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HEALTH HAZARD CONTROL IN THE PESTICIDE FORMULATING AND MANUFACTURING INDUSTRY

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The proceedings of a symposium on hazard control in the pesticide formulating and manufacturing industries sponsored by NIOSH on December 1980 are presented. The purpose of the symposium was to present technical information to improve the workplace environment, to provide opportunity for exchange of ideas among industrial, labor, and governmental sectors, and to assist in the implementation of control technology. Assessments of the pesticide industry and engineering controls of health hazards are presented. Topics discussed include factory design and layout, materials handling and transfer, blending, formulating and packaging of liquids and solids, and emission controls. Non engineering hazard control procedures are reviewed. These include implementation of good work practices through education and training, the role of protective clothing in exposure control, basic principles of respiratory protection, general principles of worker exposure monitoring, principles of emissions monitoring, medical monitoring, and financial assistance to small businesses. The symposium concluded that knowledge of control technology components is useful only to the extent that implementation occurs.

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HEALTH HAZARD CONTROL IN THE PESTICIDE FORMULATING AND MANUFACTURING INDUSTRY

Proceedings of a Symposium sponsored by the National Institute for Occupational Safety and Health at St. Louis, Missouri, December 2-3, 1980.

Contract No. 210-80-0068

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Cincinnati, Ohio 45226

April 1981

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NIOSH Project Officer: Paul E. Caplan
Project Director: Reginald L. Powe

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Preface

These proceedings of the Symposium on "Health Hazard Control in the Pesticide Formulating and Manufacturing Industry" are submitted under Contract Number 210-80-0068 to the National Institute for Occupational Safety and Health of the U.S. Department of Health and Human Services. The symposium was held in St. Louis, Missouri, on 2-3 December, 1980.

The objectives of this Symposium were: 1) to present technical information that will improve the workplace and ambient environment through the design and implementation of engineering controls, monitoring systems, work practices, and personal protective equipment programs; 2) to provide an open exchange of information and ideas among industry, labor, and government representatives; and 3) to facilitate the implementation of control technology, particularly by small formulators and manufacturers.

Co-sponsors of the Symposium were the National Agricultural Chemicals Association, the American Institute of Chemical Engineers, the International Chemical Workers Union, the Chemical Specialties Manufacturing Association, and the Pesticide Producers Association. Coordination was provided by Dialogue Systems, Inc.

Abstract

This Symposium was held to allow representatives of industry, labor and government to share thoughts on how to improve health and safety in the workplace and how to control the emission of toxic airborne substances into the ambient environment. The general findings and conclusions of the NIOSH/EPA "Control Technology Assessment of the Pesticide Formulating and Manufacturing Industry" were reviewed.

The first day was devoted to an assessment of the pesticide industry and to the engineering control of health hazards. This included: plant design and layout; materials handling and transfer; blending, formulating and packaging of liquids and solids; and emission controls.

The second day covered work practices, use of personal protective equipment, monitoring for hazard control, and implementation of control technology strategies.

This report was submitted in fulfillment of Contract Number 210-80-0068 by Dialogue Systems, Inc., under the sponsorship of the National Institute for Occupational Safety and Health.

EXECUTIVE SUMMARY

Walter M. Haag
Director, DPSE/NIOSH

In the course of the symposium on health hazard control in the pesticide industry held in St. Louis on December 2 and 3, 1980, we heard some nineteen presentations from our panel. Our intention, to generate constructive exchange of information and ideas, was fulfilled. We hope that all the participants and attendees gained something from the program that they can take back and use.

A word about our organization. NIOSH, the National Institute for Occupational Safety and Health, located within the Department of Health and Human Services in the federal government, has responsibility under the Occupational Safety and Health Act of 1970 to conduct research and to develop criteria for preventing the exposure of workers to harmful chemical and physical agents. Within NIOSH, the Division of Physical Sciences and Engineering is responsible for control technology research. This control technology program attempts to define and establish solutions by documenting successful applications of control measures and by stimulating the private sector to prevent hazardous exposures of their workers.

The first of the three objectives of this symposium was to present technical information that can improve the workplace environment. Presentations were given on the design and implementation of engineering controls, monitoring systems, work practices, and personal protective equipment programs.

The second objective was to provide an open forum for exchange of ideas among the industry, labor, and governmental sectors. A look at the list of participants shows that this goal was indeed attained.

The third, and final, objective for the symposium was to help with facilitating the implementation of control technology, particularly by small formulators and manufacturers. St. Louis was selected as our conference site specifically for its accessibility to this part of the industry.

I would like to highlight the several themes that were covered in the symposium.

Control technology was presented as consisting of engineering controls, monitoring mechanisms, and work practices, including training and personal protective equipment. These components form a system rather than operate exclusive of one another. The solution to controlling hazards is both technical, in the sense of the engineering and monitoring, and human, in terms of work practices and personal protective equipment needed.

As a rule manufacturing formulating operations are batch processes and are regionally distributed. In the presentations on engineering controls, the central theme which emerged was that it is desirable to eliminate contamination of the workplace environment. To this end, our speakers described what has been and what can be done. We heard of some fundamental changes made by determined individuals. One of the primary purposes of the NIOSH Control Technology Assessment summarized in the symposium is to document that responsible organizations and individuals have taken action. Ingenuity, not straight textbook answers, is required for each situation, and we are attempting to encourage a wider implementation of ingenious solutions.

Management and immediate supervisors have a responsibility to maintain the system and to keep the worker aware and informed, in addition to the responsibility of implementing technological or engineering solutions. Attitude on the part of the management and workers is critical to successful production and to worker safety and health. Among our presentations were some which dealt with work practices, such as training techniques and approaches that are being used to make workers aware and informed of their responsibilities to carry out certain tasks in a certain way, and the effect of these techniques and approaches on their own safety and health. The good attendance at this symposium serves to further confirm the fact that the right attitude does exist in this industry. I think this is both commendable and encouraging.

Those discussions of control technology that concerned personal protective equipment mentioned a variety of equipment and other key factors as essential to an effective program. We saw how companies can tailor use of controls to their own particular situation and how they can draw upon what is known within the industry and other areas. The guidelines that were presented can be extrapolated throughout the industry.

The ability to monitor emissions in the workplace, in the environment, and medically is critical to the successful control of production processes and the elimination of emissions that can subsequently become contaminants. It was emphasized that point of emissions are most concentrated and where it is easiest to regain control if something does go wrong.

We were reminded that knowledge of the various control technology components--engineering, work practices, personal protective equipment, and monitoring--is useful only to the extent that implementation occurs.

Of course, every technical solution has costs associated with it.

With this in mind, we have tried to indicate some of the many finance mechanisms available to the small business operation. The idea is to fit the financial program to the need of the individual operation.

Another idea born out of this symposium is the concept of regional workshops for more detailed study of problems and solutions. If you have thoughts and suggestions along this line, please write to me or to any of the co-sponsoring organizations. We look forward to doing more collective work for the good of the industry.

Also, in addition to making these proceedings available, NIOSH has made about a thirty-minute videotape covering the symposium's content. It is available free of charge to anyone who provides a blank tape onto which it can be copied.

I would like to take this opportunity to commend the many people and organizations who have participated in the NIOSH control technology studies, of which this is one. In special thanks, I would like to recognize Tom Gilding, Manager of Regulatory Affairs, and Dick Blowers, Chairman of the Occupational Safety and Health Committee, both of whom are with the National Agricultural Chemicals Association; Jim Vale, of the Chemical Specialties Manufacturers Association; Jim Champion, of the Pesticides Producers Association; Stanley Eller and Angelo Russo, of the International Chemical Workers Union; Tom Carmody, Chairman of the Safety and Health Division of the American Institute of Chemical Engineers; Doug Fowler, Project Manager of the NIOSH Control Technology Assessment; Reginald Powe, Conference Coordinator, of Dialogue Systems, Inc., New York, and Robert Hughes, Research and Mechanical Engineer for the Engineering Control Technology Branch of DPSE/NIOSH, our moderator for the first day. I would also like to thank all who participated whether by speaking or by their presence. The presentations and discussions that took place mark the beginning of a continuing partnership to better protect our nation's greatest resource, its workforce. I look forward to having more contact with all of you in the months to come.

To sum up, I recall a magazine article which I saw recently entitled "America--Bread Basket of the World." Advances in the pesticide industry have contributed to this title and are essential for that phrase to apply ten years from now. I believe that NIOSH, with its initiative in control technology assessments and its research program, and the many companies, organizations, and individuals who attended this symposium can cooperate to make a difference in America's future. Let it be said that the eighties were a decade of solutions.

NIOSH-CTA: SCOPE AND OBJECTIVES

Paul E. Caplan
Research Industrial Hygienist, DPSE/NIOSH

One of the more recent programs of the National Institute for Occupational Safety and Health (NIOSH) has focused on hazard control technology as a means of protecting workers from the effects of exposure to occupational safety and health hazards. This program is carried out by the Engineering Control Technology Branch of the Division of Physical Sciences and Engineering. It complements other NIOSH programs, such as experimental toxicology research, identification and evaluation of health hazards, industry-wide studies on the extent of occupational diseases and their causes, and health and medical care management programs in industry. The aim of our control technology program is to identify and develop solutions to the control of health hazards, once they have been identified and quantified by these other NIOSH programs.

In our concept, hazard control technology consists primarily of four elements, all of which need to be considered and coordinated for optimum hazard control. The first element is the design and installation of good engineering controls. This, in our opinion, is the major method of hazard control. The second element is the development and implementation of good work practices among the workforce through education and training. Third, we feel that a good hazard control program must have provisions for an adequate personal protective equipment program, that is, the choice of protective equipment, its maintenance, and so on. The fourth and final element is the use of environmental and medical monitoring to measure the effectiveness of the first three elements of the program, both in controlling environmental exposures and also in monitoring the effects of the existent exposures on the health of the employee.

Certain basic principles of hazard control apply to almost all work situations, even though strategic application of these principles varies from case to case. These control strategies and procedures can be implemented at the source of the hazard--that is, where the contaminant may be generated--in the general work area of the environment, or, finally, at the point of exposure of individual employees. Usually a well-planned, well-operated control program includes control at all three of these locations. (These concepts are described in detail in a paper entitled "Controlling Occupational Exposure--Principles and Practices," by James Gideon and several others of our Engineering Control Technology Branch.)

One phase of our control technology program over the past several years has involved the assessment of hazard control technology programs in more than twenty specific industries, processes, or specific chemicals. Assessments of the plastics and resins industry, textile finishing plants, ferrous and nonferrous foundries, silica flour milling, dry-cleaning plants, tire manufacturing plants, and pesticide manufacturing and formulating have been conducted. Our Control Technology Assessment (CTA) of the pesticide formulating and manufacturing industry was carried out under contract with Stanford Research Institute (SRI). The Project Director for this Control Technology Assessment was Mr. Douglas Fowler. We carried out this project as a joint effort between NIOSH and the EPA both in conduct and funding.

There were four major objectives of the NIOSH in-plant assessment. First, we wanted to document effective engineering control technology that pesticide manufacturers and formulators are using to control worker exposures. The second objective has been to assess and document other hazard control techniques, such as good work practices, protective equipment, and monitoring programs that have been effective in controlling worker exposures. A third objective of this particular study was to identify and define the operations, processes, and procedures that have not yet been completely or adequately controlled by engineering technology. These, we feel, are areas where the industry and NIOSH should join in cooperative efforts to develop engineering research and development projects. And, finally, our goal has been an attempt to produce a control technology document that will be useful to the industry as a set of guidelines for the selection of effective engineering approaches, work practices, protective equipment, and monitoring programs.

This assessment was conducted in three phases. First, specific pesticides were selected for study based on production volume, physicochemical and toxicology characteristics of the pesticides, and the types of unit operations and chemical processes involved in their manufacture and formulation. Such factors as vapor pressure and physical state under normal ambient conditions and major routes of exposure were considered, since the degree of hazard is usually dependent on such properties. Of the original list of ninety-two basic pesticides produced in quantities of two million pounds per year or more, a group of forty-three chemicals were selected to represent the variety of active ingredients and formulations to which workers may be exposed. This group includes the majority of commerical pesticides for which there are indications of potential chronic effects and environmental insult, including suspect or known carcinogens, teratagens, and mutagens.

The second phase of this study involved the selection of plants to be surveyed in order to evaluate the performance and effectiveness of selected engineering control systems in relation to the specific chemicals and processes involved. Twenty facilities were surveyed in depth by representatives from SRI and NIOSH jointly. Of these, three facilities were manufacturers of technical-grade products, nine were formulating plants only, and eight were plants that carried out both manufacturing of technical-grade material and formulation operations. Topics covered in the survey included process descriptions, building designs, maintenance programs, engineering control, industrial hygiene procedures, and area and personal sampling strategies.

The third phase of this project was the preparation of a final report to serve as a guideline for principles, practices, and application of practices for hazard control in the pesticide industry. This report was prepared from information and data presented in the specific case study reports. The identity of companies, plants, and products was held in confidence, so that data obtained could be as usable as possible. Where apparently plausible technology had been tried and found to be unsuccessful or inadequate, the causes and circumstances for such failure were sought from the company so that research and development programs could be instituted. Problems for which solutions have not yet been found were also identified as research needs, without reference to any specific company.

We hope that the findings and conclusions of this study, plus the additional information presented by our panel of speakers, will be of value to you in the definition and solution of some of your occupational health and safety and environmental pollution problems.

EPA-CTA: SCOPE AND OBJECTIVES
Richard Stern
Chief, Chemical Process Branch, EPA

I have only recently become involved in the pesticide industry, and as a "double agent," I welcome the opportunity to become more familiar with the industry, the companies, and the people.

My branch's activities relating to pesticides, in addition to what I am going to talk about this morning, is in water treatment, treatment technology, treatability of liquid waste and pesticide residuals in several concentrations, and also in engineering analysis of hazardous solid waste. A number of your companies, I am sure, have been contacted by the Office of Public Relations, and some of my branch people as well, regarding this solid waste study.

In early 1978 EPA and NIOSH entered into an interagency agreement. It had as its objectives joining forces and sharing expertise and funding in order to come up with an assessment of capabilities of current control technology practices. Paul [Caplan] has already spoken about the scope and objectives of that task, and I won't discuss it here. Doug Fowler will be following me with a discussion of the status and results of that study, so I won't discuss that aspect of it either. Rather, in the brief time available, I will discuss EPA's objectives and any potential joint activities between us.

Bear in mind that when I say EPA, I am actually referring to the Office of Research and Development, rather than the regulatory side of EPA. I am strictly interested in research and development of control technology.

In many cases, control technology that assumes full protection of occupational health may also achieve environmental health protection. Our objective, then, was to determine the state of the art and the adequacy of existing technology for controlling toxic airborne substances in the managing, formulating, and packaging aspects of the pesticide industry. The information was to be used as input in the development of research and development priorities, so that improved cost-effective controls could be made available, if necessary.

Additionally, and more importantly, this type of information, along with economic data, could provide potential regulatory processes and lead to reasonable standards. Of course, this basic objective could be applied to any industry and the end uses would be essentially the same.

Let me stress that, all things being equal, industry benefits from these interagency activities in that the approaches are coordinated (as it was with EPA and NIOSH), and industry is not subjected to unnecessary duplication. Groups are not constantly coming in to sample and analyze, so this is a benefit. The results are consistently applied, and the end result should be that industry does not wind up subjected to conflicting requirements.

One interagency activity of interest concerns the development of an airborne carcinogenics policy. The Interagency Regulatory Liaison Group (IRLG) is deeply involved in this activity, and includes agencies such as EPA, FDA, OSHA, Consumer Products Safety, and others. They should look at the same data and, I expect, come up with a specific policy and approach to any regulatory course of action.

The carcinogenics policy study was, I believe, proposed in October or November 1979. A special hearing was held in April 1980, and as of today, the comment period is still open. The earliest I expect the policy to be promulgated will be spring 1981.

I anticipate that the airborne toxics policy study will probably follow the same course of action, although the agency is not now actively working on an airborne toxics policy.

For those of you who would like to read more about carcinogenics policy, there is a fine article in the Journal of the Air Pollution Control Association, April 1980, entitled "Control of Airborne Carcinogens." You might be able to extrapolate from it to get a feel for how the EPA and the ILRG may approach an airborne toxics policy.

During the course of the symposium, I hope to learn more about the pesticide industry and about those of you with whom I may have an opportunity to work.

SUMMARY OF FINDINGS AND RECOMMENDATIONS OF
CONTROL TECHNOLOGY ASSESSMENT (CTA) OF THE PESTICIDE INDUSTRY

Douglas P. Fowler
Senior Industrial Hygienist, SRI International

This project was a joint effort between NIOSH and EPA, and was carried out at SRI. The two project officers for NIOSH were Paul Caplan, who was responsible for the final report production and for much of the effort, and James Gideon, who did the initial work. For EPA, David Sanchez had responsibility during the latter portion of the project, and the initial work was started by David Oestreich, both of the Industrial Environmental Laboratory. I was Project Unit Leader for SRI.

I had a lot of help from people who are truly knowledgeable in the pesticides industry. Particular thanks go to Henry Staaterman, consultant at SRI, who guided the investigation from the perspective of his extensive experience in the industry. If I had to work in a pesticide plant, I would like to work in one that had been designed by Henry Staaterman. Benjamin Gikis, of SRI's Chemical Engineering Laboratory, provided chemical engineering expertise and is responsible for the air pollution control technology portion. Dale Coulson, who was the first man to demonstrate the feasibility of analysis of pesticides, was responsible for the analytical support. And, finally, it was important for us to understand the structure of the industry. Oscar Johnson, who retired as Vice President for Research from FMC Corporation and had been bench chemist and a sales representative in the pesticide industry for twenty-five years, was responsible for the economics and the industry structure information.

We set out to document and evaluate control technology to determine the research and development needs within the industry to control worker exposure to, and air emissions of, chemical agents in pesticide manufacturing and formulating facilities. We also wanted to produce a set of guidelines. (The study was not intended to produce a "design manual," but to indicate what general approaches were found to be useful and practical in well-operated pesticide plants with successful worker and environmental protection programs.) Finally, we wanted to put enough information in the document so that the regulatory agency people--state, federal, and local--would have some understanding of the problems faced by the industry and of the particular and unique set of requirements for control technology in this industry. As with any effort that's a compromise, we were not completely successful in all of our goals. We did not present a document that was going to be a substitute for a course in industrial hygiene or environmental engineering or pesticide production or chemical engineering. I hope that we were able to present the salient points that are of greatest importance, and to provide enough information to permit a knowledgeable person with a reasonable technical education to go on from there.

The project was accomplished in three major steps. First was the selection of pesticides and the manufacturing and formulating plants to be studied. Second was evaluation of the performance and effectiveness of selected engineering control systems in relation to the specific chemicals and processes employed. And third was preparation of the final project report.

To identify effective control technology, it was necessary to select specific pesticides to study and the plants in which they are produced and formulated. The forty-three pesticides selected were all chemical (rather than biological) agents, and represent the variety of active ingredients and formulations to which workers may be exposed. They include the majority of commercial pesticides for which there are indications of potential chronic health effects and environmental insult. The groups studied were organochlorines, organophosphates, organoarsenicals, carbamates, anilides, triazines, and other nitrogen-based combinations.

After identifying these chemicals for study, the plants where these pesticides are formulated and produced were evaluated. Plants operated by companies known to be technically innovative and advanced were identified. Plants where large numbers of the selected pesticides are formulated or produced were also identified.

The general topics covered during the surveys were the following: process description, building/facility design, maintenance programs, engineering controls, and industrial hygiene programs.

Engineering controls involve monitoring of air, water, and soil, and medical and biological monitoring of workers. The environment should be safe without having to resort to personal protective equipment. Administrative controls cover training and work practices and education; they relate more broadly to the industry. We did not find any operations where engineering controls alone or work practices alone were completely successful in reducing exposure to a minimally acceptable level without the application of personal protective equipment.

The pesticide industry is part of the larger organic chemical industry; the specialty chemical manufacturing industry. The industry structure is comparable to a pyramid: There are hundreds of manufacturers, thousands of formulators, and millions of users. Pesticide production, as measured by consumption, is growing at a steady rate of one-quarter percent per year. Insecticides have the slowest growth rate (less than one percent), while the fungicides and nematocides have the highest growth rate (seven to ten percent). The herbicide group accounts for forty-two percent of total pesticide consumption, making it the largest group of pesticides.

Pesticide manufacture is carried out in relatively few plants, mainly in California, New Jersey, Pennsylvania, and Texas. Some seventy-four companies are actively involved in pesticide manufacture, at 139 plants. In general, a few pesticides are produced in each plant and a few plants produce each pesticide. Fifteen raw materials account for over sixty percent of the materials consumed. In general, pesticide manufacture is done in batch processes conducted at or near atmospheric pressure and at low temperature (less than 150° Celsius). The end products are unique (patentable) molecules.

Formulation labor is low paid and often transient. Costs of transporting bulk material any great distance, and competition in the industry, has led to regionalization.

As of 1975 there were approximately 3,400 firms with federal registrations for the manufacture, formulation, and/or distribution of pesticides. The majority of these were formulators. Many of the small firms have only one product registration and produce only a few hundred pounds of formulated pesticides each year. At the other end, at least one plant that operated in the range of 100 million pounds of formulated product per year has been identified. The bulk of pesticide formulations, however, is apparently produced by independent formulators operating in the range of 20 million to 40 million pounds per year.

Despite the competition that keeps profit margins at a low level, there is currently a trend toward centralization, with large national or regional corporations buying and operating the smaller firms.

A plant may be used for a single product, or it may make several formulations of one or more pesticides and supply them in different sizes. A formulation operation may involve a change in active ingredient, a change of physical state, or the addition of other ingredients. Also, formulations may incorporate additives.

You see a heavy preponderance of formulation plants in California and Texas--in the agricultural states. The plants are close to the point of use, again due to transportation costs.

The bulk of pesticide packaging is done by manufacturers and, more often, by formulators. The services of custom packers are also used. Material may be packed for either intra- or inter-plant transfer, or for application in agriculture, industry, home, or garden.

Health and safety exposure potential is great due to the limitations of the equipment available to packers, and also due to the physical, chemical, and toxicological properties of the compounds to be packaged.

Our selection of pesticides to study was based on production volume, process chemistry, physical state, human toxicity, and potential hazard. Note that I have differentiated between toxicity and hazard. They are neither synonymous nor necessarily correlated. Many hazardous materials are relatively nontoxic but can still blow up, start fires, or do other bad things inside a plant, including make people sick. Toxicity is the degree of "poisonness," or the way a material may cause disease in humans. "Risk" can be defined as the probability of harm in the setting in which a material is found. We selected pesticides that had a range of toxicities.

Process chemistry was the principal dividing point for our selection. The pesticide groups that we studied, and that were mentioned earlier, did represent a broad range of acute and chronic toxicities, physical types, production processes, and formulation processes.

The first criterion for plant selection was that the plant produced or formulated the pesticide or pesticides we were interested in. We sought out plants that had good reputations within the industry and that were representative of the characteristics we were seeking. It was also desirable that the plant produce or formulate a large number of pesticides so that we would be able to obtain information as broad-ranging as possible. Finally, the plant had to be willing to cooperate, for the surveys were all done voluntarily.

Our survey sought to gain information on plants, including a description of processes, building and facilities design, maintenance programs, engineering controls, and industrial hygiene and environmental control programs. We could not get this information in the kind of detail we wanted for all the plants we surveyed. In some cases plants did not wish us to evaluate their processes completely, as they were concerned with disclosing proprietary information to us. (Proprietary technology is very important in the pesticide industry.) Second, some plants had had unsatisfactory experiences with government agencies, which led them not to want to cooperate. Third, there were some irrational fears on the part of high-level program management as to the overall aims and goals of the project, many of which have been allayed by this time.

We found that the people who had successful health and safety programs knew what they were doing. They knew the materials they were using, they understood the pathways of exposure, they understood the processes and the limitations of available control methods.

To institute their programs they applied "the gospel according to industrial hygiene and environmental science." The programs weren't out of the ordinary, but they were well integrated. In-plant and air emission controls were integrated. Material was not pulled out of the plant and dumped outdoors without concern for the environmental impact. Materials were not enclosed to reduce air emissions without regard for worker exposure. Less hazardous material was substituted for more hazardous materials wherever possible. Processes were modified to reduce exposure to emissions wherever possible. Emissions were not recirculated. Material was enclosed, and processes were isolated, if that was the appropriate course.

In the occupational environment, ventilation was appropriately applied, and local exhaust ventilation was used in preference to general area ventilation. Administrative controls were well integrated in the control programs as adjuncts to engineering methods. This included prohibition of unauthorized entry in designated areas, requirements for hygiene practices, requirements for personal protective equipment, and requirements for disposal of hazardous wastes in secure areas.

In the area of emissions control, hazardous toxic materials were destroyed where possible, or, if that was not possible, reduced in concentration to the point where the emissions were no longer a problem. If they could not be reduced at the source, stacks were used to dilute the material and reduce its impact on the surrounding environment.

Plant design and retrofitting is one important way to incorporate controls. It is difficult, if you have an existing formulating plant, to do much about plant design. But, where possible, the principles of good design should be applied.

Compartmentalization is one safety and health design measure. Keep dissimilar materials, and materials that cause problems if they interact, separate. Do not compartmentalize, though, to the point that you are setting up a bomb--for instance, a machine room where solvent emissions can rise to explosive levels. Use control rooms to keep people away from processes and away from chemicals, but make sure they can get out of that control room and that they are adequately protected while they are in it.

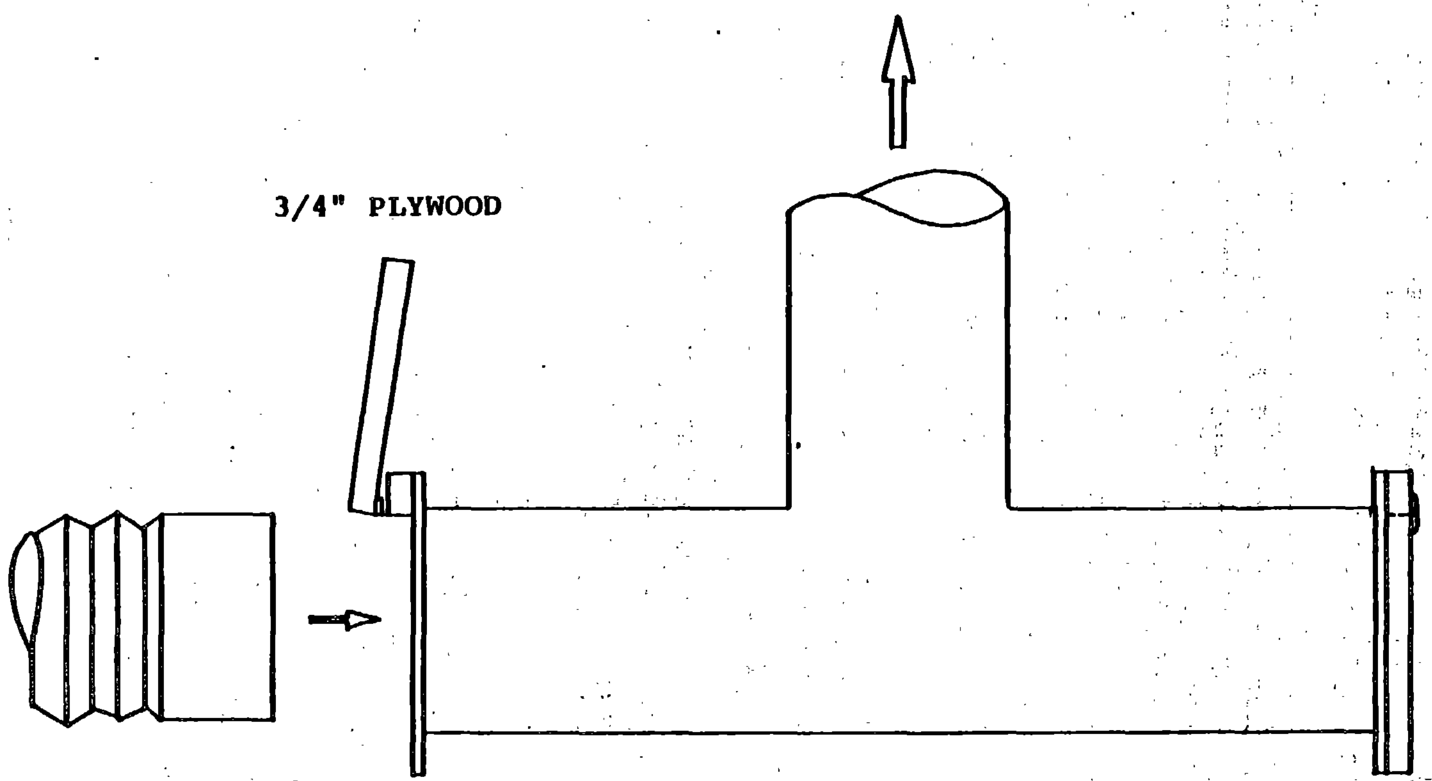
In effective plants, the crucial systems--the life support systems of the plant--were backed up. Maintenance was easy and safe. There were no pits where vapors or liquids could pool.

For good emissions control, stack height should be at least 1.3 times the building height. Intakes should be placed upwind where possible, if there is a prevailing wind. Intakes should not be placed on the side of the building where materials can sweep back around.

Figure 1 shows an example of how to make maintenance a little easier. With any T header that comes off the exhaust system, put a little plywood door on each end of the T, take a piece of hose, stuff it in, and use the hose for cleaning out the T. You

FIGURE 1

LOCAL EXHAUST HEADER



can use it for local exhaust ventilation if you have a spill; you can use it for a manway exhaust system over a reactor or a blender. You can have a number of these and not need to size your blower for all of the systems; rather you can use this intermittently throughout the plant as you see the need.

Process control is the most important thing--to understand the process and the materials that you are dealing with and the variability of the process. While automation is one good way to avoid exposures, you should have provisions for manual override of the automated system so that operators will have control of the plant if something goes wrong, not vice cersa. The rule is, things should fail safe.

Quality-control sampling in process control can be a source of dermal and inhalation exposure. One way to minimize the risk is by careful batch ingredient control; another way is to enclose points of sampling and make them remote. Figure 2 shows a side view of a quality-control sampling box. With this method, you can poke the needle (which extends to the pipeline, not shown) through the septum and into the process stream, take it out, close the ball valve, and remove the sample container to the point of analysis. This greatly reduces opportunities for exposure.

Unloading incoming containers of pesticides and formulation ingredients can be another source of toxic exposure or toxic emissions. If the pesticide is made and formulated in the same plant, it may be possible to simplify. However, this is not usually the case. Again, successful operators set standards and enforce them. If possible, standards are set for containers. Operators insist on clear, positive identification of materials. They insist on material safety data sheets from chemical suppliers, and details of other process-related instructions were available to the operators who were responsible for the plant operations.

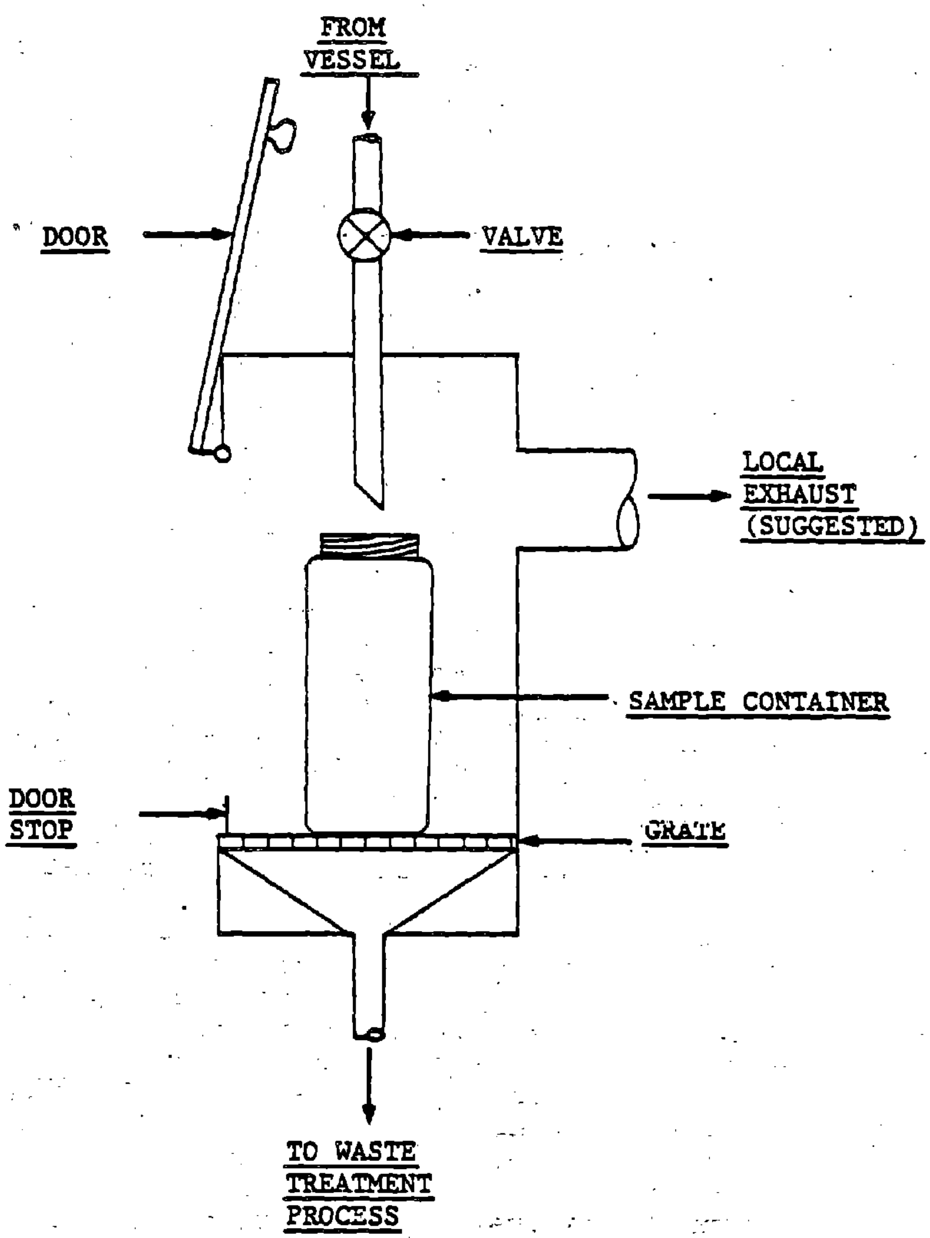
With liquids coming in in tank cars or trucks, it is good practice to connect the vent space on the car or truck with the receiving vessel or storage tank, thus eliminating much vapor loss to the atmosphere. And if recovery is not possible, vapors should be vented to appropriate treatments. In general, drums are lightly built, and emptying by pressuring, whether by gravity or pumps, is risky. In addition, pressurized lines such as those downstream of a pump can rupture or leak with consequent exposure.

With solids, formulators must be on guard to prevent dust explosions. Bin vent filters are a simple way of reducing exposure that may occur as a bin is filled. Containers should be opened in a controlled environment.

Liquids requiring bulk storage include raw materials, in-process materials, and finished products. Flammable or toxic material storage should include these features to minimize emissions and exposure: a containment dike, double walls, a vent to a pollution control device (scrubber, carbon bed, incinerator, and so on), a remote or noncontact level indicator (but beware of gauge

FIGURE 2

SIDE VIEW OF QUALITY CONTROL SAMPLING BOX



glasses), a high-level and a low-level alarm, and vapor balancing for filling and transfer operations. Separate the flammable materials from the toxic materials. In this way you minimize the danger of toxic exposure for people in the plant and in the surrounding areas. Nitrogen blankets and caps appear to be frequently used in the industry.

We were talking about the problems of getting material into the plant. Now we will discuss solid storage systems. Pesticidal powders are "difficult" for a number of reasons: They compact easily; they can be toxic; they may be corrosive; they may be explosive when dispersed in air, they are easily degraded so that the active ingredient is removed.

The usual problems related to flow exist too--that is, you can't move material from one place to another, or it moves too easily from one place to another. You have bridging and ratholing.

One of the successful applications that we saw in the industry was the use of the Tote® Bin and the Invert A Bin®. You put the material in the bin and move it in a contained package from one place to another without having to worry about open conveyors and so forth. Material can be shipped long distances if necessary, since the bins are impervious to normal handling damage and do not leak if they are well maintained. Manual handling is kept to a minimum. The pesticide is well protected from moisture degradation.

In liquid transfer the considerations are vapor balancing, use of adequate and appropriate piping and piping connectors, and valves. In one plant they could not buy commercial valves suitable for containment of the very toxic material that they were moving within the plant, so they had the machinist reface the very best valves they could buy commercially in order to get adequate sealing.

Two different views toward flexible connectors were evident during the surveys. One very successful company held that they were inherently hazardous and removed them wherever possible, while another company, also with an excellent safety record, held that flexible connectors were the preferred way to deal with the problems of multiple pipelines for conducting different reactions in the same process vessels. It is a matter of engineering judgment.

There are many systems for getting liquids from one place to the other. The preferred method will probably depend on the physical, chemical, and toxicologic properties of the liquid, and on the compatibility of the liquid with potential materials of construction. Gravity flow, pneumatic and hydraulic systems, vacuums, blowcases, and pumps are all possible transfer methods. In our experience with people in the industry, gravity flow appears to be the preferred choice whenever possible. There are potential problems, however. You end up with a lot of potentially toxic material elevated within the plant. In the event of a leak, the material can spill onto workers. It is a rare type of failure; however, it is a valid concern.

Hydraulic or pneumatic transfer has advantages and disadvantages. To transfer liquid from vessel A to vessel B, vessel A is raised to a greater pressure than vessel B. The block valves are opened and the liquid is allowed to flow from A to B.

The disadvantages involve controlling and disposing of the displaced vapor from vessel B and the gas used to increase pressure in vessel A once the transfer has taken place. Recycling is rarely used, especially in relatively small plants, because it is usually more economical to treat and dispose of the vented gas.

Vacuum transfer of liquids can be useful. Liquid flows from the higher (atmospheric) pressure tank to the lower (subatmospheric) pressure receiver. An advantage of this method is that hazardous liquids are not placed under pressure, and any leaks will be into the transfer line or vessel. The disadvantages include overfill of the receiver, which in turn can contaminate the vacuum system unless there is a trap in the line, and contamination of the vacuum source by hazardous vapors, unless it is protected by an intermediate condenser or absorber.

Blowcase systems appear to be used with some success. The blowcase is generally a smaller tank than the feed reservoir. While this figure shows a gauge glass to indicate liquid level, I do not recommend gauge glasses. Blowcase systems are useful for highly corrosive or toxic materials. Ideally, a blowcase system can operate on gravity flow. However, this require elevation of the feed above the blowcase and the receiver. Disadvantages are that the system is under pressure during the cycle, and, if a vacuum source is required, there is a possibility that the vacuum equipment and the system can be contaminated.

There are many problems with the pump. The greatest source of leaks and exposure in a low-pressure (atmospheric) liquid pumping operation comes from the pump shaft seal. (Seal manufacturers generally provide good technical backup and assistance.) Pumps used for transfer of heat-sensitive materials should be equipped with a sensing device connected to an alarm or to a control that will stop the pump if flow is stopped due to plugging or a closed valve. There are numerous considerations to take into account before using a pump system.

There are various solids movement systems, including conveyors, pneumatic systems, bucket elevators, and containerized transfer methods.

Screw conveyors were generally preferred by the people we surveyed. Drag flight conveyors are generally unacceptable if the material has any toxicity at all, because the conveyors may require frequent maintenance and repair, which increases the potential for worker exposure. Also, the channel in which the chain runs can be difficult to clean out. The vibration of vibratory conveyors may lead to excessive dust generation.

There are two schools of thought on pneumatic systems. Positive pressure can be more economical because of smaller quantities of air or gas used and because of reduced ducting requirements. Negative pressure is preferred for toxic materials because leaks will not cause emissions from the system. The disadvantage is that you need a bag house or a receiver to collect the material. If that blows out, obviously, you have problems.

Bucket elevators are most useful in dedicated service with slight negative pressure. Otherwise, the many moving parts to be maintained increase the risk of hazardous exposures and can be substantial sources of cross-contamination.

Containerized transfer may be best used where product volume is small, where batch identity must be retained, or where the characteristics of the material or the complexity or cost of containerized systems dictate its use.

Size reduction operations, all the various sorts of milling, can be substantial sources of problems within the pesticide plant. Care must be taken against foreign objects in the feed, such as pieces of metal, rocks, tools, or bottles, as they can cause sparks and even fire in hammer millings.

Fluid energy grinding (Jet-o-Mizer®) is used after processing in hammer mills to produce a finer product (the average particle size is a few micrometers). Air, gas, or superheated steam may be used as "fluid."

Other types of milling operations include paste or suspension grinding. The grinding devices used are ball or tube mills, stone mills, and sand mills. The threat of hazardous emission from operating these devices is minor. The water used to clean them can be stored for later formulating use.

The many size separation operations in the industry include screening and sifting, filtration, sedimentation, and centrifugation.

Screening and sifting can be potentially problematic. Those of you who have seen vibratory screens recognize that if the boot separates you can have a lot of dust in the environment very rapidly.

With filtration, maintenance and cleanup of the rotary drum filter are major potential exposure situations. The vacuum system is another; it must be designed to insure proper disposal of vapors from the filtration process and safe cleanout and maintenance.

Centrifugation is a very useful technique. However, we did see a couple of operations where there were noise problems in the centrifuge area, particularly where hydraulic drive centrifuges were used. In specification of centrifuges, be careful that the potential for noise exposure is noted and that the supplier can assure you that you will meet OSHA noise standards.

The purpose of all this is, of course, blending. Batch blending, which can be regulated from a control room, allows for great accuracy in the addition of ingredients. Solids mixing and blending includes these commonly used commercial types: ribbon blenders, Munson mills, Nauta® mixers, pug mills, twin-shell blenders, and double-cone blenders. Covers, seals, and connections on all vessels must be dust tight. Except for the Munson mill, the blenders and mixers listed can be equipped with heating/cooling jackets to prevent the possibility of overheating, reduce the probability of product decomposition or explosions, and reduce worker exposure or injury.

Blenders and mixers for liquids are usually made of stainless steel, or are glass-lined to prevent corrosion. Most liquid blending operations are batch processes, and they may present a mild or extreme degree of hazard of various types--toxicity, fire, and so on.

Packaging, the last major operation at a manufacturing or a formulating plant, is the area where exposure may be highest. There are multiple sizes of packages, and multiple products to be put into those packages. And these are manual operations where there is great opportunity for exposure. We found very little interest on the part of the equipment manufacturers in the problems of the small formulator or the toxic materials packaging industry in general.

There are dust emissions with solids packaging, of course. Valve-top bags are finally being phased out; wherever possible these should be gotten rid of. Open-top bags are easier to use and seal better. Form, fill, and seal (FFS) machines may be appropriate, but they are difficult to use and difficult to install. You also need more highly skilled operators to have success with this sort of packaging. This area should not be entered into lightly.

Drums can be filled relatively safely and easily. The operation is usually semiautomated. We saw a successful application of a Carter-Day vacuum packer for filling drums.

Canisters can be filled successfully, but not without trouble.

In general, material can be moved into packages by screw auger, pneumatic, gravity, or vacuum methods. (Pneumatic systems should not be used in pesticides manufacture and formulation, in my view.)

In general, control of density is the most important aspect of packaging; control should be applied close to the point at which material goes into the package.

A not very fancy system was made acceptable for packaging a highly toxic material by appropriate use of personal protective equipment. DuPont Tyvek® suits are used and changed at every break.

They use, I believe, a Whitecap® supplied air system. Although the material was very toxic, they have had no overexposures in the past year. This is a good example of careful control of work practices and use of personal protective equipment.

There are many ways in which liquids packaging can be done successfully. Rotary machines, manual filling methods, and straightline multiple filling spout machines are all used, as are pressure filling, gravity filling, and, to some extent, vacuum filling.

We did not see a successful and adequate manual liquid filling operation in our survey, though I am sure one could be devised.

Older filling machines that use a vacuum have problems because of the advent of plastic jugs rather than glass. You can't apply a vacuum to a plastic jug or it will collapse, so instead of using a vacuum to get the last little bit of material off the probe, it will just have to drip. That means contamination.

Having packaged the material, you store it for as short a time as possible and then ship it out. Pallet overwrapping with plastic material (stretch wrapping or shrink wrapping) protects containers from damage and spills, and protects the shippers and handlers as well. In general, polyvinylidene chloride, used in stretch wrapping, is more heat resistant than polyethylene, which is used for shrink wrap.

Warehouses should be clean and they should be easy to keep clean. We saw some warehouses where all of the cracks had been epoxy filled so that there were no opportunities for material to get trapped. Forklift operators have to be trained and supervised to eliminate "cowboy" behavior.

The successful operations have developed close working relationships with their local fire departments so that each knew what the other was doing.

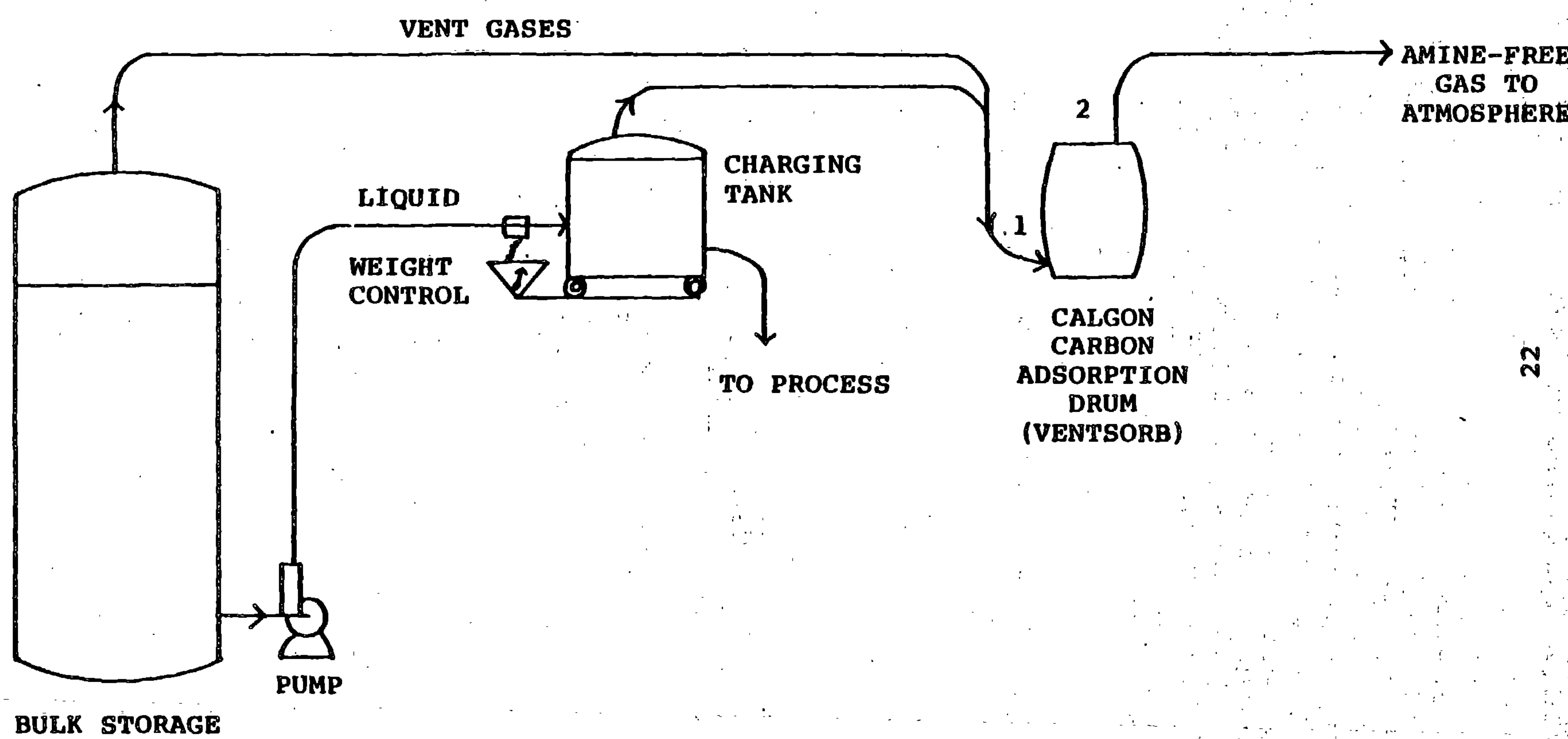
In air emissions control, processes should be closed, and, as mentioned before, integrated with your industrial hygiene program. Liquid and solid wastes should be properly disposed of and their volume should be minimized by process design. Call for help if you have trouble; don't rely on one single source of advice.

In general, emissions from manufacturing and formulation appear to be under control. They are reponsive to conventional control measures if they are properly applied. Figure 3 shows a good example of applying a control close to the source of emission. It is a simple displacement system. An amine was transferred into a charging tank, the vapors were passed through a simple carbon adsorption drum, and then the amine-free gases were released.

Substitution and process change are the first choices for gas and vapor emissions control. Methods of control also included scrubbers, which were most preferred, and carbon adsorption, which was

FIGURE 3

CONTAINMENT OF AMINE VAPORS FROM BULK STORAGE AND CHARGING TANKS



the second preference. Thermal combustion methods were not used as much as I had initially expected. Flares were used; we saw some catalytic oxidation units.

In the control of solid emissions, again, substitution, process change, scrubbers, and bag house filters were preferred. Successful operators had made sure to minimize exposure by making the bag change easy.

Settling chambers are not used much, but cyclones (inertial devices) were widely used for product recovery. We saw a successful use of a demister for particulate removal. Waste disposal activities were very carefully monitored so that emissions did not occur from the dumps.

To reiterate, in a successful operation you have to have an overall program in which the nature of the hazard and the best methods of controlling it are understood. Education and training of management and workers should be employed. Work practices should be carefully monitored. Personal hygiene regulations must be enforced. Personal protective equipment must be effective against the specific material involved. Maintenance and housekeeping are most important, and finally, monitoring--medical, exposure, and emissions--should be done.

Our report identified several areas where more research is needed: in exposure and assessment research, personal protective equipment research, engineering controls research, and research into the pesticide industry in general.

Under the heading of exposure and assessment research, studies must be done on air sampling methods. It is not generally possible to go to your friendly AIHA-accredited laboratory and have competent analyses done on pesticide samples, either for industrial hygiene assessment or stack sampling assessment. For some of the more common pesticides, methods are available that have not yet been properly validated. Pesticides are difficult molecules to analyze, and this had impeded the assessment of exposure within the industry.

Standards for surface contamination need to be set and should be discussed more openly. Several companies that we surveyed have internal standards for surface contamination that should be more broadly used and discussed throughout the industry.

Vaporization of pesticides from filters is a problem for bag houses and for air sampling methods. Apparently, even pesticides of relatively low vapor pressure vaporize when they are held on a filter surface for a long period of time. There may be some interaction with the filter material itself and also local high air velocities are probably at fault.

With regard to personal protective equipment, permeation and penetration testing for common formulations is needed for clothing and respirators. It has also been brought to our attention that there is a need for "certified" breathing air purification systems. That is, where one has a compressor with a filter adsorption medium and so forth in the plant that supplies air for breathing, we do not know how effective that system will be if the compressor is subject to a large release of a particular chemical. That needs to be defined.

There are some research needs in engineering controls as well. We got some good ideas during the course of the survey. Some of the other control technology assessment surveys have come up with some good ideas, but we need an organized and regional assessment of how to go about retrofitting an old plant to make it better. We need to know what the general principles of retrofitting are, particularly in the organic chemicals industry, the specialty chemicals industry, and the pesticide industry. You see Munson mills and ribbon blenders all over the place. It should be possible to retrofit one of those to make it safe, so that you can mix almost any kind of chemical in it.

We do not know exactly how to do that. We do not know what the emission rates are from sealing points. That information is needed and should be available for all defined conditions of the vessel or the pipe that is to be sealed.

There are also some general needs for research within the pesticide industry. We need substitutes for the old Manufacturing Chemicals Association (MCA) chemical safety data sheets. Currently there are no adequate substitutes. MCA has withdrawn the old ones and takes no further responsibility for them.

There are problems of information transfer which take the form of concerns about proprietary information and possible antitrust liability if the industry should band together to provide this information. These concerns clearly affected this survey in that they affected what information we were actually able to get in our attempt to make it available to the rest of the industry.

Finally, research is needed into the economic viability of small operations. The "fancy gadgets" that I spoke of today work reasonably well for operators with large staffs and with competent onsite chemical engineers. I do not know whether the small formulator, the seasonal formulator, will be able to do an adequate job unless he can control occupational exposures to an extent that is not now common within the industry. It is possible that the small formulator will be a thing of the past, and the question to be considered is: Is this what we really want? Control of exposure and emissions can, in fact, be done without expensive engineering systems if we are willing to pay careful attention to the details of plant operation that I discussed today.

PLANT DESIGN AND LAYOUT--NEW PLANNING AND RETROFITTING

Kenneth Bunkowski
Field Engineer, American Cyanamid Company

My discussion will cover the basic design for plant layout and equipment, and also design as it applies to plant retrofitting.

The first consideration of design is site selection and the layout and development of the site.

A basic is that the site should provide good in-and-out transportation by rail and truck. The land size of the site should be large enough not only to supply current needs, but also to accommodate any future expansion, and should be large enough to provide a suitable buffer zone from plant buildings to the nearest property line.

Strong consideration must be given to the lay of the land adjacent to the plant site, including drainage conditions. Would drainage from the site enter ditches that lead to lakes, ponds, or streams? This is to be avoided. The ideal formulation plant site would be in a rural area, or in a rural industrial park away from a residential area, with drainage contained in the area.

Another thing to consider in your site is weather. Air inversions and upsets in plant operation can generate nontoxic offensive nuisance odors from the facility. Therefore, consider the prevailing wind direction; try to build the plant in a location downwind from any inhabited areas.

Considerations for sewer conditions are particularly important. You should prepare a detailed study to determine the condition of all effluent you intend to discharge from the plant to the sewer, whether treated or untreated. This information will also be necessary for discussions with municipal sewage treatment plant people as well as other regulatory agencies. It's particularly important in the design of your plant to select proper treatment equipment and plan the kinds of operations that will be involved. Operations should be prepared by listing all possible chemicals that you will be emitting from the stacks (vapors, mists, any kind of particulate). Consider what the physical characteristics are, what the chemistry of it is, and the volumes. Volumes are very important. One of the first questions you'll be asked as you go about obtaining permits is how much you are going to discharge. In some instances these details, along with compliance with local conditions, may make the site uneconomical due to the excessive equipment required to comply with those conditions.

Determine the past use of any site you are considering. If it was a chemical operation, a pesticides plant, or whatever it was, do soil testing to determine if any persistent chemicals are present. Avoid inheriting decontamination problems. Retain those soil samples and analyses for your records. (This is particularly important when you're purchasing an existing pesticide formulation plant.)

In making your plant site layout and grading, drainage should be diverted to a central point through a collection pond--a lagoon--in such a way that all runoff for the site collects and is contained. The overflow from this point should be controlled. This collection pond should be lined with clay or polypropylene liner to avoid ground seepage that could enter and contaminate the surrounding water table. Particularly after each rainfall, water from this lagoon should be sampled and analyzed for levels of contaminant, then treated as necessary before releasing. Analysis is particularly important during the spring thaw, as winter accumulation may also raise the level of the contaminants.

Consider paving all areas where any activity is carried on that includes handling of chemical compounds. The paved areas should be curbed and should drain into control sumps. Examples of these areas would include locations where dumpsters are located for waste collection; drum and container decontamination, drum crushing, or bag baling occurs; and where empty drums are stored. Other areas of particular importance are bulk raw material receiving and shipping loading docks. Careful control should be given to the front of any shipping or receiving loading dock. Paving is needed at maintenance shops and in areas where equipment is dismantled, cleaned and reworked, steam cleaned, or sandblasted.

In planning your plant building and layout, conventional metal prefab or concrete block structures are suitable, in most cases, for manufacturing and warehouse areas.

In production areas where there may be corrosive materials, apply epoxy coatings to all metal surfaces. Wall and ceiling design should allow for flushing with water if necessary.

Substructures should be considered over raw material receiving areas. Roof in rail and truck receiving points to allow off-loading when it is raining or to prevent wind from blowing air-borne dust. Cover docks in shipping areas.

One factor that is always important--and that always seems to be short--is headroom. Provide adequate headroom in all areas. Use tower sections that will allow installation of tanks and equipment at second and third levels to allow gravity flow of materials through systems. For example, with a granular formulation system, elevate your granular carrier with a bucket elevator up to the weigh hopper; gravity into your mixer; gravity out of the mixer to the screener; gravity into the bagging hopper and through the bagging scale.

This kind of installation can reduce your capital and maintenance costs as well as decontamination costs, and reduce the risk of exposure for personnel.

Not purchasing an elevator that costs $15,000 (plus installation) will enable you to purchase a lot of structural steel so that you can provide second and third levels, a one-time cost plus minor future maintenance.

Particular attention should be paid to the design of the floors in the plant production and warehouse areas. Floors should be constructed of reinforced concrete with the surface sealed prior to use with urethane or other sealant that will be able to withstand the chemicals and solvents used in your plant. The entire plant floor perimeter should be designed with a raised curb that will contain any liquid within the plant. The floors should be pitched, allowing drainage into grate-covered gutters that, in turn, drain into controlled exit sumps so that you have control of all drainage or leakage within the plant.

There should be consigned gutters and sumps in each specific plant production area and warehouse to isolate and recover specific products. In this way, spills can be recovered and recycled, or treated for disposal.

Specific production areas should also be isolated by dust-tight partition walls and by curbs, to prevent cross-contamination of products. Herbicide and insecticide areas should be totally isolated with no connecting doors or any type of cross-ventilation. They should preferably be in separate buildings, or at least separated by a closed warehouse area.

One of your major installation expenses will be your tank farms. Tank farms for storage of technical materials and solvents must be protected by earth levies or concrete construction walls. The preferred construction is poured concrete floor and sidewalls. Sidewalls must be high enough to provide retention of the volume of liquid from the single largest tank contained within that curbed enclosure. A controlled sump should be provided in the enclosure to collect any liquid from within the area to allow analysis and treatment before disposal or pumpout. In the event people need to enter a sump, suitable safeguards must be in place.

The tank farm should be located as near as possible to the formulation area to minimize size and length of pumps and piping. All piping should be flanged and welded connections, and careful attention should be paid to the gasketing in these flanges. Generally, Teflon® is the heat preference, but the main thing is to use a material that will withstand the chemicals you're transferring.

It is good practice to install high-level limit/detector switches that are interlocked with the filler pump to prevent overfilling of tanks. Consider housing and heating sections of the tank farm for protection from freezing or to prevent high viscosities that forestall pump transfer in cold weather. Generally, maintaining a temperature of 40-50° Fahrenehit is adequate. An alternative would be electric or steam heat tracing of tanks and in turn insulating them. This alternative is expensive and can generate hazards if a product is heat sensitive. If this is the case, agitation and temperature controllers would be required.

If tank agitation is required, jet agitators should be considered. These units utilize the existing pump for motivation; they are as effective as propeller units; they are more economical; and they maintain a closed system. Conservation vent valves should be considered on all tank vents. If the tanks are housed the vents must be extended to outside the housing, be clear of building overhang, and be at least twelve feet above grade.

Where necessary, tank vents should be vented through dessicant air driers in order to prevent moisture accumulation in the tank, or through activated carbon beds in order to prevent odor emission into the atmosphere.

You always consider using closed loop venting when you have off-loading from receiving tankers into storage tanks. Vent the tank back into the receiving tanker to prevent emitting vapor into the atmosphere. When outloading from storage tanks into shipping containers, the same consideration should be given. Positive grounding and bonding should be provided on all tanks, piping, and pumps. All electric units and wiring should be of explosion-proof design.

Internal self-closing thermal-activated valves that will close in the event of over temperature, caused by fire or other high atmospheric temperatures, should be considered on all tank bottom outlets. Local ordinances may require these units in some areas.

Antisiphon units should be considered and installed on all piping from the storage tanks into the process to prevent siphoning into the process.

Discharge piping into your storage tanks should be positioned so that the liquid is discharged against the tank wall, or should be extended to the bottom of the tank. Piping should terminate not more than six inches from the tank wall or bottom in order to prevent a buildup of static electricity. This practice should be followed on all tanks, process, and storage.

An emergency plan should be developed to handle major tank ruptures, fires, and ensuing water accumulation. Determine source and availability of portable pumps and tankers to accommodate the emergency pumpoff.

Consideration should be given to man-tight fence the entire plant site for security purposes. Pay particular attention to securing the tank farm.

The lunchroom/shower/locker room facility is best constructed as an annex, or at least separate from the main warehouse and manufacturing building. This building should house the lunchroom, lavatories, change rooms for entry and exit, lockers, showers, laundry, and safety equipment decontamination area, as well as storage for spare clothing and for miscellaneous safety equipment.

The layout for this facility should include a walk-through path. Utilize a split entry so that personnel can enter into an area reserved for the removal of plant clothing and footwear. From that point personnel should be able to proceed to the lavatory, lunchroom, or the shower, which should be a one-way shower. In other words, the exit from the shower should lead into the clean room with lockers that contain workers' street clothing and clean laundered clothing. Provide a bypass from this clean area to allow personnel to change from their street clothing to their work clothing and to pick up the required safety equipment before proceeding into the plant.

The entry area should contain a foot bath to decontaminate footwear, as well as a blotting mat, if the chemical you use is slippery when it gets on the concrete floor. Footwear decontamination and blotting should always be done before removing footwear, or before personnel proceed on into the lavatory or the lunchroom.

Consider plastic-surfaced tables and chairs, impervious and easily cleaned, for all furnishings. Monitor laundry and hygiene equipment wash unit discharges to the sewer for contamination, since contamination is generally found in this waste at levels that require treating. A chemical injector unit can be used to treat the discharge flow in conjunction with an activated carbon bed. Seal or cover the floors in all areas with an impervious material to facilitate cleaning and not trap contaminants.

When dealing with your formulation equipment and ventilating systems, design for environmental control is always of prime importance. A ventilating system is one of the most important systems in a plant. Detailed layout and engineering studies should be done in order to assure that the system is adequate and covers all areas and all units within the plant. Experience has shown that a large percentage of operating plants have inadequate ventilating systems, with the greatest weakness being inadequate capacity of air-handling blowers and undersized air ducts, as well as deficient collection hoods. As part of the detailed planning and engineering for new or already completed systems, multiply all completed calculations for air volumes required and for main trunk lines by a factor of 1.5. This will allow for inherent errors in calculating friction losses, pressure drops, and other accumulated losses in the system, as well as providing for future minor additions.

Ventilating equipment for a typical formulating plant (granular, wettable powder, liquids) would include: a blower for air handling; air duct collection hoods; bag house dust collector; activated carbon odor control unit with pre-filter; discharge stack; and a central and portable vacuum cleaning system.

Straight or radial-blade fans are generally considered the better unit for blower systems because they provide good static pressure and are less likely to plug or go off balance.

Air ducts and hoods can be of standard metal, fiberglass, or plastic, depending on the temperatures involved. Install control dampers at all duct and hood inlets to control air entry or to close it off. All duct joints should be well sealed to prevent bypass air entry. Generally, transport air velocity within the ducts should be maintained at 2,500 to 3,500 fpm; with heavy dust, it should be maintained at the higher velocity.

Maintain face velocity at work/control hoods at a range of 150 to 200 fpm. Use local judgment to design the hoods and control your air velocity so that you maintain capture velocity yet do not educt product into your transport lines.

Bag house dust collectors manufactured by any number of firms are adequate. Generally an air-to-cloth ratio of four or five to one cfm per square foot is adequate. With heavy dust loading you would need the one or two to one ratio. These units must always be installed so they are maintained under a negative pressure; that is, the fan must be installed on the exhaust side of the collector to prevent the unit from being under pressure and airborne dust from escaping. Standard bags of Orlon®, Dacron®, or needled felt are adequate. Again, temperature should always be considered. When installing these units, consideration should be given to epoxy coating and sealing off all crevices on the interior surfaces of these bag house dust collectors. This measure will greatly reduce your cleaning time and the risk of cross-contamination when changing from one product to another.

Select units with large access doors for bag removal and cleaning, and with minimum obstructions inside in order to reduce personnel exposure during cleaning and maintenance.

If your system is used alternately for different products and requires decontamination from one product to another, a set of bags should be dedicated to each product. Remove the bags and store them in a sealed container until that product is produced again. The cost of these dedicated bags will be offset by the reduced labor for cleaning, or the disposal of toxic waste generated by washing, and will also greatly reduce personnel exposure. Vacuum clean the interior of the unit, and recycle your collection. If a final liquid wash is required, initial vacuuming will have greatly reduced your toxic generation.

Discharge of collection from the bag house should be via rotary air locks, and discharge should be into sealed conveyors or containers that are under negative pressure to prevent emission. If discharge is into drums, the collection area also should be housed under negative pressure, in a hooded area, for example.

Consider dual dust collection systems as well as a dedicated bag system to reduce toxic waste and employee exposure from cleaning the units. In a dual system, one system would control toxic sections and the other system would control nontoxic dust. The priority is to reduce any dust generated as well as to isolate toxic and nontoxic dust. For example, if you are dealing with granular products, prescreen the incoming carrier to remove excess fines and oversize. By doing this, toxic waste can be reduced and technical recoveries can be improved.

Install activated carbon odor control units downstream from the bag house dust collectors to control odor emission. Prefilters should always be installed ahead of the carbon unit to remove particulate. This acts as insurance against bag failure in the bag house. Dust will collect quickly on carbon, blind the carbon surface, and reduce activity and service life. Give careful consideration to selecting the size of an activated carbon unit so that size is close to optimum. Residence time of air across the bed is important for proper removal of odors, and carbon bed thickness should be from four to six inches. Deeper beds cause high pressure drops and require very high static pressure fan units. Fans should be installed on the exit side of these units so that negative pressure is maintained on the housing. Many commercial units that are being marketed are not acceptable, as they do not give adequate control for the pesticides industry. The weaknesses in these units include not enough bed thickness (generally only one and a half to two inches) and, the greater problem, the fact that the air turbulence vibrates and packs the carbon, which then settles. This permits voids in the carbon at the upper levels in the trays, and air bypasses the carbon. You also find leaks in the gasketing around trays, again allowing air to bypass the carbon. Many in the industry find that by constructing their own units they avoid these weaknesses. These units are mass-carbon-filled, have no individual trays, and provide a head of carbon that allows for settling but allows no air to bypass the carbon.

It may be necessary to change your carbon bed when changing from one formulation to another. The odor units absorbed from one formulation may be displaced by units from a succeeding formulation, and carbon beds cannot control this; they are not a cure-all. Some emissions will require wet scrubbers to remove toxic emissions. Consult with your carbon supplier as to the capabilities of the carbon and the correct grade or mixture of grades that will be suitable for your conditions.

Final air exit from the ventilating system should be through a stack, with the top of the stack high enough so that tops of nearby buildings are cleared to prevent downdrafts. It is generally considered good practice to install stacks forty to sixty feet high in any case. A jet diffuser can also be installed at the stack exit to diffuse and dilute the discharge in the event of an upset in the system.

Central and protable vacuum-cleaning systems should be considered both in production and in rework/repackaging areas. Supplemental portable cleaners should be available for use in cleaning equipment in remote areas. Portable cleaners must also be equipped with absolute filters at the exhaust. An alternate plan, if convenient, is to vent them into your existing dust collection system.

Environmental control and safety should be considered in selecting and installing all plant formulation equipment. Equipment layout and design should provide access and reasonable entry for decontamination and maintenance. Layout and design should provide tight enclosure that will allow connection to the ventilating system so that negative pressure is maintained within the unit, or it should provide hoods to control potential emissions. Prevent excessive air flow through the units by minimizing openings on all equipment. For example, provide covers on tank manholes to reduce air flows. In the case of odorous materials, the less air passed through a unit, the less odorous air is generated that will have to be treated. In all cases, design for minimum air flow through your equipment.

Avoid using rubber or fabric belt conveyors wherever possible because they are difficult to decontaminate and house, and they can generate waste. Instead consider using removable cover design screw conveyors. They are easily sealed, dust tight, convenient to decontaminate, and can be used to convey most dry materials, including granular clay. Granular materials will not be degraded if proper screw clearance and auger speed is used. Air-veying and drag conveyors provide good emission control, particularly with dust. Use flat wire belting on bag and container conveyors. Installing catch pans under these conveyors will trap any product that is spilled and falls through the open belting. This is particularly important in areas under bagging scales or fillers to collect misfires and prevent product from getting on the floor. In general, collect and recycle product at all leaks or sifts.

Consider installing dedicated systems for specific high-volume products to avoid decontamination and generation of toxic waste. Consider using electronic scales in all systems for weigh hoppers, and scale mount all liquid formulation tanks. Use scale electronic control terminal accessories to interlock pumps, mixers, conveyors, and so on, with the scales to prevent upsets in formulations. Interlock will prevent double charging, or failure to charge units altogether.

Rework systems enable you to dump back off-spec material from formulations, as well as customer-returned products, both liquid and dry.

Provide a liquid plant equipment and drum/pail decontamination system. This system would include a portable high-pressure wash unit to wash and flush tanks and equipment; storage tanks to hold reclaimed solvents; storage tanks for premixed decontamination liquids; a contaminated liquid waste treatment tank; an activated carbon wet treatment unit; and a three-station drum/pail decontamination system.

Decontamination procedure uses solvents or other nontoxic liquids for primary and secondary flush, followed with a decontamination liquid--caustic or other as required. The primary and secondary solvents, or other liquids, are recovered, stored in the reclaimed solvent storage tanks, and used in subsequent formulations of that product. Final decontamination liquids would be collected, treated, and properly disposed of.

The three flush stations of the drum/pail decontamination system are the primary, secondary (solvent), and final (caustic or other) flush. The liquids would be recycled for formulation and treated as previously described.

The drum flushing station should be hooded and exhausted through the ventilating system. Wire cloth filters that can be cleaned and reused should be considered over throwaway cartridge units. Wire cloth units can be back-flushed with a solvent used in formulation, and then the solvent can be reclaimed.

All liquid piping should be of flanged and welded construction. Pipe sections should be of a length convenient for dismantling and cleaning, again, with proper gaskets in the flange joints. Pressure-relief valves of proper size should be installed in all pipelines and tanks subject to pressure. Provide adequate safety venting when handling organic dust.

Pumps need mechanical shaft seals, and the seal area at the shaft should be shielded to prevent leakage from being centrifuged into the work area. Leakage can be collected, and floor contamination can be prevented by installing a drip collection pan under the pump shaft seal. On heated vessels, temperature control valves and over temperature alarms should be installed.

Liquid CO_2 or other inert gas systems should be considered, if any formulations require cooling or inert atmospheres.

Install grounding, and bonding, if transfer takes place, on all tanks and equipment. This is particularly important when formulating and packaging products classed as flammable, when filling plastic containers, and also if you have wettable powders going into plastics. All electrical equipment and service lines should be of explosion-proof design, including the lighting.

It is important that ventilation be controlled in warehouses. Wall or roof fans are convenient to exhaust the building after been closed over the weekend, or in the event of an upset wise, gravity roof vents are adequate. During normal ope: open doors should be controlled. Open downwind doors, an upwind doors.

MATERIALS HANDLING AND TRANSFER

Herman Schaller, Ph.D.
Manager, Mobay Chemical Corporation

I will speak today about our experiences and philosophies in dealing with the problems of materials movement and transfer.

As I see it, five main types of formulations are in general use in the pesticide industry. They are dusts and wettable powders; spray and emulsion concentrates; conventional clay granules; liquid flowables; and wettable granules. These five product types share one common technical problem--the handling or transfer of materials from one area to another or from one piece of equipment to another.

In any formulation and packaging operation, materials movement or transfer can be broken down into five main areas: movement of materials to the operation; charging operations; movement of materials between pieces of processing equipment; packaging operations; and movement of finished goods to warehouses or to shipping areas.

How we engineer a facility certainly depends on the volume of a product or the types of formulations. A large-volume product lends itself to bulk handling and to automation. However, the engineering of such facilities requires a lot of knowledge about product behavior under varying conditions in order to choose the right equipment and also to be able to apply and install the right control equipment.

In our overall facility in Kansas City, we have installed 8,000 cubic-foot silos for the handling and storage of toxic or nontoxic raw materials, as well as materials with undesirable properties besides toxicity.

Such a facility lends itself to automated packaging. We have chosen, for such a facility, to run the entire operation from control rooms. In order to really be able to handle such materials properly and to insure that proper materials transfer and proper materials movement is possible before we engineer such a facility, we employ models.

However, these facilities are the exception rather than the norm. Normally, formulation facilities are multiproduct plants. This kind of facility requires less sophistication in equipment but more thinking in design. One of our first philosophies in the design stage is not to make a distinction between insecticides, fungicides, or herbicides in terms of materials handling, dust control, and so on. Since insecticides are generally more harmful to people, and herbicides are generally more harmful to the environment, we believe it's our job to protect both.

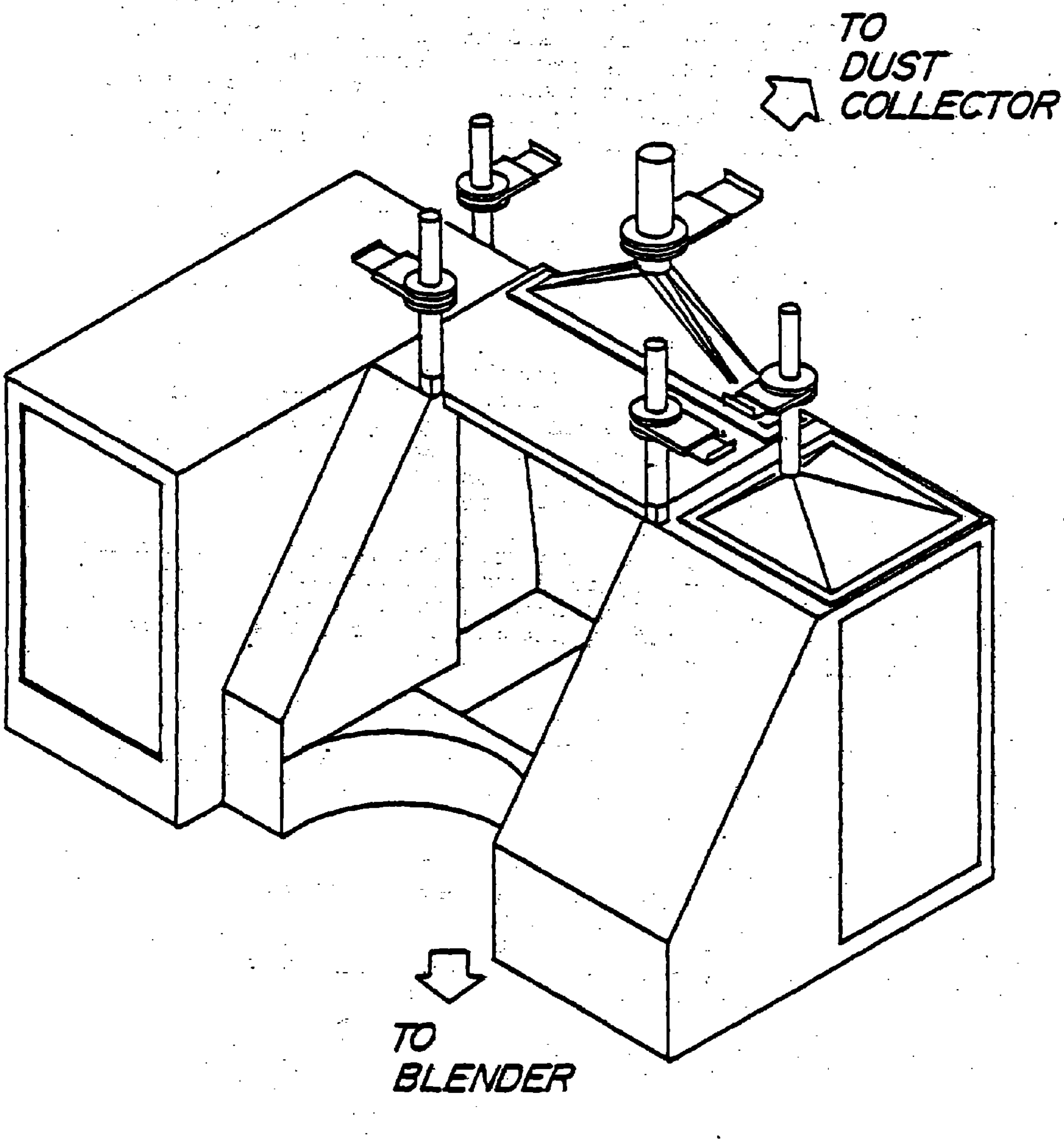
Let us turn to charging operations. As I mentioned earlier, charging of materials, toxic and nontoxic, is one of the main of concern in a formulation and packaging operation. Certainl we can solve this problem by using large volumes of ventilatic But in doing so, we automatically create another problem farth downstream at the point of treating the waste air. Remember, normally up to ten milligrams of dust pass any dust collector cubic meter per hour. Therefore, the more air we move, the la the dust collector has to be, and also the larger the scrubber any other secondary treatment device has to be. This demonstr another general philosophy, namely, we are reluctant to solve problem by creating another one. In order to deal properly wi this question of charging, we think control of stray dust is a combination of proper design of control equipment and operatic technique.

Figure 1 shows an isometric drawing of a charging hopper which use in our operations at Kansas City. This hopper is a piece equipment with three different functions. In the middle is th real charging hopper. On the right side is a containment area where empty plastic bags are disposed of, and on the left side stray dust can be removed out of drums.

This hopper, plus the associated blender which is installed fa down, requires approximately 2,800 scfm of dust collector capa for operation. The main ventilation stream goes downward into blender, thus following the trend of the particles. Every oth major dust cloud is drawn into the hood. We have provided slc air distribution plates which allow us to limit the amount of necessary to achieve velocities of about 150 to 200 fpm. We r quire that all incoming material, in drums or Leverpaks®, be pl into a plastic bag inside the container. The bag must be long enough to extend at least one foot above the top of the drum.

The dumping technique is as follows. First, the operator move the drum into the half-moon area of the hopper and tips it for into the dump area. The drum is at approximately a 45-degree from the vertical. In this position the top of the drum is ur the influence of the ventilation system. Second, the operator moves the lid of the drum. Third, he unties the plastic bag a pulls it over the outside of the container and about a foot dc from the top of the container. This is important since we war to protect the drum from contamination. I think once the drum contaminated you cannot handle the problem of cross-contaminat and of intoxication of people any more. Fourth, the operator ends the container in the hopper over the lip and empties the contents of the drum. Fifth, he removes the Leverpak® drum ar sets it to the left inside the hopper. Sixth, he shakes the c

FIGURE 1



CHARGING HOOD

tents from the plastic bag into the hopper. Seventh, he rolls up the plastic bag very tightly within the hopper and puts it into a container located in the right side of the hopper, which is also ventilated.

When the container on this right side of the hopper becomes full, a lid is placed on the container and it is removed from the right cabinet, under ventilation. A new empty container is inserted into the hopper. We have also installed bag compactors in our hoppers. However, the safety requirements for a bag compactor are extremely difficult to achieve and are not recommended without extensive study.

The operator's next task is to push the empty drum through the tunnel on the left side. This tunnel is long enough for the ventilation system to remove any stray dust from these containers. A lid is placed on the Leverpak® before it is removed from the hopper.

With this type of design we can handle drums, Leverpaks®, and bags. The overall approach leads to a virtually dust-free operation, which helps considerably to establish a good housekeeping program. But it's only possible if operators follow the instructions exactly as they are given. Then the amount of ventilation provided is absolutely sufficient to do the job.

Let us move to another issue: materials transfer in equipment. In light of the wide variety of types of formulations, this is certainly a broad issue. Therefore, I would like to offer you some of our approaches rather than specific measures, so that the information will be more applicable to other operations.

Whenever we engineer a formulation facility, we try to accomplish three main goals: use as few pieces of equipment as possible; use gravity for materials transfer wherever possible; eliminate waste as much as possible. These goals are somewhat interrelated and need further clarification.

The phrase "use as few pieces of equipment as possible" can also be expressed as "no equipment is the best equipment." Most conventional systems for the production, for example, of wettable powders use a bucket elevator, a pre-blender, a hammermill or attrition mill for preparation, an after blender, an airmill, another after blender, and packaging hoppers. Our system uses a pre-blender fitted with a system for chopping the material, thereby eliminating the separate mechanical grinding system. We have only airmills. We think that elimination of mechanical grinding equipment makes the entire operation safer. Also, we don't use a bucket elevator.

To illustrate the use of gravity for materials transfer, I will cite our facilities in Kansas City. Our wettable powder formulating facility is built over four floors, or four operating levels. Raw materials in the original package are moved to the fourth level by a freight elevator. During each processing stage or step, the material is moved to lower levels by gravity. When processing is completed, it is packaged on the first level. In one step we use the airmill as a lifting device. I should mention here that this gravity approach holds true not only for wettable powders or dusts, but also for liquid operations.

The use of a freight elevator to lift raw materials to the upper level eliminates the need for a bucket elevator. This, in turn, eliminates the need for ventilation of an elevator and also eliminates the resultant loss of material through dust collector bags. In addition, all dust collectors for ventilation discharge directly into that first blender, eliminating manual handling or transfer lines. It is important to choose equipment and designs which lend themselves to ease of cleaning with a minimum of waste. Waste costs you twice. It is product you cannot sell, and it costs you for disposal. The disposal of our waste products has become more and more difficult. It's almost impossible.

Another broad and difficult area to deal with from the standpoint of dust collection and of worker exposure is packaging.

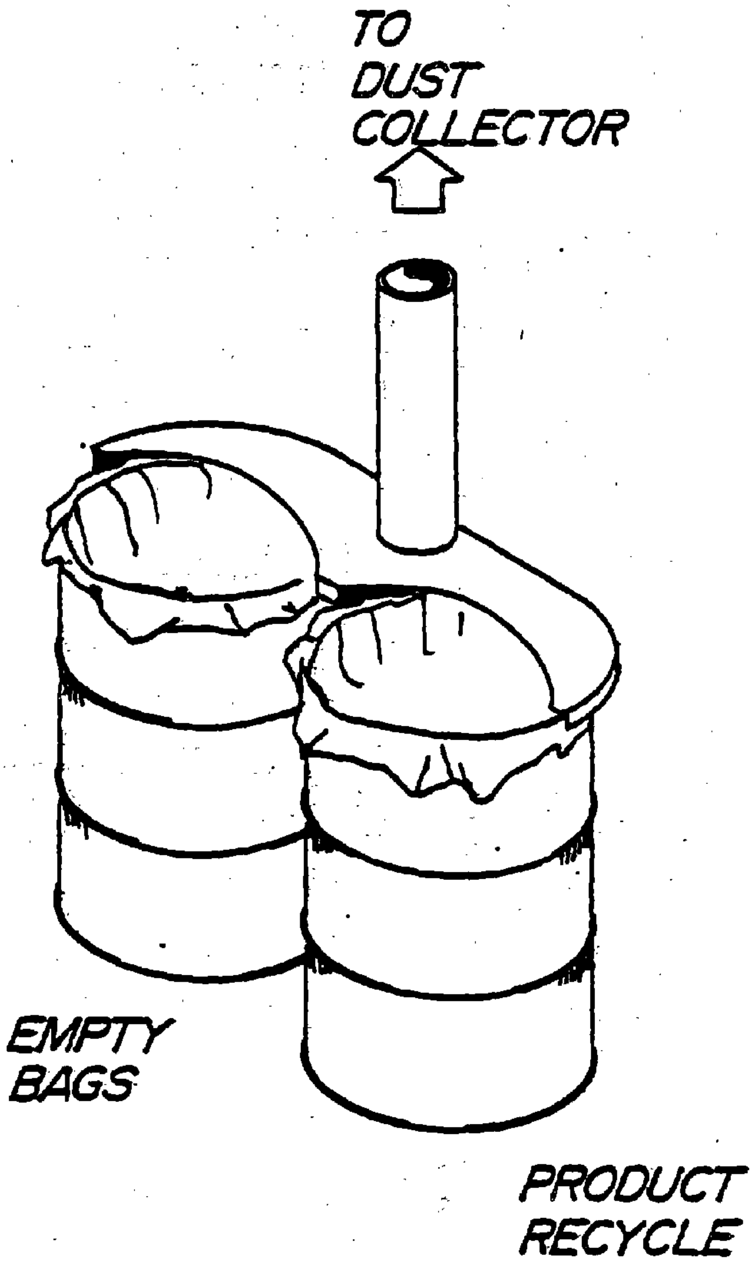
I would like to confine my remarks on packaging to some aspects of wettable powder fillings. Most of these operations use auger fillers. Some systems are sophisticated enough to use bottom-up filling, but most are not. A significant amount of stray dust is generated by the fall of the powder from the auger into the bag. Well thought out design of the ventilation system can remove most of the dust from the area. However, the handling of overweight and underweight bags becomes a problem.

Two systems are normally used to handle the overweight or underweight bag. One is to seal the bags first and then pass them across a checkweigher which will reject overweights and underweights. However, the question then arises of what to do with these bags.

The other system is to pass the open bags across a checkweigh scale and adjust them manually. This also represents a problem since a manual adjustment constitutes another "dumping operation," except on a smaller and faster scale than the charging operation.

For the recycle of closed off-weight bags, I offer you an idea which came out of our operations of form-fill-and-seal bags; so-called pillowbags. Figure 2 shows a simple ventilation device which everybody can build. Two drums, properly ventilated, are under this device. Both drums are lined with a plastic bag. Closed overweight or underweight bags are taken to one drum, and the operator cuts open the bags in one drum, puts the product in one, and puts the empty bags into the other drum. The product is then recycled. By this method the question of closed off-weight bags and the exposure to people can be handled in at least a routine and normal fashion.

FIGURE 2



Somewhat easier is materials transfer into and out of formulation areas. All raw materials purchased should be in containers that easily fit your charging operations so that you will be able to accomplish a dust-free charging operation with minimum waste. Your purchasing group should communicate your requirements to suppliers.

For example, as far as finished goods are concerned, we have standardized on a 40" x 48" pallet for all of our finished products in cartons. In addition, we have standardized on 24" x 16" cartons, with varying heights. This allows five cases per layer using an interlocking pattern between layers. In addition, we use a spiral stretch wrap system to protect the load, whereby the pallet remains stationary and the wrap moves around it. This avoids centrifugal forces which cause separation of the cases whenever the pallet moves.

For the protection of five-gallon pails we use a pallet which is approximately 35" x 46". This allows twelve pails per layer with no overhang, a loading which is also ideal for stretch wrapping.

Shrink wrapping is an alternative to stretch wrapping, and has the advantage of a top cover. It probably also protects the load better. However, the safety aspects of shrink wrapping should be carefully reviewed before making a decision.

Let me summarize. Formulation and packaging operations are complex by nature, since they are almost always multiproduct operations. There is no one single approach to every problem. However, the two specific items and the philosophies mentioned give a relatively clear picture of how we approach questions of workforce and environment. So far we have been successful.

BLENDING AND FORMULATING OF LIQUIDS AND SOLIDS

James B. Pace
FMC Corporation

I am going to be talking about some of the problems we have run into at FMC and the solutions we have come up with. In all the studies and things we have to do, we have to be flexible, not bury our heads in the sand, and question everything we hear. I think many of the textbooks and engineering manuals can be useful, but in the pesticide business we have to adapt them to what we are doing.

I have broken my subject down into four basic topics: formulation of liquids; blending and milling of wettable powders; blending of impregnable powders; and ventilation and general areas applicable to all systems.

Figure 1 is a flow diagram of a typical liquid formulation system, starting with the receiving of bulk raw materials and finishing with waste disposal. No formulation line design can be considered complete without taking the entire system into account. Receiving of raw materials by railroad tank car or by truck, were practical, is preferable to other methods. It is easier and offers less potential for exposure to hazards to receive materials in bulk.

It is worth noting that the bulk unloading area is contained, as is the tank farm and the plant, so that spills can be cleaned up, recycled or decontaminated, and disposed of rather than enter the environment.

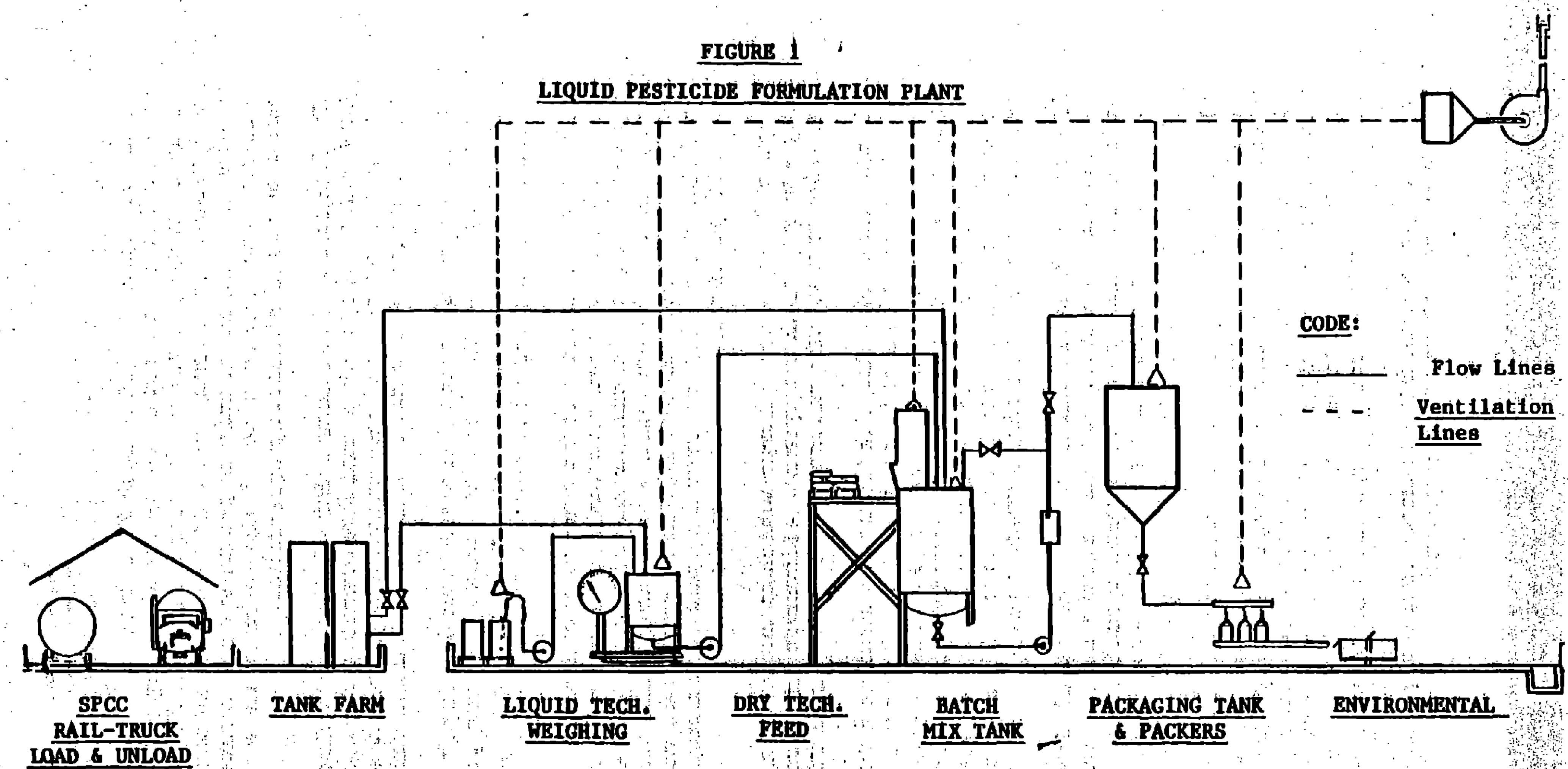
When raw materials must be received in steel drums, it is better to palletize them and move them with fork trucks than to try to do everything by hand. A vacuum or gear pump attached to a wand with a flexible hose is a clean and easy way to extract chemicals from drums. It can be stored in a sheath when not in use. Provide ventilation to remove fumes.

Dumping drums by inverting them either manually or mechanically is sometimes practiced. Unless care is taken in plant layout and design, this practice can be hazardous and messy: Spills and chemical exposure are difficult to contain.

The technicals are preweighed in a stainless-steel weigh tank and then pumped to the batch tank. Ventilation is required at this tank and any other place where fumes can enter the environment.

FIGURE 1

LIQUID PESTICIDE FORMULATION PLANT



When dry materials are added to a batch, it is usually done with the pallet of material close to the dump area. The operator will dump through a dump hood. Bags are carefully cut, shaken, rolled, and placed in a drum, box, or plastic bag for disposal. Some operators use automatic bag dumpers and waste bag compactors, but cleanup and maintenance of these units make them impractical in most pesticide-blending operations.

In Figure 2, a bag house dump hood combination is shown above the dump hood. After the dumping operation the door will be closed, the air flow cut off, and the bags agitated so that contaminants will reenter the batch. A fume vent line from the tank is required.

Blended materials can be transferred through a pump and filter to a holding tank that provides surge for the packaging operation. Once material is transferred to this tank, the crew is free to initiate subsequent batches.

All tanks, hoppers, and sources where fumes, odor, and dust can emit should be vented through a vacuum system. Emission can either be exhausted or it can be treated with scrubber, cyclone, incinerator, carbon filters, and so on, to minimize cross-contamination effects. Wastes and spills that cannot be reclaimed can be neutralized with lime or caustic, pumped to drums, and hauled to a controlled landfill, for example.

Figure 3 is a block diagram which shows a typical wettable powder high-energy milling system. Although more complicated than some installations, the principles involved are similar.

On the left is a liquid technical additive tank. The liquid handling system up to this point is similar to the liquid plant. The dump hood shown here is for bags, drums, and so on. Again, bulk diluent or technical adding systems are preferable to bags and small containers. The screw conveyor is shown taking materials from the dump hood to the elevator. This unit eliminates the need for an undesirable elevator pit.

The ribbon blender discharges to the mill feed bin where material settles and is uniformly fed to the mill. On a high-energy mill, material is air-veyed to a product collector where it is separated from the air stream and returned to a post-blender through a star feeder.

Selecting the right product collector is critical to favorable operation of a high-energy milling system. Equipment vendors sometimes quote these collectors with an air to cloth ratio as high as or higher than nine to one cfm per square foot. For the fine-grind materials usually encountered in pesticides formulating, these ratios are closer to three to one or lower. For flammable and explosive products, special considerations must be taken.

From the post-blender, material is packaged in bags, drums, or in whatever way the market requires.

FIGURE 2

DUST WETTABLE POWDER
TYPICAL HIGH-ENERGY MILLING

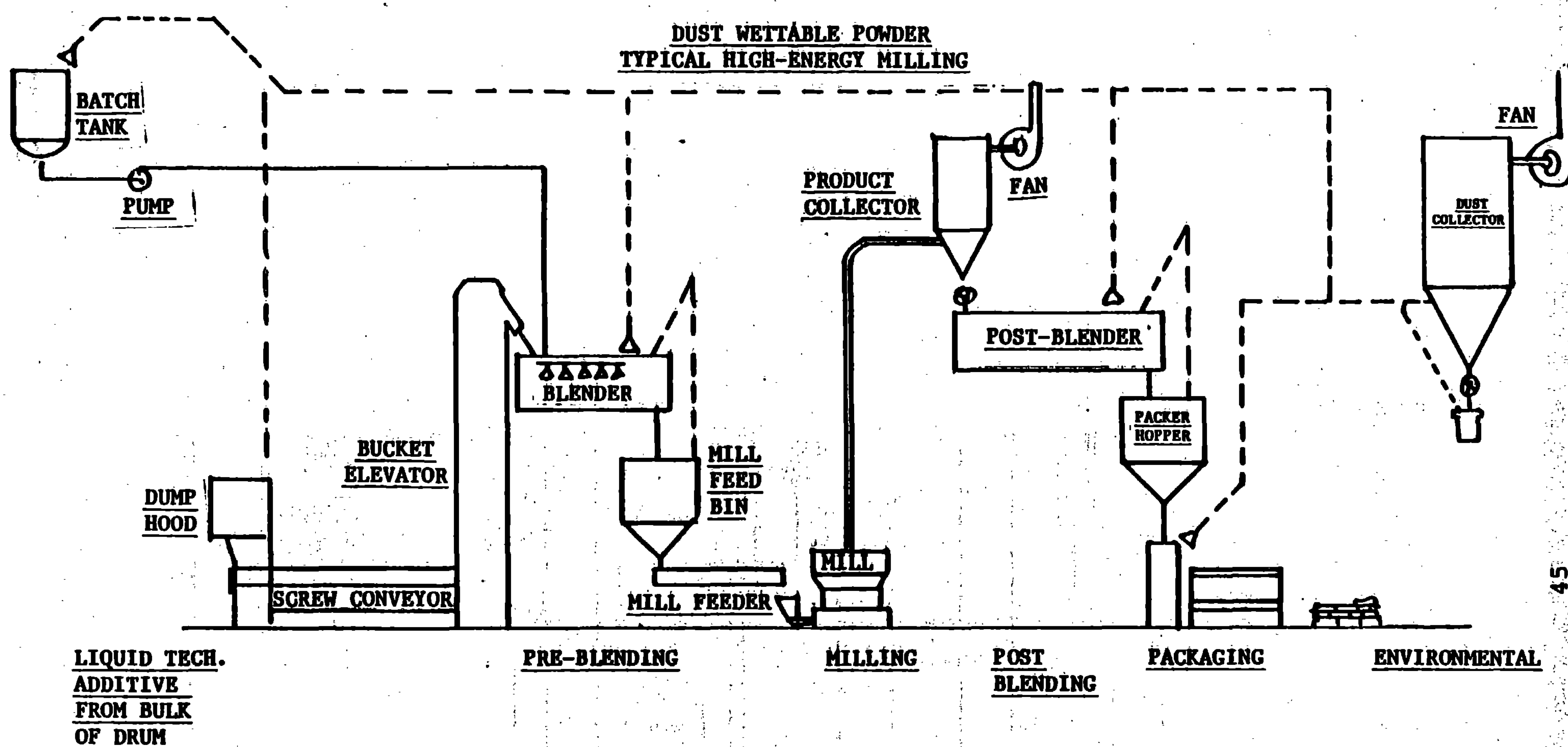
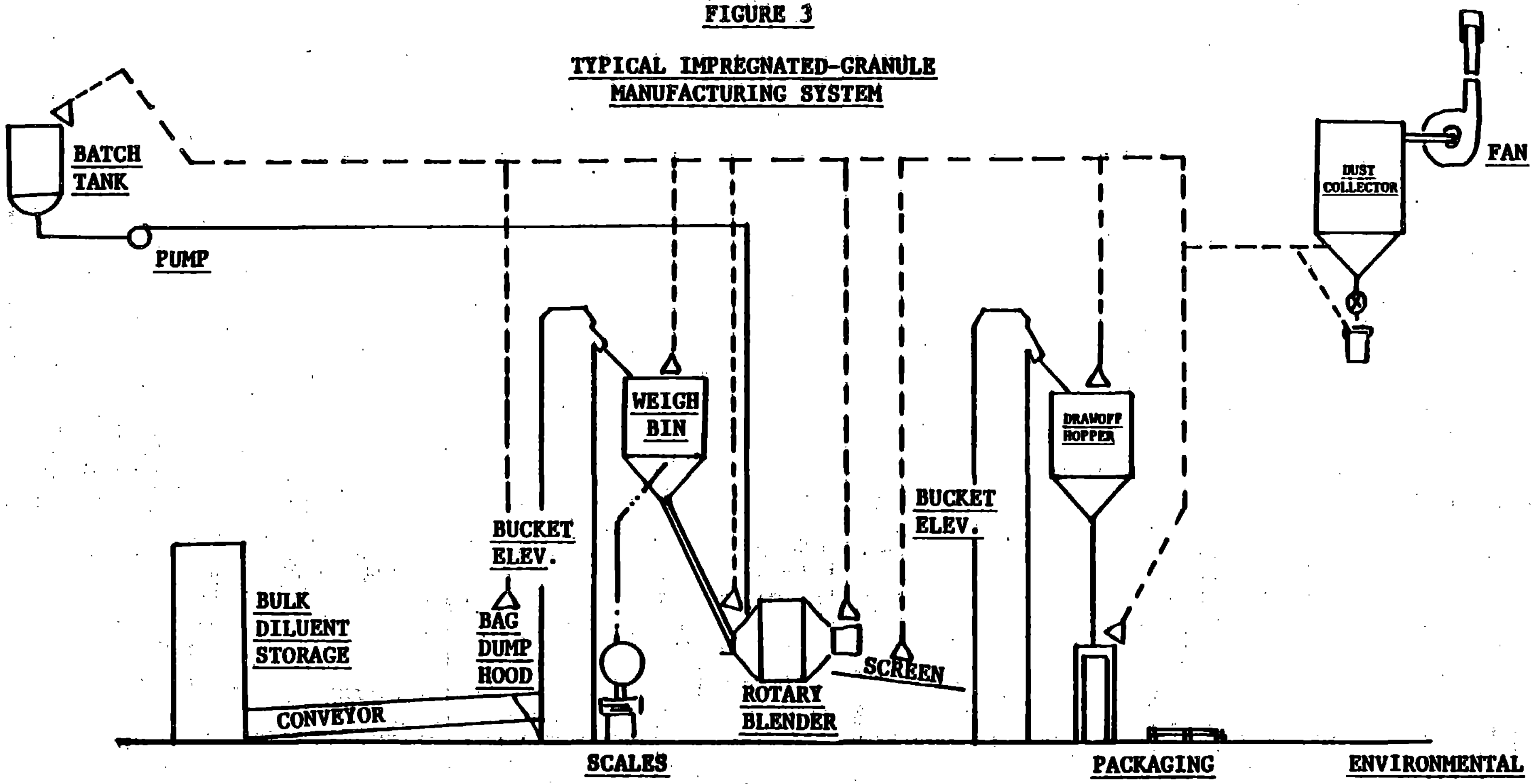


FIGURE 3

TYPICAL IMPREGNATED-GRANULE MANUFACTURING SYSTEM



All equipment in a wettable powder grinding plant is ventilated through a general ventilation collector.

Impregnated granules systems are similar to, but different from, wettable powder or dust-formulating systems. Large volumes of diluent are generally used, thus making bulk material delivery more feasible. These systems usually incorporate rotary blenders.

Technical is applied as a liquid and absorbed into the diluent. A scalping screen is used to slough off the waste fines, leaving only the granular product. The material is then packaged.

As impregnated granules are relatively fragile, equipment must be used in the formulation line in a way that protects product quality. You are not doing any milling. Safety and health considerations for this type of plant are similar to those encountered in a dust or wettable powder system.

In designing or upgrading a formulating plant, you should try to do it on the basis that no special protective equipment or clothing will be necessary. Formulating equipment should be sealed and dust tight. Ventilation hoods and ducting should control dusts and fumes. Walking, bumping, and thermal hazards should be eliminated. Management must be committed to achieving this objective with actions and money. Only after the company has done all it can to assure a safe and healthful workplace can the operator be trained and required to work smart, clean, and safe. Without the sustained cooperation of both management and operator, no amount of engineering will provide a safe and desirable workplace.

Following are areas which are critical in assembling a good formulation plant:

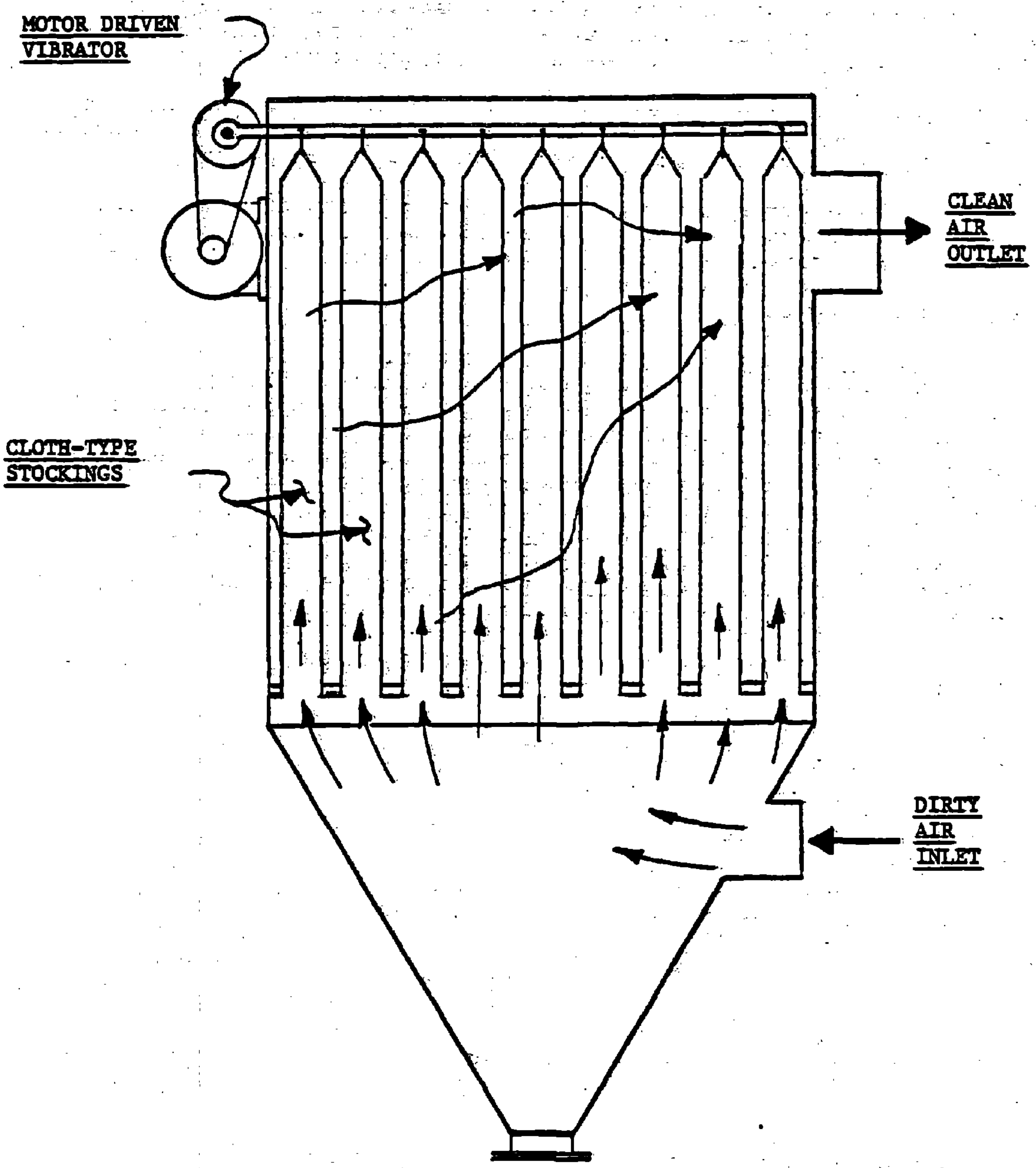
One is ventilation: A well-designed system is the first insurance against exposure, and the heart of that ventilation system is the dust collector and fan.

Dust collectors come in three general types. All have their place. The shaker collector (Figure 4) is a good standby, which consists of a woven bag stretched between a plenum and a boot. It is used to filter contaminated air. Dust coats the bag and forms what is called the filter cake. As this filter cake gets heavier, it will cause the pressure drop across the bag house to increase until eventually the fan must be shut off. The bag is agitated, causing the filter cake to fall out, and then the filtering process can be repeated. These collectors should never be run at more than a three-to-one air-to-cloth ratio; usually a lower ratio would be better. They are quite common and in general use throughout the industry.

The air-pulse automatic collector is a second type and style of dust collector, consisting of a heavy felted bag rather than a woven bag. It collects material on the outside. A timer-controlled

FIGURE 4

SHAKER-TYPE COLLECTOR



air blast blows the bag, causing the filter cake to fall off. These collectors have become more popular over recent years, with many manufacturers now entering the market. Suppliers frequently quote them at air-to-cloth ratios of nine to one. When sold under this premise, they hold quite a price advantage over shaker-type collectors. However, with the fine products handled in most pesticide operations, this nine-to-one air-to-cloth ratio drops to the range of three-to-one. These are good collectors for use as product collects on the milling system, and so on.

A third, relatively new type of collector on the market is one that utilizes a paper cartridge similar to the air cleaner on your car. It shows promise, but we have not tried one as yet.

In selecting a new collector for this business, one should look for something where the bags can be changed and where maintenance can be performed without the operator having to get inside. Probably the greatest potential for intoxication in the whole plant is while performing maintenance and replacing bags in dust collectors. Anything that can be done to reduce or eliminate this exposure should be considered.

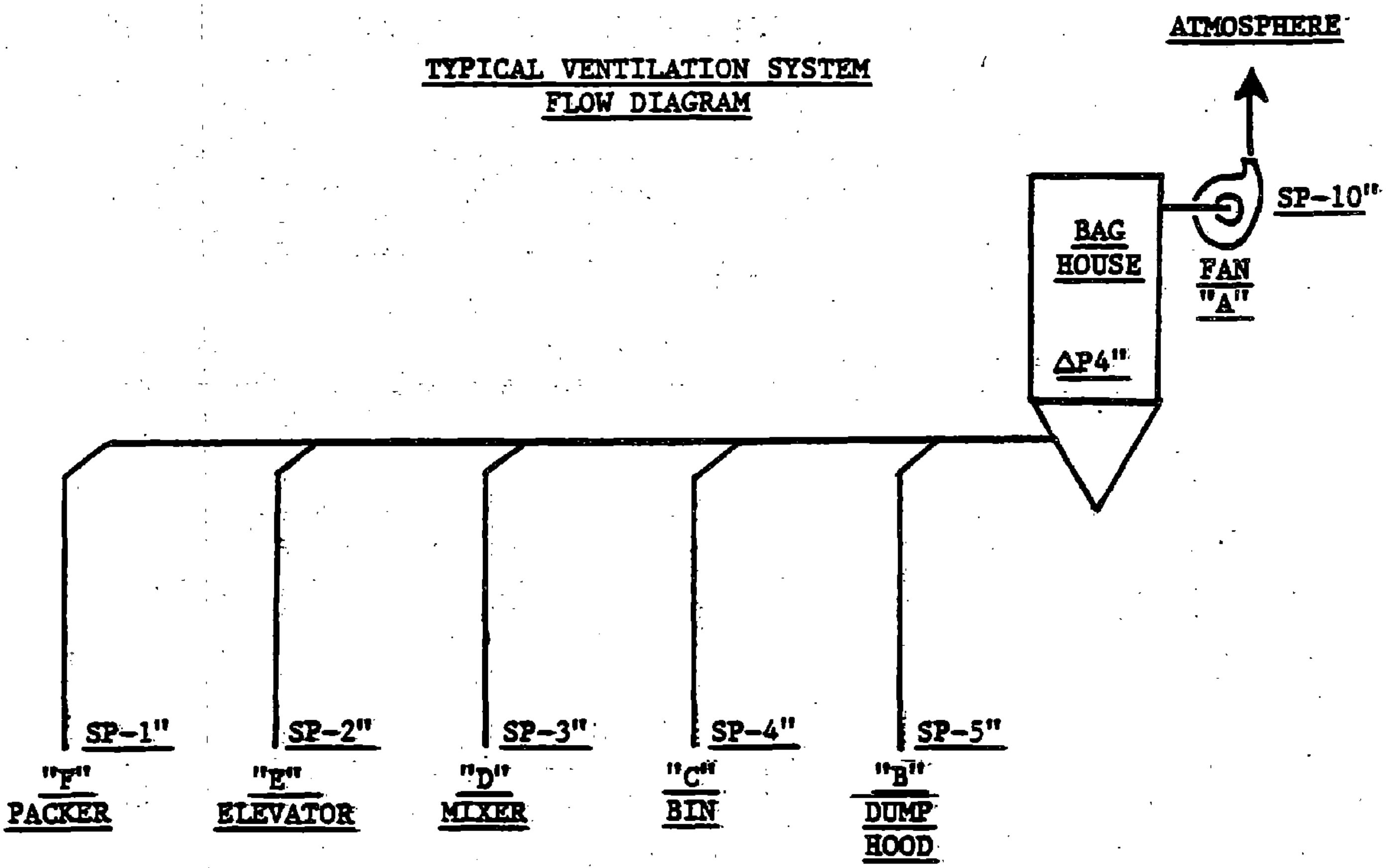
Most basic information for ventilation design comes from the Handbook of Industrial Ventilation. However, a problem exists. The handbook is designed for use in general industry, where the objective is to remove dust from work areas and product and get it out of the system. In most pesticide operations the intent is to save and keep the dust. The finer the dust, the better the product. Vast sums of money are spent to grind material finer. Most hoods and practices, if used as designed in the manual, will put these fines right in the bag house where they are of no value. Therefore, use the hoods described there but adapt them to the needs of the pesticide industry. Each application will usually require its own specific design.

Most engineering manuals on ventilation are written with the concept that the smallest possible hood should be constructed using a minimum amount of air, and that the fan horsepower should be calculated by the curves to just fit the system. A ventilation system designed on this concept will usually be undersized, and the installer will be forced to make all kinds of changes in order to make an inadequate system function as it should. Play it safe. Use ample hood sizes and excess air in designs, and then add about thirty percent extra to the overall air quantity and horsepower of the fan. The system can then be balanced and will perform with ample air. Also, modifications and additions can be made with minimal trouble.

Figure 5 shows a typical ventilation system with a total design pressure drop of ten inches water gauge. If the system were designed to operate with a bag house pressure drop of two inches, everything is OK. But if the bag house pressure drop increases to four or six inches, the hoods at the packers and those farther away from the fan will drop off and become ineffective.

FIGURE 5

TYPICAL VENTILATION SYSTEM
FLOW DIAGRAM



F	E	D	C	B	DUST COLL.Δ P	A
-2"	-4"	-5"	-6"	-7"	2"	-10"
-1"	-2"	-3"	-4"	-5"	4"	-10"
0"	0"	-1"	-2"	-3"	6"	-10"
0"	0"	0"	0"	-1"	8"	-10"

FAN DESIGN SP-10"

NOTE: HOODS ON SECTIONS OF SYSTEM WITH MAXIMUM PRESSURE LOSS SHOULD BE WELL DESIGNED (HOOD "F") HOODS CAN BE QUITE RUSTIC ON OTHER SECTION OF THE SYSTEM (HOODS "B" AND "C").

While talking about dust collectors, let's look at stacks. (See Figure 6.) Make sure they are tall enough to get the fumes up into the air so that they can be dispersed and away from your plant. It makes no sense to spend money to ventilate a plant if the stack just blows everything back in.

At this point, I would like to stress the adverse effects of a "Chinese rain cap" which you will see on some stacks. For some reason, people want to use these things. By using one, rather than the straight blow-through type of hood, a stack two feet in diameter with an exit gas velocity of 4,000 fpm loses forty feet of effective stack height.

We will now look at pressure relief design. In order to relieve pressure (and displaced air) on equipment and to keep fine dust from the collector, this technique relieves pressure from the packer to the bin, from the elevator and bin back to the dump hood, and from the dump hood to the dust collector.

On the same subject, lines coming from elevators, bins, and so on, should be as large as possible. Six- to eight-inch lines are not uncommon for this purpose. They should also be steep to allow material to fall free as it settles out. Bends should be mitered, as should takeoffs from the bins. Otherwise, material fallout can plug the lines and make them ineffective.

Blast gates should be used in vent lines for balancing. There is a tendency for people to continue to want to use butterfly gates for dampering. The trouble with these gates is that they are difficult to lock in place, and they will not hold up under conditions of relatively high static pressure.

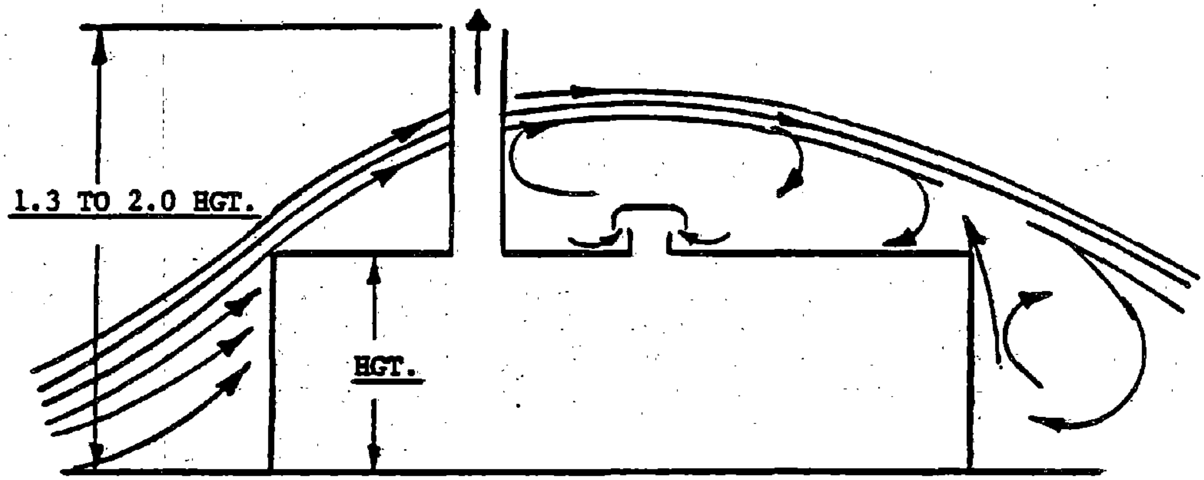
Plenums may be used in different ventilation hoods. Some poor ones are shown in the General Ventilation Handbook. Dusts will settle out in them, eventually causing them to plug up and making it impossible to clean them out. The modified hood has the taper come to the bottom slot so that tramp dust will fall out so it can be vacuumed up, or the hood scraped clean by an operator.

Avoid using canopy hoods and others that have a tendency to pull air past the operator's face. Instead, design hoods to pull contaminants down and away from the operator.

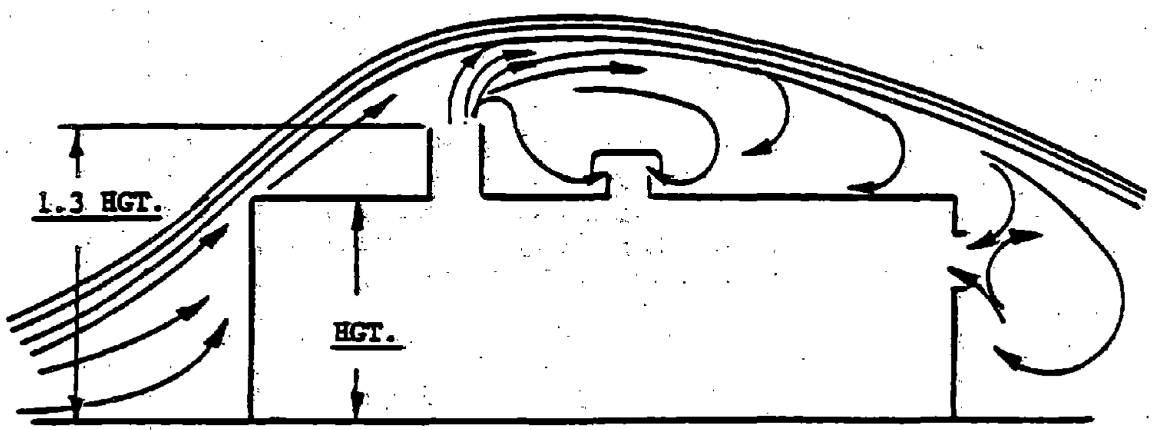
Figure 7 shows a design for a bag dump hood that should be considered. When bags are cut, an operator likes to stack four or five of them in the hood. The bags are then cut to let the material slide out into the system. Bags can be well shaken and put into the empty bag hood for later removal from the building. To dispose of them they can be carefully rolled, placed in plastic bags, drums, or cartons, or they can be compacted, tied, and removed.

If one dumps bags and piles them on the floor, there is no need for a dump hood. Likewise, if one dumps a bag and must then

FIGURE 6



GOOD
HIGH DISCHARGE STACK RELATIVE TO BUILDING HEIGHT, AIR INLET ON ROOF.

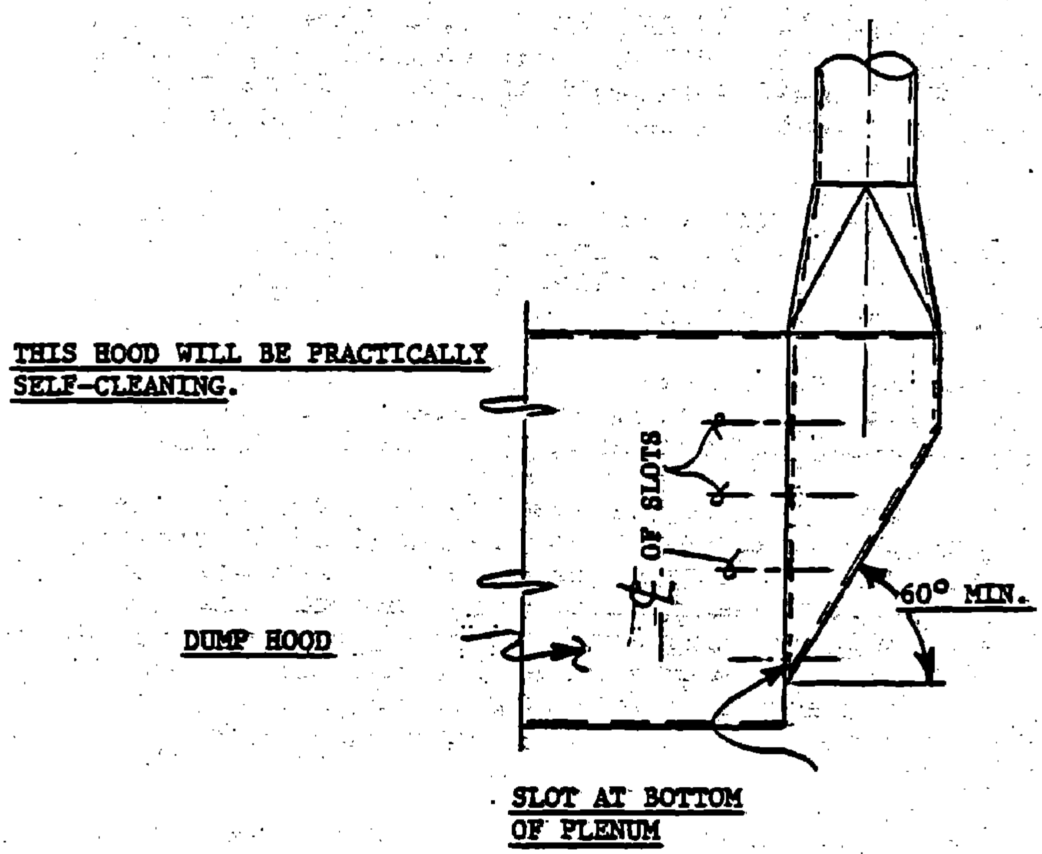


POOR
LOW DISCHARGE STACK RELATIVE TO BUILDING HEIGHT, AIR INLET ON ROOF AND WALL.

NOTE: STACKS SHOULD BE WELL ABOVE TOP OF BUILDING TO DISPERSE GASES AND STOP RECYCLE INTO PLANT.

FIGURE 7

BAG DUMP HOOD



BETTER

remove it from the dump hood before placing it into an empty bag hood, he has defeated the purpose of the hood.

Curtains sometimes help reduce the amount of air required in the hood. Operators hate them, however, as they obstruct vision and irritate the arms. With toxic materials, a minimum dump hood face velocity of 200 fpm is desired, while 300 to 400 fpm would be preferred to assure the pickup of dust that may fall in front of the hood. When the bottom bag is dumped, it can block the ventilation of the front edge of the hood so that material can spurt out onto the operator and onto the floor in front of the hood. To stop this tramp dust, a pickup on the front side of the hood is necessary.

Uncontrolled makeup air will cause undesired air flows and currents in the operating room and may cause cross-contamination. A two- or three-mile-per-hour natural, uncontrolled breeze can nullify the best of hood and ventilation designs.

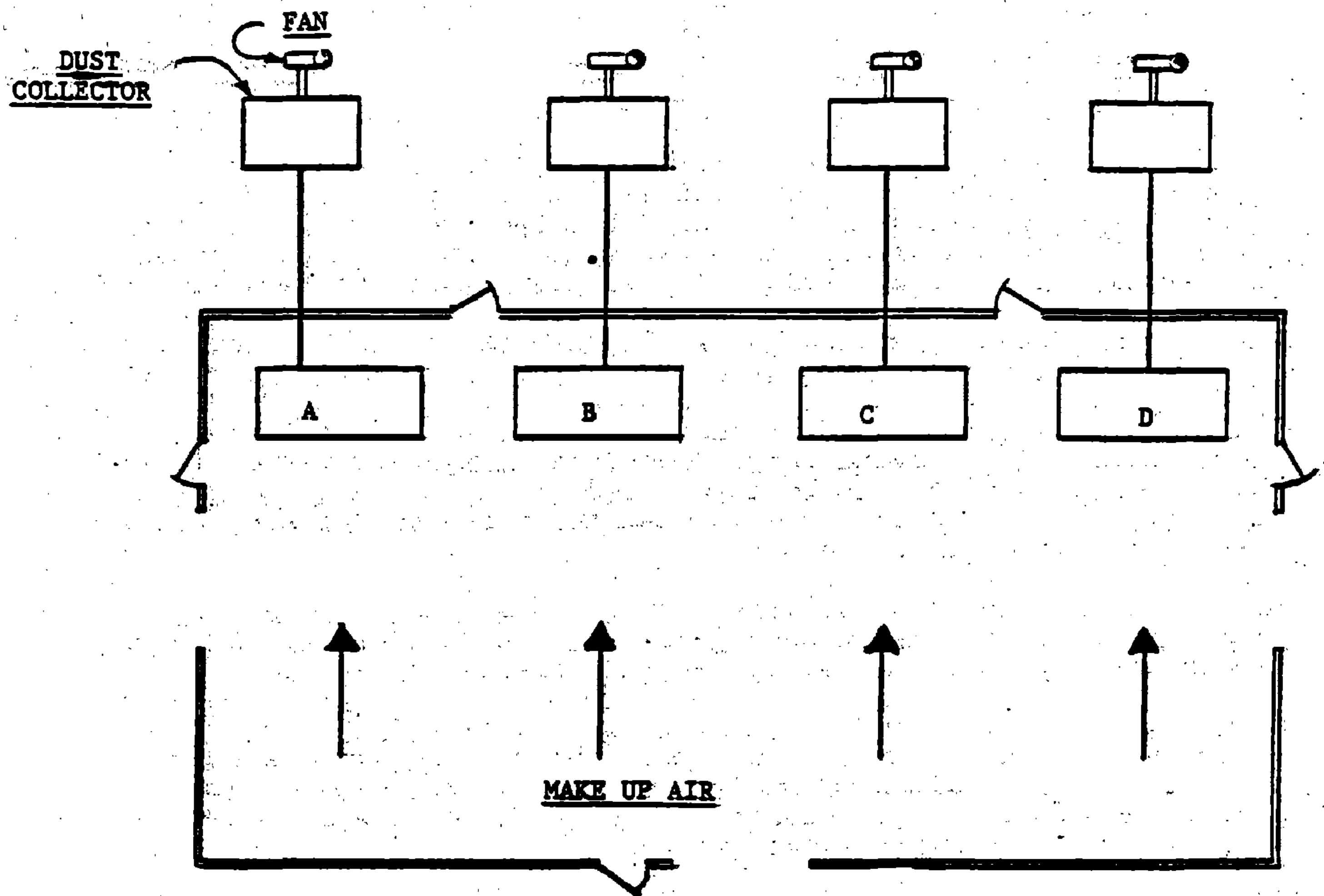
Figure 8 shows how makeup air can be used to advantage if controlled and designed into the ventilation system. The bad effects of one system contaminating another in a room can be minimized.

Dirty and improperly cared for floors are sources of much unwanted plant exposure. Fork trucks can stir up dust on floors, and their fans can blow it around. Push brooms can stir up dust, as can whisk brooms. Properly used vacuum cleaners, however, are good ways to clean floors. Riding cleaners have their place in warehouses, hallways, and so on, but they have limitations. They require constant adjustment and care, and are no good in a dusty environment because the side wheels stir up dust that cannot be picked up by the vacuum.

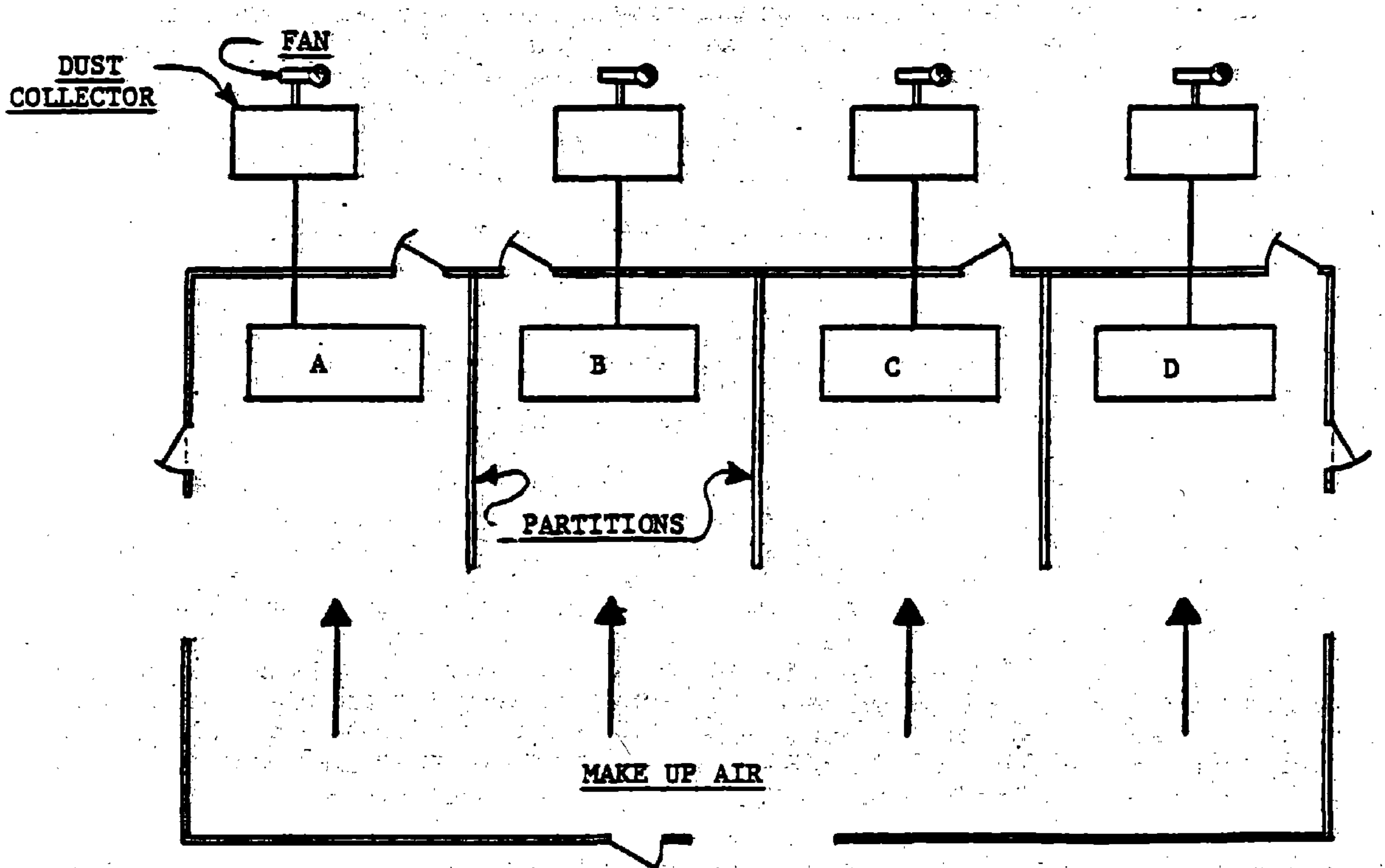
Portable vacuums have their problems too. They are always in the wrong place at the wrong time. Operators forget to dump bags, hoses lay around and get damaged and dirty. They become tripping hazards. The type and design of these collectors must be watched closely to make sure toxic exhaust fumes do not reenter the work area. The bag-type collectors that sit on drums, although popular and inexpensive to purchase, are unacceptable for use in a pesticide formulation plant. Vacuum-cleaning systems used in a formulating room should be exhausted through the general ventilation collector.

Floor washers have been used with success in warehouse aisles and in some production areas. Their advantage is that they do not stir up dust. Their disadvantage is that they require continual maintenance, and the waste product must be disposed of in a controlled manner.

The only really acceptable method of cleaning a dry formulation plant is a good, well-designed, installed central vacuum cleaner system. This type of system is on call at all times. The hoses


FAN
DUST COLLECTOR
A
B
C
D
MAKE UP AIR

GOOD


FAN
DUST COLLECTOR
A
B
C
D
PARTITIONS
MAKE UP AIR

BETTER

and tools are piped to the spill areas and are ready for the operator to use when the need arises. It is easier and more pleasant for the operator to clean up immediately rather than to wait. This central system does not stir up dust or cause cross-contamination. The discharge can, in many cases, be reworked. The use of top hat separators allows one central vacuum to be used on more than one line and still keep the sweepings separate and uncontaminated for rework.

Pits are undesirable. As a general precaution in designing a formulation plant, avoid them. They are always dirty and hazardous. Workers don't like to enter them, thus they neglect their upkeep and maintenance. Unsuspected fumes can accumulate, causing inhalation or explosion hazards.

Equipment on flat concrete pads, on the other hand, is accessible for inspection and maintenance and can be kept cleaner. In general, equipment kept this way is easier and safer to operate.

Don't put too many production lines in one building. So-called space utilization experts with eyes upon minimizing expense would love to see four batch systems in a row. It cuts installation costs and appears to be easier to manage. The foreman can stand in one place and control everything.

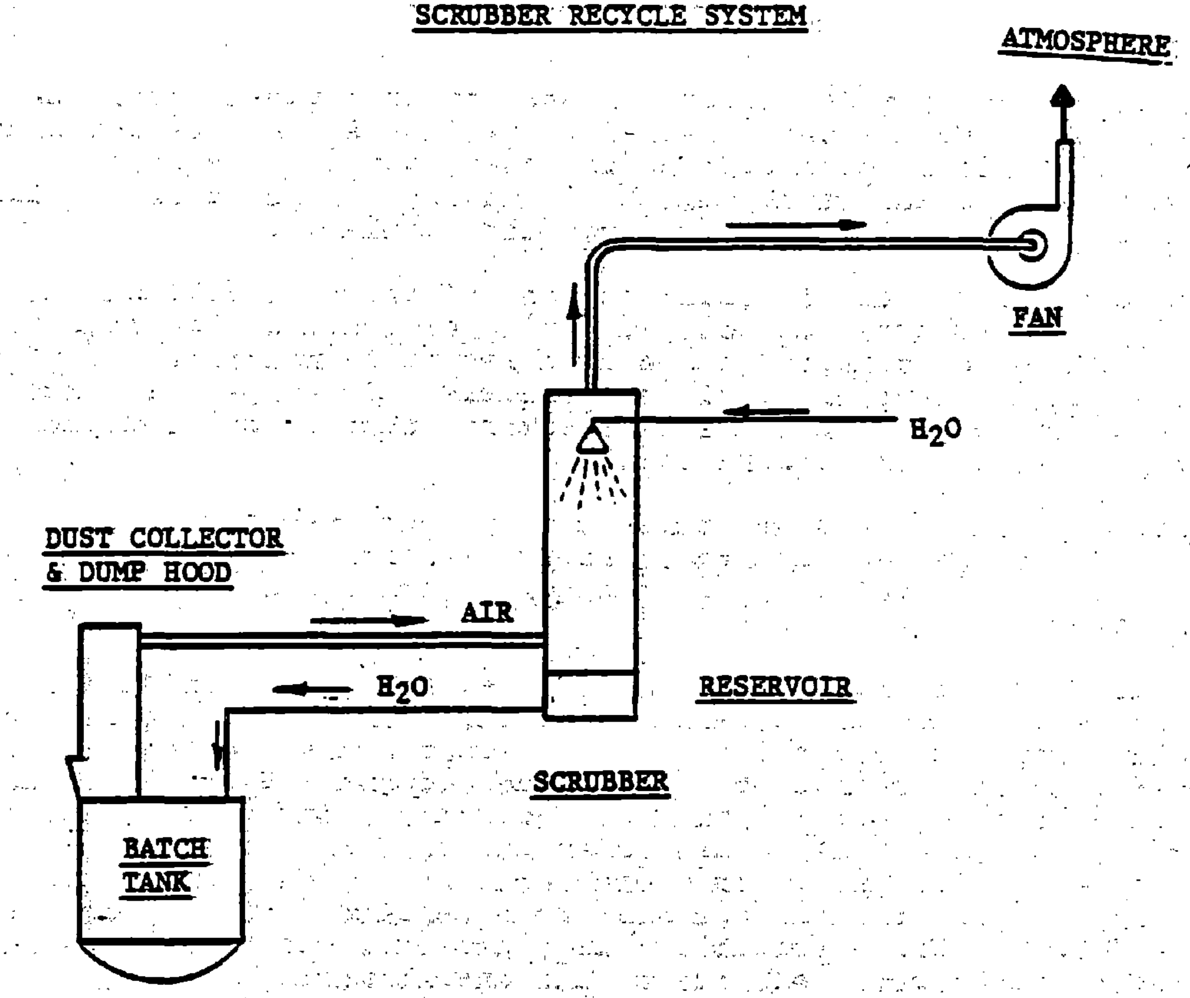
The problem comes with cross-contamination. It is difficult to keep wastes segregated for rework. Spills or upsets on any one system disrupt all other systems. Ventilation air on the strong system will capture air pollutants from other systems, creating workplace hazards. Storage of raw materials and finished goods, box and container staging, all become crowded and difficult to manage when too many production facilities are operated within a confined space. From a safety and environmental point of view, the best setup would be one production facility per building.

Plenty of space should be provided for access to equipment for maintenance, cleanup, future expansion, and avoidance of cross-contamination. Area is required for fork truck travel, storage of raw materials, and storage of materials in process. Carton staging areas are required for different packaging lines. Unobstructed access must be provided to exits, safety showers, eye washes, power switches, and fire extinguishers.

A few other points of note: Waste, where possible, should be recycled. In this dicussion I referred to spill containment, dust collector recycling, vacuum-cleaner recycling, and, in Figure 9, a scrubber recycle system. A water-soluble material is dumped into the batch tank through the dump hood. The fumes and dust are captured and run through a water-flushed packed column. The sludge is recycled back to the original mix tank, eliminating a solid-waste disposal problem. Innovative approaches must be used on all systems to control and utilize pesticide wastes to eliminate the exposure caused to operators in disposing of these wastes, and in order to live with current disposal regulations.

FIGURE 9

SCRUBBER RECYCLE SYSTEM



FUMES PASS THROUGH PACKED COLUMN WHERE THEY ARE SCRUBBED
WITH WATER AND GO TO ATMOSPHERE.
WATER IS DRAWN FROM SCRUBBER TO BATCH TANK FOR NEXT BATCH.
SYSTEM PROVIDES CONTINUOUS WASHDOWN OF PACKED COLUMN POLLUTIONS.
SCRUBBING SOLUTION AND WASTE ARE RECYCLED.

To reduce fire hazards, materials handled in a plant should be researched to assure that special conditions are met as required. Proper electrical codes must be followed, equipment must be grounded, explosion vents must be installed and maintained. Inert gas must be available when required for blanketing.

Pumps and filters are frequent sources of operator contact with chemicals. Exposures are caused during cleanout and decontamination required on changeover and as a result of maintenance. Use care. Keep systems as simple as possible. On pumps, use external bearings and seals. Spend a little more money to buy equipment that is easy and fast to maintain.

In summary, all pesticide formulation plants must be designed around the concept of operator safety. As far as possible, the need for specialized protective clothing and equipment should be minimized.

The plant must be built using basic design practice and criteria. Layouts should provide access to equipment and safety items, and to allow for fork truck travel and storage areas. Makeup air and cross-contamination must be taken into account. Ventilation hoods, vacuum cleaners, material handling equipment, and dust collectors must be designed to allow safe operation and maintenance. Pits should be avoided but if they are necessary, they must be used properly. Spill containment must be considered for all materials and effluent. Where possible, waste products should be recycled to reduce the adverse effects on the environment. Finally, remember that you can design the best plant in the world but it can be a death trap if management and operators alike do not have the right attitude and training.

PACKAGING OF LIQUIDS AND SOLIDS FOR CONTROL OF EMISSIONS

Charles DeCrane
Design Engineer, Ouachita Machine Works, Inc.

An opening thought: How much is your product worth if you don't get it into a package and either to the next process or to the customer? Along that line, the general problem in all of industry is that packaging is the last operation in the process. So many times, unfortunately, it is left until last in planning and capital expenditure considerations as well. Then we find that we have a product and no package, and no method of getting it into the package. However, if you get packaging experts and packaging machinery involved at the beginning of the program, they have lead time to come up with a solution to potential problems. Without that you end up eager to get that product to the market. You put the packaging problem and the machinery problem into the experts' laps and say, "We have x amount of dollars, and thirty days to do it." Well, there's no way that someone can come up with a solution to your problem in thirty days, or sixty days, or ninety days, if it has been chased all the way through processing down to this point. Therefore, I urge you to consider packaging in the initial stages of any expansion or new construction.

Here are some examples of the industry problems. There are many small operations. There is outdated technology and packaging equipment. Many times there is a lack of knowledge in the area of packaging and equipment at both the plant level and the consultant level. Dependable closure on a package (important to your industry especially) is a problem. Finally, there is the problem of control of health hazards.

Regarding control of health hazards, some of what I plan to present and some of what Jim [Pace] presented might seem to conflict, but it really does not. It's in the area of the hoods. As Jim stated earlier, it's the way they're applied. It all goes back to the fact that you need to analyze the specific application of everything.

I will quote an excerpt from the NIOSH/EPA Control Technology Assessment:

> A large proportion of the workers employed in the pesticide industry is involved in filling and packaging operations. Container filling and sealing offer opportunities for worker exposure that are matched only by raw materials handlings. Every effort should be made to separate filling operations from other plant processes, to provide adequate ventilation and vapor or dust collection at emissions sources, and to protect workers through the use of personal protective clothing and equipment.

There are several ways to accomplish all of these.

Number one is automation. Automation of the packaging area is undoubtedly the most desirable approach to health hazard control because it minimizes the number of people potentially exposed. Automation makes it easier to design local control because the pace of operation is consistent and all machinery operates more dependably with less maintenance if it is operated at a uniform rate.

Automation offers operating economies through reduced labor, so it should be one of the easiest items on which to show cost justification. It's a common assumption that small operations can't justify automated equipment, but if it is viewed in light of minimizing personal protection devices, more consistent control of emissions, and removing much of the labor involved, there are economies. We've had success on small operations in proving payout in about nine months, which isn't bad at all, and from then on you have many benefits.

In effect, what you've done is raised production from, say, 1,000 to 1,300 bags per man to 8,000 bags per man. Or, if you look at it in the other sense, where you don't need more than 1,300 bags per shift per man, you are doing it with one man instead of three.

There are disadvantages. The initial expenditure is greater, probably forty to fifty percent higher than manual. Some plants would require a higher grade of maintenance personnel, and the investment in spare parts would be greater. That is something you would have to weigh. Automation might require more attention to housekeeping. There are some good central vacuum units on the market. One that comes to mind is Apex, out of Los Angeles, I believe.

The next item concerns outdated technology and packaging equipment. Many packaging equipment manufacturers have been in the business for some time and have failed to look to other industries for technology that would be applicable to their industry. This is now changing. New, smaller companies are becoming involved who lean on this advanced technology and borrow from it. Ours is one of them.

One example of new technology that has become available is induction and heat sealing, a recent development designed to produce reliable hygroscopic seals. This type of seal is primarily used on screw-type containers. It uses plastic-coated foil and, through induction heating, it generates heat in the foil. It melts the plastic and accomplishes the seal, and it's a reliable seal. I don't think anything prior to it has really done a successful job. And it's all automated.

Another example of new technology is stretch wrapping. Stretch wrapping has the advantage of economy in material; it does not require the degree of energy that shrink wrapping requires. Doug

[Fowler] pointed out that it is less flammable than shrink wrapping, an advantage that I was not aware of.

The overwrap of the plastic on individual packages can provide a secure package without resorting to exotic bag construction or box construction. Many times the tradeoff is an advantage.

There are several machines on the market for filling small jars, jugs, cans, flexible packaging, and boxes with fine powders--machines such as All-fill and Mateer® electric fillers, and so on.

Equipment for filling industrial-size packages is another story. That's begin tackled right now by a combination of Ouachita Machine and Howe-Richardson Scale Company, who are coming up with a process to handle fine powders in large containers, and it looks good at this point. That's probably a year downstream somewhere.

Lack of knowledge in the area of packaging and equipment is another item. And again, I quote from the Control Technology Assessment: "Filling machinery is precision equipment that must be carefully selected for safe, consistent performance and ease of maintenance." Later in the paragraph it says, "Care must be taken because of initial capital investment." If you're looking at automation that exceeds your needs, realize that automated equipment isn't necessarily flexible. In this area, lean heavily on experts in the field. Do not get tied into one consultant or one machinery manufacturer. Consult several and get input from several. Many times common sense will tell you which one is most logical. But do this in the planning stages.

Most modern equipment will do the job within its capabilities, but it's very easy to get out of its capability, and then, very often, you can get into serious trouble, particularly in the pesticide industry. Packaging engineers are becoming more common as companies become more aware of regulations and more aware of the notorious image that the industry has with the public.

Concerning dependable closure on packages, there are many variables to consider: flexible packages, rigid containers, liquid or solid product type of closure. Since I'm most familiar with flexible packaging, I'll concentrate on that. It is the most difficult to deal with because of variations in paper weight and in construction, glue patterns, stepping patterns; different plies in the materials used--you have barrier materials, plastic materials, foil. Flexible packages can generally be grouped into two categories: open mouth and valve bags. Open-mouth bags are becoming more prominent because they offer a better closure. They're more secure, and they don't sift. Generally they use a heat seal. On a heat-seal bag you have an inner play of coated paper, film, or coated foil. All of them will seal with variable degrees of reliability, but to get a seal that is dependable, such as is required in the pesticide-herbicide industry, I would urge you to stick to polyethylene coated foil or a plastic-coated foil. This will give you a reliable seal both for vapor protection and for hygroscopic material. If it's hygroscopic, it'll protect the material against the moisture and also against leaking. Valve-top bags have been used but they're fading fast because of problems with sifting and not being able to get a secure seal.

On the processor's end, if he can't get a successful seal, many times the manufacturer of the bag can't provide a dependable seal.

Now we get into localized control of health hazards in systems that utilize hoods. I'll try to cover them in different stages.

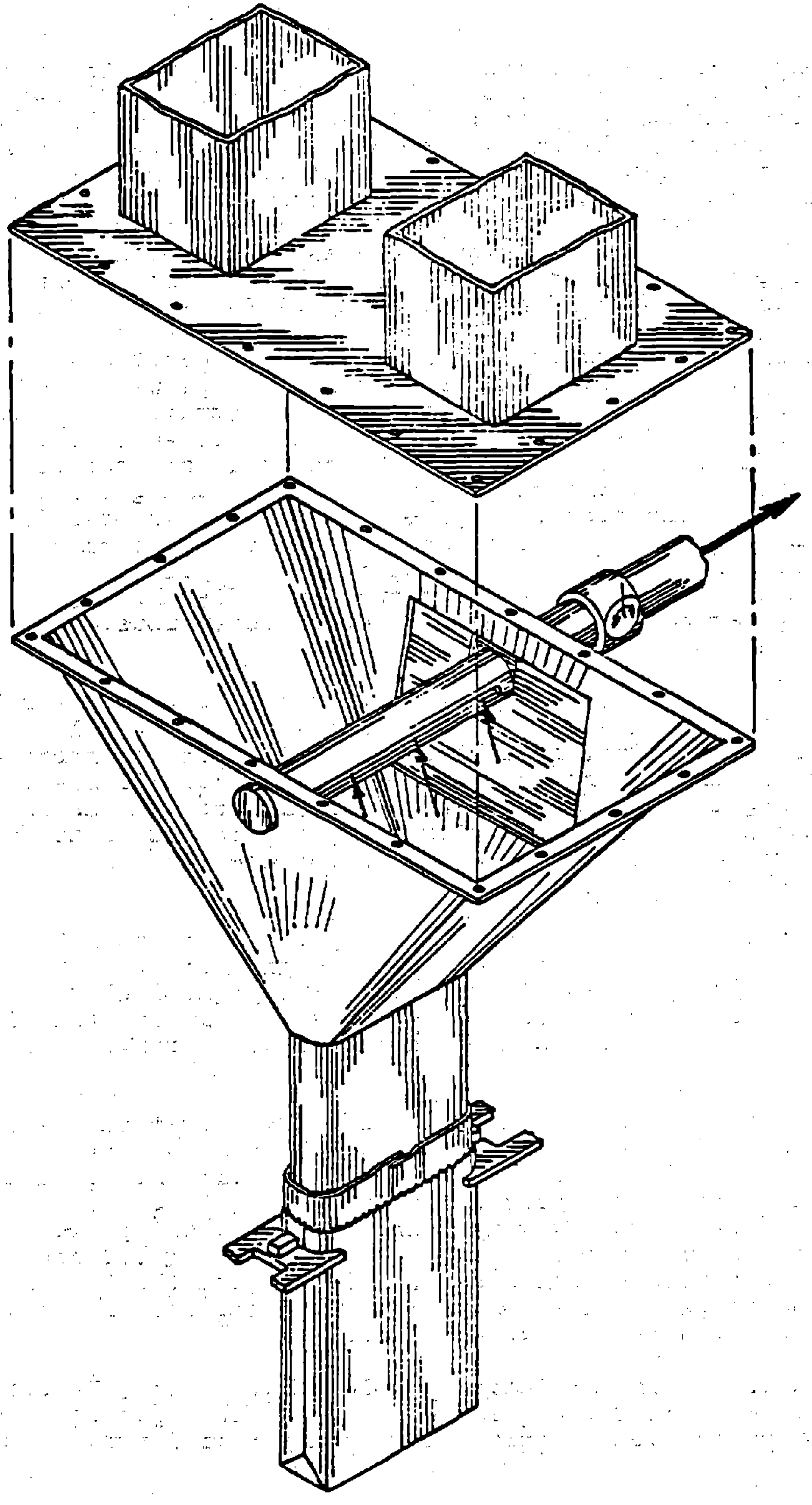
What we attempt to do is control as opposed to collect at the point of generation. If you attempt to maintain the emissions or potential emissions within a give volume, you can size all of your ducting and hoods. You can control them very closely for effective collection or control. Essentially, once you control it, you have collected it.

If you allow the emission to escape into the atmosphere in a packaging area, then you're fighting drafts, you're fighting the tendency of the emission to go in a different direction, and you're trying to collect it back or regain control of it, so it requires a much greater flow or volume of air. In that way, you increase the initial cost of equipment, including the sizing of the fans, the blowers, and the bag houses. Also, you increase energy costs, an important factor these days. Again, retain a consultant who has experience with the pesticide/herbicide industry and with your particular problems in order to control your pollutant more effectively. As Jim [Pace] mentioned, if you go by the old manuals and just pull something out of there, many times it's not going to work as it's supposed to.

Something along this line is: Avoid arbitrary addition of branch circuits after a system has been sized, or something like this can happen: A system is effective, but somewhere down the line they need a drop sump. Maintenance supplies it, and then someone else needs one downstream. Pretty soon you've overloaded the system and there isn't any one place where you're getting effective control.

I will now discuss localized control of emissions. Dust and vapor control, Level One, consists of a transition chute with exhaust duct and controls. (See Figure 1.) An exhaust duct traverses the filling chute and is operative from the time the filled bag is released by the bag-clamping action until the next bag is placed on the bag hanger just prior to scale discharge. The exhaust duct contains axial slots on the bottom center line, and forty-five degrees either side of center line. The size of these slots and the diameter of the duct are sized for each installation to meet individual requirements of product, scale, and transition chute volume.

FIGURE 1



LEVEL ONE

A damper in the duct controls exhaust action. The damper is activated in response to a signal from "bag-in-place" switches, which are located on the primary bag clamps. During the time of product discharge from the scale, the damper is closed. There is no air movement in the transition chute or the bag hanger that would disturb the product charge as it travels to the multiwall bag. As the bag is released to drop to the trough below, exhaust action clears both the transition chute and the area above the bag. Scavenging action continues until the next bag is in place on the bag hanger. Cost is approximately $1,600.

Dust and vapor control, or Level Two, consists of Level One controls plus control at the bag hanger (supplemental clamps with dust shroud). As the primary clamping action is accomplished, the "bag-in-place" switches complete a circuit which activates "supplemental clamps." These clamps contact the opposite faces of the spouted bag and gently press the remaining circumference of the bag to the spout. Figure 2 shows the two positions of the clamps, as well as the exhaust chambers that form around the overlapping portions of the expanding fill spout. The bottom portion of this exhaust chamber is formed by a flexible member attached to the bag clamp. Exhaust action is continuous. The cost varies from $650 to $2,300.

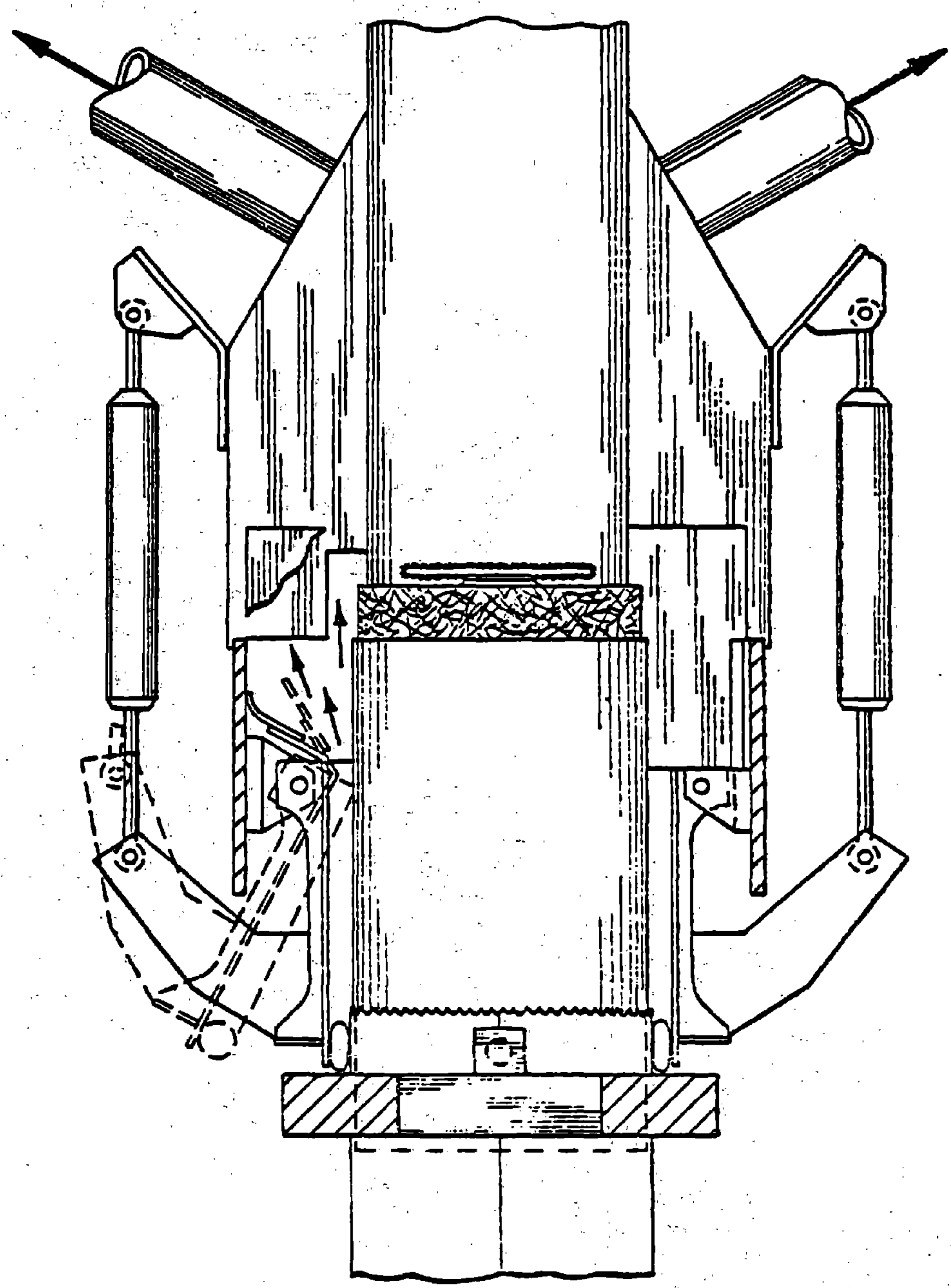
The last stage, Level Three, consists of Levels One and Two complemented by an exhaust hood which extends the full length of the machine (full dust hood/plenum). This hood incorporates a plenum chamber, created by an open mesh in the top (Figure 3), over the settling and reclosing area, to insure uniform distribution. This method is primarily for picking up vapors and light dust which the product continues to give off during the reforming of the gusset and closure process.

Required air volume increases as you move through Levels One, Two, and Three: Levels One and Two are effective with an air volume of approximately 2000 cfm at approximately three to four inches of water. Adding Level Three capability will increase the requirement to 6000 cfm. Costs will vary, ranging from $4,400 to $7,000.

Let's look at some case histories. The first one has to do with paraformaldehyde, in 50# multiwall bags. They had a problem with vapors escaping into the atmosphere in the packaging area. They had an atmospheric concentration of 7 to 10 ppm of paraformaldehyde. The operators would sabotage the machines for a reason to get out of the area. Even using personal protection devices, bagging personnel would do anything to get the line shut down. So the original line, which was rated for fifteen to sixteen packages per minute, was running about seven.

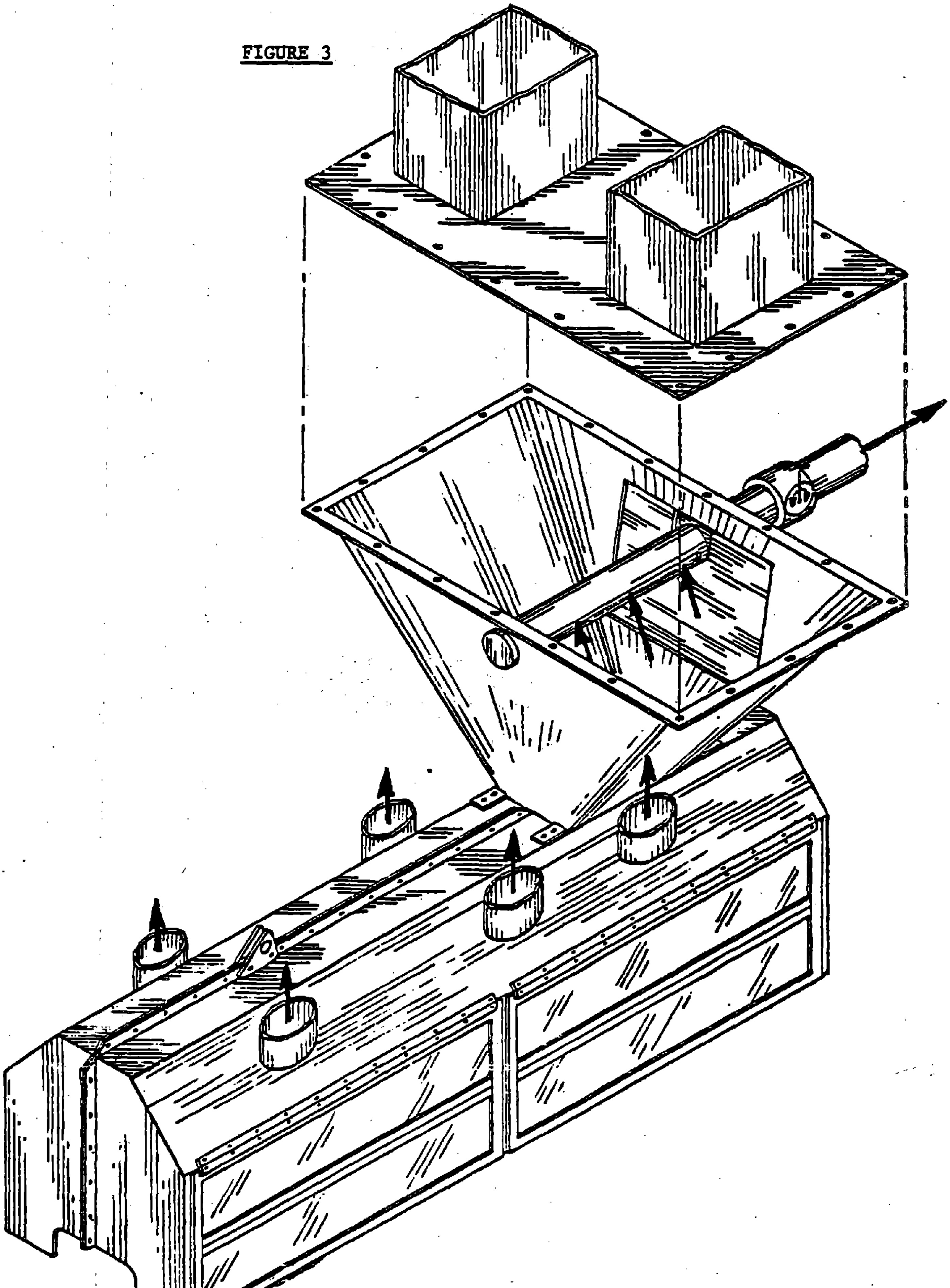
We installed an OMW-designed collection system, Levels One, Two, and Three. It raised production to fifteen packages per minute and reduced the effective concentration to 1 ppm, which, with

FIGURE 2



LEVEL TWO
(TOP VIEW)

FIGURE 3



LEVEL THREE

their methods, was the least detectable. Maintenance downtime was reduced, sabotage was eliminated, and everyone was happy.

The second case history concerns granules of a slightly toxic pesticide. They had three formulations with varying bulk density and they were operating with a different type of machine which was line rated at fourteen packages per minute. Their problems were dust, vapor, exposure, and noise, and their actual production was about nine packages per minute. We installed an OMW "sackmatic" Model 207 Automatic placer and reformer, a Westvaco® Mark V heat sealer, used a polyethylene coated-foil pinch package, and installed the whole dust control, Levels One through Three. The concentration of respirable dust was reduced from approximately two to three milligrams per cubic meter (mg/m^3) to between .1 and .5 mg/m^3. This is one that was cited in the SRI report. Production went up, maintenance went down, and noise was reduced.

In the last case history the installation only utilized the first two levels. It involved a very fine powder which attacks the upper respiratory system. They had a valve bag filler there and were trying to control the emissions by open ducting and fans. Again, this was replaced with a pinch-type package with an inner ply and the OMW dust and vapor control, Levels One and Two. Again, the result was reduced concentration in the packaging area, and production stabilized to the point where they eliminated a couple of shifts. All their packaging could be done in one shift, with a tremendous labor saving.

These cases all were with bags and fine, particulate, or granular powders. But the general technology could be and has been applied to some liquid filling. It is applicable to any operation, but would require someone who was familiar with the operations to apply it.

I suggest that you contact me or get in touch with someone else who is familiar with pesticides, herbicides, and packaging prior to getting into the packaging of your product. If you have an expansion or new construction, I can't stress enough that you should lean on people with experience.

DESIGN AND INSTALLATION OF CONTROLS-IN-PLANT: CASE HISTORY 1

Stanley L. Dryden
Manager, Industrial Hygiene, Standard Oil of California

This talk, although billed as a case history, actually presents a number of cases of successful work area exposure controls. It is given from the perspective of a large-scale pesticide formulator.

The first case involves the control of exposure to the extremely toxic organophosphate pesticide solutions. The volume of these pesticides formulated in one plant was sufficient to justify a separate area dedicated to this purpose. These products, such as parathion, have LD_{50}'s in the range of a few milligrams per kilogram. One teaspoon of technical material left on the skin for a short period of time is sufficient to kill an adult human. While some of these materials have an appreciable vapor pressure, most do not present a vapor inhalation hazard when handled at ambient temperature with even minimal ventilation. Therefore the dermal route is the greatest concern when controlling exposures.

The objectives of the dedicated organophosphate solutions formulating area were to isolate the operation in order to minimize the number of workers potentially exposed, to control vapor exposures, and to prevent skin contact. This was achieved by a combination of the following measures: (1) Unit is located in a remote corner of the plant; (2) Access is restricted; (3) Workers wear distinctive coveralls; (4) Formulating tanks are isolated from the filling operation; (5) Filling stations are well ventilated; (6) Basins are used to capture spills; (7) Floor slope and drains allow frequent washdown of the workroom; (8) Decontamination solution is used for cleanup; and (9) Contaminated protective clothing stays in area.

These engineering controls are not sufficient to assure safety. Personal protective equipment (hat, coveralls, apron, gloves, boots, gauntlets, and goggles) are still used to protect against the unexpected. In addition, a thorough, assertive, and continuous worker training program is conducted to assure that the workers know how to properly operate the equipment, prevent contact, and prevent secondary contamination (e.g., ingestion). They must also know the reasoning behind the work and hygiene rules, clearly understand the nature of the toxicity, and be able to recognize symptoms of overexposure. Finally, the program is backed up by a periodic blood cholinesterase determination; this program has been helpful in the detection of lapses in the control measures.

The second case describes an alternative method of handling in-process formulations of dry products. Traditionally in-process materials, such as premixes and products that are awaiting final packaging, have been temporarily stored in bags in the fifty- to one-hundred-pound size range. Since both the filling and the emptying of these bags present difficult exposure control problems, it was desirable to handle the material differently. The solution described is a large "transportable" bin which not only can be filled and emptied with minimal exposure to personnel, but also requires less manpower and eliminates one solid waste problem (the emptied bags). They hold about 2000 pounds of dry material. They can be handled with a forklift and with hydraulic hoists. These bins can also be used to receive the material collected from bag houses, screens, and so forth, for recycling or disposal. They also have great potential for shipment of materials from supplier to formulator; this application is to be encouraged.

Small package filling often presents dust control difficulties since, in many plants, a wide variety of product containers may be in use. Bags, boxes, canisters, and dusters may be filled in a variety of sizes. Local exhaust ventilation set up for one size and type of container may not adequately capture dust produced in filling another. An efficient method of dust control is a small, flanged slot hood located immediately behind and at the level of the top of the container being filled. However, this requires that the operators adjust the hood to the optimal height each time the product container is changed. It is a quick and simple adjustment, but experience has shown that it will not be carried out unless line supervisors are explicitly trained and held accountable for this task. Where space permits, a larger hood will solve this problem with the penalty of significantly greater air flow, larger dust collector, and so forth.

Two serious exposure problems often found around dry formulation units involve the sweeping up of spilled material and the handling of emptied bags. We have successfully controlled these sources with commercially available equipment. One vacuum cleaner manufacturer-- Nilfisk® of America, King of Prussia, Pennsylvania-- offers a push-around unit with a wide-swath pickup nozzle at floor level. This unit is well designed, not only from the standpoint of efficiency and capacity, but also with consideration for cleaning out the collected material without excessive exposure. A commercially available bag compactor, Union-Pak®, mounted near the charging point receives emptied bags without any prefolding or crushing required. It is closed and ventilated during compaction, and delivers the crushed bags inside a plastic bag.

A number of successful engineering control measures have been discussed. In every case, however, these exposure control solutions were preceded by attempts at engineering control that were not fully suitable. Although engineering controls are always the preferred first consideration, they are not as straightforward as our faith in American know-how would have us believe. Neither are engineering controls as complete and permanent as we would like them to be. Those who have never had to agonize over the conception, design, and installation of an engineering system often consider engineering controls as the perfect solution. However, we have noted problems with employees slacking off on proper work practices when they think the equipment will protect them and have also seen cases of failure to properly operate the engineering controls. This points out the need for continued efforts of education and training of line workers and supervisors.

Engineering controls often fail due to improper initial design. Ventilation system designs are often assigned to an inexperienced engineer who is not trained in the unique principles of local exhaust ventilation. Even qualified engineers often fail to consider operators' needs or maintenance needs. When this occurs the workers will make their own accommodation to these operating or maintenance requirements, often resulting in disuse or misuse of the engineering control device, and a failure to protect from exposure.

Engineering controls do not permanently control exposures without constant attention. A reliable program of periodic inspection and maintenance is required if the controls are to reliably achieve the level of protection needed. For example, even if a ventilation system is properly designed, installed, and initially balanced several things can occur to make it ineffective. The following possibilities should be investigated when you find a once-adequate system no longer performs up to par:

First, consider extension of the system. Process changes may require additional ventilation pickups. Their addition may starve the original hoods by using up fan capacity and by upsetting the system balance.

Second, investigate random adjustment of dampers. Most branched systems are balanced via dampers. If they are not locked in place, workers will invariably tamper with them in order to increase or decrease airflow to a particular hood. This may disrupt proper ventilation at another part of the operation.

Third, duct obstructions may be the cause. Ducts may become plugged by product settling in horizontal runs or by deposition of product or debris at elbows, tees, and so forth.

Fourth, there may be dust corrosion or erosion. Holes eaten in ducts by corrosive liquids or abrasive solids will admit air and thereby starve the hoods.

Or, fifth, there may be other duct damage. Ducts may be dented, separated, or otherwise damaged by careless forklift operators, hammering on plugged ducts, vibration, and so forth.

Sixth, there may be a plugged air cleaner.

Or, seventh, fan belts may be slipping.

Eighth, the problem could be the fan running backward. When a three-phase motor or controller is replaced and any two wires are switched, the motor will run backward. A centrifugal fan running backward still pumps air in the right direction, but at extreme inefficiency.

In summary, a number of engineering control solutions have been found for potentially serious exposure problems. However, these controls have not been easy to come by and may not be economically feasible for smaller-scale operations. In addition, their installation has not provided a complete and permanent answer to exposure control. They must be accompanied by the other control technology measures (training, work practices, personal protective equipment) to achieve the desired level of protection.

DESIGN AND INSTALLATION OF CONTROLS-IN-PLANT: CASE HISTORY 2

Charles Earhart, Jr., Ph.D.
Plant Manager, Platte Chemical Company

Ken Bunkowski told us about how a plant should be. When I went to Fremont for the first time, ostensibly to help them start a third shift, my thought was that somebody with a lot of experience, including experience in flowables--which were the high-technology formulation at the time--would really do well with impregnated granules. Then came the awakening.

The plant broke every one of Mr. Bunkowski's rules. The property line is one yard from the building property on the road side. Out front we have a couple of hundred feet in which to turn trucks around and park cars. This plant is not out in a rural area--it's a block and a half from Main Street. There was no dike. The change room did not have circular flow. Cholinesterase results were barely tolerable. The weigh hopper and screen were in a pit. The screen was a Link-Belt® screen, probably the most inappropriate screen for clay granules. (It's a high-frequency vibrating type that fluidizes everything within the pit.) The exhaust ventilation system had only three small bag collectors, two 339 square feet and one 236 square feet. This last one was for exhausting the bins, an open area of sixty-four square feet. My first experience in Fremont was unfreezing an air line located outside the building. The temperature was nineteen below and the wind was blowing at thirty-five miles per hour, with gusts.

We began, with some advice and help from the basics and from the Handbook of Industrial Exhaust Ventilation, to modify dust collection. The under-car unloading hopper was changed from a chute to a belt feeder to fill up the pit so we could choke-load the unloading station and just open the car hopper doors. The little dust collector that had been on the outside was moved inside (Figure 1), and that gave 3,600 cfm instead of the old 2,220 cfm for the blending/bagging area. A used dust collector was placed outside to exhaust the clay bins at about 2,700 cfm (Figure 1). We did it all with minimal engineering.

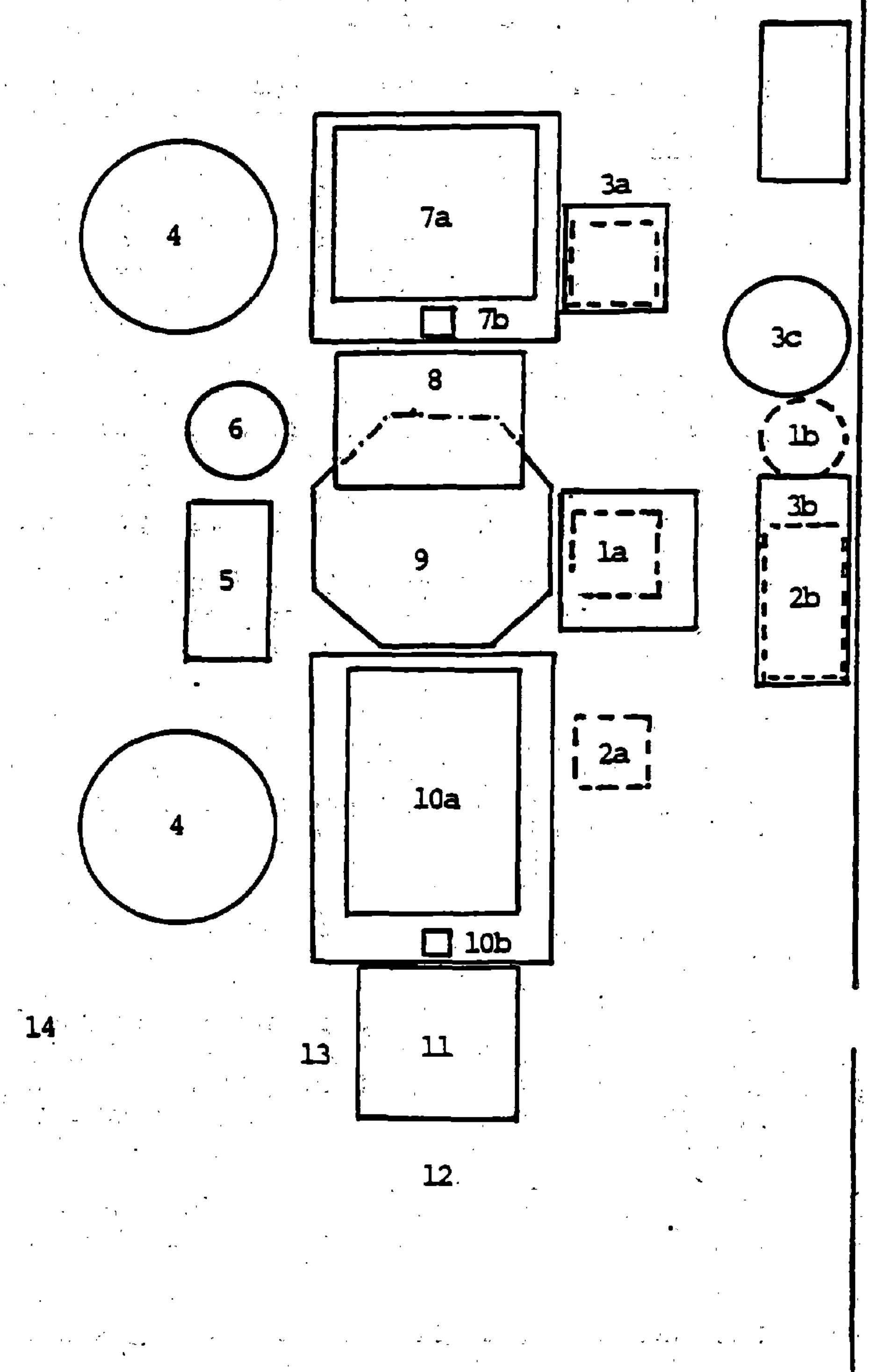
Next the change room was done. Platte is kind of proud of this because it was a great change from what we had before. Figure 2 shows the original change room. Note the break room and the utility room. The basics told us that if we didn't improve on this, they wouldn't use our services the following year. So, with a little imagination and a lot of advice, we looked at the whole situation.

BLENDING AND BAGGING AREA

1a. Original Dust Collectors
1b. Original Scrubber
2a. Dust Collector Added
2b. Carbon Absorber Added
3a. New Dust Collectors
3b. New Carbon Absorbers
4. Tech Day Tank
5. Tech Head Tank
6. Weigh Tank
7a. Weigh Hopper
7b. Elevator Leg
8. Intermediate Hopper
9. Blender
10a. Scalping Screen
10b. Elevator Leg
11. Bagging Hopper
12. Point of Loading Bags
13. Point of Sealing Bags
14. Point of Palletizing

FIGURE 1

BLENDING AND BAGGING AREA



Legend ---- old equipment, since replaced
-·-·- located under another piece of equipment

We had been running seventten people per shift, with three people under the bagger. (Platte had a Merrifield bagger, excellent for packaging sugar. But it's not designed to be maintained or cleaned, or to have pesticides around it.)

We decided to automate partially, to reduce the number of people. We eliminated one of the four showers in our redesign of the room (Figure 3), moved the break room, moved the lockers into the former break room, and moved up the entry door to the new locker room. Now we have a circular flow. While it's not perfect, it's much better than before.

The men come into the locker room and change into their coveralls through Door 1. To get into the plant they pass through the lavatory area. They go to work and come back to use the head and so on through Door 2. When they come back in after they finish work they can dump their coveralls in the washing machines and go to the shower. It is somewhat cramped and the flow isn't exactly perfect, so we have to swab out the area between shifts. It's one of the practical ways we make this do for now.

And so the change room was converted to circular flow. If you have an old plant and it seems as if it's the worst thing that could happen to you, there are places like this where you can make changes. Just take a look at it and use your head. It isn't always necessary to rip the whole thing out and replace it with something that costs three times your original investment.

The tech tanks (Figure 1) weren't there when we began our fixing up, but the little head tank was. Motor control stations were located under the head tank for the technical with the weigh tank next to it. Because all the controls are explosion-proof, they're splash-proof. Every time technical ran out of the head tank onto the motor control panel, it could be washed with bleach. One project for the 1977-78 season was to put capacitance probes into the head tank and the weigh tank. This eliminated people having to push clay under the weigh tank and sweep it back out after they ran it over.

As we entered the next season, we installed an automatic bag hanger. Figure 1 shows the weigh hopper, an intermediate clay hopper with an elevator leg going up to it, and the blender. Our scalping screen was down in a pit, and we carried it up to a bagging hopper. The Merrifield bagger was directly under the bagging hopper, and three people stood directly under the bagger, one opening the bags, one hanging them, and one putting the filled bags on the heat sealer.

With the new bag hanger, only one person is needed to introduce bags into the heat sealer. This also helped us to separate things out.

The actual installation of the bag hanger was an experience filled with trial and tribulation for Platte and for the manufacturer.

FIGURE 2

UNIMPROVED CHANGE ROOM WITHOUT CIRCULAR FLOW

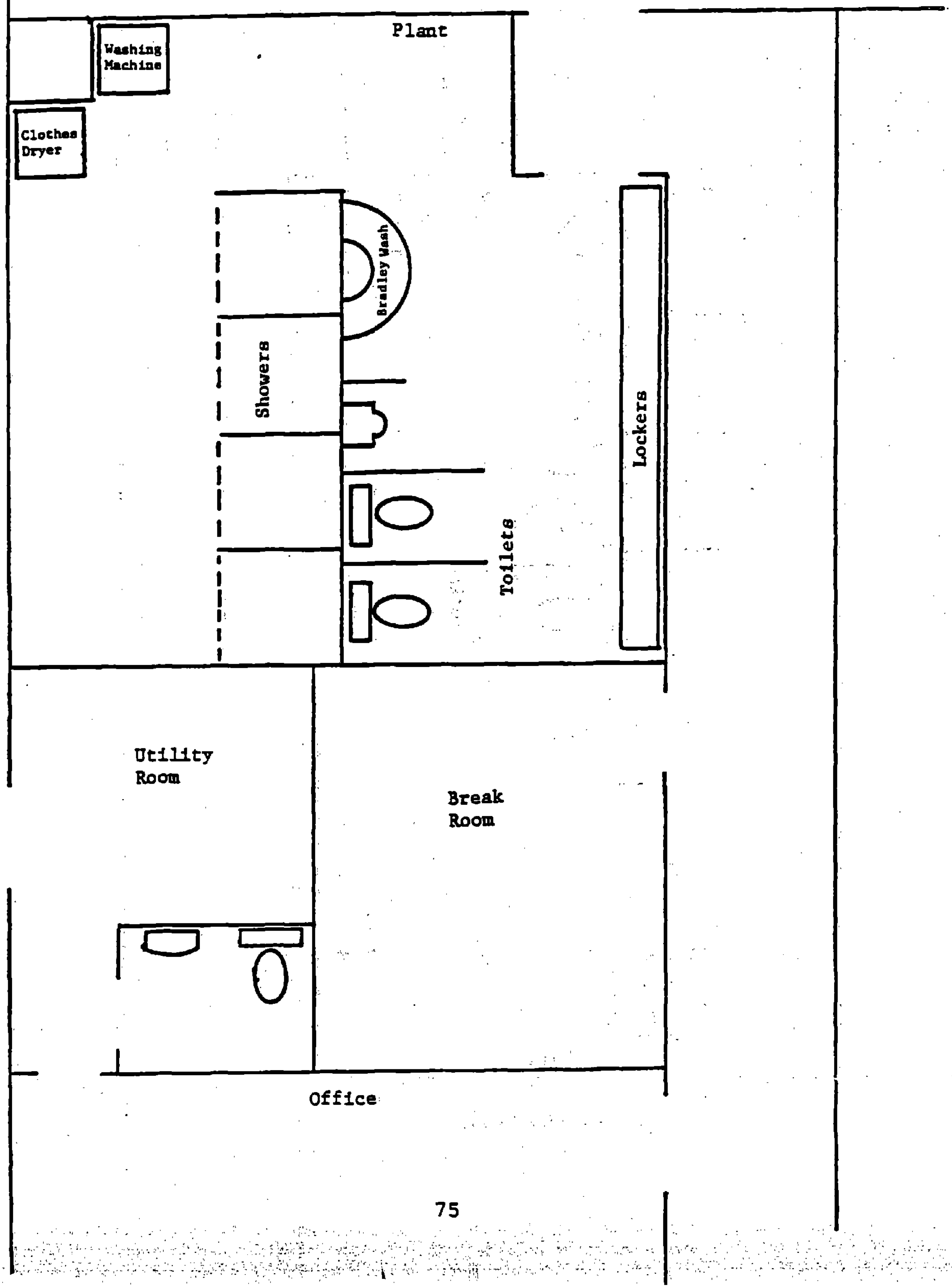
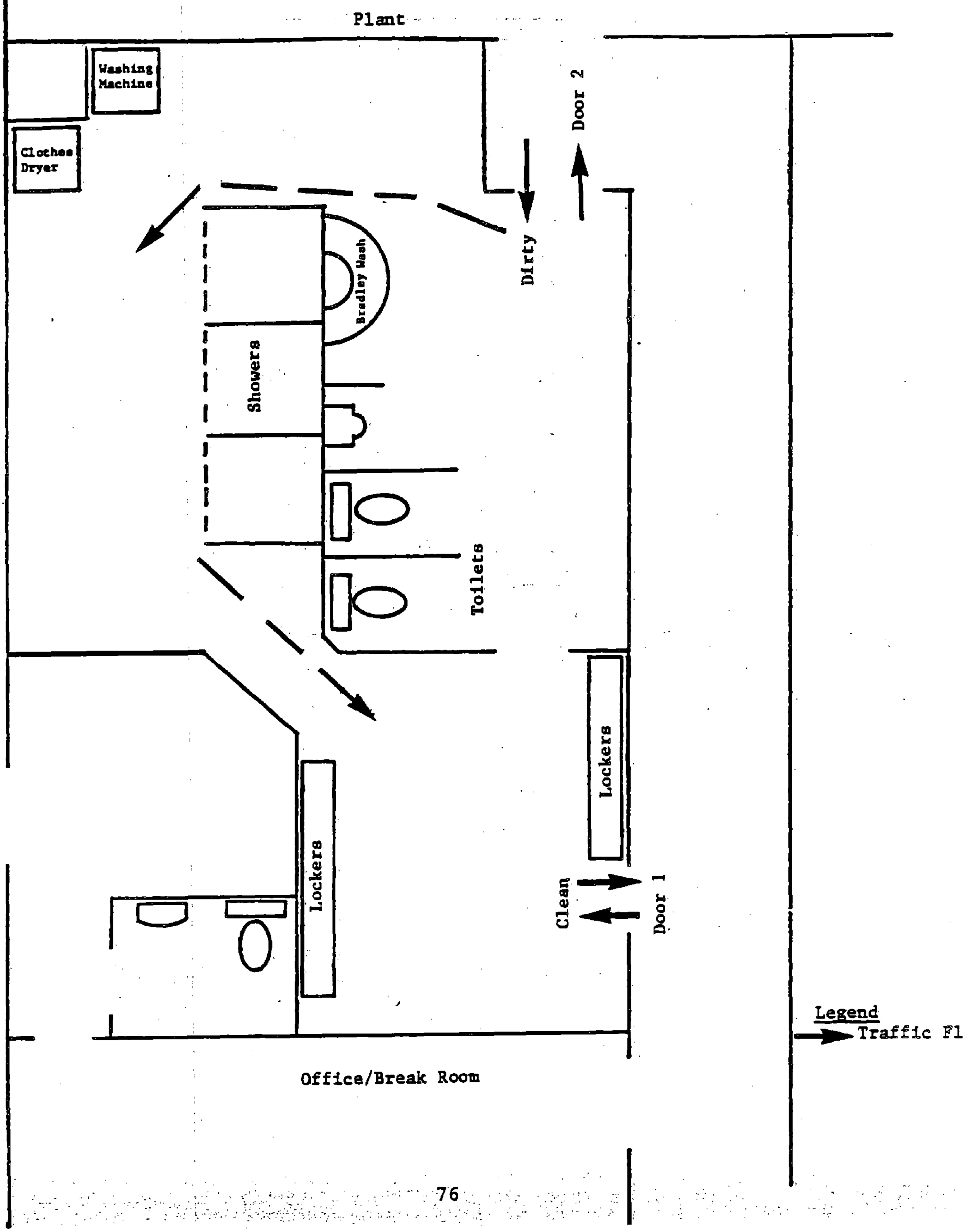


FIGURE 3

IMPROVED CHANGE ROOM WITH CIRCULAR FLOW



We even threatened to throw it away. But Union Camp stood behind their product: They came in and replaced the bag hanger with a whole new unit and control system that would hold up in a dusty environment.

In the 1978-79 season we bought carbon filters to positively control mercaptan odors. We got two (figuring that if one was good, two were better), installed them, and started up the plant. The fire department and natural gas company called us: Odor control was the poorest ever.

To try to keep our production schedule, we called in a consultant who said he could supply us with a better filter in sixteen weeks. Unfortunately, our production schedule was twenty weeks. Next we called the Calgon people, who said they could supply one in twelve weeks. We couldn't live with that either, so we talked for half an hour while they told me the results of their lab work; fluidization of carbon and so on. The result was that I took a plan scribbled on a piece of paper over to our local sheet metal man--a true mechanic. He simplified the fabrication and made it for half the original estimate. Platte's units have a six-inch-thick bed of carbon with a little reservoir on top that keep it filled. They are of a downdraft design so that they don't fluidize. We were installed and running in less than five days. Platte did produce that year.

The next year we felt we'd learned another lesson--there is no such thing as too much air. (See Figure 1.) Instead of 3,600 cfm on the hot side (the bagging and blender side) we decided to raise it to 7,700 cfm. On the clean side (the weigh and intermediate hopper side) we decided to raise from 2,200 to 5,000 cfm. In other words, we went from 3,600 plus 2,200 plus 2,700 (about 8,000 cfm) to 7,700 plus 5,000 plus 5,000, or almost 18,000 cfm of air. The old system was designed too close to work, though it worked on paper. Our solution, which worked, was to double everything.

Exhaust ventilation system number two consists of two large dust collectors, large carbon filters, and a scrubber following the carbon filter on the hot side. (See Figure 1.) (A carbon filter is used on the clean clay side because of the organophosphate insecticides. Since Platte is located downtown, it is cheaper to run the exhaust over carbon that it is to move the plant.)

In addition to a larger exhaust ventilation system, we added a new vacuum cleaner, a Nilfisk®. We placed drip pans around the pumps and moved the casing and palletizing operations out of the area. By putting a hole in the wall and running a little conveyor through, we were able to do our casing and palletizing in the warehouse. We also purchased an automatic case sealer. Essentially we removed everyone possible from the bagging area.

That concluded our preparations for the 1978-79 season. We ran through the season and it wasn't too bad. With high air flows you only have problems if you have to dump off-spec bags, if you decide to spray tech in the blender with no clay, if you decide to spray the clay twice, or if you decide not to spray the clay at all. We looked at the possibility of interlocks and decided that, for example, if you're running a ten percent granule, it was almost as bad to spray with a nine percent as it is to spray it with nothing, or with twenty percent. So, rather than put on interlocks, we decided to automate all the way.

I would like to make a pitch for automation because programmable controllers are so inexpensive now. They're relatively simple and if you have time to work on them--which people in small companies rarely do--it probably takes from three to six months for installation.

Not much was started after the 1979-80 season because that is when we began automating, a big investment for us. We had also bought the automatic bag hanger, as well as a scale with a built-in automatic checkweigher. We now have only about six underweight bags a year, so that piece of equipment has really paid for itself.

As a formulator, Platte has low margins. The automation does pay for itself in labor savings, as well as helping avoid the hazards of upset and rework.

A lot of the changes have been completed slowly. Figure 1 shows where the small dust collectors used to be and where the old scrubber and carbon filter were on the hot side. Also shown is our replacement equipment, the expansion: big dust collectors and big carbon filters.

Originally only one duct came out of the back of the weigh hopper. Then we put strips of belting across the hood to deflect the air down. But when the clays were held on the screen and the strips of belting were down, a little dust would come over the top. Our solution was to add a plenum across the top. This was possible only because the air had been increased enormously. There are now curtains on the side to help channel air into the plenum. Always progress!

If we install a programmable controller over at the weigh scale, a man will put clay in the weigh hopper. Then, based on the amount of clay discharged from the hopper, technical material and deactivator will be weighed out and sprayed onto the discharged clay: The sequencer keeps track of the batches as it moves forward through the intermediate weigh hopper into the scale. It also performs the calculations, once the formulator decides the target assay and enters the assay of the technical material. After he enters this data he has to charge between 200 and 4,400 pounds of clay. Then the correct amount of deactivator and technical material will be sprayed automatically.

The old motor control panel was ripped out in preparation for the sequencer. There is now a centralized manual control station; it has eliminated the need to run around opening up valves and gates. It is still under the head tank, but it is shielded.

Figure 1 shows where we load bags from. They're swung up below the hopper and filled bags are fed to the sealer. A sixteen-inch duct with a 400 fpm face velocity exhausts this station. Our palletizing has gone back down on the operating floor to lessen the chance of ripping those big bags.

We use Mikro-Pulsaire® because of the price they gave us and also because they fit indoors. So all the emission control equipment is inside. Two dust collectors are outside in the back at the clay unloading station, with shrouded infrared heaters on the manifolds to keep them unfrozen.

Figure 1 shows our carbon filters. We have a scrubber on the hot side. We use negative pressure up through the carbon filter. Then air is blown into the scrubber. The scrubber is there because Phil James, past President of Platte Chemical Company, told the city council that Platte was going to have a carbon filter <u>and</u> a scrubber. But when you have six inches of carbon and <u>you</u> maintain a specific velocity at the carbon face of only 50 fpm, the odor problem is handled.

Our production superintendent is the man who really did all the work--besides running the plant he also rebuilt it. Since we modified the change room, the break room took over his office. We're going to have to build him another one sometime.

CONTROL OF FUGITIVE EMISSIONS IN THE WORKPLACE

Thomas R. Blackwood, Ph.D.
Monsanto Chemical Company

As the black smokestack of the fifties disappeared from the horizons and the blue haze of the machine shop faded, it was expected that environmental and workplace air quality would improve. Though improvements have been significant on the surface, some emissions that are present in very small quantities can produce a hazardous environment more severe than a "visible" emission, especially in the pesticides industry. ("Pesticides" in this context refers to all forms of pesticides, fungicides, and herbicides as a general class of chemicals.) Because of the potential toxicity of most pesticides, general pollution control and housekeeping practices are not sufficient to control most of these substances.

It is not unusual for the major problem to be pick-up of the emission. This report describes a systematic approach to solving control problems that can be encountered in the pesticide manufacturing or formulating industry. The emphasis is on general design principles, with specific examples of successful control of hazardous emission species.

An emissions control system must consider not only the removal of air emissions, but also the prevention of catastrophic failures and subsequent exposure to the pesticides. Design is not the only issue in controlling particulate or gaseous emissions. Materials discharged into the atmosphere can reenter the workplace if the air intakes are improperly located, as was mentioned by some of the other speakers. If velocity profiles are ignored, emissions may not be picked up initially.

Before committing to a control system, it is worthwhile to consider alternate approaches which may avoid the emissions problem. As an example, for a dust control situation, one possibility is to avoid making particles small enough to become airborne. It may be possible to produce the material without fines, or with fines in the form of agglomerates. Emission situations can result from transfer of solids from bags or drums into a reactor or mixing tank whereby air is passed through a material, or a material is allowed to fall freely through the air. Reducing agitation of the material may ideally eliminate the need for an emissions control system. Fine particles which are easily airborne are also generated in the condensation or sublimation process. When the chemical processing techniques can be altered to avoid condensation or possible evaporation from a droplet, the need for collection of the emissions may be negated.

These are a few of the areas which can be investigated with an eye toward minimizing the quantity of emissions that need to be controlled.

A typical dust control system may be divided into six parts: containment or caputre of the emission; transfer of the contaminated air; separation or destruction of the emission; disposal of the collected material or by-product; movement of the air or transport gas; and dispersal of the cleaned air.

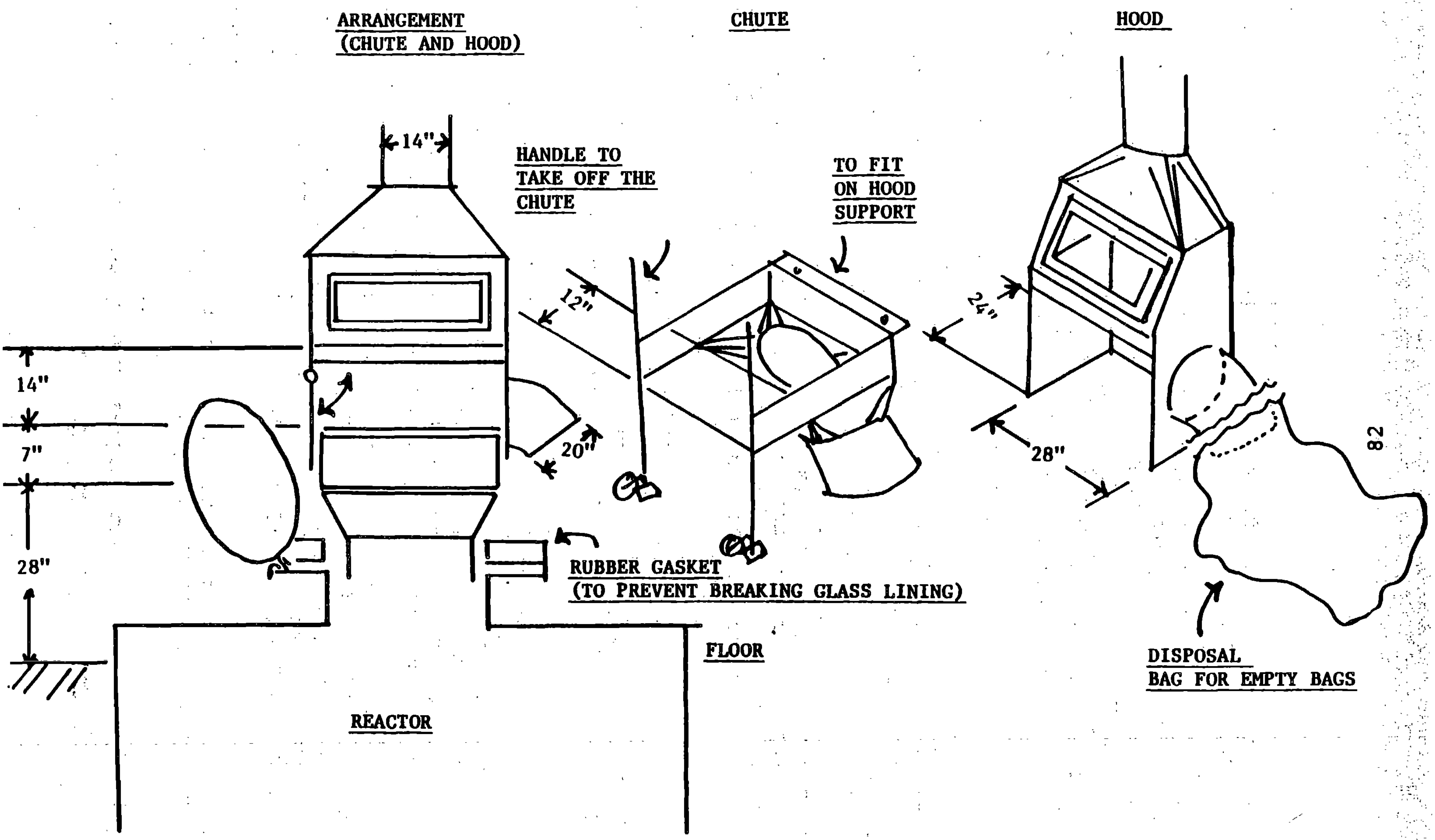
Containment refers to total enclosure of a source, and is applicable to control of emissions from storage and to transfer from one vessel to another. Containment can be used for many liquids, but this method would not be acceptable for highly flammable liquids or when the transport distance is large. Containment may be applied to bulk handling of solids. This requires cooperation between supplier and user to develop a bag and transport system.

Capture of emissions involves the use of a flowing gas, usually air, to sweep the contaminated area of emission. This is by far one of the most critical points in the design of emissions control systems. It is also the point where the most mistakes are made.

Most industrial ventilation guides recommend minimum capture velocity, depending upon the toxicity and flammability of a substance. The philosophy is that the more toxic a material is, the higher the gas velocity must be over the area ventilated in order to prevent emissions from escaping into the workplace. However, velocity of ventilation should be taken as a guideline rather than a rigid criterion. (See Table 1.) As an example, the cross-sectional area of emission may be so large that the volume of air that must be ventilated is also extremely large. Also, velocity varies significantly across the opening when the opening is very large. The velocity profile is further confounded by disturbances to the air-flow pattern caused by workers around the hood.

Figure 1 shows a hood which provides for good control of dust and uses a reasonable quantity of air. Normal engineering process would indicate that this is an adequate design. The hood was used to charge fifty-pound bags of a lacrimating chemical to a reactor. Even with the hood and a 500 fpm face velocity, the concentration of dust could not be kept below the recommended TLV® of fifty micrograms per cubic meter of air. (See Table 2.) Because of the potential of accidental spill of the chemical, respirators were used by all workers during the critical handling operation. However, an improvement in the process was required for the safety of workers in adjacent areas.

FIGURE 1



HOOD FOR CAPTURE OF DUST AND VAPORS

TABLE 1

RECOMMENDED CAPTURE VELOCITIES

FOR HOOD DESIGN INVOLVING HAZARDOUS MATERIALS

Condition of Dispersion of Contaminant	Examples	Capture Velocity, fpm
Released with practically no velocity into quiet air.	Evaporation from tanks.	100
Released al low velocity into moderately still air.	Spray booths; intermittent container filling; low speed conveyor transfers; welding; plating; pickling.	200
Active generation into zone of rapid air motion.	Spray painting in shallow booths; barrel filling; conveyor loading; crushers.	500
Released at high initial velocity into zone of very rapid air motion.	Grinding; abrasive blasting, tumbling.	2000

TABLE 2

RESULTS OBTAINED WITH THE HOOD

Location	Average Results with Former System mg/m^3	Average Results with New System mg/m^3	% of Reduction Achieved
A	2.50	0.032	97%
B	2.34	0.009	Over 99%
C	1.12	0.031	97%
D	6.28	0.010	Over 99%

The following steps were taken to improve the situation: A rubber baffle was installed around the hood opening to allow the workers to get closer to the worktable within the hood and thereby keep the air velocity high. Bags were cut on the worktable under the hood. (The workers had previously preferred to cut the bags on the pallet.) Educating the workers had convinced them that using the ventilated hood was better practice. Provision was made for vacuum cleanup of the work area and worktable prior to removing the chute. Air was discharged into the suction system. Air curtains were provided to give an air sweep if the preceding modifications were insufficient. (This did not turn out to be the case.)

Table 2 and Figure 2 show the emission levels that were obtained during an intensive sampling campaign that took palce after these modifications. Although the emission levels show almost a one hundred percent improvement in air quality, it is still anticipated that bag opening and dumping would have to be further mechanized to reduce employee exposure. The controls currently provide a reasonable margin of safety with the charging occurring about once a day.

Since air exerts a greater outreach on discharge out of a pipe than suction does into a pipe, contaminant collection can be increased using an air curtain system, which requires a smaller volume of air. High-velocity air jets or air curtains are especially useful on the redesign of an existing system, where air velocity may be expensive or difficult to change.

Figure 3 shows the use of an air jet in a push-pull arrangement. Ventilation of a vessel was needed during cleanup operations. This system is designed with a face velocity of 200 fps at the collector and a jet velocity of 4000 fpm to transport the emission to the collector. The particular operation shown in Figure 4 is located out of doors. Barriers have been installed to minimize disturbances caused by changes in wind direction and velocity.

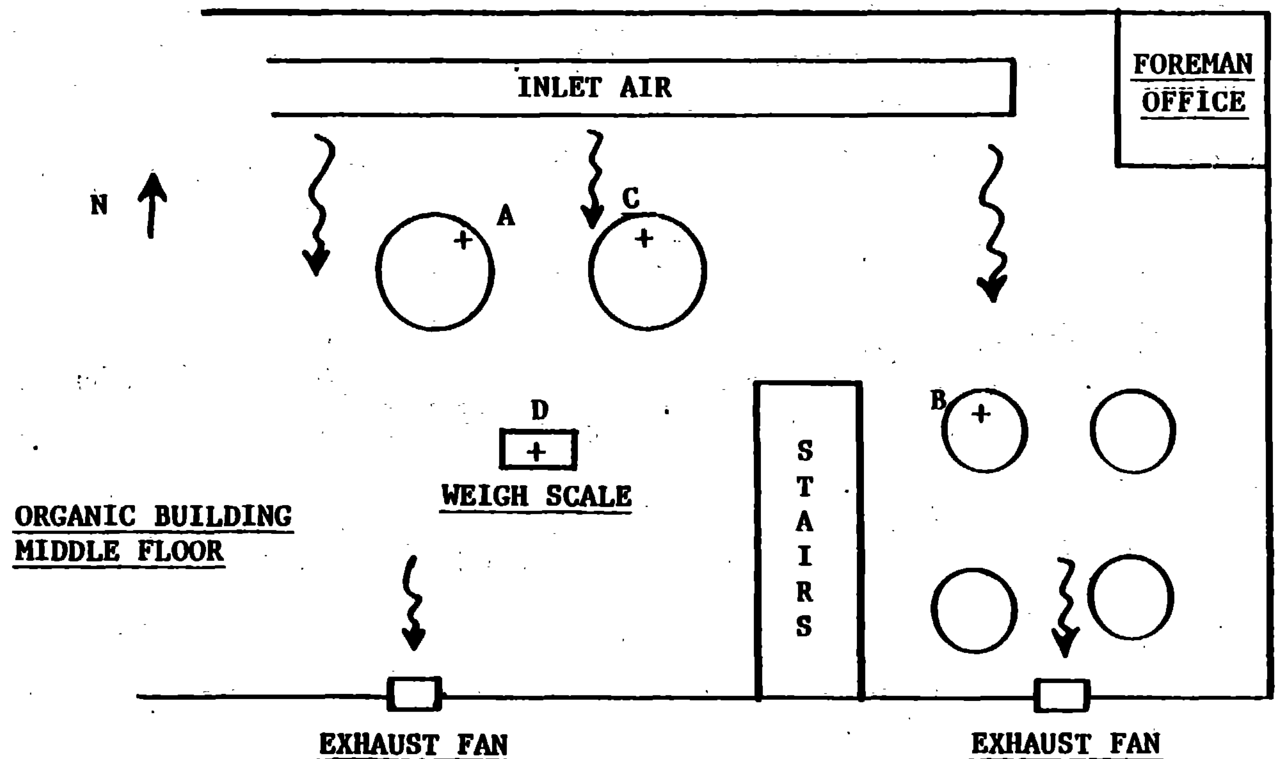
The following equation can be used in the design of air curtains such as the push-pull system just described.

$$Vc/Vo = 2.28 \left(\frac{D}{x}\right)^{1/2} \quad \text{for} \quad 5 \left(\frac{x}{D}\right) < 2000$$

Vc = centerline velocity, m/s
Vo = initial slot velocity, m/s
D = slot width, m
x = distance from slot, m

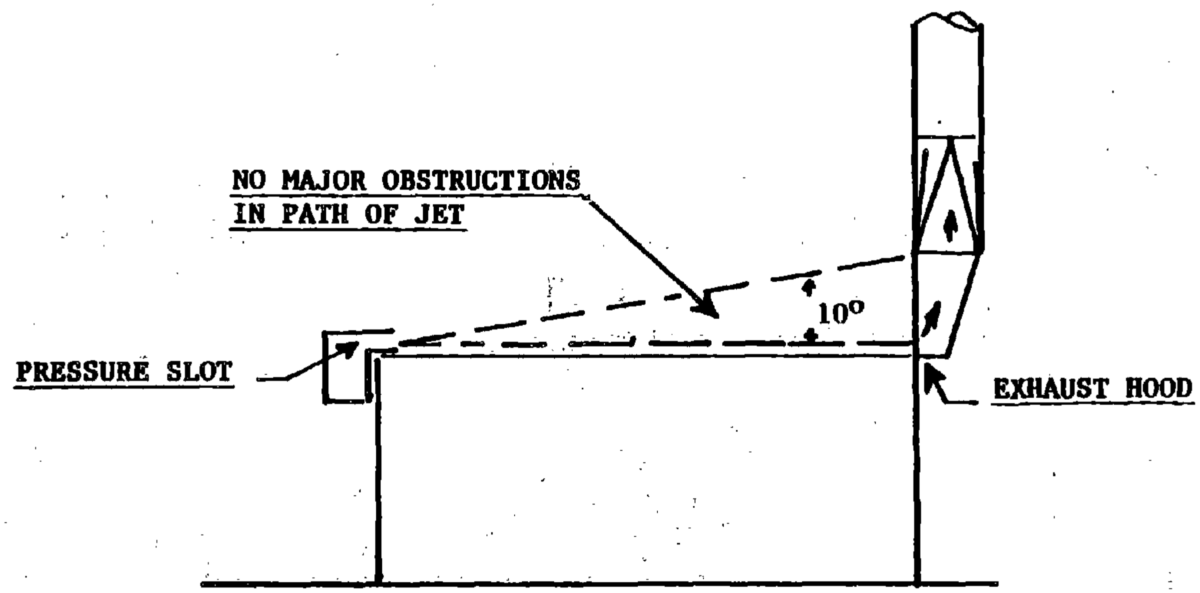
Explosion protection must be an integral part of the design of a containment or capture system. Typical protection methods include blowout doors, inert purge-gas systems to eliminate oxygen, an explosion-supression system, and pressure vessel design for deflagration.

FIGURE 2



PLANT LAYOUT FOR SAMPLING RESULTS SHOWN IN TABLE 2

FIGURE 3



AIR JET TO VENTILATE TOP OF REACTOR

Once the collection system is established, the volume of air to be transported can be calculated. Unless the enclosure is welded, gas leaks will occur at flange joints and connections. It is recommended that 10^{-3} cubic meters per second be added to the volume of air that is ventilated per flange joint. If the air volume and the quantity of emission to be caught is known, emission concentration for use in subsequent design of the collection equipment can be determined.

There is an approach to selecting proper emissions control. Figure 4 gives collection efficiencies as a function of particle size for various generic collectors. Eliminate those types of collectors that are incompatible with the process conditions: high temperatures, high humidity, corrosive gases, or abrasive material. Make an economic selection among those types of collectors you have not ruled out.

Several nontraditional techniques may have application for certain fugitive emissions in addition to the conventional methods of process control, enclosure, capture, and collection.

One recent development is the use of foam injection to control dust. Foam is much more effective than water, and constitutes only a small liquid volume when applied to the material's surface. Wetting of the fines improves. This results in a reduction of emissions. Water sprays can also be used with or without wetting agents to reduce emissions. The wetting agent will reduce the surface tension and allow particles to penetrate the water droplets. Properly directed water sprays can eliminate the need for further collection equipment when formulating a chemical in a water base. Another development is the augmentation of traditional wet suppression systems with electrostatics. Several commercial devices on the market are effective in the control of fugitive dust.

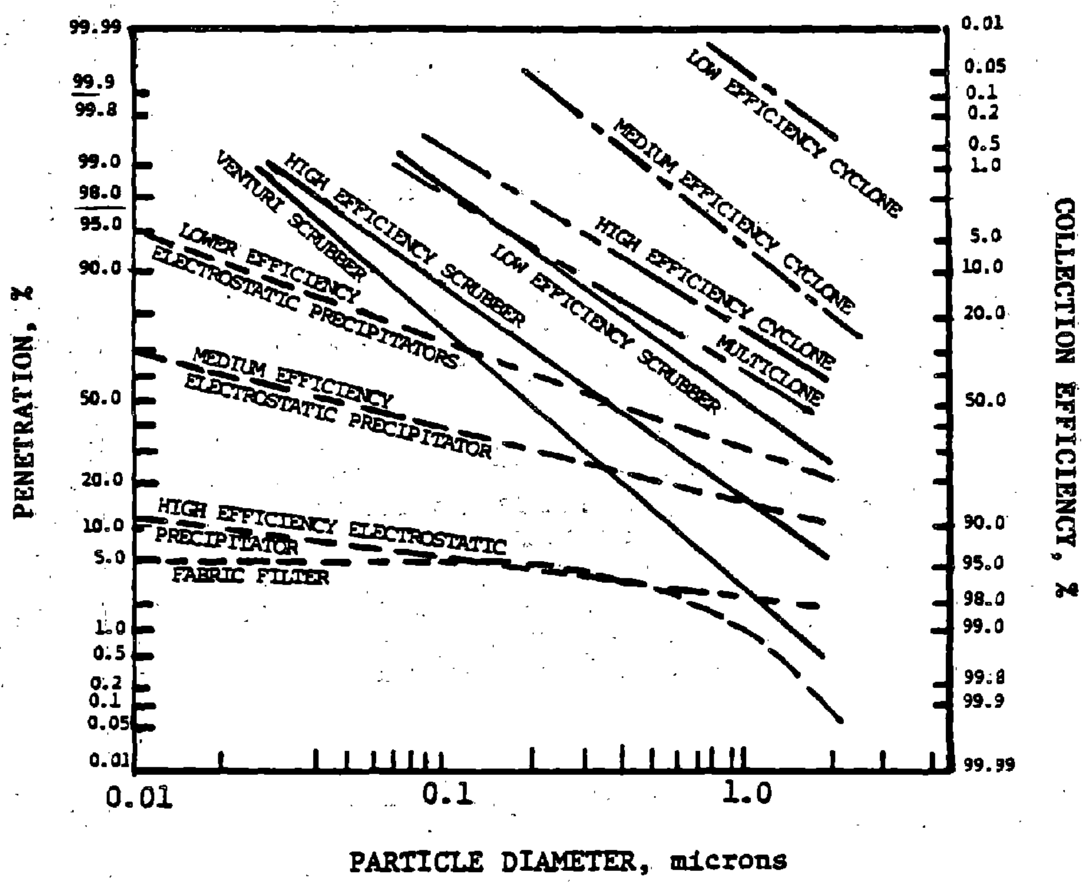
In summary, the design of an emissions control system should focus on the protection of human health and safety. With pesticide-type chemicals, the lowest possible level of emissions is the one to try to achieve; and one of the primary goals of the chemical engineer should be to design a chemical plant for worker safety and emissions reduction.

In the pesticides industry, altering the flow path of solids and liquids to prevent the contamination of the air can greatly reduce the risk associated with the manufacture of these chemicals. Containment of an emission is feasible if the process or emission points can be safety isolated from the workplace.

After these alternatives have been explored, a ventilation system for the contaminated area can be designed to capture and collect emissions. Personal protective equipment may still be employed, however, because even after all these avenues have been explored and a safe, workable level has been achieved, the risks associated with accidents still warrant the use of such equipment.

FIGURE 4

COLLECTION EFFICIENCY VS. PARTICLE SIZE



IMPROVING WORK PRACTICE PROCEDURES IN FORMULATING OPERATIONS

Vincent J. Farrell
Plant Manager, Agway, Inc.

When I was on Madison Avenue in the advertising business, I had a great idea for a commercial for a pesticide plant. Having a few years' experience in observing the people who work at pesticide plants, particularly young workers, a lot of them seem to say, "Hey, I'm a macho guy--I work in a pesticides plant." It's OK to be tough in a beer commercial, but the battle to win in the chemicals formulation business is to be safe about it.

I would like to give you some background on Agway, Inc. Agway is a farmers' cooperative, selling primarily in the twelve northeastern states. I am manager of the formulating plant located in York, Pennsylvania. We formulate and package wettable powders, dusts, granulars, emulsified concentrates, and flowables--over a hundred products for farm, home, and garden. We also custom formulate for other companies.

My talk is descriptive of our approach to hazard control. Some of the approaches have been or will be covered by other speakers.

First I will discuss engineering control. An air exhaust system on all lines controls vapor and dust. To control the hazard of fire or explosion, we have a sprinkler system and automatic and manual alarms that sound not only in the plant but also at the county fire department.

As part of our liquid formulation operation, we employ flammable gas detectors, liquid level sensors, fuse-link valves, heat controls, explosion-proof glass switches, and nonferrous grates and tools. Some of these are geared to automatic shutdown in case of a problem; others will sound an alarm. There are emergency showers and eyewash stations in stragegic locations. Acid neutralization solution is provided at the battery charge station.

In the area of employee education, we pursue several approaches. To begin with, there are several hours of "hands-on" safety indoctrination for new employees. Here each employee goes through the plant, learns how to use protective equipment, and so on.

For the last two years we've gotten into having quarterly emergency drills in addition to our quarterly safety meetings. We now have quarterly emergency injury, spill, and fire drills, all with critique and follow-up. In injury drills, only the people in a given area participate, so we can see how they are following the program. Then these little groups have a discussion and a critique. Sometimes we find major weaknesses. This follow-up method has helped us improve our program.

We also have an employee safety committee, led by a supervisor and set up with two employees, which is effective in the sense that we get some good ideas, and then employee participation carries those ideas throughout the workforce.

Safety data sheets are maintained and are available for anyone's review. A file is maintained on all ingredients that we use. Employees keep their own safety folders in their lockers. The illustration shows our Line Safety Sheet, which I will describe in detail further on.

On the subject of protective equipment, we have a standard assortment of dust masks, pesticide cartridge respirators, supplied air hoods with purified air, and self-contained breathing apparatus for emergency use in the event of a fire. These are removed from the plant to make it easier if someone has to go back to look for missing personnel. We also have chemical goggles, face shields, boots, gloves, and Tyvek® suits.

Medical testing of our employees takes place. In addition to the preemployment physical, we do tests monitoring employees' blood chemistry, and we also do an annual pulmonary function test.

We have our own on-site lab to do plant air monitoring. We use a Bendix Super Sampler for breathing zone air sampling, and we decide, from the results, what protective equipment or improvements, if any, are needed. The results are passed on to workers and a file is maintained. On-site Agway lab personnel conduct the tests and the analyses.

I shall devote the balance of my talk to those practices that we employ that I don't see covered on other speakers' agendas. I will break my discussion into five topics: identification of potential hazards, housekeeping, personal hygiene, emergencies, and other situations.

I have a broad definition of what constitutes "work practices." Today work practices involve almost everything that happens in the plant and are either good or bad practices. Good or bad, everyone is involved. I consider identification of potential hazards a good operation. I will speak primarily of potential "chemical" hazards, rather than about work practices related to forklifts or welding or things like that.

Chemical information is assembled by a supervisory group consisting of the plant manager, assistant plant manager, project supervisor, and, to an extent, the foreman.

The information we seek on a material includes oral, dermal, and inhalation toxicity; potential for fire, explosion, and reactivity; skin sensitivity or the potential for rashes or burns; symptoms of overexposure and recommended medical treatment; recommended personal protective equipment; recommended hygiene practices; and information for cleaning up spills.

Most, if not all, of this information should be available on the safety data sheets, in technical bulletins, and from suppliers, contractors, and so on. Then the catalyst that puts it all together is our own personal experience.

The important thing is, once you have gotten it all together, make use of it. It does no good unless it is transmitted to the worker. Our practice is to pass along this information as part of the original safety orientation and during safety meetings.

One information technique that we use a great deal is the Line Safety Sheet that I mentioned before, a one-page form summarizing all the information we have accrued on a given substance. The sheet is reviewed with the employees involved prior to starting production on a particular line, and it remains posted in the work area for the duration of the run. After the run, it is filed. With a hundred or so formulations, we start up a line several times a year, and it seems as if we are doing this procedure a couple of times a week. Anyone going on line after startup also reviews the sheet. All employees sign the sheet.

If an exposure does occur, say a skin exposure, it is recorded on the sheet. Also recorded is the action which was taken; in the case of a skin exposure, a shower would be in order.

Under the heading "Exposure Route" are two columns. The left column is for listing the material (technical, finished product, other). The right column is for listing actions taken to any exposure to a material.

Listed elsewhere on the sheet are the different jobs involved in producing the line and the personal protective equipment required for each: eye protection, breathing equipment, clothing, gloves, boots, aprons, and a shower midshift.

Housekeeping is another area to which we pay close attention. I think it is important that workers are involved in housekeeping. The objective is to keep clean as we operate--for example, cleaning up spills which might occur during a shift. Another part of our housekeeping effort is to clean out an area between runs. Twice a year, at inventory-taking time, we do a thorough cleanup as well.

Each area and material has its own prescribed cleanup procedure. For liquids in the production and warehouse areas, we use absorbants, followed by decontamination as necessary. With dry products, we avoid sweeping to as great an extent as possible. We use vacuums and air drawoff hookups to pick up these materials. Between products we use the floor sweeper and scrubber.

LINE SAFETY SHEET

PRODUCT ____________ TEC TYPE ____________ TOXICITY ____________

HEAT ____________ METHOD ____________ MAX. TEMP. ____________

EXPOSURE ROUTE

TECHNICAL ____________	ACTION
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________
OTHER ____________	ACTION
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________
OTHER	ACTION
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________
FINISHED PRODUCT	ACTION
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________

TYPE OF PERSONAL EQUIPMENT REQUIRED

Job	Protection		Clothing	Gloves	Rubber Boots	Shower Mid-Shift	Apron	
	Eye	Breathing						

Employees' Signatures	Date	Signatures	Date

Production

Rate 8 Hrs. ____________
Package Size ____________
Weight ____________
Target ____________
Max. ____________
Min. ____________

In the warehouse and the aisles we run the riding floor sweeper daily and the floor scrubber periodically. Broken bags must be repaired promptly.

The shower, toilet, and locker room are wet-mopped twice a day, more often if necessary. Surface areas are routinely cleaned. Workers do their own preliminary self-cleaning in the production area, as necessary.

The lunchroom, a separate room, has its floor mopped once a day, and the other surface areas cleaned twice a day. The office, too, is mopped daily, and cleaned as needed.

Our personal hygiene program is extensive. Prior to breaks, lunch, using the toilet, or smoking (in designated areas), employees are required to wash their hands and faces and make sure that their clothing is not dirty. Employees may eat only in the separate lunchroom, and are not permitted to eat, chew gum, or smoke, or carry such items in the plant.

We provide complete work uniforms, including underwear, handkerchiefs, pants, shirts, and jackets. These are never to be worn home, but are to be left in receptacles for proper cleaning in our clean room. A complete clean clothing change is available at the start of the shift for each employee. At the end of the day, employees take a thorough shower--we stress hair washing and scrubbing the fingernails. Some products require a shower at lunchtime as well, as noted earlier.

We provide special receptacles for turning in respirators or other personal protective equipment. Clothing is separated by toxicity for special handling. One individual has the job of decontaminating, cleaning, inspecting, and maintaining clothing and safety devices. This same individual does the mopping and cleaning.

Our procedure regarding respirators begins with removing the cartridges for disposal. Respirators are soaked in a high pH chlorine solution, which is easy on rubber. Respirators are then cleaned, rinsed, inspected, dried, and set out for the next use. Similar procedures are the order for rubber boots, gloves, and the like.

Clothing is inspected to insure that it is in good repair. Pants and shirts generally need to be replaced once a year.

Weather also influences our work practices. On very hot and humid days we reduce our per-shift productivity expectation. We also advocate relieving someone to get a drink of water, clothing change if necessary, and sometimes even a shower. We start the morning shift at five instead of seven so that employees do not have to work as long in the heat.

Now I will describe some of the procedures we employ in case of physical exposure. When an employee has been doused with a liquid material, he uses the emergency flood shower, followed by a thorough soap-and-water shower and a change to clean clothes. The contaminated clothing receives special handling in the clean room.

To handle a splash in the eye, the employee first uses the emergency eyebath, probably followed by a shower. If the amount or nature of the chemical is more serious, then the employee would be taken to the hospital for treatment.

We work closely with hospitals in the matter of poisonings, including keeping them informed of what we are doing in the plant, particularly in the matter of highly toxic materials. If an employee is exposed to a poison, the employee is taken to the hospital. Labels and other technical information are taken too. During their off hours, employees still carry a card for organophosphate (OP) poison symptoms. Plant management phone contact numbers are on the card. Besides instructing employees to always carry this card, they are also told to be sure their families and friends know about it and about presenting it at the hospital.

Our biggest exposure situations are the cleaning of bag houses and mixers. We have to get inside ours. We use the buddy system for shorter work periods, supply extra protection such as supplied air hoods and Tyvek® suits, and require clothing changes or shower if necessary. The electrical "lockout" program is employed.

For greater production safety, we advocate maintaining an even work pace all day long. As another measure, plant workers, including supervisors (myself included), are annually rated on safety, a rating which carries a lot of weight.

Job rotation is another measure we take to limit exposure potential. Rotation occurs on the same line during a shift and line to line on a few days to a weekly basis. Not only does this limit exposure, it also provides excellent crosstraining.

The last item I would like to mention is maintenance. Stay ahead of things. Keep air drawoffs adjusted and in good working order. Pay attention to potential leaks by keeping packing in proper condition on mixes and hoppers and so on; fix preventively. It is also up to the worker to recognize the importance of alerting the right people to maintenance problems.

IMPLEMENTATION OF GOOD WORK PRACTICES THROUGH EDUCATION AND TRAINING

Martin McGinn
Southern Mill Creek Products Company

Southern Mill Creek Products Company (SMCP) is located in Tampa, where our manufacturing facilities are. We have branches in Miami, Jacksonville, Atlanta, Puerto Rico, Costa Rica, and London. We currently employ 130 people, approximately 90 of whom are in warehousing and manufacturing. We have 182 EPA registrations, 165 of which are processed through our plant annually. Our labels include all pesticides with primary emphasis on insecticides, fungicides, and herbicides. In many instances the training and educational practices that we use are applicable to this NIOSH symposium.

There are few good books written on how to educate and train the production workers in the pesticide formulation and manufacturing environment. However, some basic guidelines are obvious. This is what my report will cover: the practical methods we use at SMCP in implementing educational and training programs for the worker.

Before discussing the training program, first I will comment on the educational, or preemployment, aspect, as this is most important. The area of overlap between training and education seems to involve more the generation of an awareness of what good work practices are. Education seems to involve more of an enlightment in attitude and perspective, something which seems to be all too often neglected. As pesticide formulators and manufacturers, we are morally obligated to disclose the full nature of the hazards involved in our business, in that materials substitution and engineering controls cannot be completely effective without worker cooperation and understanding. Educating employees to respect the materials and processes they use must yield the proper perspective without generating undue fear. They must understand that chemicals are not of themselves necessarily "bad" or "good," but instead depend on use, type, amount, environment, and so on. In other words, the subject of how dangerous a substance is can be answered most accurately by stating that it is entirely dependent upon how it is handled. For example, many chemicals are essential to good health in small quantities; in larger quantities, they are acutely and chronically toxic. The popular concerns on hazards of our environment often fail to realize that "environment" does not necessarily equal "industry." It is not technologically feasible to create a zero-risk situation. However, with good workplace practices we can achieve an acceptable level of risk.

Because of the emotional aspects of such an issue, objectivity seems best achieved through educating the attitude to achieve a good perspective. Specifically, these are some of the actions that we at SMCP implement relative to education and preemployment.

We prefer that all our plant and warehouse employees have at least a high school education. This is not mandatory, but through experience we have found it to be best if we are to properly indoctrinate and train all our employees in handling pesticides and understanding our company policies.

Three local agencies in Tampa prescreen employees for us, depending upon what the job description is. They do not charge us a fee and we do not charge the employee. We also use Florida State University for local agencies that relate to minorities.

The interviewer discusses each job description for which the employee is being hired, including the duties required. Again, it helps to have someone who can read and write, and, most importantly understand what the job actually entails.

We do not use any form of testing prior to hiring at the production level. We feel that screening by agencies, the interview with our personnel manager, and, finally, the plant interview with one of our supervisors give us a good handle on whether or not the employee will fit into our company workforce. We do, however, make it a point to discuss the potential employee's background with a previous employer.

We thoroughly explain the rationale behind our preemployment physical, including the rationales for chest and back x-rays, urinalysis, and blood work, which is mandatory for all plant warehouse personnel within our company. It is worth noting that people react negatively to preemployment physicals if they are not explained properly at the beginning.

Last, there is a thirty-day probationary period in which we have an opportunity to look at an employee and the employee in turn has an opportunity to look at us. If we have done a good job in the first thirty days, we usually keep the employee once the individual formally comes on board.

This concludes the discussion of educational and other preemployment requirements. Next we will cover our indoctrination and training procedures.

Let us start with day one. A new employee is hired at SMCP in our dry manufacturing department. During the first time frame, days one through five, few, if any, specific duties are assigned to the employee. Instead we review safety equipment requirements in the departments, including instruction on proper care of respirators, safety shoes, gloves, and so on. We review our personal hygiene programs, including medical programs, proper removal of dust from clothing, and the reasons that we require daily showers and washing of hair. We train in emergency procedures, including the actual use of a fire extinguisher and showing the employee where they are all located. New employees thoroughly review and sign our safety manual. After this first week there is a brief question-and-answer period given by the safety director, based on the manual. Finally we review company policies concerning vacation, leave, absenteeism, and insurance. To sum up, during the first five days we try to make the employee feel at home within our environment.

The second time frame is our thirty-day probationary period. During the next three weeks we begin on-the-job training in the actual job area. We teach proper handling of the materials in the plant, including the proper safety equipment required when handling certain materials, proper lifting techniques, and proper use of equipment for transferring materials, pumps, and so on. We try to give a new employee job assignments during the first thirty days in each of our manufacturing areas of operation. We want all new employees to become familiar with each job and each piece of manufacturing equipment. This has obvious benefits, allowing us to utilize employees fully for safety reasons so that we can rotate personnel over an eight-hour shift, and for flexibility, if work crews are shorted because of absenteeism or tardiness. We have weekly safety meetings every Friday morning with the safety director to explain products, safety equipment, and so on as they relate to OSHA, including medical records and TSCA, where applicable. This is over and above our normal weekly safety meeting for all company, plant, warehouse, and equipment personnel.

We have now brought the employee through the first thirty days. At this time he is evaluated by the supervisor on his anniversary date, and we look at such areas as safety, absenteeism, tardiness, initiative, handling of the job, and so on. A standard form for evaluating people is used to eliminate subjectivity. We personally discuss the situation with the employee and a "go" or "no go" decision is made at this time. If we feel he has done a good job in the first thirty days, the employee will stay on with us; if not, we choose to terminate the employee. In our opinion, the first thirty days are critical in training and indoctrination if you are to have a satisfactory employee in the future. Therefore, it behooves the employer to make a concerted effort during this time frame to create a proper environment.

With the probationary period, the next two months constitute a ninety-day time frame of further training and education. The indoctrination and training during this period consists of thorough training in the materials we handle, equipment, processes, and work practices. Training is done primarily by the individual supervisor or foreman on the job. Our policy is to review and make sure that the employee understands the safe operating procedures in each work area and each job duty. We also review the hazards involved, not only in handling the pesticides themselves, but also the inerts, diluents, solvents, emulsifiers, and active ingredients. We review so that the employee will understand the proper procedures for the cleanup of spills or discharges, along with the presence or release of a pesticide in the workplace. We also ask the new employee during this ninety-day time frame to participate in the weekly safety meetings. It is mandatory that all employees attend these meetings, as most of them relate to specific training areas of material handling, equipment, and work practices.

During the first three months of employment we get a good feel for the safety habits of our new employees; identifying those who are careless and require frequent medical attention and those who are simply accident prone, as some people are. Certain actions are required of all employees during this period. We monitor his personal hygiene and sanitary habits, including daily showers, hair washing, wearing clean underclothing, wearing safety shoes, and washing properly prior to eating or breaks. Monitoring is done by the safety director and by the immediate supervisor in that department. We monitor to see that employees properly use and properly care for those uniforms that are not to be worn outside the work area. We make certain that these uniforms are placed in the disposal area for contaminated clothing and are properly worn during the work day. We prohibit smoking and eating in areas where pesticides are handled.

After this ninety-day period has elapsed, we do blood and urinalysis tests for monitoring and put the results into a medical history file. The three-month followup gives us a good baseline on the overall health of the employee. Based on our files and the recommendation of the immediate supervisor and the safety director, we again sit down with the employee, this time to evaluate the first three months and to set the stage for the future.

Three months to one year makes up our ongoing education and training program. By now we feel the new employee can contribute significantly to our future workforce and move within our organization. The employee recieves an automatic pay increase within this time frame, directly related to job performance during the initial three-month period. We don't just bring an individual in at a base salary and then leave him there for a year before we evaluate him. If we have done a good job during this three- to twelve-month period of training and education, we will keep the employee within our organization. For example, of our existing workforce of seventy-five to ninety people in the plant (dry and liquid), depending upon the time of the year, ninety percent of these employees have been with us over one year. This is unusual, since in Tampa, due to the tremendous amount of construction going on, there is no unemployment. Over seventy percent have been with us five years. Proper indoctrination and training minimizes employee turnover and dissatisfaction, and believe me, ladies and gentlemen, that comes down to the bottom line at the end of the year.

Our ongoing training and education during this period consists of some other elements, which I would like to review with you. The first is participation in company-sponsored programs. Tow motor training is one. We want all of our plant and warehouse personnel to operate tow motors, so they are sent to school and trained by the company whose tow motors we are using.

We sponsor two Red Cross training days annually. We pay for the training manuals and the time involved. This program has benefited us on a number of occasions, both at work and outside the work environment where employees who have had Red Cross training have assisted at the scene of accidents.

After employees are with us at least six months, we encourage them to take advantage of our Educational Assistance Program. Supervisors and management must approve courses prior to enrollment. Once approved, the company will pay for the course, the books, and even transportation, after management has received the employee's transcript. Currently, in the operation area of our company, we have two people working on advanced degrees, eight people working on undergraduate degrees, and four enrolled in Hillsborough Community College, a small junior college in the Tampa area. We encourage this Educational Assistance Program. Employees, in turn, feel a closer tie to the company and, in the long run, make much better employees.

We have an education program to teach the use of a fire extinguisher. Annually, we schedule a session (through the local fire department) in which all employees of our company, including secretaries and front office, are required to handle a fire extinguisher and actually put out a small fire. This program has paid for itself on a number of occasions. Also, all plant and warehouse supervisors are certified by the local fire department where they receive advanced training in a day-long seminar.

We also have other company educational training programs through our industry contacts. I send select company personnel to these meetings, which cover areas such as supervisory training. Here they learn to motivate, train, and understand young employees. We spend a great deal of time in this area. To bridge the language gap with minorities, primarily Latins, we have supervisors in the plant who are bilingual. We also use outside assistance in training these employees. Key employees, primarily supervisors and lead persons, attend meetings of government agencies such as OSHA, DOT, EPA, EPC, and others, or attend seminars if they are in the Tampa area or the southern part of the United States. The more that we, as employers, make the employee aware of his job and what it entails, the better off we are.

In summary, by walking you through with a new employee and showing how we implement education and training through the first year, and the ongoing training that we utilize, I hope I have given each of you some idea of how a successful program can benefit both the employee and the employer. Whatever methods are used to train and educate workers in the pesticide environment, the most fundamental means involves that which is exemplified by management. If this is not present, the rest will not follow readily.

ROLE OF PROTECTIVE CLOTHING IN EXPOSURE CONTROL

Joseph L. Wolfsberger
Monsanto Chemical Company

I will be discussing personal protective equipment in general and then work from the head down, describing some of the types of equipment that are applicable to the chemical and pesticide industries.

My definition of personal protective equipment is that it is a barrier between a person and a hazard. As I see it, there are four major uses of personal protective equipment. The first is when engineering controls are not feasible. The second is the interim measure after you have discovered a problem. You are putting in the engineering controls and continuing to work on the control solution. Another use is during emergency situations. Finally, protective equipment can be used when the potential exists for an unexpected occurrence which could cause serious physical harm. The most common equipment in that situation are safety shoes, hard hats, and glasses.

To begin discussing safety equipment, let's start with head protection. There is the full-brimmed hard hat (the brim signifies that it is an actual hard hat). The most commonly seen helmet in the industry is known as the hard cap. It is brimless with a peak, and is made of plastic.

There are a number of classes of safety helmets. The first is Class A, which provides limited voltage resistance for general service. Regulations provide that the Class A helmet shell be slow burning, water resistant, and that the helmet weight not exceed fifteen ounces.

The next type is Class B. It is similar to Class A, except for the electrical properties. Class B helmets offer high-voltage resistance. The shell has no holes or metal parts, and should be water resistant and slow burning. Weight is not to exceed fifteen and a half ounces.

Class C is the hard cap, which has no voltage resistance. It is lighter than plastic, of metallic construction, and weight is not to exceed fifteen ounces. It is commonly used on construction sites where there are no overhead electrical hazards.

The fourth type is Class D, which provides limited protection for firefighters. The shell must be fire resistant.

There are some accessories for hard hats. The suspension is what actually gives the helmet its protective quality, because it keeps the helmet one and a quarter inches above the head surface. The shock of any impact is distributed over the whole head, rather than localized. There are also hard hat liners to protect the head against the cold; and chinstraps are available too.

You can tell whether a helmet meets ANSI standards. Those that do are imprinted with the manufacturer's name, ANSI designation, and class; you can generally find this underneath the brim, printed or raised.

Another head protection is the acid hood. Acid hoods are made from chemically resistant material. You may need supplied air systems with this hood.

A number of face shields are available to provide face protection. There is the type that is attached directly to the head and offers crown protection, covering the top of the head. There is the type without crown protection, just the face shield itself with no lip over the top of it. There is also the type which has crown protection and goes even farther, offering protection under the chin and on the sides of the head.

It is important to remember that face shields are not designed to protect the eyes. If there is a chemical explosion, the person usually turns his head, which opens up the whole shield. The types of lenses (windows) that go with the shield should be chosen depending on their applicability to the situation. The most common is the clear transparent type, which is what you would use in most chemical situations. It provides good visibility. There is a tinted transparent lens, a wire screen (more applicable to heavy industry), and a combination of plastic and screen, and then there is the fiber with filter plate mounting. Generally face shields should be worn in conjunction with proper eye protection.

Safety glasses are probably the most common type of eye protection in controlled situations. These have impact-resistant lenses and frames. A drop test is used, where a steel ball one inch in diameter, weighing 2.4 ounces, is dropped fifty inches into the lens. If it passes that test, it gets ANSI approval (Z87.1).

There are options on safety glasses. Side shields, either permanently attached or the add-on type, are one option. Tinted lenses are another, for outdoor workers especially; prescription glasses are another.

There are two basic types of goggles. One is chemical splash goggles. They are not intended to have the impact resistance of safety glasses. So if you are in a situation where you have had impact as well as splash problems, you ought to back up the splash goggles with the safety goggles. Another type, vapor goggles, cannot be worn with safety glasses because they fit too tightly.

Another disadvantage of vapor goggles is that a tug will break the seal (as with full-face respirators) and allow the vapor in.

There are many hearing protective devices. Most simple is the plug, and there are various types of plugs: disposable foam rubber, Swedish wool, wax-coated Swedish wool, and plastic. Plastic plugs need maintenance in that they must be kept sanitary. Attenuation on these types is ten to twenty decibels. Swedish wool is similar to cotton, but cotton does not have the attenuation properties of Swedish wool and should not be used in its place.

Another hearing protective device is muffs. There are various types. The over-the-head type cannot be worn with a hard hat. Other types are behind the head, front of the head, and helmet mounted. The cushions themselves are filled either with liquid or foam. Liquid-filled cushions are cooler as a rule.

At this point I would like to expose a common fallacy concerning hearing protection. People say that they can't hear as well with hearing protection on. In a high-noise situation, you can actually hear better. The noise level is reduced twenty or thirty decibels to a range in which the ear is actually more sensitive. With a combination of plugs and muffs, you get a reduction of thirty to thirty-five decibels.

For hand protection, there are many types of gloves. Canvas is most common, but is not good in this industry because the canvas can act like a sponge. The leather glove is used more for maintenance and heavy equipment. It too absorbs chemicals like a sponge. Rubber gloves can leak solvents through. Neoprene has good acid resistance but not a good chemical resistivity. Polyvinyl chloride (PVC) has better resistance to chemicals and acids. PVC gloves come in a variety of styles: high gauntlet, short glove, and cotton lined. A problem with PVC gloves is that some solvents will go right through them, so a new type, polyvinyl alcohol (PVA) was developed, with a better solvent resistivity but not as good in some aspects of chemical resistivity.

A new glove, made of Viton®, has good chemical and solvent resistivity and also does not swell or deform in water as PVA can. These gloves are not cheap, but there are situations where they are applicable. There are also gloves made of n-butyl rubber nitrile. [A list of chemicals and their effect on rubber is included at the conclusion of this speech.]

The range of body suits is wide. There are full acid suits for extremely hazardous situations. Most have provisions for supplied air. The material and construction will vary, though most are hot and tough to work in. There are also chemical-resistant suits, which are lighter and flexible and which may also have provisions for supplied air. Rain suits are generally made of PVC, resistant to chemicals and acids. There are also disposable coveralls Tyvek®. One type of Tyvek® suit is designed to breathe and the other is not, so if you are buying them to prevent exposing your workers to chemicals, don't defeat your purpose by buying the semi-permeable one. And, finally, there are flame-retardant coveralls, but after one or two washings, the flame-retardant properties are gone.

Regarding safety shoes, ANSI has a number of different classifications for them (Z41.1). There is Classification 75, capable of withstanding an impact of seventy-five pounds and compression of 2,500 pounds, while maintaining 16/32 inches of clearance between the steel and the toe. Classification 50 is capable of withstanding an impact of fifty pounds, compression of 1,750 pounds, and clearance of 16/32 inches, and Classification 30 withstands an impact of thirty pounds, compression of 1,000 pounds, and clearance of 16/32 inches.

Safety shoe accessories include metatarsal guards and metal instep guards. The basic difference is that the metatarsal guard is higher on the foot and is incorporated into the shoe itself.

There are different "rubber" boots and shoes. Neoprene shoes have good acid protection but poor chemical resistivity. We have vinyl boots which do have good acid and chemical resistivity. All these shoes are available with steel toes and shanks.

This is how I regard protection in the chemical and pesticide industry.

CHEMICAL DEGRADATION GUIDE FOR GLOVES

	CHEMICAL	RUBBER	NEOPRENE	POLYVINYL CHLORIDE (PVC)	POLYVINYL ALCOHOL (PVA)	NBR NITRILE
1.	Acetaldehyde	E	E	NR	NR	P
2.	Acetic Acid	E	E	F	NR	G
3.	Acetone	E	G	NR	P	NR
4.	Ammonium Hydroxide	E	E	E	NR	E
5.	Amyl Acetate	P	NR	P	G	E
6.	Aniline	G	G	F	F	NR
7.	Benzaldehyde	F	NR	NR	G	NR
8.	Benzene	NR	NR	NR	E	P
9.	Butanol	E	E	G	F	E
10.	Butyl Acetate	P	NR	NR	G	F
11.	Cargon Disulfide	NR	NR	NR	E	G
12.	Carbon Tetrachloride	NR	NR	F	E	G
13.	Castor Oil	E	E	E	E	E
14.	Chlorobenzene	NR	NR	NR	E	NR
15.	Chloroform	NR	NR	NR	E	NR
16.	Chloronapthalene	NR	NR	NR	G	P
17.	Chromic Acid	NR	NR	G	NR	F
18.	Citric Acid	E	E	E	F	E
19.	Cyclohexanol	E	E	E	G	E
20.	Dibutyl Phthalate	G	F	NR	E	G
21.	Diethylamine	NR	P	NR	NR	F
22.	Di-Isobutyl Ketone	P	P	P	G	E
23.	Dimethyl Formamide	E	G	NR	NR	NR
24.	Dioctyl Phthalate	F	G	NR	E	G
25.	Dioxane	F	NR	NR	P	NR
26.	Ethanol	E	E	G	NR	E
27.	Ethyl Acetate	G	F	NR	F	NR
28.	Ethylene Dichloride	P	NR	NR	E	NR
29.	Ethylene Glycol	E	E	E	F	E
30.	Ethyl Ether	NR	E	NR	G	E
31.	Formaldehyde	E	E	E	P	E
32.	Formic Acid 90%	E	E	E	NR	F
33.	Freon	NR	G	NR	G	F
34.	Furfural	E	G	NR	G	F
35.	Gasolene (White)	NR	NR	P	G	E
36.	Glycerine	E	E	E	G	E
37.	Hexane	NR	E	NR	G	E
38.	Hydrazine 65%	G	E	E	NR	E
39.	HCl 38%	G	E	E	NR	E
40.	HCl 10%	E	E	E	NR	E
41.	Hydrofluoric 48%	G	E	G	NR	E
42.	Hydrogen Peroxide	E	E	E	NR	E
43.	Hydroquinone Saturated	G	E	E	NR	E
44.	Isobutyl Alcohol	E	E	F	P	E
45.	Iso-Octane	NR	E	P	E	E
46.	Isopropanol	E	E	G	NR	E
47.	Kerosene	F	E	F	G	E
48.	Lactic Acid 85%	E	E	E	F	E

E - Fluid has very little degrading effect
G - Fluid has minor degrading effect
F - Fluid has moderate degrading effect
P - Fluid has pronounced degrading effect
NR - Fluid is not recommended with this material

	CHEMICAL	RUBBER	NEOPRENE	POLYVINYL CHLORIDE (PVC)	POLYVINYL ALCOHOL (PVA)	NBR NITRILE
49.	Lauric Acid 36%	G	E	F	NR	E
50.	Linoleic Aicd	P	E	G	G	E
51.	Linseed Oil	F	E	E	G	E
52.	Maleic Acid Saturated	E	E	G	NR	E
53.	Methanol	E	E	G	NR	E
54.	Methylamine	E	G	E	NR	E
55.	Methylene Bromide	NR	NR	NR	G	NR
56.	Methylene Chloride	NR	NR	NR	G	NR
57.	Methyl Ethyl Ketone	G	P	NR	F	NR
58.	Methyl Isobutyl Ketone	F	NR	NR	F	P
59.	Methyl Methacrylate	P	NR	NR	G	P
60.	Monoethanolamine	E	E	E	F	E
61.	Morpholine	E	P	NR	G	NR
62.	Naptha	NR	NR	F	E	E
63.	Nitric Acid 70%	NR	G	F	NR	NR
64.	Nitric Acid 10%	G	E	G	NR	E
65.	Nitric Acid Red Fuming	P	NR	P	NR	NR
66.	Nitric Acid White Fuming	NR	NR	P	NR	NR
67.	Nitromethane 95.5%	E	E	P	G	F
68.	Nitropropane 95.5%	E	G	NR	E	NR
69.	Octyl Alcohol	E	E	F	G	E
70.	Oleid Acid	F	E	F	G	E
71.	Oxalic Acid Saturated	E	E	E	P	E
72.	Palmitic Acid Saturated	G	E	G	P	G
73.	Pentane	P	E	NR	G	E
74.	Perchloroethylene	NR	NR	NR	E	G
75.	Perchloric Acid 60%	F	E	E	NR	E
76.	Phenol	E	E	G	F	NR
77.	Phosphoric Acid	G	E	G	NR	E
78.	Picric Acid Saturated	G	E	E	NR	E
79.	Potassium Hydroxide 50%	E	E	E	NR	E
80.	Propyl Acetate	F	P	NR	G	F
81.	Propyl Alcohol	E	E	F	P	E
82.	Propylene Oxide	P	NR	NR	G	NR
83.	Sodium Hydroxide 50%	E	E	G	NR	E
84.	Styrene	NR	NR	NR	G	NR
85.	Sulfuric Acid 95%	NR	F	G	NR	NR
86.	Tannic Acid 65%	E	E	E	P	E
87.	Tetrahydrofuran	NR	NR	NR	P	NR
88.	Toluene	NR	NR	NR	G	F
89.	Toluene Di-Isocyanate	F	NR	P	G	NR
90.	Trichloroethylene	NR	NR	NR	E	NR
91.	Tricresyl Phosphate	E	F	F	G	E
92.	Triethanolamine 85%	G	E	E	G	E
93.	Tung Oil	NR	E	F	E	E
94.	Turpentine	NR	NR	P	G	E
95.	Xylene	NR	NR	NR	E	G

E - Fluid has very little degrading effect
G - Fluid has minor degrading effect
F - Fluid has moderate degrading effect
P - Fluid has pronounced degrading effect
NR - Fluid is not recommended with this material

RESPIRATORY PROTECTION PROGRAM: BASIC PRINCIPLES

James J. Murphy
Senior Industrial Hygienist, Monsanto Chemical Company

My discussion today centers around a specialized form of personal protective equipment--respirators--and some basic concerns related to their use for protection against dusts and vapors. The definition of a respirator is "a device worn over the mouth and nose for protecting the respiratory tract." The proper use of this type of protective equipment is not so simple, as we'll soon see.

To put our discussion into perspective, let us review just where respirators fit into the overall exposure control effort. Respirators are used when engineering controls are not feasible (for example, during nonroutine maintenance or repair of formulation equipment); while engineering or administrative controls are being instituted and evaluated; and during emergencies such as fires and large spills.

For moderate to large employers (firms with more than ten employees) OSHA regulation 29CFR1910.134 addresses specific requirements of respirator use. These requirements can be summarized into eleven points, including: written standard operating procedures; selection; training and fitting; individual assignment; cleaning and disinfection; inspection and repair; storage; surveillance of use; program evaluation; medical surveillance; and the use of only NIOSH/MSHA respirators approved for the specific hazard. These eleven points combine to form a comprehensive respiratory protection program.

My discussion will concentrate on four major points of the eleven just mentioned: selection, fitting, training, and maintenance.

In selecting the correct respirator for the exposure situation, the nature and extent of the hazard, the work requirements of the job, and the characteristics and limitations of the specific types of respiratory protection commonly used in pesticide applications (chemical cartridge, gas mask, and supplied air respirators) must be carefully reviewed.

Respiratory hazards can be broken down into two major categories: oxygen deficiency, that is, a work situation where the oxygen content is less than 19.5 percent, or in the presence of toxic contaminant (in the form of gases and vapors, particulates, or a combination of both). In most cases, excepting confined space entry, the hazard may also involve low oxygen content (less than 19.5 percent).

To determine the nature and extent of the hazard in order to select the correct respirator, some basic information must be gathered. Before selecting a respirator, you should always ask the following questions: What is the chemical name of the material? What is its exposure guideline (for example, ACGIH-TLV or OSHA-PEL)? Will it be used in liquid, solid, or gaseous form? What is the maximum expected concentration where the respirator will be used? Will the material be heated? If so, is it flammable? Does the estimated concentration approach the lower exposure limit (LEL)? What is the odor threshold (the concentration at which you can first smell the material)? Does the material have good warning properties? At what concentration is the material considered to be immediately dangerous to life and health (IDLH)? Can the material be absorbed through the skin? Is the material an eye irritant? At what concentration? Does the material adsorb well, on charcoal and other substances?

The NIOSH/OSHA decision logic for selecting a respirator can also be used, and the chemical and respirator manufacturers and NIOSH can be contacted for their recommendations.

In quantifying the concentration of the material present in the workplace, air sampling measurements should be made by an industrial hygienist or a safety engineer trained in air sampling. Once the range of airborne concentration of the material is determined, this information is matched with a respirator that will provide adequate protection. Different styles (quarter, half, and full face) and classes of respirators (air purifying or air supplied) provide different degrees of protection. The degree of protection afforded by a respirator, the protection factor (PF)*, is basically a measure of respirator-to-face seal leakage.

A protection factor (PF) is valid only if, first, the wearer can clearly obtain a good facepiece-to-face fit, without facial hair interference, for example. Second, if the cartridge/canister/filter has adequate service life for the material, and, third, if the material has adequate warning properties.

The maximum-use concentration (MUC) can now be calculated to the specific respirator to be used and the TLV or PEL (MUC=PF x TLV/PEL).

If the measured-air-contaminant concentration is lower than the maximum-use concentration for the respirator, then the respirator should provide adequate protection. If not, you must select a style or class of respirator which has been assigned a higher protection factor. We'll talk more about how protection factors are determined later in our discussion of respirator fit testing.

*Protection factor (PF) is the ratio between the concentration of contaminant outside and inside the facepiece.

Respirators are commonly broken down into two major classes, air purifying and atmosphere supplying. There are limitations to the protection that each type of equipment can provide. An air-purifying respirator does exactly what its name indicates--it purifies, or removes contaminants. It is important to note that it does not supply oxygen and should never be used in oxygen-deficient atmospheres (less than 19.5 percent O_2). This air purification is accomplished for particulates (dusts, mists, fumes) by filtration. Activated or chemically treated charcoal or other sorbents are used in varying amounts (cartridges or canisters) to adsorb, absorb, or react with a gaseous contaminant and to remove it from the inspired air. There are a number of different types of air-purifying cartridges designed for removal of specific air contaminants.

Although an air-purifying respirator may be approved for a class of materials (for example, pesticides), this does not mean that it is adequate for all pesticides. Certain pesticides may not sorb well on activated charcoal, have poor warning properties, and so on, and for these types of materials, air-supplied respirators would be the proper choice.

Air-purifying respirators can be purchased in a half-mask or a full-face style for additional protection. Full-face pieces should also be used when the material being handled is an eye irritant. For use in higher contaminant concentrations, an approved full-face pesticide gas mask or supplied air equipment should be used.

The second major class of respirators is the air-supplied type. These provide respirable air to the wearer and should be used for protection against high concentrations of contaminants, in oxygen-deficient atmospheres, or where air-purifying respirators are inadequate to remove the pesticide contaminant in question, due to poor adsorption on charcoal, poor warning properties, and so on.

Two types of air-supplied respirators are currently approved by NIOSH/MSHA and are applicable for pesticide use. The first type, an air-line respirator, uses a stationary source of compressed air which is supplied to the user through a high-pressure hose. Air-line respirators are available in "demand", "pressure-demand", and "continuous-flow" configurations. Air-line respirators provide a high degree of protection, but their use is limited to concentrations of materials judged <u>not</u> "immediately dangerous to life and health," since the wearer is totally dependent upon the integrity of the breathing air line for safety. In an unknown concentration of a material or a concentration which <u>is</u> known to be immediately dangerous to life, an air-line respirator must have an auxiliary air supply to protect against failure of the air-line hose or primary air supply. The combination air-line and self-contained breathing apparatus (SCBA) respirator is essentially the same as an air-line respirator, with an added small compressed air cylinder, and can be used during emergency escape from an immediately hazardous situation.

A second type of air-supplied respirator is the self-contained breathing apparatus (SCBA). In this case the wearer carries the supply of breathing air with him. A typical open-circuit SCBA consists of a cylinder of high-pressure compressed air carried on the back and a multistage regulator, which reduces air pressure to an acceptable level and feeds it through a corrugated breathing nose to the full-face piece. SCBAs are used widely for firefighting, spill cleanup, and so on. A pressure-demand (positive pressure) SCBA provides the maximum amount of protection for the user and is recommended in any situation which could potentially be immediately dangerous to life.

The second point in our discussion today, and a major part of any good respirator program, is fitting. It is important that a respirator be fitted properly to the user at the time it is issued. The respirator will not provide the necessary protection for the user if it is not sized properly for the user's face or if the user wears it improperly.

The purpose of the fitting test is, first, to select the best fitting respirator from a number of brands of the same style; and, second, to teach the user to don the respirator properly.

There are two types of fit tests, qualitative and quantitative. Qualitative fit tests are fast, simple, and easily performed, but have the disadvantage of relying on the wearer's subjective response. Quantitative fit tests indicate respirator fit numerically and do not rely on the wearer's subjective response, but the fit test equipment is expensive, requires a specially trained operator, and is of limited use due to its complexity and bulk.

Positive and negative fit tests are "quick check" tests, which should be used after donning the respirator but before beginning work in a respirator-use area. These tests should not be used to select the best-fitting respirator. The two major qualitative tests use isoamyl acetate (banana oil) or irritant smoke. The irritant smoke test uses a smoke tube containing stannic chloride or titanium tetrachloride. The tube ends are broken and, using a squeeze bulb, air is passed through the tube to generate an irritating smoke. The wearer steps into a test enclosure, or hood, closes his eyes, and the irritant smoke is sprayed around the respirator facepiece seal area. If an air-purifying respirator is being tested, it must be equipped with high-efficiency filters. The irritant smoke test must be performed with caution since the smoke is highly irritating to the eyes, skin, and nose and throat. This test has the major advantage that the wearer reacts involuntarily to leakage due to a poor fit by coughing or sneezing. This qualitative test is much less subjective than the isoamyl acetate test. Isoamyl acetate, a low-toxicity substance with a bananalike odor, is also widely used in testing facepiece fit. In this case, the air-purifying respirator should be fitted with oragnic vapor cartridges. A disadvantage with the isoamyl acetate test is that the pleasant odor can quickly dull the wearer's sense of smell.

The isoamyl acetate test is similar to the irritant smoke test in concept, however.

Quantitative respirator fit tests involve placing the wearer in an atmosphere containing an easily measurable, relatively nontoxic vapor or aerosol. The atmosphere inside the respirator is sampled continuously through a probe in the respirator. The leakage into the respirator is expressed as a percentage of the test atmosphere outside the respirator, called percent of penetration.

As was mentioned previously, the purpose of fit testing is to insure that the respirator selected for the wearer provides adequate protection. The amount of protection a respirator provides is called the "protection factor." Each type of air-purifying and air-supplying respirator has been assigned a protection factor, based on quantitative fitting research performed by Los Alamos Scientific Laboratory of the University of California.

Several factors can negatively affect the respirator-to-face seal and reduce the level of protection provided by a respirator. These factors include facial shape, facial abnormalities, dentures, eyeglasses, and facial hair. Facial hair lying between the sealing surface of a respirator facepiece and the wearer's skin will prevent a good seal and will result in excessive leakage into the facepiece and a loss of protection for the wearer.

Selecting and fitting the right respirator for a specific pesticide application is important. Equally important is that the wearer be properly trained in using the respirator correctly. Both supervisors and workers must be trained in basic respirator protection practices. Training should include an explanation of the nature of the hazard and what happens if the respirator is not worn properly; and explanation of how the respirator was selected and why the respirator is required; a discussion of the capabilities and limitations of the respirator; and instruction and practice in wearing, adjusting, and determining the fit of the respirator (testing the facepiece-to-face seal).

Finally, the fourth major point of my discussion involved maintenance. An ongoing maintenance program for respirators is a necessary part of your overall program. Wearing poorly maintained or malfunctioning equipment can be more dangerous than not wearing equipment at all, since employees wearing such a respirator think they are protected when in fact they are not. All respirator maintenance programs should provide for the cleaning and sanitizing of equipment, inspection for and repair of defects, and proper storage.

When respirators are used on a routine basis, they should be cleaned daily. Individuals should be assigned their own respirator whenever possible. Individual workers who maintain their own respirator should be trained in the cleaning of the equipment.

One practical method of respirator cleaning involves the following six steps. First, remove and discard the filter or cartridge. Second, wash the respirator in a good detergent containing a disinfectant or soap. (Use the manufacturer's recommended cleaner if possible, and warm water, at least 120° Fahrenheit). Rinse the respirator completely, in clean, warm water. Air dry it in a clean area. Inspect the valves, headstraps, and other parts; replace any parts that are defective. Finally, place a package of new, unopened cartridges in the plastic storage bag along with the clean respirator for facepiece. The respirator is now ready to be reissued.

All respiratory protective equipment should be inspected before and after each use by the employee, and during cleaning. Equipment designated for emergency use should be inspected after each use, during cleaning, and at least monthly. Self-contained breathing apparatus should be inspected at least monthly. A minor defect in any of these may be repaired on the spot. If a major defect is found, the respirator should be removed from service until it has been repaired. Never use a respirator that is known to be defective.

Respirators should be stored in a single layer with the facepiece and exhalation valve in a position that will prevent distortion of the facepiece. They should be located in a clean, uncontaminated but readily accessible area, protected from sunlight, heat, extreme cold, and excessive moisture. One practical storage area for respirators is a standard steel storage cabinet.

Acknowledgments

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EVALUATION OF QUALITATIVE AND QUANTITATIVE FIT TESTING TECHNIQUES

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First I would like to thank NIOSH for the opportunity to speak here, and I would also like to acknowledge the real authors of the content of my presentation. They are Dr. Orrin Skretvedt and Joe Loschiavo, who have been carrying out this work within my group at Haskell.

I am going to be discussing fit testing, specifically a fit test procedure that we put together, and talking about the basics of a well-run respirator program, which, if followed, will provide an adequate respiratory protection program for your workers. OSHA is starting the rewrite of 1910.134, which is part of the general industry standard for respirators. OSHA needs a better technical basis with which to write this new standard. What we are trying to do within Haskell is help develop a new procedure, and also letting you know that we are at a point to be in the driver's seat to help provide this good technical base. NIOSH and OSHA are willing to listen as long as we come up with good data that can withstand peer review, and that is what our purpose happens to be.

While it is true that engineering controls must be and are being instituted as the first lines of defense against hazardous workplace atmospheres, it is also true that they cannot sufficiently lower the workplace concentrations to obtain the needed levels. Respirators must often be used as a second line of defense. New chemicals are produced daily, while allowable exposure limits are continually decreasing. Because of these reasons, respirator use will increase in the future.

There are many unanswered problems concerning respirator use. If industry wants to continue to use respirators, they must document the facts associated with respirators. Haskell Laboratories Industrial Hygiene Section, under the direction of the Corporate Respirator Research Committee, has been identifying and addressing several questions needing resolution.

To be effective, respirators must fit well. We have developed a simple test procedure for determining if a respirator fits a person's face. The diversity of face size is just as great as it is of foot size. Yet for decades each manufacturer produced only one size of respirator. We have realized this error in recent years, and we now have different sizes facepieces.

Now I, as a respirator program director, must find the size which fits you as a wearer. I will provide you with the respirator that is most comfortable and that also provides the least amount of leakage. Government regulations specify that a test atmosphere be used to check respirator fit. Unfortunately, they have not stated what constitutes a test atmosphere. For decades two types of chemicals have been the predominant test atmospheres used by pioneers in this field: isoamyl acetate, a pleasant-smelling chemical having a bananalike odor, and the second chemical, stannic chloride, an irritant smoke which causes an involuntary cough. If either chemical was detected by the test subject while he was wearing a respirator, he was believed to have an improper fit. Both of these methods are qualitative. That is, we must rely on the person being tested to give us the response. Isoamyl acetate requires a voluntary identification of the bananalike odor, and irritant smoke produces the involuntary cough.

Despite the fact that these methods have been in use for year, no one has assembled a standard operating procedure for conducting either type of qualitative fit test. A variety of test techniques have been used for conducting isoamyl acetate tests: Cotton Q-Tips®, cotton balls, and the Marsh® stencil brush have been used. These applicators also vary in a lot of different ways. They have different surface areas, and they produce inconsistent results. They are subject to air currents in the test area and to the rate of speed that the vapor source is moved around the face. Some testers stand five feet away, wave the thing around, and ask if you got a response. Other testers are up very close and go at a very slow rate. Obviously this can be a broad source of error in an actual fit test. These variables affect the concentration of isoamyl acetate achieved at the sealing surfaces of the respirator, which in turn accounts for the inconsistent results.

Such inconsistencies, and lack of proven operating procedures, have led the government to abandon qualitative fit test methods in several recent health standards. Instead they mandated the use of quantitative fit testing. This recently developed method monitors test agent concentration inside and outside the mask and does not require subjective response by the person begin tested. Unfortunately, the method is very expensive and is not without problems of its own. Until the recent benzene decision, OSHA never considered cost as part of their decision-making process. However, the recent lead, arsenic, and acrylonitrile standards all specify that quantitative fit testing be performed every six months. OSHA is now seriously considering requiring that all respirator users be quantitatively fit tested.

I believe fit testing is necessary, but not to the extent of sophistication and cost of the present quantitative fit test units. The investment in conducting quantitative fit tests is substantial, and when you consider the thousands of companies using respirators, the cost becomes staggering. Many companies have just begun using respirators and are just now becoming aware of the basics of a respirator program. They cannot handle the costs and do not have the technical expertise involved in quantitative fit testing. We have developed a qualitative fit test or a semiquantitative fit test protocol that can be implemented by any respirator user. We are documenting that protocol to prove that it assures people of receiving a proper-fitting respirator.

The test protocol consists of three components. Component one involves the construction of a chamber having a standard test atmosphere. The chamber is assembled by slipping a fifty-five gallon clear polyethylene drum liner, open end down, over a twenty-four-inch diameter plywood disk. The disk is suspended at the appropriate height. Isoamyl acetate concentrations are generated within the test chamber by adding .5cc isoamyl acetate to a 4 x 5 inch piece of single-ply paper toweling. This nearly saturated towel is then hung inside the chamber. Within two minutes, 150 ppm concentration is reached and is maintained throughout the several minutes it takes to conduct a fit test. This concentration was determined by the Wilks infrared analyzer, which recorded concentrations during a fit test. Field verification conducted in several plant sites involving monitoring isoamyl acetate levels, using both personal sampling pumps and DuPont's test results, correlated with our experimental data. We are convinced that our protocol eliminates the problems that have been inherent in qualitative fit testing. Our system reduces interferences from environmental conditions, can be constructed at minimum expense, is easy to operate, and guarantees a stable test atmosphere.

Component two of our protocol concerns these subjects' ability to detect low concentrations of isoamyl acetate. For many years researchers sought an easy method for producing low, stable concentrations. Using simple tools such as a Mason jar, spring water, and a calibrated eye dropper from a liquid vitamin bottle, they have developed a method for generating a 1.5 ppm atmosphere of isoamyl acetate. The atmosphere is maintained in the vapor space over the mixture of water and isoamyl acetate. A placebo jar containing odor-free water is presented along with the isoamyl acetate jar. The subject is asked to identify the jar having an odor. All persons fit-tested with this protocol have been successful in identifying the correct jar. We have now established a lower limit of detection for those people. Of about 500 people tested, there have been only four who did not respond to 1.5 ppm. Three of them had colds and were retested a few days later. They then passed the test. Another person had lost the sense of smell following brain surgery.

Component three concerns the inverse relationship between comfort and leakage. The more comfortable the fit, the less leakage. This is an important aspect of fit testing that has been overlooked by others. It is another reason that several sizes must be available for worker selection. We usually have two sizes from one manufacturer and three from another. We found that we could fit ninety to ninety-five percent of the people in half masks utilizing these five different sizes. That percentage goes down a bit when we use only three of the sizes. Also, the available sizes still do not fit women very well. That is a problem. However, in general, using the five half-mask sizes together offers comfort and adequate protection for a wide range of facial dimensions. If the test subject is given some guidance on how to determine comfort and is offered a selection of respirators, he becomes quite adept at selecting a respirator which provides a high protection factor. A comfortable fitting respirator will quite commonly have leakages of .05 percent or less. For example, in our chamber we have an atmosphere of 150 ppm. A leakage of .05 percent would mean that the concentration inside the respirator would be .05 percent of 150 ppm, or .075 ppm. A one percent leakage would mean the concentration inside the respirator would be one percent of 150 ppm, or 1.5 ppm. Based on this relationship, our test chamber should detect a minimum theoretical leakage of one percent. We have a 150 ppm test chamber, and we know the subject will respond to 1.5 ppm concentration. This ratio, 150 over 1.5, gives the one percent maximum leakage that our system should detect. Incidentally, this leakage is ten times less than that allowed by the government, since they normally allow a ten percent leakage for half masks.

This third component of our protocol, then, helps the subject to evaluate comfort, select his respirator, and then properly put it on prior to entering the test chamber. This is important. A good training period time is during fitting, because the wearer gets a chance to adjust the respirator. He sees how it is supposed to fit, and you receive some feedback because he knows whether or not he is getting breakthrough from a leakage point.

Let's see how these three components relate. We prepare a test chamber, we conduct an odor sensitivity test, and we assist the subject in properly selecting a respirator. We have him step into the chamber. If he detects the odor, he has a poor fit and returns to the selection area. The odor-sensitivity test is then repeated to be certain that the test subject's sense of smell has not been fatigued. To avoid this problem, we usually recommend that the selection process and the odor-sensititivy test be conducted in a room separate from where the actual fit testing is taking place. When his odor sensitivity returns, he selects an alternate respirator. The procedure is repeated until a proper-fitting respirator is found. If a fit cannot be obtained with a half mask, a full-face respirator or an air-supplied respirator can be used.

To document the validity of our protocol, we used the quantitative fit test method as our standard. Each qualitative fit test was followed by a quantitative fit test. This quantified the leakages resulting from our qualitative fit test protocol. Currently over 400 subjects have been fit tested. The results indicate that we are ninety-nine percent confident that ninety-five percent of the people passing our protocol will have leakages less than one percent. That's just statistics. What the bottom line really is to me is that we have found that out of the 400 subjects who have passed the qualitative fit test protocol, only one person has had less than a one hundred protection factor in the quantitative fit test, and that was a ninety-six. It's working. We are continuing to gather data to strengthen our case. Our protocol is inexpensive, uncomplicated, and yet assures us that each person will be provided with the best-fitting respirator we can reasonably find. Also, to insure that this protocol can be reproduced, several small industries will be participating in an interindustry study. Using our protocol, they will fit test their employees. Then a quantitative fit test will be conducted to document the fits. The results of this cooperative effort should substantiate that industry in general will be able to effectively utilize this protocol, and that the protocol will provide proper selection of respirators and proper fits.

This protocol is only a small portion of the questions that need to be answered. A few others that we are currently addressing (and there are the other ones that we'd like other people to be looking at) are working protection factors. We know we have quantitative fit test data and that others have qualitative fit test data. We know that we can provide this kind of protection in a laboratory situation, but we also want to document in the working place, under working conditions, what kind of protection is being provided by the respirator mask itself. So we are setting up monitoring and measuring inside the mask and outside the mask, while people are carrying out their various normal job functions in various sites. We're trying to put this data together. We're also trying to put together some guidance for developing medical guidelines, recommending who should be in a respirator, who should not, and so on.

Cartridge canister lifetime is something else that we are looking into. We have been doing cartridge canister lifetime studies for a long time. We are studying other ways of looking at lifetime for these materials. We are examining what constitutes an adequate training program, including what essentials are necessary to make sure that you have gotten the purposes of a respirator across to employees, how to care for the respirator, and how the respirator can care for the employee.

In conclusion, respirators can provide adequate worker protection, but their use must be supported by a sound program that continuously assesses respirator adequacy. After all, this is no less than what we have to do for a good engineering control program. Improperly used respirators, like clogged ventilation ducts, never protected anyone.

WORKER EXPOSURE MONITORING--GENERAL PRINCIPLES

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The subject of biomonitoring the work environment is a very large area, and in thirty minutes the best we can do is brush across the subject. In this discussion I aim to review the monitoring methods that are available and pin down where most of our problems lie in the pesticide formulating industry. I'd like to start off on the subject of why we need pesticides. In a sense, pesticides are very similar to drugs in that they are biologically active. Because these pesticides have biological activity, they have to be controlled to some extent. In order to control them, we must know something about the work environment. Pesticides are biologically active materials readily absorbed from tissue of the upper and lower respiratory tract; many pesticides are readily absorbed through intact skin. Not all materials are readily absorbed through the skin, but have varying penetration capabilities. Pesticides may cause both acute and chronic toxicity, particularly in mammals; and pesticides may cause serious systemic injury, even death. But if you look at the forty or fifty years we have been using pesticides, you will find that normally when a death occurs it occurs from human error: Either someone has misused the product, or children have gotten into it and have swallowed it, or people have been exposed either through inhalation or through the skin.

No operation is hazardous in itself, but if a misuse occurs or something goes wrong, you wind up with a hazard. One of the potentially hazardous operations we tend to run into in formulating plants is milling. If one is going to reduce the size of the material, you may use a hammermill, and you can reduce materials down to approximately seventy-five microns in size. That doesn't present much of a problem, at least from inhalation, but if you reduce material by air milling down to a two- to five-micron size, then you have a material you can inhale. (Any material below ten microns can be inhaled. Any material above that size will probably be bounced right out of the respiratory tract.)

Another operation that has hazard potential is blending. Here you take a material and either dilute it or blend it with another active ingredient.

A third situation can occur while dispensing. If a material is dropped from a feed tank into a container, there is potential for spillovers and leaks. Thus a hazardous operation has occurred.

During screening, or sizing, material is shaken and can become airborne. Once airborne, it becomes hazardous.

Sometimes you'll use a highly volatile solvent in conjunction with a pesticide and the solvent itself becomes the primary problem. The application of this mixture to an inert surface, say corncobs, may produce high airborne concentrations of solvent.

One final potentially hazardous situation is the dilution of concentrates with inerts.

In order to talk about monitoring we should take a look at the four routes of exposure. First there is ingestion. Most people won't ingest material they know is toxic. It turns out that a lot of materials are formulated as powders: captan, carbaryl, and chlordane. As dust, these can settle on gloves. A worker wipes his face and gets some in his mouth, and in this way there can be some ingestion. It's an accidental type of thing. With such chemicals as paraquat, even three-quarters of a teaspoon can cause death. The second route of exposure is the eye. Normally, when handling concentrates, we recommend goggles to protect the eyes. Direct cholinesterase inhibitors may cause miosis: TEPP (tetraethylpyrophosphate), which has a phosphorous double-bonded oxygen, is a direct cholinesterase inhibitor and does not require activation. If it gets on any part of the body, there can be a local effect. There can be constriction of the pupil of the eye, or there can be twitching of the eyelids. Most of the cholinesterase inhibitors that are handled are phosphorous double-bonded sulphurs, and these materials must be activated first before they become active in the body.

To evaluate inhalation of airborne contaminants, one of the best ways to sample solids in the work environment is to use membrane filters or matching-weight filters. The membrane filter is placed in a filter holder and is attached to a pump. Air is pulled through at a known rate and dust is collected on the filter. The filter is weighed and is quantitatively analyzed for the active ingredient, to determine the concentration in the air.

A very common way to collect materials for which there are no other good means of collection is to use impingers. In this case, solvent (predetermined by the analytical method) is put into glass cylinders. Air is passed through the impinger, the material is collected in the solvent, and the solvent is then quantitatively analyzed for the active ingredient.

The Anderson sampler, another evaluation device, is simply a series of tins or pans with different-size holes in them that collect dust. You can then determine the range and breakdown of particle sizes.

The NIOSH-recommended method for carbaryl involves the use of a glass membrane filter, 37 mm, mounted in a two-piece holder to collect the material. There is a specific flow rate given at 1.5 liters per minute, and a total of 90 liters of air is recommended for the total collection, with subsequent analysis for the carbaryl. We also must keep in mind that dust exposures can be a potential source of skin absorption.

Now we get into the inhalation route. We're talking about liquids and the collection of vapors and aerosols. One of the fastest growing areas is use of solid sorbents. This is simply where you take a solid material and place it inside a glass tube. You then place the tube in the breathing zone of a worker. You allow the individual to work normally while the tube is attached to a pump that pulls air through it at a known flow rate. When you are done you break the tube, desorb the active ingredient off the sorbent, and analytically determine how much is collected on the tube. In this way you determine the concentration in the air. This is a popular method of collection. Silica, for example, can be used to collect one of Dow's products, N-Serve®. We use it all the time. Using carbon you can collect a whole host of materials, such as EDB and DBCP. I don't personally know of any pesticide that has been collected on alumina but it probably has been done. Resins are sometimes used. Phenoxy herbicides are easily collected on resins. The trick, of course, is not only to collect the active ingredient but to get it back off again, in order to determine what's there. Finally, Chromosorb® is a chromatographic packing that can be used as a solid sorbent to collect a whole host of organophosphates.

Next we will consider bubblers; the use of fritted glass impingers. Here you take a vapor or an aerosol is actually sparged through a collection liquid. We try to break up the particles. In order to do this, we use the fritted glass filter. The liquid collects the material which is subsequently analyzed. An advantage of using a high-flow bubbler is that if you have low airborne concentrations you can collect for a short period of time and still get enough to see analytically.

Then there is the modified cartridge respirator. The field people who have been monitoring have used this very often. They take a respirator and replace the charcoal filter with about thirty-two layers of gauze on the outside. Then they take a funnel, cut the tip off it, cut two holes in the bottom, and plug up the end with a cork. The worker wears it on his face as he works. Eventually they take the gauze and analyze it for the active ingredient. In this particular case, the man is the pump, and as he inhales, the material is collected on the gauze. The trick here is to know pretty much what the breathing rate is.

If you look at some of the pesticides that are currently being used, you will find, for the most part, that the vapor pressures of these materials are extremely low. When I talk about vapor pressure, I'm talking about the tendency of the material to get into the air. For example, if you put water on this desk and came

Table 1

ATMOSPHERIC CONCENTRATION AT SATURATION

MATERIAL	VAPOR PRESSURE*	CONCENTRATION AT SATURATION (PPB)*	AIRBORNE GUIDELINE (PPB)**
Carbaryl	4×10^{-5} (25°C)	52	24 (5 mg/m^3)
Chlordane	1×10^{-5} (25°C)	13	30 (0.5 mg/m^3)
Chlorpyrifos	1.9×10^{-5} (25°C)	25	14 (0.2 mg/m^3)
Diazinon	1.4×10^{-4} (20°C)	184	8 (0.1 mg/m^3)
Parathion	3.8×10^{-5} (20°C)	50	8.4 (0.1 mg/m^3)
Dichlorvos	1.2×10^{-2} (20°C)	16,000	22 (1 mg/m^3)
Phorate	8.4×10^{-4} (20°C)	1,000	5 (0.05 mg/m^3)
Paraquat	immeasurable		13 (0.1 mg/m^3)
Diquat	immeasurable		35 (0.5 mg/m^3)

*British pesticide manual
**Threshold limit values (ACGIH)

back tomorrow morning, more than likely it would be gone, because it has a certain amount of vapor pressure and therefore it gets into the air. But if you were to put most pesticides on this table and leave them there overnight, you would find that pretty much of it would still be there when you came back, because of lower vapor pressure. Table 1 shows a saturated concentration at the temperatures given in parentheses. Under a static condition, if you were to take these pesticides, leave them around in a room, shut the doors and all the windows, these are the concentrations that you would obtain at equilibrium. For chlordane you only get 13 ppb in the work environment even if you have this type of imaginary situation where the whole place is closed up. However, if you were to do the same thing with dichlorvos, the active ingredient in Vapona®, you would find 16 ppm, or 16,000 ppb, in the work environment because the vapor pressure is higher. Compare this with the acceptable airborne guidelines at equilibrium. I don't want to mislead you into thinking there is no problem from inhalation, but under static conditions, where you are actually draining a tank and filling receptacles with these materials, it is difficult to obtain a dangerous vapor concentration in the atmosphere for most pesticides.

If you are handling a dust, it is a somewhat different matter. If the dust gets into the air and the particle size is very small, then, because of the extra surface area, you can have vapor coming off the dust particles. When you are exposed to a dust you may have more than a dust problem; you may have a vapor problem too.

More hazardous from a vapor exposure standpoint are the solvents. A broad range of solvents is used in diluting materials, for example, the alcohols--methanol and isopropanol; the aromatics--xylene, toluene, and other alkylated aromatics; the chlorinated solvents--such as methylene chloride and 1,1,1-trichloroethane. Methylene chloride is highly volatile. I see situations where this material is used to spray in conjunction with another material onto corncobs, and then this material is flashed off. This can be a problem if these vapors are not controlled through local exhaust ventilation. Aliphatic solvents such as hexane, and also some of the others which are lower in volatility, such as heavy aromatic naptha, kerosene, and fuel oil, are also used.

Table 2 is taken from Homer Wolfe's paper, titled Chemical Safety--Pesticides (U.S. Dept. of Commerce, National Technical Information Service, 1974). In it he breaks down the amount of exposure that an individual receives, not only in a field condition but also in two incidents in formulating plants. He determined that the greatest amount of exposure comes from skin contact. In this particular work, he found that with DDT 524.5 milligrams per hour was the dermal exposure of the individual he was monitoring, and 14.11 milligrams per hour was the exposure through the respiratory tract. This suggests very strongly that skin exposure seems to be a much greater problem than inhalation. This is not to play down inhalation; however, in this particular case and in many other cases that I have read about, skin exposure seems to be the big problem. In other words, that's where we really ought to be looking for our problems.

Table 2

Routes of Exposure

Compound	Activity	Exposure: Dermal mg/hr	Exposure: Respiratory mg/hr	Total % toxic dose/hr
DDT	Spraying apples	54	0.10	0.03
DDT	Indoor house spraying	1,755	7.10	1.02
DDT	Outdoor house spraying	243	0.11	0.14
DDT	Formulating plant	524.5	14.11	0.39
Parathion	Spraying apples	17.3	0.02	1.19
Parathion	Spraying citrus	18.0	0.03	1.17
Parathion	Spraying potatoes	4.7	0.01	0.32
Parathion	Dusting potatoes	7.8	0.16	0.64
Parathion	Thinning apples	8.4	0.06	0.61
Parathion	Flagger--crop dusting	84.0	0.02	5.72
Carbaryl	Spraying apples	59.0	0.09	0.02
Carbaryl	Formulating plant	73.9	1.10	0.03
Carbophenothion	Spraying orchards	41.3	0.11	1.12
Ethion	Spraying orchards	44.2	0.04	0.26
Endosulfan	Spraying apples	24.7	0.02	0.27
Endrin	Spray orchard cover for mice	2.5	0.01	0.21
Fenthion	Mosquito spray	3.6	0.01	0.02
Fenthion	Hand granular	12.3	0.08	0.06
Perthane	Spraying apples	59.4	0.14	0.01

Calculated on the basis of the worker wearing a short-sleeved, open-necked shirt, no gloves or hat, with his clothing giving protection of the areas covered.

Source: WOLFE, Homer, Chemical Safety-Pesticides. U.S. Department of Commerce, National Technical Information Service, 1974.

How do skin exposures actually occur? Most of them are human error: runovers, spills, leaks, maintenance, changeover (that's not a human error, it has to happen), broken bags (also due to malfunctioning equipment), surface contamination (normally not considered too much of a problem unless the material being handled had a high degree of dermal toxicity, with no protective gear, and, finally, improper protective gear--for example, using a dust mask when you should actually be controlling vapor. In work done by Kazen, he found that chlordane and dieldren have persisted on the hands of a former pest control officer (PCO) for at least one year. Methoxychlor, captan, and malathion have persisted on the hands of fruit and vegetable growers for at least seven days. Parathion, a very active organic phosphate, was found on the hands of one individual two months after his last known exposure. What this means is that there was an analytically detectable amount, but not necessarily a dangerous amount, on the skin.

In some work done by Maibach (Table 3), studies were done on the application of a pesticide to a particular part of the body, in this case, the forearm. A five-day urinary output was taken for various chemicals to test total absorption. With parathion, 8.6 percent of what was put on the forearm was eventually collected in the urine, meaning that only a certain amount was absorbed through the skin. Carbaryl seems to have the greatest penetration, with 73.9 percent collected in a five-day urinary output.

Table 3

PESTICIDE ABSORPTION THROUGH SKIN
(Forearm)

	Type	Absorbed
Parathion	OP	8.6
Malathion	OP	6.8
Carbaryl (Sevin)	Carbamate	73.9
2,4-D	Phenoxy	5.8
Azinphos-methyl	OP	15.9
DDT	CH	15.0

Table 4 notes the effect of confinement to the skin. In the control experiment, material was just placed on the skin and removed, and the five-day urinary output was collected. Other subjects wore a saran cuff on their forearms to keep the material confined to the skin for twenty four hours. The numbers indicate that extended exposure resulted in excessive absorption of the material through the skin. The point is, if a worker is splashed in the work environment, get the garment off. To leave it on would have the same effect as cuffing the material to the skin.

Table 4

EFFECT OF CONFINEMENT OT THE SKIN
% Absorbed (Forearm)

	Control	24 hours
Malathion	6.8	62.8
Parathion	8.6	54.8
2,4-D	5.8	14.7
Azinphos-methyl	15.9	56.1

With damaged skin (Table 5)--for example, dermatitis--there is an increase in the amount of active ingredient that is actually absorbed through the skin. The numbers in this figure also reflect a five-day urinary output. The experiment was conducted on skin which was damaged by applying tape and lifting it off before applying the active ingredient.

Table 5

EFFECT OF SKIN DAMAGE ON ABSORPTION
% Absorbed (Forearm)

	Control	Damaged
Azinphos-methyl	15.9	60.5
Parathion	8.6	73.2
2,4-D	5.8	33.8

How do you evaluate skin exposures? This is really a problem, and anybody who has ideas in this area could have himself the better mousetrap that everybody's been looking for. In field studies absorbant gauze patches are put on the outside uniform of the worker. He works and collects spray all day, and then the gauze is taken off and dropped into a solvent, which is analyzed for the active ingredient. This can be done in a work environment, but normally in a formulating plant you won't encounter a great deal of mist or aerosols, and I would not venture to guess how this would work for dust collecting. I imagine you would probably get very poor correlation between it and the actual skin absorption.

Looking at the literature, we find that hands seem to be a key spot for the absorption of pesticides due to spills, runover, no gloves, and so on. Field people have also devised a method where the worker sticks his hand into a bag, solvent is added to the bag, it is shaken, and the solvent leaches off into the bag. The solvent is analyzed for the active ingredient. Very high levels can be found on the skin of formulaters and fieldworkers. There is also a modification of this method, the spray rinse, in which solvent is sprayed onto the skin from a spray bottle so that it rinses the material off the skin and into a container. Then it is analyzed. Some of the solvents that have been used are ethanol and hexane. I don't recommend hexane because of associated toxicity. On the other hand, everyone is exposed to ethanol to some extent, and it seems to be a fairly good solvent for rinsing off such things as organophosphates, though it is probably not as good for chlorinated hydrocarbon pesticides.

Another method of evaluation uses skin swabs. Here one takes a swab that is doused with solvent, cleans the skin, and analyzes the solvent extracts of the swab.

Finally, there is evaluation through wipe testing. The way we do it at Dow is to use Whatman W® #2, 5.5 cm filter papers with or without solvent. Solvent usually does a better job; you get much more efficiency in picking up the material you're after. Then you wipe 100 square centimeters of surface, put the material in a vial, and have it analyzed for the active ingredient. You will come up with milligrams or micrograms per wipe, though I hope you won't find milligrams. It is not very effective for highly volatile materials because you would probably lose it very quickly, either in taking the sample or in the analysis. For most of the organophosphates, though, it would work very well. Some wipe-test guidelines should be established based on what you see in biomonitoring your employees. You want to know whether biomonitoring correlates well with your wipe testing. It's rather difficult to see any correlation in situations where the variation in cholinesterase levels is subtle. In general, however, we do seem to see some general tendencies for ups and down when we do wipe testing. In other words, the wipe-test samples will generally tend to be a little bit higher if plasma cholinesterase levels seem to be varying somewhat.

High wipes may mean that a cleanup is necessary, but more than that, that employees must be supervised more closely to correct poor work habits.

In evaluating the work environment you want to consider some questions. First of all, does a suitable, validated sampling method exist? For many materials it does not. Many suppliers have not gotten involved in establishing these methods. Dow has come up with very good sampling methods for its materials under actual end-use conditions. The second question is, does an analytical method exist for the material? These two questions go hand in hand. Third, who is going to do the work of sampling in a formulating plant? We at Dow have a concept we call "product stewardship." It starts with the employee working at the bench with the material and goes right to the end when the material is disseminated into the environment. We feel that it's necessary for suppliers to know what is happening during the transition from the bench to the actual environment as it gets sold to the customer, stored in warehouses, and so on. Everybody in between ought to know what are the consequences of overexposure to these materials, or what happens when they are mishandled. The supplier can, and to some extent should, act as a consultant for the formulator. Our doors are always open in terms of consultation with our customers. There are in turn consultants involved in the business of monitoring pesticide formulators. There are also a number of consultants in the industrial hygiene field. The American Industrial Hygiene Association Journal lists some 200 consultants in the back of each journal. You can also go to the universities and have university people evaluate your work environment, though here you may not be dealing with people as expert as suppliers or consultants. Another approach is to go somewhere like Midwest Research Institute (MRI), which is also involved in this kind of business and does excellent contract work for formulators.

Let me sum up. With some exceptions, exposure to pesticide vapor is probably not very important, but I want to qualify this by reiterating that if there is a very fine dust exposure, there will be a certain amount of vapor. Second, solvent vapor may be a source of worker exposure. We do not look at solvents as inerts; they can be inhaled to a certain extent and should be monitored. Third, dust exposures may be of great importance in some formulation plants. The Kepone® situation was a very dramatic one in which there was an awful lot of dust exposure to that material. Fourth, skin exposures are responsible for greater than ninety percent of the exposure to pesticides under field conditions and in their formulation. Skin exposure is where I think we ought to be keying in. Hand rinses or swabs are probably the best evaluation methods, other than biomonitoring. Fifth, exposure to the hands is of key importance in the formulating operation. Efficient and appropriate gloves are the first line of defense against skin exposure. Unlined rubber gauntlet gloves are recommended.

Unlined is specified here simply because if a glove lining becomes contaminated, you pretty well have to throw the glove away. If contamination occurs on the inside of an unlined glove you can rinse it out, wash it, and probably reuse the glove. We specify gauntlet gloves because they protect the upper portion of the hands and wrist.

Sixth, wipe testing may be used as an "after the fact" approach to determine whether a cleanup is necessary, which is primarily the way we use it. And seventh, education and strong incentives should be used to reduce employee exposures. We find this to be probably the most important factor in evaluating or dealing with exposure in formulating plants. Attitude is so important. If the attitude of the employer is positive toward safety, the use of protective gear, and the education of his employees, the employees will absorb that attitude to some extent. A well-educated worker is, by far, one of the best preventions against overexposure.

EMISSIONS MONITORING--GENERAL PRINCIPLES

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The total area of pesticides is very broad, encompassing many chemicals of varying toxicity and principal properties. I think that a lot of discussion often gets focused on the most toxic aspects of the pesticide grouping, and we assume that that is true for all pesticides when it really isn't. When I looked at an approach to monitoring from an emissions standpoint, I thought, "We're going to have to come up with something a little bit broader in scope." It's difficult to come up with any kind of simple technique that applies across the industry as a whole. Just recognizing that this pesticide group is a very diverse area is important before starting to evaluate the monitoring of either environmental emissions or industrial hygiene problems.

I think it's important that we look at a number of things that we all face every day in the chemical industry in general, not just with pesticides. I think that when we talk about our monitoring approach we are really looking at the same kinds of questions, whether it's a plant for organic chemicals, inorganic chemicals, or pesticides, or whatever. So the first step is to define what it is that we need to examine.

In the first place, we need to define why we are monitoring. Second, we identify the contaminant or what it is we're concerned about. Third, we select a monitoring parameter, what we are going to measure. Fourth, we select the sampling and monitoring method, or how we are going to do it. Fifth, we select the sampling strategy, or when to sample. Finally, sixth, we select the nature of the final strategy. We will also talk about some specific examples in areas of concern that occur primarily within the formulating and manufacturing of pesticides. This is a very simple, commonsense approach that involves the who, what, when, where, why, and how of monitoring.

It's not difficult, but I think it's important that we address ourselves to these concerns in order to conserve resources and a lot of the energies that we put out for so-called scientific study. If it has not been thought out thoroughly before, these energies may be misplaced.

One objective of emissions monitoring is to meet the regulatory or legal requirements of an abatement agreement, or some type of local or Federal EPA regulation. Monitoring may be to obtain confirmation or documentation of emissions control in order to have legal evidence of controlled emissions.

You may also monitor the control loop instrumentation of emissions control equipment in order to effectively control the performance of that piece of equipment. You may monitor to test the alarm, shutdown, or early warning for critical emissions devices if you have an extremely toxic material, or one that isn't quite so toxic. If the environmental effect is one that you're concerned about--for instance, if you're dealing with a herbicide--and a bag blows on a dust collector, thereby dumping the herbicide into the local environment, killing a lot of trees and foliage, then that's a critical emission.

You may be monitoring in order to evaluate emissions control effectiveness, and if that is the case, you may not need to do it continuously.

In order to know exactly what we're concerned about, we have to determine what the contaminant is, in other words, what chemical is involved. Then, in addition to knowing the chemical, we've got to know what the physical form is of the chemical we're after. Are we out here trying to collect liquid aerosol or a solid particulate, or is it a gas or a vapor? The toxicology of the material is extremely important, though that doesn't necessarily mean that we are only concerned about those materials which are highly toxic to mammals. Avian toxicity and phytotoxicity are also important. I think we have an advantage in the pesticide industry over other portions of the chemical industry that is often overlooked, in that we have more toxicology information available to us to make these assessments. Also important is the environmental fate. We need to know the chemical half-life in the environment. (Half-life is the time required for the degradation of a given quantity of a chemical to one-half its original amount.) For instance, if we're going to sample cumulatively, does the contaminant have a half-life of two weeks or a half-life of six months? Going back to toxicology, are we looking at something which has a direct acute effect or something that will accumulate and have an effect later on in the environment at higher levels? All of these factors become input in determining how to go about setting up a monitoring program. To sum up these factors, I use the term "hazard rating." In other words, we ask ourselves, "Exactly what kind of hazard are we dealing with here? Is it in fact something that's going to affect plant life only, or will it also affect birds, fish, and on up to higher trophic levels? To what degree will it have an effect?"

There are two general classes of monitoring parameters: direct and indirect. The most obvious way is to monitor directly. We take a contaminant concentration and then it's only a matter of selecting where we are going to monitor it--at the source, in the environment, or at the point of impact. It's a fairly straightforward thing. But we can also do a good job of monitoring, sometimes more effectively, certainly more economically, if we take an indirect approach, one that we are confident will give us a relative reading that we can use to determine whether we're controlling emissions or not. Five indirect monitoring parameters are mentioned here.

First is total mass concentration, either by gravimetric analysis or light scattering techniques in exhaust ducts. Second is the subjective response. While it's not totally peculiar to the pesticide industry, odor certainly is a problem in organophosphate manufacturing, as is odor intensity. The plume opacity in some cases can be important. A third way of indirect monitoring is the exposure effect of cholinesterase inhibition. This one is not really very common, or wouldn't be in an environmental case. However, foliage color may be, particularly around a herbicide formulation plant. A fourth indirect method involves emissions control equipment parameters, such as pressure drop across scrubber columns, bag houses, or carbon absorption units. Fifth, the process control parameters can be an important indirect means of measuring the effectiveness of a control, particularly if you know a range of optimum control for the process.

Because of the wide variety of chemicals, and depending on our initial purpose for monitoring, we can either select direct-reading equipment or collection equipment whereby you would first take a sample and then have it analyzed. The choice is strictly based on the needs of that particular monitoring.

If the method used is sensitive, parts per billion or less are often required. We have to remember that, environmentally, we generally are not dealing with kinds of concentrations we see in the workplace, and there are not very many methods that are going to be specific enough to go out and effectively measure half a mile from a plant, for example. The technology just does not exist. That doesn't mean to say we can't do some of it, but we need very large sensitivity. As to accuracy, I should say plus or minus twenty-five percent is excellent. When you consider all the factors that go into environmental monitoring in particular, the accuracy, the fluctuation in the number that you get from what the correct number is, is often going to be quite large. It's not that we can't deal with a large variation in accuracy, it's just that we have to know what we're dealing with, and the number involved.

When it comes to the cost factor, it's generally accepted that the more sophisticated, the higher the cost. But that doesn't necessarily mean that if we go to direct reading instrumentation, for instance, and to highly automated sampling, that in the end the cost will be the highest. Even if we collect samples ourselves, the cost of analysis, the number of samples, and other factors have to be worked out. It can also be a very costly sort of thing. Economics will actually determine what we can and can't do in smaller operations. The same is true of availability. Laboratory services or professional assistance is not always available. If we are located in a place where we don't have access, it doesn't mean we can't do sampling, but it severely limits our ability to use a lot of techniques that are available. (Later on we'll talk about some examples of the methods that might be used in dealing with particulates, vapors, gases, pesticides, and odors.)

The selection of a sampling strategy is relatively simple if we are going to go to continuous monitoring. Then it is simply a matter of getting the equipment and determining how many points to monitor. Intermittent monitoring gets into the questions of how many samples are needed and how often. If you take one sample per year and try to extrapolate that across an entire year to get an emissions level, there is a lot left to be desired in terms of confidence. If you up the confidence level with statistical analysis, you may have to close your doors because of high monitoring costs. More likely you end up somewhere in between with a compromise. It's important to understand that if you have a highly toxic material and have to control it within very tight range, you may have to do a great deal of sampling to insure that. If you have a less toxic material, with less severe environmental effects, there's a range that you can work in. It's strictly judgment. But at least statistical analysis can help you arrive at it.

With regard to sample location, it is generally easier to do sampling at the source because there are higher concentrations to deal with. Therefore, you have a wider range of methods available to you to do the analysis and to understand the sampling. If you go to the fence line, it becomes more difficult. Concentrations are lower and you have more factors, including environmental factors (wind direction, temperature, rain, snow), to contend with. Soon it has become a whole new ball game. And next, when you get out to environment even beyond that, it becomes quite difficult.

If you're doing PSD (prevention of significant deterioration) monitoring, you have to set up a station. You may be taking environmental modeling to determine the best site. A stationary monitor could be useful environmentally in a case like that but, in general, if you're going to do some sort of monitoring out in the environment, a mobile unit is more effective or more cost effective.

Now to discuss some of the individual things that can be done. If we're dealing with particulates, just looking at particulates altogether, we can do stack sampling, simply as a collection on filters. Air flows to the filters must be isokinetic, which means we must sample at the same velocity and direction as the particles are flowing in the stack. Particle density measurements are another method. There are instruments that measure light scattering. We can put that instrument after a bag house and determine if a change in the concentration of particles in that stream occurs. Of course, then particles involve plume opacity. Environmental sampling, on the other hand, is primarily done for particulates by collection on filters. You have to understand that you will be doing it gravimetrically and that it will just be a composite of the source and the fugitive emissions.

There are several methods to monitor vapors and gases. Stack or vent sampling can be done, including on-line gas chromatographs, which can be very specific for the material you're looking for, but not continuous. There will be some sort of cycle time per sample. The on-line flame ionization detectors are continuous and give a good readout, but they are not specific, since anything that has a response is going to show up on that detector. On-line infrared detectors are specific and can be used either as continuous or noncontinuous samplers. They're quite effective if you have a material that has an infrared absorption signature. That eliminates a large block of other materials. Effective methods of sample collection include using solid adsorbents, liquid absorption, or gas collection, all of which involve laboratory analysis.

You can still use a gas chromatograph in the environment, but you end up with a limited sensitivity, particularly with simple gas injection. Portable flame ionization detectors and portable infrared detectors are good for a survey of fugitive emissions near the source--in tank farms or around pumps--but their sensitivity falls off very rapidly and you're really dealing in the part-per-million range. Collection on solid adsorbents, followed by laboratory analysis, is the best way. Probably selection of the proper adsorbent is key in that case. Thermal desorption techniques would get you the greatest sensitivity per sample because there's no need for any liquid dilution of the material. Unfortunately, not all materials respond well to thermal desorption. There are many cracking and stability problems. Solid state and electrochemical detectors can be used, such as H_2S detectors, carbon monixide detectors, and so forth, but they vary in sensitivity and selectivity.

Environmental modeling is important particularly with vapors and gases. After taking sample data at the source, and getting good data there (especially if the emissions are primarily from a stack), you can then use environmental modeling to extrapolate to areas in the environment where sampling is not feasible. This will usually cut costs in terms of the amount of sampling that must be done. If that is the case, then you just need to do less follow-up sampling.

The volatile pesticides would be treated as gases or vapors, just like any other chemicals. You treat solids essentially the same as particulates, with the exception that chemical analysis supersedes gravimetric analysis for determination of environmental concentrations. It's important to note here that you need not always use very sophisticated collection techniques. Fallout sampling, if that is, in fact, the way that contamination of the environment occurs, is acceptable, and can be appropriate in some areas, because after all we are looking at how much material falls in a particular area. Nonvolatile pesticides are not unique to the pesticide area, but nevertheless they occur with a lot of organophosphates. When you collect the material on a filter, the material may be a liquid aerosol or a solid particulate. Then, with the impact of air going across it, the material is stripped off the filter, either by sublimation or evaporation. So in fact a two-stage sampling system is needed in order to have effective collection. That makes it much more difficult, but it can be done. Probably the best method now available is glass fiber filters followed by a bed of porous polymers or chemically modified solid adsorbents. It will work for a general range of pesticides that fall into this category. Impinger sampling, using successive impingers and a variety of absorbing solutions, is cited in the literature. There are a lot of errors associated with impinger sampling because of variations in particle size, and so forth.

Odor evaluation is rather peculiar to organophosphates. Subjective evaluation, using scentometers, olfactometers, and odor panels, have certainly been commonly used. Semiquantitative evaluations using odor fingerprints have not been very successful. Quantitative evaluation is possible only when one or two chemicals are known to be responsible for the odor, which just doesn't happen very often. Monitoring odor control equipment and processes is really a better way of assuring control of emissions. A liquid oxidative scrubbing can be monitored by use of redox (reduction oxidation) electrodes in the recirculation loop or a pH probe in the recirculation loop. We mentioned pressure differential across the column earlier. It's the same with carbon adsorption and thermal oxidation. You can measure and monitor temperatures and flow and so forth.

To summarize, obtaining valid data is absolutely the most important element of any kind of emissions monitoring program. If we fail to understand that fact completely, we get a lot of data that is useless and that, unfortunately, is not perceived as such by those who collect it. I can only say that if you go through a very logical and thorough approach to establish a plan for any monitoring venture, you're going to have a better opportunity to cover all the aspects that will make it a valid sample. In general, I think, experience has shown that, particularly in smaller formulating areas, if you monitor the emissions at the source you can do it more economically yet still have a reasonable margin of safety.

MEDICAL MONITORING IN THE PESTICIDE INDUSTRY

Robert Shaw, M.D.
Stauffer Chemical Company

I shall discuss how to start up an occupational health progr how to conduct medical monitoring on employees in pesticide facturing and formulating plants. To do this I would like t ly discuss the following: the objectives of employee health toring; how to develop a local medical program; the medical inations involved; special medical testing; and useful medic reference material for the location doctor.

Medical monitoring is not as complex as is believed. The ba objective of an occupational health monitoring program is to guard employees from significant health effects resulting fr tential workplace exposures to physical, chemical, or biolog agents. An important related consideration is also to meet obligations placed upon company activities under federal, st or local occupational health regulations.

In providing these occupational health services, a fundament consideration is that the health of employees is an area of concern to management when it has the potential to affect th performance of work assignments or when it relates to the oc tional environment. Reasonable safeguards for maintenance o health, promotion of well-being, and prevention of job-relat illness or injury are in the best interests of both employee company.

The goals here are very simple: to protect your employees' against known biological, physical, or chemical hazards dete to be inherent in the work environment; to periodically eval employee ability to do certain tasks safely; to maintain emp in an occupationally healthful environment; to provide emerg health services in case of illness or injury which occurs on job whether or not it is the result of occupational factors; acquire health information about your plant and your employe that you can periodically assess the safety and health condi in your plant; to develop resources for employee health mana and to document your compliance with some of the regulations impact on the workplace.

Now for some of the program components. I will generally be ing about what we do at Stauffer, but I will try to make it cable to the smaller pesticide formulators and manufacturers well so that you get an appreciation of what you can do prac

An effective occupational health program involves industrial hygiene and toxicology. Relative to what is being used in the workplace, you need to know what the known health effects are from either short- or long-term exposure. Toxicologists conduct studies involving bacteria or mammalian species, monitor any health effects during the testing of animals, and provide interpretation of the results. We use some case reports as examples of what can occur in adverse situations. For instance, we know of situations where individuals have inadvertently come in contact with certain pesticides such as organophosphates and have had bad reactions or have even died.

In our situation, since we have a corporate medical staff, we have identified local doctors who work for us part-time, on a fee-for-service basis in our plants. We keep files or medical records that we have developed from examinations. OHIS is our own code name for the Occupational Health Information System, which is simply a method by which you can manage medical information and make judgments by doing epidemiologic investigations. That's very sophisticated for some of the smaller operations, but the idea that I want to bring out is that there should be some system, either with a plant doctor or with a consultant, by which the medical information that is generated can be gathered together. You or the doctor or consultant can periodically use the information to determine whether any health effects are developing.

In our program, an industrial hygienist goes into the workplace and takes a look at the conditions there: the manufacturing processes, the nature of the raw materials, the intermediates, and the finished goods that are produced. On the basis of that he makes an evaluation of the potential for exposure and the kinds of potential conditions that could exist there. The toxicology department then tells us what kinds of tests have been done, referring either to the literature that's available worldwide or to tests specifically done either by our toxicology research program or through consultants and contract labs regarding the health effects that have been noted in short- or long-term animal studies. Tests involve inhalation, eye contact, skin contact, bacterial studies on mutagenesis, mutation, and so on. That information comes to us over in Occupational Medicine. On the basis of hygienic evaluation and toxicological analysis, Dr. Northrup [Director, Occupational Medicine Department, Stauffer Chemical Company] and I make recommendations for an examination program that will define the kinds of examinations needed in this particular plant, and we then provide that information to the plant doctor. He goes out and periodically does the physicals. We do it on an annual basis. As more information comes from either industrial hygiene or toxicology, we advise the doctor to modify the program, change it, expand it, and so on.

Here's how occupational medicine works for us. We talk directly to the plant doctor, and the plant manager, who is in communication with both the plant physician and the employee. For smaller manufacturers, the information would come from the plant manager or his consultants to the plant physician to the employee. smaller companies that do not have corporate specialists, i: trial hygienists, and toxicologists, a lot more of the deve. ment work for a program has to be done by you and the physic Though it's not as bad as you might think, I'm not going to mize the fact that there is some work involved. The first t to consider is what raw materials, intermediates, and finish goods you have in the workplace and gather data on them. Or way to get data is to request information from the supplier. you're buying raw material, the supplier has to make out mat safety data sheets, or what we call Product Safety Informati Sheets. Stauffer has an active program developing Product S Information Sheets in which we tell about the physical and c cal properties, chemical reactivities, stabilities, fire and plosion hazards, and firefighting techniques. We include se on toxicology, animal studies in ingestion, skin contact, ir tion, and eye contact. Based on that information, we incluc first aid section on ingestion, eye and skin contact, and ir tion. We include industrial hygiene recommendations such as handling, nature of the corrosivity of the materials on cons tion materials, storage requirements, and disposal. Many of larger companies, and a number of the smaller ones, have bee veloping these Product Safety Information Sheets. If you bu ucts from these people they should provide you with a copy. a good way to get some basic information for you and your ph

The medical doctor can look up poisoning textbook references toxicology texts. [Recommended references are included in Ap C.] One of the other resources I have used extensively in oc tional medicine is something put out by NIOSH, called Regist Toxic Effects of Chemical Substances (RTECS). It's publishe annually, it's an excellent reference, and it is a good thir you and your plant physician to have.

Once you have determined what raw materials, intermediates, finished goods you have, and you've started to gather some c information, ask yourself what potential for exposures there the plant. The industrial hygiene folks who talked earlier have described well the kinds of program requirements you sh have in industrial hygiene. Some of the guidance they've pr can be very useful to you when you develop your program. Sc idea is to get this information together and sit down with y doctor to develop a general medical examination and surveil] program that will meet some of the potential health effects you can identify from the compounds that you use in the work

By now you're thinking about how to select a doctor who can you develop your program. My first recommendation would be body who has some experience or familiarity with occupationa medicine. He should be familiar with preplacement examinati biological monitoring, return-to-work examinations, periodic examinations, health screenings, and special problems. He s be familiar with workplace regulations, OSHA regulations, ar workmen's compensation laws.

But these physicians are not plentiful. I belong to the American Occupational Medical Association, as do about 4,000 doctors in the United States. So in many situations you would have to use physicians who are trained in other areas of medicine. My recommendations, in order of my philosophy on the general familiarity of different specialties of physicians with the kinds of problems you will be dealing with in occupational medicine (respiratory, skin conditions, conditions related to diseases of the liver and the kidneys), include persons experienced or familiar in general medicine; persons familiar with the subspecialties of internal medicine (cardiology, pulmonary diseases, and gastroenterology, for example); persons who are board certified or familiar with family practice; and last, but certainly not least, the general practitioner or family doctor. There are a few physicians who would not be as useful as these individuals would be to you--psychiatrists or pediatricians for example. Obviously, their areas of expertise are not primarily in occupational medicine or general internal medicine.

Another consideration is that if you are going to establish a relationship with a local doctor, it's helpful to choose somebody in group practice. Single practitioners go on vacation, they can get sick, they can retire from practice, and if you've developed a program with a physician who decides to leave his practice, you have to start all over again developing the program with somebody else.

How do you find an appropriate doctor? The American Medical Association (AMA) comes out with a five-volume annual listing of physicians registered and licensed to practice in each state. The AMA now also has a specific listing of female physicians. The American Occupational Medical Association (AOMA) also comes out with an annual listing of its members. These are people who are interested and who also have some specific expertise in occupational medicine. If you don't have access to those books, the county or state medical society will have lists of people who are certified to practice in certain fields--board certified in internal medicine, pulmonary diseases, and so on. The chief of staff of your local hospital would probably know of a group practice that would be interested in your kind of work. You can also get recommendations from other plants in your area if they have a similar kind of program.

The idea, then, is that once you have some doctors who you would be interested in, you meet with them, explain your interests, the kinds of medical programs that you think you need to have, review the kind of information that you've gotten from material safety data sheets and from your industrial hygiene review of the plant, and explain what you think should be done. The doctors, in turn, will probably have some additional ideas. Even if a doctor says he's not familiar with occupational medicine, it is possible for him to become familiar with it.

Once you start the program, the doctor should visit the plant, to get an idea of what kinds of processes and activities go on. He should visit annually to review the work processes, look at the plant, and familiarize himself once again with the kinds of work that you are going to be sending him. He'll need an idea of the work your employees do. You should also have him come back to the plant if you've made any significant changes in your process since his last visit.

If your doctor is unfamiliar with occupational medicine, or with general concepts of industrial hygiene, toxicology, OSHA, and so on, there is extensive literature that has become available in the last ten years. As I mentioned, the AOMA publishes a journal which is very good and is practically oriented. Many books are available. You can even sponsor his participation in some local or regional subchapters in each state, and they meet periodically. For instance, I belong to the Connecticut OMA and we meet about five times a year in addition to the annual meeting.

Now you may be asking, what examinations are we going to need? We have examinations for people who are potentially exposed. This group is comprised, by and large, of the people in the plant who work in the processes; they're production workers, safety managers, plant managers. In other words, they're the people who will be around the entire worksite, doing or checking certain processes. An examination should be done periodically to determine which workers can be medically certified to safely wear a respirator in the workplace. There are periodic noise measurements and audiometric examinations that should be done if you have workplace noise exposure. Then there are production-related examinations, specifically cholinesterase biomonitoring, which I will detail later in this discussion.

You should also plan for preemployment or preplacement examinations. The main reason for this, of course, is to establish that an individual is medically capable of performing the duties of the job for which he or she is applying. It's also to assure that people are placed in jobs which are appropriate to their physical and emotional health. Another important reason for these examinations is to establish a detailed profile of the individual's health at the time of employment. This information provides a base for subsequent comparative measurements and analyses of future health trends in that individual or among your employees as a group. By comparing subsequent health results you can see whether or not there is any relationship between workplace exposure or workplace activities and the development of occupationally related diseases.

The doctor, when he does these examinations, will have to know a bit about the current state of the applicant's health, with due consideration to significant past medical history. It is important for the person to give the doctor a detailed past employment/past health history, including what kinds of jobs were held in the past, what serious illnesses the person has had, any major operations, and family history. We are discovering more and more about the relationships between certain genetic factors and some diseases which are not necessarily occupation related. The doctor will have to know what job the applicant is seeking so that he will know what areas to focus on. You're also going to have to give the doctor some idea as to whether there are any special environmental considerations on the job, including protective clothing, respirator use, and so on.

The scope of the basic preplacement and periodic examination involves a health history, travel history, perhaps military history; then the physical examination itself by the doctor; and some laboratory studies. A useful screening series of laboratory studies includes a complete blood count, a urinalysis, and a screening series of biochemical tests that look at liver function, kidney function, protein metabolism; then some general clinical studies: pulmonary function tests, breathing tests, electrocardiogram, chest x-ray, and audiometric testing for a baseline evaluation with subsequent testing if there's a noise problem in the plant. The doctor should review all these factors together and then provide you with his recommendations regarding whether or not he feels the person can continue to work safely in the workplace; and, if the person needs respiratory certification, whether he feels that the person can wear a respirator safely.

The objective of periodic examinations is to evaluate the current health status of your employees relative to their work. Periodic examinations should be given to those employees who work with OSHA-regulated substances. Vinyl chloride is one good example; asbestos is another. Acrylonitrile and BCME are two others. In other words, periodic examinations of your employees should take place if they work with substances which mandate such examinations, or if your company decides that periodic examinations are necessary to identify and preclude adverse health effects, or to look at safe job performance for those employees who are in specific work assignments.

With regard to special examinations, two additional programs which I'd like to talk about that may be required in your facilities are clinical testing for respiratory certification and laboratory testing for cholinesterase biomonitoring. An OSHA recommendation (29CFR1910.134) states that individuals should not be assigned to use respiratory protective devices unless a physician has determined that they can do so without risk to their health. Broadly speaking, this means that an employee who would use a respirator should have a periodic medical examination by a doctor. OSHA suggests that it be done annually, to make sure that the employee has not developed any health conditions, such as cardiac disease or respiratory disease, which would make it difficult for him to wear a respirator safely. For this testing, a brief health history review is needed along with the physical examination by a doctor. A pulmonary function or breathing test, a periodic chest x-ray, an electrocardiogram, and perhaps some other clinical studies are called for. If your employees have periodic medical examinations, it's an easy thing just to have the doctor add those other tests that he feels are appropriate to accomplish the respiratory certification. If they do not get an annual or periodic medical examination, then you may need to identify for the doctor those employees who are going to wear respirators so that he can do the appropriate clinical testing.

On the question of laboratory testing for cholinesterase inhibition, this is a little more involved, and a brief explanation is in order. Exposure to organophosphate chemicals may result in the inhibition of human acetyl-cholinesterase, an enzyme vital to the maintenance of effective nerve and muscle function. Because of this, periodic cholinesterase testing is useful in the health supervision of workers exposed to cholinesterase-inhibiting organophosphorus compounds. This testing allows for detection of potentially significant individual exposure to organophosphorus compounds before the occurrence of clinical illness.

Although carbamate compounds may also inhibit this enzyme, any inhibition which occurs tends to be very short, owing to a rapid reactivation of the enzyme. Thus, while it is important to recognize that carbamates may inhibit cholinesterase and to be alert for symptoms of illness, periodic monitoring of cholinesterase levels among individuals working solely with carbamates has little clinical usefulness in occupational biomonitoring.

The organophosphate tends to form a very stable complex with the acetyl-cholinesterase enzyme. So, in that situation, you would have to use two drugs--atropine to block the effects (which are salivation, pinpoint pupils, nausea and vomiting) and then 2-pam chloride, which helps to selectively lift the organophosphate off the acetyl-cholinesterase enzyme. You can reverse the inhibition of organophosphate insecticides on acetyl-cholinesterase by using drugs. The carbamate compounds form much more tenuous, loose associations. And we find that in most situations, unless there has been severe carbamate inhibition, when technicians in a laboratory start to add the reagents to a blood specimen to do the laboratory analysis, the equilibrium constant of the carbamate with the acetyl-cholinesterase enzyme changes, and it dissociates. The result is relatively normal acetyl-cholinesterase levels. Because of this we don't recommend that people exposed only to carbamate insecticides receive periodic cholinesterase biomonitoring. Instead they should be monitored primarily on other medical conditions, and they should be primarily looked at for evidence of symptoms. Periodic cholinesterase biomonitoring will not be useful unless there has been a massive exposure.

The cholinesterase test is sensitive to time, temperature, and technical factors in the laboratory. Thus periodic testing should be in the same lab, using the same technique if at all possible. We also urge all the laboratories we use to tell us in advance if they're going to change the technique, because we'll want to do dual sampling, to switch over from one baseline to a new baseline before we give up the old technique.

Although several cholinesterase testing methods are available, the most useful program, I think, is to assess cholinesterase activity involving a combination of red blood cell cholinesterase and plasma cholinesterase. The red blood cell cholinesterase is the enzyme that is found in the nerve-muscle junction. It's depressed very slowly, more slowly than plasma cholinesterase, but the depression is much more specifically attributable to organophosphate exposure, and its level accurately reflects the degree to which the enzyme is inactivated at the nerve-muscle junction. The technique for performing red blood cell cholinesterase studies is technically involved and very detailed; there's a lot more variation to it in the laboratory than with plasma cholinesterase.

Although plasma cholinesterase has less analytic variation, it has much more physiologic variation. Plasma cholinesterase will change depending upon a person's alcohol intake, recent infections, liver disease, and it also changes to some extent with the hormonal cycle of women. Thus it is a little more difficult to establish a baseline level for plasma cholinesterase. The plasma cholinesterase usually reacts quickly to organophosphate exposure, but it's not specifically attributable to that. A person with a head cold may have a reduced plasma cholinesterase level which is not related to organophosphate exposure. Unless the doctor has the combination of red blood cell and plasma information to make a judgment, it will be hard to make identification of what is causing this variation in the cholinesterase level.

To begin a cholinesterase biomonitoring program, it's recommended that a preexposure or a working baseline cholinesterase value be established against which subsequent values can be compared. Such values may be classified as preexposure baselines depending on whether or not the individual has been exposed to any cholinesterase-inhibiting compounds in the last sixty days. But for either preexposure or working baselines, you should have two successive samples which differ from each other by no more than fifteen percent. Either value should be determined before you put a person to work with cholinesterase-inhibiting materials. The calculated preexposure or working baseline levels for each employee should be given to the plant physician for use in evaluating the results and periodic monitoring.

How do you determine when to pull a person from exposure? We set limits--and these are available in one of the NIOSH Criteria Documents on Pesticide Manufacturing and Formulating--at levels that I believe are not likely to be associated with any clinical manifestations of cholinesterase inhibition. It is definitely not a good idea to wait until a person has salivation and pinpoint pupils, nausea, vomiting, and diarrhea to know that he's been exposed. By and large, the guidelines that have been set will reveal a person who has had a slight exposure and get him out of a continuing potential exposure situation long before symptoms occur. Generally speaking, once you've established your baseline, a reduction of thirty percent or more from either the red blood cell or plasma cholinesterase baseline requires that the person be promptly removed from exposure. Removal from exposure means avoidance of contact with open containers or with equipment that is used in manufacturing or formulating organophosphate or carbamate compounds. An employee removed from exposure to cholinesterase inhibitors can still perform work activities at locations which do not involve significant potential for exposure to these compounds. The decision to remove an individual from exposure should be made only by the location doctor, based upon a comparison of the latest cholinesterase test results to the individual's baseline. If the baseline has been reduced to this extent, another blood sample should be taken for confirmation of the test results. You should interview the employee to determine where the exposure could have occurred and review the worksite of the operation, so that sources of potential exposure are identified to prevent exposure to other personnel.

When a worker has been exposed and removed from exposure because his cholinesterase level has fallen below the recommended limit, the plant doctor should order cholinesterase testing every three to seven days. The employee can return to work once the cholinesterase level returns to within twenty-five percent of the baseline. In that situation the individual should be able to return to work doing the same duties as in the past without any significant reduction in his ability to work.

In summary, we've discussed the objectives of employee monitoring, the development of an occupational health program, how to select a local doctor for your program, medical examination components, some special medical testing such as cholinesterase and respiratory protection, and some useful medical references. I hope I've been helpful to you in deciphering some of these medical mysteries.

[Following is the text of the questions that followed Dr. Shaw's presentation.]

Question: Doctor, could you tell me what the effects of long-term chronic exposure to cholinesterase inhibitors are, where you don't have a critical or acute level?

Dr. Shaw: That's a tough question to answer, quite honestly, because we've only done those studies in animals for up to two years or so. I have not as yet seen any reports in the literature, nor am I aware of any specific reports which indicate a long-term health effect from low-level exposures to cholinesterase-inhibiting compounds, because the enzyme is so rapidly reactivated in the plasma situation and in red blood cells as well. Unless you have continuing massive exposures where you know the person exhibits eighty or ninety percent inhibition, they come back for a period of time and are knocked down again. I don't suspect that you would have a long-term health effect. However, the information is still unclear on that. There is a need for more epidemiological studies among individuals working in pesticides manufacturing and formulating plants. They would have to be done over a fifteen- to twenty-year period, and even if different groups were doing the studies, they should study people of the same age group, the same sex, and the same levels of exposure to get really definitive results. Follow-up would be needed to make sure that there was not a specific relationship between some health effect and the history of workplace exposure to organophosphates or cholinesterase-inhibiting compounds.

Question: Isn't there some indication of demyelinization as a result of organophosphates?

Dr. Shaw: Yes. In chickens there is some indication of demyelinization. But the chicken, unfortunately, is not a good representative animal of man. And that's one of the complications; when you expose animals to these compounds for a period of time, you usually use massive exposures to get something akin to an effect within the short lifespan of the animal. In some situations, such as the chicken, the animal is ideal for delayed neurotoxicity. It appears, however, that a number of things can cause delayed neurotoxicity in chickens, so it's a very uncertain area still.

FINANCIAL ASSISTANCE TO SMALL BUSINESS
John L. Carey
District Director, Small Business Administration

I welcome the opportunity to talk to you about my favorite su the Small Business Administration (SBA). I'm going to give y little information on what SBA is, and, more particularly, wh kind of financial assistance we can provide to those of you w are involved in small businesses, including the programs we h that would assist you in complying with the requirements of s of the regulatory agencies, such as EPA and OSHA.

The Small Business Administration was established by Congress 1953 as a temporary agency to aid, counsel, and assist small nesses throughout the country. The experiment was successfu in 1958 SBA was made a permanent agency of the government. E ally, what do we do? Our assistance programs are broken dowr four major categories.

First and foremost are our advocacy efforts on behalf of smal business. In other words, we at SBA try to represent the vie the small business before the Congress of the United States, also, and maybe more especially, before the regulatory agenci this country. It is pretty well recognized, especially amon businesses, that while the rules and regulations established regulatory agencies may appear equal and uniform on the surfa when it comes to application, the impact is nowhere near equa across the spectrum of business. Large business is much bett able to cope with all the reporting rquirements, process char requirements, and so on, than small business is. Small busir goes into it undercapitalized to begin with, so obviously it at a great disadvantage.

A second area SBA tires to assist with is that of doing busir for the government. The United States government is a very l purchaser. It probably purchases about $60 billion a year ir and services from businesses throughout the country. In the ten to fifteen years, our efforts in trying to provide opport ties for small business has resulted in those businesses obta on the average, about one-third of that business, or around $ billion.

A third area in which the SBA is active is management assista Most authorities--economists and business experts--agree tha small businesses fail because of lack of expertise, especial management areas of operating the business. SBA tries to meet this need by providing one-on-one counseling through our resources in-house and particularly through our cooperative arrangements with different organizations throughout the country, such as the National Association of CPAs or the academic community. Also, we try to co-sponsor training programs on the business management aspects of running a small business. This is done in conjunction with Chambers of Commerce throughout the country, the academic community, and any other interested organizations.

The fourth item, the main subject of my remarks here today, concerns financial assistance provided by the agency. SBA is a small agency as government agencies go. We have approximately 4,500 employees throughout the country to service approximately 13 million constituents. The organization has over 100 field offices throughout the United States and the island of Puerto Rico. Every state but Delaware, however, has at least one field office. Texas, being the seond largest state in the country, has five offices.

SBA is one of the few agencies in the government that operates under what we call a decentralized authority. In other words, each one of these 100 field offices has the responsibility and the authority to provide all types of assistance available under all the programs SBA has to the small business client. What this means is if you make an application for financial assistance from a field office, say, the St. Louis office here, we have complete authority to review your application and make a decision on whether or not it's a creditable proposal. If we deem it is, we approve that loan and provide disbursement of the monies you've asked for in the loan.

Our financial assistance program covers about seventeen different subprograms. The one well call our 7(a) program is a regular business loan program that encompasses the bulk of our assistance. Under this program we can provide direct loans as well as guarantee loans provided by a bank to a small business. About ninety percent of the financial assistance we provide is through this bank guarantee program. And as a result, only $1 out of every $12 that we are involved in providing for financial assistance actually comes from the government. The rest comes from the private sector and is supported by our guarantee. Under this program we can provide a guarantee for up to $500,000 of any loan that a bank would be willing to make to a small business. If a business cannot obtain bank financing even with our guarantee, we can provide up to $150,000 in direct loan assistance. A word of caution: Congress's efforts and the government's efforts to reduce direct government outlays have significantly kept the available direct funds extremely low over the past ten years or so, much lower than demand. Last year, for instance, of $3.2 billion in financial assistance provided by SBA, less than $300 million was in direct funds. This represents about a ninety-to-ten breakdown.

Who is eligible for assistance? Under our programs, any small business that cannot obtain financing through the normal lending channels is eligible to apply to the agency either for our guarantee on a bank loan or for direct loan assistance. What is a small business? A small business is one that is independently owned and operated, not dominant in its field, and that meets a certain size standards established by SBA for the industry in which that business operates.

There are a few types of businesses ineligible for our assistance. Any business that is what we call speculative in nature, or a business that is primarily involved in investment--for example, people who hold real estate for rental purposes, apartment owners, or a small loan company--is not eligible for our financial assistance. Businesses that operate in the area of what we call "thought molding"--for example, newspaper publishers, book publishers, advertising agencies, those kinds of businesses--are not eligible. The position of the government is that we do not want to be put in a position where, if we provide financial assistance, it could appear in any way that we are exerting control over these businesses that are involved in thought molding. The government takes an "arms length" attitude. One significant change is that we will now make loans to purchase or establish radio or television stations. The reason this position has changed is that through the Federal Communications Commission (FCC) there is enough control of those types of businesses, and anything that we might do would be insignificant.

I mentioned size standards established by SBA that a business would have to meet to qualify for our financial assistance programs. For example, in the area of manufacturing we have size ranges of up to 1,500 employees. Under this broad heading of manufacture, there are some subcategories. Generally, under 250 employees qualifies it as a small business. However, in some of the industries--for example, automotive--a manufacturer could have up to 1,500 employees and still be considered small.

Volume of industry is another criterion for size. In the business of wholesaling, the range is from $9.5 million to $22 million in annual gross receipts. The reason for the range is that subcategories exist, based on the product that is being wholesaled. Service businesses range from annual gross receipts of $2 million to $8 million. In the construction industry, a general contractor can have up to $7.5 million gross annual receipts and still be considered small. For some of the trade contractors--plumbing, electrical, and so on--the size standard is a maximum of $2 million annual gross receipts.

Some other requirements for our financial assistance are our credit requirements. These are basically the same as the standard credit requirements that any lending institution would have for an application for financial assistance. The owner-operator must have demonstrated the management skills to operate the business successfully. The owner-operator must have sufficient equity in the business, that is, a reasonable amount of his own money at stake, before we will put the taxpayers at risk. We also look for the owner of the business to be of good character.

A key requirement is whether that business operation or potential business operation will generate enough profit to repay the loan out of profits. Many lending institutions make what they call collateral loans; in other words, if there's enough collateral it's immaterial whether the business if profitable or not. Our business is to promote small business and to promote the economy. So we want to provide assistance for businesses that are going to succeed. Repayment ability out of the profits of the business is our main requirement. Then, to protect taxpayers' interest, we look for adequate collateral to secure the loan. The terms of these loans can be up to twenty years.

The loans are broken down into different categories. We can provide loans for working capital to provide for inventory for the business, for example, or just free working capital to pay expenses, provide for payment of payables, and finance receivables. That kind of loan normally has terms of about five years.

If the purpose of the loan is to provide machinery and equipment, the loan goes for about ten years, or for the economic life of the machinery we're providing the loan to buy. We can provide financial assistance in the acquisition of the business, either through purchase of an existing facility or construction of a new facility. Those loans go for about twenty years.

Generally the first step in applying for assistance is either to discuss your needs with your banker or to come down to the SBA. You're going to need some information for either one of these discussions, including current financial information and three years of historic financial information (balance sheets and profit-and-loss statements of the business). You're going to need personal financial statements on anyone who owns twenty percent or more of the business. You're going to need a list of the collateral which would go to secure a loan if obtained from the bank or SBA. You need a statement of the purpose of the loan and the amount you are applying for.

If it is a new business venture you'll need three additional items. First, you need a personal history statement. This is required to substantiate that you as an individual have the background, the experience, and the capability to operate the type of business you're going into. You'll need to put together a plan on the prospects of the business, including what kind of market you want to attract, what the potential market is, and so on. In addition, you will need a detailed cash-flow projection for the first year of operation to support your loan request.

The other loan program which I think is of interest here is called our Regulatory Compliance Loan Program. In other words, SBA can provide financing under our disaster loan-making authority to any small business that needs help in complying with some of the requirements of the Clean Air and Water Act, Occupational Safety and Health Act, Consumer Protection Act, and the Coal Mine Health and Safety Act. We got into this in 1969 with the Coal Mine Health and Safety Act, and we've been adding to it since then.

For a small business to apply for this type of loan, we need some evidence--certification, citation, or something--from the regulatory agency that demonstrates that the business is required to make certain changes in equipment to comply with the act. Because it is a loan and not a grant from the government, we need financial information to support repayment ability of your loan request. The use of the money is restricted to fixed assets only, because what the compliance citation usually requires is changes in the machinery, equipment, or your building itself, or something like that. In this case, under our disaster loan program we have more direct money than we do under our regular business program. Therefore, most of these requests can be billed on a direct basis. The terms of the loan are 8.5 percent and the length of the loan can be up to thirty years. We can adjust the length of the loan depending on the business's ability to repay. The maximum amount of a loan under this program is $500,000.

SBA has the ability to grant a larger loan, but it is beyond the authority of the field office. We could, however, send the application to our central office if a business demonstrates significant need or hardship that requires more than $500,000. For example, if it is a business that is the major employer in a community, that would qualify it for a loan larger than $500,000.

That sums up the financial assistance available from the SBA, particularly the assistance available under our Regulatory Compliance Loan Program.

CONTROL TECHNOLOGY PROGRAMS--DEVELOPMENT AND IMPLEMENTATION IN GENERAL DISCUSSION ROUNDTABLE

Keith R. Long, Ph.D.
Director, Institute of Agricultural Medicine and Environmental Health, University of Iowa

Vincent Farrell (Agway Corporation): Regarding testing for respirators, suppose that an operator uses one size respirator one day and the same size but a different type of respirator the next day. Where does that fit into the program?

James Murphy (Monsanto Chemical Company): To review, the reason you are fitting a person to begin with is to determine which of a variety of facepieces out of a group of respirators fits the person best. In the past procedure consisted of giving everyone one standard respirator, and everyone wore the same immediate size. Now we know that to get a good fit you need a wide variety of sizes.

If you are using a half-mask air-purifying MSA respirator that fits a certain worker well, and you've determined that by using an irritant smoke or a quantitative fit test, and he changes to a full-face piece for material that may be an eye irritant, that is a different style of respirator. It is still the same type, air purifying, but the style is different, full face. More protection should be afforded by the respirator, but you need to determine that with a fit test.

Again, the comment I made in my talk referred only to using positive pressure self-contained breathing apparatus. In the past a style which supplied air only on demand of the user was common. They came up with the innovation which creates positive pressure in the facepiece.

Basically, with these respirators, if the fit is not grossly inadequate, fitting in that case is not mandatory. But for the air-purifying type, and for all negative-pressure-type respirators, fitting is necessary. Each time you change a style, it would be a very good idea to refit the person.

Keith Long (University of Iowa): I am going to be a bit provocative here. Doug [Fowler], during a break you had a couple of questions with respect to efficiency. Since we are discussing respirators, would you care to pose those questions?

Douglas Fowler (SRI International): One of the questions that has arisen is the potential problem with chromatographing of material through the charcoal of a respirator. For instance, if one is using a formulation that contains a solvent, is it possible to drive the active ingredient through the charcoal because of the solvent contained as a vapor in the air?

James Murphy: I'm not an expert on solvent sorption or absorption on charcoal or other sorbents. What I am told relative to protective equipment in general is that the highest potential for exposure really relates to a dermal contact. In a potentially contaminated atmosphere, as long as you are wearing a NIOSH-approved pesticide respirator comprised of a prefilter for dusts and mists and a charcoal canister for organic vapors, most of the time you will load the filter before you load the cartridge or the sorbent. As a result, breathing resistance will increase. That is one of the signs that you need to change the cartridge. And, in our case, we change the complete cartridge and dispose of it. Some people argue that you can change filters and keep the organic sorbent portion of that combination or package to reuse, but we feel it is a better idea that you dispose of the entire cartridge. If you follow that approach, you minimize the potential for breakthrough.

The other comment on your question relative to sorbents: I have read of some cases where people have used respirators in contaminated situations, put them aside, and reused them the next day. What you find is that the material sorbs on the charcoal and then desorbs from it. In effect, you are drawing air through a contaminated filter, and you are worse off than in the first place without wearing a respirator. We feel that good work practice is that even if you use a respirator for only fifteen minutes, if there is one job a day where a worker needs to wear a respirator, change the cartridge and put a new cartridge in, and also go through cleaning and disinfecting. Skin contact is a problem if you've got pesticide dust or contaminated respirators. You don't want to be putting it back on your face.

One of the biggest questions related to air-purifying respirators is in the area of breakthroughs for any type of organic vapor. And one final point is that even though you have an organic vapor cartridge, and even though it is certified by NIOSH/MSHA for organic vapors, it doesn't mean that it will adsorb on all organic vapors. You have to do your homework; you have to check and determine that it's a good sorbent.

Keith Long: While we are on the subject of respirators, where does a small formulator or manufacturer get respirator information?

James Murphy: I'm glad you asked. A small pesticide manufacturer can get information from any of a number of sources. If you know you have a problem and you are using a respirator, the first people to talk to are the people you are buying the respirators from. Major respirator manufacturers (MSA, Norton, and 3M--although 3M doesn't market the pesticide respirator yet) are excellent references in general. We call them all the time on questions like those Doug Fowler just asked about breakthroughs. A lot of times manufacturers will do screening tests to determine whether the material sorbs on the type of charcoal they use. A second excellent reference is NIOSH. NIOSH has a respirator testing certification division out at Morgantown. People over there are very knowledgeable. A third reference may be the chemical manufacturer. They ought to be knowledgeable about the materials they make and what respirator protection and other personal protective equipment is good for that particular material.

Paul Caplan (NIOSH): NIOSH gets questions all the time as to why our certification program doesn't certify a respirator against a given material. The answer is that our program is set up to respond to requests for certification from the respirator manufacturer. Until MSA or Wilson or some other manufacturer asks for certification with regard to a particular material, we do not do a test for it.

The procedure is that when somebody in the pesticide industry or the agricultural industry or some other industry wants a respirator that will protect against a material, they do to the respirator manufacturer. The manufacturer, in turn, asks NIOSH to set up a certification program for the material. That is the general rule.

Jim Vaccaro made a comment that since the skin was a rather significant route of exposure, and since contamination levels are a good way to determine whether there will be skin exposure, I wonder whether Dow, or DuPont, or Monsanto, or any other major company has any guidelines for what they consider to be effective decontamination standards for a given surface that might be a source of skin exposure. Do any of the major companies do anything even if there are not official levels to decontaminate to? Are there any such levels that they recommend? In the radiation business, of course, it is very common for alpha radiation decontamination to decontaminate to a certain number of counts per square foot. Is there any data on that?

James Vaccaro (Dow Chemical Company): No, Paul, not off the top of my head. We, like Jim [Murphy], use wipe testing, not as an indicator of exposure but as a gauge of work practices and contamination in an area. I don't know that we have anything specific; we may.

Steve Paul (Monsanto Chemical Company): As far as reducing levels, we don't have any set level. We would certainly want to go somewhere beneath a level that would cause a health effect, but with every different chemical there is a different level. So it would be a practical tailored custom level, depending on the material you are working with.

Zack Mansdorf (Midwest Research Institute): This is not an answer to your question, but along another line there is ASTM Committee F23, which is the Committee for Chemical Protective Clothing. They recently proposed a standard for penetration, and they have a test chamber that was actually developed by one of the chemical companies. There will also be permeability tests and other tests along those lines. I would suspect that within the next year there will be some information available. If you want some direct information now you can contact Jerry Colletta of National Semi-Conductor, who is Committee Chairman.

Paul Caplan: On the subject of penetration of chemicals through different types of clothing and materials, NIOSH has a project out at Los Alamos (LASL), testing penetration of various materials (particularly chlorinated hydrocarbon materials, among others) through different types of cloth. As Zack [Mansdorf] mentioned, Arthur D. Little has done a lot of this type of work. Another reference that might interest you is the Personal Protective Committee of the American Industrial Hygiene Association. AIHA has one committee that deals with respiratory protection and one that deals with personal protective devices other than respiratory. They also have two active committees working on standards, certification criteria, and so on.

Robert Hughes (NIOSH): Yesterday there were several mentions made of ductwork design that would prevent buildup and clogging. My question, as a member of the Industrial Ventilation Committee and, since it was stated that there was very little in the Ventilation Manual of this nature, is: Is design information available concerning pressure drops, proper angles, and so forth, so that information could possibly find its way into the manual?

Thomas Blackwood (Monsanto Chemical Company): There is a whole body of information that is related primarily to fluidization, pneumatic conveying, and that kind of thing. You can calculate single particle saltation velocities and then loaded dust concentration saltation velocities in the horizontal pipe, and you can calculate choking velocities in your vertical rises. Then, through appropriate engineering design which you will find in books like Fluidization and Fluid Particle Systems by Frederic Azenz and Donald Othmer, you can find out and calculate what those formulas are. They are very precise. As a general rule, you find that perhaps two times saltation velocity is all you need to use for a pickup to make sure that something does fall down if the gas flow is off, or if you get an exceptionally high loading, or if you have a bad angle. That kind of information is available in a variety of books on that subject. It's not usually found in the general air pollution or even occupational area, and many times some of the design criteria for velocities are unacceptable.

For instance, let's say that you design the line for 3,000 fpm and you put a material like a carbon--black, powdery, one micron, very fine material. The stuff will salt out very easily because it will build up along the walls and just keep moving the boundary layer away from the wall. Eventually it will plug the duct. Material like that is very difficult to handle, but there are guidelines for doing that kind of thing. You may have to have, instead of 3,000 fpm, maybe 8,000 to 12,000 fpm in order to carry material like that through there. That information can be calculated. We at Monsanto belong to a couple of research consortia who research that kind of thing, and there is a small body of people out there who are doing it, so that kind of data is available.

The theory is so precise in this particular area that experimental reproducibility verification is just phenomenal. We have seen research work that has been done where that exact point of cutoff is very precise. And it can be calculated once you have a good idea of what the particle size distribution is. It's not as vague and not subject to as much engineering judgment as you would think.

Paul Caplan: Chuck [DeCrane], do you have any comments with respect to that?

Charles DeCrane (Ouachita Machine, Inc.): In response, I would like to add that I think this points up why it behooves even the small formulator to utilize people who have applied some of this technology that is not necessarily directly related to the problem and to benefit from that experience. Certainly if a small operator attempts to handle the problem alone, he could use the material available in the Ventilation Handbook, and that would be a very good starting point. But sometimes borrowing technology from another field can be a tremendous benefit. I would suggest that they consult people who are familiar with the problem.

Ronald Hutton (Petrolite Corporation): My question, or comment, is really directed to Mr. Vaccaro from Dow, but maybe it could generate some discussion from the panel members. It relates to the role of dermal contact versus inhalation, and the role of pesticide toxicity. He mentioned a size range of one to ten microns as being a respirable range for pesticides, indicating that particulates larger than that would not contribute to overall body burden. I wonder if that is not overlooking the problem associated with impinging in the upper respiratory tract and mouth and being swept up and swallowed. Larger particles, perhaps, contribute more to body burden than the material inhaled because of the mask. He also mentioned a figure of something like 1,500 milligrams per hour on the skin versus a couple of hundred milligrams per hour inhalation contact, indicating the problem associated with dermal contact. He really did not, at that point, give any consideration regarding skin penetration of the particular material. I wonder if either of those two points might generate some discussion.

Douglas Fowler: I think I can start a discussion on that. There is no question but that when pesticidal dust, whatever size, settles on the skin, or is captured in the nose or the upper respiratory tract at any point, it has the potential to be absorbed. That very much depends on the individual chemical properties in relationship to the skin and to the bodily fluids, the mucous membrane permeability to the specific chemical. But yes, that's true. Respirable dust sampling, in general, is an inappropriate way to evaluate the potential for harmful exposure in a pesticide plant, because so many of the pesticides do penetrate the skin or may be taken up in the upper respiratory tract. It's not like silica dust, where the material is insoluble on a very short contact with mucous membrane and requires prolonged exposure in the lower lung to cause the harmful effect. Second, the larger particles may settle out on the skin, but the very fine particles are attracted to the skin and may be captured relatively effectively, particularly on sweaty skin. So yes, there is clearly a large potential for exposure. If I am not mistaken, Homer Wolfe did include, in his consideration, that table that Jim Vaccaro showed. This was a consideration of the permeability of the material through the skin. With that dose per hour--milligrams per hour by dermal route and by inhalation--I think he assumed that the inhalable material was quantitatively absorbed. I think he applied an appropriate penetration factor to account for the fact that all the material would not be taken up through the skin.

Paul Caplan: Several papers have been published by Homer Wolfe and Wayland J. Hayes, M.D., and Griffith E. Quinby, M.D. that have to do with this particular phenomenon. If you look in the literature under those names you can find out. Most of the work was done in the fifties and sixties, so that it is quite revealing. One thing I might also point out, which is not to be overlooked, is that the larger particles that are impinged in the nose and the upper pharynx tend to be swallowed. This phenomenon has always been a complicating issue when you are dealing with people who are exposed to dust without respiratory protection. I am not sure if there is any way of quantifying that, but at least it is something that we ought to recognize.

Stanley Dryden (Standard Oil of California): I agree wholeheartedly with what Doug [Fowler] said. There is a tendency to confuse the two concepts of respirability, which is generally considered to be the ability of particles to reach the alveoli, the deepest part of the lung, and inhalability, which is the ability of a particle to just get into the upper respiratory tract. Once materials like pesticides or lead get in there, there is a good chance they will be swallowed and thus be available for absorption into the system. One point I would like to correct Doug [Fowler] on, and I have not heard this brought up in the past two days, is that there is a place for respirable sampling in the pesticide industry, since many of these inert clays that we use contain a significant amount of silica. As was pointed out earlier, we often overlook the solvents when we are looking for the actives. Sometimes we overlook the so-called inert dust when we are looking for the actives as well. Significant amounts of silica have been found in many of the blending clays we use, and we are trying to get rid of them to the extent we can.

Doug Fowler: Stan is absolutely right and I stand corrected.

Lt. Col. Reuben Sawdaye (U.S. Army Chemical Systems Laboratory): I've got a request for the panel and the members here on the floor. One of our research development groups, the U.S. Army Biomedical Laboratory, is trying to gather human toxicity data on acute, subacute, and chronic exposure to organophosphates. We do have work that has been done on this since World War II, but there are some large data gaps which have been brought out here today. We are willing to open a formal exchange of information with anybody on this topic. The second thing I would like to comment on is quantitative respirator fit. The National Cancer Institute has their draft paper on the carcinogenic properties of dioctylphthalate in which it was proved that this material is a carcinogen in mice and rats. So if you are looking along those lines, start looking for a substitute item, because it won't be long before we will have another problem.

Stanley Dryden: The person who made the comment may well be aware of this, but I thought I would point it out. All pesticides in the country have to undergo a very thorough registration procedure, and this involves a great deal of submission of toxicity data on acute through chronic effects in a well spelled out protocol of testing. These data are submitted to the Office of Pesticides and Toxic Substances of EPA, and I believe that information is public record information. I am sure that you would have access to it.

Lt. Col. Reuben Sawdaye: What we are looking for is the human, and not the animal, because of the species variation. We have had some problem correlating the data.

Paul Caplan: We are going to wrap this up in a few minutes, but I am going to be selfish and pose a question that all the panel can respond to. Often the only time the small formulator or manufacturer realizes he has a problem is when he has a catastrophic event occur. I would like the panel to respond to, one, where can the independent formulator or manufacturer go to realize that he may have a problem before he has a catastrophic event, and, two, what mechanisms are there available for training of the independent manufacturer or formulator, so that he becomes aware of this?

Douglas Fowler: The independent formulators that we observed relied very heavily on the basics. Of course, they have had some catastrophes. I think it is very difficult to find a consultant, without help, who is knowledgeable in the field, who has the requisite engineering skills, the analytical chemistry knowledge, and so forth, to be able to do an adequate job of evaluating an overall program. The recommendation was made that you could look up consultants in the back of the AIHA Journal. That is pretty risky business, as a lot of those folks do not know anything about pesticides, and this is a specialized enough area that you have to be sure of getting appropriate advice. Similarly, many engineers know relatively little about health protection. I have seen some very strange ventilation systems designed by competent professional mechanical engineers. I think that first you need to use your basics: use the suppliers and get their advice, ask them who they know in the field of occupational health and environmental sciences--who would be a competent consultant. Use their professional contacts. I think that is the simplest and best way to go about it. Sometimes state health departments have knowledgeable people. There are people like Dr. Keith Long at the University of Iowa. There are, in some of the regions of NIOSH, knowledgeable people in this particular area. It is just not a common area of interest and expertise, and you have to be careful whose advice you rely on.

Keith Long: This is a very difficult question to answer, I realize. It is the purpose of this symposium to try to figure out this kind of soft spot. The comment was made that engineering controls and implementation favor the larger companies because of financial outlay, personnel involved, and the cost of those personnel; and that consequently the small operator may be left out in the cold. I think that we need to look at that from the standpoint of how we can keep the small operator in business, and how he can get the necessary training to implement the kinds of things we have heard here in this symposium.

APPENDIX A

PARTICIPANTS AT NIOSH SYMPOSIUM
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3. Banden, Mark
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4. Bardsley, C.E.
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5. Bash, John E.
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6. Batton, Everett
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7. Benefiel, Robert
   Elanco Products Co.
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8. Bepler, Mike
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9. Bicknell, Ralph
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11. Blackwood, Mary Jo
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14. Blanton, Roy
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15. Blowers, Richard
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16. Bogart, David
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17. Boncek, Joseph
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18. Brinkman, William
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19. Brister, Ed
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20. Brocker, William
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21. Bunkowski, Kenneth*
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31. Champion, Mike
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32. Clarke, Thomas
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33. Coan, Michael
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34. Colton, Craig
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35. Cooper, Steve
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36. Corbett, W.J.
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37. Costello, Nick
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38. Crider, Chuck
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39. Crowley, Paul
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Sargeant Bluff, IN

40. Currie, Gene
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41. Danz, Albert
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42. Darst, William
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45. Dexheimer, Jim
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46. Ditchfield, David
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47. Dobby, John
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48. Doeflein, Edmond
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49. Doritty, George
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50. Dryden, Stanley*
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51. Earhart, Charles, Jr.*
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52. Farrell, Vincent*
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53. Ferraro, Charles
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54. Fowler, Douglas*
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55. Garuccio, Richard
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56. Gerety, Peter
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58. Gilding, Thomas
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59. Godier, Gerry
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60. Gold, William
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61. Gorbandt, Mark
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62. Grady, Charles
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63. Green, Tim
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65. Habermehl, D.E.
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66. Hackathorn, David*
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70. Heath, Luckey
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91. Knieriem, Betsy
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92. Kolcun, J.P.
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93. Lattire, Floyd
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94. Lawhon, David
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105. Matsumoto, Gene
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110. Miller, Richard
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132. Richardson, Ronald
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133. Richter, Paul
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134. Riemann, Roger
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135. Ries, Gerald
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157. Vesper, James
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158. Wagner, Clarence
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159. Warder, Dale
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160. Watson, David
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161. Weiskopf, R.A.
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162. Wheler, Roger
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163. Wile, Ray
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164. Wilhelm, Cathy
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APPENDIX B

PANEL BIOGRAPHIES
(alphabetical)

THOMAS R. BLACKWOOD, Monsanto Chemical Company
Dr. Blackwood currently serves as a consultant on solids processing technology in Monsanto's Corporate Engineering Department in St. Louis. He is a graduate of the University of Michigan and has over ten years of experience in air pollution control. He has also published over fifty papers and reports on measurement, control, and assessment of fugitive and hazardous emissions. Within Monsanto, he provides technical assistance to plants on workplace exposure control as well as general air pollution control. He is a member of the American Institute of Chemical Engineers and the Air Pollution Control Association.

KENNETH BUNKOWSKI, American Cyanamid Company
As Field Engineer of the Agricultural Division of American Cyanamid, Pesticide Department, Kenneth Bunkowski is responsible for supervising contract formulator locations. He provides technical and engineering service to customers in setting up formulating and packaging facilities, and assists in developing formulation procedures and packaging for Cyanamid products and other miscellaneous technical and engineering fuel services.

PAUL E. CAPLAN, DPSE/NIOSH
Paul E. Caplan is a Research Industrial Hygienist in the Engineering Control Technology Branch of the Division of Physical Sciences and Engineering, NIOSH. Before joining NIOSH in 1971, he served with the California Bureau of Occupational Health as a Senior Industrial Hygiene Engineer, where he worked extensively in Agricultural Health programs. He holds B.S. degrees in Chemistry and Chemical Engineering and has a Master's degree in Public Health, Industrial Hygiene Engineering. A Registered Chemical Engineer and Safety Engineer in California, Mr. Caplan has been certified by the American Board of Industrial Hygiene and the Board of Certified Safety Professionals. He serves on technical committees of the American Industrial Hygiene Association, the American Conference of Governmental Industrial Hygienists, the American Society for Testing and Materials, and the National Society of Professional Engineers.

JOHN L. CAREY, Small Business Administration
John L. Carey has served in various key positions with the Small Business Administration since he joined the organization in 1969, as Associate Administrator for the Management and Procurement Assistance Office in Washington. Currently District Director in St. Louis, Missouri, Mr. Carey has also served as the District Director in Houston, Texas, and as the Chief of the Loan Administration Division of the New Orleans District Office. Prior to joining SBA, Mr. Carey was employed by General Motors Corporation and Pratt and Whitney Aircraft.

CHARLES E. DeCRANE, Ouachita Machine Works, Inc.
Currently Design Engineer at Ouachita Machine Works, C.E. DeCrane has fifteen years' experience in the aerospace industry as a designer and design engineer. He has had eight years' experience in the packaging industry. Mr. DeCrane has been assigned four patents on dust/vapor control systems.

STANLEY L. DRYDEN, Standard Oil Company of California
Stanley L. Dryden received his B.S. in Environmental Engineering from California State Polytechnic University and his M.S. in Industrial Hygiene from Harvard University. Currently Manager, Industrial Hygiene, for Standard Oil Company of California, he is responsible for the development and direction of all industrial hygiene services for Chevron operations. He has also been affiliated with Lawrence Radiation Laboratory. Mr. Dryden is a member of the American Academy of Industrial Hygiene, the American Industrial Hygiene Association, the American Petroleum Institute, and past president of the Northern California Section, AIHA. He has also been a consultant on occupational health standards, and has been a member of the Advisory Committee on Airborne Contaminants of the California Division of Occupational Safety and Health.

CHARLES E. EARHART, JR., Platte Chemical Company
Charles E. Earhart, Jr., received his Ph.D. in Physical Chemistry from the University of Houston. He continued his education in the Development Department of J.R. Geigy, McIntosh, Alabama, plant. After CIBA-GEIGY Ag Division assignments in Switzerland, Florida, and North Carolina, he spent two years with Transvaal, Inc., prior to joining Platte Chemical. He is currently Operations Manager for Fremont.

VINCENT J. FARRELL, Agway, Inc.
Vincent J. Farrell graduated in 1960 from Rutgers University with a B.S. in Agriculture. He served three years in the U.S. Navy as a communications officer. He has worked for Agway, Inc. for sixteen years in sales and service, product management, and, currently, in production. For the past five years, Mr. Farrell has been Plant Manager of Agway's pesticide formulation facility.

DOUGLAS P. FOWLER, SRI International
Douglas P. Fowler is currently Senior Industrial Hygienist with SRI International. He received his B.S. in Preventive Medicine from the University of Washington in 1967 and his M.S. in Occupational Health from U.C.L.A. in 1970. He is a Ph.D. candidate in Environmental Health with the University of California at Berkeley. A Certified Industrial Hygienist and registered Radiologic Technician, Mr. Fowler is a member of the American Industrial Hygiene Association, the Air Pollution Control Association, and AAAS.

WALTER M. HAAG, DPSE/NIOSH
Walter M. Haag received a B.S. and his M.S. in Industrial Engineering from Pennsylvania State University. He also received his M.P.H. in Health Planning from the Univeristy of Michigan. He has

taken graduate courses in management from the American University and from George Washington University, both in Washington, D.C. At present he is a U.S. Public Health Services Commissioned Officer, and is Director, DPSE/NIOSH. He is a member of ACGIH, the American Management Association, American Institute of Industrial Engineers, and the Association for Systems Management. Mr. Haag has been awarded a USPHS Commendation Medal.

DAVID R. HACKATHORN, Mobay Chemical Corporation
David R. Hackathorn received his Bachelor's degree in Chemistry in 1967 from Park College. In 1969 he received his Master's degree in Organic Chemistry from the University of Arizona. He is a Certified Industrial Hygienist, Comprehensive Practice. Mr. Hackathorn has ten years' experience in Industrial Hygiene and Air Pollution Control, most of it related to agricultural chemical products.

RONALD E. HEMINGWAY, E.I. DuPont de Nemours & Company
After receiving his B.S. in Chemistry from the Citadel, Ronald E. Hemingway spent two years with the U.S. Army, Chemical Corps. Upon completion of his Ph.D. at the University of Texas in 1974, he joined DuPont. He is a board-certified industrial hygienist and is currently Chief of Industrial Hygiene at DuPont's Haskell Laboratory for Toxicology and Industrial Medicine.

ROBERT J. HUGHES, DPSE/NIOSH
Robert J. Hughes has been in the Division of Physical Sciences and Engineering at NIOSH for ten years as a Research Mechanical Engineer. He received both a B.S. and his M.S. in Mechanical Engineering from the University of Cincinnati. Mr. Hughes is also a member of the American Conference of Industrial Government Hygienists, and a member of the ACGIH Ventilation Committee. Mr. Hughes served as NIOSH's moderator during this symposium.

KEITH R. LONG, University of Iowa
Keith R. Long is Professor and Director, Institute of Agricultural Medicine and Environmental Health, Department of Preventive Medicine and Environmental Health, College of Medicine, University of Iowa. He received a Bachelor's and his Master's degree in Microbiology from the University of Kansas in 1951 and 1953, respectively, and in 1960 received his Ph.D. in Microbiology from the University of Iowa. He is or has been a member of: the Scientific Advisory Committee to Iowa Chemical and Technology Review Board; National Task Force on Occupational Exposure to Pesticides; Public Health Advisor, Technical Services Division, Office of Pesticide Programs, Environmental Protection Agency; Governor's Science Advisory Council; Legislative Environmental Advisory Group; and Secretary of Agriculture, Pesticide and Fertilizer Advisory Committee.

MARTIN W. McGINN, Southern Mill Creek Products Company
Martin W. McGinn has been employed at Southern Mill Creek Products Company, Inc., Tampa, Florida, since 1973. He has overall respon-

sibility for operations, including manufacturing, warehousing, distribution, equipment, and so on. He is a 1959 graduate of the University of Notre Dame with a B.S. degree in Chemistry and Philosophy and has been associated with the agricultural and pets industry since 1969. Prior to employment with SMCP, Mr. McGinn worked for ICI America for twelve years in sales, sales management, marketing, and marketing management. In his current position at SMCP, Mr. McGinn has served on many committees of the National Agricultural Chemicals Association, including OSHA, Regulatory Transportation and Distribution, and Formulators.

JAMES J. MURPHY, Monsanto Chemical Company
James J. Murphy received his B.S. in Environmental Science from Rutgers in 1975 and his M.P.H. in Industrial Hygiene from the University of Michigan in 1977. He is currently a Senior Industrial Hygienist in the Department of Medicine and Environmental Health with Monsanto, where he provides direction and technical support to Monsanto Chemical Intermediates Company in industrial hygiene program development and implementation. He provides specialized technical staff expertise corporate-wide in respiratory protection program development and selection of appropriate protective equipment for specific hazard situations. Mr. Murphy is a certified Industrial Hygienist in Training (ABIH), 1977, and a full member of the American Industrial Hygiene Association.

JAMES B. PACE, FMC Corporation
James B. Pace received a B.A. in Industrial Management from Brigham Young University in 1957. He has had over twelve years' experience in upgrading, design, and implementation of agricultural formulation plants and systems throughout the U.S. He has had extensive prior experience in materials handling, mining, and plant operation in the Industrial Chemical plants of FMC Corporation at Green River, Wyoming, and Pocatello, Idaho.

HERMAN SCHALLER, Mobay Chemical Corporation
Herman Schaller is the manager at Mobay in charge of formulation products and warehousing. He joined Mobay in 1975 in this capacity. Dr. Schaller graduated from the University of Wurzburg in Germany and he has his Ph.D. in Organic Chemistry. After a postdoctorate assignment at the University of Wurzburg, he joined the Formulation Research Department at Bayer Ag. in Leverkusen in 1968. In 1972, he headed the construction and operation of a formulation and packaging company in France.

ROBERT SHAW, Stauffer Chemical Corporation
Dr. Shaw is a graduate of Ursinus College, Hahnemann Medical College, and Johns Hopkins University School of Public Health. He has been active in occupational medicine since 1972. Upon completion of his doctoral program at Johns Hopkins in 1974, he served in the U.S. Navy as Fleet Epidemiologist to the U.S. Pacific Fleet. He joined Stauffer Chemical in 1978 as its Associate Director of Occupational Medicine. Dr. Shaw is a member of the Society for Epidemiologic Research, the American Thoracic Society, Connecticut

Occupational Medicine Association, the American Medical Association, and he is a Fellow of the American College of Preventive Medicine and the American Occupational Medical Association.

RICHARD STERN, IERL/EPA
Richard Stern is currently Chief of the Chemical Processes Branch of EPA. In his previous positions with EPA he was involved with flue gas desulfurization and flue gas denitrification. Prior to EPA he worked with Rockwell International for approximately twelve years in technical management and administration of division-level research and development. He was also Senior Project Engineer on the Minuteman Project.

JAMES R. VACCARO, Dow Chemical Company
Jim Vaccaro received an A.B. in Chemistry from Hope College in 1965. He has worked for approximately eight years in the Industrial Hygiene Laboratory at Dow Chemical Company. He has spent five years in agriculture-related industrial hygiene activities. His work has placed heavy emphasis on insecticides, particularly organophosphates. In 1979 he was certified in the comprehensive practice of Industrial Hygiene.

JOSEPH L. WOLFSBERGER, Monsanto Chemical Corporation
Joseph L. Wolfsberger is a graduate of the University of Missouri at Columbia, with a Bachelor's degree in Biology and Psychology. He received his Master's degree from Central Missouri State University with a major in Industrial Hygiene. He has worked as an environmental sanitarian for the Missouri Division of Health, a Compliance Officer for OSHA, and has held several hygiene positions at two large chemical plants within Monsanto. He is a member of the ACGIH, and is currently President of the St. Louis Chapter of the American Industrial Hygiene Association. Mr. Wolfsberger has also served as the Secretary-Treasurer and Vice-President of the local AIHA section. Mr. Wolfsberger is also a professor for Central Missouri State University and lectures in the Industrial Hygiene graduate program. He is certified by the American Board of Industrial Hygiene.

APPENDIX C

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General Reading

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Outside assistance on respirator questions can be obtained from

1. Respirator maunfacturers
2. NIOSH--Respirator Testing and Certification Branch, Morgantown, WV.
3. Outside consultants certified in respiratory protection by the American Industrial Hygiene Association (475 Wolf Ledges Parkway, Akron, OH, 44211).

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