Inherent Safety as a driver for business success in the Oil & Gas Industry

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Abstract

Inherent safety is not a new concept and is recognized in the oil and gas industry following the works of Trevor Kletz [1] and others dating back to the 1970s. However, despite the progress made to date in the process safety management arena, incidents have occurred resulting in a renewed focus by regulators to follow-up with more stringent regulations. Two recent studies, covering a span of 20 years (1998-2018), revealed that 19-36% of these incidents could have been avoided if an Inherent Safer Design approach was utilized [2]. Some barriers to adoption and implementation of inherent safety include lack of full understanding of Inherently Safer Design (ISD) principles, lack of assessment tools to showcase ISD benefits, and lack of ISD application framework. This paper will demystify ISD definition, examine the barriers to ISD application, propose a framework to overcome them and share recent successes in application of ISD at Chevron.

Keywords: Inherently Safer Design (ISD); inherent safety; barriers

Introduction

Over the last 40 years, there have been incidents that highlighted the importance of process safety awareness and management to protect people and environment. Noteworthy incidents include Flixborough, UK 1974 (Explosion – 28 Fatalities), Bhopal, India 1984 (MIC release – 4,000-20,000 fatalities), Piper Alpha, UK 1988 (Explosion – 167 fatalities), Pasadena, US (Explosion - 23 fatalities), Texas City, US (Explosion – 15 fatalities), and Deepwater Horizon, US (Explosion – 11 fatalities and catastrophic environment damage). Possible causes include increase in scale and complexity of new plants; complex relationships between people and automation; limitations of current probabilistic risk assessments.

Despite the technological advancements in process safety engineering and management processes, the re-occurrence of these process safety incidents questions the assumptions and notions of progress in terms of hazard reduction. This begs the question “How can we build safer plants while satisfying overarching project objectives? Hence, the concept of inherently safer design.

What does Inherently Safer Design mean?

Inherently safer design is a design philosophy that prioritizes hazard elimination or reduction in hazard likelihood or severity of occurrence rather than addition of layers of protection to prevent and minimize hazards. This is accomplished by means that are inherent in the process design such that it is permanent and cannot be removed. A system may be defined as Inherently Safer if – after an upset – it stays or returns to a safe and stable state without involving human intervention or automatic controls. The expectation is to focus on what can be done to eliminate the hazard before considering how to control the hazard. In some instances, we recognize that application of some of the ISD strategies may prove challenging because of the chemical nature of hydrocarbons, e.g. flammability, is often what makes the commodity valuable. Consequently, it may be infeasible to eliminate all hazards.

A report by the Centre for Chemical Process Safety (CCPS) [3] in 2010 for the U. S. Department of Homeland Security (DHS) Chemical Security Analysis Centre (CSAC) emphasizes that ISD evaluation and selection decision process must consider the entire life cycle, the full spectrum of hazards and risks, and the potential for transfer of risk. Technical and economic feasibility of options must also be considered.

ISD Strategies

Approaches to inherently safer design have been grouped into five major strategies and summarized below:

Strategy		How?
Elimination		Eliminate the hazardous material or activity
Substitution		Replace a hazardous material or process with an Alternative that reduces or avoids the hazard; e.g. Replace Hot oil with Hot water as a heat media
Minimization		Use small quantities of hazardous substances or reduce inventory or energy; e.g. Reduce pipe, equipment size
Moderation		Use dangerous materials in their less dangerous form or identify options with less severe conditions; e.g. optimization of production separation pressures
Simplification		Designing processes equipment and procedures to Eliminate unnecessary complexity and human error; e.g. Containment within process equipment (design for maximum pressure and full vacuum)

It is important to understand that there is no hierarchy in terms of risk reduction potential within the different strategies except elimination is considered First order and other four strategies are considered second order [3].

What are the barriers to adoption of ISD approach in the industry?

There are barriers to its full adoption by practitioners due to following reasons:

1. One of the major problems related to the adoption of ISD principles is the perception that the only way to make a plant safer is to add more systems to it. As facilities become more complex, there is a need to focus on eliminating/reducing hazards rather introducing more avenues for failures.
2. Limited knowledge of Inherently Safer Design strategies and their role in achieving the key objectives of hazard management principles (Prevention, Control and Mitigation) during Engineering has made adoption of ISD approach difficult. However, many installations incorporate some ISD principles initiated through ‘good ideas’ or cost reduction initiatives rather than a deliberate application of principles throughout the project life cycle. This means systematic application of the principles could lead to a widespread adoption and implementation of ISD.
3. Lack of development of structured design review techniques in oil and gas industry to identify Inherently Safer Design Opportunities has been a challenge in consistent application of ISD strategies [4]. In comparison, PHA and QRA risk analysis techniques have been sufficiently developed and applied in the oil and gas industry. However, current literature [5][6] shows examples of successful application of ISD techniques/methodologies to the design of offshore platforms. For example, on an offshore project, the operator implemented ISD strategies through a series of workshops from concept level to operations.

Framework for implementing ISD

Effective application of ISD strategies requires a structured and multifaceted approach. This involves broad alignment and support from key stakeholders, integration of ISD principles into project and design philosophies and solid understanding and acceptance of ISD strategies among practitioners. This will require creating a workflow and process with methodology and tools to achieve desired ISD goals and objectives, as well as providing a platform for showcasing ISD successes and contributions to decision making. The steps involved in systematic application is given in Figure 1.

- Clear and inspiring ISD project vision
- Continuous interest in hazard identification
- Visible commitment to risk elimination/reduction

- Strong Organizational Capability
- ISD Champions
- Performance Measurement

- Adequate training programs
- Clear ISD implementation plan
- ISD Register and Tracking
- Strategically timed design evaluation workshops

Figure 1: Steps for systematic ISD application

1. Role of Leadership

Strong leadership is the foundation on which ISD success is built. Business leaders, project leaders and engineering leaders need to define the approach to safety early during the concept selection phase.

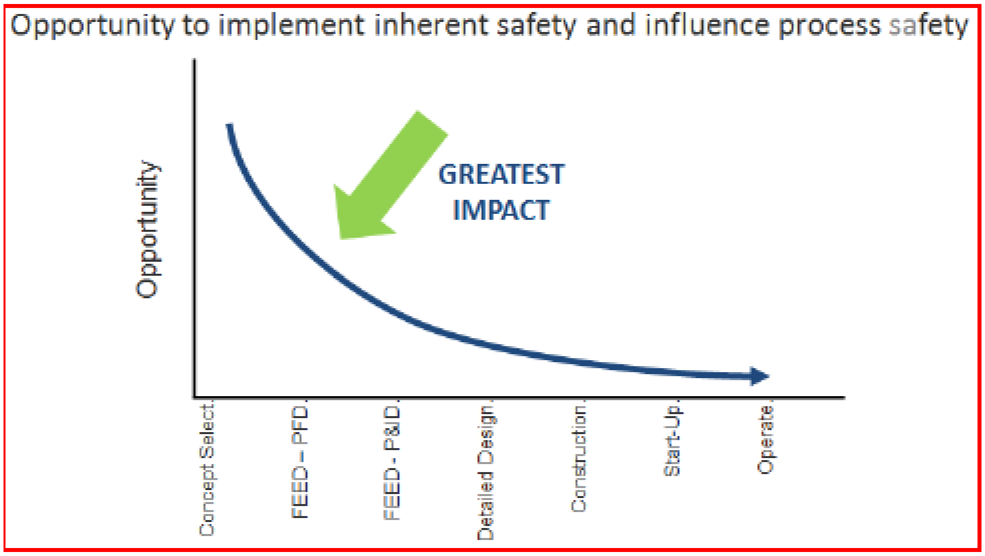

Figure 2: Opportunities to implement ISD [5]

It is worth noting that the greatest benefits of applying ISD thinking are derived early in the design process (concept stage). However, there are more benefits from maintaining this hazard elimination/reduction mindset throughout the design process although with diminishing returns.

Successful cultivation of ISD mindset and culture begins leaders charting a clear set of expectations relating to design safety; a continuous interest in the hazard identification by project leaders; and a visible commitment to risk reduction, will set a visible example which will permeate through the different phases of the design process.

On a past project, the ISD project vision was to deliver an inherently safer design that satisfies the following tenets:

- Reduced probability of unwanted events
- Reduced facility attendance
- Reduced damage potential
- Reduced scope for smaller incidents to escalate and overwhelm the facilities
- Clear focus on simplicity, reliability and longevity to reduce exposure

Leaders challenged the project teams to start the hazard management process with the mindset of hazard elimination rather than using risk analysis techniques to aim for an ALARP solution. Project teams were challenged to justify adding any equipment or instrumentation to the design. A similar approach was successfully applied by Woodside during the design of the Angel Platform and resulted in significant CAPEX reduction [7].

Leaders are responsible for driving a cultural change that encourages innovation. This involves strengthening ISD awareness and fluency via subject matter presentations, training, campaigns and workshops; incorporating ISD into all layers of design decision making – For example, ISD lunch and learns exercises where leadership provide examples that demonstrate how the incorporation of ISD in early phases of projects have minimal cost impacts as well as lessons learned from missed opportunities which resulted in add-on safeguards.

2. People

Incorporating an ISD objective in each project team member’s performance expectations have proven effective towards focusing the wider team to actively adopt and steward the routine application of ISD. On a recent project, project leaders nominated ISD champions within the respective disciplines to help identify ISD opportunities, track the opportunities to action and communicate ISD application examples to wider stakeholders to increase overall fluency. During workshops, standing meetings, and model reviews, ISD champions asks probing questions to challenge the design teams to consider ISD alternatives. The ISD champion provides broad support across the project but should have focused engagements with the process and mechanical engineering and operations representative’s teams as most of the ISD opportunities lay in those functions.

3. Process

One of the challenges leaders must overcome is creating the ability among practitioners to consistently apply ISD principles in a reproducible manner. This will involve creating a process/workflow to identify ISD opportunities and measurement and verification. On a past project, the project team identified ISD opportunities via a series of strategically timed design evaluation workshops where the team critically examined the selected design to identify opportunities to reduce risk during the early phases through the application of ISD strategies. The workshops are facilitated sessions with a cross functional team. The facility under review was divided into nodes and critically examined for opportunities to apply ISD principles. When an ISD opportunity was identified, the team discussed the benefits and potential trade-offs to assist in further evaluation of the opportunity during the facility lifecycle. ISD opportunities were recorded in an ISD Opportunities Register and tracked to closure on a frequent (weekly to monthly) basis. Table 2 gives an example of the structure of an ISD Opportunities Register [8].

- *Table 2: ISD Opportunities Register - Example*

Hazard	ISD Principle	Description (concern – options – benefit – trade-offs)	Owner	Status
Pressure	Simplification	Current design: Acid stimulation is a practice to improve well productivity in deep water subsea environment. Spent acid is often sent to topsides prior to disposal. The topsides manifold is not designed to handle acid flowback. Consider eliminating acid flowback to topsides with a safer alternative Benefit: Eliminating a hazardous activity and operations exposure. Tradeoff: Evaluate the feasibility and cost of acid flowback alternatives.	John Doe	Pending

On another project, the design team adopted the strategy of the 'Biggest Loser" Program, leveraging from the TV series, to implement ISD strategies to identify and track removal of redundant equipment and/or instrumentation from an offshore platform in order to achieve weight and cost objectives [5]. The integrated (company and EPC) design team were encouraged to submit their ideas for weight and cost reduction to project leaders and monthly prizes are awarded to selected ideas. This resulted in 6,000 tons in weight savings and 15-20% reduction in associated costs.

ISD application examples

This section lists examples from offshore oil & gas projects demonstrating how ISD strategies were incorporated for meeting project vision for inherently safer facility.

Eliminate

(i) Elimination of high-pressure gas handling hazard: Enhanced Oil Recovery (EOR) through gas injection, chemical injection or water injection is one of the strategic decisions during concept select for offshore field development projects. In one greenfield project, EOR by gas injection, was preferred alternative for improved recovery of oil. This process includes additional equipment, such as gas compressors for generating the high pressures needed and requires buy-back of flammable gas to the facility. Handling high flowrate of high-pressure gas increases the risk to personnel on board which leads to addition of active and passive safeguards like high integrity instrumented protection system and blast resistant walls. Through ISD application, the project team eliminated high pressure flammable gas handling hazard by electing not to pursue EOR by gas injection despite an expected reduction in total oil recovery.

(ii) Elimination of asphyxiation hazard: Fire suppression is an important mitigative safeguard and can be achieved with multiple technologies, including water mist, chemicals or foams, and carbon dioxide (CO_2). The use of CO_2 for fire suppression introduces an asphyxiation hazard for personnel due to the potential for spurious activation of the CO_2 system in enclosed areas like equipment cabinets or electrical rooms. The design philosophies prohibited the use of CO_2 fire suppression systems in enclosures. By not allowing the use of CO_2 systems, the projects eliminated the potential asphyxiation hazard while still ensuring fire suppression can be achieved by other technologies.

Substitute

(iii) Substitution of flammable chemical: Hydrates, which occur due to the presence of water and gas in production fluids and the high pressures and low temperatures of the systems, can block flowlines and create operational and flow assurance concerns. The project planned to use a highly flammable chemical that is injected in the production flowlines to prevent hydrate formation. Storage and handling of the chemical introduced flammable hazards requiring area classification, additional fire and gas detectors and fire suppression system. Through ISD application the design team substituted the hydrate inhibition system with a less hazardous (non-flammable) chemical. Risk reduction achieved without impact to production and saved cost of installing and maintaining the safeguards related to flammable chemical.

Minimize

(iv) Minimization of hazardous inventory: Initial project design specified storage of thousands of barrels of diesel in the hull to support power generation to meet facility availability targets. The estimated diesel storage volume could be met only by utilizing multiple pontoons of the hull requiring complex piping network for the diesel storage and handling. Through application of ISD minimization strategy, the project team was able to reduce the diesel storage needs by 75% through power use optimization effort and by choosing duel fuel alternative for power generation. The selected design option had some impact on the operational flexibility (in the event of a fuel gas system disruption), but significantly reduced the risk and simplified the design.

Moderate

(v) Moderation of hazardous drain system: Bilge water in the hull is typically routed to the hazardous drain system on the topsides as the waste stream can accumulate small quantities of hazardous spilled material. The project designed a dedicated hazardous drain system that will collect potential hazardous spills from equipment in the hull and routes to the hazardous drain system on the topsides. The hazards associated with the bilge system, which manages a large waste stream, have been moderated and the flows can be routed to the non-hazardous drain system.

(vi) An example of application of the moderation principle for an onshore, greenfield liquified natural gas MCP is provided. Molecular sieve beds are used to remove water from natural gas prior to export and these beds must be periodically regenerated to remain effective. Regeneration can be done using a high pressure or low-pressure system options. Dewatering natural gas using sieve beds regenerated with a high-pressure system is a more energy efficient process but requires operation of the entire dewatering system at very high temperatures and pressures. The team selected a low-pressure regeneration system that allows the dewatering system to operate at much lower temperatures and pressures and the severity of a potential incident are reduced.

Simplify

(vii) Simplification with reduction in human performance dependence: Chemical injection into production flowlines or into the well-bore is a common operational activity to manage the impurities in the oil (e.g. hydrates, waxes) and provide other critical flow assurance functions. On one MCP, the proposed strategy for distributing chemicals consisted of using one pump and multiple valves to allow for multiple chemicals to be injected using the same piping configuration. The team identified that misalignment of the valves and inadvertent introduction of the wrong chemical was a credible concern. The design was reconfigured to provide dedicated pumps and piping networks to simplify the operations procedures and minimize the potential for human error.

(viii) Simplification by enhancing the design rating: Subsea production flowlines can be subject to immense pressures during the initial phases of production in a reservoir or as the result of pressure buildup if subsea pumping is anticipated. High Integrity Protection System (HIPS), a complex and expensive instrument and control system, is often used for controlling pressure surges. A greenfield MCP elected to fully rate the subsea flowlines for the maximum expected pressures with incremental costs associated with the procurement and installation of thick-walled pipe. Through ISD application the risk was significantly reduced, and the complexity in maintenance of HIPS was avoided. In this example, the application of ISD provided a cost benefit for both Capital Expenditure and Operational Expenditure during the facility life.

4. Conclusion

This paper demonstrated risk management through a systematic application of the concepts of Inherently Safer Design through project design stages. It highlights the importance of project leadership and the relevance of approaching ISD as a mindset rather than a one-time risk assessment activity. The relevance of ISD training for project personnel and the value of an ISD opportunity tracker is discussed. Examples in this paper demonstrate that the maximum value of ISD application is realized when applied early in the project (before the layout is finalized and decisions on choice of equipment / process is made). Though ISD application yields benefits, the paper discusses trade-offs that need to be considered.

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