What Does Inherently Safer Mean?

A primary area of concern to the U.S. Dept. of Homeland Security (DHS) is the potential for intentional release of toxic chemicals caused by a domestic terrorist attack. More than 80,000 compounds are produced, shipped, and consumed in the U.S. every year. Of these, about 360 are listed as chemicals of interest to DHS in Appendix A of its Chemical Facility Anti-Terrorism Standards (CFATS) (6 CFR 27). The DHS’s Chemical Security Analysis Center (CSAC) has initiated a program to enhance the safety and security of these hazardous chemicals.

The use of inherently safer technology (IST) is often cited as the best way to achieve such safety and security. However, although implementation of IST to a specific process appears to be a reasonable approach to increasing security and safety, it needs to be examined in a broader context. Its impact on the entire supply chain needs to be considered so that risk is not inadvertently transferred to another industry sector.

As a first step, CSAC asked AIChE’s Center for Chemical Process Safety (CCPS) to develop a formal scientific and technical definition of inherently safer technology. More than 30 subject matter experts, representing government, academia and several sectors of the chemical industry, collaborated on this project.

The resulting definition is intended to express the concept of inherently safer clearly and without appeal to any political agenda or viewpoint. CSAC sought a definition that: considers the full lifecycle of the chemical enterprise, including manufacturing, use, storage, and transportation; is broad enough to address the full supply chain; and helps to resolve a challenge posed by IST — that of tradeoffs where a safety improvement in one process or supply chain dimension may lead to degradation of safety in another dimension.

This article presents the definition of IST developed by CCPS. The discussion also provides additional clarification and insight to help chemical engineers and others to develop a full understanding of the concept of inherently safer.

Defining inherently safer technology

Inherently safer technology (IST), also known as inherently safer design (ISD), permanently eliminates or reduces hazards to avoid or reduce the consequences of incidents. IST is a philosophy that is applied to the design and operation lifecycle, including manufacture, transport, storage, use, and disposal. IST is an iterative process that considers such options as eliminating a hazard, reducing a hazard, substituting a less-hazardous material, using less-hazardous process conditions, and designing a process to reduce the potential for, or consequences of, human error, equipment failure, or intentional harm. Overall safe design and operation options cover a spectrum — from inherent through passive, active and procedural risk-management strategies. There is no clear boundary between IST and other strategies.

ISTs are relative. A technology can only be described as inherently safer when compared to a different technology. The comparison needs to consider the hazard or set of hazards, their location, and the potentially affected population. A technology may be inherently safer than another with respect to some hazards but inherently less safe with respect to others, and it may not be safe enough to meet societal expectations.

ISTs are based on an informed decision process. Because an option may be inherently safer with regard to some hazards and inherently less safe with regard to others, decisions about the optimum strategy for managing risks from all hazards are unavoidable. The decision process must consider the entire lifecycle, the full spectrum of hazards and risks, and the potential for transfer of risk from one impacted population to another. Technical and economic feasibility of options must also be considered.

The implications

Inherently safer technology/design (IST/ISD) is a philosophy — an approach to safety that focuses on eliminating or reducing the hazards associated with a set of conditions. IST is applicable through the entire product or process lifecycle and over the entire footprint of any system that manufactures, transports, stores, or uses hazardous materials or hazardous processing conditions. IST permanently and inseparably reduces or eliminates process hazards that must be contained and controlled to avoid incidents, rather than controlling those hazards by added-on protective equipment. Although IST applies throughout the lifecycle of a process, plant, or material, the greatest opportunities for significant IST benefits are early in the lifecycle — before the technology becomes deeply integrated into the infrastructure of an industry, from raw material suppliers through final product users, and before major investments in plant and equipment are made.

A material, process, or technology can only be described as inherently safer when compared to a different material, process, or technology. This description must include the definition of the particular hazard or set of hazards that were considered in making the comparison. Thus, it is not appropriate to say simply that a technology is inherently safer than an alternative technology.

An appropriate description would be: Technology A is inherently safer than Technology B with respect to the...
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hazard of acute toxicity of the vapor and the hazard of flammability of the vapor. Note that this statement makes no judgment about the relative inherent safety characteristics of other possible hazards — Technology A may be inherently less safe than Technology B with respect to other hazards, such as chemical reactivity, chronic toxicity, or potential for hazardous decomposition.

IST options can be location- and release-scenario-dependent, and different potentially exposed populations may not agree on the relative inherent safety characteristics of the same set of options. For example, a toxic gas might be delivered in 1-ton cylinders or 10-ton truckloads. To a population several miles from the site, the 1-ton cylinders would be inherently safer because the maximum potential release size is smaller and less likely to expose them to a hazardous concentration of the gas. But the operators who would have to connect and disconnect 10 cylinders for every 10 tons of material used, instead of a single truck, would consider the truck shipments to be inherently safer.

Thus, evaluation of IST options can be quite complex, and heavily dependent on the local environment. There is currently no consensus on a quantification method for IST, and there is no scientific assessment for evaluation of IST options.

Risk-management decision-making

Inherently safer design is part of an iterative decision-making process for risk reduction. It is ongoing and continuous throughout the lifecycle of a technology, from initial conception through commercialization, operation, and, when obsolete, shutdown and demolition. It should consider the entire footprint of the process — raw material sources and supply, transportation, downstream users and their technologies, and ultimate material disposition.

Decisions on the appropriate overall risk-management strategy need to consider potential conflicts and tradeoffs among:
- hazards
- likelihood of failure
- consequences to all potentially exposed populations
- other important risk considerations, such as environmental impact
- impact on risk in other locations or sectors of the overall economy
- process and product supply chains and lifecycles, including distribution and final user considerations
- technical feasibility, which may be location-specific
- economic viability, which may be location-specific
- regulatory requirements, which may be location-specific.

Evaluation of IST options for a particular system must consider the overall effects of all other impacted systems. It is essential to understand the impact that a change in one technology will have on hazards and risks elsewhere in society. In particular, it is important to identify all such impacts and to make informed decisions about the best overall way to manage risk throughout society.

Risk-reduction criteria will be determined by the nature of the hazards or threats, and will require consideration of conflicts among multiple hazards and threats. Tools for understanding societal expectations for risk management include national and local government regulations and other legal requirements, consensus codes and standards developed by technical and trade associations, and internal corporate standards and requirements. The potential hazard of a major release resulting from an accident, as well as security or vulnerability concerns such as theft of materials, contamination of products, and degradation of infrastructure, must all be considered. Hazard identification, risk assessment, and security vulnerability analysis tools are used to identify and characterize risk.

Risk can be reduced by many methods, including inherently safer design, but methods must include the full spectrum of risk-reduction approaches (passive, active, and procedural risk-management systems). This is particularly important in managing multiple hazards and risks. It is unlikely that any single technology will be inherently safer with respect to all hazards — multiple approaches are required to manage the full range of hazards and risks. Ultimately, society must decide which hazards and risks it wants to manage primarily with inherently safer design approaches and which hazards and risks will be managed in other ways.

The inseparability of IST from the overall objective of the safe design and operation of hazardous material manufacturing, transportation, storage, and use is apparent when considering chemical security. An IST with respect to a catastrophic release hazard from a fixed manufacturing plant may not address — or may conflict with — other hazards, such as theft or diversion of materials, contamination of product, or degradation of infrastructure. Or, it may create new security hazards.

The CCPS book “Inherently Safer Chemical Processes: A Life Cycle Approach” (1) describes several levels of inherently safer design:
- First-order ISD refers to the identification of alternatives that completely eliminate a particular hazard. Note that this definition does not include anything about the impact on other hazards, which may be increased, decreased, or remain unaffected by the change. For example, painting a room in your house with a water-based paint instead of a flammable-solvent-based paint eliminates the hazard of exposure to low levels of potentially toxic solvents and the fire hazards associated with a flammable solvent.
- Second-order ISD reduces the magnitude of a hazard or makes an accident associated with a hazard less likely to
occur by the design of the equipment, rather than through add-on safety devices. This, too, does not include anything about the impact of the change on other hazards, which may be increased, decreased, or remain unaffected. An example of reducing the magnitude of a hazard is manufacturing explosives in small continuous reactors containing a few gallons of material rather than in large batch reactors containing thousands of gallons of material. An example of inherently making a hazard less likely to result in an accident is installing a feed tank that holds exactly the required amount (and no more) of a raw material that can cause a runaway reaction if added in excess.

- **Layers of protection** are often categorized as passive, active, and procedural. These layers include risk-management features such as containment dikes to manage spills and leaks (passive), safety alarms and shutdown systems (active), and safety procedures and operator actions (procedural). When all of the multiple hazards associated with any technology are considered, it is unlikely that managing all of the hazards inherently will be possible, and layers of protection will almost always be required as a part of the total risk-management program. IST/ISD concepts can make these layers of protection inherently more reliable and robust.

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**Literature Cited**


**Further Reading**

