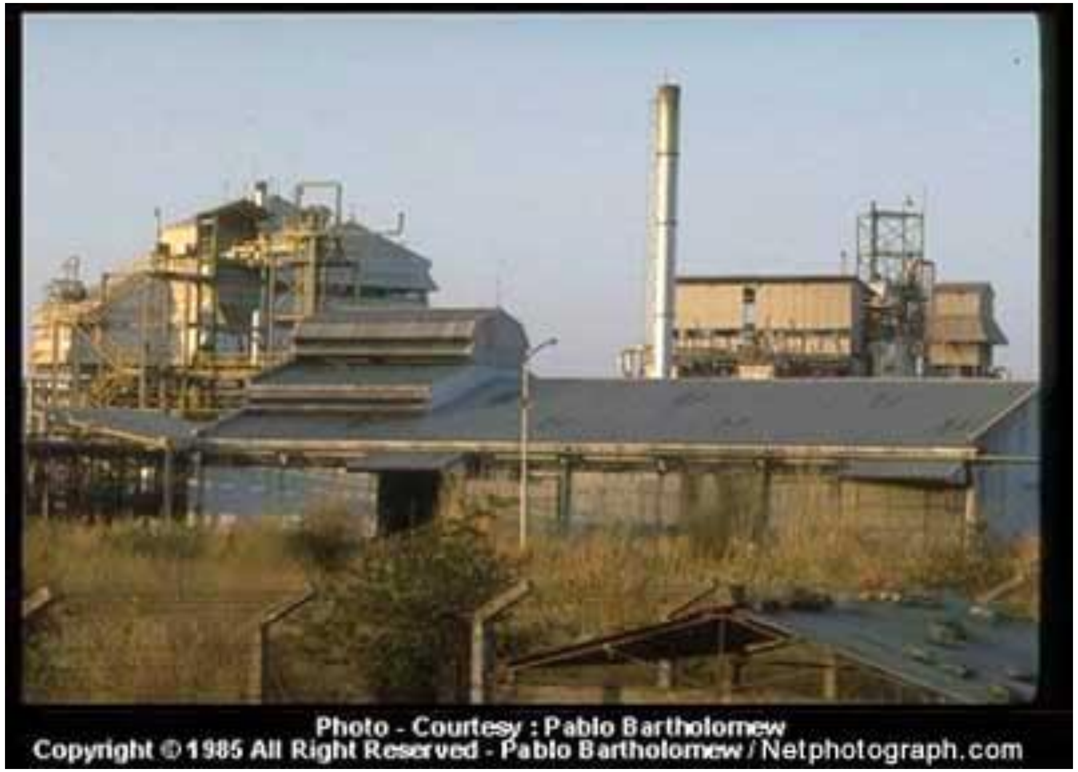
The Senate Environment and Public Works Committee
Dirksen Senate Office Building
June 21, 2006

Inherently Safer Design (ISD) at Bhopal

- 3 December 1984 – Bhopal accident 35th anniversary this year.
- This incident is a stark reminder of the potential for ISD
- What could have been considered in retrospect?

Bhopal Disaster

- The Union Carbide plant at Bhopal produced the product ‘Sevin’ an insecticide for spraying on crops.
- The capacity of the plant was 5,000 tonnes of Sevin per annum. It commenced full production in 1980.
- The factory was located at the northern end of the town of Bhopal in what was originally a relatively sparsely populated area.
- Over the years though unplanned urban growth meant densely populated suburbs were allowed to be built at the southern edge of the factory. (encroachment)



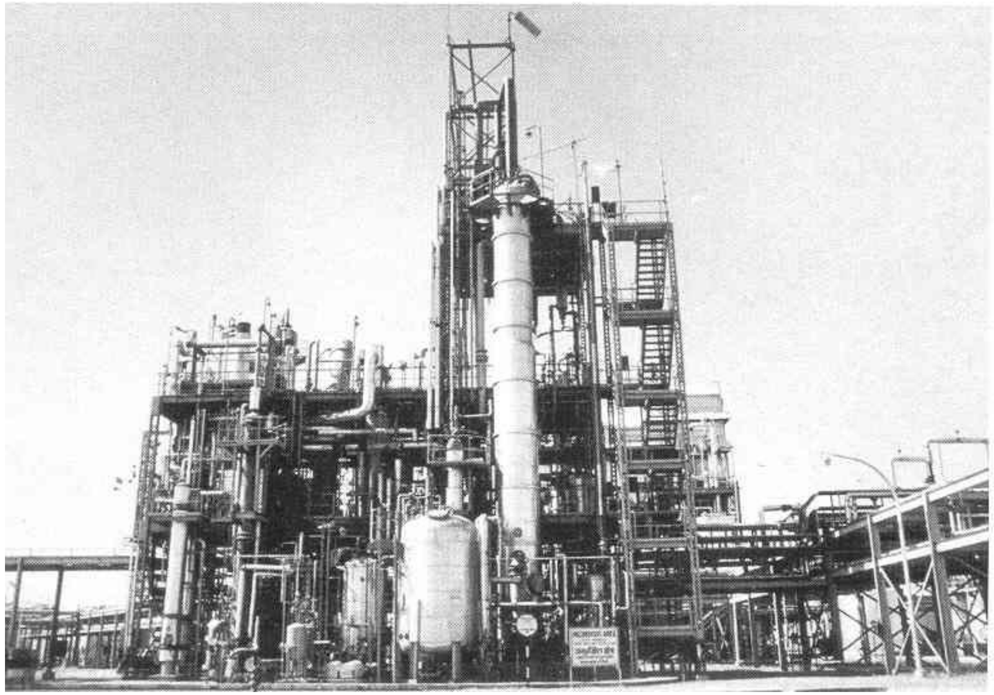
Bhopal Process Chemistry

Stage 1:

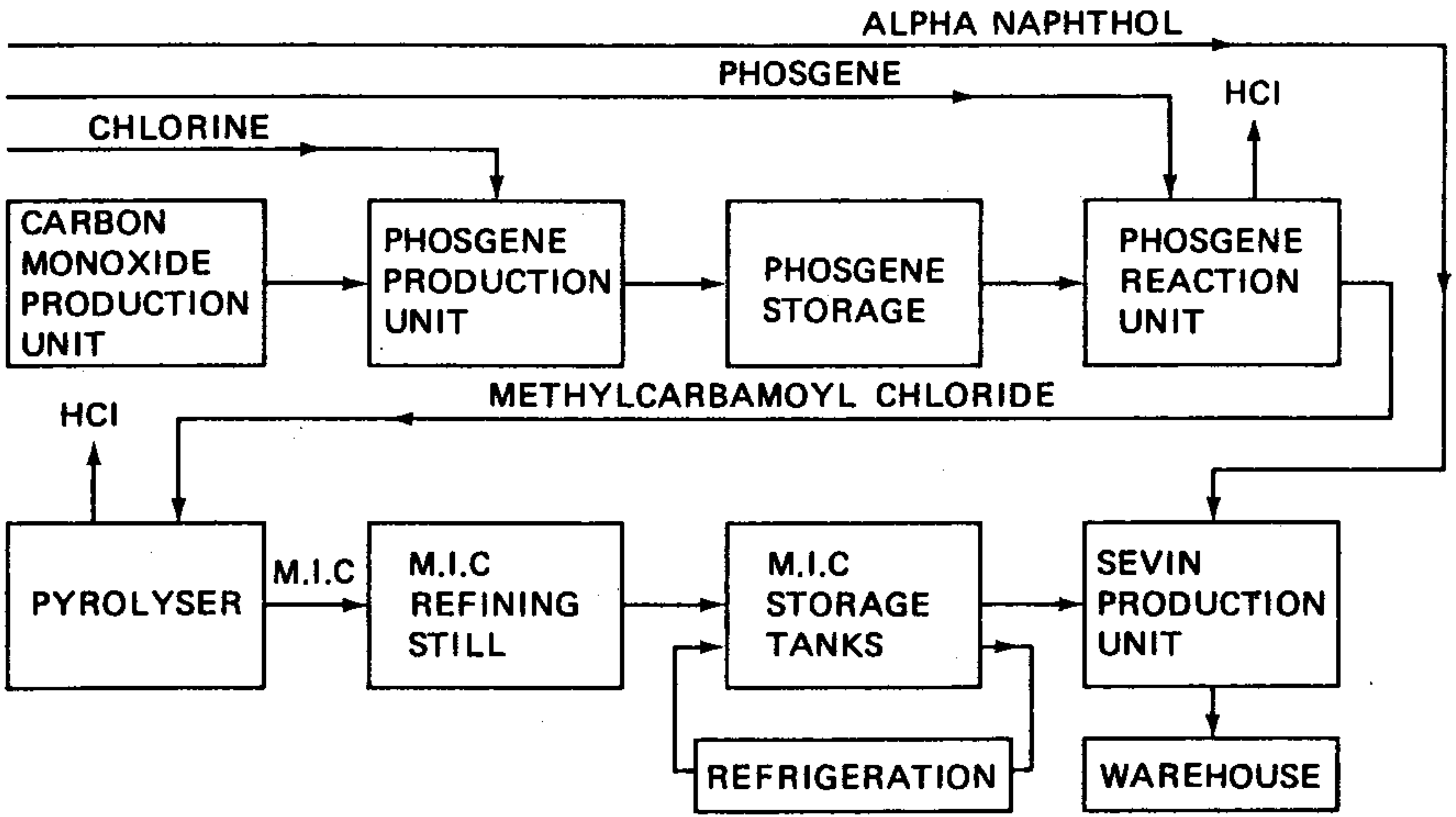
- Carbon Monoxide Production
  - Carbon + Oxygen → Carbon Monoxide
- Phosgene Manufacturing Plant
  - Carbon Monoxide + Chlorine to → Phosgene
- Methyl Isocyanate Plant
  - Phosgene + Methyl Amine → MIC **(<u>to Storage</u>)**
- Alpha Napthol Plant

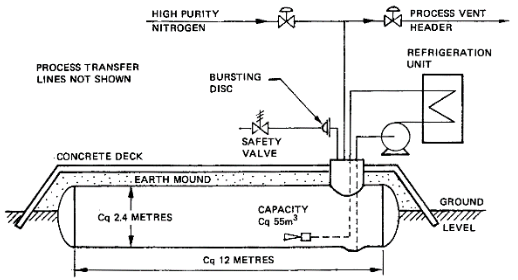
Stage 2:

- Sevin Plant
  - MIC **(<u>from Storage</u>)** + Alpha Napthol → Sevin

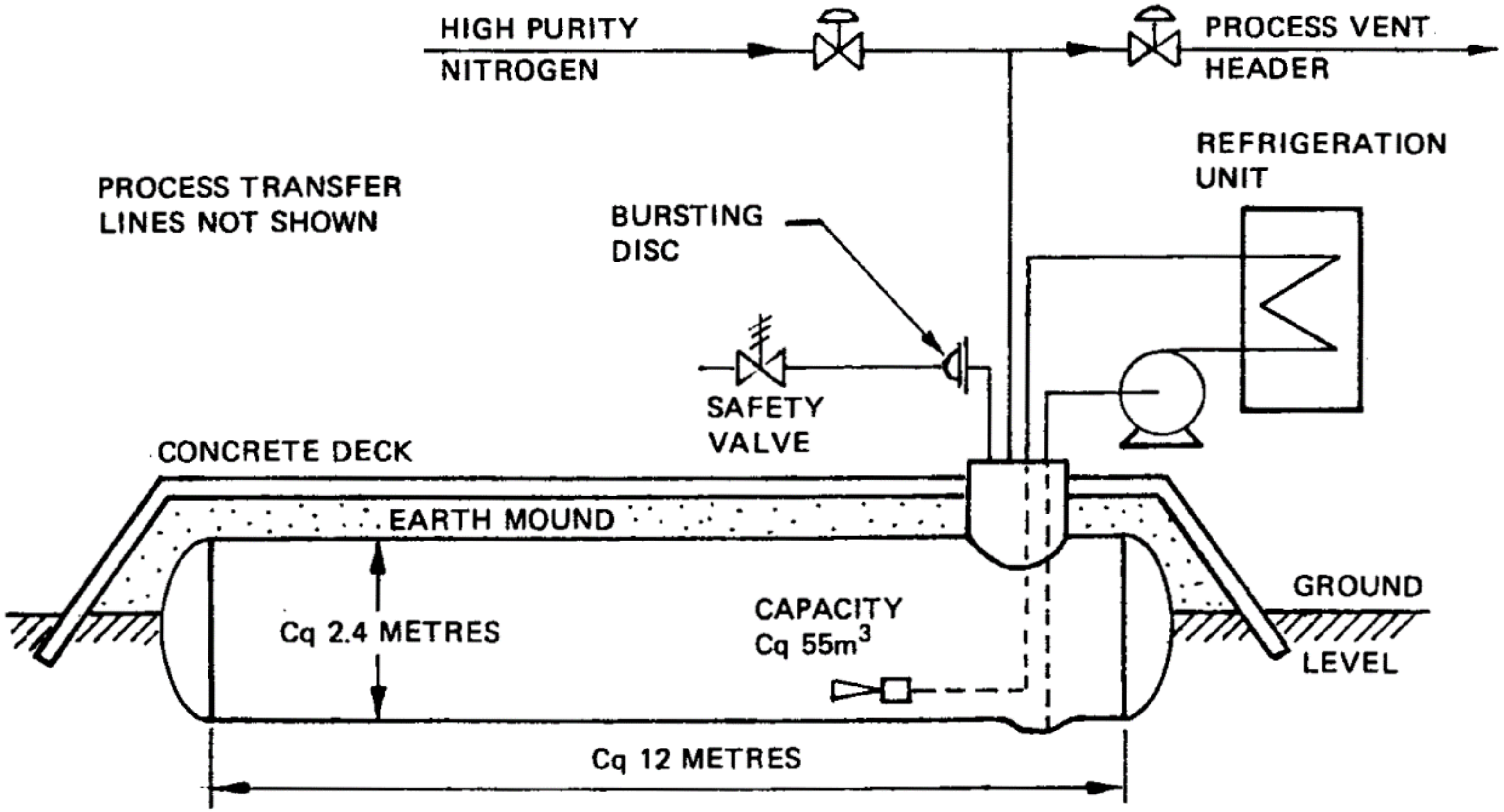


Bhopal Process Flow Diagram





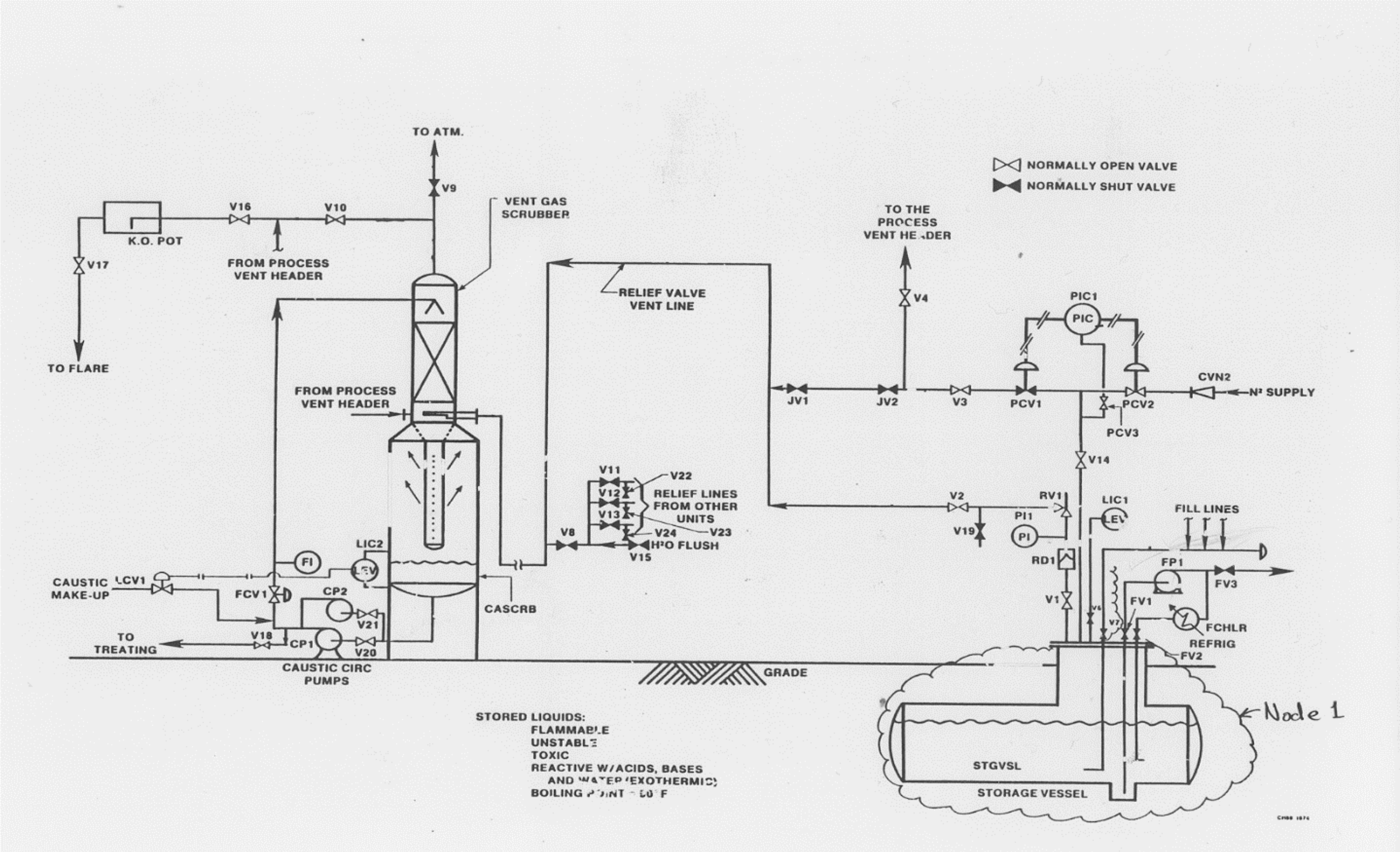
Bhopal MIC Storage Tank Design



Bhopal – Layers of Protection

- A Nitrogen line was connected to the tank to transfer the product by inert pressurization of the headspace. This could also be used to maintain a positive pressure inside the tank and thus prevent the ingress of unwanted liquids.
- The tank was fitted with a pressure relief valve and rupture disc.
- The vent line from the valve exhausted into a scrubbing tower filled with caustic soda (NaOH). This would neutralize the MIC to form Sodium Isocyanate.
- Any residual gas from the scrubber was sent to a 30 m tall flare stack where it would be burned off.

Bhopal – MIC Storage and Flare/Scrubber Layout



Bhopal – MIC Storage and Flare/Scrubber Layout

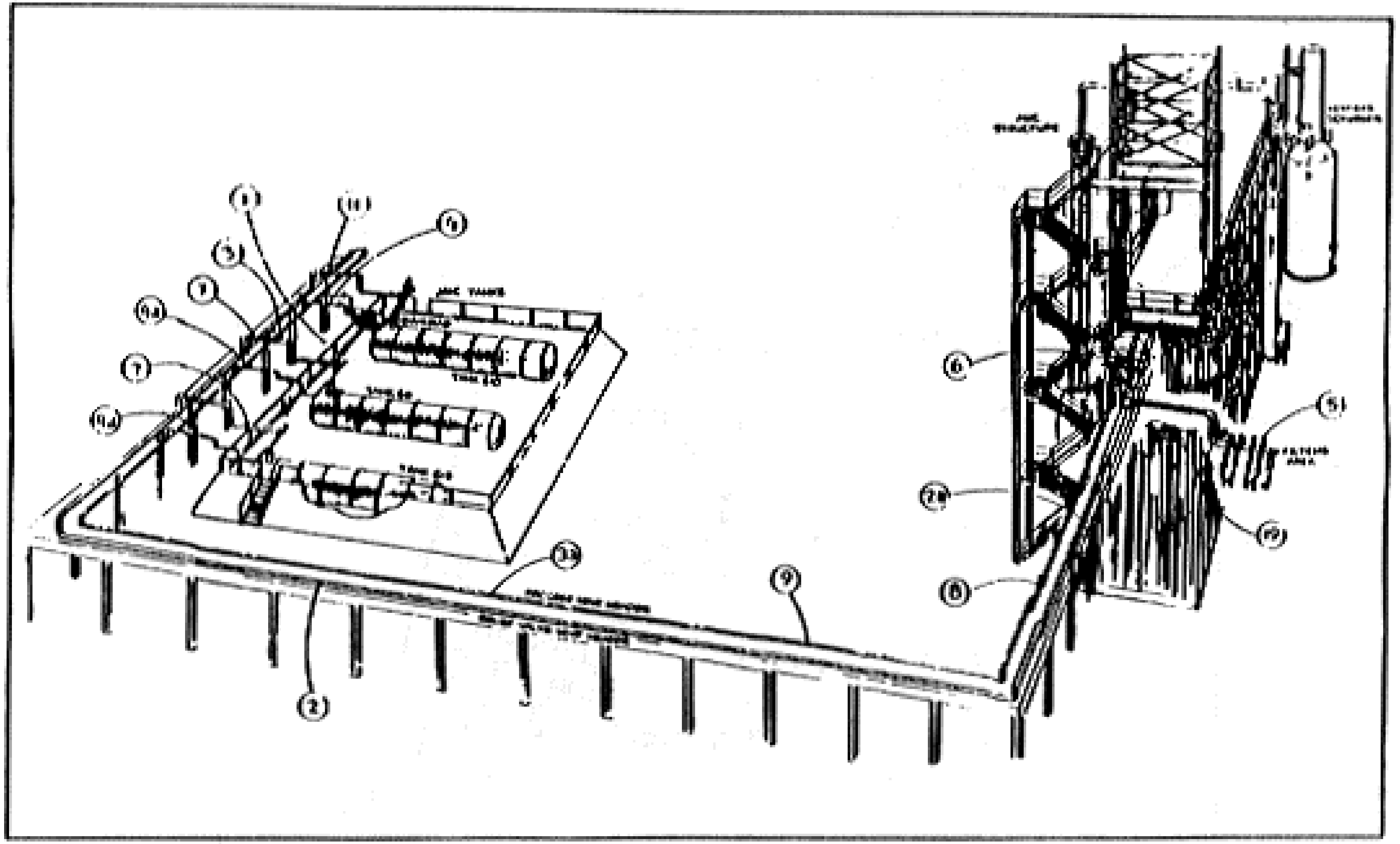


FIGURE 2. LOCATION OF MIC STORAGE TANKS

Bhopal – How It Happened

- Other important contributors:
  - The refrigeration unit for keeping MIC at low temperatures in the storage tanks had been shut off for some time
  - The caustic scrubber had been shut off for maintenance
  - The flare tower was out-of-commission awaiting for replacement of a corroded piece of pipe (open path to atmosphere)
  - Storage tank temperature alarms were out-of-commission

Bhopal – How It Happened

– The water curtain was too short to reach the top of the flare tower from where the MIC was released
– Tank 610 and Tank 611 contained 41 tons and 20 tons of MIC respectively and a storage tank (Tank 619) which was supposed to be held in reserve for excess MIC already contained the MIC – not in accordance with SOPs
– Design questions regarding the capacity of the scrubber and the flare
– Pre-accident UCC safety inspections – no follow-up

Inherently Safer Design (ISD) at Wanhua

- Wanhua Chemical Group Co., Ltd, has embraced inherently safer design (ISD) and has introduced the concept to all of its major global chemical complexes and employees
- This is an excellent example of a company determined to use ISD routinely and at all levels and opportunities to the maximum benefit for process safety.

About Wanhua

- Wanhua Chemical Group Co. Ltd. is a Chinese chemical company that is the world largest producer of isocyanate (MDI or methylene diphenyl diisocyanate) in terms of capacity(2.1m tonnes/Year)
- A leader in process safety in China, Wanhua has embraced the concept of ISD and made process safety as its core management theme for three consecutive years from 2017

ISD Has Proven Value at Wanhua

- 2018-2019 AcuTech project to lead 5 ISD studies at Wanhua on existing processes to demonstrate value
- AcuTech also provided training to over 400 personnel
- Each study took on average 4 days
- Recommendations: 193 total or 38 per study on average
- Benefits:
  - Different focus on directly addressing hazards v layers of protection
  - Recognition of key hazards and all options to control
  - Actual risk reduction by hazard elimination and reduction, which reduced risks, capital costs, operating expenses, ongoing risk management requirements from more complex layers of protection

Wanhua ISD Introduction and Training

- Wanhua initiated ISD Training company wide with AcuTech in September 2018
- More than 200+ attended the initial ISD training with CEO and most VPs of the company in Yantai
- Translated training material into Chinese and distributed to all manufacturing facilities
- ISD concept and PSM Strategies were circulated with all manufacturing units with basic concept testing
- Encouraging all process safety related personnel to attend one of the ISD evaluation sessions for learning the process.
- Issued company guidance to conduct ISD evaluation for new and existing process units.

Wanhua ISD Evaluations

- Wanhua conducted ISD evaluations for 5 different process units company wide in Yantai, NingBo and BorsodChem in Hungary (all major Wanhua manufacturing bases) to make sure all manufacturing sites having chances to witness the ISD processes
- When we conducted the ISD evaluations in sites and we have conducted the ISD training for all site personnel with all management level people attended.
- These units were selected due to its expansion project, major modifications, or simply to find out if there are any opportunities exited for applying the ISD concepts to improve the process safety.
- With most of the recommendations can be applied related easily.

Wanhua ISD Evaluations

- ISD evaluation recommendations were divided into three categories:
  - Priority 1 (High): more easily implemented and should be considered as priority.
  - Priority 2 (Medium): require additional evaluation and screening before application or may require more effort to implement.
  - Priority 3 (Low): substantial evaluation before application or may require more substantial effort or cost to implement.
- Out of 193 total recommendations on 5 process units, number of priority is listed as following:
  - Priority 1: 86
  - Priority 2: 69
  - Priority 3: 38

Wanhua ISD Evaluations Benefits

- Wanhua has started to apply ISD concepts into all levels of the project phases such as from very early stages of process development to all the way to running process units (MOC indicated if the changes are ISD related)
- Instead of using the layer of protection, ISD concept application will eliminate those BPCS, SIS, and PRVs necessary – significant to reduce the project and maintenances costs for installing and maintaining those protection devices and equipment.
- Reduction of equipment and instrument will reduce the possible operation errors by human
- Minimizing those most dangerous chemicals stored on site to greatly reduction of environment and human impacts to employees and communities surrounding our facilities.
- Real Improvement of process safety from the root of process design to reduce all associated safety equipment - Project and maintenances costs

Examples of Recommendations

ISD Opportunity	Benefits
• Build a plant onsite versus using additional trucks for feedstock delivery to the process.	This will reduce the number of trucks transiting the roads to the chemical complex and within the plant and the number of offloading; a direct feed to the plants will simplify the operation and potentially avoid multiple product movements in 3 tanks. Note: Need to evaluate the trade-off risks.
• Eliminate one of storage tanks (500M3 each).	This will reduce the amount of chemicals stored for safety and will simplify the operation and potentially avoid multiple product movements in 3 tanks. Note: Need to evaluate if this would then cause a less stable system with less options for operational flexibility.
• Eliminate E-35201A/B preheater by enlarging the shell and tube E-15204A/B-3 heater	To reduce exposure from chemical loss of containment and reduces needless equipment.
• Locate combustible liquid containing equipment at lower levels of the process and away from personnel exposure or equipment exposure	To reduce the potential energy which may increase a leak pressure and to reduce consequences.
• Evaluate the feasibility of using an alternative technology instead of phosgene.	Reduces the toxic risks.
• Evaluate if the process N2 pressure to the unit can be reduced.	Lowers N2 pressure to reduce risk of overpressure of interfacing equipment.
• Use hot oil instead of 30 bar steam for vaporization.	Reduces high pressure steam risks. Note: evaluate the combustible hazards of hot oil v risk of tube leak and corrosion of downstream equipment.

Conclusions

- Application of ISD may not be fully utilized by most companies in the process industries.
- Formal recognition of its value is essential to encourage management to implement directives requiring its use.
- Real adoption of ISD will be with firms that engrain the concept into the culture of the organization throughout the entire lifecycle of their processes.
- Wanhua has made very significant progress in adoption of ISD and proven value in risk reduction

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