SAFETY MANAGEMENT:

A CHALLENGE IN INFORMATION, COMMUNICATION, AND CONTROL

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Our concepts of chemical plant safety have expanded over the past decades from concentrating on the plant and its operation to the effects on the environment, and on nearby and even distant communities. Safe transportation and final disposition of products and waste materials, prescribed by law in a growing number of countries, have become the responsibility of manufacturers, extending their liability beyond geographic boundaries and stretching it over time.

Such broad areas of responsibility require over-all management control. To sustain it, management structures must be set up, activities precisely programmed, and contingency plans readied. For all of these activities information and communication are critical. They are tools to help coordinate people, equipment, and materials across great distances. This paper examines information and communication as tools that enhance safety management.

As industrial processes have become more complex and companies are carrying out global trade activities they must increasingly rely on the fast developing computer and communication technologies to maintain the necessary control. Industrial experience built up over the years, improved management tools, and insights gained from research in the social and cognitive sciences, all contribute to ensure that operations are safe, that people respond to the challenges of the job in routine situations and react swiftly to control emergencies. Some excellent work has been carried out in the chemical industries to make the work-place safer and the environment unpolluted. We have also progressed considerably in our understanding of the complexities of safety management. Yet, as Roger Batstone commented recently, we have reached a lowland plateau in the identification, assessment, and prevention of major hazards.[1]

Safety and emergency resource management is such an enormous challenge because it goes beyond process design and technology; greater consideration of human factors is needed but, even if better understood, this would not by itself be sufficient. In this paper when I refer to safety, I include human, material, and environmental protection and safety preparedness. References to management practices and community interaction are based on practices in the United States. Albeit there are significant differences between the Japanese management style built on consensus, and the U.S. pattern of management by directives emanating from the top, in reality, management of the best companies in the two countries also bear great similarities. In any case--whatever the culture, whether a company or a government department is involved--it is essential that feedback and evaluation capabilities be built into the system, and, most of all, that the flow of necessary data to those responsible for decision making be ensured and messages concerning required actions are signalled down the line.

Safety concerns arose gradually in organizations, touching on internal as well as some external operations, and becoming the responsibility of different units. Safety within the plant was in the jurisdiction of one group; process design was the responsibility of engineering; environmental and health concerns may have been assigned to different departments; and community response has become more coordinated only in recent years. A flurry of internal reviews and installation of additional safeguards follows each major industrial accident, as the list of disasters is repeated at professional meetings like a cadence of a mourners prayer. There is a need, however, for integrated safety management, and for making deliberate, well thought-out changes over time rather than reacting to major disasters with soul searching intensity. Unless management attitudes toward safety undergo a fundamental change, however, this pattern is bound to continue.

Information and communication are management tools that will enable better coordination. They have also been managed in a disjointed fashion in major organizations. Only with the development of powerful computing capabilities, improved telecommunication, reliable desk-top computers, distributed networks, and the availability of increasingly sophisticated software have steps been taken towards coordinating corporate information systems.[2] These developments, together with robotics and the new possibilities offered by the still unexploited interactive optical disc technologies, can provide opportunities to build a suitable infrastructure needed for better coordinated safety management.

It has been shown that major disasters had been the result of multiple small failures—of inadequate control. A change in conditions, in which failures are pointed up and then corrected at an early stage, can only be brought about by a changed attitude towards safety in the organization. Successful safety and emergency response management in a company is a major, expensive, and continuous effort. Therefore, it can be carried out effectively only if senior management is fully committed to it. Only such a commitment can create the climate that encourages concern for safety and consistent practices throughout the organization. Companies are putting great effort into training and taking a variety of costly safety measures. Nonetheless, in many cases they will only comply with explicit safety measures required by government regulations and, imposed more subtly, by the socio-political climate in the country.

In this paper I am suggesting the use of and development of an additional tool to tighten up safety and emergency management and build in preventive measures throughout the organization: an information/communication-check (ICC). Just as electric lines or the soundness of pipelines are checked out, the transmission of information and communication that affects safety can be checked out throughout the entire system. Just as energy audits were instituted in the United States in the 1970s to exercise control over the total use of energy, it is suggested to examine critically the breadth of information transmission and communication in all areas that might affect safety, health, and the environment.

The suggested ICC would be more complex by orders of magnitudes than the more straightforward electrical check, requiring considerable time, effort, and cost. An ICC could, however, be started in critical areas and then extend to others. Once set up, however, information and communication channels could be checked out regularly, gaps could thus be identified, and specific areas needing improvement pinpointed. If well done, feedforward and feedback could be ensured and evaluated. Whenever a change is made in operations, the information and communication components would also be reviewed, ensuring that they are properly connected up, and thus bring about a safer transition and reduce future risk.

The ICC would not be a substitute for risk or safety analyses or other measures for emergency preparedness. But examining the system from a new angle, ICC offers an additional mechanism for a more coordinated, tighter safety and emergency management. If a safety device were disabled, for instance, the ICC would point up questions must be raised, whenever there was no clear-cut response to a signal, or a need to install a secondary device. Systematic information/communication checks would also help the integration of safety management. Thus the resolution of questions raised by an ICC would do more than improve safety: it would also strengthen the overall management of the organization.

Based on experience in the management of corporate information resources, we know that tracking all information flows for all likely scenarios would prove to be too time consuming and therefore could not be carried out. To achieve the desired goals, however, ICC should be carried out for specific situations and should draw on the best available knowledge--on past experiences, understanding of processes and people, and also on recent research findings. I am also suggesting the separation of information from communication when carrying out such audits. For instance, in the case of an overheated pump, one should consider first what the contents of the message should be, who (or what equipment) should receive the signal, and then determine how the data should be communicated in order to elicit the appropriate response.

Control

Major accidents bring about soul searching, careful examination of current practices and often result in sweeping long term changes. In the United States the first major railroad accident became a turning point in safety management that brought about significant improvements throughout the industry. In 1841, two trains running on a single track railroad in Massachusetts, collided head-on. Two people were killed, eight were maimed, and nine others injured. With trains traveling at times at the "high speed" of 30 miles per hour, the magnitude of the accident created a public outrage. The investigation showed that the cause of the collision was failure of communication and insufficient programming. Plans for contingencies had been laid down but the various functions were not well integrated and lacked precision. To prevent similar accidents from happening in the future, the railroad's management devised the first extended industrial bureaucracy, instituted innovations in information processing and communication, and also established uniform procedures and contingency plans to exercise better control. As a result, railroad travel became relatively safe because of the new procedures and the coming of telegraphy in the 1840s, which provided the necessary control.[3] The small American railroad companies were then able to proceed to develop a network that ultimately opened up and helped conquer the American frontier. Similar crises in control have been the result of the Industrial Revolution, as Beniger points out.[4] Today we have immense companies and more complex processes. But we also have greatly improved equipment and powerful tools for information and communication and, in day-to-day operations at least, we are able to exercise better control.

Some people would argue that safety management is no different from the management of other projects. But this is not quite the case. Even if safety is incorporated into the goals and objectives of the company, it must adjust to the on-going activities within the organization, and the various areas within the organization are bound to be affected by the newly imposed concerns. Safety must not be an add-on project; it has to be woven into the fabric of ongoing operations. At the same time it must also have its own secondary structure within the organization with its own administrative staff, procedures, and subsidiary communication networks. Safe practices and processes must be fully incorporated into process planning and design, which adds an additional dimension to the work. For those who still consider safety as an add-on, incorporating it into all activities implies great expenses and sub-optimal operations; in particular, retrofitting a plant that has not been designed to operate under the safest conditions adds further complications.

The various attempts to quantify the state of safety, whether they are risk analyses, number of lost time accidents, statistics on material losses, mean time between failures (MTB) or accidental releases into the environment, do not measure the effort involved in staying alert to prevent those accidents or even the effort to change everyday habits and routine operations. Quantifyinf the combination of factors necessary to reduce risk or evaluation and training--especially the training needed to respond to emergency situations--is still rather fuzzy.

<u>Process engineering</u>. Design predetermines the inherent risk in a chemical plant. Albeit engineers intend to design safe processes, lack of knowledge,

cost considerations, or time pressures have often resulted in designs that were inadequate from the standpoint of safety and environmental control. With the changing societal expectations, however, consideration of these risks has become mandatory and has shifted the cost/economics factors coming into play when a process is being selected. From a safety standpoint the storage and transportation of the feedstock, product, and byproducts must now be considered at this early stage. Who can authorize and who can make changes in the process or in the equipment, and who can supervise repairs must also be determined.

A critical series of data to be collected during the design phase would be a listing of the assumptions of the designer about the process and the equipment specified. This kind of information is not now collected systematically. It is cumbersome to define fully; in the past it would have resulted in a maze of paper, making it difficult if not impossible to find the critical data when most needed. Desktop computers, cheap storage, good database-management software, and, the more recent optical disc systems make it easier to record the assumptions made during the design phase and to store them for easy retrieval. Such information can be useful years later, when, for instance a reaction vessel needs repair or when a heat exchanger is about to be re-used. Then the knowledge whether the equipment was expected to withstand 800°F or 1000°F temperature and 500 lb/in^2 pressure, will be valuable from a design as well as a safety standpoint.

To have a record of the changes made when a plant was put on stream or during operations would be most important for process design and engineering. Information of past experiences would also be useful in the development of knowledge-based or expert systems.[5] A database of mishaps and accidents would be useful in maintaining safety in the plant, and invaluable for process design. Records of "near misses," similar to those required for flight safety, would make such databases even more useful. Regrettably, however, the trend for suing companies has created such an adversary climate in the United States that companies are hesitant to expend the cost and effort to keep more extensive records only to leave themselves open to further lawsuits.

When ICC programs are initiated, the data elements making up such databases should be defined and their organization determined critically. To be truly useful, the database should contain all the information describing a unit and what was done to it during its history. Here again it would be important to include what the assumptions were at the time of repair (e.g. that the ambient temperature would not go below the freezing point, or that the pressure to which a pipe will be exposed would not exceed the type of welding done at the time).

A frequent cause of accidents is a "small" repair job, where someone wanted to fix a broken piece of equipment in a hurry to keep the plant running. To prevent careless and dangerous repairs, first of all, ways should be devised with the aid of computer graphics or interactive optical disc systems to make it easier for operators to record such changes. Prompts and menus could help in entering the information semi-automatically. Besides having the information about the repair available for review, the requirement to make a record will by itself make people more cautious.

An ICC would call for the planning and inclusion of feedforward activities at the time when the process or the plant is designed. Not only what information should be conveyed but also how it should be communicated should be a concern of the designer. But, as in other areas of information management, appropriate experts, such as experienced operators, human resource specialists, or robotics specialists, should be consulted to create the appropriate prompts and responses. To reduce failures and improve safety, interactive magnetic or optical disc based repair manuals could be built directly into control equipment. Thus, when in the future an indication that any part of the plant is about to be repaired is entered into the computer/workstation, appropriate warning messages, graphics, and minimum specifications should be displayed automatically. These would not only alert operators and engineers, but such communication would also aid and educate them at the time when they must act in a hurry but might not know enough about the process to make sound decisions. Such communication may be equally useful for less experienced supervisors who have to approve the completed work. Being in such an interactive mode operators could stay alert, receive prompts or further training on the spot if needed and would be helped in making sound decisions under pressure.

Communication and Information

Timely information transfer and communications links are essential to reach people at the appropriate level or for signalling to equipment. They are crucial for community emergency response, for large organizations in general, and for operations of complex chemical plants. To prevent accidents various scenarios must be considered. Several good methods have been developed, such as the hazards and operation analyses (HAZAN and HAZOP), which are most useful but not sufficient for safety management.

Through an information/communication check the control of operations would be extended. The information or data that must be transmitted would be determined more carefully together with the array possible responses, and how they should be signalled. Training, to be discussed later, is another mode of information transfer that should be examined critically.

The probability for accidents to occur is much higher at physical or divisional interfaces and must therefore receive additional attention. What information is necessary, how it should be communicated for each step at the time of startup or shut down, who must have the information, and who must be reached if the reaction gets out of hand should a major emergency arise, are some of the questions that must be asked, and would be followed up as part of an information/communication check-out. The ICC would thus call to attention to the need for more effective preventive measures, by forcing further analysis of unstable situations.

But an ICC should also consider the feedforward information needed. Moving backwards in time, for instance, some elements in the training of operators may be added as a result and a fresh look at testing the operators' understanding; the ICC should also lead to questions as to what knowledge supervisors should have so that they can critically evaluate and manage a potentially perilous situation. It should bring out discussions among those involved to determine whether additional warning lights, flashes, sounds, or images on the monitor screen would be most helpful for decision making and would most likely to elicit the necessary action. Such analyses, tieing certain situations directly to specific operations and actions that are to be carried out ahead of time and giving direction to activities that will be happening considerably later is a strength of an ICC, ensuring review and feedback.

Transportation of chemicals, another vulnerable operation, belongs to a different category, where an ICC will lead to determining more precisely the appropriate interaction with the community, the carriers, and organizations providing fast and reliable information about loads of chemicals en route. The latter has been enhanced in the U.S. by recently enforced laws and by the Federal Emergency Management Administration that reaches into communities and ensures regionally coordinated response to emergencies. In a country unaccustomed to centralized control except under war conditions, amakudari, a migration of officers from the military into civilian jobs provides needed leadership. With their training in decision making, communication and control, they can impose control on the structure and improve coordination of federal, regional and local action.

Information. An ICC cannot be suddenly produced for the entire organization but should be gradually developed and the loose ends tied down with care. More so than with other projects, external information must be gathered. Making it available throughout the organization is more important because much of the information is collected in different parts of the company.

Information on legal requirements must be gathered and data on compliance must be collected. For safety management, however, the professional staff must also be aware of the internal policy of the organization to know how to interpret the letter of the law. In case of partially owned overseas subsidiaries, for instance a determination will have to be made whether to operate according to local or domestic standards. Recently, when Beechnut, an American company built a baby-food processing plant as a joint venture with China, the company insisted following the product safety standards required in the U.S. Thus employees of the plant had to become familiar with standards that differed considerably from local practices.

Small companies often cannot afford information services that can compare with those of large enterprises. And some of the large companies are concerned how their small customers will safely dispose of hazardous chemicals. Small organizations, however, should be able to ensure that they obtain the external information needed for safety management. They can turn to their manufacturers association, government agencies, or professional associations for assistance. In several countries governmental or semi-governmental organizations can provide such support. In others, such as the U.S., small companies should also consider negotiating such support as part of the business contract they draw up with the large firms that are their suppliers or their customers.

The coordination of internal information needed for safety management is more complex because it is so closely tied to information resource management (IRM) in the organization, which typically is not well coordinated either. Similarly to general information resource policies, those for the internal information needed for safety management must be established. Databases must be made accessible across the company and be compatible with one another. Searching through relational databases, which would make such access possible, can be slow. Yet, to be truly useful, databases should be so organized to enable future users to analyze and correlate data in ways that were not expected when the database was first designed. These concerns are vital when considering information for safety management: today one of the problems of gathering data is that they may well be available in corporate databases but are buried because the databases had been organized to suit other organizational purposes.

Other practices gained from organizing corporate information should also be followed. It is essential that all groups affected by the data or have special expertise in areas related to safety, be involved in determining what information is needed, how valid data can be obtained, and what databases should be set up. Therefore, establishing a company-wide safety information committee would be most useful. This group would be different from but should cooperate with the plant safety committee. Its members should also include people from computing and others with technical knowledge of instrumentation; management participation is important; in addition, outside engineering contractors might also be called in, if their contribution would be relevant. Internal information issues should be determined by such a committee, which would be similar to other panels of data managers. The committee on safety information should be able to decide on the person who should be responsible for making changes in the databases, what response should be signalled, and in what form the data should be communicated--from failure prevention to emergency readiness. Some of the decisions would be detailed and appear minor, yet they can be critical to the company and the surrounding community.

Such detailed work takes considerable time and effort. It is costly, not only because of the expense of computing and control devices required, but because the best people, who can least be spared from their regular assignments, are the ones who should be involved in determining internal information needs for safety. Therefore, without senior management commitment, such a broad-based activity would not be possible. It seems to me that organizing such an effort is more difficult in the United States than in Japan, where management is based in consensus. Work habits differ. Even the way offices are organized in the U.S., where everyone works at his or her own desk, the people are not attuned for continuous personal interaction.

Still, just as safety can be built into process design, information support for safety management should also be part of a corporate information plan. That challenge, however, requires additional thought and careful planning. The technical developments in computers and optical systems, computer graphics, and personal computers, brought about a shift in the way information is managed in companies. How the information is organized and how fast it moves up or down the line to the individuals for decision making or action, however, is more important for safety management than in other areas of information resource management. Bureaucratic actions must also be translated precisely into the powerful computer programs governing emergency responses. Some of the safety and emergency response systems, carried out in a paper or microfiche-based environment, would not have been viable and would have led to a mire of paperwork. With compatibility of databases, connectivity of documents, and some use of knowledge based systems, better and faster access to the needed information can be provided throughout the company and even to the outside community.

Communication. Information is tied to decision making and to operations. When there is a deviation from normal, a critical factor in preventing major damage is a fast response to the signal received. Automatic responses, and the fine points of automatic control are being refined by equipment manufacturers. In safety management not only the content of the message but how it is transmitted can make a vital difference. The symbols and signals used, should depend on the specific situation. Clearly an indication should be given when a pump is overheating, for example; a more powerful indication, possibly some pre-recorded verbal prodding could be next. Such sequential prompting would cut down on the possibilities of the situation getting out of hand when an alarm would be needed.

Traditionally the choice in the way in which messages were communicated was fairly limited. Now a number of options are available, such as flashing lights, sound, prerecorded messages, text and images on monitor screens, in addition to people talking, instructing, or cajoling one another. Some control systems are superbly efficient. A well planned ICC would follow up on the effectiveness of the communication methods, would provide feedback for trainers and initiate evaluation of changed practices. If a database of past corporate experiences existed, pertinent information could be retrieved to help in the evaluations. Many options exist for data presentation, and are being used extensively. Data, for instance can be analyzed and re-formatted to make it more easy for an engineer to evaluate a process, or a manager to absorb the information. But not all changes are in the high-tech areas. Placement of gauges and signs in the plant, for instance, should be at eye level, be legible and be presented in a sequence that would be most comfortable for people. For safe practices, human engineering should also be considered in all instrument design.

To alert operators about an impending failure the information on the monitor can be a scheme of the equipment, a cartoon, a graphic interpretation of a complex analysis that was carried out automatically, or step by step instructions delivered through a menu. Troubleshooting can be greatly assisted by diagrams, and optical discs allow operators to "walk around" the plant, obtain information about any piece of equipment, and receive expert advice on how to repair or install it.

Memoranda are being enhanced by inserting computer-aided calculations; two people on different continents can recall the same graphics in order to consult on a specific problem. In case of an impending emergency situation voice instructions can be triggered automatically when warning lights start to flash.

Because safety warnings are at times ignored or overridden, an ICC should explore how often messages should be sent, what sequence of signals would be most useful. Sometimes people do not react "properly" to a warning signal. If it becomes obvious that their intuitive reaction is different, not only should the signal be changed but,as a result of an ICC, the training should also be modified. In some sensitive situations an information/-communication check can indicate that alternative signals are necessary when experience indicated was no response to warnings. For example, at this point certain decisions would have to be made how best to signal that high readings of a thermocouple should be investigated, whether it should be controlled by automatic sensors flashing lights, the use of luminescent paint on the equipment, or a foreman insisting that operators check out all possible causes before assuming that the thermocouple is defective.

Another concern that an ICC should address, is how often a message should be repeated as a reminder or for reinforcement. When are weekly reminders or monthly newsletters useful and when should a message be signalled when readings are outside a safe range? Will the intuitive reaction of operators to flashing signals be different from the prescribed actions? It has been shown that many accidents are caused by operators ignoring safety messages rather than not knowing about them. Some feedback mechanism should be established that would give an internal indication when people start ignoring safety related messages.

An ICC is not designed to differentiate between operator and management failures. The ICC is just a tool which will call attention to potential information and communication gaps that would endanger safe operations. An attempt to find answers to the questions raised should not be restricted to shallow changes in information transfer or modification of signals. The questions raised might lead to further examination of the cognitive issues raised by Rasmussen,[6] and to the exploration of how people are likely to react in a certain situation. A pragmatic ICC can also lead to the review of equipment design or even a modification of processes, thus, ultimately, bringing about safer operations.

Areas ripe for research will also become obvious after a thorough information/communication check. But even without deep research studies, some pragmatic tests can be run. At whom is the information aimed and is it communicated in the best possible way? Is it directed to the executive officer of the company or to operators? Did they understand the communication, how well did they absorb it, or remember it? Did they act on it, or would they act on it under frightening emergency conditions? Did they consider the message important enough to discuss it with others and make certain that others understand it?

So far I have discussed direct communication. But more subtle, indirect transmission of messages can also contribute significantly to safety management. Such subtle messages can emanate from the inherent culture, the attitude of senior management, perceptions of fellow workers, the effect of various training methods, and a person's own psychological and physiological constraints. All of these affect safety management and their effect cannot be easily quantified and might escape discovery during an ICC.

None of us, until confronted with another culture, is aware of the peculiarities of our own cultural orientation. Changes in formal communication can be effected by fiat, a simple decision. But changes are occurring in society. They come subtly and gradually, as sociologists in many countries have pointed out. The messages conveyed by a small community or by the corporate culture cannot be changed overnight. But it is possible to make deliberate changes in attitude. In recent years, for instance, a renewed emphasis on quality and reliability in American companies has also contributed to their safety.

The attitude of senior management towards safety management, as senior management attitudes in all other areas of importance, will be picked up rapidly by subordinates. There are stories in quite a few U.S. companies on how plant managers turned poorly functioning plants around and dramatically improved their safety records. They could accomplish this by being present at the time when shifts were changing, listening to problems, noticing spills and asking about them, and by discussing the technical problems and follow-up actions with department heads. Their attitudes were quickly conveyed to the middle managers and were carried through even faster when middle managers were held responsible for breaches in safety. A single manager was able to turn a poor plant around by creating an esprit de corps.

Coming into a new position, these plant managers stated that the plant was going to be improved and become a model operation, and then provided the necessary leadership. Administrative steps were taken, and existing problems were explored. Such managers can instill in the workers a pride in the plant, which then leads to their willingness to ensure the quality of their own work.

Thus management has many ways to turn attitudes around through its actions. If a chief executive officer or executive vice president demands to hear of any lost time accident, or middle managers then have to report on actions taken to avoid similar accidents in the future, the results will be visible and the message will be clear down the line.

Training is a crucial part of safety management and draws on all aspects of knowledge transfer. It involves everyone form operators to executives. The experience of motivators, psychologists, and educators can lead to more effective courses and development of useful training aids.

With processes and equipment becoming more complex, and in the U.S., the change to an increasingly multi-ethnic population, which may be less well schooled than earlier generations, training has become more important on the operator level, and for the university graduates, who need further practical training in the technical, administrative and management aspects of safety. Training must be carried out on such a large scale in multinational companies, that any efficiency that can be introduced without damaging the quality of training can save millions of dollars. Interactive videodiscs have shown themselves to be effective tools; in some specific areas they have proven to be as good as instructor based training. Since the number of good instructors is limited, and scheduling can be made at the convenience of the trainee, the popularity of interactive training is fast gaining support. Furthermore, if the course is well planned, the most effective training methods can be used in installations throughout the country, and, if necessary, modified to suit different physical or cultural conditions at plant locations abroad.

Whether operators get hands on experience or use simulators, attend classes, read notes, watch video tapes or participate in interactive computer or optical disc programs, is secondary to the message that has to be conveyed. No matter how it is delivered, training must be evaluated. Using more interactive technology, where objectives must be clearly determined to be effective, and testing can be built in, better ways to evaluate training effectiveness will be devised. In the case of safety, however, such evaluation may be more difficult: many who are perfectly capable of answering safety related questions will not necessarily carry over their knowledge into their daily activities.

Earlier in the discussion I mentioned that feedforward training should be initiated at the engineering design stage, and feedback at a point when equipment failed, an accident occurred, or repairs were needed. Training should be ultimately included in an ICC—not to devise courses, but to ensure that the proper interconnections are made and the feedback and feedforward cycles are properly attuned. Such information would also ensure that operators returning from a long absence or substituting temporarily in jobs with which they are not entirely familiar, will have the proper knowledge to carry out the job safely. Here too, interactive courseware can be well used.

As mentioned earlier, the subtle aspects of safety consciousness come from every area of work, should be, and typically are included in technical training, as well as the training for technical managers on the job. A young engineer, however, will not be exposed to safety management training during his university years. While safety will be mentioned in courses, the interest of faculty members lies in other areas of engineering and safety will rarely be taught as a major challenge to engineering and to good design.

Clearly, well run companies are carrying out excellent safety programs. These programs, however, vary greatly; every subsidiary has different procedures--with the critical proof being the absence or reduction of accidents, safety is one of the few corporate areas where no uniform procedures exist. The actual cost of safety training, very likely far exceeds estimates.

New activities, added benefits

At the very least an information/communications checkup should improve safety and emergency readiness of the plant. Improved methodology for safety management would be another benefit, as would be a greatly improved estimate of the true cost of safety training. A review and consolidation of ICC findings could enable senior management to obtain an integrated outlook of the state of safety and emergency readiness in the organization.

From a safety management point of view, an ICC would ascertain that communication channels are clear: that messages are communicated to people at the appropriate levels, with the appropriate timing and urgency.

With the kind of documentary backup an ICC follow-up can provide, companies will also be in a better position to advise manufacturers of equipment or software producers, explain their needs more clearly or suggest modifications that will make it easier to carry out safe practices. These changes might suggest changes in signals, in frequency, or recommend an automatic forwarding of messages be it control of equipment or messages up the line from operators to executives, from citizens to emergency response centers.

Such advice from an operating organization is especially important, because there are not enough programmers available in software houses who fully understand the technical as well as the human engineering requirements of an organization.

There are areas to which we do not have clearcut answers, and systematic work will have to be done to determine optimal situations. One of these is how to ensure improved safety through automation and still keep operators interested and alert to recognize unusual situations. Since their jobs can become less interesting the keenest operators might , and possibly be replaced by less capable people in order to save costs. While these people may be qualified to carry out daily operations, they may have difficulties coping with emergencies. Thus, creating interest in the task, which has become practically fully automated, is a challenge to operating companies and to the research community.

The findings of an ICC could be most useful for academic researchers--in part giving information to questions they may already have been asking, and, just as importantly, to raise questions in their minds that would lead to meaningful research. At this stage the research areas that would benefit safety management most have not yet been delineated. One of the fortuitous results would be some the cross-pollination of industrial experience and know-how with university based fundamental research in the technical, management, and cognitive sciences.

Conclusion

Safety must be built into process design, operations, and all other plant activities. The information/communication check discussed in this paper is a suggestion to carry out more systematically what is being done piecemeal in everyday practice.

An ICC can serve as a tool to conceptually integrate safety management throughout the organization, and emergency readiness with the outside community. The information and communication system supporting safety should ideally be integrated into the corporate information system, yet have its own character.

A major contribution of such an ICC would be to identify barriers, which can then be overcome. The checkups suggested will not solve the problems of safety and emergency response but will add another strong tool to insure that all that can reasonably be done to reduce failures and avoid accidents, will be done. The result will be a better managed safety and emergency response program, greater accountability by individuals, and, ultimately, a better managed organization.

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Safety Management: the Importance of Information, Cognitive, and Analytical Sciences

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The relationship of safety management, chemistry, and information science is symbolized by two International meetings that are being organized by Professor Shizuo Fujiwara, director of the Institute for Information and Knowledge of Kanagawa University, in Yokohama. The U.S.-Japan Forum on Safety Management (to be held November 10, 1987, co-sponsored by the American Institute of Chemical Engineers) and the International Conference on Information and Knowledge (November 11 – 13) will cover the topics in breadth and explore some of their fundamental aspects.

Laboratory chemists do not have to be reminded of the importance of safety or the increasing role of analytical chemistry in maintaining process conditions by monitoring chemical reactions, testing materials, or determining environmental effects. Control, instrumentation, and information are essential factors when attempting to

1) maintain desired (normal) conditions
2) monitor deviations to make it possible to take control before a situation gets out of hand
3) be prepared to react appropriately to totally unexpected events
4) be ready to take effective action if the situation should get out of control.

Information management has also been a continuing concern to chemists, who were the first scientists in the nineteenth century to establish an abstract journal in the field to gain control over the fast growing technical literature. With the emergence of new and improved information technologies, and work in the cognitive sciences, we have barely begun to grasp the close relationship of control, instrumentation, information, and human factors.

Safety management, which includes the laboratory or plant, as well as the total environment, offers a fertile field of exploration for information scientists. Information support for safety management must transcend traditional information work. Special attention must be paid not only to what information is transmitted but how it is communicated and how it is controlled. Thus information transfer for safety management encompasses the breadth of the field, from instrument sensing and robotics to knowledge transfer and training. Information must be transmitted in ways that individuals at various levels can absorb, remember, and act upon: information about the chemical reactions, instrumentation, about the need for safe practices, and what to do in emergencies. We are just beginning to take into account the cultural and social factors when considering both information and safety management.

Over the past century technology has become increasingly science driven. Yet only recently did we begin to use the findings of cognitive science, how the human mind works, perceives the world, and interacts with it. This young science, evolving through the consolidation of several disciplines, can provide a deeper understanding of the ways people categorize their experiences and sensations or how they might react in certain situations. Thus the insights gained through cognitive science can make crucial contributions to both safety management and information science.

Few areas offer challenges of the magnitude and variety to imaginative information management as does safety management, where practical experience, engineering knowledge and scientific findings must all be applied. Information must be sensed, transmitted, received, and interpreted, whether the communication occurs between objects——such as a pipe, a reaction vessel, or a heat sensor; at the human-machine interface; or, among people——be they operators, professionals, managers, or, in case of emergency, the governor of a region. The information activities might involve: instrumentation and control through robotics for mechanical sensing, encoding, and transmitting messages; training of individuals; or data collection, transmission, and development of a consensus to determine normal conditions in complex situations. Beyond paper-based information and direct personal communication, the advances in computerization on all levels, telecommunication, the availability of optical discs are tools offering a boundless variety of ways to provide information.

As a director of the Management Division of the American Institute of Chemical Engineers and vice chairman of the Information for Industry Committee of the International Federation of Information and Documentation (FID/II) these issues have been of particular concern to me, and to colleagues in both of these organizations and outside them.

New technologies and developments in the cognitive sciences compel us to take a fresh look at both the safety and information fields. We must re-examine what information should be collected, explore how it should be packaged and transmitted and test to what extent it is absorbed, remembered, and used. Better control to ensure safe processes, to protect people, property, and the environment, clearly, are challenges not only to scientists, engineers, managers, and environmentalists, but also to information scientists.

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