Hazard control in the industry

Safety in the oilseed solvent extraction industry is an important consideration. Adequate precautions and a good safety plan are warranted, considering the flammability of the solvent hexane.

Perhaps the worst accident, in terms of dollar damage, in recent years in the industry occurred six years ago, when hexane escaping from a soybean extraction plant triggered a series of explosions in the sewers of south central Louisville, Kentucky. The early morning explosions injured four people, demolished streets and damaged homes, property and vehicles. The blasts also cut utilities and disrupted the daily routine of a neighborhood for more than a year. The company owning the plant at the time paid over $38,500,000 in settlements and fines arising from the incident.

Presented in this issue is a summary of talks on hazard identification presented at the 1986 AOCS annual meeting in Hawaii and a look at the standard governing fire protection for the solvent extraction industry.

Six talks on hazard identification were presented in a special session at the 1986 AOCS annual meeting. Here are highlights from that session, chaired by John Heilman of Continental Grain Co., New York, NY, and Earle Fritz, Union Camp Corp., Savannah, Georgia.

Overview

Bill Goldthwaite of Battelle Memorial Institute's Columbus, Ohio, division, substituting for Paul Baybutt, presented the following overview of hazards analysis:

All industrial processes present some risks. Industry's responsibility is to control these risks and reduce them to acceptable levels through proper risk management. A necessary first step is hazards analysis.

There are two approaches to hazards analysis: traditional, or retrospective, relying on experience, good practice and precedent; and modern, or predictive, relying on creativity, imagination and innovation if there is no wealth of experience to tap.

Significant accidents in the recent past have included five chemical and three nuclear industry accidents or incidents. Chemical plant accidents occurred at Flixborough, England, in 1974; Seveso, Italy, in 1976; Mexico City, Mexico, in 1984; and Bhopal, India, in 1984. There also was a serious incident at Institute, West Virginia, in 1985. A nuclear accident occurred at Three Mile Island in 1979; there was a serious incident at Davis-Besse in 1985, and a severe accident at Chernobyl, USSR, in 1986.

As a result of these major accidents, a number of responses have been taken. For instance, in the United Kingdom, all new plants are required to undergo hazards analysis before the facilities are put into operation. In the United States, the American Institute of Chemical Engineers' Center for Chemical Process Safety and the Environmental Protection Agency are studying what has occurred in past accidents; for example, the EPA has formed a Bhopal Task Force.

Hazards of top concern include toxic material releases, fires and explosions. Motivating factors for hazards analysis include public and employee health and safety; economic considerations, such as damaged or destroyed plants, loss of production and liability; and public relations and reliability.

Hazards analysis can be used in design, construction, operation and decommissioning of a facility. Areas to be analyzed include processes, storage and transportation.

Predictive hazard evaluation includes describing the system, identifying possible accident scenarios and estimating their probability and consequences. Often the most difficult step is determining whether this risk is acceptable. If it is deemed unacceptable, this results in modifications, which then require additional hazards analysis.

Guidelines for Hazard Evaluation Procedures was published by the American Institute of Chemical Engineers (AIChE) in October 1985. It describes and categorizes procedures and gives guidelines for their selection and use. Procedure descriptions give their purpose, tell when they are used, outline the type and nature of results, and describe the requirements for data, staffing, time and cost.

Eleven hazard evaluation procedures are described: process and system checklists; safety reviews; relative ranking (using Dow and Mond indices); preliminary hazards analysis; "what if?" analysis; hazard and operability studies (HAZOP); failure modes, effects and criticality analysis; fault tree analysis; event tree analysis; cause consequence analysis; and human error analysis.

A plant hazard study should be done at the design stage of a project, before construction. Problems thus are identified when they are most easily and cheaply corrected (see Table 1, an example of savings because a plant hazards analysis was conducted before

TABLE 1

Plant Hazard Study

	$ 000	%
Total capital cost	38,000	100
Cost of study	60	0.2
Cost of corrections	647	1.7
Cost of corrections if study not done	1,487	3.9
Savings	780	2.1
Savings of continuing costs	262	0.7

construction started). For existing plants or systems, a hazards analysis is beneficial because it can identify problems before they become incidents.

Hazards analysis also can determine the relative importance of problems. True problems can be determined, to take precedence over those that are topical or politically expedient. Improvements can be planned optimally. Resources are directed where they are most effective. Hazards analysis also can help resolve conflicts between parties with different goals. It provides an objective basis for decision-making and an objective standard against which to judge changes. Particularly in areas of innovation, a rigorous analysis identifies problems that would not otherwise be predicted. It also facilitates a deeper understanding of the system.

Conclusions

Hazards analysis provides a thorough, systematic, element-by-element examination of a process, plant or system to identify, evaluate and control hazards and the ways in which equipment malfunction or human error could cause an accident. A variety of hazards analysis procedures is available. Each has strengths and weaknesses; choices are made on a case-by-case basis. The cost of a hazards analysis is very small when compared to other facility costs. Responsible risk management entails the use of hazards analysis as an integral part of operating an industrial plant.

Time needed to do a comprehensive hazards analysis depends on the size and complexity of the facility; generally it will take more than a month and less than a year, with perhaps two to six months being the average.

HAZOP

S.J. Schechter of Rohm & Haas, Bristol, Pennsylvania, presented a talk on HAZOP (hazard and operability) studies, a specific type of hazards analysis. Before introducing a description of HAZOP itself, the presentation included a survey of major accidents, general process safety considerations and the role of hazards analyses.

Accident survey

A hazard survey of the chemical and allied industries was conducted by the American Insurance Association in 1979. Investigated were 465 serious incidents during the period 1960–1977. Contributing hazard factors and their percentages of the total were as follows: equipment failure, 29%; operating failure, 21%; inadequate material evaluation, 16%; process upsets, 11%; material movement, 9%; ineffective loss prevention, 6%; plant site, 4%; plant layout, 2%; and non-code structures, 2%.

Fires represented 37% of the incidents, while explosions were 38%; both fire and explosion occurred in the remaining 25%. Of the 465 incidents, 51 involved a vapor cloud explosion or release.

Safety considerations

Process industries use a number of safety precautions to reduce the chances for accidents or mitigate their effects. Among these are the following, with examples:

- process fundamentals (physics, chemistry, mass balance, energy release, toxicology)
- materials sciences (corrosion, strength of materials)
- corporate standards (spill containment, vapor emissions)
- consensus codes (fire prevention)
- legal codes (building, siting, pressure vessel, health)
- insurance review (loss prevention)
- process design (intrinsic safety, minimum in process inventory, fail-safe controls, redundancy, automation, utility reliability)
- personal factors (protective gear, cleanliness)
- personnel training (operating procedures, know-how, drills)
- hazards analyses (safety check lists, HAZOP, fault tree, consequence estimate)

Hazards analyses

Hazards analyses have been introduced to seek out the hidden causes for potential accidents and to reduce the chances or mitigate the effect of such accidents. Hazards analyses are needed in addition to the more traditional factors for a number of reasons:

- no standards for unique process designs
- increasing complexities due to such influences as environmental control, recycle management and energy conservation
- larger scale operations
- diverse skills involved such as chemical, engineering, instrumentation, automation, corrosion
- cost effective use of safety resources.

Three recent accidents profoundly affected interest in hazards analyses in the chemical industry: the cyclohexane explosion at Flixborough, England, in 1974; the dioxin release in Seveso, Italy, in 1976; and the methylisocyanate (MIC) release at Bhopal, India, in late 1984.

We use several types of hazards analyses in our company. A basic type is a general safety, health and environmental (SHE) review, where related experience is examined, hazard threats are identified and plans are established to deal with them. The second type is the HAZOP review, where potential accident scenarios are sought. Finally, we may use elements of quantification for our risk assessment, involving accident consequence analysis, fault tree probability estimates and development of risk profiles or hazard zones. These techniques are tools that lead to the most cost-effective risk management.

HAZOP

The overall objectives of a HAZOP analysis include identifying causes for possible malfunctions, estimating the ultimate consequences of malfunction and developing recommendations for actions to reduce risk. We apply the technique to both existing and new processes.

The HAZOP method is a multidisciplinary activity involving engineers, operators and safety personnel, usually a total of five to seven people. Up-to-date study materials are used, including plot plan, flow sheets, procedures, chemistry, physical properties and toxicology. The group holds brainstorming meetings but follows a somewhat formal procedure. In evaluating processes, the committee can recommend that the process is acceptable, that it needs changing or that more information is needed. The group is expected to provide final documentation covering initiating events for accidents, estimated consequences and recommendations.

The HAZOP procedure begins with defining the steps of the process, stating them as intentions and process parameters. Key deviations for each parameter are postulated and the group seeks to find events that might cause the deviations. Should causes be found, consequences are estimated, including possible fire, explosion, environmental hazard, toxic hazard, injury or operability problems. Next, lines of assurance are examined, with the likelihood of failures estimated. Finally, recommendations are made to accept the design or to make improvements.

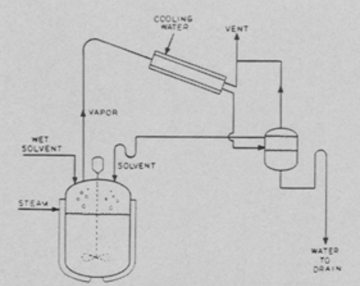

FIG. 1. HAZOP example—removing water from solvent by distillation

To help understand the application of a HAZOP study, see the accompanying example (Fig. 1 and Table 2).

Types of recommendations from a typical HAZOP study for a new process include operating procedures, 28%; equipment design, 24%; instrumentation, 15%; more information, 28%; start-up tests, 4%; and maintenance, 1%.

A typical HAZOP study of two or three process vessels requires approximately 40 manpower days: five to gather information, 30 for group sessions (six people for five days); one to assemble recommendations; three to review recommendations (six people for 1/2 day); and one to report the recommendations. The cost would be approximately $16,000, based on $400 per man-day. We believe that the ultimate benefit of the HAZOP effort is a reduction in the chances for serious accidents. Additional benefits include improving the company's ability to respond to malfunctions; training in critical analysis of any process; understanding of the process; reducing costs via improved on-stream availability and less material waste; and improving product quality by better process control.

Dow's index

Thomas O. Gibson of the Dow Chemical Co. made the following presentation on Dow's Fire and Explosion Index:

The Dow Fire and Explosion Index (F&EI) is a number from which the degree of risk can be evaluated, along with the dollar value for property damage and business interruption. This systematic approach does correlate with some engineering data and, therefore, has a great deal of reliability in risk management application. The system looks at material response and risk exposure along with the protective schemes installed. This index can help evaluate the impact of protective schemes on the days of outage and property damage.

The "Fifth Edition of Dow's Fire & Explosion Index Hazard Classification Guide" published by Dow's safety and loss prevention group in October 1980 provides plant and project management with a systematic approach for identifying process areas with significant loss potential. It is a system that evolved from the "1964 Factory Mutual Chemical Occupancy Guide."

It is important for managers to understand the risk associated with capital invested in their chemical processes operations. The new guide is a tool to identify and quantify that risk. The calculation procedure also identifies methods for reducing the hazard and the risk in a process operation.

Development

Recent insurance company data

TABLE 2

HAZOP Example—Process: Remove Water from Solvent by Distillation

Location: Plant X Participants: Date:

Process intention: Using steam heat, vaporize solvent and water. Condense mixture with cooling water, separate phases, return solvent to still pot, remove separated water.

Parameters: Still temperature, 95 C; pressure, 1 atmosphere; condensate at 50 C.

Possible consequences: fire, (F), explosion (X), environmental (E), toxic (T), injury (I) and operability (O).

		Possible consequences							
Deviation	Possible causes	F	X	E	T	I	O	Other	Recommendations
No separation	Emulsification/ contaminants	X	X	X		X	X	Solvent in sewer ignition	Sample water to sewer. Install collection pot.
	Fast rate/excess steam	X	X	X		X	X	Solvent in sewer ignition	Control steam by measuring condensate rate.

gives some insight on the importance of analyzing the risk associated with chemical operations. As can be seen in Table 3, major chemical industry losses reported to insurance companies from 1978 through the third quarter of 1980 totaled over $116 billion for 967 incidents. The majority of occurrences and dollar losses have been attributed to fire and explosion.

It is obvious that such dollar losses are cause for attention; however, the potential for personal injury and death from fires and explosions makes a systematic approach to hazard evaluation a necessity.

Looking at fire losses greater than $100,000, we see that the primary causes include flammable releases and overheating. We need to analyze carefully such potentials in our operations.

It is important to understand that this procedure (F&EI) has been developed by analyzing past losses in chemical processing industries. It has been developed by identifying the factors that have produced losses and whose presence warns of potential future losses

Background

Hazard evaluation involves understanding the interaction between the material response and the process environment. Some of the significant factors in the process environment include temperature, pressure and the presence of gas or liquid phases. When we evaluate material response, we are primarily interested in its flammability and reactivity. Significant factors in material response include exotherms, endotherms, flammable range and corrosivity.

TABLE 3

Losses in the Chemical Industry, 1978-1980

Peril	Frequency	% $ Loss
Explosion	23.4%	66.2%
Fire	41.6%	20.6%
Subtotal	65.0%	86.8%
Windstorm	14.1%	8.1%
All other	20.9%	5.1%
Total	100.0%	100.0%

We also are interested in factors that contribute to the probability and severity of an incident. Such factors include vibration, type of pipe fittings and instrumentation. Maintenance factors include frequency of vessel and line opening, hot work permit systems and preventive maintenance programs.

Once we have identified and quantified the hazard, we can look at the risk exposure. Significant factors contributing to risk exposure include capital density of the plant, open or closed building design, critical equipment availability, market environment and the use of protective measures.

The decision-maker uses the risk analysis results to weigh design trade-offs and the cost of protective features against considerations of human safety, property damage and business interruption. The procedure then is used to evaluate the contributing factors and to provide information so that the decision-maker can better control the risk.

System verification

The procedure has been developed by analyzing history. It is a systematic way for a manager to analyze a process and determine if the risk is acceptable. The system gives answers that are in the same ballpark as those more scientific approaches would give.

For example, for a 10,000-pound benzene spill, we can evaluate the fire and explosion exposure in several ways. If we assume the spill formed a three-inch-deep circular pool, we could calculate a fire exposure radius of 15 feet. If we assume some pressure and temperature conditions, we can calculate the 15 psi overpressure radius from a vapor cloud explosion. Well-known procedures for this type of calculation predict a 15 psi overpressure of 55 feet. Within this circle, there would be total destruction. The "Fifth Edition" procedure predicts an area exposure of 54 feet.

In these cases, the F&EI approach gives us comparable results to more scientific approaches.

Protective systems

The guide also recognizes that hazards and risks can be controlled by following some basic principles for protection. They include good administration, appropriate construction, adequate water supplies, automatic fire protection, manual fire protection, good drainage, adequate separation, duplication of facilities, proper inspection, preventive maintenance, good process design, proper material hazard evaluation and good operator training.

The system can be used to evaluate any operation where a flammable, combustible or reactive material is stored, handled or processed, except in power generating plants, offices and water treating and distribution systems. These latter areas are being reevaluated as to F&EI application.

With the F&EI system, the actual maximum probable property damage and maximum probable days of outage for a plant or process can be calculated.

Getting started

It is important that the person doing the evaluation know the chemistry and the process. Without this basic information and the plot plan, it would be difficult to do the risk analysis. Additional important information is piping and instrument diagrams (P&ID) and spared equipment; the chemicals in the process and their characteristics; pressure, temperature and volume of material in each vessel and their reactivity; problem areas; replacement value of equipment; resource people; calculation sheets; and F&EI manual.

The first process evaluation is the hardest because of the lack of experience. Subsequent ones become much easier.

Calculation

In the Fifth Edition, the process unit is defined as a primary item of process equipment. Examples include pumps, compressors, reactors and distillation columns. This is a change from the "Fourth Edition," where the process unit was considered an area of the plant.

The concept of the damage factor has been clarified; it can be determined by knowing the material factor and the unit hazard factor, and is the fraction of the property damaged within the area of exposure. The radius of exposure determines the area affected by an incident. It is determined after the F&EI has been calculated.

In the "Fifth Edition," the loss control credit factors have been expanded and further defined. There are additional credit factors for process control, material isolation and fire protection.

One of the new features of the "Fifth Edition" is the addition of a graph of maximum probable days of outage. The graph can be used to estimate the business interruption loss from an incident. Once the actual maximum probable property damage has been determined, the maximum probable days of outage can be read from the graph. The median number of days of outage and the 70% probability range can be determined. The graph has been developed using data from 137 incidents. Judgment must be exercised to determine what value in the range to select for a certain situation.

Material factor

The new guide has provided additional information for determining the appropriate material factor for a calculation. The material factor is a measure of the intensity of energy release from a chemical compound, mixture of compounds or substance. It is the starting point for the F&EI calculations. The material factor is determined by considering the flammability and reactivity of a material and is denoted by a number from 1 to 40.

Material factors for pure compounds that are common in Dow plants are listed in the appendix of the guide. If a material is not listed, a table is included in the manual to help determine its material factor. If reactivity and flammability data are known, the material factor can be determined. The greater the reactivity and flammability, the higher the material factor. Reactivity can be measured by adiabatic decomposition temperature, differential thermal analysis/differential scanning calorimeter (DTA/DSC) data or other means. Flammability can be measured by flash point and boiling point for liquids, rate of pressure rise for dusts and density and cell form for solids.

Calculating F&EI

The procedure for calculating the unit hazard factor—F&EI maximum probable property damage (MPPD) and maximum probable days of outage (MPDO)—is shown in flow diagram form in the manual. Briefly, steps for calculating the F&EI are as follows: select the pertinent process units; determine the material factor; calculate the general process hazard factor; calculate the specific process hazard factor; determine the unit hazard factor; calculate the F&EI.

The risk analysis includes determining the exposure radius, assigning a replacement value to the exposure area, determining the damage factor, calculating the base MPPD, determining the actual loss control credit factor, calculating the actual MPPD and determining the MPDO.

When the proper penalties and credits are applied, the final figures will help management assess the degree of risk.

Oilseed processing

The following talk on hazard control for oilseed processing and refining was presented by Harold J. Sandvig of Cargill Inc., former chairman of AOCS' Technical Safety and Engineering Committee:

Vegetable oil solvent plants and refineries plus associated oilseed storage, drying and loadout are normally of a physical size and sophistication that would seem to set them apart from a full-blown multifaceted chemical plant. Moreover, staff and crew sizes are often much smaller than in chemical plants, where frequently a single department is staffed as well as an entire solvent extraction plant. Still, without question, hazard identification and control must receive the same critical attention that large chemical manufacturers like Dow and DuPont give their facilities.

Sometimes staff size, time and need, as well as the comparative lack of sophistication, are reasons used to justify why a chemical plant should do a total plant safety audit and a solvent plant need not. However, I believe most would agree that the identified hazards in a vegetable oil solvent plant are no less important and the consequences of poor management are no less severe than in a chemical plant.

Policies and procedures are two of the most effective and least costly hazard control devices at our disposal. When a solvent plant operator is faced with an untenable situation, e.g., a machine, system or control device fails resulting in spill, or a vessel containing solvent or equipment laden with hot solvent vapors must be opened, a serious accident or dangerous condition can be avoided by having policies and proper procedures in place.

Policies and procedures should define who is authorized to open a vessel and under what specific conditions. They may identify the parameters within which the plant must operate or insure that the plant will be shut down rather than exceed those parameters. They might specify in detail how certain hazardous jobs are performed, such as opening the desolventizer or purging the extractor under load.

During the 1970s and continuing into the 1980s, the grain industry had to come to grips with hazards that resulted in catastrophic losses of property and personnel. Those in the grain industry had to identify the causes—hazards, if you will—that resulted in elevator explosions.

Slipping conveyor and leg belts, belts rubbing on leg casings (or structural supports in the case of horizontal belts) and bearing failures were identified by the industry as potential hazards. Beyond coping with the hazard, industry leaders agree that good housekeeping—a dust-free plant—is a secondary means of hazard control, because a clean plant is not likely to sustain a large secondary explosion should there be an initial "pop."

I will briefly explain different philosophies and methods of hazard identification and key in on some examples of their monitoring. I also will describe the consequences of the lack of hazard identification and control in solvent extraction plants, including elevators and refineries.

In the 1940s and 1950s, solvent extraction of oilseeds was relatively new in the United States, and the industry flew by the seat of its pants. Column extractors were in use then, and it was not uncommon once or twice a month for the plug screw to wash out, dumping gallons of hexane and miscella six inches deep on the extraction floor. This is an example of a situation in which policies and procedures, good or bad, were essentially our industry's only hazard control.

Today, we have better extractors, desolventizers and related equipment, and we have improved the design of our solvent plants. Many of these improvements were a result of unfortunate experiences, some that involved fatalities. Our industry has learned, and is still learning, although to a much lesser extent, by its mistakes.

In contrast to the old column extractor process, some facilities now have control panels in the preparation area, where the start-up is controlled by computer. Today, we have more resources; we have benefited from the past. We can draw from other's experiences in meetings like this, or benefit from standards of the National Fire Protection Association (NFPA) 36 Committee on Solvent Extraction.

TABLE 4

Critical Safety Device Requirements

Solvent plant locations	Test frequency
Vent system high pressure alarm and shutdown switch	Daily
Low steam pressure alarm and shut down switch	Daily
Low cooling water pressure alarm and shutdown switch	Daily
Water in hexane work tank alarm	Weekly
Solvent water separator, interface alarm	Weekly
Hexane or high level alarm in safety surge tank of solvent water separator	Weekly
Water in ext. vent seal overflow alarm (if applicable)	Weekly
High temp alarm above vent seal	Daily
High level alarm for extractor discharge hopper	Weekly
Rotocel door closing limit switch cutoff	Weekly
Rotocel clutch limit switch cutoff	Daily
DT top deck high level alarm and switch	Daily
DT 2nd deck temp recorder and alarm (below 200 F)	Daily
DT control deck level control auto operate discharge	Daily
DT control deck high and low level alarms (top sparge)	Daily
DT discharge temp recorder, loq temp alarm and shut down	Daily

Solvent plant locations (cont.)	Test frequency
High pressure alarm and shutdown bottom deck (bottom sparge)	Daily
First compartment skim pit hexane level alarm	Daily
High level alarm for hexane storage tank	Daily
High level alarm for hexane underground surge tank	Daily
Gas alarm to monitor	Daily
Water reboiler discharge low temp alarm and shutdown	Daily
Hexane detect, final skim pit compartment	Daily

All locations: boilers	Test frequency
Two low water cutoffs, each boiler	Weekly
High stack temp cutoff, each boiler	Daily

All locations: bucket elev	Test frequency
Slow down device on each bucket elev tail/knee pulley	Daily

All locations: belt conv	Test frequency
Slow down device on each belt conveyor tail pulley	Daily

However, we're far from finished with the work of hazard identification and control. Solvent plants differ in design, equipment, size, products, location, topography, mean ambient temperature and, not the least, operating philosophy. What may be defined as a potential hazard at one location may not be at another. As part of a co-op or corporation, operating management may have identified, via policy and procedure manuals, certain generic hazards and control for all locations. However, updating and making additions must be ongoing. All individual locations must develop a formal or informal hazard identification system to cope with specific differences and must make revisions as the plant changes.

Two types of informal hazard identification are experience and sharing. Another—observation, or management by walking around—has been around for a long time and is finally getting the credit it deserves. As plant managers, superintendents and operators visit, operate or inspect the plant, they must be constantly aware of changing conditions, unsafe acts and circumstances that affect a process or plant's operation. They should consider what they see, hear and smell and ask, "What if?" What if we experience loss of cooling water, low steam pressure, loss of control air, low wastewater temperature, loss of electrical power or high vent or vapor pressure? What if we experience hexane spill, hexane vapors in the preparation area, undesolventized meal, immobilized extractor, dryer fire, seed or meal tank fire?

There are a hundred "what if" questions to be asked that can be done by an individual, without a committee. Some may have been previously resolved by others and can be crossed off the list.

More formal methods of hazard identification take the form of total plant safety audits, risk analysis audits or technical safety audits. Major chemical companies have assigned audits similar to these to identify hazards in new processes, new equipment design or those resulting from process design changes.

A full-blown chemical plant safety audit may be performed by a committee of six. In a solvent plant, a committee may consist of only two or three—the plant superintendent, production foreman and maintenance foreman, one of whom may double as safety committee chairperson.

At times, engineering plays a large role. When new processes are considered, equipment is retrofitted, plants are modified and new plants are constructed, it is important to look more closely at layout and design. At this time, hazards and controls should be reidentified.

Some companies purchase their engineering and design while others generate a large percentage in-house. However it is done, it is appropriate for engineering and plant operations people to audit together proposed changes during the total plant safety audit. This is the time to look inside vessels and equipment, to consider piping changes, to look at the utilities package, and to ask, "What if?"

There have been several good articles written about hazard identification and total plant safety audits. We've also heard and will hear about similar programs used in the chemical and oleochemical industries.

I'd like to discuss the practical side of specific hazard control devices—critical safety devices—and some actual examples of the consequences of the lack of a control device or the failure of plant personnel to understand the purpose and use of a critical safety device.

Critical safety devices are used to control identified hazards and maintain critical operating parameters, which in most cases are the same thing. Tables 4-6 offer a quick overview of control devices and the frequency of testing. Tests are used to verify both the alarm circuit and the sensing circuit under actual, if possible, or simulated operating conditions.

To conclude, I will describe the circumstances surrounding selected incidents that demonstrate what can happen when hazards are not identified, monitored and controlled, and if employees are not trained in such procedures. These incidents are from my recollection; they did not necessarily occur at a Cargill installation or in the United States.

Low deck level alarms and low temperature shut-down devices for meal discharging from the desolventizer were made standard at a solvent plant after a flash fire. The operator was having a problem with the extractor discharge conveyor (DT feed bulk flow). He neglected to call for supervisory help, thinking he could resolve the problem, and let the DT levels run low. The operator finally shut down from the bulk flow-back, but let the DT run very low before stopping it. On the ensuing start-up, solvent-laden white flakes filled the DT before lower level temperatures were proper. Hexane vapors spilled from the DT discharge converyor, crossed the yard on this particularly still evening, reached the boiler room, and flashed back to the solvent plant.

TABLE 5

Critical Safety Device Requirements for Thermal Oil Heaters/Vaporizers

Shutdown device	Test frequency	Shutdown device	Test frequency
Thermal oil heaters		Thermal vaporizers	
High liquid temp	Weekly	High vapor temp	Weekly
High stack temp	Weekly	High stack temp	Weekly
Expansion tank low level	Monthly	Low liquid level (two required)	Monthly
Low circulation flow/ pressure differential	Monthly	High pressure	Monthly
Low and high circulation pressure	Monthly	Pressure relief valve	Annual
Live steam to fire box	Annual	Live steam to fire box	Annual

Heaters and vaporizers combustion: Check company manual

Solvent water separators have been periodic sources of problems over the years. Hazards have been identified, and controls have been developed for: water being pumped to the extractor; hexane being forced out by vapor pressure exiting with the water phase and overloading the wastewater evaporator; emulsion, excessively deep interface or poor separation between hexane and water phases resulting in moisture coating the bed or basket and causing poor drainage.

Another incident that involved the solvent water separator and the wastewater evaporator was one of the more serious accidents in recent history. The solvent plant had gone down for emergency repairs in February and the weather turned very cold. After repairs were made, the employees attempted to thaw out and start up the plant. They continued to have problems, and the plant never got running very well. The temperature of the water from the wastewater evaporator was too low; they could not get it above 130 F. Continuing to try to run the plant and raise the temperature, personnel eventually noted there was almost no overflow back to storage even with the plant running for a time and hexane continuing to be pumped in from storage. After some time, hexane was noticed backing up into the plant from the containment sump. There was concern that hexane had gotten down the drain and off the property. The plant was shut down, the metropolitan sewer district was notified and employees began to recover hexane from the pit. However, as had been feared, hexane had gotten into the sewer system and at about 5:30 a.m., some 24 hours after employees first tried to unthaw and restart the plant, there was an explosion in the city sewer system.

An artist's view of the inside of a solvent water separator reveals a rupture in the elbow on the water discharge pipe from the solvent water separator. Ice frozen during the shut-down had ruptured the pipe, allowing hexane from the light phase side of the separator to flow directly with the water, through the wastewater evaporator, to the sump and eventually to the sewer.

Here, a control that has since been adopted by almost all solvent plant operators would have resulted in an automatic shut-down because of low effluent water temperature, and a light phase monitor system on the containment sump would have alerted operators that the sump was filling beyond acceptable limits.

In edible oil refineries, the deodorizer is a key unit and the boiler (Therminol or Dowtherm) is the heart of the operation. As seen previously by the critical safety device list, there are several critical operating controls that must be monitored.

A supervisor was seriously flash-burned when attempting to start up a deodorizer from a cold start. A pressure switch is used to monitor the flow of 550 F mineral oil from the boiler to the deodorizer heat exchanger. The deodorizer was very slow to heat up, making it appear almost that there was no hot oil flow. Believing the process to be low and in need of more mineral oil, the supervisor transferred more from underground storage to the system. After an hour, the temperature still was not high enough. Thinking they were out of mineral oil, the supervisor opened the storage tank and hot vapors reached the boiler and flashed, burning the supervisor.

TABLE 6

Critical Safety Device Requirements for Flash Desolventizing Systems[a]

- High level alarm and shutdown, vapor cyclone
- High level alarm and shutdown, vapor cyclone (back-up)
- Vibration switch(es) alarm and shutdown, fan
- High level alarm, scrubber
- High level alarm, stripper
- High level alarm, stripper condenser
- Low cooling water alarm and shutdown
- Low temp alarm and shutdown, discharge stripper
- High level alarm and shutdown in cooker
- High level alarm and shutdown , cooler cyclone (dust collector)
- Low temperature shutdown, hexane primer
- High temperature alarm, fan bearing(s)
- Low flow alarm, absorption
- Low flow alarm, scrubber
- Amp indicator alarm (minimum) normal operation
- High pressure alarm in loop
- Temperature alarm at pressure relief valve

[a] All devices tested monthly.

As it turned out, there was plenty of oil at more than sufficient temperature. However, the pressure (flow) switch was adjusted to the limit and so it acted as though it were bypassed; it would not shut down the system on no flow. The operators knew only that if the system shut down on no flow, they could adjust the pressure switch to keep it running. Only after this incident did management become aware of the problem. They disassembled the pump and discovered the impellor was almost totally carbonized and incapable of pumping more than 30–40% of the mineral oil required.

The operators knew how to make the deodorizer run, but they had not learned that the safety device was trying to shut the system down for a reason—lack of hot oil flow. In this case, the control was in place, but the employees had not been trained to use it or to understand the warning.

It is logical that hazards first must be identified. This extremely important yet difficult task, by whatever method, is to be followed by monitoring and control. But the job isn't done if control devices are not properly maintained and employees are not properly trained to use the control.

It's the wrong tool if your employees don't know how to use it.

Oleochemicals

Robert C. Slagel of the Chemical Products Divison, Union Camp Corp., Savannah, Georgia, presented the following concerning hazard identification and control in the oleochemical industry:

I believe it would be an understatement to say that the chemical industry has a tarnished image when it comes to safety, health and environmental issues. Whether or not the public is presented with the true facts, the message given by the media is that we are "bad" guys who have poisoned the public or injured our employees. In truth, according to the National Safety

Council, our 1984 safety record with respect to incident rates is the best of all of the principal industries in the United States. However, we are not pure enough to live in a glass house!

In a speech given before the Industrial Research Institute fall meeting in Minneapolis, Minnesota, last October, Douglas A. Rausch of the Dow Chemical Co. spoke of operating discipline. He illustrated the chemical industry problem of public confidence by describing three recent events:

> In 1974, a fire and explosion at a chemical plant in Flixborough, England, killed 28 employees and injured 36. Property damage extended over a wide area and a survey showed that 1,821 houses and 167 shops and factories had suffered damage to a greater or lesser extent. The problem arose when the plant had to repair one of the six reactors and rushed to refit the plant to bypass the disabled reactor. They jury-rigged a scaffolding to support a 20-inch pipe connecting reactor four with reactor six, bypassing the disabled reactor, and violating industry and manufacturer's recommendations in assembling and testing their bypass piping. Plant employees tested for leaks, but not for the strength of the assembly.
>
> Several years later, an explosion occurred at a plant producing trichlorophenol in Seveso, Italy, that changed the course of regulations in Europe. In this case, the production run itself ended at 6 a.m. Saturday—a time that coincided with the closing of the plant for the weekend. This is important in view of the procedures employed that morning following the completion of the reaction:
>
> - instead of distilling off 50% of the solvent after the end of the batch, as required by the operating procedure, the operators distilled off only 15%.
> - instead of adding 3,000 liters of water to cool the reaction mixture to 50-60 C, as required by the operating procedure, the operators added none.
> - instead of continuing to stir until fully cooled, as required by operating procedure, the operators stopped the stirring after 15 minutes.
> - instead of remaining with the unit until cooling to 50 to 60 C, as required by the operating procedure, the operators left at 6 a.m.
>
> The exothermic decomposition, which took place some 6.5 hours later, caused the rupture disc on the vessel to break, venting material that contained dioxin into the atmosphere.
>
> The third accident is the more recent disaster at Bhopal, India. The detailed report shows that the scrubbing system (which should have absorbed the vapor discharged from the relief values), the flare system (which should have burned any vapor which got past the scrubbing system), and the cooling system for the tank were not in commission or not in full working order. Press reports state that high temperatures and pressures on the tank were ignored, as the instruments were poorly maintained and unreliable.

Mr. Rausch went on to say, "In each of these cases, the technology was not lacking, but the discipline required to follow procedures and good operating practices was. Could it be that through our technology we have built in so many safety features that we depend on them and forget to use discipline and judgment?"

In an article in the Nov. 11, 1985, issue of *The Wall Street Journal* titled "Under public pressure, chemical firms push plant safety programs," a description was given of a 1984 accident at the American Cyanamid plant near Linden, New Jersey. This plant was operated for more than a decade without a major accident. Luck ran out when saltwater from the cooling system leaked through pipes into a storage tank holding 12,000 gallons of malathion. A runaway reaction ensued. Heat and pressure building up within the tank went undetected for lack of an automatic alarm, and the skeletal crew on weekend duty didn't check the tank's temperature by the single thermometer at the bottom of the tank. Malathion gas erupted with explosive force and spread an amber cloud of insecticide for 20 miles. More than 140 people sought hospital treatment.

In this case, why was a facility designed without proper controls for an obviously hazardous operation? Lack of attention to detail? Cost cutting? Short cut?

I am sure that we all can point to numerous similar situations within our own operations. Five years ago, Union Camp's safety record was not enviable. We were below average for both the paper industry and the chemical industry. Our top corporate management then made a commitment to become a leader in our respective industries. Because of this dedication, in the last four years we have reduced lost work day cases by 68%. Our incident rate (total recordable cases) has improved as follows: Forest Products Industries, 9.2 in 1980, 8.3 in 1985; Union Camp Corp., 13.6 in 1980, 4.4 in 1985; Chemical Industries, 6.8 in 1980, 2.8 in 1985; Chemical Products Division, 8.1 in 1980, 3.0 in 1985.

How have we done it? In the Chemical Products Division, we have done it by management commitment, employee training, peer review of operating procedures, peer review of process design (HAZOP), special emphasis on laboratory safety and audit and reward.

Management commitment

From our chairman on down, all division and department managers are responsible for safety objectives against which they are measured annually. Success or failure can affect incentive bonuses for the year.

Employee training

The DuPont Co.'s commitment to and expertise in safety management have made it the world leader in industrial safety. Union Camp subscribes to the DuPont philosophy and approach. Working safely is a learned behavior, so training of personnel is imperative. Our departmental managers all receive two days of training which, in turn, results in more specific training for each person in the company. Detailed written procedures are available and are used to train personnel, particularly in the hazardous aspects of their jobs. In our industry, this could be in operations involving hydrogenation, solvent separation and extraction, toxic chemicals, high pressure, vacuum, dust and tank cleaning.

For example, in hydrogenation facilities, particular attention must be paid to adequate ventilation to prevent hydrogen from building in pockets, especially under the ceiling or roof. Ignition sources must be eliminated, e.g., welding tools, electric motors or instruments not properly wired for code, and smoking. Spark-proof tools must be used. Portable combustion meters must be provided. An alarm system is advisable so that an operator may signal and summon help in case of an emergency. Proper maintenance of the reactor is vital. Scheduled inspections of agitator, manway and valve seals, as well as relief valve or rupture discs, should catch worn, plugged or damaged parts. Cleanliness of the reaction vessel and catalyst feeding system is important, not only to the safe operation of the system but also to the efficiency of the reaction. Handling of the catalyst, either as virgin material or as filtered residue after reaction, can be tricky because of its highly reactive state, especially if allowed to dry in the presence of air. In such a hazardous operation, it is imperative that detailed training be given to operators and supervisors on operating and emergency procedures, including shut-down and evacuation.

Many of the same precautions and training pertain to solvent separation or extraction operations. A major concern is static spark in solvent transfer. This can be prevented with proper inert gas purging and grounding equipment. In some cases, solvents have the added problem of toxicity. This means that special equipment must be made available, including protective clothing, air packs or respirators and personal monitoring devices. In addition, under the new right-to-know legislation, material safety data sheets and other exposure data must be made readily available to each employee. The same attention should be given to other toxic chemicals such as amines, formaldehyde, certain alcohols and some strong acids.

Special training in pressure or vacuum operations deals with properly coded vessels, relief valves or rupture discs, valves, seals, vessel purging, emergency release of toxic material, corrosion that would weaken the vessel, accuracy of gauges, procedures for opening the vessel and emergency shut-down procedures.

Dust explosions or generation of static charge while adding a dry crushed or powdered organic material to a hopper or reactor are not uncommon. Prevention is normally by proper grounding of vessels and/or control of the atmosphere by inert gas purging or even humidity control. Thorough operator training is critical.

In our industry, it is common to need to enter confined spaces such as reactor vessels, storage tanks and tank trucks or cars for maintenance. Industrial accidents, many of which result in death, from such activities are all too frequent. Confined entry procedures are now very detailed and include proper opening, purging, air control and a dedicated person to stand "watch" outside the vessel.

All Union Camp manufacturing facilities use the DuPont safety training observation program (STOP). The program requires that first-line supervisors tour their area of operation at least once per shift and look for safety concerns. Action is then required, either on the spot or at a scheduled time, to correct any problems found. Follow-up is a must.

Peer review

We have developed a standardized format for transmittal and review of operating procedures specifically for introducing a new product or process or modifying an existing product or process.

Whenever a new product or process is ready for expanded development or commercialization, detailed procedures are prepared by appropriate laboratory personnel. Included are product description, process flow scheme and description, equipment description, material balance, raw material and product specifications/tests, safety and regulatory status (Environmental Protection Agency, Food and Drug Administration, Toxic Substances Control Act, Department of Transportation, Resource Control and Recovery Act). The procedures receive a detailed peer review requiring the signatures of the preparer (chemist or engineer), environmental engineer, analytical services manager, development manager and process engineering manager.

The approved document is then reviewed by the manager of the plant (and appropriate staff) in which the product or process is to be used. Any problems are worked out between the plant manager and the manager of process engineering. Once a development product has been made on a plant scale a sufficient number of times to establish an operating procedure, a copy of the procedure is forwarded to the manager of process engineering for review and approval. Following his approval and that of the appropriate product development manager, the process becomes standard.

A very important factor in hazard control is control of process change. Thus, future major changes to a standard product or process must go through the same review.

HAZOP

We have come to rely on a systematic peer view of process and facility design to save our skin. Several of our recent plant expansion projects have resulted in considerable cost overruns. We asked ourselves why. After careful review, the key conclusions were the following:

- there was no "ownership" of the job; either no one wanted it or the assignments were not clear.
- because of a rush to prepare the job for presentation, insufficient engineering detail led to inaccurate cost analysis.
- pressure to keep job cost low led to an unrealistic estimate and the need to return for additional funds.
- there was no peer review with a team consisting of representatives for all key functions.
- there was a lack of continuity with key peer group members, e.g., shifting the main engineer off the project midstream.

Obviously, if such factors exist, we are likely to miss important design items that will not only cause increased cost but also may lead to operating and safety problems. Even detailed engineering after job approval will likely miss important criteria because of the lack of cohesiveness.

It was after these cost overruns that Battelle Laboratories presented to us its seminar on risk analysis and hazard and operability studies (HAZOP). Unlike other methods of hazard identification, HAZOP studies are a systematic, experience-based, creative approach based on teamwork.

HAZOP can be used for design of new plants or modification of old plants. This approach allows discovery of deviations from design intent and identification of potential hazards and operating problems resulting from such deviations. Also, with a deeper understanding of the system created by the peer group review, fewer engineering changes occur, resulting in time savings and reduced engineering and construction costs.

We have also had very successful expansion projects. The factors we feel have contributed include frequent communication among members of the project team; continuity of the team for the life of the job; dedication of time for those on the team (team members did not have other major outside activities that would divert their efforts); and well-established ownership of the job.

What approach do we now take? We follow closely the HAZOP teachings:

- provide sufficient time to prepare the job. Do it right "up front."
- establish a peer group (multidisciplinary team). The group is chaired by the general manager of manufacturing. Other core members include the manager of process engineering, project engineer, main process engineer, a chemist and a representative from operations (manufacturing site).
- pull in other functions as required, i.e., consulting engineer, environmental consultant.
- form the group when the job is conceptual. Other key sessions should occur before the job is submitted, as required after approval and for any scope changes.
- ensure that all group members are dedicated and on call as required for the life of the job.
- review all aspects of the job in detail as a group rather than just independently. This includes review of P&ID and calculations on key items as appropriate.
- ensure continuity of key personnel on the job. This includes all those in the peer group but especially the project engineer, process engineer, operating representative from Union Camp and project manager from an engineering company, if used.
- conduct a risk analysis where more than the usual uncertainty exists in any major part of a job.

How well does this work for us? Contact me in two years for the results.

Laboratory safety

I am particularly pleased to use our own division product development and technical services laboratory in Savannah, Georgia, as a model for laboratory safety. This lab includes product development activities for upgrading our raw material base to performance chemicals in key markets, as well as technical service support for all of the division's 360 products. There also is a substantial pilot facility.

While my remarks are directed to a lab operation, the principles can be applied to other operations, including manufacturing.

Recently, we achieved a milestone of one million man-hours without a lost-time accident. This may seem like a minor accomplishment to those of you with large operations. However, in our case, it took nearly seven years to achieve this record. We have since gone on to achieve the seven-year record as well.

What are the reasons for our success? There are four factors: an organized approach to safety, management commitment and involvement, employee involvement and luck.

We have a safety committee made up of the safety chairman, the technical director and the managers of each department as permanent members. We also have representatives from each lab group, who rotate each year on a staggered basis.

The committee activity includes a monthly safety inspection by the chairman, each department manager and a lab representative. Safety devices such as showers, eye wash fountains and fire extinguishers are checked for working order. Housekeeping is reviewed, and gas cylinders are checked to be sure they are chained, with pressure off the valve. Other items reviewed are labeling of chemicals, use of safety glasses, excess solvent, hazardous waste handling and storage, electrical coding and guards on machinery. Monthly safety committee meetings include a review or audit inspection, near-miss report, accident report, development of an action plan and follow-up on the previous action plan.

The committee also ensures safety training through monthly sessions for all laboratory personnel. These sessions are mandatory and are held at varying times so that everyone can attend. Those who miss receive a note from the technical director. Covered in the training sessions are items of general interest, reviews of accidents and near-misses and a review or update on one or two areas of safety. The latter might include hands-on training with a respirator or fire extinguisher or a vendor or film presentation on eye or hearing protection, chemical handling or labeling. Individual training for all new employees and training for specific jobs are also provided.

The committee also reviews job safety analysis and establishes and implements a reward system. Rewards include drawings for shoes, fire extinguishers and smoke alarms, an annual drawing for a $100 savings bond, recognition as laboratory of the month or year and an annual safety outing.

If commitment, involvement and an organized approach are not in place, luck does not have a chance to play a role.

You and I can reverse the poor image of the chemical process industry with respect to safety health and environmental issues. The challenge is on our shoulders and no one else's. As managers, scientists and engineers, we must insist on proper equipment design and control of operating procedures, thorough training of personnel and continual critiquing of our operation. With discipline, we can do it. Let's give our industry a good name!

Hydrogen safety

The following was presented by S.N. Milazzo of S.N. Milazzo Associates Inc., Greenville, South Carolina, on safety in hydrogen manufacturing and hydrogenation processes:

The basic methods of producing hydrogen for our industry are still allied with the economy, with energy costs being the paramount factor. One must weigh the pros and cons to properly evaluate which production route to take, with feedstock costs the most important consideration in continuing day-to-day production.

Once the decision has been made on the type of plant, the next step is to consider the location.

The goal, of course, is to safely and continuously produce pure hydrogen with limited interruptions and unforeseen shut-downs.

Since any producing plant must be controlled electronically, continuous monitoring is important to assure safe operation. Stand-by automatic electrical generators afford this kind of trouble-free peace of mind, with regular start-up of the emergency system a necessary preventive tool.

In recent years, package-type systems have been used to augment or supply the hydrogenation plant. These systems are maintained by the liquid hydrogen supplier, and the tanks are kept at a level that ensures continuous supply of vapor at the required pressure. The systems are fenced off from the working plant to prevent possible problems and to limit access to the storage and vaporization controls. The liquid system has been an ideal way to increase hydrogen storage without multiple pressure storage tanks; however, regular continuing use of hydrogen in process must be ensured to realize optimum production volumes of hydrogenated fats and oils.

The potential hazards in a working hydrogen plant must be addressed to afford safe, trouble-free operation. Operating manuals outline the steps for start-up and shut-down, with emphasis on the necessary precautions for plant maintenance. No short cuts should be taken, for obvious reasons. Purging should be carried out with care, and in all systems, the atmosphere must be checked for possible explosive concentrations of hydrogen gas. One can never justify limited attention to specific safety procedures by saying it never pays. I am reminded of the saying on a plaque in a former employer's office: "There is no excuse for failure." It is just good operating procedure to be alert, take regular process readings and ask for assistance when it is necessary.

Atmospheric conditions must be considered to achieve an efficient plant. One example we experienced was the effect of low temperatures on a solenoid. When the holder level called for more hydrogen from the storage tanks, it was automatically energized. The freezing temperatures regularly affected the impulse switch; the problem was eliminated when we installed a motorized solenoid.

Today's hydrogenation process conditions are directly related to the particular items produced. All systems have been tailored to facilitate efficient day-to-day operation, with quality and reproducibility most important. Since the product mix is tailored to each company, with emphasis on supplying intermediates for captive use or end-products for their customers' needs, one must first address the industries being serviced.

We have been involved in both areas, namely, producing for captive use and for sale to other companies. It goes without saying that the parameters necessary for performance with end-use products cannot be realized by an inferior plant, poorly designed with minimal process control. A successful business is built on process know-how, and experience always can justify the expenditures required for a safe, efficient working plant. All areas of doubt or question must be resolved before the plant is started up. This includes the various process reactions to be carried out and the necessary preparation of the system to afford an oxygen-free atmosphere before introducing hydrogen.

Our aeronautical space engineers have experienced what happens when all systems are really not ready; the environmental conditions affected the performance, with a tragic ending. No launch had been carried out before at such temperature extremes, and the result was terrible. Surely the investigators will try to resolve the reasons, but the tragedy could have been prevented. Again, nothing will reverse the events, and one can only ask, "Why?"

Over the years, I have been made aware of countless events that involved serious explosions within operating areas. One comes to mind vividly, as I had warned the plant manager that his poorly designed system was being operated in an unsafe manner. Since the plant had operated without a problem for a few years, he took issue with me and assured me he knew what he was doing. Three weeks after my final visit, I received a frantic call from the plant manager advising me they had experienced an explosion, killing two operators and rocketing the reactor three miles away into a field. The town authorities would not let the plant operate until the reason for the mishap had been identified and corrected. Our presence was needed to pinpoint the specific problem and list the corrective measures needed to prevent a recurrence.

Another experience involved outside riggers installing pressure storage tanks on our concrete pads. I was responsible for the operating hydrogen plant and the hydrogenation department, and it was necessary to maintain the regular continuous production in both areas while the riggers were doing their work. Naturally, I cautioned everyone involved about the three existing storage tanks and the manifold containing pressurized hydrogen. The rigger supervisor assured me he knew what he was doing and would be careful. During an attempt to remove one new storage tank from the low-boy, the

crane cable broke. It was then that I really became concerned: the crane's capacity was 25 tons, and we were installing 25-ton tanks. We took issue with the rigger boss and the next day, they arrived with a 50-ton crane. I felt better. They hooked the cable to the tank clips and began lifting the tank, which was about six inches into the ground after the cable broke. I noticed no chocks had been placed to prevent the tank from rolling and brought it to the attention of the supervisor. He answered, "Listen, son, I know what I am doing." The next instant, the tank rolled and broke the manifold, causing 200 pounds of hydrogen to escape and impinging on the tank being raised. In a few seconds, the hydrogen ignited with a loud boom. Suddenly, I was all alone. The plant fire chief was right behind the riggers who were running down the road. My hydrogen plant operator came back when he saw I was alone. I directed him to check the nitrogen rack, which housed 30 full cylinders; we should be all right. Naturally, we had to wait for the tank pressure to go down. When it was at a few pounds, we started introducing nitrogen from the top quarter-inch nozzle, to which we had connected the nitrogen rack, while the fire continued. We did what was necessary to prevent a potential rocket from lifting off—something that could have occurred had the right amount of oxygen been allowed to mix while still containing burning hydrogen. This serious event took place long before the space program.

These events emphasize the importance and necessity of following special precautions when designing and carrying out hydrogenation processes. Some of the obvious are the following:

- the equipment must be designed to prevent vessel failure, with specific pressure relief equipment and necessary knockout pots.
- the hydrogenation process should be separated from other operating areas.
- all explosion-proof controls and recorders with alarms should be checked regularly by operators, to alert them of potential or impending problems.
- the lighting must be vapor-proof, for obvious reasons.
- compressors must be serviced regularly to afford efficient process turnover times without leakage.
- agitators and pumps should have mechanical seals to minimize hydrogen and product loss; these must be checked regularly.
- all equipment and piping should be properly insulated to prevent plant freeze-ups from higher melting point products and inclement weather.
- plant cooling towers must be chemically treated regularly, with daily checks to prevent scale build-up in process equipment and resulting poor heat transfer.
- repair of process equipment that has been on-stream necessitates obvious precautions. These include installing blanks to prevent accidental introduction of hydrogen and feedstock to the reactor; purge with steam, followed by nitrogen, until the system is hydrogen-free; test with a working meter (the test meter should be periodically checked); and followed by steam and nitrogen.
- as in any working system, preventive maintenance should be done on a regular schedule. This point cannot be overemphasized.

I have tried to outline the most important areas of concern to the production manager and operating team. When a plant can be run 24 hours a day for a whole year with no unforeseen interruptions, everyone can sit back and be proud. All concerned know with assurance that it can be done on a regular basis. Given a cooperative effort, all should share in the fruits of a job well done.

NFPA 36

The following is a look at the standard governing fire protection for the solvent extraction industry.

The National Fire Protection Association (NFPA) Standard 36, Solvent Extraction Plants, outlines provisions for safety to life and property in the design, construction and operation of solvent extraction processes involving the use of flammable solvents.

This standard was tentatively adopted at the 1957 annual meeting of NFPA, and a revised edition was adopted as a continued tentative standard at the 1958 annual meeting. At NFPA's 1959 annual meeting, the standard was officially adopted; it subsequently was revised in 1962, 1964, 1967, 1972, 1973, 1974, 1978, 1983 and 1985. The 1974 revision was the first version written to conform to the Occupational Safety and Health Administration (OSHA).

NFPA is not a legislative body, according to C.L. Kingsbaker of C.L. Kingsbaker Inc., current chairman of the NFPA's Technical

Committee on Solvent Extraction Plants. However, if a plant has an accident or is inspected by OSHA, OSHA officials will use NFPA 36 as a reference, and any citations made will refer to the NFPA standard. Consequently, a company can be fined or given a jail sentence by OSHA based on violations of mandatory sections of the standard.

The standard originally was developed at the request of individuals in the solvent extraction industry who felt there was need for greater uniformity on fire protection for solvent extraction plants. The purpose of the standard is to provide reasonable guidelines for the design and operation of those plants.

Other members of the NFPA committee are George E. Anderson of Crown Iron Works Co.; Kenneth D. Harp of Kings County Fire Department; John E. Heilman of Continental Grain Co., who represents the National Soybean Processors Association; John Madej of The Mill Mutuals; La Rue Medders of Lloyds; N. Hunt Moore of N. Hunt Moore & Associates Inc.; Harold J. Sandvig of Cargill Inc., who represents the Corn Refiners Association Inc.; C.E. Scott of the Kemper Group, who represents the Alliance of American Insurers; R.I. Spencer of Industrial Risk Insurers; and Leslie R. Watkins of the Food Protein Research and Development Center, Texas Engineering Experiment Station, Texas A&M University.

NFPA requires that all committees have a balance of members, so that one group cannot exceed one-third of the total. "This is to prevent one faction or interest group from controlling an NFPA committee," Kingsbaker said. Currently the 12 members consist of four insurance representatives, four users, one enforcement representative, one manufacturing representative and two special experts.

Kingsbaker, Anderson, Heilman, Moore, Sandvig and Watkins all are members of AOCS. Kingsbaker, as chairman of the committee, has selected Anderson to serve as liaison to the committee for AOCS. As such, Anderson will report to the AOCS Technical Safety and Engineering Committee at the annual AOCS meeting on what has transpired at the latest NFPA 36 committee meetings. He also will report any suggestions or comments made by the AOCS Technical Safety and Engineering Committee back to the NFPA 36 committee.

The 1978 revised standard was in effect at the time of the Louisville explosion. According to Kingsbaker, the committee considered a number of changes as a result of that and other accidents in the industry. The current NFPA Standard 36, dated 1985, and the previous revised standard published in 1983, reflect associated changes made by the committee.

Meanwhile, the Louisville plant involved with the sewer explosion in 1981 was subsequently redesigned to conform to the NFPA Standard 36 in effect at the time. Changes included diking, a new separation basin and installation of critical devices such as alarms, controls and instruments. Many millions of dollars were spent to renovate the facility and make it conform to requirements of the standard.

According to Kingsbaker, an important addition to the 1985 standard is paragraph 5-2.4.4: "An emergency means shall be provided to prevent the outflow of solvents, miscella or oil from the sump to the sewer system."

"This does not tell what that emergency means shall be, to allow flexibility," Kingsbaker said, explaining that it could be an automatic or a manual shut-off valve. "The main purpose is to provide a way to isolate the sump from the sewer system."

The previous provision 5-2.4.4—"A pump shall be provided to recover oils, solvents, or miscella collected in the sumps"—was added

Contents of Standard 36

Contents of the NFPA Standard 36, Solvent Extract Plants, include the following:

- **Introduction** (Chapter 1)—purpose, scope, existing plant, enforcement, definitions
- **Basic rules** (Chapter 2)—general requirements; emergency procedures; repairs in restricted and controlled areas when plant is shut down and purged; extractor start-up; solvent transfer equipment; piping, valves and fittings; controls; exits; fire protection
- **Bulk solvent unloading and strorage** (Chapter 3)—location, design and construction; sources of ignition; fire protection equipment; unloading procedures
- **Preparation process** (Chapter 4)—application, construction of building, electricity, dust removal
- **Extraction process** (Chapter 5)—location of extraction process, construction of extraction process, ventilation of extraction buildings, ignition sources and heating, electricity, static electricity, lightning protection, process equipment and flammable vapor detection
- **References publications** (Chapter 6)
- **Appendices** to Standard 36 include a general description of the solvent process and operational practices.

To obtain a copy of the standard, contact the National Fire Protection Agency, Batterymarch Park, Quincy, MA 02269.

in the 1983 version, and became 5-2.4.5 in the 1985 version.

Also added in the 1985 version was section 5-8.9.5, providing for the automatic shutdown of the plant. It is worded as follows: "Automatic systems shall be provided to stop the discharge of meal or water at temperatures below which there would be a significant hazard."

"A light will start flashing at a specific temperature level, then an alarm will sound, and finally, the plant will automatically be shut down as the temperature drops," Kingsbaker said, adding, "This prevents the operator from trying to run these facilities at too low a temperature."

Another addition was provision 5-3.2: "Ventilation fans intended to handle solvent vapors shall be designed with the increased horsepower necessary to handle higher density vapors."

Most recently generating much discussion by the committee was Section 1-3, a clause governing existing plants. It currently is worded: "The provisions of this standard pertaining to design, layout and construction do not apply to existing plants. However, any major modification or expansion made to an existing plant shall enhance safety to life and property. Such major modification or expansion shall not be prohibited because of space limitations provided that an equivalent degree of protection, approved by the authority having jurisdiction, is achieved, and all other provisions of this standard are complied with."

"An old plant built, say, before 1957, doesn't have to follow the standard," Kingsbaker said, adding, "The problem then arises when an existing plant is modified. What is a major modification? That is not defined."

At the committee's most recent meeting held Oct. 6–7, 1986, this section was finally rewritten. After much discussion and numerous versions of this section presented at the past three meetings, committee members drafted a new section that satisfied them. This proposed draft still must be publicly reviewed and any comments studied by the committee; the committee must vote on any changes that might result. The committee is slated to meet in late March 1987 to do this. The final form is scheduled to appear in the new standard, to be published in 1988. For the proposed wording, see the accompanying article.

Sandvig, chairman of the AOCS Technical Safety and Engineering Committee from 1984–1986, also felt that one of the main points of contention with Section 1-3 was the definition of major modification. "On the committee, we spend a lot of time on the language of the standard," Sandvig said. "Clearly this section was a problem only as a matter of interpretation. Normally, operators of solvent plants like Cargill Inc. would consider the total process and the effect on other systems when a modernization change is made."

Sandvig said the NFPA 36 committee sometimes goes for two to three years without making a revision to the standard. "If there isn't a need or any issues pending, the committee might not meet for a year, but the committee meets more frequently when it actually is revising the standard." Sandvig said that because of the complexity of the standard-making process, it takes a number of years on the committee to understand what the committee is all about. "It's important to be on the committee for a time," he said.

Kingsbaker agreed. "The new member usually sits there and keeps quiet for the first two meetings, until he understands how the committee functions."

Proposed change

The following is the proposed draft of the paragraph offered by the committee to replace 1-3 Existing Plants, as shown on Page 36-4 of the current standard:

1-3—Application to Existing Plants

1-3.1. The provisions of this standard shall apply to all solvent extraction plants. Existing plants which conform to the NFPA standards in effect at the time of construction[a] may be considered to be in compliance with this standard provided that they do not constitute a recognized hazard to life or adjacent property as determined by the authority having jurisdiction.

1-3.2. Modifications shall comply with the standard in effect at the time of the changes. When modifications adversely affect the intended function or the adequacy of other systems of the existing plant those affected systems shall be upgraded consistent with good engineering practices and the provisions of this standard.

1-3.3. Modifications shall not be prohibited because of space limitations, provided the modifications comply with the provisions of 5-1.6.

In 5-1.6, line 3, change the word "section" to "standard."

[a] Refer to 6-1.1 for a list of NFPA standards, in addition to NFPA 36, which may apply.