

**Presentation to the U.S. Chemical Safety and Hazard Investigation Board
Public Meeting to Release Interim Report and Safety Recommendations
Resulting from Chevron Refinery Investigation
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Mr. Chairman, Members of the Board, Ladies and Gentlemen:

I would like to begin by offering my expression of concern for the workers and members of the public who have been adversely impacted by the process incident we are discussing this evening.

I also want to thank the Chemical Safety Board for inviting me to be here and to give this presentation. On the advice of the California Board for Professional Engineers, Land Surveyors, and Geologists, I declare that while I am registered as a licensed professional engineer in the province of Nova Scotia, Canada, I do not hold a similar license in the state of California.

There are two main areas on which I have focused my presentation. First, I will comment on the CSB's interim investigation report from the perspective of inherently safer design. Second, I will comment on the need for the adoption of a "lessons-learned" mentality in the process industries.

Let me start by saying that I wholeheartedly agree with the analysis and conclusions on the above points which are contained in the interim report. I am a strong proponent of inherent safety and lessons learned. As a process safety educator and researcher, both have figured prominently in my teaching and research efforts.

The discussion in the interim report on inherently safer design is perhaps the most direct and extensive use of the language of inherent safety that I have read in a CSB report. Inherently safer design (ISD) – or inherently safer processes (ISP), or inherently safer technologies (IST), or just inherent safety – is a proactive approach in which hazards are eliminated or lessened so as to reduce risk with a decreased reliance on engineered or add-on devices and procedural safety measures. The concepts of inherently safer design have been formalized in the process industries over the past 35 years, beginning with the pioneering work of Trevor Kletz – largely in response to the cyclohexane explosion at Flixborough in 1974.

Trevor Kletz and many others worldwide, including key individuals here in the United States, have formulated a number of principles or guidewords to facilitate inherent safety implementation in industry. Four basic principles have gained widespread acceptance: (i) minimization, (ii) substitution, (iii) moderation, and (iv) simplification. The CSB interim report thoroughly covers the issue of substitution of alternate metallurgy to help address the problem of

sulfidation corrosion. One also sees in the report, the need to moderate process temperatures when these approach or exceed design limits for existing pipe materials.

Rather than continue with a lecture on the principles of inherent safety, I will simply state that numerous resources on the topic are now available. There are books – including those by Trevor Kletz, and the Center for Chemical Process Safety (CCPS) of the American Institute of Chemical Engineers. There are journal articles, conference presentations, trade publications, and company guidance documents. What is noteworthy about these resources is that most are written by industrial practitioners – industry people at all career stages, from the newly arrived to those with a full career in hand.

So the call for widespread use of inherently safer design principles in industry is being made largely by people in industry. People like Trevor Kletz (formerly of ICI in the United Kingdom) and Dennis Hendershot (formerly of Rohm & Haas in the United States). Of the 18 committee members responsible for the production of the 2009 CCPS book *Inherently Safer Chemical Processes. A Life Cycle Approach*, 16 are listed as having affiliation with industrial companies; one is affiliated with a municipal regulator and one with a federal regulator. Again, the call for expanded ISD usage in industry, is coming from within.

Earlier in my remarks I referred to myself as a “strong proponent of inherent safety”. That is true – but it does not mean that I think inherent safety is a cure for all ills, or that ISD principles can always be fully implemented in all scenarios. There are some very practical issues related to inherently safer design that should be recognized by anyone either proposing or regulating its use. These issues are well-addressed in the Chevron interim report, as I will now demonstrate.

First, there is clear recognition in the report that inherent safety works with other means of reducing risk – namely, passive and active engineered safety, and procedural safety – within a framework commonly known as the hierarchy of controls. Inherent safety, being the most effective and robust approach to risk reduction, sits at the top of the hierarchy; it is followed in order of decreasing effectiveness by passive engineered safety devices (such as explosion relief vents), then active engineered safety devices (such as automatic fire suppression systems), and finally procedural safety measures (such as inspections – corrosion-related or otherwise). This hierarchical arrangement, however, does not invalidate the usefulness of engineered and procedural safety measures. Quite the opposite; the hierarchy of controls recognizes the importance of engineered and procedural safety by highlighting the need for careful examination of the reliability of both mechanical devices and human actions.

Second, inherent safety is referred to as being hazard-specific, meaning the risk of any new hazards that might be introduced must be adequately managed. The interim report makes ample reference to the use of management of change (or MOC) for this purpose.

Third, the report comments that ISD principles should not be restricted to only process hazard analysis, but should be implemented wherever it is possible to make improvements in the process safety management system. Examples would include the just-mentioned management of change, as well as incident investigation, training, and human factors.

Fourth, the interim report references the need to provide thorough documentation of process hazard analysis results and implementation of the findings. Dennis Hendershot reminds us this is especially critical when dealing with ISD features that could be put at risk because the reasons they were implemented were not clearly and adequately documented. Facility safety could be compromised when future modifications are made by people who do not understand the intent of the original designer.

Fifth, the report makes clear reference to inherent safety being most easily and effectively introduced early in the process life cycle – for example, at the design/build stage. Extended turnarounds, such as would be required to replace process piping, also afford excellent opportunities in this regard.

Finally, the report introduces the concepts of LOPA and ALARP in the section on *Inherently Safer Systems*. LOPA, or Layer of Protection Analysis, can be used to determine the adequacy of safeguards (or layers of protection) for a given scenario. It is interesting to note that in the classic CCPS depiction of LOPA, inherently safer process design sits at the central core of the layers. As explained in the report, ALARP, or As Low As Reasonably Practicable, involves the implementation of risk reduction efforts until the incremental effort to further reduce risk becomes grossly disproportionate to the level of additional risk reduction achieved. ALARP is therefore a risk reduction goal that can be assessed by tools such as LOPA and the combination of a fault tree and an event tree in what is known as bow-tie analysis. The general point here is that in addition to more qualitative tools such as ISD checklists, some form of barrier analysis is highly beneficial – so long as the barriers cover the full spectrum of the hierarchy of controls.

I have spent considerable time in my presentation on the matter of inherently safer design. So I will just comment briefly on my second topic – that of the importance of learning from previous incidents and using the lessons in activities such as process hazard analysis and inspection scheduling (whether inspections are risk-based or more deterministic in nature).

It is imperative that an industrial site examine and act on lessons learned from its own operations, from those within its company operations, and more broadly from what is happening within the industry itself. The interim report contains numerous examples in each of these categories: (i) results from previous corrosion inspections at the Chevron Richmond refinery, (ii) sulfidation corrosion incidents at other Chevron refineries including the El Segundo refinery, and (iii) a sulfidation corrosion incident and ensuing fire at BP's Cherry Point refinery.

CSB investigation reports themselves offer many lessons for the process industries. A 2006 Safety Bulletin on *Positive Material Verification* provides further information on the specific matter of corrosion of carbon steel (in this case by high temperature hydrogen attack). More generally, I had occasion a couple of years ago to review with my research team about 60 CSB reports – essentially all that had been published at that time. We found over 250 examples of actual and potential prevention and mitigation measures drawn from the hierarchy of controls. Ninety-three of these examples were related to inherently safer design.

I would like to commend both the Chemical Safety Board and the Chevron Energy Technology Company for their upcoming efforts that are clearly aimed at promoting the concept of “lessons

learned”. I will be attending the 9th Global Congress on Process Safety being held in San Antonio, Texas starting April 28. I noticed in the technical program that CSB lead investigator Don Holmstrom will be presenting a paper titled *CSB Investigation of the Chevron Richmond Refinery Fire* in the closing session titled *Case Histories and Lessons Learned*.

A couple of weeks ago I received notice of the SChE (or Safety and Chemical Engineering Education) workshop being held this August at the Chevron Energy Technology Company in Richmond, CA. These workshops are designed to expose chemical engineering professors to important concepts of process safety. The August 2013 workshop includes a tour of the Chevron Richmond Refinery and a session on materials of construction and their relation to corrosion.

These presentations by the CSB and Chevron will clearly help to spread the lessons that must be learned about sulfidation corrosion and the need for inherently safer design solutions. Should these lessons be acted upon with determination and vigor, then perhaps the need for such presentations in the future will be lessened.

To conclude, I'd like to quote from a letter that will be published in an upcoming issue of the journal *Process Safety Progress*. It was written by John Murphy – an industrial practitioner and well-known figure in the loss prevention community. John writes:

So why should chemical engineering professors take the time to teach the basics of hazard evaluation procedures and the concept of inherent safety to undergraduates? For those of us who have spent our careers in process safety, the answer is obvious. To prevent future catastrophic process safety incidents that will result in fatalities, injuries, property damage, business interruption, and loss of respect from the chemical industry stakeholders.

I agree with John. In fact, he nicely describes why I do what I do as a chemical engineering professor. I would suggest though, that if there is an obligation for people like me to educate the next generation of engineers in matters of inherently safer design, an equally strong argument can be made for the obligation of industry to implement inherently safer design principles to the greatest extent reasonably practicable.

Thank you, Mr. Chairman.