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CHEMICAL SESSIONS

TRAINING AND ORIENTATION OF CHEMICAL WORKERS

By CLAYTON B. HILL, JR.
E. I. du Pont de Nemours & Co., Deepwater, N. J.

The objective of my presentation is to present one installation's experience with the orientation and training of chemical workers, with special attention to their safety preparation. It has been said many times before that the responsibility for safety is a line responsibility. I would like to emphasize this in describing our procedures for receiving and training our new employees. I would like to stress the importance of total training. The greatest part of learning that any of us acquire is based on the example of our superiors, on the regular contacts we have, and most of us attend some meetings one way or another. We can't escape the importance of the routine day-by-day influence of the impact of these contacts. For this reason, in our orientation and training we involve the line organization in establishing the goals, deciding on the plans and organization, and conducting and evaluating the entire experience. It is not left to the Employee Relations Department or the Safety Department.

After the necessary screening and physical exams have been satisfactorily passed, on the first day that the new employee reports to the Employment Building, he is welcomed by a member of the Employee Relations Department and the necessary pass, time cards, and assignments are made. He is given a handout which contains a letter from the plant manager, a booklet for our plant, and *The Green Manual of Safety*. Also in the packet is an area guide for the first and 14 day orientation. While he is still in the Employment Building we provide him with a "New Employee Safety Training" course, which is a programmed instruction course developed on the Chambers Works to inform new employees of our safety policies. As he has completed the programmed instruction course, the area manpower coordinator meets the new employee at the Employment Building, escorts him to his area, and makes introductions to super-

vision and his fellow employees. In his area the first-day orientation is conducted by either the manpower coordinator or his supervisor. Some of the subjects covered are:

1. Introduce man to other appropriate supervision and fellow workers.
2. Explain his job duties and responsibilities; emphasis should be placed on the purpose of his job.
3. Introduce the Du Pont philosophy of safety (all injuries can be prevented) as a means for making all that follows meaningful for the employee.
4. Discuss the Chambers Works safety rules in detail.
5. Thoroughly discuss the area safety rules.
6. Explain the house safety rules.
7. Itemize the emergency signals.
8. Detail the evacuation procedure and point out the exact location of the rally spots.
9. Explain the fire protection system.
10. Demonstrate how to report a fire.
11. Point out location of fire alarm boxes and fire house.

Within two weeks his first level supervisor must see that the new employee has been introduced to higher supervision. He must have a safety review including the importance of off-job safety, and a further discussion of the job and his responsibilities. Within one month the first level supervisor must review all safety regulations of the company, works, area, and building; his function in the area; the raw materials and products of his area; and further explanation concerning overtime, time cards, rate progression, etc. At the end of 90 days, the fourth part of his orientation reviews the

general safety program as well as on and off the job programs. The disciplinary action and special contacts procedures are reviewed and the employee benefit plans are introduced in a general way.

Within the first month he attends a meeting in the administration building for a more complete introduction to the company and the works management. There is an address by the plant manager who welcomes them, makes comments on safety, and discusses career opportunities which are available. There are presentations on the organization and a discussion of the types of products manufactured at our location. He receives a booklet, "Welcome to Du Pont." During the next six months there are performance reviews scheduled at 30, 90, and 150 days. The purpose is to assist the new employee in getting off to a good start by evaluating all phases of his performance and to give him a further opportunity to ask questions.

Just before his one-year anniversary with the company he attends a chart presentation discussing the important features of Du Pont's benefit plans, with adequate time allowed for questions. He receives a copy of our Industrial Relations Plans booklet at this meeting.

All of these programs have been generated by our line supervisors. The foremen agreed that these were the items that needed to be covered, agreed on who would be the ones to cover them, and agreed on the content of the presentation.

Depending upon the direction of his work assignment (whether in labs, production, or engineering), he will have the opportunity to attend further training sessions to help prepare him to do an effective job. While our requirements have been for only high school graduates, as you can expect with the N.A.B. requirements, we have been hiring the disadvantaged and hardcore, and they have had the same type of training which I am about to describe. In developing a program for our laboratory technicians, again our first level supervisors, with help from the chemists under the guidance of the Training Section, developed objectives for our technician training program. One of our most effective tools is Robert F. Mager's *Preparing Instructional Objectives*. I can assure you that the first time that our team of

instructors approach the problem they do it with a great deal of misgiving, but after they have been through it once or twice they feel that it is an excellent tool which they can use on the job regularly. Our technicians have a program of 112 classroom hours conducted four days a week in the morning from 8-12. They return to their regular assignments in the afternoon and on Fridays. The content of the program includes: job definition; recording technology; mathematics; physics; chemistry; unit operations; laboratory equipment; and process and product development.

The team of instructors agree amongst themselves as to the content, the extent of the coverage of each of the items, and who will do the presentation. Lesson plans are prepared and the instructors dry-run the presentations within their own group before ever presenting it to our new employees. The program consists of programmed instruction, classroom demonstrations and, of course, learning by doing. The best advice I can give to management is to assign the questions to your team of instructors, define their objectives very clearly, and then step back out of the way. The props and aids which were used in our course were entirely self-generated by our team of instructors and evidence the kinds of ingenuity that are developed by such a team. During the course there is a coffee break each morning; there is ample time for the instructors to have discussions with the employees. Sometimes it is necessary for an instructor to do some individual counselling, since we do use testing throughout the entire program, either with the programmed instruction material or with classroom presentations. In addition, in the learning by doing, very often the testing is in the form of the kinds of demonstrations which the students can present in laboratory setups, bending of copper tubing, or setting up a pilot plant installation. These are the things which we expect the employee to be able to do. It is important to recognize their achievement; we do have a graduation ceremony where certificates are presented by plant management and the union officers. We must, of course, evaluate the effectiveness of our program and some of the comments have been summarized: He is more aware of what is going on around him—He is more alert—He shows more initiative—He has greater self-confidence—He now uses the slide rule

in his daily work—He is able to do more of the calculations involved—He is enrolled in a college chemistry extension course.

However, there are some additional benefits which these techniques contribute to the building of an organization. There are many pluses in opening the communications between the supervisors and the employee. There are many pluses in the development of the first level supervisors who use the know how which they have experienced on their job daily. There is a constant upgrading of the program, feeding new instructors into the program on a scheduled replacement

basis, and the introduction of new ideas and new lesson plans. There is also the benefit of the new employee feeling free to talk to his first level supervisor about any aspect of the job, so he knows he can rely on his supervisor to be concerned about his safety and his job performance.

The orientation and training of new employees is a line responsibility. We can't separate safety from the job; they go hand in hand. In developing a safe attitude in our employees, we are also developing an organization which can solve problems effectively both now and in the future.

THE HIPO-TECH METHOD

By WILLIAM W. ALLISON

Safety Consultant, Sandia Laboratories, Albuquerque, N. M.

Successfully used for over 15 years, the Hipo-Tech method has proven to be a predictive, professional method to analyze and eliminate both existing and future hazards to people and things—a total and logical concept that benefits employers, employees, and the public by eliminating the vital few hazards that now pose high potential losses of injury, damage, and liability.

Management urgently needs this predictive information that will eliminate the unpleasant surprises of serious injuries, property losses, and the product hazards that lead to multimillion-dollar liability suits. How can management have any opportunity to determine what actions are necessary and what priorities are required unless we provide this predictive information?

Too many people in 1970 are amazed when their new computer data shows that 40 per cent of their employees have 100 per cent of all the injuries or that only 1½ per cent have 10 per cent of all injuries. So what's new? Poisson figured that out many years ago with a pencil and paper! So it is called the Poisson distribution, which describes the probabilities of chance.

What is new, is that we've discovered many previously unrecognized ways in which the dice have been loaded (inadvertently) so that probabilities of chance human errors have been greatly increased. So it is now

more likely that 1½ per cent may have 20 per cent of all injuries, 10 per cent may have 70 per cent, and only 20 per cent of the people may have 95 per cent of all injuries. Among other things, the technical and economical control of hazards helps us to recognize and eliminate those loaded dice which increase the probability of major injuries and damage.

Today we are bombarded on every side with pressures to use the new, the modern technologies and techniques. I am wholeheartedly in favor of new and better tools. Perhaps we should pause and be reminded that in 1700 Ramazzini, in his historical work, *Diseases of Workers*, advised that the following techniques would protect the worker: "ventilation, personal protective equipment, isolation of processes, heat shields, selection of safer materials, rest periods, and selection of workers."¹ And Ramazzini made respirators out of goat skin to protect against lead poisoning back in 1700.

Let us constantly recall the fact that without benefit of computers and other modern tools, this man's wise and discerning observations revealed remedies that are today's modern professional guidelines. We dare not lose sight of the fact that modern-day computers and instruments are merely fancy calculators and tools which cannot

replace the penetrating observation and judgment which only the human mind can provide.

Heinrich, in a large insurance company headquarters in the late twenties, applied the computer of his day (the calculating machine) to the large mass of injury data available to him. He arrived at some impressive conclusions based mainly on the only data available—injury data. Two generations of safety engineers have been taught on the basis of injury data as seen by a calculating machine or a computer—85 per cent of all injuries are caused by unsafe acts of persons—because that is the raw data we feed into computers based on less than two per cent of all accidents.² However, Heinrich did some investigative and followup analysis, probing specific accident cases and their causes. From that work, he made the astute observation that there was often a misdirection of effort and research when based on recorded injuries rather than on accidents and their causes. Dr. W. P. Yant was more specific in his observation that there frequently was no relationship between the apparent causes of injuries and the actual causes of accidents. Dr. Yant further observed that real accident causes were often remote from the scene of the injury; i.e., the real causes involved design, fabrication, specifications, etc.³

But, since there were no numbers readily available to feed into a calculator or computer, this idea has faced an impenetrable wall of resistance. Neither Heinrich nor others have seen how to free themselves or us from the inherent fallacies of the relatively easy-to-come-by injury data.

The Hipo-Tech method was developed and is practiced on the basis of discerning observations and good judgment. It is, in other words, both a professional and a practical nuts and bolts method. An understanding of the method enlarges our concepts, increases our knowledge, and improves the astuteness of our observations.

Hipo-Tech Steps

There are some eight major steps required to achieve technical and economical hazard control. Two of these are basic to all others.

1. The first of these is attitude; that is, the mental position with regard to the fact that accidents are caused. Only when we accept the fact that accidents are caused can

we successfully learn the real causes and understand how they can be controlled by management.

2. Secondly, we must acquire a greatly improved and expanded knowledge of hazards. We will all agree that the thousands of children who were seriously cut by running into fashionable glass doors did not have any knowledge of the hazards. The women painting radium dials in factories during World War I certainly had no knowledge of the cancer hazard they were exposed to, suffered, and died from. Today, how many managements, supervisors, teachers, purchasing agents, and engineers (the millions of employees and college students) are knowledgeable about the deadly hazards of such very commonly encountered materials as carbon tetrachloride, carbon monoxide, nitrogen, carbon dioxide; or such deadly hazards as the lack of a lower limit switch on an electric crane; the lack of an overhead guard on a forklift or the need of such a guard to resist failure under at least twice the weight of the forklift; which two of six Coast Guard-approved life vests float the victim face up rather than in the deadly face-down position; which roach poison contains thallium for which there is no antidote to save a human life; or which gas mask won't support life in either a heavily smoke-filled room or a carbon dioxide-filled tape storage vault, etc.?

3. Only with the proper attitude and knowledge can we approach the problems of designing, procuring, installing, and building safe facilities that are not literally booby-trapped with designed-in or built-in potential accident situations. With a good knowledge and an aggressive utilization of human engineering,* industrial engineering, and material-handling engineering, we can design safe facilities so that people can use, operate, test, maintain, and service them without constantly facing the multitude of booby traps that now literally beset every human activity. When all the hazards are designed out, we will then be able to determine which accidents are caused by unsafe acts or faults of persons.

*The term "human engineering" has two almost opposite meanings. I will be referring to the science that deals with the design of mechanical devices for efficient use by human beings so they match human capacities and limitations.

4. With knowledge of toxic, anesthetic, asphyxiant gases, fumes and dusts, of noise, lighting, etc., we can design and provide a safe environment. Occupational environmental hygiene engineers provide this knowledge.

5. With knowledge of human engineering, safety engineering, and industrial engineering we can design and provide safe, efficient tools, equipment, and machinery.

6. With increased knowledge of hazards, we can explain why we must develop and follow safe procedures. Then, by communicating knowledge of hazards, we will find an amazing increase in willing cooperation of the employees and all other users of the designs of engineers, architects, and scientists. Furthermore, such intelligent and thorough communication of hazards will stimulate and encourage a tremendous contribution toward improved design and greatly improved safe procedures from that generally untapped and immense reservoir: the knowledge, experience, and practical intelligence of employees.

7. There are relatively few plants which approach the reasonably attainable maximum in hazard control. Some of these award liberal prizes of cash for suggestions, but not all of them. The one thing that these plants have in common is the willing and open recognition of the worth of the individual employee's ideas. To consummate that reasonably attainable maximum of hazard control, this reservoir of valuable knowledge must be fully utilized. This may be done, for example, by means of such well-developed programs as the nationally recognized "Suggestion Systems" or Error Cause Removal. It can also be done informally in some circumstances over the phone and out on the job. The degree of our success depends on the degree of our willingness to accept and value the individual employee's ideas.

One can be assured that few high potentials will ever be reported if the reaction to employee reports of hazards is anything like this: (1) Employee reports a hazard; (2) Safety calls his superior and says, "We just had a report from your man, Tom Jones, who claims you are overloading the crane." If we really want to know about high-potential hazards and to be able to correct them before tragic accidents occur, we must have the integrity to respect the

trust which an employee shows us. Isn't it worth getting out of the chair and wandering into the lab or shop to see for ourselves if a man's life may be at stake? We certainly cannot expect to see the occasional but nevertheless extremely dangerous situations that do occur at normally unobserved times and places.

It is not a matter of catching someone; it is a matter of managing to identify and locate the very situation that will otherwise eventually surprise us with a major loss in health, sight, limb, life, or facilities. An apparently smooth operation often only reveals its real hazards at moments we might never observe ourselves.

8. Urgently needed is a logical, practical, and proven economic and humanitarian method or guide to separate the wheat from the chaff or the important from the unimportant. How can we most efficiently and most effectively utilize the knowledge that accidents are caused and can be prevented; the expanded knowledge of hazards; the human, industrial, and material-handling engineering know-how for safe facilities; the hygiene engineers know-how for safe environments; the human engineers know-how for safe tools and equipment; the communication of hazards; and the employees' know-how?

We can best prepare ourselves to do this by fully digesting two little-appreciated facts:

First, there already exists a management tool to readily measure safety performance results in clear and readily audited methods. It is a realistic measure of performance common to all—the direct cost of compensation plus medical treatment per \$100 of payroll. Every company already has such cost data. Its conversion to a cost rate based on payroll is straightforward and tends to balance or adjust itself for variances of costs in different areas. As the president of Briggs Transportation Company emphasized in a recent article, "A company's safety program can be measured more accurately by its accident and injury costs than by the number of trophies or plaques in its lobby." Certainly, if we are to make any real progress, we must take a hard look at the tangible results of hazard control to date.

Using this measure of performance in an actual experience with the high-potential

method with a 6,000-employee group over a 10-year period, the high-potential method did foresee and prevent tragic injuries before they occurred. The Hipo method also resulted in reducing compensation costs to a low of one cent/hundred dollars of payroll compared with a corporate average cost of 29 to 39 cents/hundred dollars of payroll. This, mind you, in a corporation with one of the best safety programs and lowest frequency rates, the Westinghouse Electric Corporation with over 100,000 employees. In terms of dollars of cost, this actually involved a direct cost for medical and compensation alone of two million dollars to the corporation, deducted directly from profits.

The record shows that in that division with the best hazard control, the actually expended dollars were only one cent/hundred dollars of payroll compared to the overall corporate costs of 29 to 39 cents. So, the actual record proves that with the best hazard control, average costs were only 1/29 to 1/39. For easy computation, let us say that this equals 1/30 of \$2,000,000 or a mere \$66,000. This \$66,000 is all the total corporate costs would have been if their cost rate were as low as the cost rate of the division with the best hazard control. So a direct savings of \$1,444,000 is obviously attainable by means of the Hipotential method, the method used by the division with the one cent/\$100 of payroll costs, the Bettis Atomic Power Laboratory.

The second little-appreciated or known fact is that, out of any large number of accidents that have resulted in reported injuries, it has been shown by several independent studies that only two per cent of all (reported) injuries account for over 80 per cent of all costs. I had come up with data showing that only two per cent of all reported injuries and only two per cent of all accidents had any causative relation to those high-potential cases of major cost, injury, or damage. Subsequently, I was advised that Gordon Lemke (Mutual of Wausau) had come up with 33 per cent of all compensation cases, accounting for over 94 per cent of all costs. It happens that 33 per cent of all "comp" cases equal between two per cent and three per cent of all accidents. With a much smaller number of cases, over 70 per cent of the costs arise from only two per cent of the cases at Sandia. In the

August 1968 issues of *Safety Engineering*, Harold O'Shell states that, "One specific study involving 400 locations showed that one location was responsible for 37 per cent of the total losses for all 400 locations. Only 11 locations accounted for 80 per cent of the total injury experience." (When we divide 11 by 400, we see that between two per cent and three per cent accounted for 80 per cent of the total costs.)

I am reasonably sure that we would find these eleven locations also represent about two per cent of the cases which account for 80 per cent of the costs. So if we accept the premise that important things—that is, major injuries and major costs—should come first, we are faced with the problem of how to recognize the important hazard-control items before they become tomorrow's major injuries, major damage, or major cost items.

The Hipo-Tech method has successfully recognized and foreseen these major cases. It is now being taught, in part, in several universities including New York University, Brown University, and Oklahoma University. It is being used with many variations in dozens of companies. Yet, the method has not been at all understood by some and not fully understood by many.

However, changes are not only in the wind, they have and will continue to occur at an accelerating pace. Liability claims are rapidly increasing in both numbers of claims and costs of claims awards. All will soon find the economic necessity of devoting 80 per cent of thought, effort and money on designing hazards out of their every design and of devoting the remaining 20 per cent to clearly communicating both the knowledge of the hazards and of the safe procedures required for total hazards control. Liability awards, already as high as one million dollars each, will soon force this radical change upon all of us.

Where did we get confused and so far off the track to hazard control? At fault is the engineer's concept of man as a servo-mechanism or a computer with certain kinds or amounts of input resulting in certain amounts or kinds of output. Of course, the psychologist had his chemical and electrical scientific lab work to add to this concept and lead him off into the wild blue yonder. Even our newly developed systems engineering literature reflects these er-

aneous concepts. Less appreciated is the fact that the most extensive research work done to date has failed to show its practical application.⁶ One can program what a man did yesterday, but not what he will do today or tomorrow.

The basic problem has been and is the failure to realize that everything, no matter how automated, is designed for man's use. So the designer must recognize and design compatibly with that already fixed but nevertheless variable design of that most important component of all systems, man. If any design is to work effectively and result in a useful system, the designer must design for the total man-facilities-tools-environment system. He can no longer blame the nut behind the wheel for the chrome-plated spear that designers once produced as car steering wheel posts. He can no longer escape either the moral or legal responsibility for his designed-in hazards that permit any vehicle to be started while it is in gear, when a \$3 solenoid in the design would remove this high potential hazard.

Let us examine the man-facilities-tools-environment components of all equipment systems. Too many designers conceive a hazy picture of an equipment system and some of the required tools, subequipment, and machinery. From this, they too often proceed to "fix" a design. We all know how impossible it seems to be to change any design once it is fixed. They build this marvelous and very costly thing, squeeze it in, and bolt it to a facility. And every facility has an environment. It is ready to go.

You may ask, "How are men going to get in to operate, to adjust, to service, to use, and get a useful, economical function out of this costly system?" A designer might reply, "What's wrong with your outfit? Can't personnel find men that can fit a job?"

In reality, no one can. It is really impossible to stretch a man, or to shrink him, or put arms out of his back, or eyes on top of his head, or give him a third hand. So how should one begin a design?

One should begin with man, that already fixed-design component, and then design around him.

Equipment systems include: for example, airplane, crane, kitchen stove, lathe, fork truck, computer, motor vehicle, etc.

Facilities include: clear and adequate or obstructed and inadequate work area; work surface and access to install, service, repair, operate, deliver and remove the work to be done, the finished work, and the scrap in all of its forms.

Environments include: ventilation, lighting, heating, noise; toxic, irritating, caustic, acid, obnoxious, or distracting fumes, dust, noise, light waves, radiation, radar, ultrasonics, wind, rain, cold or hot temperature extremes and their effect on work space and on design of controls.

Tools, subequipment, and machines include: knives, pliers, cutters, riveters, saws, electric drills, or grinders, etc.

These components, man-machine-facilities, and the variable environments encountered in actual use by man, are both so complex and yet in a sense so obvious that they have, in the past, literally been ignored by designers and psychologists and systems engineers. For example, despite three space-chamber high potential fires prior to the Apollo disaster, the design and systems engineers continued to rely solely on the human skills of man to avoid the obvious flash-fire hazards. Historically, the engineer's predominant attitude has been to concentrate on making designs which had mechanical and style appeal and let "safety" worry about those who could not avoid getting injured with the marvels the engineers created. After all, what were safety engineers supposed to be doing but conquering the 85 per cent cause of all injuries—unsafe acts of persons?

Unfortunately, most present-day hazards are literally designed into products because of the above attitude. If every design engineer were required to serve a year's apprenticeship in the actual field operation and maintenance of his designs, the safety and efficiency of designs would leapfrog ahead two full generations in only two years. Some of us realized this in the chemical industry nearly 30 years ago, and demonstrated these design concepts in plants such as the Koppers Company Chemical Division's plant. Subsequently, the same concepts dominated the Westinghouse Electric Corporation's Bettis Atomic Power Laboratory. In both cases, the savings in lives and money have been outstanding over all their years of operation. One of the most recent of all-out safe designs is the Norair Plant of the

Northrup Corporation in Torrance, California, where 80 per cent savings in compensation costs are being realized. An Alcoa Plant with an all-out safe design has also experienced both lower production and lower accident costs over its approximately six years of operation.

The hundreds of people who have already emerged alive from totally demolished new-model, safety-designed automobiles, should convince everyone of the real needs for all-out safety design for all equipment, tools, machinery, and facilities.

All equipment should be designed to fail-safe; and it must, for maximum effectiveness and usefulness, be designed so that it is compatible with the human user, that already designed component of all equipment systems. The practicality of the fail-safe concept is perhaps best illustrated, on the negative side, by the numerous fatal electric shocks despite three-wire grounding; and, on the positive side, by the fail-safe solution so dramatically achieved by the double-insulation fail-safe design of portable electric tools.

There is really nothing mysterious about high potential. There is, however, a real mystery involved—the mystery of why the safety movement in general is so persistent in teaching everyone to see through filtered or dark glasses. Through slides, films, posters, safety-subsidized psychologists and motivators, they insist that we must not see clearly, as a child, but become a man and see as through dark glasses.

The psychological motivators, the human relations experts, personnel, and executive safety leaders, the zero defects advocates, and so many others see, in safety films and in their plants, "Horseplay Harry" or "Careless Carl" and the need for safety consciousness on the part of the operator, and his foreman, too. They see the need to train and, if necessary, to discipline "Careless Carl" to try harder to be safer. Some clinch this problem to their satisfaction by adding, "and 'Careless Carl' should be trained not to use a lift truck for high loads unless he uses an overhead guard."

In the concept of the high potential technical and economical control of hazards, the very same scene means something very different. It means that here is a very high-potential, accident-prone situation that will

lead to a fatal or crippling injury. It means that here's some guy trying to do a job to earn a living. He is using the equipment which his employer specified and provided him. This lowly operator doesn't specify what equipment or facilities the company's talented engineers specify and provide for the job.

Such a scene also means that we have a question we must ask the responsible manager, engineer, psychologist, training and safety director: "If your son happens to be assigned to operate a forklift truck, which would you prefer that his employer do—install adequate overhead guards or depend solely on training to prevent or remove this common cause of fatal and crippling injuries?" If the responsible manager insists that there are guards on some forklifts and the man knows he is supposed to use one of them, there is a final question to be asked: "Will you guarantee, in a pinch or when a very important shipment must be rushed through, that no foreman will, under pressure, order an operator to use a readily available forklift which does not have an overhead guard?"

There is nothing mysterious about high potentials. The Hipo method starts and ends with emphasis on the real hazard-control point—the situation before any major damage or injury occurs. It emphasizes the control of causes of accidents as contrasted with after-the-fact injury-oriented safety programs. It is now obvious that, with 80 per cent of the emphasis on Hipotentials, the utilization of safety engineering can readily and permanently remove hazards such as the forklift overhead and the front loader starting-in-gear Hipo accident-prone hazards. The high-potential situation hazards control method provides a realistic picture of the true hazard problem areas. It provides guidance and direction to effective hazards control.

But exactly how do we recognize high potentials before tragic accidents occur? We can do it generally by considering what will happen if this or that conceivable unsafe situation develops. In other words, by asking "What if . . . ?"

More specifically, Hipo's are determined by asking: Can this situation, incident, practice, procedure, or process lead to a fatality

or to serious damage to health, sight, limb, equipment, or facilities under similar or possibly different circumstances or possible changes in the existing situation? Changes in timing, distance, or sequence of events. Changes of environment such as temperature, sun, storm, or soil conditions. Changes in materials such as compatibility, corrosion, wear, evolution or residue of peroxides, conductivity, or strength. Changes of personnel who will vary in height, weight, experience, age, strength, sex, specific training, or habits established on different types of equipment. Changes of equipment with different operating characteristics, controls, etc.

Failing to ask these questions is like playing Russian roulette with hazards. However, when we do conscientiously ask and answer such questions, we can thus be forewarned of the future's tragic accidents, and we can prevent them by concentrating on Hipo situation hazard control and corrective action before crippling injuries and major damage occur.

The high potentials indicate both the problem areas and the problems. Combined with a judgment analysis of facilities, this provides the safety department and management a realistic picture of the true hazard problem areas. It provides guidance and direction to effective hazards control.

The high potentials are a small sample—but a sample selected by the use of good judgment—as those few which are truly significant cases because they forewarn of impending tragic injuries and losses. For example, in a 7,000-employee plant, we typically have only nine known high-potentials to concentrate our real efforts on. Only nine for a 7,000-employee corporation, instead of the 290 minor injury total or the 148 minor injuries in the three divisions with the most minor injuries.

In comparing the old standard method and the Hipo method, when the same experience is reflected for the same month we get conflicting results. The Hipo method produces a true hazard analysis that almost totally refutes the Standard Injury Report findings. On the front and back sides of a single sheet, an entire month's report of the significant data and a concise report of each Hipo accident is covered. The Delta Drilling Company reduced lost time injuries 85 per

cent and costs 58 per cent. Thiokol used a single sheet to summarize their Hipos the first month they reported them.

To give only a few examples of thousands of high-potential situations today and the price we pay for them: thousands of persons each year die with a very clear imprint of the designer's steering post in their chests. (An orthopedic surgeon told me he could usually identify the car just from examining the injured.) Hundreds each year are crippled or killed when scaffolds fail. Hundreds die from inadequately shored excavations. Thousands are crippled from the almost total lack of understanding and appreciation of the high-potential, accident-prone situation concept on the part of the designers in regard to just electrical and material-handling equipment.

I have emphasized attitude and increased knowledge and communication of hazards. Then, I especially emphasized safe design because we can achieve permanent and almost unlimited improvement in the control of the high-potential hazards, through physical improvements of tools, equipment, facilities, and environment.

Safe design is the basic element required to permit positive control of hazards. But, we must first have improved attitude, knowledge, and communication of hazards. Then we will find it relatively easy to understand and be fully aware of Hipopotentials and how to remove their causes through safe design combined with safe procedures.

Then we will find a ready awareness of Hipos, such as the perchloric acid bottle placed beside the bottle of alcohol (or any other organic); chemical splashes that just miss your eyes; the partition or the overhead fixture that falls when no one is present; the acid line that leaks; the distillation that flashes on a hot plate; the reaction that blows up inside a hood and hurts no one; the "proof" of an oven or reactor; the wire rope or chain that breaks; the heavy load that tips; the object that falls from above—all such "incidents" are high potentials.

You can save lives, limbs, sight, money, and even your place of employment by a little extra job planning and a little more thought about the fact that, before a tragic accident occurs, there are about 14 incidents with a capability or high potential to maim or kill. Unless we recognize and report these no-

injury and no-damage Hipos, we can be the surprised victims of tragic accidents.

The employees, first-line supervisors, and in-plant safety engineers are already aware of the high-potential near misses and situations. Unfortunately, safety contests, standard reporting methods, and our own programs and emphasis have effectively discouraged reporting high potentials. We have inadvertently taught too many supervisors (and employees) the wonderful saving grace of burying the mistakes, the close calls, the high potentials. Until management reverses this and insists that everyone devote their major efforts to these high-potential situations, we will continue to be surprised by tragic accidents and to be trapped by the overwhelming emotional and other pressures to write and publish defensive reports. We will continue to waste our employer's money and our fellow man's health, sight, limb, and life.

We now have a time-tested and proven method which gives us the means to foresee and prevent tragic injuries and losses before they occur. We can now reduce by at least 50 per cent present loss costs of hundreds of thousands of dollars in each of the thousands of small facilities and up to several million dollars in each of the hundreds of large corporations. These savings will be added directly to dollars of profits. These are not the intangible nor the indirect costs discussed in the safety literature. These are the real dollars that every business reflects in its annual profit and loss statement.

The 85,000 crippled, the tens of thousands who lose their sight, limbs, and lives at work each year are not just statistics either. So let us meet the challenge and start taking the eight steps to the Hipopotential technical and economical control of hazards.

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THE DIFFICULT INSURANCE SITUATION IN THE CHEMICAL AND PETROCHEMICAL INDUSTRIES

By W. H. DOYLE

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Why the insurance "crunch"—the inability of certain insureds to buy complete fire insurance protection? Some people don't want to buy insurance coverage, they want "maintenance policies" that will completely relieve them from any financial loss caused by inadequate research, design failure, poor construction practices, poor metal inspection

programs, operator error, etc. Others want insurance companies to agree to pay potential losses beyond reason in size. To both requests, the answer is very simple: the insurance companies can't make money filling these particular demands.

The reason the companies cannot make money is that insurance is based on averages.

There is no "crunch" in the life insurance industry because the answers can be figured out statistically; the average person eventually dies. Fire insurance is basically different, since the average insured risk does not go for a total loss.

The short course in the basics of fire insurance will now come to order. Since it is a short course, I will have to make some dangerous oversimplifications.

The function of fire insurance is to spread the risk equitably. This means high rates for high hazards and lower rates for lesser hazards. If adequate statistics are kept, it should be possible to adjust things in order to make money in the future on any class of risks where past experience is known. The important features of past experience are the average loss, loss frequency, and the largest loss. All of these must be examined thoroughly on an annual basis to see if any one shows any perceptible trend. Unfortunately, so far as the insurance companies are concerned the chemical industry is highly innovative, with the result that the risks for which there are careful and detailed statistics on past performance are often completely different by the time the past performance receives adequate analysis. This problem can be overcome by putting in a lack of knowledge factor, which probably should be exponential. A year or so ago, an insurance company president expressed this by saying: "Today, if you are 20 to 30 months behind the times, you are further behind than your dad was when he was 20 to 30 years behind, and your grandfather if he was 200 to 300 years behind."

Now, we must consider the individual insurance company. No well managed company will commit more than a very small part of its reserves to any single risk. Companies vary widely in size and differ in philosophy, but we will assume that an average company is willing to lose \$50,000 on any single risk. To write a \$500,000 policy requires ten companies, \$5,000,000 requires one hundred companies and \$50,000,000 requires a thousand companies (with a thousand policies and two safes for the buyer to store them). Some time ago, this particular problem was solved by organizing groups of companies. A formal group of one hundred companies with the same \$50,000 individual limit could write one \$5,000,000 policy with no problem. Following this approach further, a pool of fifty

companies could write a \$5,000,000 policy if each company would commit itself for \$100,000, \$25,000,000 could be written on a one-half million dollar average commitment but a \$50,000,000 policy would require a million dollar commitment per company. While there are several companies in the United States with the capacity to make such a commitment, their number does not total fifty. Since insurance policies for more than \$50,000,000 are written with some degree of frequency, we should next look at the technique involved.

First, the \$50,000,000 policy may be written to cover more than one risk. If we have one \$25,000,000 plant in Hartford and another in Chicago, the \$50,000,000 policy actually covers two \$25,000,000 risks and a \$500,000 commitment from each of the fifty members of our mythical pool is adequate.

Next, we can get automatic fire protection in the way of sprinklers, or more sophisticated and more expensive substitutes, automatic fail safe process controls, or house a low hazard process in a fire resistive building and anticipate reasonable success in getting the individual half million dollar commitment increased to a larger figure.

Third, we can make use of the probable maximum loss technique. At this point, I must give some highly specific definitions of terms that are valid for this presentation but which may be used differently under different circumstances.

Normal probable loss; this assumes that some sort of an accident, usually a fire, occurs and that all of the protection built into the plant functions properly. An example might be a fire in product storage in racks 50 feet high but with protection provided by ceiling sprinklers, intermediate sprinklers, and a large assortment of fire pumps. Since the sprinklers will probably not operate until the fire has spread from the floor to the roof, a normal probable loss might be as much as one-half million dollars. The Manufacturing Chemists Association has just published *Guidelines for Risk Evaluation and Loss Prevention in Chemical Plants*. In this publication, the term "maximum probable loss" is used to mean what I have defined as the normal probable loss.

We now come to what some insurance people regard as the maximum probable loss. Staying in the context of the 50 feet high rack storage, we assume that one of

the sprinkler systems is shut off. Under those circumstances, the stock protected by that particular sprinkler system will be a total loss and, unless the water supplies are exceptionally heavy, all of the stock in the warehouse may be involved since the heat from the uncontrolled fire will overpower all but the strongest water supplies. The MPL estimate, assuming \$5,000,000 stock contents, might well be \$5,000,000.

We then come to the concept of maximum possible loss for which there are synonyms, such as maximum foreseeable loss and Armageddon. Here, the total failure of the rack warehouse ruptures the underground mains, putting the water supplies out of service, breaks the fire wall separating the warehouse from the rest of the plant, and the resulting large fire burns so fiercely that the fire storm involves all of the outbuildings as well.

Maximum foreseeable loss also includes such things as the explosion of two shiploads of ammonium nitrate in an adjacent waterway à la Texas City, April 16-17, 1947.

General insurance industry practice is to operate on the concept of the maximum probable loss, as I have defined it, for each individual risk covered by the policy. As an illustration, a \$50,000,000 plant might be divided by an interstate highway so that no portion of one was nearer than 100 feet to any portion of the other part. We would then have two \$25,000,000 risks, and if our probable loss estimate on each were 40 per cent, we would have a maximum probable loss of \$10,000,000. Our mythical fifty company organization would foresee no real problem in insuring such a risk, but it would be relying on someone's judgment that the maximum probable loss for each part was not greater than 40 per cent, and it would be relying on the assumption that an accident in one risk would never spread across the highway and involve the other. To protect against such a contingency, the group might follow a design engineer's philosophy, apply a factor of safety of four, and buy reinsurance to cover for \$40,000,000 above and beyond the \$10,000,000 that is the maximum probable loss that might be paid by the group.

This is the end of the short course in insurance.

Now, we have a potentially profitable business on the premises that [1] we have

separate risks, [2] they are protected risks, [3] they have reasonable maximum probable loss potential and [4] reinsurance has been purchased to take care of the unthinkable errors in judgment and the unforeseeable circumstances that lead to an excessive loss.

I have spent forty years in the insurance business. I have always worked for an insurance organization not unlike the imaginary one just described. It is only within the last few years that circumstances have forced me to do a little re-thinking about our fool-proof system of operations because, as it has turned out, it is not that foolproof after all.

Let's go back and look at the four basic procedures or assumptions that permit the writing of a large insurance policy. When we examine the concept of separate risks, we run into the problem of the hurricane where risks several miles apart may be severely damaged by the same storm. I have mentioned the explosion of two ships containing ammonium nitrate at Texas City. There, not only was Monsanto Chemical damaged to the tune of approximately \$18,000,000, but there was tremendous damage to the town itself and to adjacent oil refineries, a grain elevator, etc.

Next, look at the practice of estimating a lower maximum probable loss on a property well protected by automatic sprinklers, etc. as opposed to the same property lacking such protection. In 1969, I gave a paper at the meeting of the American Institute of Chemical Engineers in New Orleans analyzing the FIA five-year record of chemical plant losses larger than \$100,000 each. This showed that out of eighty-three losses, 53 per cent of the number and 68 per cent of the dollars paid out were because of explosions rather than fires. Obviously, sprinkler systems and water supplies are not much of a factor in minimizing explosion losses. Maximum probable loss estimates based on fire are seldom reached because, under fire conditions, private fire departments, public fire departments and plant employees do tremendous work in cutting down the size of the fire even under adverse conditions. Explosions are different. With an explosion, it's "here it is," and next, "there it was." Obviously, where there is an explosion potential, the philosophy of protection [I am not talking about prevention] is not very helpful.

Next, capacity to write a large risk depends on an accurate estimate of maximum probable loss. A good example of the problems here is described in Volume 9 of the AIChE Technical Manual Series, *Safety in Air and Ammonia Plants*. A particular loss occurred at the ethylene plant of Petroleum Chemicals, Inc. in Lake Charles, La. on July 13, 1965.

Finally, there is the concept of the maximum possible loss. For that, I turn to another explosion in Lake Charles, Louisiana. This occurred on August 8, 1967 at the plant of City Service Oil Company. The loss paid was approximately \$36,000,000, and the maximum possible loss estimate was about \$15,000,000. The loss was paid because insurance companies do not wish, but the particular group responsible for insuring the plant and making the estimate has been dissolved.

Recently there was an explosion at the new ethylene plant of Union Carbide Corporation at Texas City, Texas. I have not categorized this under either maximum probable loss or maximum possible loss because I do not know how the underwriting was done. I am thankful to be in a position where that is no part of my responsibility. An excellent report on this loss appears in the September 7, 1970 issue of *Chemical Engineering*, entitled "Report on Explosion at Union Carbide's Texas City Butadiene Refining Unit."

I have taken examples from Volume 9 of *Safety in Air and Ammonia Plants*. I used Volume 3 of *Loss Prevention*, the most recent one published. I have used a current industry magazine. If losses are to be minimized and prevented, engineering information on past losses, however embarrassing to the company involved, must be made generally available and the availability must be in adequate technical depth. It is not enough to make your own plant safe—the chemical industry must be made safe. It is not enough to make the chemical industry safe—all large conglomerations of values must be made safe. When a department store burns in Brussels or a tanker is wrecked in the English Channel, you are involved. John Donne said it best: "Send not to ask for whom the bell tolls, it tolls for you."

We are now ready to look at causes and effects. Let us get specific and consider the Factory Insurance Association, a business

group looking for an annual profit, with an annual income—gross, not net—of about \$120,000,000. How much of that can prudently be committed to any single potential probable loss? Certainly not all of it, nor half, nor even a quarter. Possibly somewhere around one-eighth or one-tenth, if the major risk is fire; or one-sixteenth, if we think explosion. Three of the losses mentioned above were materially larger than these figures. However, by hindsight, the fact that these losses could occur should have been foreseeable. As a result, everyone charged with the responsibility of estimating maximum probable and maximum possible losses is exercising more imagination than ever before and foreseeing these losses over larger areas of inflated values.

There have always been cases where any underwriting group has had a problem with inadequate capacity. In order to offer capacity under these circumstances, insurance companies and insurance pools have in the past entered the reinsurance market to buy pro rata reinsurance; that is, insurance that would participate in any loss.

Currently, however the reinsurance market shows a very decided unwillingness to participate in risks, hazardous or non-hazardous, on a pro rata basis. Where this pro rata market at one time gave us additional capacity, its disappearance now makes us underwrite completely within our capacity limitations.

Another facet of reinsurance, which can still be purchased, is excess coverage to protect against mistakes in deciding what are separate risks, mistakes in evaluating the value of protection, and mistakes in estimating maximum probable and maximum possible loss. It should be remembered, however that the primary purpose of such reinsurance is not to furnish excess capacity; it is to spread the payment of any major catastrophe loss over a period longer than one year. Reinsurers must recover their losses, which means that eventually all mistakes in underwriting and engineering judgments must be borne by the primary underwriter. Furthermore, these mistakes in judgment reflect against the primary underwriter with the result that the reinsurers recognize the possibility of this error and try to remove themselves as far from the loss as possible. This means the primary underwriter's first retention (that is the re-

insurer's deductible) continually increases, and the cost of buying excess coverage increases even though this coverage is more distantly removed from the area of probable maximum loss.

In view of these limitations, it is vital that manufacturers wishing to buy insurance properly measure the loss exposures anticipated in any proposed facility and consult their insurance markets regarding availability of coverage prior to committing an investment in a new plant. Let me close by giving one fictional example.

It is well documented by Bureau of Mines reports that ammonium nitrate, unconfirmed, can be detonated if exposed to a sufficiently severe shock. It is known from the experience at the University of Wisconsin Physics Research Laboratory that there are people who know how to set off a severe explosion when they are convinced that they should. I will not go into motivations or rights or wrongs.

Since ammonium nitrate is a valuable article of commerce, it will be made, and we now come to the imaginary situation where a manufacturer wishes to store 10,000 tons

in a plant complex worth \$50,000,000. If this material is stored in accordance with NFPA Pamphlet #490, I believe that it is inconceivable that it can be detonated by an accidental fire, explosion in plant process equipment, or what we might term normal risks. However, there is a chance of malicious intent by a person or group having the relatively elementary knowledge required to detonate the storage. Not too many years ago, the insurance company attitude could be expressed, "It won't happen once in a hundred years." Today, we say, "It may happen once in a hundred years." From that attitude, it logically follows that we must collect \$50,000,000 during the next one hundred years from that particular plant. This is an extra \$500,000 per year premium, and I don't see much chance of selling such a proposition to a plant that has been buying insurance for the whole property for somewhere between \$100,000 and \$200,000 for three years. Even if this amount of premium were made available, it is still doubtful that the necessary reinsurance could be purchased. So, I return to my punch line, "The insurance companies can't make any money filling this particular demand."

FINDING AND USING CHEMICAL INFORMATION

By WILLIAM G. MEADE

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This is not going to be a list of chemical reference books, although there will be many tips given on new books. Mainly, however, this is an approach to the entire problem of chemical information. The interpretation and use of this information is fully as important as finding the information in the first place.

Why is this such an important subject? There are very few business organizations that don't use chemicals of one sort or another. But they don't call them chemicals! Regardless of what they are called, it is chemical knowledge that is needed, and it just might be easier to find if the substances were called chemicals and the necessary information were sought on that basis.

Part of the approach to finding suitable information is going to depend upon how

new the chemical is. If it is completely new—if you are the first to even make it—you have no choice but to let your research chemist determine its physical properties in his own laboratory. His next job is to help you translate these properties and characteristics into your own needs for safe handling and safe processing.

If you aren't the first, but are still a pioneer with a particular substance, it will probably still be necessary to have your research chemist look up your new material. He will have access to some entirely different sources of information than you will normally use. Information at this point will probably be confined to original journal articles, some of them in foreign journals and in the original foreign language. Many of the best reference books on this type of

material are in foreign languages and may require a specialized knowledge to even use the index.

If the chemical is somewhat rare, but you are not a pioneer, your best source of information is the manufacturer. He will already have determined the basic physical properties and the hazards in connection with handling and using it. He will also know the chemical reactions it will enter into, particularly those of commercial value. All of the better chemical manufacturers, and not necessarily just the larger ones, will have data sheets prepared which contain this information and these data sheets will be freely available to their customers. This will normally be an integral part of their marketing efforts and there should be little difficulty in obtaining this type of information.

If the substance in question is new only to you, but is already marketed widely, you have many sources of information—almost too many. It will appear in many types of handbooks and encyclopedias. Some of the references to it will go into quite a bit of detail. You may even find that separate data sheets or booklets have been published by a number of organizations, such as manufacturers, trade associations, governmental agencies, and others. In fact, one of the problems you may encounter is finding several different values given for a given physical or chemical property, such as melting point or boiling point. You will be forced to make a choice as to which is the most accurate for your purposes. In most instances, this won't cause a real problem. If you are writing a data sheet of your own, it does give you some decisions to make, and in some instances you might wish to verify some data in your own laboratories.

It has often been said, "There are no safe chemicals—there are only safe ways of using them." The use that you plan to make of a chemical may be a great influence in determining where you go to get information about it. Are you merely going to store it? If so, in what quantities? What containers? Are you going to transport it? If so, how much? Where? By what means? How often? Will it be over the highway, through an industrial complex, or from a close-by storage area into a processing area? Are you going to mix it with some other chemical in a simple mixing process or do you

plan to react it with some other chemical? Will this be used solely as a solvent?

Most chemical use is as a solvent involving no chemical reaction with any other substance. In such instances the properties of the substance are the only thing that it will be necessary for you to deal with. A detailed knowledge of the chemistry of the compound is often not needed.

As a first approach to the problem, what do you really want to know? While you might be tempted to answer "Everything," this answer isn't really practical, and it's contrary to human nature. Most of us tend to do only what is immediately needed. Even with a very healthy curiosity, the average human being will not go far beyond his actual needs in his quest for information.

Later, we will go into detail about some of the pitfalls of getting incomplete information. This can be dangerous, and in some cases worse than having no information at all. Nevertheless, the actual need for specific information is going to be a strong factor in deciding where to look for it and references in this presentation are classified according to the type of information that they contain.

Fire and Explosion

One of the first bits of advice I would give to anyone seeking information on fire and explosion hazards is to be thoroughly familiar with basic definitions and what they mean in terms of safety before you look up a single chemical. The longer I am in this business the more I am shocked to find people who are concerned with safety but don't yet understand the differences between, for instance, flash point and ignition temperature.

The flash point of a liquid is defined as the temperature to which a liquid must be heated in order to give off sufficient vapors to form an ignitable mixture immediately above its surface. The flash point will give an indication of the hazard, and may be helpful in selecting another solvent or another material. It will also give an indication of the stringency of the measures needed to control smoking, open flames, electrical sparks, etc.

In discussing "high flash point" and "low flash point," many people get these mixed up with volatility and will consider a high flash point substance to be extremely dangerous, rather than relatively safe.

Ignition temperature is the temperature to which a substance must be heated in air in order for it to take fire without the introduction of an outside source of ignition, such as a flame. For many substances, this value has no particular significance other than confirming that the substance will ignite. On the other hand, a particularly high or a particularly low ignition temperature would be significant. For instance, carbon disulfide has an ignition temperature of 212°F, which in practical terms means that it can be ignited by contact with a hot steam pipe.

The lower and upper explosive limits, or preferably, flammable limits, often cause confusion. Below the lower flammable limit, the mixture is too lean to burn. If a source of ignition is introduced, the only burning which will take place is right at this source. There are not enough molecules close enough together to build up enough heat to propagate the flame away from the source. Above the upper limit, the mixture is too rich to burn, since there is not enough oxygen to consume the molecules present, and the flame will not propagate for the same reason. In the range in between, there is an ignitable mixture which will propagate flame away from the source and which can cause a fire or explosion.

This range is quite significant in planning fire protection. A substance with a very low flammable limit will be dangerous with any kind of small leak or spill. A substance with a wide flammable range will be dangerous in almost any concentrations that will be encountered. A substance with a high LEL and a narrow range will be very difficult to ignite because normal operating conditions will not normally produce this concentration. For instance, ammonia has a flammable range of 12 to 15 per cent. In spite of the fact that there are a few ammonia explosions on record, many people do not think that ammonia will burn or explode, and even the ICC does not require it to be labeled as a flammable gas.

Vapor density is another characteristic property which should be understood to properly plan fire protection, ventilation, etc. This is the ratio of the weight of the saturated solvent vapor or gas vapor to the weight of an equal volume of air. Vapor density will give information as to whether a vapor will tend to rise, tend to mix, or tend to settle close to the ground. While it

may not always follow these predicted patterns in every situation, at least you can plan ventilating systems so that they aren't working against the normal tendencies of the substance, but instead will be taking advantage of it.

In reviewing these definitions, it becomes apparent that no one property will determine the degree of hazard. All of these things must be taken into consideration in evaluating the chemical and in planning protective measures. It is essential that all information be obtained and that we don't settle for just a flash point or just an ignition temperature or just a flammable range. Short cuts here could lead to a real catastrophe loss.

As far as references are concerned, there are many in this general area. Perhaps the starting point should be NFPA Pamphlet 704M, *Identification System for Fire Hazards of Materials*. This is the diamond symbol which is split inside into four smaller diamonds of blue, red, yellow and white and a system of identifying numbers for health hazard, fire hazard, and reactivity. Anyone working with chemical hazards should be familiar with this identification system.

The numbers given are useful in many respects. In case of fire, these numbers are based upon flash points and boiling points and really don't tell the whole story. However, they do give a good overall indication and a quick evaluation and serve as an excellent starting point for further research.

Perhaps the first place to go from 704M is to Pamphlet 325M. This will give, in table form, flash point, ignition temperature, flammable limits, specific gravity, vapor density, fire extinguishing information, and the complete hazard identification code as outlined by 704M. For further detail, the next step would be NFPA Pamphlet 49, which gives a further description of most of the chemicals listed in 325M. It goes into a further listing of properties and some major reactions, and is in narrative form under each chemical.

As a final step, NFPA Pamphlet 491M contains a listing of the hazardous chemical reactions which may take place between various substances. Where Pamphlet 49 discussed these in general terms, 491M is quite specific and is laid out so that these reactions can be easily identified.

Having gone this far with individual NFPA Pamphlets, it should be pointed out

that all of these are contained in a single volume, also published by the NFPA, called *Fire Protection Guide on Hazardous Materials*. In addition to four just mentioned, Pamphlet 325A, *Flash Point Index of Trade Name Liquids* is included.

Health

When we think of protecting the health of the worker, one of the first criteria for determining a health hazard is the Threshold Limit Value as given by the American Conference of Governmental Industrial Hygienists. While this is useful information, there are few values which are more generally misunderstood and misused in industry. Most people using this booklet of values turn immediately to the numbers. What they should do is turn to the preface and study the concepts and definitions thoroughly. Threshold limit values represent time weighted average concentrations to which the normal employee may be exposed for a normal workday without ill-effect. These concepts and definitions refer to a normal employee, not everyone. They refer to a normal fluctuation during a workday and not to extreme fluctuations or an emergency condition. They represent guidelines and not a fine dividing line between safe and unsafe.

Threshold limit values are *not* a measure of toxicity. The definition refers to "ill-effects" but the number itself does not tell which ill-effect will result from exposure. This ill-effect is not always systemic poisoning. It may be a narcotic effect which will cause lack of coordination and possible injury. It may be irritation to the eyes or to the upper respiratory tract or to the lungs. It may merely be an index of the amount that a normal human body can tolerate and eliminate without ill-effects as compared to a lesser tolerance for some other substance.

It is the gravest of errors to assume, therefore, that a substance with a TLV of ten parts per million is five times as toxic as a substance with 50 parts per million. Very often the substance with a low TLV is an irritant, and while it must be admitted that an irritant can do extreme damage to the body in many cases, the substance with the higher TLV may very definitely be more toxic. It is essential, therefore that we go beyond the TLV to find out the individual properties of the individual chemicals and their effect on the human body.

One of the first approaches to finding out more about the individual chemicals is the *Documentation of Threshold Limit Values* published by the American Conference of Governmental Industrial Hygienists. This book will give the basis used for setting the TLV's, including original research references. It will spell out the effects on certain types of laboratory animals at specific concentrations and will indicate the margin of safety that has been set. It will indicate in some cases how much of a fluctuation in concentration can be tolerated without running into problems. It helps to translate single specific figures into some working guidelines and supplies the explanations necessary to better understand the chemical under consideration.

The numbering system in NFPA 704M is also useful in evaluating a health hazard. It is the figure given in blue, and like the figure for fire it runs from 0 to 4, depending upon the degree of hazard. This is a useful figure, but like any single figure it has extreme limitations. It doesn't tell the individual properties or idiosyncrasies of the substances. It should also be remembered that 704M was originally proposed as a warning system for firemen who needed a single number in an emergency and didn't have time to read the directions and labels and to study up on the individual chemical properties of all the substances in an emergency area. This number is designed to tell the fireman whether he can go in and fight an ordinary fire without any more than the normal fireman's risks, or whether he needs to put on full protective equipment, including self-contained breathing apparatus, chemical clothing, and everything that goes with it. This figure does not necessarily translate into an industrial application. Nor is it an indication of protective means that should be provided for a worker in doing unusual jobs. Even a substance with a low hazard rating on the 704M scale could prove fatal in such an application as cleaning out a tank without proper precautions, etc. While this is a useful number, it should not be the end of your search for information, nor should the TLV.

The American Industrial Hygiene Association Hygienic Guides contain excellent information on health hazards of chemicals. There are over 150 of these available, and they give considerable detail on control

measures, effects of higher concentrations, effects on the organs of the body, etc.

One other good source of information are the American National Standards Institute standards on various chemicals in the Z-37 series. There are about 35 of these available, and this is quite a small number compared to the vast number of chemicals which you might be interested in. These standards are also expensive on an individual basis. However, they do give considerable amount of detail, particularly in regard to figures that might be useful as guidelines, such as emergency exposures, self-rescue figures, occasional increased exposures during clean out or charging operations, etc.

If you are interested in transporting a particular chemical, your basic reference would be the ICC Regulations, more specifically known as "T. C. George's Tariff No. 19." It contains all you would need to know about containers, labeling, and packaging for all forms of transportation. Your main problem will be in trying to use the index.

Another useful document both for transportation and for general information is *Evaluation of the Hazard of Bulk Water Transportation of Industrial Chemicals*. This was prepared for the United States Coast Guard by the National Academy of Sciences.

Detailed Information

If you are looking for detailed information on safe practices in all phases of handling, the Manufacturing Chemists Association publishes a series of data sheets covering 100 or more chemicals. It would be very simple to take the information in here and use it to develop a set of operating practices for your own organization.

The same type of detailed information is available in the Chemical Hazards Bulletins published by the American Insurance Association. These are oriented for the insurance company safety engineers working for the various individual insurance companies and describe the uses as well as the manufacturing processes and the hazards that will be encountered at various stages. The references given are complete enough for a thorough examination of almost all commonly available material pertinent to that chemical.

In this same category are the National Safety Council data sheets, which presently

cover about 75 chemicals. Here again, there is sufficient detail to get a good picture of the individual chemical, its uses, handling practices, precautions, first aid measures, etc.

Anyone looking for detailed information on chemicals would do well to consult Ethel Browning's book *Toxicity of Industrial Organic Solvents*. Anything listed in this book would have considerable detail on the effects on the human body. Another book containing considerable detail on operating practices, control measures, good industrial hygiene techniques, as well as rather complete descriptions of chemical properties, is Patty's *Industrial Hygiene and Toxicology*.

If the information you are seeking is oriented toward manufacturing and manufacturing methods or to uses of the material, I would suggest three sources, depending upon the detail you are seeking. First is Reigel's *Industrial Chemistry*. It contains a good description of almost all modern chemical manufacturing processes. Another excellent reference, more oriented toward materials and their uses, is the *Materials Handbook* by Brady. If you want still more detail and can afford to invest \$850 for your own library or can get access to it in a public library, you might wish to know about the Kirk-Othmer *Encyclopedia of Chemical Technology*, a 22-volume set.

Trade Names

One of the big problems in getting information on chemicals is getting behind the trade name and finding out the actual substance involved. Some trade names are, of course, acronyms for longer chemical names and thus have come into the chemical literature. Many of the trade names, however, are those of individual manufacturers, and in many instances it requires an extra effort to find out exactly what substances are involved. In many cases, of course, the ultimate solution is to go to the manufacturer, but there are situations that do not permit this when information is needed in a hurry. One of the best sources of information is *Clinical Toxicology of Commercial Products* by Gleason, Gosselin, Hodge, and Smith. This book is a standard reference book for poison control centers throughout the United States and can be very useful for someone who has to deal with trade names and the composition of trade named products.

Another trade name source is *Handbook of Material Trade Names* by Zimmerman and Lavine. This was originally published in 1953, and four supplements have been published since. However, a new supplement has not been published since 1965, and some of the material in the earlier volumes is outdated. It is also necessary to go through all five volumes to be sure that you have what you want.

If you are willing to settle for just flash points, you can fall back on 325A.

Brief Information

Quite a few reference books contain brief listings of large numbers of chemicals. These are usually confined to basic physical and chemical properties, a few of the principal uses, and some of the more outstanding hazards and general reactions with other substances. One of the best as far as completeness is concerned is the *Condensed Chemical Dictionary* by Rose. Another good reference book of this sort is the *Merck Index*. This one is particularly valuable for someone who has some chemical knowledge, since it does give structural formulas.

For pure information on physical and chemical properties with no hazards given, there is, of course, the old stand-by: *Handbook of Chemistry and Physics*, published by the Chemical Rubber Company. The *Handbook of Laboratory Safety* by Steere gives a tabular listing of chemical properties of many substances.

Another book that will be found to have a good listing is the *Accident Prevention Manual* of the National Safety Council. A book found in many chemical libraries is Kingzett's *Chemical Encyclopedia*. The listings here are in somewhat of a narrative form and contain some descriptive material.

Specialties

If you are interested in pesticides, there are several good references available, among which is the *Pesticide Index* by D. E. A. Frear. This contains brief listings of about every pesticide in common usage and can be a good basis for further search. Another useful reference in this area is Hanna's *Handbook of Agricultural Chemicals*.

In the field of medicine and drugs, there are many good reference books. One of the

most voluminous is the *United States Dispensatory* by Osol-Farrar. All of the drugs listed are described in considerable detail, including a great amount of information on their side-effects.

If you are interested in minerals, *Minerals Handbook*, published by the U. S. Department of the Interior, has now been expanded to three volumes.

If you are handling gases in cylinders, the *Matheson Gas Data Book* has some very valuable and detailed information.

Miscellaneous

One extremely valuable reference is the National Safety Council *Data Sheet 486* which lists about 500 chemicals. While it contains no specific chemical information, it does indicate the various data sheets and source material available for each of these chemicals. It would be an excellent place to start in finding out specifically whether a detailed data sheet is available and would save looking in several other indexes.

For some individuals there may be a need to have a better working knowledge of technical terms, and a technical dictionary of some sort might be of help. Van Nostrand's *Scientific Encyclopedia* is one source of this information; a shorter reference is Chamber's *Technical Dictionary*.

In interpreting chemical information, particularly in the field of toxicology, a medical dictionary might also be useful. In our particular office we have Stedman, and there may be others that will be just as useful. Many toxicology books refer to symptoms in medical terms, rather than a layman's.

For some individuals there may be a need to strengthen their backgrounds in chemical operations just to have a better understanding of chemical processing, general safe work practices, handling methods, etc. One book which would furnish excellent background on this as well as giving specific information is *Safety and Accident Prevention in Chemical Operations* by Fawcett and Wood. It is recommended reading for anyone heavily involved in chemical operations or the use of chemicals.

Another item of background interest is the *Survey of Hazards in the Chemical Industry* published by the American Insurance Association. This publication is rather specific in listing the types of accidents that

have commonly occurred in the chemical industry and the unsafe conditions and unsafe practices that have led to them.

I'm sure that I have omitted some of your favorite references. I know I have omitted a few of my own. I did not intend to give a complete list, however, but an approach to the entire problem of finding chemical information and then using it in its proper place. Finding chemical information is a problem for almost everyone using chemi-

cals, and yet for most substances there is plenty of information readily available.

However, I think we all recognize that the rarer chemicals will give most of the problems. If you can't find it in a book or a pamphlet, just remember that someone, somewhere, had to have experience with it or you wouldn't be interested in it now, so don't give up. The best starting point is either your supplier or your research chemist. Good hunting!

CHEMICAL EXPOSURES IN THE PLANT

By CARL M. OLSON
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Forty-two years ago last June, I arrived fresh out of college as a chemist in a plant employing a total of about 400 people. This plant manufactured elemental phosphorous, amorphous or red phosphorus, phosphorus chlorides, phosphorous pentoxide, phosphorus sulfides, various acids of phosphorus, other phosphorus compounds, and oxalic acid; also chlorates, perchlorates—and later, perchloric acid.

In a small plant, it is not uncommon for one person to wear several hats. Starting as a control chemist and first aider, my work quickly included some research and development, plant operations, and pilot plant operations. The latter could involve long hours at times with only one person to work all shifts—and I soon became the best pipefitter in the business! I speak not in jest. We had not yet heard of Schedule 40, Schedule 80, or Schedule 120; but we knew standard, extra heavy, and double extra heavy pipe.

Those days there were no jurisdictional restrictions or specified safety rules to keep me from using the various craft shops and tools and equipment. Overalls were the dress of the day for all except top management—even for attending meetings in the president's office.

Speaking of chemical exposures in the plant, we used hair oil those days to slick our hair down and wore felt hats. I remember no hard hats. The felt hats got greasy, so we would pour a liter or so of carbon tetrachloride into a dish-pan size evaporating dish and dunk the hat until the

oil was extracted. This was done on a table and left a pleasant odor in the room. We hadn't heard of air fresheners you can buy now. We hadn't even heard of Threshold Limit Values (TLVs), or Maximum Allowable Concentrations (MACs), but carbon tet was not considered very toxic then; the book said that it was safe to work in an atmosphere containing 1,000 parts of it per million. Now the industrial hygienists have reduced that figure to only 10 parts per million, so carbon tetrachloride apparently has become quite toxic over the years.

I said that I started as a chemist and first aider—although I had no first aid training. We used a rancid linseed oil preparation for burns and debrided them with tweezers and scissors. Usually, however, first aid was left to one of the lab boys.

Ether did a fast job removing adhesive tape for a redressing, but was said to be quite flammable—and it did work beautifully in the carburetor starting a cold automobile—so it could be dangerous around people who were smoking. We had never heard of the formation of ether peroxides on long standing, which could detonate by friction of the glass stopper. This was before the advent of Standard Taper glassware, so each stopper fit only its own bottle, and we used a diamond pencil to mark each to keep them from getting lost from each other.

Chloroform, being non-flammable, was substituted for removing adhesive tape. In a clear glass bottle exposed to sunlight, it

developed a sharply pungent odor—phosgene! I wonder if some of the early surgical fatalities might have been caused by such phosgene formation and subsequent use of the chloroform for anesthesia.

Carbon tetrachloride was the obvious thing to use instead of chloroform for removing tape; but, it, too, was superseded by 1,1,1-trichloroethane when it became available and was advertised as only one-twentieth (1/20) as toxic as carbon tetrachloride, which we were beginning to realize was not as completely harmless as we had long thought. Checking a local pharmacy for solvents sold, all were found to be carbon tetrachloride or flammable petroleum products. On apprising the local hardware store of the dangers of carbon tetrachloride, the owner substituted 1,1,1-trichloroethane but reported that some customers would listen to his explanation, insist on carbon tet, and walk out to get it someplace else. But, he stuck to his guns and does not sell carbon tetrachloride.

Getting back to the plant, we had two kinds of fire extinguishers: a water hose or a soda-and-acid extinguisher for Class A fires; and Pyrene, which was carbon tetrachloride, for Class B & C fires. They were pump-type extinguishers and we had glass balls of carbon tetrachloride to throw at the fire. Maybe we didn't know that phosgene could be formed by pyrolysis of CCl_4 .

Carbon tetrachloride was used as a rubber cement solvent in rubber-lining open tanks with only natural ventilation. It was not flammable like benzene, so was considered safe. Degreasing of parts and tools was accomplished by sloshing them in an open bucket of CCl_4 in the shop; not the way it is done properly now with enclosed and ventilated equipment using some less toxic solvent such as trichloroethylene.

I wonder just how many have died from exposure to carbon tetrachloride. Several years back, twelve such deaths were reported in one year in my state alone—and there are fifty states! Years back, dry cleaners used carbon tet extensively and often with little or no precautions. I recall one death in my home city and, in the city next to us a boy was found dead in the home basement where he was using it to clean his bike before painting it.

Then there is the synergistic effect with alcohol. It has been estimated that the two together may be as much as 300 times as

toxic as carbon tetrachloride alone, so exposure to it after drinking is especially dangerous.

Although no safety department existed as such in this plant, there were safety rules and practices; some very well and permanently posted. Making such powerful oxidants as chlorates and perchlorates on the same general premises as acutely oxidizable and highly flammable phosphorous and its sulfides required that the respective workers and other personnel stick to their own territory and not trespass on the other. This was accomplished by providing white overalls for all oxidants workers, and blues or browns for phosphorous and sulfides workers. There were entirely separate locker rooms, lunchrooms, and laundries for each of the two groups.

Because of the hazard of oxidizable substances with such powerful oxidants as chlorates and perchlorates, the white overalls and jackets were laundered daily—or oftener if known to be contaminated. Rubber shoes were required and provided for all of these workers, and rubbers to be worn over leather shoes of anyone, without exception, entering chlorate or perchlorate areas! Any leather shoe contaminated by oxidant liquors is destroyed, since complete removal of the oxidant by bleaching with water cannot be guaranteed.

To illustrate this hazard with leather shoes, in the early days a supervisor wearing a leather shoe so contaminated suffered hospitalizing burns on one foot many months later when the contaminated shoe burst into flame on contact with a piece of hot slag.

The dry chlorate or perchlorate dust embedded in cloth makes it equally dangerous: a spark from a grinding wheel ignited a worker's sleeve so contaminated, causing permanently-scarring burns and forty days of lost time from work. Before the days of hard hats, white cloth caps were provided, but a bald welder wearing his own cloth headgear contaminated with the oxidizing dust experienced somewhat the same as a hotfoot to his head when the cap ignited. He quickly doffed the flaming cap!

Smoking, obviously, was prohibited while wearing the white clothing provided, or while in any chlorate or perchlorate area. A young worker found out why when he ignited his overalls while sneaking a smoke. As recently as late October 1967, a young worker in

Michigan nearly died from burns on 52 per cent of his body when he lit a cigarette and ignited his chlorate-contaminated clothing. Warnings had not been heeded or enforced. Several farm workers have suffered burns from ignition of chlorate-contaminated clothing, one fatally that same year.

Another example of the danger from oxidizable substances with oxidizing agents is illustrated by an accident in the 'twenties: Crystalline potassium perchlorate was ground in a small mill, which was cleaned daily to avoid trouble. However, some of the fine chemical got into the bearing on one side and the lubricant or carbonaceous residue from it exploded the bearing, decapitating the operator.

To prevent this happening again, such equipment was designed with outboard bearings to prevent the contamination and was heavily armored with sufficient space to contain the shrapnel in case a bearing exploded. Another practice has been to enclose motors under positive, clean-air pressure to prevent entry of any oxidant dust into bearings. There have been other explosions of mill, or motor, or conveyor, or drive bearings.

For many years now, non-oxidizable lubricants for oxygen service have been available, but must not be contaminated with other lubricants. Aluminum (and possibly magnesium) seals, sleeves, and cages must not be used, as the fluorinated lubricant may break down and explode if finely divided aluminum and other active metals are present. In the case of pumps for oxidant liquors, in addition to proper inert packing, lantern glands for continuous addition of water by purge meter prevents the possibility of an explosion.

Fortunately, very few people are bothered by contact with chlorates or perchlorates, and these chemicals are only mildly toxic on ingestion. Fifteen to 30 grams may be fatal, as it oxidizes hemoglobin to methemoglobin but, in 1957, a research physician survived a measured 40-gram dose taken by mistake instead of sodium chloride, the table salt. He was saved by an artificial kidney and massive transfusion of 18 pints of blood and made complete recovery.

Since tooth cavities and gum defects serve as avenues of entry for elemental phosphorus into the body, a dental dispensary was maintained on the premises for examination and

care of phosphorus workers, including periodic X-ray films of the whole mouth.

Increased exposure to fumes or vapors of elemental phosphorus during wartime production resulted in a few cases of necrosis of the jaw, requiring drastic and prolonged treatment by an oral surgeon. Only one case involved the upper jaw, a 32-year old worker who had falsified his age to get a job at 16. Observing this victim's personal habits, the oral surgeon attributed the affliction to frequent contact of his possibly "phossy" fingers with his face and mouth. This was the most serious case of phosphorus necrosis of the jaw, but he finally recovered and is working there as an active storeroom clerk, messenger, and chauffeur.

Measures taken to prevent any more cases included (1) engineering refinements for better confinement and/or removal of vapors, (2) closer attention to personal hygiene, and (3) doubling the number of workers assigned to work with elemental phosphorus, so every such worker spent alternate weeks or months on jobs involving no exposure to vapors of elemental phosphorus. There have been no more cases of phosphorus necrosis of the jaw in this plant since the 'forties.

One of the by-products of phosphorus manufacture is ferrophosphorus from the iron content of the constituents fed the electric furnace. Molten, it reacts with water to liberate hydrogen. Being heavy, it collects at the bottom of the furnace. In the 'thirties, a leak developed in the bottom and the molten "metal" came out. Perhaps thinking to quench it, the plant engineer, who was a mechanical engineer, turned a water hose on it! The hydrogen evolved diffused with air and, with the source of ignition right there, exploded, doing structural damage. Several men were badly burned by the flame; the engineer so severely that he died within a few hours. I remember, but omit, the gruesome details. This may not be a case of direct chemical exposure, but certainly shows the need for accurate chemical knowledge and the avoidance of chemical mistakes.

Carbon monoxide, CO , which kills more people than any other gas, is another product of phosphorous manufacture. It comes off the furnace along with the phosphorus vapor, which condenses to a liquid and becomes solid when cold. The CO was piped to vertical, high-pressure absorption vessels to become the starting point for the manu-

fracture of oxalic acid. The department superintendent went down through the 11" x 15" oval manhole into a recently emptied absorber to inspect it inside. Pipelines to it had not been disconnected or blanked off; only valved off. No ventilation of the interior had been provided. Much alkaline sludge remained on the sides and on and behind the steam coils. It probably had trapped and slowly emitted CO. His safety belt and lifeline were back in his office! After all, he had been doing this for many years without incident—and the 11" x 15" oval manhole was small enough without encumbrances.

Having seen his boss go down in and not come back up within a reasonable time, the operator took a look—and saw him lying at the bottom apparently unconscious! He excitedly yelled for help, went down in, and carried his boss up the ladder to the manhole, where he was pulled out. However, the operator then collapsed on the bottom, so another man went in, got him up to the manhole, and collapsed. This tragic farce continued until nine men had been involved, one by one!

It was back in the Schafer prone-pressure artificial respiration days, before the advent of mouth-to-mouth or mouth-to-nose respiration and of hyperbaric chambers, which, reputedly, can save any carbon monoxide victim entering alive. Instead of straight oxygen, Carbogen (93 per cent oxygen, seven per cent carbon dioxide) was administered at the hospital to which the first two victims had been taken. The operator hyper-ventilated so strenuously that he could be heard out in the hall, and died. The superintendent recovered and eventually returned to his job. He lived many years beyond his retirement age.

Measures taken to prevent recurrence are rather obvious: excessive amounts of sludge to be cleaned or hosed out; all pipelines to be disconnected or blanked off before entry; vessel to be ventilated and atmosphere to be tested for CO; everyone entering to wear wrist-type safety harness and lifeline; overhead snatch block to be provided for lifeline; observer to be present at all times; not to run errands; stand-by oxygen with sufficient hose and administration mask.

In later years, work permits insured compliance with the above; also, larger manholes were specified for such new installations. This accident instigated development

by one of the mechanics of the first wrist-type safety harness, since a person can be most easily pulled through a small opening suspended by both arms over his head with wrists together, his most streamlined body position. This also brings up the slumped head of an unconscious person. Think what a simple job study or systems safety analysis could have prevented!

One other carbon monoxide accident seems worthy of review. Two painters wearing respirators supplied with air from a contractor's gasoline driven compressor developed multiple symptoms of CO poisoning. Three investigators could not determine the source of CO, so I took a look at the work area. A rain flap atop the vertical exhaust pipe of the gasoline engine deflected its exhaust gases toward the air intake of the compressor, a condition easily corrected. Know or trace what to look for on investigations. Be systematic.

A separate air line should be provided for breathing purposes, using a proper type of compressor and filter; or, a supply of large cylinders of compressed breathing air is maintained for such use at the plant in question, as it is located adjacent to a cylinder gas plant with an oxygen compressor, which is used to compress breathing air. Compressed air can become contaminated with CO by breakdown of lubricating oil in a piston-type compressor running hot.

My most recent experience with CO took place in a closed control room where the supply of dry instrument air had failed, so dry inert gas was temporarily substituted. Later, a group of men working on the instruments suffered various stages of CO intoxication from the CO in the inert gas bled from the instrument lines while working on them; another case of the right hand not knowing what the left hand was doing—or had done—and which points up the need for adequate communications in order to work safely.

Hydrogen sulfide, H_2S , shares with CO the record as the greatest chemical killer of all time, according to the book *Safety & Accident Prevention in Chemical Operations*, by H. H. Fawcett and W. S. Wood. In my personal industrial experience, H_2S has been three times the killer. Let's first talk about some of its undesirable properties in less than fatal concentrations. My earliest industrial experience with H_2S involved its irri-

tating effect on eyes of those screening and packing powdered phosphorus sesquisulfide in which impurities decomposed to give off a small amount of H_2S . Although the concentration was not sufficient to cause respiratory irritation, headache, or illness, the men got such acutely sore eyes that they frequently and regularly suffered at home a day or two a week at half pay. Forty years ago, this arrangement was considered a part of the job—and the department superintendent strenuously objected when, later, these frequent absences were called occupationally-disabling injuries. Strangely enough, these afflictions all but disappeared completely when a hinged glass shield was installed in front of the operator's face; the exhaust ventilation was improved; and each operator was assigned to other work the day following, so no one was exposed a second consecutive day. If it had been considered economically feasible, there is no doubt that equipment could easily have been designed to eliminate all exposure. Manufacture of this product was discontinued in the late 'sixties.

Probably the best known property of H_2S is its rotten egg odor in low but harmless concentrations. Dangerous concentrations paralyze the sense of smell; in the most disastrous H_2S accident I have experienced, of the 35 people affected, not one of the 33 survivors remembered smelling it. Those approaching the area from a distance did detect the odor momentarily. I know from personal experience that the same happens rather quickly with even low concentrations, so we cannot depend on the odor to detect the presence of H_2S .

How do these H_2S accidents happen? There was some rotten egg odor, which soon disappeared (?) and a workman repairing equipment suddenly slumped to the floor unconscious, but quickly came to on removal from the area. In a similar incident in an entirely different department, a repairman slumped unconscious to the landing at the top of a flight of stairs he was about to descend after walking away from H_2S -emitting equipment he was working on. He was revived by mouth-to-mouth respiration, rescue breathing. In the third case, a young worker under close observation inside a still, cleaning it, passed out. The two supervisors immediately pulled him out by his lifeline. His jaws were clenched, so the chemical engineer of the two quickly revived him by

mouth-to-nose respiration. This chemical engineer became the first person awarded the National Safety Council President's Medal for successful resuscitation by rescue breathing.

How do these H_2S emissions come about? Although not the only way, the classical example is that of a soluble sulfide or sulfhydrate coming in contact with an acid—and the overlooking of details that bring this about. It doesn't always have to be an acid; a substance such as phosphorus pentasulfide reacts with water—or even with moisture—to produce H_2S , and I have heard of several deaths by this route. That is why a closed truck or a closed room of the material should always be ventilated upon opening before entering.

The very essence of safety is attention to details, so consider the following: (1) a vertical storage tank of sulfhydrate liquor with an outlet near the bottom of threaded pipe to the shut-off valve and a cast iron centrifugal pump, which had been in use many years and not inspected for thinning from erosion and corrosion; (2) the use of so-called high pressure instead of reduced pressure steam to clear the pump and lines of crystallized material; (3) no dike to contain possible spillage from the storage tank, nor tapered wooden plug to stop a line break; (4) a surface drain nearby to a sewer serving an acid plant; (5) sloppy pipefitting with the shut-off valve connected to the storage tank by only a few threads; and (6) the area somewhat congested by buildings, operations, offices, and facilities confined against a high railroad embankment.

Steam pressure burst the pump, breaking off the valve at the threads of the tank outlet so the contents drained out and flowed into the sewer. A number of the H_2S victims lost consciousness and were revived by rescue breathing, but two men, found too late in a little rest room, were dead. As was stated regarding the CO death, think what a relatively simple but thorough, step-by-step job study or systems safety analysis might have prevented.

Here is another case to consider:

To prevent freezing, a vertical drain pipe from a flat roof was installed inside a building and service corridor to below ground level, where it elbowed horizontally, without a trap, to a manhole of a sewer serving acid

plants and receiving condensate from a steam coil in a sulfide liquor tank.

This service corridor had been in use more than 50 years, and the drain pipe elbow had developed a hole, which apparently had not been noticed. The steam coil mentioned also developed a hole, but too small for detection—except that the volume of liquor in the tank being heated could have been noticed to very slowly increase. It is thought that, when the steam was turned off of the coil, its trap permitted the cold condensate and sulfide liquor from the tank to trickle into the sewer, where H_2S was formed and found its way through the hole in the drain pipe elbow, contaminating the atmosphere at that point in the service corridor.

A healthy process repairman with 35 years experience in the plant entered the long corridor to check a pipeline in the area of the drain pipe elbow with the hole in it. When he had not returned after about 10 or 15 minutes, his buddy, working at the entrance, went in and found him lying face down. He could not be revived.

This happened in June 1968. Since then, accurate, dependable, low maintenance, relatively inexpensive instrumentation has become available for continuous monitoring of H_2S in the atmosphere. The same is true for CO , something that was not previously possible in the presence of certain interfering substances.

Phosphine is a far more toxic gas, and I have known a number of people ill from inhalation of it working with the alkaline reaction of phosphorus to produce hypophosphites, and with zinc phosphide, or with aluminum phosphide. It probably is not of general interest.

The same can be said of phosgene (carbonyl chloride), $COCl_2$, as to toxicity and general interest. It can be inhaled from equipment leaks, inadequate scrubbing of effluent gases, gaseous or liquid spills from cylinders of it, etc. Anyone suspected of exposure must be removed from further exposure and have absolute rest under medical observation even though he may feel able to be up and about. For further information on treatment, consult the special supplement to the August 1970 issue of the Manufacturing Chemists' Association (MCA) *Accident Case Histories*. The address is 1825 Connecticut Avenue, N.W., Washington, D. C.

Getting back to elemental phosphorus, which burns so rapidly and fiercely on exposure to air, and at nearly 6,000 calories per gram, leather or rubber gloves or suitable equivalent are provided for work with it. Still, there were too many badly burned fingers when, say, a pipefitter had to take five or 10 seconds to get to water when phosphorus had ignited on a hand and/or fingers. This problem was largely alleviated by the simple expedient of making it standard procedure to always provide a bucket or two of water at the immediate job site before starting work on a pipeline, or atop a phosphorus tank car, etc. If, then, some phosphorus ignited on a hand or finger, it was instantly doused in the water before a serious burn occurred. This very practical practice is mentioned for its application to other chemical exposures as well; it is cheap, simple, and effective.

If mishandled, chemicals that hydrolyze or react with water with evolution of much heat can be dangerous. Sulfuric acid or oleum are well-known examples. Metallic sodium is another. Another example is phosphorus pentoxide or phosphoric anhydride. Phosphorus oxychloride or phosphoryl chloride may not be as generally known in this respect.

An experienced chemist had some of this liquid spill into one shoe. Although it is not so immediately corrosive to skin that he did not have time to take the shoe off, he panicked and ran water on it. Only a little got inside with the $POCl_3$ —just enough to give him a shoeiful of steam and a badly burned foot a long time healing.

An operator berated himself afterwards for having allowed a fellow worker to play a water hose on his thick wool trousers saturated with a spill of $POCl_3$, as just enough water got through to make steam inside and scald his leg, so he was off work six weeks. He realized that he had ample time to take the trousers off first—or that the hose could have been put inside his trousers at the waist and have caused no burn. I have long and often advocated practicing accidents that could happen, so they won't, or, if the "practiced" situation does arise, we react safely to it without panicking.

This brings to mind another example of dangerous panicking. An operator carrying a tray of flammable chemical powder to one

of a battery of rotary brush screens spilled some on one trouser leg. A flash fire ignited the trouser leg and, although standing two feet in front of a safety shower provided at each machine, he ran out of the place and was burned so severely that he was off work 15 months!

From that day, every operator had to test his shower every day—or at least fondle the chain to fix its purpose in his mind. Six months later, another operator's overalls ignited the same way. He reacted perfectly: stepped back under his shower, pulled the chain, changed into dry clothing, and continued working! There were fires, but no more burns, the next twenty years the process was continued. Draw your own conclusions as to the value and necessity of training and of "practicing accidents."

Chemical burns can be as nasty as, or worse than, thermal burns. They can occur in combination with them if the offending chemical is at an elevated temperature, which increases its corrosivity to body tissues. Among the worst are hydrofluoric acid (HF); caustic potash (KOH); caustic soda (NaOH); other strong alkalis, acids and irritants; phenol (carbolic acid); hexachlorocyclopentadiene; and many others. Antimony trichloride may attack the nasal septum and perforate it.

Immediate and prolonged flushing with water is the best initial treatment for a chemical burn and, if the skin is not broken, washing with soap and water to mechanically assist the flushing—especially for phenol, and even for caustics. In addition, such volatile and sparingly soluble irritants as hexachlorocyclopentadiene, for example, require aeration of the eyes or skin by a fan or strong breeze until the reddening fades, showing that the offending chemical has volatilized. Body areas exposed to volatile or other absorbed chemical irritants must not be covered by ointments, bandages, or clothing.

Severe burns have resulted, not only from neglecting to remove a corrosive chemical from the skin, but from wearing clothing or shoes contaminated with it, either knowingly or unknowingly in both cases. Leather shoes or gloves are notorious in this respect and must be destroyed, as one cannot be sure that they have been decontaminated. Clothing may require not only thorough laundering but aeration until all traces of contaminant disappear, which may be several

days. Such clothing should not be taken home for laundering and decontamination.

Sometimes first aid treatment for trivial chemical exposure, or exposure thought trivial, is ignored or delayed until the effect becomes serious. Self-treatment may be inadequate—or harmful. Even supervisory people have been guilty of this for the workers.

Exposure to such chemicals can be by drips, leaks, spillage, splashes, poor house-keeping, inadequate facilities, malfunctions, deviations from standard operating procedures (or lack of them), absence of emergency procedures, failure to provide or to use adequate protective equipment, haphazard training or discipline, etc. Sometimes a chemical line thought or supposed to be empty proves to be under pressure when broken into, or spills residual chemical contents. Or, probably, poor technique is used breaking a flange or otherwise opening a line. Process equipment released to maintenance personnel as clean may prove not to be. Even hydrofluoric acid (HF) exposure has so resulted from handling contaminated gloves, tools, etc.

A tank car loader in Michigan died when the fill pipe raised up from the force of the stream coming out and deluged him with 73 per cent caustic soda solution. Later, a fill pipe popped out of a tank truck in the company's plant in another state, but this victim was back at work within a month. It was agreed to anchor fill pipes, but the chain as provided merely acted as a leash, so another fill pipe popped out, but the spill injured no one. Two years later, it was discovered that tank cars were being loaded without anchoring the fill pipes! There had been personnel changes, and communications not posted or otherwise effectively recorded get lost. Perhaps this shows how difficult it is to change habits or maintain proper procedures.

Several times there have been eruptions from adding a whole charge of caustic soda at once instead of in small increments. One such incident resulted in hospitalizing burns and permanent impairment of vision. The young operator was in a hurry to play ball after work.

It is recommended that liquid caustic be pumped, but it can be transferred by controlled air pressure. The air supply had failed, so steam had been used a week to maintain production. Mistakenly assuming he had blown the tank truck empty, and not

making certain that the steam pressure on it had been released, the operator opened the dome cover! The hot caustic erupted. The combination chemical and thermal burns required long hospitalization and he lost one eye! He was wearing shielded safety spectacles, but not his face shield.

Improvisation has been called one of the imps that cause accidents and is usually not recommended or permitted, but it need not always be so. The ability to improvise safely is even commendable; may at times be used to actually promote safety. However, sufficient compensating precautions must always, without fail, be instigated and followed without deviation or exception!

I have attempted to give pertinent examples of some chemical exposure experiences I've had in the hope that the usually obvious conclusions to be drawn and philosophies to be embraced may be applied to some of your problems. These examples are but a drop in the bucket compared with the case histories collected by and available from the Manufacturing Chemists' Association. Although in no way a part of it, I cannot

help but put in a plug for that excellent book, *Safety and Accident Prevention in Chemical Operations*, by Howard H. Fawcett & William S. Wood. And among many other sources of good information, there is the 6th edition of the National Safety Council *Accident Prevention Manual for Industrial Operations*, a bible and veritable encyclopedia of safety information. The dilemma is that we do not have or take time to actually study and apply this wealth of sound advice and information available to us for safety.

A favorite topic is the first aid treatment of burns by cold water. I was in charge of a plant hospital where many chemical and/or thermal burns were treated. It was gratifying to see the immediate relief from pain, the reduced trauma, and the faster and better healing if cold water treatment was started immediately and continued long enough, sometimes several days. Workers learned to apply cold water fast—even snow—before first aid or medical treatment. In a medical symposium of physicians, the plant physician was heard to say that it was so remarkable one could almost call cold water a drug.

HOW TOXIC AGENTS ENTER THE BODY

By ED ALPAUGH

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If we are to protect people against injury from toxic materials in industry we need to know how these materials enter the body and how they act in the body. Ordinarily, when we think of normal industrial exposures to chemical compounds, ingestion by drinking or eating is relatively uncommon. It is true that if people are working with compounds that are highly toxic and absorbed from the gastrointestinal tract into the blood, such as lead oxide, there must be no eating or smoking in areas where these materials are used. Also, careful and thorough wash ups are required before eating and after working. Thus, this particular hazard can be controlled by relatively simple procedures. With respect to the absorption of toxic compounds through cuts or abraded skin, industrial exposure is negligible because people usually have the cuts bandaged

and are careful to avoid exposure to almost any contaminant, including water. Nevertheless, if accidental exposure occurs, absorption can be quite rapid through skin lesions and can cause serious problems.

The fact that some chemical compounds can be absorbed through intact skin does cause problems in industry. Some gases and liquid materials are absorbed through the intact skin by way of the hair follicles, and others are absorbed to some extent because of their solvent ability for the fats and oils in the skin. Generally, most electrolytes and water are not much of a problem. However, some of the compounds that can be hazardous by skin absorption are alkaloids, phenols, lead acetate, lead oleate, (salts of lead, antimony, arsenic, bismuth, and mercury), nitrobenzene, nitrotoluene, aniline, and nitroglycerine. Other bad actors are tri ortho

cresyl phosphate, parathion and related organic phosphates, and tetraethyl lead. Compounds that are good solvents for fats, such as benzol, toluene, and xylene, are absorbed through intact skin and may cause problems, although they are not as hazardous as those mentioned previously.

We now have covered, in a matter of minutes, four of the five ways that toxic materials gain entry into the body. We have one route of entry left—inhalation—and this is one we must consider in some detail.

Why must we be so concerned about the entry of toxic compounds into the body by way of the lungs? The average person breathes at a rate of about twenty breaths per minute. If he works a forty hour week and fifty weeks a year, he will have breathed some two and one half million times while at work. A man with a moderately heavy job will breathe about one liter (0.035 cubic feet) of air per breath so that in one year he will have inhaled and exhaled some 87,500 cubic feet of air, enough to fill a 55 foot diameter balloon. At 32° F this volume of air would weigh 7,000 pounds. Thus, the air weighs more than the food and water we take in during a year's time.

The respiratory tissue in the lung that transfers the oxygen from the inspired air to the blood has as much surface area as the floor of a room 20 feet wide and 30 feet long. Although the circulation of the blood depends upon the degree of activity, the average time for a complete circuit of the blood is usually less than one minute. Thus, it is easy to visualize the speed with which a gas, vapor, or mist can be absorbed and spread throughout the body. Even particulate matter, if soluble in body fluids, can be rapidly absorbed in this manner.

Contaminants that can be inhaled into the lungs can be physically classified as gases, vapors, or particulate matter. Particulate matter can be further classified as:

1. Dust—solid particles temporarily suspended in air.
2. Aerosol—solid or liquid particles temporarily suspended in a gas.
3. Fog or mist—dispersion of liquid particles in a gas.
4. Fume—solid particles that have condensed from the gaseous state usually following volatilization from melted substances.

5. Smoke—small gas-borne particles resulting from incomplete combustion.

6. Smog—Smoke and fog mixed.

The hazards associated with the entry of particulate matter into the lung are related to the size of the particles. If the particle size is large, the particles tend to settle out of the air before they are breathed, or, if they are inhaled, they are too large to get past the upper respiratory tract. Particles of one micron or less in diameter are the ones that cause the problems because they can penetrate deeply into the lungs and once there, resist removal. Density of particles also has some bearing on toxicity since the more dense particles, even though very small, tend to resist sudden changes in direction and impact on the walls of the upper respiratory tract, where they cause no serious problems. However, it is true that some of the larger particles are swallowed as they are cleared by ciliary action and thus contribute to the total intake of toxic material by being swallowed.

As particle size is important with respect to the inhalation of particulate matter, solubility is important with respect to the breathing of a gas or vapor. If the gas is very soluble, such as ammonia or sulfur dioxide, it is absorbed in the upper respiratory tract and does not penetrate very deeply into the lung (depending upon concentration, of course). If the gas is not very soluble, such as carbon disulfide or ozone, it will reach the pulmonary alveoli.

Contaminants, when inhaled, can cause problems for several reasons: (1) They can be irritating (formaldehyde). (2) They can be asphyxiants (carbon monoxide). (3) They can be anesthetic or narcotic (acetone). (4) They can be systemic poisons (organic phosphates). (5) They can be fibrogenic (quartz). (6) They can cause allergic reactions (TDI). (7) They can cause malignancy (asbestos). (8) They can be inert but still be a nuisance above a certain concentration (grey iron dust).

Since it is impossible to have a working environment entirely free of contaminants, and since the human body does have a defense mechanism that allows it to tolerate foreign substances to varying degrees, attempts have been made to establish so called safe working limits for a large number of

substances or chemical compounds used in industry. Probably the best known efforts to establish such limits are the TLVs of the ACGIH.

TLVs for some 400 substances have been developed over the years since about 1947 by a committee of the ACGIH. The committee consists of 12 or 13 members well qualified in the field of occupational health, M.D.s, toxicologists, and industrial hygienists. They meet annually to review and update the list. New additions to the list or revisions to existing limits appear as a notice of intended changes and are carried as trial limits for two years. Thus, if anyone does not agree with the intended changes, he has time to accumulate and submit data to substantiate his views. It does seem that the trend in establishing these limits is downward; for example, carbon monoxide, nuisance dusts, formaldehyde, iron oxide, and zinc oxide.

TLVs for contaminants in the gaseous phase are usually expressed in parts per million. When the contaminant is dispersed in the atmosphere in solid or liquid form as a mist dust or fume, its concentration is expressed as milligrams per cubic meter (weight per volume basis) or millions of particles per cubic foot (particles per volume basis). Perhaps some of you are wondering why we don't talk in terms of per-

centages, since most of us are more familiar with this terminology than ppm. It could be done but would be quite awkward. For example, 1.0 per cent is 10,000 ppm; 0.1 per cent is 1,000 ppm, and the hygienist seldom is looking for concentrations of this magnitude. Frequently we may be concerned about concentrations ranging from 0.0001 per cent to 0.01 per cent, and it is much easier to say from 1 to 100 ppm.

As simple as ppm is, one part of contaminant in a million parts of air, the concept is still elusive to most of us. Really, one ppm is not very much, but people get a much clearer picture of just how much when you tell them that one ppm is one cubic foot of carbon monoxide evenly dispersed in a ballroom having a diameter of 124.1 feet. Other examples are: one inch in sixteen miles; one cent in ten thousand dollars; one ounce of salt in 6,250 pounds of sugar; one ounce of Scotch in 7,350 gallons of soda; a one ppm martini would be one drop vermouth to 66 fifths of gin.

An analogy for the concept of milligrams per cubic meter is a little more difficult but, for example, let's look at the TLV for lead, 0.2 MG/M³. Two seeds of merion blue grass pulverized into dust and evenly dispersed in five empty 55 gal. drums would be a reasonably good comparison.

PLANT PREPARATION FOR A CHEMICAL EMERGENCY

By MARY W. SMITH, R.N., B.S.

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Registered professional nurses are employed in many industries for the simple reason that management has found that the nurse can make a significant human and economical contribution to the success of a business enterprise. In my opinion, nurses should be hired for the same reason that you hire an engineer or an accountant—to provide professional services to help increase the efficiency and productivity of the organization. Emphasis on health maintenance is logical when you consider the needs and situation

of modern industry. As industry becomes more complex or technical, management invests more time and money in the training and equipping of their workers. As a result, the worker is more productive and more valuable than ever before. Therefore, anything such as an injury or personal illness which destroys or decreases the worker's potential represents a dollar and cents loss to the business. Cost control alone should dictate that industrial management take steps to protect the well-being of its worker.

Chemical Section

Industry has organized Occupational Health Units and has sought the services of physicians, nurses, and hygienists. They have encouraged these people to use their knowledge to develop better techniques for industrial health maintenance. The day has passed when industry only owed a pay check to the worker for a day's work done. In fact, its archaic! We all know that most employers believe, and act on that belief, that they are morally and socially obligated to make the conditions of employment as safe, healthy, and pleasant as possible. The nurse is directly concerned with the health and welfare of the worker and is thus, obviously, due to more frequent employee contact than the physician or hygienist, an important agent of the employer discharging this moral and social obligation.

Although the nurse is shown on the organization chart as working for management she is, of necessity, a neutral person assuming a position between the employer and the employee. Or, it may be between the employer and the physician or a community agency. She is a liaison person. The employee comes to the nurse with a problem, and she may be the person who contacts management or the plant physician concerning that problem.

Other situations require that she act as management's agent. For example, if she takes a man to the physician with an industrial injury, she may convey to the physician her management's stand on the injury. Also, she may handle other business, such as arrangements for hospital room, special nursing care, therapy, etc., which usually require immediate action and cannot wait for a management decision. This means, in some instances, that she assumes a great deal of responsibility.

Since I have mentioned the liaison portion of the nurse's duties, I will go on and briefly describe some of her other duties. They include:

1. Administer first aid and see that the employee gets medical attention if it is required.
2. Check all first aid cases that happen on other shifts, as well as her own shift, and see that they get the required attention.
3. Inspect and change dressings, administer medically prescribed injections, order and maintain supplies for the dispensaries, and assist the safety personnel with monthly re-

ports and correspondence. Assist with fitting of some safety equipment. Other duties as assigned.

Actually, what this adds up to is that about 10 per cent of my time is spent on industrial first aids and the other 90 per cent on employee counseling and guidance, insurance claims (both personal and occupational), health teaching, pre-employment and periodic physicals, and record keeping.

In the average plant today only about 20 per cent of the nurse's time is devoted to actual emergency treatments. There are a few exceptions in some of the larger industries where the medical department is assigned a clerk to do the bulk of required record and paper work and the nurse can perform about 90 per cent nursing functions. For those nurses not fortunate enough to have clerical assistance, the work day probably consists of duties much as I have described. In my opinion, and I might add that this opinion is not necessarily that of my employer, a company which allows imposed clerical duties to take more than 50 per cent of the nurse's time is not taking full advantage of the total professional capabilities of the nurse. I hasten to add that some clerical duties are both necessary and beneficial to the nurse, particularly those which lead to, or are in connection with, counseling employees.

If a plant has a dispensary, the nurse may be responsible for suggesting and ordering the equipment and supplies for the unit. Many times she is largely responsible for helping with the initial plans for the layout and the design of the medical or first aid facility. The equipment and supplies, including drugs, are determined by the type, or types, of products made and the chemicals handled in a particular process or plant. What one plant provides in the way of services or facilities will not coincide with what another plant provides. The reason for this is that management will recommend according to its desires, and the medical consultant, or physician in charge, will order to suit his own individual preferences or needs.

There are still many firms who do the initial pre-employment physical and furnish necessary first aid treatment only. However, there is an increase in the number of industries who are now furnishing periodic physicals to their employees. There are even

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more who are realizing that they must protect the investment that they have in the worker and are offering special blood work, electrocardiograms, respiratory tests, and glaucoma screening after the employee reaches a certain age.

Getting back to the basic medical dispensary, there should not be a great deal of variation of the basic facilities furnished in any plant. The only exception, from plant to plant, will be the size required to accommodate the personnel, according to the services offered.

A chemical plant should, ideally, have an eye wash fountain and a shower in or near the medical facility. Unless there are disciplinary rules governing the amount of time to stay in the emergency shower or eye wash fountain, three out of five people exposed to a chemical will panic and will not stay in the water long enough. All they can think of is getting to the dispensary, and the time between the emergency wash and the dispensary is their undoing. I have found that the fellow worker is about as upset as the injured person, and you cannot depend on them to keep that person in the emergency wash even the minimum time. We teach, and recommend, at least 15 minutes of water deluge at the primary site of injury and 10-15 minutes more in the medical unit. Some companies require that an injured person be kept in the eye wash or safety shower at least 15 minutes or until a representative from safety or the medical group reaches the scene. Without disciplinary action as a back-up, you will find that you will have a never ending education program on the proper use of safety showers and eye wash fountains.

If you experience even a relatively small disaster at your plant, many times you will also experience electrical damage or failure. The use of electricity is something that we have begun to take for granted. Every medical facility should have provisions for emergency lighting in key areas, particularly where light will be used in doing treatments during the emergency. Permanently mounted lights should be supplemented by flashlights or other portable, hand carried, battery operated equipment.

Have you ever calculated how many people you can administer oxygen to at one time? Do you know the location, and the number

of, resuscitators you have in your plant? When you mentally condition yourself for the emergency in a chemical plant, or any other type plant, have you noted where the industrial oxygen is stored and thought about who would bring you a cylinder, or cylinders, when you need them? Industrial oxygen is safe to use in an emergency. Have you checked to see how your regulators hook onto the bigger bottles? Is there a regulator wrench handy?

How many stretchers do you have in your plant? Who knows their locations? How will you transport a number of victims out of your plant to the nearest medical aid? Most important, where will you send them? If you have a hospital that can handle eight to ten severe injuries at one time you are very fortunate.

How will you know which injured person goes to what medical facility? Community agencies, such as the Red Cross, and I'm sure there are others, have a tagging system. This type tag could be adapted to the use that you want. Some tags are made with a carbon copy which is kept with the log sheet indicating where the injured person was sent. Some plants have a kit which contains a log sheet, tags, list of emergency transport companies, a list of the hospitals, a list of doctors, and all of these have the telephone numbers printed too. The kit contains easily read, simple, clear cut instruction for the person in charge to follow.

Many emergencies in a chemical plant involve burns. There are several burn hospitals, or hospitals with a burn unit, throughout the United States. These people are equipped to care for the severely burned patient. However, they all have certain things that they would like for the patient to receive before the initial treating party dispatches the injured to them. It would be wise to do some preliminary investigations concerning these requirements. Many victims of fires are lost enroute to the hospital because they did not receive proper treatment initially. If you have a burn and you have not had time to check on the requirements, all you have to do is call the hospital and the doctor in charge will give you instructions.

I have just mentioned items which deal directly with some emergency equipment and methods of expediting care of the injured. Another factor in emergency planning is the

chemical, or chemicals, handled in your plant. This could be the chemicals used in your process or the chemicals your process makes. There should be good communications between the people who are responsible for ordering, using, or manufacturing any chemical that has potential hazards and the medical personnel in the plant. Not only should they provide a list of these chemicals, but, also, the effects of the chemical exposure on the employee. A plan of treatment should then be developed and should be accessible to anyone who will be treating the chemical exposure. Some plants have a toxicity chart. This chart has all the pertinent data, which can be obtained at a glance, and at the same time has treatment to be given. From this information the treating physician can be informed about the type of chemical that the injured has been exposed to.

Emergencies in a chemical plant are not always chemical exposures. Although we are a chemical plant, I see a larger ratio of thermal burns and lacerations of the hands and fingers than I do chemical burns.

You don't have to prepare for the emergency that you can prevent. Sound simple? Well, it is and it isn't. It takes time and involvement. By involvement, I mean that I think the nurse should learn the plant layout. A part of the job should be to know something of the area that an employee works in. The nurse should know the type of work that goes on in each department or section. Not only is this knowledge helpful when counseling the employee but the nurse's contribution to the safety program could be greater. Rendering first aid and at the same time analyzing the reported injuries can aid the safety department. Of course this depends on the alertness of the person and it makes no difference whether it is the nurse, or another trained first aid person. Hazardous conditions can be discovered, or uncovered, if there is reasonably good knowledge of the environment, jobs performed, and the mental capabilities of the personnel involved in the accident.

I would like to give some examples of the type of involvement that I have had since I was employed at USI. The first example involved a noise level problem in what we call a finishing section. The decibel levels were enough to cause headaches and ringing ears for some of the employees. Employees

in this particular section were being exposed to noise which was generated from two machines. In one place, on one side of the machine, it was 99 db and on the other, at the operator's station, it was 97 db. I searched and searched and could find only one written opinion stating specifically what the maximum noise exposure should be for anyone to work in for a number of hours, or any period of time. We did much research and finally, after many conversations with different doctors and engineers, we set a maximum exposure standard of 90 db. Since that time, which was eleven years ago, the Walsh-Healy Act has adopted that temporary standard also.

It takes a lot of correction to achieve a noise reduction of only one db. In one place we had to come down nine db, and in the other, at the operator's desk, seven db. We thought of putting a sound proof booth around their control board but this would still allow lengthy exposures when trouble arose and we didn't feel that the cost was justified when we still had to expose the operators. We tried an acoustical tile baffle board screen. It was ineffective, along with the fact that the operators could not see the machines. Next we decided to laminate two inch thick polystyrene onto the machine in question. This cut the noise level considerably, but the machines would become overheated and maintenance became a problem. Finally, we were able to design an insulated acoustical cover that was air cooled by a small fan. The original cost, with engineering and pattern design, was about \$5,000, but the next cover only cost about \$3,000. They were effective and the answer to our problem because they reduced the noise level to near 85 db on the one side and 84 db on the side next to the operator's desk.

The second example of involvement concerns chemical burns. During the first years of operating we had several burns, and one particular case that happened in April, 1962, had the potential of being a severe acid burn. The operator had just come on duty in our Utility Section. At approximately 3:50 P.M. he uncoupled an air line that was being used to blow out an acid line. Acid had gotten in the line due to a blind that was down the line and a valve that was turned wrong. The pressurized acid sprayed about his face, neck, and arm. He had previously had serious

burns from acid, while in the employ of another company, and had, on occasions, stated that he was afraid of chemicals. When the acid hit him he ran and jumped onto the plate which activates the safety shower. The metal cable broke and the shower did not activate. A construction worker walking by guided him into the eye bath until the shower could be manually activated. Fortunately, this man only received minor burns with the exception of one area on his neck where he has a small scar. Upon investigation we found that a type of cable, subject to corrosion, had been used on the original installation of the showers. The rust was not visible because the cable had been painted and on periodic checks of the shower it was not noticed. We now have stainless steel cables, which are not painted. In addition I asked why we did not have some alarm system for the remote showers and eye wash fountains. I was assigned the task of writing a job change request and we now have flashing lights and a horn on all remote showers and eye wash fountains in the original unit. In all of our new units the alarm is wired to the central unit control board and when a safety shower or eye wash is activated the operator on the board knows it immediately.

The third involvement concerns heat exhaustion. We were plagued by heat exhaustion in the summer until I chanced upon some information at one of my professional nursing meetings. Our plant furnished two types of salt tablets. But not all people tolerate salt tablets and those people were not taking anything; that is, until we started the Vitamin C Program. I had obtained literature on the use of vitamin C for prevention

of heat exhaustion and had submitted it to our plant physician for his opinion and approval. The Safety Department also thought it was a good idea and was willing to help with the education program necessary to get the personnel most involved with the hot areas started on vitamin C. The pipe fitters, insulators, mechanics, and welders comprised the group that was having problems with heat exhaustion. At one time on a hot day, prior to the use of vitamin C, I had two mechanics in the dispensary with fairly severe heat exhaustions. Since we have introduced this preventive program we have had only one case reported that was taking vitamin C. Upon questioning, he admitted that he had a G. I. upset several days earlier, with vomiting and diarrhea. This program has reduced our first aid cases by roughly ten per year.

The fourth, and last, example involved the use of air conditioned hoods for sand blasters. While using regular blasting hoods they had worked 15 minutes and rested at least that long. After the air conditioned hoods were installed we have not had a case of heat exhaustion in this group and their work output is much greater due to the fact that they can now work for two to three hours without a break.

These are just some of the ways that I have become involved to help remove some of the conditions which created, or could create, an emergency at my plant.

Remember my previous statement, you don't have to prepare for the emergency that you help prevent!

MANAGEMENT TECHNIQUES FOR ACHIEVING PROCESS SAFETY

By WALTER B. HOWARD

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Although the title of this talk is "Management Techniques for Achieving Process Safety," it might well have been "Management Techniques for Achieving Safety in Processes." Process safety itself can refer to a specific area of safety much like we

also refer to personnel safety, electrical safety, mechanical safety, fire protection, and others. However, the emphasis in this paper will be on achievement of all these areas of safety in the processes which we operate. The emphasis here will be on safety

in the process industry in terms of dollars and "sense." The intent is to provide a context for spending of money for safety. The basis to be used here is loss prevention reviews.

Loss Prevention as Management Control

Loss prevention is part of overall business control. As companies in business to make a profit, and also as companies existing in our total society, we must achieve an optimum minimization of hazard exposure to our plant people, our business, and our public.

Loss prevention is also part of overall operation control. From the standpoint of safety we must take the broad view of the term "operation." Operation must include not only the manufacturing function itself but other functions which impinge on manufacturing. This includes, for example, plant maintenance, plant technical service, new project design and construction, etc.

This paper will discuss loss prevention reviews as a means to identify and solve hazards. Only by recognizing hazards in advance and controlling them in advance can we accomplish loss prevention. In this sense, loss prevention reviews constitute a management control tool.

Loss Prevention Through Hazard Control

Another title on this paper could, in fact, be "Loss Prevention Through Hazard Control." The emphasis must clearly be on the word control. This hazard control must pertain to everything we do in connection with operating units. It must also pertain to the design and construction of new facilities. As we shall see shortly, the techniques to be employed are similar in both cases. Practically everything we do in our plants has associated with it a number of hazards. To prevent those hazards from getting the best of us, we must be in control of them. That is, we must be in the driver's seat. We only have accidents when we somehow let these hazards get control of us. It's a simple question of whether or not we are truly in control. Every one of our accidents should be viewed as a challenge to our egotistical beliefs that we are truly operating in control.

From one standpoint, we can say that our plant equipment is basically designed with safety in mind. For example, plant equipment is designed to run dependably, day after day. It is designed to stay there once we

install it. That is, it is designed so that it will not fall apart or will not spew out toxic materials or will not rupture at operating pressure. It is designed to perform its normal functions dependably and is, hopefully, designed to take care of abnormal conditions. It is designed to make a quality product at reasonable cost so we can make a profit from the product as long as the market holds up. The equipment is also designed so that it can be maintained safely when the maintenance is properly executed.

The concept of safety as an inherent feature of design can be looked at further as we examine a typical fractionating column. Such a column is designed to separate dependably the products which we wish to obtain from that column. Thus, the column contributes its part to the dependability and profitability of the ultimate product from the plant. The fractionating column is designed to avoid malfunction; e.g., to avoid flooding or to avoid product overheating. The column is also designed to hold a certain pressure so that it will not have a risk of blowing apart during use. The same thing can be true for vacuum capabilities. The column will also have pressure relief to take care of abnormal pressure conditions. And finally, the column will be designed so that it can be maintained safely.

So a point can be made that we do automatically consider safety when we design and build our plants. A further point can be made that our operation (manufacturing, maintenance, etc.) is designed or planned so that it will also be safe. Yet, in spite of all this, our corporate loss experience shows us that losses continue. We are constantly having minor and major accidents, even catastrophes. These affect people as well as equipment; in the ultimate, they affect our profits. Most of the accidents are found to be preventable. We have too many surprise incidents. At least one reason that preventable and surprise incidents continue is that our safety review analyses are too shallow. It is particularly noteworthy that long operation without accident is no guarantee of safety. Meanwhile, we find that insurance is becoming harder to get.

How Safe Is "Safe"?

What should a plant's safety program be? How safe should a plant be? How safe is "safe"? These are tough questions and yet

they are questions which we must face in our respective businesses. In hazard control we are concerned about what we often call the three P's of safety: safety of people, safety of property, and safety of profits. The term, "safety of people," is clear, but we shall have more to say of this a little later. Safety of property relates to safety of the equipment which we use to make products, as well as to safety of those products in process, i.e., while they are in that equipment, while they are in storage, and while they are in transport to our customers. Safety of our profits hinges directly on the first two areas of safety. It also hinges on the dependability of the quality of our product as we make it in the equipment, store it, and transport it. So the money which we spend for safety must be related to these three P's. We must therefore consider what our basic approach will be to these three P's of safety.

One approach to safety, of course, can be that of zero initial spending. In this ultra-conservative approach we can say to ourselves that we will spend no money for safety until we have an accident. Once we have an accident, we shall spend only enough money to correct the accident cause in the most limited interpretation of that cause. On the other hand, as we all know, our spending for safety can be so great that we spend ourselves out of business. This concept is all too well known to all of us. Although the concept can be used as a red herring to discourage spending of money on any kind of safety proposal, we do know that, in business, money for safety is limited, just as it is for any other phase of business. Obviously, we must still make our profit for our respective businesses to stay alive. This type of spending can be likened to Henry, the newly-arrived angel in heaven. Two of heaven's old timers observed Henry to be flying around with his new wings and playing his new required harp. They also noticed that he had a pack strapped on his back. The old-timers to the new arrival always was rather guard against pro-welt-and-suspenders only because such money, but also quickly lead to a companies.

Ingenious Spending For Safety

As an alternate solution to the above-mentioned approaches, some might suggest that the best spending for safety is the "optimum" spending. However, such an emphasis could lead to decisions for safety spending primarily on the basis of cost without evaluation of possible alternate safety solutions. It is suggested, rather, that the basic guide be "ingenious spending." Within our own company, where careful attention has been given to this, there have been numerous cases where the final spending for safety was not at all that which was immediately apparent as an optimum when the hazard problem was first recognized. No doubt this has been an experience in other companies as well. It is suggested that the emphasis be on achieving the optimum solution rather than on optimum spending. There is a subtle difference here. The emphasis on achieving the optimum solution leads to the better evaluation of alternates and leads to more innovation. It is not intended that this should be a great time-consuming activity. Neither, on the other hand, should we consider as the only available solution that single idea which might first pop into our minds. Oftentimes, with just a little thought, alternates will come to mind which were not at all apparent at first blush. When we find that ingenious solutions have been developed within the company, we try to pass the word to other parts of the company.

Another noteworthy point is that the cost of a given safety solution is not just the first cost, i.e., whether it be capitalized or expensed. In addition to the first cost, a safety solution can also involve operating costs, maintenance costs, dependability factors, other hazard exposures, etc. Therefore alternate safety solutions need to be evaluated on all these bases, not just on the basis of first cost only.

One example of ingenious spending occurred in one of our plants which was facing the problem of changeout of safety sight glasses in the heads of a number of batch reactors. These reactors had originally been supplied with what are nowadays considered to be non-safety type sight glasses. On the basis of later knowledge and new technology it was decided that these old sight glasses needed to be replaced with safety-type sight glasses. Each kettle had two sight glasses, one for installation of a light outside to

shine through the glass onto the contents inside the kettle. The other sight glass served as the viewing port. The plant found that the cost of replacing all these glasses was going to be quite high. They therefore decided that it was time to scratch their heads a bit more. The basic question confronting them was whether the initially apparent solution was truly optimum. Someone suggested that they use a single sight glass for both the light entry port and the viewing port. A further suggestion was that the viewing could be helped by use of a light shield placed essentially across the sight glass diameter and shielding the viewer's eyes from the light source. This proved to work well. A simple viewing hood was mounted over each glass at very nominal cost. The other sight glass nozzle on each kettle was then blanked off with metal. This resulted in a fully acceptable solution at lower cost than that initially contemplated.

Another example of ingenious spending is use of the design equations developed by W. J. Boyle, Jr.⁴ for determining the necessary cross-section of a relief device and vent pipe for pressure relief of equipment containing material which can undergo highly exothermic reactions, and which will vent primarily as liquid phase material. The calculation procedure takes account of the increase of reaction rate as temperature increases due to release of energy by the ongoing exothermic reaction. Prior to the development of this calculation procedure, the sizing of vents had to be done on various empirical bases. This older procedure could either result in vents which were larger than necessary and thus more costly than necessary, or it could result in vents which were too small and which therefore did not provide the safety needed. It is obviously better to spend the right amount of money for safety instead of too much or too little to accomplish a given safety objective.

Another point in this connection is that, in general, we need to seek the simplest safety solution in trying to arrive at the overall optimum. For example, two alternate solutions might achieve the same hazard reduction for the same total cost. However, if one will require much more difficult maintenance than the other to keep the safety-related equipment fully functional and dependable, then obviously the one requiring less and simpler maintenance has the edge.

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Hazard Definition: Loss Prevention Reviews

So much for the solving of safety problems. How can our companies find or recognize safety hazards in the first place? The recommended procedure is use of loss prevention reviews. The review techniques are similar for existing plants and for new projects. We shall first discuss these reviews in terms of existing plants.

It is recommended that existing operating units have loss prevention reviews, in depth, approximately every two years. The objective, of course, is to minimize loss exposure in terms of the three P's of safety. The economic justification for the review is the reduction of hazard. Such reviews do represent appreciable investment of manhours. We find that our plants consider these reviews to be fully justified on a economic basis. The frequency of the reviews does not need to be exactly every two years; it may be every 18 months or every three years. The reviews should be often enough to take account of the subtle changes that go on in our operating units, both in equipment and in operating procedures. They should also be often enough to take account of new knowledge which may have been obtained, either within the operating unit itself, or from developments in the company's research activities, or from information contained in publications or other form of communication. These reviews are much more than a safety inspection, much more than running through a ready-made check list. They need to be done in considerable detail and depth in order to "catch" or recognize those hazards which are simply waiting to gain control over us.

Plant Manager's Commitments

Plant management needs to make a significant commitment before beginning loss prevention reviews in the particular plant. The reviews are to be done by a team, as will be described later. Plant management must set a priority for the meetings of this review team. Unless the review meetings are assigned a top priority, the team members will not give regular attendance. This is probably the most difficult policy to enforce. Another commitment from plant management must be that the team membership will consist of high caliber people. This usually means the busiest people in the plant. On the other hand, if a man be appointed to a team

just because nothing else can be found for him to do and because he's a good old Joe, that man will not make the necessary contribution to the team's deliberations. The team members must also be of such high caliber that the recommendations resulting from their review will be respected because of the plant management's respect for their judgment. Plant management also needs to commit, from the very beginning, to spending money for optimum solutions of the safety problems uncovered or else justify not spending this money. The justification cannot be simply that there is not enough money or not enough time or not enough people. The justification for not spending money must be on as firm a basis as the recommendations themselves. Plant management also needs to commit to a total program of reviews to give a complete plant coverage over the normal frequency period. The complete coverage should include not only the manufacturing operations but also such other operations as the various shops, field maintenance, etc.

Review Procedure

Several points are very important in the review procedure. It is important that the team have membership representing each of the plant functions that impinge on the particular operation to be reviewed. For example, the team should include not only people from manufacturing and the plant safety department, but also from plant technical services, maintenance, and any other department which may have activity relating to the particular operation. One example would be research, if the operation were such that the research group were intimately associated with it. The manufacturing representation may be more than one person. For example, it is advisable to have the manufacturing superintendent as a team member if at all possible. Oftentimes it is also advisable to have the foreman of the particular operating unit as a team member. It is quite possible that the manufacturing supervisor needs to be a member of the team, too. Similarly, representation from the maintenance area may consist of more than one person. Because of the highly specialized nature of much modern instrumentation, there may need to be representation from the instrument maintenance group. This could well be in addition to representation from the mechanical maintenance group. A

helpful procedure followed by many review teams is to call into specific meetings certain people to serve as consultants for particular parts of the review. The consultants in this case may include not only people of special technical qualifications but also hourly people.

As mentioned earlier, the meetings of the review team should have such a high priority, designated by the plant manager, that all members of the team will be present at each meeting unless prevented from attending by only very major matters such as a catastrophe at home or in the plant. No other plant meeting or related activity must be permitted to take precedence over the team meetings. Again, it is important that the plant manager state and enforce this policy.

The team needs to meet often enough that the team members do not lose their thought continuity between meetings. Thus, meetings held once a month are too infrequent. If this were done, much time would be spent at each meeting recapping the discussion of the previous meeting. A good frequency is often found to be twice per week, although some teams have been known to meet once per week, and others have been known to meet for five consecutive days in a week. The meeting length should also be sufficient to make real accomplishment. A meeting duration of one hour is too short. Meeting lengths of four hours or even longer are found to be useful. In the scheduling of meetings it is usually desirable to provide short periods at the beginning, middle, and end of the day for each team member to have available for some small amount of routine business. Most of this routine business must obviously be delegated by a team member to someone else. He may, therefore, use his short business period only in checking with the person to whom he had delegated the responsibility. Again, it is important that attendance at the team meetings be prompt.

The review team will need a very simple organization. There needs to be a chairman to control the overall progress of the meeting. Often this is a representative from manufacturing directly or from manufacturing technical service. There also needs to be a secretary for the team. It is desirable that this not be a member of the plant safety department. The secretary should keep very

simple notes of each meeting and issue these in raw form to all the team members between meetings of the team. This is most usefully done by simply Xeroxing copies of the secretary's hand-scribbled notes. The secretary also needs to draft the report for the team, review it with key members in team meetings for revision and, finally, issue the team's report.

The team needs to analyze the particular operation in depth. It is good that the team have some preparatory instruction regarding this; this can usually best be done by holding a meeting of the team with the plant manager and with the plant safety manager. In this connection it should be stated that it is fully recognized that many plants may be small and may have only one person in the total safety department. In this case, he is automatically the safety department representative on each review team. This one safety man may even wear other hats, such as personnel manager, etc. In any case, he should recognize that the meetings of the review team provide a golden opportunity for a full exploration of safety aspects of the particular operation being reviewed. The function of the safety representative on the team is not to raise all the points nor to ask all the questions. In fact, to the extent that the other team members do this in the meeting as they should, the safety representative is well advised to keep quiet unless he is approached for particular safety information. On the other hand, he has a primary responsibility to be sure that the proper questions are asked throughout the review.

The team members will quickly find that the old expression is true, that several heads are better than one. There is a catalytic effect of all minds upon one another. The team members may feel that they have been communicating a great deal already, before the team meetings begin. However, they will find in the team meeting that they will truly be communicating as they never have before. The meetings have a further benefit of clarifying possible misimpressions, erroneous information, etc. The reviews inevitably lead to better understanding of the operations as well as better understanding among the team members. Some practical side benefits that frequently result are described later.

In-Depth Analysis

It is important that the team review the operation in depth. We refer to this as an

in-depth analysis. It is not sufficient to review the operation in terms of the normal sequence of events. For example, if the operation be a continuous manufacturing process, it is insufficient to review only the steady state condition for operation. It is most important that the abnormal operating conditions be examined for all potential hazards which can develop. For example, the review needs to cover startup, shutdown, upsets, and combinations of malfunctions. As all of us know, our serious accidents are usually caused by two or more non-normal incidents occurring at the same time. Each of the simultaneously occurring non-normal incidents may have a particular probability. However, the probability of simultaneous occurrence of two or more of these non-normal incidents is not necessarily the product of individual probability as would be predicted by probability theory. The reason for this is that very often the particular non-normal events which occur may not be completely independent of each other. Strictly speaking in the probability sense, the probability of the concurrent happening of the non-normal events could be handled as a product, provided that product took full mathematical account of the mutual interdependence of the respective events. Many examples of this could be cited.

It is also important that the team members not assume the original design of equipment used in the operation to be sacred. How often have all of us done Monday-morning quarterbacking after an accident only to find that there was some mistake in the original design such as insufficient venting area for pressure relief? Nor should it be assumed that all of the original construction was correctly done. In one of our company's plants a review team for a manufacturing operation decided that it should review, in the field, the proper fail-safe action mode of all automatically operated valves. Certain team members were assigned to do this. The fail-safe mode was, of course, related to the valves as well as to the basic operating mechanisms or instrumentation. Upon making the analysis, the team members found three valves which in fact failed in an unsafe manner. Had a particular one of these three ever failed thus, a major plant accident, or possibly a catastrophe, could have occurred. The plant manager, by the way, felt that this finding alone gave a major

return on the manhours invested in the total review.

A similar point can be made for the operating procedure. Because a given operating procedure may have been in effect for many years, this does not make that operating procedure correct. Operating procedures can sometimes contain hazards which are not readily apparent yet which can lead to accidents to people or equipment. So the operating procedures need to be reviewed very carefully in terms both of potential people hazards and potential process hazards. All of us have also had the experience of finding that, through the years, changes in operating procedures have taken place without any formal recording of these changes in the operating procedure manual. Sometimes such changes, without the proper analysis at the time, can contribute hazards.

Some examples should be cited to illustrate what is meant by a review in depth or an analysis in depth. Many good check lists are available to help in the review of an operation and to help in the evaluation of severity of hazard. No attempt will be made here to provide an exhaustive listing. One example is the check lists contained in the publication, *Hazard Survey of the Chemical and Allied Industries*, by E. W. Fowler and Arthur Spiegelman.⁸ Another is *Process Safety Manual*, published by The Dow Chemical Company.⁹ Still another is the book, *Safety and Accident Prevention in Chemical Operations*, by H. H. Fawcett and W. F. Wood.⁷ This complete book can be viewed as a check list. A similar comment is true for the book, *Accident Prevention and Loss Control* by C. L. Gilmore.⁹

Beyond check lists, the review needs to probe deeply into the hows and whys. For example, a check list might call attention to the need for a venting provision for certain process conditions. In the review on the given operation, however, the review team should probe much more deeply than merely confirming that there is a venting provision. For example, if the venting be on a process vessel, should that venting be provided by a relief valve, or by a rupture disc, or by a rupture disc and relief valve in parallel, or by a rupture disc in series with a relief valve, or by a rupture disc in series with a relief valve together with a different rupture disc in parallel? What should be the basis of decision for the type or types of venting

required? Has information gained through operation and from technical literature since original construction of the facility pointed the way toward improvement of the venting provisions? Perhaps the original design called for a relief valve in series with a protective rupture disc because it was feared, at the time of design, that an unprotected relief valve would become fouled during operation. However, possibly the operation through the years has shown that there is no fouling of the nozzle to the relief elements and no fouling of the underside of the rupture disc. This could say, then, that the rupture disc could be omitted with a possible improvement in the overall safety of the venting system.

Or, if a rupture disc and relief valve must be installed in series, is the intervening space provided with a pressure gauge and a flow check? And are valves absent from this particular pressure gauge and flow check hookup? What is the relief valve trim size? What is the basis for selection of this trim size and is it correct for the necessary venting capabilities? What is the basis of calculation for the maximum necessary venting capability? What are the initial and full-open pressures of the relief valve versus vessel strength, including allowance for aging? What are the effects of backpressures on operation of the relief valve? Where does the relief valve vent line discharge to? Is this the best location for safety and pollution reasons? When the relief valve functions, what will discharge; gases only, or gases plus liquids? Will the gas or liquid be properly handled by the vent discharge arrangement? How does the vent line design compare with criteria for orientation, size, strength? Does the vent line need support near the end to prevent bending or whipping? How is water accumulation and freezing in the vent line prevented? After venting, is air suckback into the system a hazard? Does the vent line need heating or cooling?

Unless all these questions, and possibly more, can be satisfactorily answered, we cannot know that we have an adequate relief valve even though we could check affirmatively the question concerning venting provision on the reactor. Additional questions need to be asked concerning a rupture disc installation on the same reactor and concerning a series combination of rupture disc and

relief valve. Especially helpful literature on venting has been published by API.

A similar example of analysis in depth can be cited in the area of operations. For example, we know that operating equipment must be provided with certain safety instrumentation which in turn may need to actuate alarms or interlocks or both. At the same time, we know that safety instrumentation, although it is installed, is of no value unless it is fully functional. Therefore, in reviewing the safety instrumentation the review team needs to analyze very carefully the means used in the operation for assuring dependability of the safety instrumentation. For instance, the safety instrumentation may receive a yearly check which is often called "preventive maintenance." However, it is entirely possible that the dependability of particular instrumentation needs to be checked more often than this, possibly once per shift, or possibly once per month, etc. So there is the question of whether the safety instrumentation is checked on a routine schedule determined on the basis of need, and also just how this checking routine is set up to assure its execution. Furthermore, the very method of checking needs to be analyzed. For example, does the checking include checking of the basic detection or response element? And does the checking proceed through the entire system to determine the full system operability, including the particular alarm or interlock involved? Still further, is the amount of safety instrumentation sufficient? Do highly exothermic reactions have dual independent safety instrumentation? Is some of the safety instrumentation unnecessary and therefore confusing?

One of the items sometimes overlooked in reviews, when personnel safety is being considered, is the provisions which need to be incorporated in either equipment or procedures to protect people against their own inadvertent unsafe acts. Even the best intentioned person will slip at times and needs to have a barrier between himself and the accident which would otherwise occur. Sometimes this requires a very analytical review of the procedure manual; sometimes it requires a field analysis of just how a given operation is conducted.

Information Helps

Sometimes a review team will find that it needs some particular information which is

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not readily available. If this be information which can be obtained by a bit of searching or perhaps by some phone calls, it may delegate one of the review team members to secure this. On the other hand, certain tests may need to be performed in order to obtain such information. In such a case, the team may need to make a request of its particular plant or company research department to obtain such data. One example is unstable material, i.e., compounds which can undergo exothermic decomposition. Programs for testing of such materials have been described in several papers. A non-exhaustive list of these includes papers by R. A. Wankel,¹¹ L. Silver,¹⁰ and R. D. Coffee.⁵

Another kind of aid for review teams in some companies is publications often referred to as safety packages and as safety standards. Sometimes a given company will have the same or very similar processes carried out at a number of locations, sometimes at several locations in the states, and sometimes also in additional locations abroad. In such cases it is very worthwhile to publish a set of comprehensive safety guide lines for design and operation. The various locations can then be required to adhere to these guide lines or else to show justification for exceptions. Review teams at the various locations can then use such safety packages as part of their review coverage. It is important in these cases, however, that the review not be limited just to the coverage of the safety package material. The safety package cannot be 100 per cent comprehensive; it may even contain some errors. Justifications for exceptions should also be reviewed in detail.

Sets of safety standards are also desirable for designs which apply broadly throughout a company. Examples include such items as fire resistant valves, safety showers and eyebaths, permanent ladders, etc. Such standards can be very helpful to the review team.

Use of Check Lists

In general, it is recommended that review teams use various check lists for just that purpose only. That is, it is best to do most of the review without reference to a detailed check list and to use the check list at the conclusion of the review only to be sure that certain areas were not omitted from consideration. It is found that direct use of a check list throughout the review will limit projection of thinking. Attention tends to be focused too much on the check list item

to the exclusion of considering implications beyond the check list item itself. Check lists can, however, serve a very useful function in avoiding omissions. It should be recognized that no check list can give 100 per cent coverage for this type of review. It is generally best to use questions that cannot be answered with a simple yes or no but require thought in wording and answer. None of this comment about check lists and use of check lists is intended to be derogatory toward use of check lists for safety inspections. Safety inspections are another, and necessary, useful function, different from the loss prevention reviews. In fact, information found in safety inspections can often be of very great value to the review committees.

Throughout the review it is important for the team to keep before it the point that the team is not to engineer the solutions to the safety hazards. They are to analyze for the sake of identification of hazards and are to make recommendations for elimination or reduction of hazards. They should also assign responsibility to proper departments or groups for engineering the solutions.

It often becomes important to analyze the economic justification for safety measures involving safety of equipment, dependability of operation, or dependability of product quality. This cannot be done readily for safety measures related to people safety.

Review Report and Followup

The review team needs to conclude its activity by issuance of a review report. This report should summarize the hazards listed in earlier review reports and on which action is not yet completed. Each of these needs to be examined carefully and further recommendations made. Then the hazards uncovered in the present review should be listed and recommendations made concerning them. The recommendations can include such items as the securing of new knowledge and revisions of operating procedures. Attached to each recommendation should be a listing of responsibility for action and a realistic target date for action completion. It is best for these to be reviewed with the respective groups to whom responsibility is assigned before the report is issued. It is usually worthwhile, also, to assign check dates following the target dates to assure completion of action. This checking can normally best be done as part of the agenda

of regular meetings of the plant manager's executive safety committee.

Manhour Requirements and Justification

It is usually found that the total manhours involved in the review of a moderately complex manufacturing operation, including those hours spent by team members in securing special information, will amount to 200 to 400. Some time ago our company was discussing such reviews with another company that uses a very similar procedure and found that their normal manhour expectation is 600. Successive biennial reviews after the first one may require somewhat less total manhours. However, care must be exercised lest there be an inherent assumption that the prior review really covered all of the safety areas and that very little more needs to be done beyond followup on the prior recommendations. Every plant should learn from its operations during the two-year period. Oftentimes there is also published material which presents new information. All of this should be ploughed into later biennial reviews. It is also, of course, desirable in most cases to have a different group of people constitute the review teams for successive reviews. It has been our company's experience that once plant managers have instituted loss prevention reviews they wish to continue them. The basic justification is minimization of hazard, that is, loss prevention through hazard control.

Side Benefits

In addition, a number of side benefits have been encountered as a result of these reviews. Review teams sometimes come up with previously unforeseen ways to increase capacity. Sometimes they run across ways to enhance product quality. Sometimes they can see ways to improve manpower distribution. These and other side benefits will not necessarily result from every review, but they do occur often and show a real financial benefit.

Safety Reviews for New Projects

The same general objectives and procedures apply to loss prevention reviews for new projects. Such reviews are needed not only for new major facilities but also for expansions of old facilities and other types of modifications of old facilities. From the project viewpoint, the criteria for a good plant are several. Without attempting to list

these in any priority sequence, we can include the following: product quality, low manufacturing cost, ease of operation, low startup cost, timing, low capital. Throughout all these safety must permeate. Safety must be an integral part of every phase of design, rather than something added at the end of the design almost as an afterthought. In fact, this latter approach is, of course, much more expensive. It is strange, however, that even in this modern, enlightened society this still happens from time to time on projects. A good example is the purchase of a pressure vessel. The vessel is specified for a given operating pressure and design pressure, and the order is placed. Then, after all this has been done, the design engineer may realize that he has forgotten to specify the pressure relief provisions. He may then find himself very tightly squeezed between process operating pressure and vessel design pressure, to provide relief provisions of suitable pressure characteristics which can still fit within the allowances of the ASME unfired pressure vessel code. On the other hand, if he includes the relieving provisions as part of the overall considerations in vessel specification, he can allow for suitable margins between operating pressure and relieving pressure and still stay within the code limits.

The project loss prevention review is a very useful tool in accomplishing safety in new projects. Again, the review should analyze in depth and should cover all safety aspects. As before, also, a formal report needs to be issued with recommendations and responsibilities defined.

In large projects, or those involving significant degrees of complexity, we find that several loss prevention reviews may be needed at various stages of a single project. These may occur at such steps as the process development stage, the scope stage, the design basis stage, and the pre-startup stage just before the equipment is to go into operation. In this overall sequence the bi-

ennial plant loss prevention review simply becomes part of a total coordinated program of overall safety management. Project reviews, like plant reviews, therefore constitute a management control tool.

Conclusions

Loss prevention reviews for both existing plants and for new projects constitute a very valuable management control tool. They are part of overall business control and part of overall operation control. Properly conducted and reported they can lead to a proper priority of monetary expenditures for safety. Properly followed up they can lead to reduced losses from accidents and can help prevent catastrophe. In the final analysis, loss prevention can be accomplished only through hazard control.

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FERTILIZER SESSIONS

A TOP FERTILIZER EXECUTIVE LOOKS AT SAFETY

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Director, Gold Kist Food Dept., Cotton Producers Assn., Atlanta, Ga.

In the late fifties, CPA/Gold Kist was beginning to have enormous safety problems. These had arisen due to our increase in size and diversity of operation. No one was coordinating safety and as a result few plants were motivated to spend time or money in this area. Of course, I'd like to say here that a notable exception to this was the Plant Food Department. Mr. Elam Nunnally, who was in charge of the Plant Food Department in 1953-54 when I came with CPA, insisted that we join the National Safety Council and that we do something about our safety program. We joined the National Safety Council in 1954-55.

However, overall in CPA, large losses were occurring. Our workmen's compensation insurance carrier, The Travelers, was unhappy. I have a memo written by Travelers to the General Manager at that time, insisting we take drastic action at once. Our loss ratio was over 170 per cent, (it is now about 28 per cent) so you can understand why the carrier was upset. Earlier, we had been dropped as a poor risk by Liberty Mutual Insurance Company for failure to bring our bad experience under control. One accident, a dust explosion in our grain department, ended up with a loss of three men. We were to pay an additional retrospective premium at the end of each year because of high losses and this was, of course, economically poor business.

Travelers had been recommending for sometime that we assign a full-time person to work on safety, and in August, 1960, Jerry Brooks was assigned full-time on our safety program. We received our first refund at the end of fiscal year 1960-61—\$8,000; from then on our refunds have been substantial—\$28,000, \$79,000, \$68,000, and in 1968-69 about \$120,000.

In 1966, we went a step further on safety and assigned Jerry responsibility of fire protection and fleet safety. Our fire losses have dropped from \$240,000 in 66-67 to less than \$4,000 in 68-69. We are receiving good dis-

counts, about \$140,000 on our fire insurance; so you see, safety pays!

Our fleet losses have been low for several years, and we're receiving discounts of about \$60,000 per year based on size and a good record. Three of our fleet units have received the coveted Hi-Mile Award from Cotton States Insurance Company for having exceeded a million miles of operation without a chargeable accident.

In 1969, Security was added to the Safety Department's responsibilities, and this department was designated "Safety and Security." Jerry added an assistant, and you can understand why when I tell you that in 1960-61 we worked 2.8 million manhours, rising to over 10 million in 1968-69. It took a long time for us to understand that safety pays, but when we finally woke up we got full support from top management. In our case, top management became concerned, and this concern was put into action. The results have been outstandingly rewarding (lives, records, money).

We feel that we have two vital ingredients in our operations which contribute to our success and must be protected—our employees and equipment. No operation is considered more important than the safety of the employees and equipment involved with an operation. A facility manager has the basic responsibility for the safe operation of his facility, and I'll add here that we still have one plant manager who is not completely sold on safety. Actually, this comes from within, not from without, and we are still working on it.

We are working on a number of problem areas. First, there is employee training and development. Fifty-two per cent of the CPA/Gold Kist injuries occur to those employees who have been with us less than six months, so you can see that we have a major training program in this area. Second is safety oriented planning. Many plant process and equipment changes are being

made with inadequate pre-planning for equipment and employee safety; this is something which our Safety Department keeps on top of and keeps emphasizing. Of course, a third is employee motivation. Injuries are still occurring in a safe environment solely due to an unsafe act by an employee who knew better. This was the case when we had a man at our Hanceville Plant who will be an invalid the rest of his life simply because he did not adhere to safety rules and in front of some men violated one of these rules. The result is an invalid.

CPA/Gold Kist has been a member of the National Safety Council since 1954-55. We presently utilize much of their safety material in our program, including *Industrial Supervisor*, *Family Safety*, *Farm Safety*, *Safe Driver* (both the truck and the car edition), safety posters, safety slides, and safety film. We have all our truck fleet drivers enrolled in the National Safety Council transportation program. Several CPA/Gold Kist people have or are presently serv-

ing on a Section Executive Committee and in the Industrial Conference.

CPA/Gold Kist Safety and Security Department has published safety information on the handling of anhydrous ammonia, an employee's safety manual, CPA drivers' manual, FMX drivers' manual, a Gold Kist's employee handbook and, monthly, publishes *Safety Guides* and *Protect*, which is a manager's security bulletin. It publishes a Workmen's Compensation Accident Analysis Record and presents numerous safety awards at our Mid-Year Management Conferences. It also publishes safety guides for the FMX's, which are our 105 retail stores and holds a company "Roadshow" each year for our truck drivers.

We all know that safety is extremely important. In order to motivate your employees you must have the backing of top management, and this we have in CPA. Take top management backing, stir in a good safety director, add good safe facilities and outstanding personnel, and you have a successful program in which everyone can take pride.

CHEMICAL SPILLS AND SPLASHES

By MIKE ELLISON

Plant Protection and Safety Dir., Mississippi Chemical Corp., Yazoo City, Miss.

The history books of the future will record the 100 year period through which we have just passed as an era where mankind made more progress in science and technology than he had made in all of the years of civilized history added together before this date. So rapid has this breakthrough been that it can be truthfully said that 90 per cent of the greatest scientists the world has ever known are alive today.

In many cases, the chemical industry has been out front in this race of discovery and utilization of the elements found on our planet. Whenever you ride in a beautiful car, plane or boat; when you sleep in a modern bed; watch color TV, take a miracle drug that may save your life; when you wear a fine pair of shoes or a modern suit of clothes; drive a golf ball down the fairway; when you have a heart or kidney transplant, a nylon tube or plastic valve put into

your body, you are reaping the rewards and enjoying the benefits of the chemical industry's science and technology.

Although there are multiplied hundreds of benefits to mankind through chemicals, there are also many dangers connected with the formulation, manufacture, and transportation of these useful products. In the formulation and manufacturing end of the chemical industry, there are four basic dangers present: human error, unexpected chemical reactions, failure to use proper safety equipment, and spills and splashes.

The plants where chemicals are made have the greatest number of safety risks because here the workers are constantly subjected on one hand to pressures from management for more and more production, often with outdated or worn out equipment; on the other hand, they have inadequate knowledge of the processes they use, the chemicals

they make, or the vessels and piping structure throughout their own particular areas as affected by other sections of the plant. This is understandable because if they had this knowledge, they would be promoted in the company structure and new, untrained workers would be hired to replace them out in the plant.

Spills, splashes, and fires are our chief problem at MCC and are controlled by the proper use of steam, water, and dry-chemical extinguishers by trained workers who take this type thing in stride of everyday's work.

But the problem does not stop at the plant gates, for in recent years, hundreds of people have been killed or crippled for life by chemicals spilled in train or truck wrecks or customer tank failures. It is impractical to have a well informed chemical engineer to supervise the final use and application of all chemicals throughout our country, because once their expertise is developed, they could demand higher wages by moving into the research and development group or the formulation and manufacturing end of the chemical industry.

But the dangers still exist in alarming and increasing proportions, because today hazardous chemicals are made in such large quantities and shipped out over such wide areas throughout our country that everyone sooner or later will be exposed in some degree to the dangers involved in a chemical spill.

Chemical names and formulas are all-explanatory to the chemist, but mean nothing whatever to the average layman. Where the chemicals are manufactured, the watchful eye of the chemist provides every protection, and through his knowledge and guidance the very best and most modern safety equipment is used. However, as they are shipped out over the country, they pass within a few feet or yards of thousands of people's homes and through hundreds of towns. A tank failure or train wreck anywhere along the way could take the lives of innocent people who had no idea of the problem or knowledge of how to protect themselves. Therefore, every wreck which involves an unknown chemical should be treated just as if it were: (1) a poison gas which was likely to explode upon ignition or contact with other chemicals or gases; (2) a highly corrosive liquid which is toxic and could poison

you through the skin and give serious burns upon contact with human flesh; (3) a chemical which would react violently with water, metals, or certain other chemicals, and may form still another third chemical which might be explosive and poisonous.

Every person living in America today is subject to the hazardous conditions that would exist in a chemical spill near them. Therefore, to point up the problem, let me say that if you live in an average city with a trunk line railroad running through it, or a super highway, the chances are that over 100 chemicals have been shipped within 2,000 feet of your home and loved ones during the past 24 hours.

About 90 per cent of these chemicals are extremely dangerous and under certain conditions can be catastrophic. Some are explosive and could cause great damage to life and property if they were detonated. Some will ignite spontaneously upon contact with air, water, metal, or other chemicals. Some are highly flammable and would burn ferociously over a wide area if ignited. Still others are highly destructive to human flesh and very corrosive to machines and equipment.

It would be economically impossible for every town or village in America to train and maintain an up-to-date protection force to guard its citizens from the dangers which would confront them if a train or truck loaded with chemicals were to have a major wreck in the heart of their city. For instance, a three to six block area may instantly become a roaring inferno of flames under pressure going in all directions, with perhaps other railroad cars or tank trucks exploding, throwing pieces of tanks and corrosive liquids hundreds of feet from the railroad right-of-way or the superhighway.

The storm sewers, drainage ditches, and lower areas of the town may well be a catch basin for liquids giving off poisonous fumes or highly explosive gases. Even if you lived high on a mountainside, near where the wreck occurred, the lighter than air fumes of some chemicals could float up the mountain and kill you while you slept in your bed.

This situation is not going to improve with time. Indeed, it is getting worse as more and more chemicals are discovered, manufactured, and shipped, and the need to make larger profits is forcing the railroads to spend less and less money each year on

maintaining their tracks and rolling equipment and forcing the tank manufacturing companies to come closer and closer to the danger line while building their pressurized vessels.

Looking back for just a moment, we can see that in 1830 it only took 300 chemical plants to meet the needs of less than 13,000,000 people in the United States of America. By 1961, it took 13,500 chemical plants located in 50 states to supply the needs of 187,000,000 American people. Today, with over 205,000,00 people in the United States and with America feeding and helping over 400,000,000 other people throughout the civilized free world, there are over 17,000 chemical plants running 24 hours every day, many of them with their own pilot plants and research groups creating new chemicals to be added to the ever-expanding industry, and no end of the industrial explosion is in sight.

All of these dangerous commodities must be shipped from the manufacturer to the consumer by rail, water, or truck, and the train or truck or barge on which they ride may wreck in your city or village.

There is no overall sure-fire method of controlling all types of chemicals under any condition that the layman could understand; locations, conditions, types of chemicals involved, and method of firefighting or neutralization procedure for that particular chemical without complications to the surrounding area must all be taken into consideration for each different chemical in each particular case.

To point up the magnitude of the problem in numbers alone, the 1968 NFPA Bulletin 325A lists 7,300 trade name products classified as flammable liquids. The *Handbook of Laboratory Safety* by Dr. Norman V. Steere lists 1,094 different chemicals, with 260 of them classified as toxic and 150 classified as strong irritants with their respective threshold limit value is exceeded by human contact or intake.

The Interstate Commerce Commission requires that "Dangerous" placards be placed on all cars containing explosives and class B flammables, which includes several liquids, solids, oxidizing materials, and compressed gasses. However, in relation to the chemicals now being shipped, these placards are far

too vague and totally inadequate to convey to the average citizen the proper steps to take in cases of tank rupture, train or truck wreck with a resulting fire or explosion.

The first duty of those in charge at the location of a train or truck wreck involving chemical tank cars is to prevent injury and loss of life. Then, as far as practical, to prevent destruction of property. To do this intelligently, it is necessary to know what materials are involved and to have some knowledge of their behavioral characteristics. This is not always possible because, many times, the placards were not put on in the first place or were destroyed or burned off before the firemen arrived on the scene, or the tank cars are piled up so high that it is hard to tell which car is ruptured.

Case history studies of past records indicates clearly that the vast majority of deaths, injuries, or property damage have been caused by tank cars which bore placards reading "Dangerous." Since the chemical industry cannot furnish experienced help to ride "shotgun" on every load of its products, and since there is always a time factor between the wreck or spill and arrival of the rescue team from the nearest chemical plant, a common rule should be made public throughout the whole country which would give every citizen a better chance of survival. Some of the directions given in that rule should be:

Caution: The dangers faced from a train or truck wreck today are not fire and explosion alone but include poisonous and corrosive liquids and gases. Therefore, if a wreck or derailment occurs in your city, the following action should be taken immediately:

1. Exercise the utmost caution both for your own protection and for the safety of all the people near the scene of the wreck.
2. Avoid actual body contact with the contents of any car or inhalation of the gas or vapor; the fumes of many gases and chemicals are deadly.
3. Clear the area of all people; reroute traffic around at least a four block area in all directions. Keep everyone up wind from the spill.
4. It would be a wise idea for the fire and police departments to have up-to-date maps of storm sewers and drainage ditches

near the railroad tracks and trunkline highways through their cities and familiarize themselves with the direction of flow so they could alert the people and check for possible explosions in the direction which the product is moving.

The conductors way-bill of the train should show the contents of every car, or perhaps the number on the damaged cars may be readable. If so, these could be phoned to the nearest railroad dispatcher who will give you the address of the chemical plants where the chemicals were made or loaded and they will send experienced men at once to help control the dangers caused by their products.

6. Only those persons necessary to clear the wreckage and control the fire or chemicals spilled should be allowed in the vicinity of the wreck, and they should be cautioned to stay upwind from the escaping fumes.

7. Keep in mind that it is not always the right thing to put water on the contents of a ruptured tank car and that no one should walk or ride through an area where the air is filled with mist, spray, or strong odors coming from a ruptured or leaking tank car or truck. Keep upwind from the leak and if you detect an odor or feel the least bit unnatural, move still farther back from the wreck area.

Let's take propane for example: It may not ignite when the wreck first occurs and there may be a two-inch stream of propane spilling out on the ground under pressure. There will be a large white cloud of gas following the liquid in the surrounding lower areas and under houses. As soon as the vapors rise to the height of a pilot light or are otherwise ignited, there will be a flash back all the way to the leaking tank. If there is enough air space above the liquid in the ruptured tank, it will explode also.

Meantime, if water has been applied, it will only float the liquid over a wider area and cause more fumes and gases to boil off, thus increasing the problem.

The proper procedure in this case would be to evacuate the entire area and expect an explosion. Then, when the flames feed back to the tank, control the burning until all the propane has been consumed.

Quite a long time ago, a methane tank ruptured in Cleveland, Ohio. This was a

real catastrophe. The problem was that the methane was flowing into storm sewers and creating explosions long distances from where the tank failed.

On August 22, 1967, a train pulling chemical tank cars wrecked at Texarkana, Texas. Two cars of vinylidene chloride ruptured, spreading this highly flammable chemical over a wide area. It ignited, causing a fire which burned out of control for nine hours despite help of firemen from several cities. The following morning, a tank loaded with butadiene exploded, sending a column of fire 1,000 feet high and 300 feet across and throwing pieces of metal as far as one-half mile from the scene. The tank car was split lengthwise from end to end and flattened out. The fire continued to burn for another five hours, and about 50 people received injuries ranging from bruises to third degree burns.

It is always better if flammable liquids ignite instantly when the wreck occurs because then the contents of the tanks are consumed by the fire before it covers a wide area.

If possible, all other cars should be removed from the scene because many liquids regarded as safe, such as oils, asphalt, and other petroleum products, vegetable oils, animal fats, and so forth, can be ignited and burn furiously if left close to burning cars.

Let's assume that the wrecked tank car contained anhydrous ammonia. It would follow the low places just like the propane did and boil off a white cloud of vapor near the leak, but the vapor becomes invisible as it mixes with air, making it impossible to locate the body of escaping gas by sight alone. However, as this body of ammonia fumes moves slowly along the ground, it can be detected by its strong pungent odor from 50 to 200 feet ahead of the main body of gas. When you smell ammonia, if you move quickly away into an area of fresh air you will be safe, provided the prevailing wind does not overtake you with the main body of fumes. Always travel upwind from a spill and perhaps crosswind. Actually, it would be better to travel crosswind if possible. Evacuate all personnel which are downwind from the spill.

A person who gets ammonia in his eyes should flush them with running water for at

least 20 minutes, holding the eyelids open, then see a doctor at once. Do not put salve on any ammonia or acid burn.

As little as 1,700 parts per million (0.17 per cent) may produce serious lung edema (copious discharge of blood serum in the alveoli spaces of the lungs.) Unless this condition is properly treated, death will result. A victim thus affected should be given oxygen at once and carried to the hospital immediately.

INDUSTRIAL NOISE, A NEWLY RECOGNIZED FORM OF POLLUTION

By ED ALPAUGH

Supvr., Industrial Hygiene Service, International Harvester Co., Chicago, Ill.

Industrial hygiene is defined as the recognition, evaluation, and control of environmental conditions or factors that might be hazardous to health, that might be very irritating or uncomfortable, or that in any way might interfere with the ability of a person to perform his normal job.

Industrial hygienists and others working in the environmental health field have recognized for a number of years that continued exposure to high intensity noise is an environmental health problem. They also have recognized that some sounds can be irritating and can interfere with a person's ability to perform certain kinds of work. The problem has been that not until recently has there been a good realistic guideline for evaluating the effects of exposure to noise. We now have such guidelines, or TLVs, and as a result many people are beginning to pay attention to this newly recognized form of pollution.

There are some interesting facts about sound that most of us may be aware of but seldom think about. For example, sound is nothing more than a wavelike disturbance that can occur in a gas, a liquid, or a solid. If this wavelike disturbance occurs in a gas, such as air, at sea level and a temperature of 36°F, it travels with a velocity of 1,127 feet per second. The velocity of sound in a liquid, such as water, is about five times

An ammonia spill to atmosphere does not present a serious fire hazard. Its flammable limits are 16 thru 25 per cent. The ignition temperature of ammonia is 1,200°F. Even if there was a large pool of ammonia on the ground with vapor boiling off rapidly, you could throw a lighted flare into the pool and it would not burn. Another flare may start a weak fire on the outer perimeter of the body of gas fumes, but it would soon go out. However, ammonia trapped in sewers or close places may cause a serious explosion.

that in air, and in a solid, such as iron, it is about 15 times that in air.

Perhaps it is fortunate that we do most of our hearing in air. Otherwise, there might be many more people with noise induced hearing loss than there presently are. Air is a relatively poor conductor of sound. For example, the detonation of 50 pounds of dynamite in air can be heard for perhaps 10 miles in still air. In water it can be heard at about 1,000 times this distance, roughly 10,000 miles.

Sounds have two main characteristics: frequency and intensity. The frequency is the number of waves (usually called cycles) that pass a given point in a given time. The modern terminology for cycles per second is Hertz. The brain, as it receives sound through the ear, interprets the frequency as pitch—how high or how low the sound is. An average young man can hear tones from about 15 cycles per second to 20,000 cps, but as he ages he may in time be unable to detect a sound above 10,000 cps. Fortunately, the speech frequencies lie well within this range, and music falls in the range below 10,000 cps. The lowest note of an organ made with a pipe 32 feet long is about 16 cps. The lowest A on a piano is 27.5 cps. The lowest note a basso can sing is about 80 cps. A soprano may be able to reach 1,200 cps, a piccolo 4,186, and an organ

8,372 cps, with a pipe less than one inch long.

People differ in their sensitivity to pitch. Some are unable to hear the differences in frequency. Others, piano tuners for example, are able to detect the difference between *A* at 440 cps and *A* tuned at 441 or 442 cps, which some orchestras prefer to use. It is estimated that about only 25 people in one million have the ability to sound the perfect 400 cycle *A* or any other note from memory—in other words the gift of absolute pitch.

The other main characteristic of sound is its intensity, or loudness. It is measured in decibels, which is somewhat unfortunate because the dB is a difficult concept to understand. The dB scale is logarithmic and, consequently, every upward step of 20 dB represents a ten fold multiplication of sound energy. Thus, a 60 dB sound is 10 times as powerful as a 40 dB sound, and a 90 dB sound is 100 times as powerful as a 40 dB sound.

Examples of sound pressure levels that most of us have experienced in normal living range from very low—possibly 25 dB for dry leaves rustling in a breeze—to as much as 120 dB when a jet engine plane flies over at a low altitude. Other examples of sound intensity that might be of interest are: 100 feet from the whistle of the Queen Mary, you would have a reading of 123 dB. A big city air raid siren at 100 feet would be 125 dB, while a large coast guard fog horn would be 128 dB, which is just exactly twice the power of the air raid siren.

These intense sounds can cause temporary or permanent hearing loss, depending upon duration and frequency. They also can cause some odd physical affects, such as blurred vision from oscillating eyeballs. Very high intensities of very low frequencies, for example, approximately seven cps, can cause physical damage in the chest cavity, but sounds of such intensity and low frequency are not encountered in industrial noise exposures.

Sounds of such high intensity have been considered for use as military weapons or in mob control. Some experimentation has been done with a low frequency, high intensity boomer which supposedly confuses rioters to the point where their actions be-

come unorganized. Even dentists have done some experimental work with high intensity sound, on the theory that there is a limit to the ability of the brain to receive and identify sensation. Consequently, if the brain is receiving a huge amount of sound, theoretically it has little capacity left to perceive pain sensation. There are cases where teeth have been drilled and even extracted under these conditions, with the patient claiming to have no sensation of pain. I believe that this does not work on everyone. The major drawback to the use of sound, especially as a military weapon, is that equipment necessary to generate such tremendous power levels is simply too bulky and too heavy to move around easily and quickly. Also, it is very expensive.

I stated earlier that industrial hygiene involves the recognition, evaluation, and control of environmental health hazards. In applying this definition to noise, the recognition of the problem usually is fairly straightforward, if:

1. It is necessary to speak loudly directly into a person's ear to be understood, the noise level is, in all probability, excessive.
2. If there is ringing in the ears after working in the noise for several hours, the noise level is excessive.
3. If there is temporary loss which seems to muffle speech upon completion of work but which disappears after several hours of rest, the noise level is excessive.

Evaluation of the problem is deceptive, even though at first glance it may appear simple. You say, "What is so complicated about it? Good meters are available at a fairly reasonable cost for measuring noise. You need to obtain readings only on the *A* scale, slow response, and TLVs are available to evaluate the exposure once the readings are obtained." Well, I wish it were that simple. Admittedly there are situations occasionally in industry where the noise source is broadband, fairly steady, and the exposure time is well defined. Thus, you can make some good assumptions relative to exposure, but you do not have the complete story until hearing test data is available. When one is faced with evaluating a working environment having varying broadband noise, mixed in with impulse type noise, the problem of evaluating exposure becomes difficult. If you would like to

complicate matters even further, add to all of these variables the practice of bumping (rotating of personnel) especially in a large operation involving hundreds of people, and the job of keeping track of exposure time becomes a real challenge.

Despite the problems involved in obtaining data on representative sound pressure levels in work areas and exposure patterns, an effort must be made to relate exposure times to noise levels as accurately as possible. Such information plus good hearing test data will do much to make a hearing conservation program successful. With respect to a hearing conservation program, I believe there are four essential requirements that must be met to protect people against excessive exposure to high intensity noise.

1. Audiometric testing. All new employees must be given a hearing test. All employees working in areas designated by noise surveys to be high noise level areas should have annual hearing tests. This also should apply to areas designated as borderline areas. All employees working in areas where impulse noise approaches 140 dB peak should have a hearing test at least every six months.

Employees returning to work from extended disability or layoff (three months?) should be given a hearing test. Employees leaving your employment should, if possible, be given a hearing test.

Audiometers must be calibrated annually by the manufacturer or his representative. A subjective check should be made every month by testing three people known to have good hearing. If the audiograms are questionable, return the audiometer for a calibration check. The nurse or technician giving the hearing test should perform her own audiogram daily.

Precise records must be maintained with respect to daily, monthly, and annual calibration. The nurse or technician must have documented proof of some formal training in audiometry by an audiologist or M.D.

The background noise level in the hearing test room or booth must meet the standards set by ANSI for such test facilities.

2. Engineering control. Every effort should be made to reduce excessive sound pressure levels by the use of engineering controls.

3. Hearing protection. More than one type of ear protector should be made available. Where engineering control is not possible, not feasible, or under consideration, people working beyond the time limits specified for varying noise intensities must wear ear protection.

4. Sound pressure level surveys. Noise surveys should be made with appropriate instruments to determine areas that need engineering control or where ear protection is required.

The third and final portion of the definition of industrial hygiene refers to control. We have touched somewhat on control in discussing a hearing conservation program, which in itself is a form of control. Control of noise is a very complex subject and all we can do here is to look at some of the very basic aspects. For example, every noise is generated by some kind of a source that is emitting or radiating energy. Secondly, the energy that is being emitted must travel along some path. Finally, a good portion of this energy ends up at a receiver—someone's ear. The control of noise concentrates on working with one or more of these three component parts.

Control at the source is illustrated by the use of mufflers on high pressure, quick release air exhausts. Another example would be the substitution of a smooth V type drive belt for a tooth type drive belt, or the substitution of nylon gears for metal gears. Control along the path would include the use of enclosures, barriers, flexible couplings in ductwork, vibration damping mediums under machines, etc. Control at the receiver could be the use of a sound proof pulpit for operators on noisy jobs, ear protection, or even curtailed or regulated exposure time.

Industrial noise problems can be very complex and there are very few standard solutions, one of the few being availability of mufflers for the exhaust ports of air actuated machines. Most industrial noise problems require individual study and the application of acoustical engineering principles to achieve control, not to mention the high costs involved in putting some of the engineering controls into effect. Unfortunately, it is not uncommon to spend considerable time, effort, and money on acoustical controls and find that the results are well below expectations.

Nevertheless, the first approach to a noise problem is to attempt in some manner to achieve control without resorting to ear protection. Of course, if genuine efforts to achieve engineering control fail or are prohibitively costly, the only alternative is to require ear protection.

In closing I would like to quote the foreword of the 1970 report of the Second Intersociety Committee on Guidelines for Noise Exposure Control. The guidelines have not changed, but it seems to me that the statements made in the introduction to this guideline, although brief, state the problem very clearly: "Noise has long been recognized as one of the several causes of hearing loss. Exposure to high noise levels may cause temporary or permanent changes in hearing threshold level. Permanent hearing loss which impairs communication by

speech is a handicap or impairment. Competent medical specialists have defined impairment as average hearing threshold level in excess of 15 dB, ASA-Z24.5 (1951), at 500, 1000 and 2,000 Hz. This definition is accepted for this document.

"Noise-induced hearing loss increases with both the intensity of the noise and the duration of exposure. Generally, many years of exposure to high noise levels are required to produce significant permanent impairment in the exposed group; however, there will be marked differences in the hearing of individuals and in their response to noise. A portion of all of a hearing impairment may be due to causes other than noise exposure. These guidelines will be directed toward the prevention of that portion of the permanent hearing loss resulting from exposure to steady noise, whether continuous or intermittent."

Project Safe—USA presents a plan for a new and United Safety Action program, promoted by the U.S. Department of Labor to assist in the national safety program effort.

Last year, some 9,500,000 workers were injured, 2,200,000 disabled, and 14,000 died as a result of industrial accidents. The effect on the national economy is measured by some 245 million man-days lost due to work accidents, resulting in staggering financial losses. The consequences of these often preventable accidents are appalling, in both human and economic losses.

Experience demonstrates that what is being done to combat the accident toll is not enough, as injury rates are not going down in most industries. It has also been demonstrated that industrial efforts must be supported by concentrated organized programs involving definite actions by all organizations and persons involved.

Usually, State, Federal, and county governments, labor groups, industry, and associations can implement a well organized and coordinated program, because their efforts can be concentrated to reach intraorganizational groups having common interests. Sponsors of this type can launch and promote successful safety programs, such as *Project Safe—USA*, and become leaders in support of this national safety effort.

This program is designed as a "self-help" plan. The concept: making available a basic prestructured safety program, easily adaptable to almost any specific need.

The program outlines the basic elements of an action safety program and can, with slight improvisation and augmentation, be adapted to suit the programming needs of any industry, State, labor group, or association willing to sponsor and coordinate the program plan.

The Department of Labor has provided the basic working plan for *Project Safe—USA* in the form of an outline. It illustrates typical slides to be used with instructions for suggesting the type of data to be inserted (common to the industry, spon-

sor, or association), and to orient this data to suit audience needs.

The suggested materials can, after augmentation, be developed in very effective visuals (slides, flip charts, and/or transparencies) to lend necessary impact to the presentation. Suggestions are made on how to present the program and actions to be taken by the sponsor to keep the program "alive."

The program is structured in four parts. Part 1 consists of a selling presentation to be held at a regional, district, chapter, or other major division meeting of the sponsoring master organization. For example, this may be presented in conjunction with a regular annual meeting of a local group or at the national meeting of a major organization. This may be done by a representative of the U.S. Department of Labor, or by a person designated by the sponsoring organization to implement and monitor the program—the objective being to advise these groups of the program so they may then be the sponsor and present the remainder of the program. Part 2 is training for management. Part 3 is training for supervisors. Part 4 is training of employees by supervisors and the use of this training in the monthly action program.

Part 2 serves as a catalyst to motivate executives and top-level management on the need and economic importance of carrying on an aggressive and continuing action-type safety program in their facilities. This presentation is made by the sponsor. Examples: accident rates, relating specifically to the affected management or organizations; various statistical summaries, illustrating accident facts; and cost indexes, related to employee safety and injury compensations. Per capita costs are used, as well as an interplay on the dollar value and related production and sales requirements, to offset such accident costs.

This part of the program is intended to generate managerial motivation and self-analysis, and act as a stimulus for responsible executives to recognize the need for

PROJECT SAFE—USA

By EUGENE L. NEWMAN

Chief, Office of Training, Bureau of Labor Standards, Washington, D.C.

Scope and Plan of Program	½ hour
Planning for Safety	1 hour
Safety Organization—Responsibility	1 hour

In preparation for the next phase of the program, the U.S. Department of Labor will, if requested, conduct an institute for training persons chosen by the sponsor to train supervisory personnel. This would require a minimum of 30 hours. These instructors would then conduct Part 3 of the program which establishes a training criteria to orient plant supervisors and workers on the necessary basic training requirements so they can better understand their own safety problems. The safety training should be presented in a recommended pattern and chronology so the recipient obtains a better understanding of the concept of the program. The planned training criteria, coupled with industry oriented accident data and information, are then presented. Because of the variation in plant size and the time limits of available personnel, Part 3 has been designed so the series of safety training sessions can be presented in 1 to 2 hours' duration for each. The amount of training to be presented is determined by management and the enthusiasm of its employees to improve safety conditions. The

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mended training exposure should be about 20 hours.

First Day—	
Scope and Plan of Program....	½ hour
Planning for Safety	1 hour
Safety Organization—	
Responsibility—	
Legal Requirements	1 hour
Government Regulations and Laws	
Applicable to the Industry ..	1 hour

Accident Causes	2 hours
Inspection for Safety—	
Investigation	2 hours

Working Surfaces—Housekeeping 2 hours
Handling Materials 4-6 hours
(Truck, Rail, Bridge, Crane,
Monorail, Conveyors, Lift Trucks,
Cables, etc.)

Machine Guarding—Operations . . . 4-6 hours
(Bandsaw, Hacksaw, Shears,
Rolls, Drills, Punch Presses,
Benders, etc.)

Welding-Burning	1 hour
Electricity	1 hour

NOTE: Selected physical or technical subjects pertinent to industry will also be an integral part of the supervisor's training program.

The sponsoring organization must assume the responsibility for most of the work for its associates and/or membership, and must assume the important role of monitoring and coordinating the program project. A typical chronology might be:

1. Sponsoring organization approves program and designates person or group to be responsible for its direction.
2. Sponsor prepares training or educational materials applicable to the industry or occupations. (Examples:

1 Subjects selected for Fabricated Structural Steel Industry only.

How To Inspect Charts, Occupational Safety Aids.)

3. Sponsor obtains data and statistics relative to accident experience in the industry. (Examples: Structural Fabricated Metal Industry Charts.)
4. Sponsor promotes the program with local associates. (Example: Suggested letter.)
5. Sponsor obtains injury rates of participants—prior to program and annually thereafter—making periodic reports of program progress available to U.S. Department of Labor annually.
6. Sponsor provides training sessions for management and supervisory personnel. (Example: Suggested subjects, outlines, etc.)
7. Sponsor makes quarterly review of individual safety program activities. (Example: Suggested form.)
8. Firms or plants participate in organizational meetings and training sessions.
9. Firms or plants provide information on injury rates and program activities.

10. Firms or plants grams.
11. U.S. Department of Labor consultation and technical services, views reports, records injury rates.
12. U.S. Department of Labor will provide instructor institute training (in group sessions) for those selected by association or other organizations to present training sessions for *Project Safe*.
13. The U.S. Department of Labor will provide, without charge, instructor training outlines to trainers participating in the instructor institutes.
14. The U.S. Department of Labor will make available initial copies of suggested training aids, and give permission to reprint.
15. The U.S. Department of Labor will provide to the sponsor suggested materials for monthly training and discussions.
16. Staff of the U.S. Department of Labor will meet with organized groups or governmental bodies to provide technical programming advice relative to *Project Safe—USA*.

REACHING THE SUPERVISOR IN ACCIDENT PREVENTION

By W. A. WILSON

Safety Director, Minerals & Chemicals Div., J. R. Simplot Co., Pocatello, Idaho

The title is just another way of saying "Motivating the Supervisor" or "Getting the Supervisor to Fulfill His Responsibilities." By definition it means "to impel or incite to action in the area of accident prevention."

Seems to me that human beings need motive power just as an automobile needs fuel and woe be to the employer who carefully chooses intelligent, capable, people, trains them well—and then forgets them.

It is suggested that the supervisor needs "motive power" in all aspects of his job function, but the great need is in the field of accident prevention. The problem or question is "How do you do it or how do you go about it?"

There are many theories on how to motivate people and good arguments for most of them, but other than job satisfaction, achievement, recognition, growth, advancement, etc. what do you think about—

EXAMPLE

All subordinates, at whatever level, must feel that their superior is practicing what he or she preaches and is not just talking a good game.

It is not a question of what is preached by the way of policies and pronouncements or even procedures, but let me show you by my action what is important.

What is acted upon and followed through on, or what has failed to be acted on or followed through on really conveys what is important. In other words, those who work for me get their cues on what really is important or unimportant from my behavior and I'm convinced that personal passiveness practiced by many middle and top level management people is the greatest stumbling block to any accident prevention program.

PARTICIPATION

For our purposes, we can think of "supervisory participation" as any activity in which the supervisors, individually or

in groups, are given the opportunity to offer suggestions or influence decisions in matters affecting them, with of course, final responsibility for the decision resting with their supervisors.

Lewin, Katy, and Kahn, in their book *Readings in Social Psychology* say, in effect, "that a person is motivated almost in direct proportion to his involvement in the things that affect him." Unfortunately many top level management people never permit the foreman or supervisor to voice an opinion or make a recommendation although the supervisor is the one responsible for implementation of the policy, procedure or work function.

As important as "example" and "participation" are, I'm convinced that the one powerful motivating action that can and should be taken by all levels of management is "consistent accountability." It is especially so in accident prevention.

It is so because people will naturally place the emphasis and importance on those areas of responsibility for which they are held accountable.

You may be sure that those you supervise not only are aware of the things for which they are responsible, but they also know the things for which they will be held accountable. You don't really have to be brilliant to conclude that the things that count to your supervisor are those things for which he holds you accountable.

Rule #2 of the 10 published by the National Association of Manufacturers, regarding safety says:

"Foremen must be impressed with the idea that they are responsible for safety in their departments, that they are accountable for accidents occurring in their departments."

Many of us with staff positions believe that this is the most important of the ten (10) listed.

Certainly there must be pre-planning, training, procedures, good communications, etc.; and "consistent accountability" will emphasize their necessity.

It must be emphasized that the "accountability" we are talking about is before the fact not after. Most of the time if there is any "accountability" at all it is usually after the accident or injury. Before is the key—prevention is the name of the game. Concentrate on preventive safety instead of after-the-fact correction.

An emergency observation was made recently by David M. Fisher, Jr., Mgr., Wey-

erhauser Canada, Ltd., Richmond Hill, Ontario. He wrote "It is absolutely amazing what most people will do when exceptional things are expected of them. If managers, supervisors, foremen, all the way down the line, have a high level of expectation in any and all of their pursuits, they will get exceptional results."

Why not expect, or even demand, exceptional performance out of those you lead or supervise? Hold them "accountable" in all areas of their responsibility. Don't leave out accident prevention. You'll be pleased with their accomplishments.

THE SUPERVISOR—BRIDGE OR BOTTLENECK IN SAFETY COMMUNICATION?

By ROGER W. HOFFMAN

Manager, Safety, Kerr-McGee Chemical Corp., Oklahoma City, Okla.

C. W. Keller of Monsanto Company's Central Research Division tells the following tale: "In the days of John Paul Jones, it was common to have the ship's Marines tie themselves in the rigging in order to shoot down on the enemy ship. In the grueling moonlight battle between the British ship *Serapis* and Jones' ancient flagship *Bonhomme Richard*, the *Richard* was ablaze. Captain Pearson of the *Serapis* called across the decks to Jones, 'Do you ask for quarter?' Flinging away his empty pistols, Jones made his famous reply, 'I have not yet begun to fight.' Up in the rigging, it is said, one exhausted marine turned to another and sighed, 'There's always some blockhead who doesn't get the word!'"¹

Because someone "didn't get the word," how many serious accidents have probably occurred? What have and what are supervisors doing these days to pass along the "safety word?"

Why is the supervisor the one who should be passing the word, communicating safety to his employees, rather than members of top management or the safety engineer or possibly even the janitor? I'm convinced that the supervisor is indeed the key man in today's production world. He is also the middle man, the man who is, in essence, the bridge between top management and workers and, conversely, between the workers and management. Thus he is the one person who has to be depended on to do the communicating and to do it correctly. The supervisor helps you involve all persons affected in safety decisions to get their support.

We all work for enlightened and progressive organizations and have a workable accident prevention or safety program. Good communication is the life blood for getting this program across. Information on safety has to be gotten to the grass roots worker level and certain information has to be passed upward from these employees to top management. Who but the immediate supervisor is in the best position to do?

The good supervisor, the properly trained-in-safety supervisor is, in reality, a teacher motivating workers to excellent job performance and adherence to the company's accident prevention program. He practices his profession every day of his work life. He's the communication bridge. If he is instead the bottleneck, how in the world will he get any job done, let alone get it done safely? Good supervisors are the first to insist that safety responsibility belongs to them. Even if there is no formal safety program, a modern supervisor's responsibilities include the safety of his men.

A supervisor who has a keen interest in safety and can arouse a safety first attitude in the people working for him should have an accident-free operation. He arouses this attitude through communication, by the example he sets in safety, by written or oral instructions, by safety huddles and safety meetings.

We've found in surveys conducted in our plants that the workmen are constantly eager and willing to learn more about safety. The supervisor is the instrument through which this desire is fulfilled. Because he speaks their language, workers can communicate directly to the supervisor about their safety problems and, through him, cross the bridge to top management when that is necessary. The bridge becomes, in truth, a two way street and is an important means of continuing the fight for the prevention of accidents and subsequent injuries. To be a successful communicator today, a supervisor must make sure that the exchange is mutual and information or knowledge passed is fully understood by both sender and receiver. Proper follow-up is essential to be certain of this.

How can we help the supervisor keep the bridge open between his work group and other departments and thus prevent potential bottlenecks? As safety people, we can spend time with him on a regular basis and let him know what is going on at our

level, help him set realistic safety goals for his department, see that he gets honest and deserved recognition, back him up when necessary, and make sure we give him the proper tools to work with in understanding and promoting safety. Remember, keep communication lines open and establish mutual trust and confidence.

Communication failures — bottlenecks — may have several causes. There may be an authoritarian atmosphere in the firm. The company may have a poor reputation for keeping its promises or be indifferent toward employee interest and ideas. The difference in meaning which some words may have to the sender and the receiver, fear of reprisal, lack of time and facilities for communication are others.

An example of good communication may be found in another story titled, "A Tale of Two Foremen."

"Foreman True White and Foreman Bart Bull, both oldtime line bosses with the same company, are considered experts in directing their work crews to get a job done. There is one great difference, however, in their performance records: While True's crew consistently captures the company safety award year after year, Bart's crew just as consistently turns in a poor safety record.

"Each crew does similar work, and each draws its men from the same stable community. Each foreman, furthermore, has about the same experience and capability as the other: So, how do you explain the wide difference in safety records? There has to be one thing that Bart is overlooking and True is practicing.

"The difference is that True, with the best company safety record, stopped using the word *safety* as a substitute for job instruction. Instead, he makes sure each of his men knows the proper way to do his job. Bart talks about safety, but not enough about job skills. Instead of telling his men to work safely, True takes the time to in-

struct them on proper handling of tools, operation of machines, routines of maintenance and housekeeping, and just plain good work attitudes—things that Bart neglects.

"True knows that proper work habits, good engineering practices, and common sense cover much more ground than the word safety. You cannot tell a maintenance engineer to oil a machine safely, or a truck driver to drive safely, or a tractor operator to operate safely, or a crane rigger to rig safely, unless the engineer is taught the machine's operation, the trucker how to drive, the tractor man how to drive his machine, the rigger how to handle cables and weights.

Bart Bull takes safety. Foreman True White talks good work habits to his workmen who are trained to do a specific job. The results are obvious: A trained workman with good work habits knows safety, because safety is a part of his job."

We all know both of these foremen types, I'm sure. Obviously, Foreman White is an excellent communicator, he has mastered the bridge approach. Foreman Bull is just as obviously a bottleneck. Which one would you rather have bossing your work crews? The answer is, of course, obvious.

Ideally, the supervisor, being the key man, is the most important communicator one could have in putting safety across. Unfortunately, it is a fact of industrial life that there are many in top management and a lot of supervisors who either don't hold with this philosophy or, if they do, don't practice it. It's our job, therefore, to convince them, to communicate to them, if you prefer, that it's the only way to go. The only safe way, that is.

REFERENCES

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RESEARCH and DEVELOPMENT SESSIONS

MANAGEMENT'S VIEWPOINT OF SAFETY IN THE LABORATORY

By VIRGIL O. WODICKA, Ph.D.

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The modern laboratory director makes use of the latest management techniques in program planning, budgeting, cost analysis, promotion, advertising, and public relations. He provides forceful direction when he is assigned a scientific problem by setting forth a plan of action and assigning responsibilities. I believe safe operation of a laboratory is essential to high productivity and warrants the same approach in development and implementation of a program to reduce laboratory hazards. First off, the managers must be aware of the importance and benefits of a safety-oriented facility. Aside from the obvious humane consideration, laboratory accidents may cause critical project delays, unnecessary expense, unfavorable publicity, and adverse effects on personnel morale. A clean, uncluttered laboratory is more efficient as well as safer.

We engage in technological forecasting and practice foresight in our scientific endeavors. How much effort goes into anticipating safety precautions when we begin work in a new area? New substances come on the horizon every day. Often, it is only after the formulation or isolation of new materials that toxicity is explored. During the period of exploring new materials (characterization, synthesis, and study of physical properties) are we concerned with occupational safety? Is decontamination and development of safe handling procedures inherent in the research plan? It should be!

Several years ago the FDA laboratories became involved with the aflatoxin problem. This is a chemical toxin produced by certain mold species. Carcinogenicity had been demonstrated in certain animals. Toxicity to man has not been proven, but indirect evidence shows a high probability of liver cancer. During our early exploration, competent professionals handled these materials with respect. Even so, we found a very low level

of contamination distributed in our laboratories. We suspect that aflatoxin particles or minute droplets acquire a static charge which cause attraction to airborne dust, resulting in fallout and accumulation. Fortunately, this problem was discovered early by alert chemists developing methodology, and corrective procedures were instituted. Special facilities were constructed and a comprehensive safety program was instituted. Decontamination was studied, and we found that ordinary laundry bleaches were good detoxification agents.

The work in our Bureau is often focused on hazardous materials. Our researchers have a responsibility for developing methods for daily use in our district laboratories throughout the country. Decontamination and safe handling procedures must be inherent in the development of these methods if we are to protect laboratory workers with less experience who rely on our instructions.

From our past experiences, we are zeroing in on precautions that should be taken before work begins through routine monitoring of work areas to insure that contamination of these areas does not occur, and the dissemination of proper information to researchers so they know the problems and hazards.

A part of our mission is the determination of toxicity of materials. At the outset of a study, the nature and extent of possible hazards are unknown. In learning to protect the consumers, our laboratory workers must first protect themselves.

An example of the kind of problem we encounter is given by the chick edema factor. This was a mysterious substance sometimes found in poultry feeds that produced heart damage in poultry. In studying the toxicity of some pesticides, we found some

impurities present that were many times as toxic as the pesticides. They turned out to be chlorobenzodioxins, compounds so unusual as not to be found in most organic chemistry books. They also turned out to be the main components of the chick edema factor. Even now we do not know all the places these materials may occur, but our present knowledge is based on almost ten years of work, most of it on substances that were then unknown in chemical structure and in toxicity to man.

During all the years of developing our knowledge of these materials, which turned out to be toxic in concentrations of a few parts per billion, our scientists were having to work with the uneasy feeling of exposure to an unknown hazard in kind and amount. This is not an isolated problem, but only one of a sizeable family.

The laboratory facilities under my jurisdiction are basically research facilities dealing in the fields of analytical chemistry, biochemistry, pharmacology, toxicology, microbiology, and radiochemistry. These fields have the obvious hazards of caustic and toxic compounds, flammable solvents, toxic and irritating fumes, violent reactions, implosion and detonation, pathogenic microorganisms, disease transmission from animals, and radiological contamination.

We have the normal personal protective equipment available; isolated safety-designed facilities to handle pathogenic microorganisms; special rooms with built-in carbon dioxide fire extinguishing systems for operations requiring the use of large quantities of flammable chemicals; areas with unique filtering devices; and many of the latest applications of safety engineering design. Yet, safety equipment alone will not prevent laboratory accidents. The attitude of every employee is of paramount importance. Few colleges and universities today are stressing adequate safety precautions to their science students. Laboratory researchers become complacent through their daily experience with hazardous materials. Laboratory support personnel, technicians, janitorial workers, and others are often not properly educated to the dangers in their work areas.

The image of the research scientist willing to sacrifice himself on the altar of research is passing, but convincing the scientist that safety precautions which may

slightly impede his progress are worth the effort is a problem that remains with us today. I believe that many researchers are unaware or, more likely, unconvinced of the potential hazards attendant to their daily operations in the lab. As an example of this, consider the perennial problem of getting employees to wear safety glasses. It is not a condition of employment in our Bureau, nor do we impose restrictions on employees who do not wear them. However, since our Bureau has hired a full-time safety officer, employees have become more aware of the inherent hazards of their employment and the resulting dangers to eyesight through a vigorous education program. Employees now can be seen not only wearing their safety glasses in the laboratory, but also with side shields and full face shields as conditions warrant, a happening that was quite rare in previous years.

Safety education is often resisted by researchers who doubt that safety specialists have anything to offer in their areas of experience. To overcome this resistance, we have supplemented the activities of our full-time safety officer with a rotating inspection team system. Among our Divisions we have safety committees, with one individual assigned primary responsibility for implementation of a program developed in cooperation with the safety officer. Professionals in various disciplines are assigned to inspection teams which make laboratory visits each month. A rotating membership stimulates more widespread participation of professionals in the safety program.

This system offers a number of advantages. Suggestions are more readily accepted when they come from a colleague down the hall. A knowledgeable colleague more removed from a specific work area lends objectivity to the safety inspections. A chemist's training and experience can be brought to bear on inherent problems in a toxicology laboratory for which those scientists may not have as keen an awareness and vice versa. Participation on the team creates a revived interest in safety and an appreciation for the difficulties in implementation of a safety program. This improves the laboratory habits of the inspection team members themselves.

Because of management's involvement in safety, employees are not only developing

an awareness to occupational hazards but are becoming personally involved as well. Management is more attuned to safety needs and is realizing that safety in the laboratory requires more than lip service. Implementation cannot be relegated to chance. Programs tailored to the needs of each facility

must be pursued to identify hazards, provide funds and controls for corrective action, anticipate hazards, and educate and instill interest in safety. The initiative and forceful lead must come from the laboratory director who today has better management tools for an effective attack.

CONTROL OF LABORATORY AND PILOT PLANT WASTE WATER EFFLUENTS

By IRVING G. YOUNG and CHRISTOPHER P. BLAKELEY
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In the United States, there are about 5,000 industrial research laboratories and pilot plants¹ and about 80 independent commercial laboratories.² These figures do not take into account the very large number of research and development laboratories associated with universities and institutes of various kinds. At a conservative estimate, therefore, we can say that there are about 10,000 laboratories of all kinds in this country. Despite this, the problems of treating the wastes from these establishments have received little attention in the literature and, thus, laboratory managers have little material available to them for guidance. Perhaps, the reason for this is two-fold:

1. We can anticipate that for the great majority of laboratories and pilot plants, the nature of the waste water effluents will be very much the same as for the main production plants which they serve. Therefore, the treatment of the effluents will present the same kind of problems as treatment of the normal plant effluents.

2. It is assumed that dilution of the laboratory and pilot plant wastes in the public sewer system obviates the need for special treatment. Where this is the case, and the municipality is willing and able to accept these wastes, it is the simplest and cheapest solution.

However, the very nature of research and development work may create wastes of a type that may be detrimental to combined treatment with plant wastes and may be unacceptable to the municipal sewage system. A recent example comes to mind. A large clinical laboratory doing research and con-

tract analyses for numerous hospitals in the Philadelphia area was told that their effluent, about 100 gallons per minute, was unacceptable to the sewer system. Investigation revealed that 75 per cent of the waste was generated by banks of automatic analyzers, with the balance being unpredictable wastes from bench work. The automatic analyzers provided extremely acidic wastes, but no materials toxic to sewage bacteria. The bench wastes, only about 25 gallons per minute, could contain a great variety of toxic materials. Dilution with wastes already in the sewage collection system, however, would obviate their adverse effects. Simple pH control and adjustment to neutrality to prevent acid attack on the collection system was recommended and proved acceptable to the authorities. Obviously there are laboratory and pilot plant waste problems that do not have such a simple solution. To arrive at any conclusions, an understanding of all the criteria involved is essential.

Criteria for Treatment of Special Effluents

The criteria usually used to describe polluting load of domestic sewage are BOD, COD, and suspended solids. These are inadequate descriptors for many industrial waste waters and are totally inadequate for most research laboratory and pilot plant effluents. Klijn³ has provided a list of criteria which are somewhat more helpful in evaluating the quality of waste waters and the appropriate methods for dealing with them. Of the 15 listed criteria, the most important ones to be considered are: nitrogen and phosphorus; immiscible organic liquids; dyes and other color bodies; toxic

inorganic ions; toxic and persistent organic substances; substances causing taste and odor; radioactive substances; pathogenic organisms; and surface active substances.

Their importance is due to their potentially deleterious effects on the standard sewage treatment process or, when improperly treated, on aquatic life and the environment. The list is important because it indicates the many parameters that must be considered in dealing with the wide variety of laboratory wastes. It also shows quite clearly the need for qualitative analysis of the effluent. Quantitative analyses of unusual materials involved are equally essential so that waste segregation, effects of dilution, and various treatment processes may be considered. The science of waste management, discussed by Blakeley⁴ for industrial plants is equally applicable to the research and development laboratory and pilot plant.

General Treatments

The treatment and disposal of research laboratory and pilot plant waste water effluents will be quite similar to the treatment of the major manufacturing facilities to which the labs and pilot plants are attached. However, because of the very much smaller quantities of waste water involved, the problems may be mitigated. For example, if particularly stringent requirements for toxic materials are imposed, it may be possible by suitable timing and dilution to meet the requirements without any special waste water treatment. This is a consideration that should be firmly kept in mind, since it may be a solution frequently available to the laboratory or pilot plant installation. Another one which should be considered is the combination of the pilot plant or laboratory effluents with those of the main manufacturing facility in those cases where the effluents are similar in character. In this case, an additional treatment facility need not be installed since the effluents are similar in character and may be treated in the same plant and because the volume from the smaller facilities will not place an undue load on the major treatment facility. Finally, we may mention the general plan of segregation of waste waters of differing characteristics and the separate treatment of the different collected waste waters. We will discuss these general treatment strategies in somewhat more detail.

Because of the similarity of effluents from laboratories and pilot plants to those of the major facilities to which they are attached, it is useful to discuss in rather broad strokes the treatments accorded the waste waters from the larger facilities. The paper by Gloyne et al⁵ is of special interest because data are provided which indicate the kind of criteria which waste waters from a chemical type of facility must meet in a not uncommon legal jurisdiction. Some of the data from Gloyne's paper is of interest for a number of reasons. It indicates, for example, what the effects of dilution can be in meeting the requirements of the local legal authority with respect to stream quality. For example, a BOD of 50 mg/l is acceptable in the effluent of a zone 1 body of water and this, because of dilution, can be expected to meet the stream quality objective of 2 mg/l for BOD. The dilution effects can also be seen for several other of the parameters. With respect to toxic materials which are of most concern in this connection, there is no quantitative limit placed on the amount of toxic materials, but rather that they shall be below the concentration which will cause death or ill effects to man or animal or aquatic life, and in many cases this can also be achieved by suitable dilution. Lately, however, most states have placed quantitative limits governing toxic materials on all outfalls.

In another paper of general interest, Meriwether⁶ discusses a philosophy of mixed industrial waste water treatment, which is very well applicable to the consideration of effluents from laboratories and pilot plants. He calls his general philosophy the "centralized treating concept," which is divided into four steps:

1. In-Plant Segregation. The purpose of this step is to conserve uncontaminated waters which are separated to flow into normal drainage ditches. Contaminated surface waters and industrial waters go to the "clean" stream collection point, the "biological" stream collection point, or the "non-acceptable" collection point. In the latter category, waters are treated by in-plant incinerators, deep well disposal unit, or go to a pre-treatment facility. It should be noted that deep well disposal is increasingly coming under attack due to potential contamination of ground waters by seepage.

2. Collection. Above the ground concrete lined channels are used to bring streams of

a similar character together to a water treatment plant, which is specifically designed to treat the waste in those streams.

3. Treatment.

4. Disposal.

It is of interest to see how Meriwether segregates waters for various treatment processes. For his "clean" streams, the following criteria are applied: (1) No more than 50 mg/l BOD, no floating organics, no more than 5 mg/l oil (APHA method, "oil and grease"), no more than 10 mg/l of oil (API method 733-58); (2) No more than 50 mg/l suspended matter; (3) No measurable toxicity (APHA method "Bioassay for Acute Toxicity of Industrial Waste Water to Fish").

In order to keep the "clean" water clean, Meriwether recommends that plant waters shall not be mixed with it which would cause the clean water to have a color above 20 units (Pt-Co method) or a pH above nine or below six. In summary, the "clean" stream is basically one which has less than 50 mg/l of BOD requiring little or no treatment.

The streams which are meant for biological treatment have the following characteristics: (1) The plant waste water shall contain organic matter amenable to biological treatment; (2) The addition of a particular plant waste water shall not cause the central collector to have a pH below 5.5 or above 9.5 and shall not raise the temperature of the central collector water above 130°F.

In summary, the biological stream is for any biodegradable contaminant with no BOD limit and is treatable by standard primary and secondary sewage treatment methods such as simple aeration and sedimentation or the activated sludge process.

The non-acceptable wastes, according to Meriwether, have the following characteristics:

1. Contain highly volatile and inflammable materials.
2. Contain asphalt, tar, clay, catalyst, slag, millscale, sludge, slurry, and other materials that settle or adhere to conduits.
3. Contain noxious or malodorous gases or materials capable of creating a public nuisance.
4. Contain pickling or plating solutions.
5. Contain spent caustics to the extent of five per cent NaOH equivalent or higher.

6. Contain spent acids to the extent of five per cent H_2SO_4 equivalent or higher.

7. Contain organic solids to the extent of five per cent concentration of organic material or higher.

8. Contain emulsions of oil, polymer, and so on to the extent of one per cent or higher.

9. Contain toxic or refractory materials not amenable to biological treatment, including materials which cause acute or chronic toxicity to aquatic life, such as chromate, cyanide, mercury, etc.

10. Contain any substance which may cause a nuisance aquatic growth, such as excessive nitrates or phosphates.

It will be seen that Meriwether's criteria offer a sensible and judicious scheme for the separation and treatment of appropriate laboratory and pilot plant effluents which may then be diluted or, where necessary, treated prior to discharge.

Special Effects of Laboratory Waste Waters on Standard Treatment Facilities or River Waters

It is appropriate at this time to discuss situations where failure to adequately treat an effluent from a laboratory or pilot plant might lead to special difficulties either in treating ordinary waste waters or in causing undue hazards or nuisance to the public. Baay and Vrijburg⁷, in a study on the effect of waste waters from an organic chemical lab, showed that organic solvents when suitably diluted had little or no effect on aerobic processes to reduce BOD in a sewage treatment plant. However, the anaerobic processes in the sludge digestion facility were very seriously disturbed by the presence of a number of organic solvents. It was found that 80 per cent of the waste waters from an organic laboratory contained materials harmful to sludge digestion. In order to avoid this difficulty, the authors installed a tank for aeration of the laboratory waste waters with 15 minute detention and found that they could remove the volatile solvents causing the trouble and remove the disturbance to the sludge digestion.

In another study, Puter et al⁸ investigated biological treatment of waste waters from the production of organic materials containing surfactants. These waste waters had an extremely high BOD of 1,000 and a COD of 2,000 mg/l. In addition, they contained 21.5 mg/l of anionic surfactants of which 39.5

per cent were non-biodegradable. BOD removal was possible by the activated sludge process, and the average reduction was found to be COD, 55 per cent and BOD, 85 per cent. If the effluent from the aeration process was coagulated with alum and the floc removed, the overall COD was reduced by 70 per cent and the overall BOD reduced by 95 per cent with about 65 per cent of the surfactant removed by the alum precipitation. However, the presence of nondegradable organic compounds interfered with anaerobic digestion of sludge. The constituents in a waste water which interfered most with the aerobic and anaerobic processes were biologically undegradable anionic and cationic surfactants and organic compounds from pesticide production. Sludge dewatering followed by incineration may well be investigated in these cases.

These experiences indicate that:

1. Special attention must be given to the constituents of the waste water.

2. Preliminary tests must show that ordinary treatment processes can handle the waste water constituents.

3. There is no inhibiting effect on either aerobic or anaerobic treatment processes. In those cases where interference is found, special treatments must be worked out to provide a safe, acceptable effluent.

Special Treatments

There are a number of special treatments which have not been especially economical on a large scale which, however, may be quite suitable for small scale operation of low volume effluents. It is mandatory in this approach that good segregation of waste streams is practiced.

Electrolysis

Hillis⁹ discusses electrolytic treatment of copper and ferrous pickling solutions where the metal is plated out on the cathode and oxygen is evolved at the anode. In a similar way, chromic ion may be oxidized at the anode to regenerate chromate which may be recycled to the original process. The same author points out that cyanide may be destroyed at the anode at one-third the cost of chlorine oxidation. In a first step, the cyanide is converted to cyanate and further electrolysis will convert the latter to carbon dioxide and nitrogen. However, it is usually not necessary to prolong the electrolysis, since hydrolysis will convert cyanate to am-

monium and carbonate ions. The electrolysis of cyanide solutions is done at high temperatures near the boiling point of the solution. The author points out that the electrolytic process for the destruction of cyanide is economical for concentrated baths but is not practical for rinse waters. For dilute cyanide rinse waters, sodium chloride may be added. On electrolysis the oxidation processes described occur as well as destruction of the cyanide by free chlorine also liberated by electrolysis. For phenolic wastes the author recommends addition of sodium chloride, operation at 70-75°C, the use of a graphite anode and a steel cathode at 2.3 to 2.8 volts. No phenol is detected in the waste waters after sufficient electrolysis. Malathion may be destroyed at a platinized titanium anode.

In an interesting paper, Ivanov and Makrinov¹⁰ show that electrolysis of waste waters from vitamin syntheses can destroy acetone and chloroform, and they discuss the possibility of using electrolysis for other waste waters which are not amenable to biological treatment.

Ion Exchange Methods

J. Pilot¹¹ gives a general discussion on the use of ion exchange resins for treatment of industrial effluents. He points out that the sulphonic acid resins may be used at any pH for the removal of heavy metals while the carboxylic acid resins must be used at high pH in order to remove metallic ions. With respect to anion exchangers, the quaternary ammonium resins may be used at any pH to remove anions from solution, while the amine resins must be used at low pH in order to accomplish the same purpose.

In a similar piece of work, Hartinger¹² shows that ion exchange methods can achieve complete removal of heavy metals from waste waters, and this can be done irrespective of the pH. He points out the need to define toxicity limits so that the ion exchange process may be run economically.

Finally, Ocenasek et al¹³ show that germanium in an effluent may be reduced to less than two per cent of that in the influent by the use of an anionic exchange resin when the germanium is in a fluoride solution.

Ozone Treatment

While ozone has not achieved wide usage for waste water treatment where large quantities of effluents are involved, it may

be worthwhile for small quantities to take advantage of this technique. Kandzas and Mokina¹⁴ discuss the use of ozone for purifying industrial waste waters. They point out that ozone destroys cyanide when the latter is in concentrations greater than 3-4 mg/l, independent of the pH in the range 10.5 to 12.0. The oxidation of cyanate is slower and greater than stoichiometric amounts of ozone are required. The rate of oxidation of cyanate is at a maximum at a pH of 12 and begins when the cyanide concentration falls to around 3-4 mg/l. The complex metal cyanides of zinc, copper, and nickel are readily oxidized, but that of cobalt is more resistant to ozone oxidation. This work indicates that fairly concentrated solutions of cyanide can be destroyed, even if certain complexing metals are present, and the cyanide brought to relatively low levels which on dilution may very well bring the cyanide within suitable limits in the effluent.

A recent paper by Ogden¹⁵ discusses the latest technology of ozonation. After describing the basic ozone hardware, the use of ozone in water purification, preparation of pyrogen-free water, and controlled-scale treatment is discussed. Of special interest in the present context is the application of ozone to waste water treatment problems. Ozonation of waste water from a large petroleum refinery successfully treated water with a high COD load as well as cyanide, phenols, oils, detergents, sulfides, and sulfites. Ozonation was especially successful in destroying cyanide in waste waters.

It is of interest to mention at this point a very recent development by the Krupp works in West Germany.¹⁶ In their Katox process, oxygen is applied to liquid wastes in the presence of a catalyst. It is claimed that organic content is reduced by 90 per cent and cyanide, nitrite, and other poisonous substances destroyed. The most heavily contaminated water can be processed in four hours and further biological treatment is not generally required, compared to several days by biological treatment.

Special Wastes

Radioactive Materials

In a useful general review paper, Strauss¹⁷ discusses the regulations on treatment and disposal of gaseous, liquid, and solid radioactive wastes from a nuclear plant. Of special interest to us in this context are his remarks on liquid wastes. A very useful re-

view of maximum permissible concentration (MPC) of radioactivity in liquid and gaseous effluents is given as well as the requirements for the rate of release of radioactive materials.

The basis for design of water management systems where radioactive materials are involved is the concentration and maximum confinement of radioisotopes. For liquid wastes, this involves a delay period for radioactive decay, followed by filtration, evaporation, and demineralization. The latter is accomplished by ion exchange techniques in which the resins remove dissolved radioactive solids from solutions. When the resin is saturated, it is either replaced or regenerated by suitable chemical treatment. The concentrated radioactive liquid produced by regeneration is stored in a waste holdup tank, followed by evaporation of most of the water and, finally, the concentrated radioactive material is sealed in steel drums and shipped for burial. With powdered resin units, the demineralizer bed itself is treated for disposal.

This general review of liquid waste treatment at the plant level may be used as a model for handling of radioactive liquid waste at the laboratory level and is discussed in a number of papers. Gotte and Talsky¹⁷ discuss the handling of radioactive isotopes used in the research laboratory. Waste waters from the laboratory are separated into different categories for ease of treatment and are treated by chemical coagulation and dilution before discharging to sewers. The precipitated radioactive sludge is stored in steel drums.

General procedures for control of radioactive wastes at the UK Atomic Research Establishment Laboratories at Harwell, England are discussed in a paper by Burns.¹⁸ The waste waters are segregated into low, medium, and high level effluents at the source. The high level effluents are treated by the ferrocyanide-phosphate process. The effluent of this process is subjected to ion exchange on a crude vermiculite in a basket centrifuge, or to evaporation. The sludge is subjected to freezing and thawing before vacuum filtration and the effluents are discharged to the Thames River at below the maximum permissible levels. Solid wastes are disposed of by incineration or dumping at sea. At another establishment, evaporation was the only treatment technique for radioactive

waste from a research laboratory.¹⁹ It is clear from this paper that if the volume of effluents is small enough, evaporation may be quite economical and still meet the legal requirements for radioactivity in waste waters.

Komatsu²⁰ discusses the use of titanium hydroxide to coprecipitate radioactive strontium and mixed fission products from waste waters and indicates that titanium is more effective than iron or aluminum in removing such products from waste waters.

Viscose

Woodruff et al²¹ discuss the treatment of waste waters from the manufacture of cellophane. The contact stabilization process is used with a first neutralization step and then addition of nutrients. BOD was reduced by 80 per cent and COD by 75-85 per cent. This kind of waste from the laboratory, if in sufficiently small quantity, may be added to the domestic sewage system if no other deleterious materials are present which might disturb the operation of that system.

Toxic Materials

In a very interesting paper, Brebion²² discusses the removal of certain toxic materials of chemical origin from industrial waste waters. He points out that cyanide, sulfide, and sulfite can be removed from waste waters biologically if the concentration does not exceed the bacteriostatic dose. However, if the waste waters are mixed with municipal waste waters, bacteria capable of metabolizing these toxic constituents may perish and the wastes thus pass through the sewage treatment system untreated, though considerably diluted. Another hazard is that these toxic materials may be absorbed in the sludge and later on interfere with the sludge digestion process. Precautions are, therefore, necessary if mixed waste waters contain toxic substances. The best plan is to remove the toxic materials by preliminary treatment or maintain the effluent at a constant quality and develop suitable bacterial cultures that will attack the toxics. This means that the toxic materials can never be allowed to exceed the value that will destroy the active cultures and implies instrumental analysis and control of the effluent waste waters.

Dyes

There is nearly always a requirement to remove coloring matter from treated waters.

Dyes, therefore, represent a special problem and are discussed in a number of papers in the literature. Iida and Endo²³ discuss the precipitation of direct and acid dyes by means of iron salts. Ferric iron as 80 ppm of $FeCl_3$ removed 96 per cent of direct dyes and 60 per cent of acid dyes from 100 ppm solution. Ferrous sulfate at a pH of 10 removed 92 per cent of direct dyes and 36 per cent of the acid dyes. The amount of removal was adversely affected by addition of sodium sulfate and sodium carbonate. In another paper, Weiner et al²⁴ discuss decolorization of dye works waste waters in somewhat more detail but essentially their treatment is also based on the use of ferrous sulfate.

Antibiotics

It would appear that the disposal of waste waters containing large quantities of antibiotic materials would destroy bacteria needed in the normal municipal sewage treatment plant. Madera et al²⁵ have shown that waste waters from a tetracycline manufacturing plant affected biological treatment most. On the other hand, Grunwald and Melzer²⁶ showed that in sufficiently small concentrations, certain antibiotic materials had no adverse effects on BOD removal in an activated sludge process. These papers teach us that each situation must be carefully evaluated in order to prevent adverse effects on the treatment plant.

Fluoride

Zabban and Jewett²⁷ discuss the treatment of fluoride waste. The acid wastes are neutralized with lime and sedimentation is promoted by the addition of a polymer coagulant. The pH of the effluent is reduced before discharge. The effluent contains less than 20 mg/l of fluoride or suspended solids. The fluoride may be reduced to 1.3 mg/l by passing the effluent through a bed of activated alumina using the ion exchange method of Savinelli et al (WPA 31, No. 1342-1958) or to 1.0 mg/l using a column of Fluo-Karb. Where small quantities of hydrofluoric acid wastes have to be treated, the lump limestone method may be the simplest and most economical. The hydrofluoric acid waste is permitted to percolate through an airscrubbed bed of lump limestone. It will react with the limestone surfaces to form the water-insoluble calcium fluoride. The pH measurement of the effluent is a positive indication

of bed condition. When the effluent pH drops below pH 7.2, the lump limestone bed is exhausted and must be replaced.

Animal Wastes

The subject of animal waste is of some interest since the number of laboratories which maintain animals for test purposes of one kind or another have increased markedly in the past several years. Bloodgood²² has discussed this subject in a great deal of detail in a recent paper. He is concerned with a large scale laboratory where cattle, sheep, chickens, and other species are kept for laboratory and production purposes. In this situation, the waste from the various animals are all separately treated by biological processes. In smaller laboratories, this may not be necessary and it would appear that animal wastes may be generally acceptable in the municipal sewage system.

Waste from Photographic Laboratories

Mohanrao et al²⁹ studied wastes from the photo film industry with respect to their pollution effects and abatement. The principal waste waters were emulsion wash water, white water, and laboratory effluent. Bioassays with three fish species showed that the toxicity of emulsion waste waters was due primarily to free unionized ammonia. The toxicity could be reduced by boiling and reducing the pH from 8.9 to 6.5. White water was the least toxic waste water and, in addition, its volume was quite low. The laboratory effluent was found to be most toxic and the most active constituents were found to be hydroquinone and metal ions. They also noted synergistic effects when the latter were present together. Finally, they found that the lab effluent seriously affected the activated sludge process unless it was considerably diluted. Coagulation with alum reduced the toxicity of the composite waste waters by a factor of four. However, it was still too great for discharge into the river. An activated sludge process was developed wherein 620 volumes of alum-treated effluent and 380 volumes of domestic sewage were mixed and the effluent from the process was found to be non-toxic to fish.

In another paper, Hennessy et al³⁰ also discuss the rationale of photographic laboratory waste water treatments in some detail. The main steps in their program are: (1) classify the waste; send the waste waters which meet specifications into the sewer and

treat those which don't in the appropriate manner; (2) concentrate over-specification waters and truck off to special plants for treatment.

Two types of waste water were considered in film processing. The first was chemically-laden waste streams resulting from overflow of process tanks which were automatically replenished as tank levels fell. The second was overflow of spray or immersion type wash tanks. The first type of waste water is highly concentrated and suitable for disposal to a source accepting non-reclaimable waste or to a sewer system with large dilution. The second type can be very dilute depending on circumstances and is best and most economically treated by suitable dilution with other waste waters.

Summary

Laboratory wastes can vary considerably from domestic sewage and manufacturing plant waste waters. Quantitative and qualitative analyses will permit segregation of wastes into three major categories:

1. Those that meet applicable pollution limits and can be discharged without treatment.
2. Those that are compatible with municipal sewage or industrial waste treatment practices, taking into consideration the effect of dilution in the collection system.
3. Those that must be treated prior to discharge.

Thus, only the smallest volumes are admitted for treatment reducing capital expenditures and treatment costs. A wide variety of treatment methods are available, ranging from electrolytic destruction through ion exchange, chemical precipitation, aeration, ozonation, and simple pH adjustment. Automatic analysis and control is available³¹ so that most treatment facilities can operate continuously on a virtually unattended basis, providing a safe effluent and a permanent record of compliance with legislation at minimum labor cost.

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WASTE CHEMICAL DISPOSAL APPARATUS

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The waste chemical disposal apparatus to be described was patented by the Navy on 29 July 1969 and assigned the serial number 3,457,881. It may be used by or for the Government of the United States of America without payment of any royalties thereon or therefor.

Today we are indeed living in a chemical world. Our national economy, scale of living, and in numerous instances our existence, is geared to the use of a vast array of materials and physical agents which enhance the quality of our lives. The development and widespread utilization of plastic materials and synthetic fibers are two examples which have caused significant changes in our mode of life. Elaborate precautions have been taken in industry and the laboratory for using chemical materials which can be harmful to the individual if they are handled improperly. However, until comparatively recent date, chemical wastes have not been regarded as another end product of research that must be made innocuous in the interests of protection of the public health and conservation of our environment. Little attention has been directed to this problem by the laboratory researcher because of the many different types of chemicals being used and the small quantities of material which are usually consigned for disposal at any given time. Another factor is the different characteristics of these materials and the form in which they exist. These conditions create special problems in the handling and treatment of chemicals to render them harmless. Consequently, there is a dearth of information on small scale operations that can be utilized by a laboratory for disposing of unwanted chemicals without creating a hazard to personnel or unduly contaminating the surrounding environment.

The invention described herein was developed by three employees at the U. S. Naval Research Laboratory, Washington, D. C. Valuable assistance was rendered by their colleagues in the various divisions throughout the laboratory during the development stage and after completion of the design to determine whether or not the unit is func-

tional. Modifications were suggested and made in the design following these consultations. The equipment is still not operational and must ultimately be phased through a R and D stage to ascertain its limitations, a standard operating procedure, and a safety manual developed.

This invention relates to the disposal of solid, liquid, or gaseous wastes by incineration in one facility. Contamination of the environment due to the discharge of hazardous combustion products is prevented by optimum combustion, by scrubbing, by neutralization of acidic materials produced from burning chemicals such as halogenated hydrocarbons, and by removing entrained solid materials. All waste water is neutralized prior to discharge to the sewer and waterways in a liquid effluent system. Combustible materials collected from the incinerator ash pit and all precipitates collected from the liquid effluent systems are periodically hauled away to a suitable landfill. The system is so designed to provide a safe disposal facility for flammable and toxic liquids. Likewise, it provides a secondary burner and neutralization means along with a scrubber unit to reduce air contamination. Another feature of the invention is a facility for safe removal of chemicals from paper, glass, metal, and other containers and collecting their contents for disposal in the incinerator. A further object of the invention is the provision of a holding tank and a dilution box to prevent contamination of streams and waterways. A still further object is to provide a novel safety interlock device which prevents flashback when flammable materials are charged into the incinerator.

The disposal apparatus consists of four units; (1) crushers to grind and receivers to collect solid and liquid waste material; (2) an incinerator to burn the material, a secondary incinerator to reduce soot in the combustion gases; (3) a neutralization means to neutralize acidic combustion compounds with a scrubber to remove entrained and soluble materials from the combustion gases along with a stack to further reduce contamination; and (4) an effluent treatment

system for neutralization of liquid wastes. Safety devices are incorporated throughout the system to prevent injury in case of explosion. Provision is made to flush down the entire system to facilitate cleaning and to minimize corrosion problems.

Propane or butane gases are used to fuel the incinerator. The operating temperature is designed to range from 1,500° to 3,000°F. Such things as explosives, insoluble inorganics, arsenicals, cyanides, mercury compounds, radioactive materials, and beryllium cannot be handled by this equipment.

(Following is the commentary which accompanied a series of slide depicting the disposal apparatus.—Ed.)

The first feature is the reinforced concrete personnel barrier behind which the equipment is operated. At the top of the barrier is one of the waste loading trays below which the operator stands and stokes materials into the unit. The waste loading tray is connected to a sliding chute with a can and bottle crusher at the base. The crusher empties into the materials receiver box, which is operated by control rods which control the stoking operation.

At the base is the incinerator and ash pit clean out door for the furnace. The circular configuration of the burning unit enhances its strength and facilitates the cleaning operation. The wash down drain for the furnace, which is connected to the liquid effluent system, is at the bottom in front of the furnace.

The explosion relief doors are located at the top of the after burner and scrubber sections. Both openings are used to flush down and clean out the system.

Containers are placed in a two angle tray which has the pivot point at the intersection of two angles. This serves as a tray when open and a door to the chute leading to the crusher when closed. This type of chute is preferred because it protects the operator against back flash in the event of an explosion. The chute leading to the crusher unit is provided with an explosion relief door set open at a pressure of five psi.

The crusher unit may be a hammer mill or suitable can and bottle breaker. Material from the crusher is discharged into the receiver and loading tray, a metal receptacle attached to the incinerator. The incinerator

side of the receiver is open, providing an opening through which waste is charged to the furnace. A portion of the upper wall of the receiver is open and adjacent to the crusher discharge.

The two rods which control the operation of the material receiver protrude through the blast wall above the working platform. A metal pusher plate is attached to one end of the bottom rod and has the general configuration of the end wall of the receiver. The pusher plate is supported by the bottom of the receiver and moves freely in a horizontal direction toward the opening of the incinerator. The pusher plate is parallel to the incinerator wall during movement.

At the top of the receiver is a metal shield which is moved horizontally by the second rod. The shield is designed to be positioned between the crusher and the top surface opening of the receiver. The shield is supported in a horizontal plane by metal tracks welded to the side walls of the receiver. When the receiver is filled, the top lever is pushed forward to close the opening between the crusher unit and the receiver. A micro switch cuts off the crusher unit so no containers can be crushed when the cover plate is closed. The top rod has a release device to the bottom lever which can now be moved forward to push the contents of the box against the free swinging door in the furnace opening, allowing the contents to enter the incinerator. After the bottom rod (pusher plate) is returned to its original position, the top rod (cover plate) is returned to its original position.

The safety device on the rods is so arranged that the rods must work in the following sequence: top, bottom, bottom, top. A slot is cut in each rod by a plane orthogonal to the bar axis, and positioned to provide maximum distance between the slots. A portion of said locking plate is within at least one slot at all times. A recessed slot on the first bar and a chamfered shoulder on the second one, together with a spring means, enables the locking device to be in contact with at least one of the bars. The micro switch becomes operable when the said spring means is compressed.

The incinerator consists of an outer casing which forms a fire box separated into three sections by a dump grate and perforated base plate. The casing is preferably made of half-inch stainless steel, Type 347, rein-

forced by channels and angles and set on a concrete base. Stainless steel serves a two-fold purpose of providing good resistance to corrosion and preventing contamination of the material of construction.

Chromite brick is used for the inner lining of the furnace because it is capable of withstanding high temperatures and is difficult to fuse or corrode. Magnesium carbonate, which is a good heat insulator because of the greater number of microscopic dead air cells in the material, is used as an insulator between the outer casing and inner wall. The reasoning for the insulation is to maintain the heat in the furnace and conserve fuel.

The upper section of the fire box is the main burning chamber and is divided by a metal flame baffle. The inside of this chamber is lined with a cast iron grating to prevent overheating of the outer casing. The lining is attached to the vertical walls of the main burning chamber or first section of the fire box. The first section has a waste material feed opening covered by a horizontally pivoted rotatable closure fixed to one of the walls of the first section. The first section is provided with an inlet opening for introduction of volatile combustible solvents from the solvent receiver. Still another opening is provided to allow gases from used cylinders of compressed gases to be introduced into the burner chamber.

Spray devices may be connected to the openings, if desired, to provide more uniform distribution and burning. Means for burning combustible materials (fuel jets) in cooperative relationship with the first section provide the necessary heat to incinerate the combustible material introduced at three openings (solid, liquid, and gas openings). While any oil or gas burner or its equivalent may be used, it is preferred to employ propane gas burners to insure optimum combustion of the waste.

The preferred location of the incinerator propane burners to provide optimum waste combustion is two burners located approximately one foot above the grate level in opposite sides of the first section of the incinerator with the flames concentrated toward the center of the first section. Two additional gas burners are located directly below the perforated plate in the third section or ash pit in the opposite sides from the

first section burners to insure complete combustion of residual material entering the second and third sections. One or more burners are located in the secondary incinerator (after burner) unit to insure combustion of all materials before being discharged to the atmosphere.

A large access opening is provided at the top of the first section which serves a two-fold purpose; to allow ready access for clean out and to provide a large relief door opening in case of explosion. The access opening is covered with a closure to act as an explosion relief port at a pressure of five psi. Either a simple metal cover, hinged doors, or their equivalent may be used. The closure is provided with an opening which allows the incinerator to be washed down without necessitating removal of the closure.

A dump grate of conventional design separates the main burning chamber from the second section of the incinerator. This grate allows the noncombustible materials such as glass or metal containers which are too large to pass through the openings of the grate to be dropped into the second section for removal.

The middle part of the fire box or second section is the debris clean out chamber. The base plate is preferably a two-piece perforated stainless steel plate. Although no burning means are provided in this section, good combustion is maintained due to the heat generated by the burner units above and below the section.

The third section of the incinerator or ash pit is that section between the perforated base plate and the incinerator's concrete base. The concrete base, in addition to providing a support for the fire box that encloses the incinerator, is sloped to the center of the furnace to provide a recessed area for easy cleaning. Means for burning combustible materials in cooperative relationship with the third section provide the necessary heat to incinerate material contained in the ash pit. Vermiculite is placed in the bottom of the third section to enhance the burning of materials.

A clean out door is provided at the vertical side of the incinerator to give access to the second and third incinerator sections. The closure may be a flat plate hinged door or any suitable equivalent.

Connected to, and in cooperative relationship with, is an after burner or secondary

incinerator. It is fabricated with the same material used for the incinerator. The after burner is provided with a propane burner which serves to consume flammable material entrained in the products of combustion leaving the incinerator. Also, it is provided with a means for neutralizing acidic gaseous products which result from combustion of halogenated organic compounds and other chemicals. The means for neutralizing may consist of simply an opening to allow for the entrance of gaseous neutralizing agents or a suitable spray or fog of liquid neutralizing agent. Ammonia is a preferred neutralizer.

Connected to the after burner, in a cooperative relationship therewith, is a scrubber unit. The scrubber unit is made of corrosion resistant metal; for example, stainless steel or the like. The scrubber is provided with one or more spray nozzles which provide a fine spray or fog of water within the scrubber. The scrubber is divided into two or more sections by suitable baffles; one extending vertically from the roof and a perforated baffle extending from the scrubber floor. Gaseous products entering the scrubber unit are contacted by a water spray or fog which removes entrained solid materials and water soluble products contained in the gas. Water from the spray is collected at the bottom of the chamber, exits through the opening, and flows to the effluent system.

Products of combustion leaving the scrubber are passed to the atmosphere through a metal or corrosion proof brick stack. A blower may be added to expedite the flow of air through the stack. The stack is provided with one or more spray or fog nozzles to minimize the quantity of entrained solid material discharged to the atmosphere. Provision can be made for inserting a probe in the stack to monitor the quality of the air being exhausted. An electrostatic precipitator may also be engaged in the stack if the operation demands it.

The concrete wall, as previously noted, provides a barrier through which wastes are charged to the incinerator admitting receiver and thence to the burning chamber. The wall is curved to minimize the blast effects of an explosion which further enhances the safety of the operator.

A secondary barrier wall is provided to insure protection for the liquid waste collection tank, the contaminated gas cylinders,

neutralizing gas cylinders, and manifolds. The cylinder contaminated gas manifold charges waste bottled gas through an inlet opening in the first section of the furnace. The neutralizer gas manifold is provided for supplying neutralizing gas to an inlet opening in the after burner area of the furnace.

A flash back loop is built into the liquid waste line leading into the furnace for safeguarding the liquid collection tank in the event of an explosion.

The wash down drain for both the incinerator and the scrubber chamber are connected and empty into the liquid holding tank.

Containers of organic waste liquids are charged to the crusher unit through the concrete barrier by opening the rotatable closure and depositing the containers therein. The closure serves as a tray when open and a door when closed. The containers proceed down the metal chute, which has an explosion relief door on the top, into the crusher unit. The loading tray, chute, and the crusher unit are the same types as those which are utilized for handling solid material wastes.

The liquid wastes pass through the perforated bottom of the basket strainer in the receiver to a waste liquid collection tank. Solid container debris which is collected in the basket strainer of the receiver is disposed by manual transfer to the solid material unit and charged to the incinerator. A wash down line is provided for flushing out the system which in turn drains into the neutralization holding tank.

A bulk liquid receiver is provided which is connected by suitable piping to allow for large amounts of liquids to be directly discharged into the collection tank.

Liquids stored in the collection tank are disposed by pressurizing the tank with a suitable inert gas, such as nitrogen. The liquid is forced through a suitable metal line to the orifice opening in the first section of the incinerator.

The tank is provided with a pressure relief valve to prevent excessive build up of pressure. Manual or automatic pressure regulators may be used to regulate tank pressure and force the waste flow of liquid to the incinerator.

A liquid effluent system is used to dilute and neutralize all liquid wastes before discharge to sewers or waterways. The liquid

effluent system consists of a steel or cement holding tank wherein water from the scrubber unit and other liquids from cleanup work are stored. The holding tank is provided with an ejector connected to a water supply line which meters a controlled quantity of liquid stored in the holding tank to the dilution box through a pipe line.

Waste liquid from the holding tank is diluted with fresh water in the dilution box, which is made of concrete or other suitable

materials, and is discharged to the sewer through a line. A portion of the chambers of the dilution box contain a source of alkaline material such as calcium carbonate, limestone, or the like, so that acidic liquid wastes passing through the dilution box are neutralized before discharge to the sewer. The dilution box is also provided with an inlet from the scrubber unit so that, when desired, the holding tank may be by-passed.

CHEMICAL WASTE DISPOSAL

By J. A. PHOENIX,

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Safe and routine disposal of chemical waste should be an integral part of college and university safety programs. Without a program, there is a high probability that many potential dangerous chemicals are being introduced to the community via sewers, air, or ground waters. Of equal importance, many chemicals will be held in dead storage in laboratories and similar facilities, and deterioration creates a potential of explosion and fires.

A program which places the responsibility for disposal with the individual or department creating the waste is probably unsatisfactory at even a small college, but it is definitely unsafe at larger universities where extensive chemical research is conducted. The total quantity of waste generated makes a central disposal facility necessary. The hazardous properties, combined with the variety of chemical wastes to be handled, require program supervision by one or more people knowledgeable in the field.

A waste disposal method must be developed which can handle the relatively large total quantity of waste made up of a large variety, and relatively small quantities, of different chemical wastes. The inherent hazards of many items make any of the community scavenger services undesirable because of moral and perhaps legal responsibility for final safe disposal of the waste. Any disposal methods must include necessary safeguards against pollution of the environment with toxic materials. Dilution can be

used only to the extent which the existing environment will tolerate. In most instances, additional efforts and controls will be required. These requirements immediately introduce economic considerations into the waste disposal program.

To date, the disposal method which will provide complete protection of the environment, handle relatively small quantities of numerous toxic and explosive chemicals, and has a facility cost which is within the budget of even a large university has not been developed. Procedures which create what appear to be reasonable compromises of total goals have been undertaken by several colleges and universities. Without question, these methods and their acknowledged compromise of environmental pollution, will not be satisfactory within even a few years. They do, however, present a base line for consideration and study of new methods and procedures.

One common method of disposal of chemical wastes is by controlled burning and burial. The program at the University of Minnesota is an example. Present procedures and proposed additions produce a method outline which follows. It should be noted that control of supplies and laboratory storage must be an integral part of the waste disposal program.

Storage and disposal of chemical wastes originating both in and from university and research laboratories has been a problem in the past. Previous procedures were to allow

the individual department heads to plan for storage and disposal; but with increased use of hazardous chemicals, it has grown to such large proportion that individuals have neither the means, money, nor manpower to accomplish this. As a result, the waste was disposed of by means of regular rubbish disposal or using the sanitary sewers. Another problem facing those interested in disposal is the large variation of the types of waste now found, along with the quantity. Quantity here is not the real problem, because if you have quantity it is easier to show the need for a safe and economical disposal system; whereas, the nondescriptive and noncompatible assortment of chemicals pose the real threat. The solution to this is a central, knowledgeable department to handle chemical disposal program.

This university was fortunate in the past to have had at its disposal the U. S. Army Ordnance Depot to handle any unknown or hazardous chemicals. However, due to the conflicting schedules, this method was terminated. Since then, much time and effort has gone into solving our own disposal problems with an eye on possible future demands which will require rapid and continuing change to meet the needs. Following is a general outline of what should be expected to provide a good, safe disposal program. It should be noted that this procedure is for programs which do not have readily available use of a commercial, licensed disposal service or the worry of an imposed type security problem which at times requires unnecessary exposure during storage and handling. It is felt, even with a licensed disposal service, the responsibility still lies with the vendor. Scavenging operations by an outside party open the avenues of lawsuit should a mistake in assignment of certain chemicals occur which may result in property damage or loss of life.

Organization

It must be selected and approved by an authoritative body and given the necessary tools and authority to act in the best interests of the organization. It must also have the necessary monetary backing to keep it functioning. The latter is usually the first problem and will determine the effectiveness of the program. The old adage, "You pay for what you get," is very true, especially in manpower.

Research and Development Section

Knowledgeable people must have direct contact and control. Preferably, a man with a strong chemical background and experience is needed for top management. Hiring of others is left to this individual.

Advertising the department to others, is necessary to have the program function as effectively as possible. The more people who know about the service, the lower the overall cost will be, especially in the field of fire and accident loss prevention.

Establish a good rapport with those divisions with which you will be working. Along with this, dependability on the part of the department is necessary to maintain this good rapport.

Know your local and state codes. The establishment of divisional codes will be necessary to formally guideline for internal operations. Safety information and education originates from and must be maintained by this department. In addition, an extensive and up-to-date reference library is also a must.

Receiving the Chemicals

Central warehousing is important in controlling the waste disposal program. Bulk solvents, when received, should be repackaged to smaller one pint or quart containers, if possible, and labeled. Some chemical suppliers ship solvents in metal-covered containers to protect from breakage. This should be encouraged if at all possible.

An up to date inventory of those toxic and flammable chemicals shipped to various departments must be kept. This will alert the disposal facilities as to what they may expect in regard to quantity. It will also alert the department to the use of excessive toxic or hazardous materials which may be beyond the capabilities of the department and may require outside help or a change in the prescribed disposal method.

Continued upgrading and substitution by the storehouse should be made of those items which can be substituted! i.e., 1,1,1, trichloroethylene can be substituted for carbon tetrachloride for cleaning operations in some situations.

Supply the department with up to date information on safe handling and disposal methods and/or changes that may occur. Packing standards may be required by this

department to be supplied to the manufacturer or distributor of certain chemicals. Here ICC regulations will have to be met.

Handling of radioactive materials can be undertaken by this department, but separate standards and guidelines will have to be established according to the Atomic Energy Commission requirements. Disposal and storage will be in accordance with AEC standards and not taken up in this departmental organizational outline. At the University of Minnesota it is handled differently than most, and it may not fit normal operations.

Chemical Storage in Laboratories

Procedures for storage of chemicals. Here is where the problem of waste starts. It must be made known to those using the chemicals that the waste disposal department must be informed whenever an accumulation of waste chemicals exists. In turn, the disposal department will provide the information for packaging waste chemicals prior to pickup. Also, a holding facility, preferably outside the building, should be made available to store these chemicals until such time as a pickup can be made. Since there is usually a change in chemicals from what they were originally, they tend to be even more toxic and hazardous and should be treated accordingly. If stored outdoors in a local cabinet, a special key system should be matched between the laboratory and the disposal pickup department.

Removal of Waste Materials

If the organization has followed the preceding outline and they have obtained the utopian program, there is little to worry about beyond merely hauling out the waste and disposing of it. But due to human error, various problems arise such as old, unlabeled, and unknown chemicals. Also, the noncompatibility of these chemicals should they come in contact with one another is a problem. Following are the precautionary measures necessary in transporting such chemicals.

A pickup, preferably three-quarter ton, should be provided with a blast arrester to store these chemicals while in transit. Presently, there are blast arresters designed specifically for explosive transportation, but in this instance the total protection isn't necessarily needed. The unit design should be

flexible enough to handle the variety of chemicals that is normally found. It should be noted that under normal conditions this unit will be used only occasionally and should be so designed that the truck can be easily converted back to normal use. This will also help in the overall expense of the program. If flammable chemicals comprise the total of that being transported, then labeling, packaging, and separation are the only necessary protection required. Trailer use has been ruled out due to the possible mechanical failures that may occur.

If explosive chemicals are to be transported in the equipped unit, a direct route should be made to the disposal point. No loitering by the driver on the way should be tolerated. Due to heavy traffic usually found during normal working hours, it is advised that an early starting time be made to avoid the rush hour traffic. Upon arriving at the site, it is suggested that a building be provided in the demolition area to store and sort those chemicals which may require special handling. Also, separate storage of igniters, such as primacord, blasting caps, and explosives can be provided there which will eliminate continuous transportation problems and exposure.

Site Selection

A detailed study by a professional in this field is usually required to determine the exact site and location. A multiple purpose site should be considered if at all possible, thereby eliminating dual fund requirements.

The area should be as remote as possible. Size will vary a great deal, depending on the availability of land. For disposal of explosive wastes, a three corner parapet enclosure eight feet high, with a clearance of 500 feet from the center of blast to any road or public access area, should be allotted. This distance is a minimum for forces equivalent to five pounds of TNT. Normally, one to two classes are more common, which would require less distance; but to provide a safety factor, the 500 feet should be maintained. Larger quantities can be considered if land area is available.

Prior to use, topographic, geographic, and soil considerations should be studied to determine exposure to land owners in the immediate vicinity. A well log may be required to determine possible ground water

conditions. Also, local and state requirements should be followed.

Air pollution should also be considered. Quantities of waste destroyed at one time may have to be reduced to provide sufficient air dilution.

Written procedures as to types of waste and the methods of handling are to be posted at the site, and employees are to be thoroughly trained prior to accepting the responsibility of this task. In addition to this, each individual should be familiar with basic first aid and toxicology. Since the chemicals being handled may expose those individuals to toxic vapors, they must be able to recognize the symptoms and be able to administer first aid. A first aid kit should be included with basic equipment, along with two self-contained breathing apparatus. Additional equipment such as coveralls, rubber gloves, and eye protection should also be supplied.

Example of Site Selection and Utilization

The University of Minnesota has a five-fold use of the waste disposal area. A parcel of land is fenced off around an open pit approximately 50x150 feet, with the bottom covered with rock and salvaged concrete slabs. Two blast shields are placed at opposite ends to provide protection to those individuals disposing of the flammable solvents. The packaged bottles are thrown into the pit intact and ignited by a safety flare. What isn't burned at the time will either evaporate or leach into the soil. The fence is necessary to reduce possible scavenging by others. In close proximity to this burning site, another area is used for sanitary land fill for disposal of solid waste which cannot be burned or disposed of by normal incineration. Also in this general vicinity is an explosive waste area where the chemicals and cylinders of toxic gases and chemicals are disposed. For highly toxic chemicals and gases a trench is dug, the chemicals or cylinders are laid out in parallel, and a light explosive charge is set to break or split the containers, exposing them to the atmosphere. The trench is then covered immediately to protect the environment. Any residue or scrap remaining in the general vicinity after the blasting can be disposed of in the land fill.

This university has the use of a professional blaster on a consulting basis to

handle all explosive operations. A full time man is not necessarily required, and this will help with the overall operational cost. But it is important that when he is available, all interested parties should observe the methods of disposal. This makes a good training program for new personnel and chances to iron out any foreseeable problem.

Also in the close proximity of this area, but in a more remote section, is a small site also fenced which is used by the health physicists to evaporate low-level radioactive flammable waste. After the liquid has been evaporated, the residue is packaged in specially designed containers and shipped to the AEC burial grounds. This method reduces the cost of a large bulk quantity shipments. A new method of burning flammable radioactive waste is being considered and plans are being made to build a test facility.

Summary

Summarization of important points must be done only generally, since in a program of this type all points are important and must be fully understood and followed to provide a safe, economical program. This writer feels the most important part of this program is the manpower selection. A strong, knowledgeable person in need to provide liaison between the various departments found at most universities and research laboratories. Again, funds should be provided to run the program sufficiently and effectively. Without sufficient funds, the operation is doomed to failure. Next is the ability to provide up-to-date information to the various departments and facilities, being certain that they understand and have confidence in the program. Last, but not least, is the ability to be flexible. If the department is always looking for new ideas and is willing to change when a new idea or program is selected, this is a great asset to the overall program.

As with any proposed facility of this type, many variables have to be considered. This department has reviewed various programs of handling, storage, and disposal methods used by others and, hopefully, selected those items or ideas which fit our particular needs. There are many good ideas and methods yet to be considered and possibly to be incorporated in the existing program.

HOW ADEQUATE IS YOUR EMERGENCY CARE SYSTEM?

By JOHN T. GOETZ

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Suddenly there's an emergency. A cry for help. Someone is seriously injured, and it demands immediate action. Time is critical, because what happens in the next few moments may mean the difference between life and death. Who is responsible? Where is the help? Are we prepared?

Crisis situations often produce fear and panic which can interfere with the logical emergency care procedures that must be taken quickly, efficiently, and in a calm manner. To illustrate this point, visualize the engineer who said, "When you are up to your elbows in alligators, it is difficult to remind yourself that your initial objective was to drain the swamp!"

Can we be sure that proper action will be taken so the victim will be handled efficiently, without compounding his injuries and creating additional suffering and possibly permanent damage? Are industrial workers paying too high a price for the limitations of effective emergency assistance? How do you feel about the expense of accidents in terms of death, disability, and monetary costs? Are they excessive? Is it possible to significantly reduce the number of accidents, deaths, the severity of disabilities, and the resulting financial losses? What vehicle is needed to reduce this unnecessary human and financial waste?

The gruesome statistical story shows that 55 American workers are killed each day on the job. That 8,500 American workers are disabled each day on the job. That 27,200 American workers are injured each day on the job.

That's only part of the story. An official government study estimates that job casualties may be ten times higher, but the many deaths and accidents don't get recorded in the statistics.

Will this endeavor require a coordinated, organized approach? Or can it be handled by one individual who is responsible for safety?

I have attempted to raise questions to make you explore the effectiveness of your

own programs. We know for a fact that one blueprint will not work for every organization, because the size, scope, hazards, and structure of each laboratory and plant are different.

However, the ingredients necessary to initiate an effective program in organizing, maintaining, and carrying out an emergency care system are basic. Let's examine some of these elements.

First, let's look at safety management. Safety management must establish the basic interest, set an example of safety for all personnel, and exert influence in all elements of the safety program. Is this being done?

Management is responsible for providing a safe workplace and environment and must prescribe specific safe work practices and procedures. Management must provide competent safety supervisors with designated responsibility and authority.

If management does fulfill these responsibilities, why should accidents happen?

We know that engineers can build safety into equipment and facilities; management sets the pace for safety; the supervisors and safety men add safeguards and teach safe practices—yet, people get hurt. Of course, they should have known better; nevertheless, accidents will happen.

The next link in the emergency care system is the safety director or supervisor, depending upon the organization size and structure. He is charged with the responsibility of knowing all the possible hazards on the job. He must determine what materials are dangerous, and must develop safe handling procedures. His continuing function is to control hazards and be certain these controls are effective.

The supervisor determines what personal protective equipment is necessary on the job and sees that it is used. The supervisor trains personnel in the proper work practices and sees that these practices are followed. When unsafe conditions or work methods are noted, he must take corrective action. He must assure that personnel will recognize unsafe

equipment, tools or environmental settings and will report any of these hazardous conditions immediately.

It is the supervisor's job to make sure that employees have the knowledge and skills to be safe and, in the event there is an accident, to respond effectively. That's why training or teaching or job instruction is such an important part of the supervisor's job.

We all know that each manager's job is different from those in other companies and other departments. Every supervisor's job is also different. They deal with different safety, economic, policy, and supervisory problems. They have different mechanical problems. They work with different materials and equipment, and they face different production problems. But, from job to job, from department to department, laboratory to laboratory, all supervisors have one problem in common—people. People are the same everywhere, subject to the same desires, hopes, expectations, fears, aspirations, ambitions, attitudes, and feelings and they all, potentially present the same problems.

It is people who have accidents, so what part do the people play in this system?

The employee must observe all prescribed safe work practices; after all, they are developed for his benefit. He must use the protective devices and safety equipment correctly, as these, too, were designed to keep him safe. He should report to the supervisor any hazards that are found, so he and others will not be hurt. If someone is injured, even slightly, it must be reported so the cause can be studied and, hopefully, eliminated.

It is only when the safety problem is accepted by the worker, the management, and the supervisor that effective cooperation for injury reduction and accident prevention can be expected.

We have reviewed the areas of responsibility for cooperative action. We should agree that even though we may have the best management and support, the best supervisors and guidance, and employees who are truly a part of the safety team, accidents will happen.

Because each individual organization and industrial plant differs greatly, and has its own peculiar emergency hazards, emergency planning must take place with these hazards in mind through a cooperative effort of

management, the safety supervisor, the employees, and with cooperation of community resources.

Have you planned a total emergency care system to take care of situations and potential disasters which may occur within your own laboratories? Do you have medical supervision over your safety program—whether it's full time, part time, or on a consultative basis? Does your medical resource have a part in the responsibility for emergency planning and in establishing policies, or does he merely handle the injuries after they have occurred? Have you consulted the medical supervisor regarding specific information and procedures for handling accidents which may be uncommon, but associated with the hazardous materials or environmental conditions within which you are working? I have not attempted to go into any of these hazardous areas or conditions as they vary greatly. For example:

Since the turn of the century, more than 500,000 new chemicals, solvents, and compounds have been introduced in industry. Some of these chemicals, solvents, and compounds have long-range effect, sometimes from 10 to 15 years. In some cases, once the employee becomes ill from one of these chemicals, solvents, or compounds, there is nothing that can be done to save his life.

Extra precautions must be taken where special hazards are involved so as to insure the safety and health of the employees.

Has consideration been given to care for the mass emergency in which many individuals might be affected—such as explosions and fires? Have safeguards been developed that may require special emergency procedures for those employees working with special hazards located in remote work areas?

Let's assume that all the planning and coordination with the medical base have been accomplished. The next logical step would be to meet with authorities representing local hospitals, medical personnel, ambulances, police, rescue squads, fire companies, utility companies, and other appropriate individuals to discuss the planning which has been developed. The specific procedures developed to cover various emergencies that may occur should be thoroughly discussed and understood by all. Areas of responsibility should be determined and designated. Communication systems should be agreed upon and

tested frequently when emergency practice drills are conducted.

Individuals assigned the specific responsibilities will alert their personnel, who also become a link in the system. Training must take place at each level so if an emergency does occur and the total emergency system is called into action, it can respond in a positive, coordinated, efficient manner.

First aid training is an integral part of any emergency care system, because the medical or paramedical personnel are seldom immediately available at the accident scene, and the employees must have the knowledge and skill to react quickly and intelligently to save lives and minimize disability.

First aid training is also a powerful influence in developing safety awareness, better attitudes and habits, and is a prime ingredient in reducing on the job as well as off the job injuries. The content of these first aid efforts must be specifically and directly related to today's technological needs.

Arrangements for first aid training can be made through local Red Cross chapters. Most industries prefer to select key personnel to receive training as instructors who, in turn, can conduct classes for fellow employees. Others may wish to arrange for employee training by instructors provided through the chapter.

Key individuals should be selected from various strategic locations within the facility, and they should be thoroughly trained in every aspect of first aid. They should hold, as a minimum, a current advanced first aid certificate awarded by the American National Red Cross or an equivalent nationally recognized certificate of proficiency.

All employees should receive competent first aid instruction with emphasis on hazards particular to the laboratory; for example, special training in first aid for exposure to chemicals—disposal of chemical wastes with regard to environmental pollution. The program must teach the prevention of accidents by instruction in the causes, effects, prevention, and first aid for accidents which should result in the development of positive safety attitudes for safer living. Periodic refresher courses should be conducted as necessary to maintain a high degree of efficiency in providing emergency assistance.

Basic rescue techniques should be a part of the training program for all employees,

and specialized training should be required for personnel assigned to these duties. Some basic rescue techniques are rather simple; for example:

An employee does not follow the prescribed preventive methods of operating machinery and reaches into the conveyor belt without throwing the master switch. The belt catches the worker's arm and jerks him under the machine and over the machine; around and around he goes. Finally, the switch is thrown by the supervisor, who waits for the machine to stop. The machine slows down and flings the employee on his back. His arm is mangled. The supervisor with horror in his face leans over the injured man and says, "Speak to me! Speak to me! The injured man responds, "Why should I speak to you now! I passed you four times a few minutes ago, and you didn't even say, 'Hello!'"

First aid supplies and equipment should be provided in accordance with the needs established by the consulting physician, based upon the possible accidents that might occur.

Instruction should be given in the use of any special equipment applicable to the hazards concerned in the general area. (Example: High frequency of electric shock—special training might be indicated in cardiopulmonary resuscitation.)

We have already conceded that accidents will happen. When they do, it is necessary to thoroughly investigate and analyze the accident so as to determine trends in accident occurrence and to plan for and apply remedial measures.

An emergency care system can be highly effective only when every person involved is capable of successfully carrying out his individual responsibilities.

In closing, let me summarize a few key points:

Industrial workers are paying too high a price for limitations in effective emergency assistance. The expense of accidents in terms of death, disability, and monetary costs are of staggering proportions.

It is possible to significantly reduce the number of accidents, deaths, the severity of injuries, and the resulting financial losses. The mechanism needed to reduce this unnecessary human and financial waste is a coordinated, organized, cooperative approach. Management must exert influence in all

elements of the safety program and set the pace for safety.

The medical profession must continue to guide and participate in these programs.

The safety director or supervisor has a well defined responsibility to protect the employees from existing hazards, to train them in proper practices and in the use of equipment and materials, and to see that personal protective equipment is used. First aid training is an integral part of any emergency care system. First aid knowledge and skills are of great importance in emergency situations involving small or large numbers of casualties in which medical assistance is not immediately available at the accident scene, and employees must have the knowledge and skill to react quickly and intelligently to save lives and minimize disability. Laymen can effectively learn and use first aid skills, and this will contribute to the prevention of unnecessary loss of life and disabilities.

EXPLOSIVE CHEMICALS DISPOSAL

By D. J. KVAM

Lawrence Radiation Laboratory, Livermore, Calif.

There are a number of laws dealing with the manufacture and use of explosives. Commercial and military explosives are well understood and adequately regulated, but laboratories have unstable compounds and mixtures with little provision for handling or disposing of these potentially violent materials. Picric acid with 15 per cent water is a standard reagent, but let it become contaminated with some heavy metal ions, then let it sit on the shelf a few years and lose its water. A new researcher takes over the lab and decides to throw out the old bottles. This is the laboratory situation under discussion. The range of possible combinations which could create a problem is very wide; however, most substances of this type are characterized by certain atom groups such as:¹

O—O	Ozone, peroxide
O—Cl	Chlorate, perchlorate
N—Cl	Chloride of nitrogen
N—O	Inorganic compounds
N—N	Diazo compounds, azides
N—C	Fulminate
C—C	Acetylene

Specialized training in rescue techniques and advanced first aid training is essential for key industrial workers who are assigned these duties as part of their work. The training should emphasize the hazardous situations and definitive rescue techniques.

An effective communications system with an alternate backup system, which assures prompt response is needed in order to call into action the emergency teams from hospitals, police and fire departments, rescue squads, and others who provide the necessary life support at the scene of an accident and during transportation. Hospital and emergency care facilities should be staffed and trained to handle the potential emergencies and have the proper equipment to provide this care.

Finally, it is essential that all components work together in a coordinated, efficient manner, so that the goal of quality care for the emergency victim can be realized.

There are five main mechanisms which produce difficult handling and disposal problems in the laboratory:

1. A responsible researcher deliberately designs an explosive experiment. An example would be a chemist who mixes explosive gases in order to utilize the resultant energy release.

2. A not so responsible student decides to make his own fireworks. An example is the boy who covers some iodine crystals with ammonium hydroxide.

3. Compounds that age or autoxidize and, without much help, change from relatively harmless material into an explosive. An example is ethyl ether, which autoxidizes and forms a peroxide.

4. Material that has lost its identity and becomes an "unknown." An example would be the picric acid mentioned earlier without the label on the bottle.

5. The researcher just doesn't know the hazards of the resultant product. For example, a worker mixes a solution of sixty

per cent perchloric acid and forty per cent acetic anhydride for electropolishing.

A complete listing of explosive substances and reactions would fill a large volume. These substances do exist in all types of laboratories and make their appearance with amazing frequency. At the Lawrence Radiation Laboratory in Livermore, each year we dispose of about ten top hazard situations such as the five real examples just given. Some explosives go through chemical disposal systems without anyone being aware of their hazard. This is because there are unknowns, mislabeled bottles, thousands of proprietary names, and even a knowledgeable chemist has difficulty predicting all problems. The entire subject of chemical disposal should be viewed with suspicion.

Assuming the laboratory is confronted with a highly unstable substance, there is an orderly approach that should be taken:

1. *Is there a real problem?* Not long ago at LRL there was an emergency call from the warehouse reporting they had several cases of dioxane and the bottles were filled with crystals. Dioxane does form peroxides by autoxidation and, in sufficient concentration, the peroxide forms shock-sensitive explosive crystals. Many people responded and crowded around to see the explosive crystals. Fortunately, someone looked up the freezing point of dioxane and related that temperature to the cold dock where the dioxane had been stored the night before. The dioxane was partially frozen. First, clear the area of people and then get all the facts.

2. *Can the material be desensitized?* In many cases a material is less sensitive if it is frozen. Perhaps a tube can be placed around the explosive container and the tube filled with liquid nitrogen. Do not try to open a container but, if accessible, certain dangerous residues can be destroyed. For example, halogen nitrogen compounds are destroyed by making alkaline with ammonia, azides and silver fulminate by acidifying, diazo compounds by boiling water, acetylides by decomposing with ammonium sulphide, and peroxides by reduction. Just the addition of water desensitizes materials such as nitrogen triiodide or black powder. Acetone will soften or dissolve many explosives such as smokeless powder, lead azide, tetryl, PETN, TNT, and dynamite. Nitroglycerin can be destroyed by a solution of sodium sulphide, ethyl al-

cohol, acetone, and water.² Keep in mind that even after desensitizing the material should be handled remotely, if possible.

A piece of tubing 1/4-inch in diameter and flared on the ends makes a handy tool for adding a liquid while staying ten to fifteen feet away. By threading a fish line through the tube and tying a slipknot in one end you can also pick up a flask and lower it into a shielded container.

3. *Must the explosive material be moved?* In the early years of World War II, an explosive ordnance disposal group (EOD) was formed to disarm the delayed action bombs that were being dropped on London. After a number of these EOD men were killed, some of the survivors started carrying demolition charges in their tool bag. They would place it near the fuse, pretend to listen to the bomb, then leave, forgetting their tool bag. No one expected the EOD man to work on a ticking live bomb. "Blimey, it's ticking," they would certify. They lost a lot of tools and a few extra buildings, but they didn't lose as many bomb disposal people. The point is, if you cannot desensitize the explosive and it looks to be really hazardous material, then blow it in place—don't try to move the explosive. Remember that some explosions are initiated by the heat of a finger or the weight of a housefly. It is better to lose windows than people.

Some preparation should be made if it is apparent an explosion may occur:

Clear the area of people. If the situation has an amount of material equivalent to five pounds of explosive, then the minimum safe distance from fragments in the open is 900 feet. This five pounds will demolish a three to five foot radius, cause irreparable damage at five to nine feet, reparable damage at 20 feet, and minor damage at 100 feet. Low explosives will do proportionately less damage.²

Clear the area of equipment and reagents if possible, particularly flammables. Open doors and windows to vent the area and minimize blast damage. Mattresses or other baffling or buttressing materials will reduce damage.

Notify the fire department, obtain extinguishers, and notify the security or police department. Shut off gas and fuel lines. Put medical aid on standby.

Using remote means, drop a weight on the explosive or drop the unstable material into a sturdy container. If, indeed, the material is unstable, this rough handling should solve the problem.

4. *Where will the material be disposed?* After being loaded on the truck, the explosive material is transported by a previously arranged and cleared route to as remote an area as is possible without traveling any more public road than is necessary. Remember that 300 yards is the minimum safe distance for a five-pound H.E. detonation in open area. At Livermore, a concrete building open on one side is used with a selection of steel blast shields which permit traffic within 50 yards. This area is used for disposal operations involving less than one pound of explosive. Potentially higher yields require increasingly more remote facilities. Site 300, which is eleven miles away from Livermore, can shoot 1000 pounds when the weather conditions permit. As the amount of explosive increases, much more elaborate facilities are needed. Shielded bunkers, magazines, lightning detectors, a weather station, etc., are just a few of the disposal requirements. For the laboratory situation, any reasonable remote open area, where the public can be excluded, will generally suffice. Be mindful that any smoke or gases resulting from the disposal operation may be toxic and note wind direction.

5. *How is the material disposed of?* If the suspected explosive material has not blown at this point, one can breathe a little easier but no less cautiously. In the case of unknowns, particularly, they should first be tested for shock sensitivity. LRL has three basic tests. The choice of test usually depends on the type of container. For sturdy containers such as the pipe section, a 12 gauge riot gun firing 00 buckshot from 12 inches is used. The gun is sandbagged and a fishline is attached to the trigger so that the gun can be fired remotely. This technique works extremely well as a package opener and disposal device. It can be set up and operated effectively in a short time.

The second opening system tests effectively for shock sensitivity. A 1,400-pound steel block is suspended eight or ten feet over the explosive with a quick-disconnect hook. The weight is dropped remotely by releasing the hook with the aid of a long rope. The

weight drops onto the sensitive material which has been placed on one-inch steel plate. If anything remains, the plate is tilted and residue is slid into a slit trench.

A third opening technique is used primarily on peroxide forming solvents such as ether. Using heavy gloves, 1/4-inch thick lexan face shield, and flack vest, the glass container is lobbed into a reinforced, 16-inch thick concrete container. On impact, the operator is well below the rim of the concrete and out of danger from flying glass. Any liquid that fails to explode evaporates harmlessly. At Livermore, a thousand bottles are disposed of annually in this manner.

The small shaped or other type of explosive charge is an excellent disposal and opening device. It solves more problems easier and faster than almost any other technique. At LRL, administrative controls limit the use of explosives to the disposal of gas cylinders or other explosives such as detonators. Most bulk H.E. is disposed of by burning in shallow layers on a bed of flammable material, and this burning technique frequently can be useful in the laboratory generated situation. In any burning disposal of explosive, assume it will explode rather than merely burn.

Sturdy portable blast shields are essential in unstable chemical disposal. One particularly useful shield is the armored workbench. Built of one-half and three-quarter inch steel, this work bench has three laminated glass view-ports and is designed to protect a worker from a one-pound explosion. Remote manipulating arms can be incorporated for de-activating a material. A remote operated hydraulic system can be used to pull or push or cut a potentially hazardous material. The operations that can be performed remotely on this workbench are limited only by the imagination of the disposal technician.

The safe handling and disposal of explosive chemicals is too large a subject to be covered in this brief discussion and cursory treatment is not appropriate where explosives are concerned. There is either success or complete and instant failure. Good luck!

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THE SAFE USE OF COMPRESSED GASES IN LABORATORIES

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What is a compressed gas? The Federal Department of Transportation has defined it as "... any material having, in the container, an absolute pressure exceeding 40 psi at 70°F or, regardless of the pressure at 70°F, having a pressure exceeding 140 psi at 130°F or any liquid flammable material having a vapor pressure exceeding 40 psi absolute at 100°F..." Certain other materials such as many class A poisons must also be shipped in cylinders even though they do not fit the definition of a compressed gas. Many low vapor pressure materials are packaged in cylinders which are pressurized with an inert gas. An example of this is the aerosol spray developer for thin-layer chromatography.

What does a cylinder look like? Compressed gas cylinders vary in shape from spheres through tin cans to long skinny cylinders and tubes. So far, no one has made a pressurized shipping container with flat side and angular corners, although I wouldn't be surprised if one appears on the market at any time.

These varied containers will have internal pressures varying from essentially atmospheric to 10,000 psi and above. They can release to the air from a few cubic inches to over 3,500 cubic feet of every conceivable flammable, poisonous, toxic, radio-active, oxidizing or inert gas or gas mixture in a very short time.

Recent developments in analytical instrumentation such as gas chromatography, as well as expanded interest in such compressed gas using areas as space and underwater research, hyperbaric chambers, air pollution studies, and fuel cell research, have placed compressed gases into most academic, gov-

ernmental, and industrial laboratories. In these laboratories, the gases will be used by technically oriented persons whose primary interest is the particular project on which they are working. These persons are notoriously intolerant of anything, such as an unexpected form of valve outlet, which will interfere with the project. As a result, home made adaptors, modified regulators, and jury rigged fittings abound in hidden corners of even well regulated laboratories.

This, then, is the problem. There is, of course, no easy solution or way out. I have prepared a set of safety rules which, when followed, lead to the accident free use of compressed gases under almost all conditions of exposure. Since the Israelites were able to mold an entire society around ten commandments, I have restricted these rules to ten.

1. Know the Contents of the Cylinder

Don't guess. This is a major problem area between suppliers and customers. Federal regulations relative to cylinder labeling, except for the medical gases, are vague unless the cylinder has been shipped by common carrier. However, ANSI Z48.1 "American Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained" and Compressed Gas Association pamphlet C7 "Guide for the Preparation of Labels for Compressed Gas Containers" contain adequate guidelines for cylinder labeling.

This label should be the entire method of identifying the contents of a cylinder. Color has been proposed a number of times as a means of classifying cylinders by hazard. However, except for the medical gases,

each gas supplier uses a different code. Even more important, colors change under different types of illumination, such as incandescent, fluorescent, mercury or sodium vapor, etc. The amount of type of change will depend upon the type of paint, the pigments used, the vehicle, etc. Many persons are color blind. Cylinders are not always so well painted that their original color can be determined. Finally, I would personally be at a loss to select the color or color combination which should be used on some of the exotic gas mixtures which have been ordered from us.

As far as I am concerned, cylinders with missing labels or with the labels so torn, faded, or stained that they cannot be easily read, should not be given room on the receiving dock and, if found in a laboratory, should be immediately returned to the supplier.

2. Know Properties of Contents

This is the responsibility of the user. Knowing what is in a cylinder only gets you into the ball park. How you play the game will depend on what you know about the safety related properties of the contents. Are they poisonous? Flammable? Anesthetic? Corrosive? Strong oxidizer? Inert? Are they liquid in the cylinder and, if they are, what does the vapor pressure curve look like? If they are permanent gases, what is the pressure in the cylinder?

Many gases have combination properties. Carbon monoxide and hydrogen sulfide are poisonous and flammable. Acetylene is flammable, unstable, and forms explosive compounds with copper and mercury. High concentrations of nitrogen can kill without warning by oxygen deprivation. The list goes on and on.

3. Use With Suitable Equipment

Presently, almost all cylinder valves have outlets in accordance with ANSI B57.1 with the exception of some non-refillable throw away cylinders and lecture bottles. These outlets are intended to separate the gases by hazard. This is accomplished by varying thread size, right or left handedness, and by male or female. Additional separations are accomplished by the internal design of the mating parts. For small medical cylinders used with a yoke type connector, coding is achieved by a series of holes in the valve outlet face and mating pins in the yoke.

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I said, "Almost all." The reason that I cannot say all is that, since this is a voluntary standard, many users refuse to accept cylinders with outlets which do not conform to their equipment, providing little incentive to the supplier to assume the cost of conversion.

It is reasonably simple to make up an adaptor which will allow the use of a single regulator for all cylinders. It is also extremely hazardous. A regulator not cleaned for oxygen service and thereby completely free from combustible materials can explode when high pressure oxygen is admitted to it. Even a brief use of an oxygen regulator in other service can so contaminate it that the pressure gauge can explode, endangering the eyes, when it is again used for oxygen. Regulators or other apparatus may contain stressed high tensile steel parts which will fail rapidly in hydrogen service. Corrosive gases will rapidly destroy incompatible regulators. The only safe practice is to have enough regulators so that an adaptor is never needed. Don't economize on this point.

4. Handle Cylinder With Care

Gas cylinders are primarily shipping containers and as such are designed to a minimum weight and wall thickness consistent with safety and durability. The non-refillable, throw-away cylinders are even lighter since they need last for only one filling. Rough handling or abuse such as using a cylinder for a hammer or anvil, as a roller to move heavy equipment, as a convenient ground in an electric circuit, or spilling acid or caustic, could weaken a cylinder seriously.

5. Don't Repair Regulator or Cylinder Valve

A large cylinder valve has two protrusions. One is the outlet; the other contains some form of safety device such as a fusible metal plug or a rupture disc. If the safety nut is removed, the entire contents of the cylinder will discharge through the safety device. It can be removed either by deliberately loosening it in error, thinking it is an outlet cap, or by tightening to stop a leak, thereby over-stressing the threads and causing them to fail. The packing nut threads can also fail if the nut is over tightened to stop a leak. In this case, the top works of the valve will be ejected forcefully. Don't attempt to repair leaking cylinders or cylinder valves. Remove the cylinder to an out of doors location and notify your supplier.

A regulator is a precision piece of equipment and is designed, through spring selection, diaphragm and seat area, flow passage diameters, seat material, etc., to safely and accurately reduce cylinder pressures as high as 10,000 psi to use pressures as low as a few inches of water. Incidentally, regulators should be used only over the inlet and outlet pressure ranges for which they are designed. Only special regulators will withstand pressures in excess of 3,000 psi. Any uneducated tampering with the regulator could cause an unexpected and uncontrolled release of the contents at inlet pressures.

6. Use a Regulator

Almost all cylinders contain pressures considerably in excess of that which most apparatus can withstand. There are extremely accurate needle valves on the market which can be set reproducibly to a very low flow. However, they will continue to discharge gas until the down stream and up stream pressures equalize, as can happen should a vent plug, a vent valve be closed off, etc.

7. Close Valve on Empty and Out of Use Cylinders

Regulators are not shut-off valves and should not be used as such. A seat leak can allow the down stream pressure to equalize with the upstream pressure. Use the cylinder valve for this purpose. If you always do so, you will always know whether a valve is opened or closed, a valuable piece of information in an emergency. Also, it will keep foreign material from being forced into the cylinder as it empties and the downstream pressure equals or becomes greater than the cylinder pressure.

Closing the valve on empty cylinders, marking the cylinder "empty" and either returning it to the empty stock pile or disposing of it (for non-refillable cylinders) in accordance with the manufacturer's instructions will accomplish two things. First, it will reduce the possibility of using an empty cylinder under emergency conditions such as for resuscitation; second, it will keep wet air out of empty cylinders. This wet air, which can enter because of changes in atmospheric temperature and pressure, makes it very difficult to get high purity gas out of the cylinder after the next filling and, for acid gas service such as chlorine or hydrogen chloride can rapidly corrode the cylinder.

8. Use and Store Cylinders in Well Ventilated Areas

Use and store cylinders in well ventilated areas away from heavy traffic and sources of ignition. Store cylinders of flammable gases together away from other cylinders. Always chain or otherwise restrain in use or storage. A falling cylinder can break legs and crush toes. Even worse, the valve could break off and the entire 130 lb. cylinder could become a rocket. If a regulator attached to the valve should break off the cylinder would become an oversized, erratic pinwheel. Small cylinders should be restrained from rolling or falling off of a bench for the same reasons as large cylinders.

Never heat cylinders uncontrollably. If they must be heated (e.g., to raise the vapor pressure of a liquified gas), do it in a water bath and limit the temperature to 100°F and an absolute maximum of 130°F. Some cylinder safety devices are, as was mentioned before, made of a fusible metal with a melting point as low as 165°F., and even on those with rupture discs the rupture pressure can be approached at this temperature. The result of the functioning of the safety device would be the release of up to 3,500 cubic feet of toxic, flammable, corrosive, or non-life supporting gas. The volume alone could cause serious over pressure in a tight room.

9. Always Move Large Cylinders on a Wheeled Cart

Few persons have sufficient skill to hand-roll large cylinders. I have already mentioned the injuries a falling cylinder can cause. Always leave the valve protection cap on a cylinder in transit or storage until the time of actual use. This will prevent the valve breaking off a falling cylinder. Don't drag a cylinder by the cap. Aside from the danger of falling, the cap might pull off, striking you in the face. In general, muscle pulls and back injuries caused by the improper handling of cylinders are a major problem in our industry.

10. Don't Refill Cylinders

This final rule is the single most important one. The consequences of violating it have been death or permanently disabling injuries in far too many instances. Unless you are a packager of compressed gases, it is unlikely that you possess the specialized knowledge necessary to do it safely. An increasing

number of laboratory cylinders are legally non-refillable and cannot withstand repeated filling. Other hazards are: the refilled cylinder may have a lower service pressure than the one from which it is filled; too rapid filling raises the temperature by adiabatic compression; there may be an unknown residue in the cylinder being filled; the cylinder may have unrecognized physical defects; or the cylinder may be past the date by which it must be hydrostatically tested.

A cylinder filled with a gas which is liquid in the cylinder must be filled by weight to make sure that there is sufficient vapor space in the cylinder to accommodate liquid expansion as the contents warm. If this is not done, the cylinder can fail by hydrostatic pressure. The permitted weight will vary both with the size of the cylinder and the identity of the gas.

Finally, and this statement is going to be very unpopular with those servicing emergency breathing equipment, resuscitators, or any apparatus delivering gas for human consumption with a layman's viewpoint, it is probably illegal to refill such cylinders under Part 132, Title 21 of the Code of Federal Regulations without registration with the Federal Food and Drug Administration and its state and municipal counterparts. Any one so registered would be expected to adhere to the various Food and Drug Administration regulations pertaining to drug packagers.

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Beyond these general rules, there are, of course, the usual safety rules concerning horse play, uneducated experimentation, etc. High pressure, low density gases such as hydrogen and helium escaping through a small orifice held against the skin can penetrate it, causing large painful bubbles. Cryogenic gases can cause severe slow healing burns. However, all of these are outside of the scope of this paper.

There is a very good safety suggestion which can minimize attention to the ten rules. It is: keep cylinders out of the laboratory by chaining them to a wall in an unfrequented area and piping the individual gases to the laboratory.

These then, are the ten general rules of cylinder handling safety. If followed, they allow the safe use of compressed gases. Much additional valuable information is contained in the publications of the Compressed Gas Association, the Chlorine Institute, the Manufacturing Chemists Association and, of course, the National Safety Council.

Don't let this discussion scare you away from the use of compressed gases. I would estimate that close to one million cylinders of compressed gases are filled, shipped, stored, and used each day with a remarkably low accident frequency for a multitude of uses varying from heavy industrial processes to way-out research projects.

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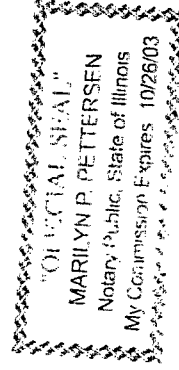
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