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MONDAY AFTERNOON SESSION

October 6, 1947

Presiding: Dr. A. L. Brooks, Medical Director, Fisher Body Division, General Motors Corporation

Recognition and Control of Fume and Dust Exposure

By V. J. CASTROP

Research Laboratories Division, General Motors Corporation

Illness which can be attributed to the occupation may occur in the automotive and allied industries. While occupational disease cases are much fewer in number than those resulting from accidental injury, there still remains the need for vigilance in maintaining a healthful working environment. The responsibility for employee health is delegated by management to the medical director with the safety director charged with matters pertaining to safety. For the smooth functioning of either department it is necessary that these individuals work in close harmony with each other.

A safety engineer who is capable of recognizing conditions which may be detrimental to the health of the employee is an excellent teammate for the doctor in any employee health maintenance program. The safety engineer need not be capable of actually sampling air in the environment or designing a ventilation system for the control of toxic materials. He should, however, have knowledge of the materials which have been proved harmful, should be fairly well informed of how these materials may be used safely, have some understanding of basic control measures which are normally recommended when such materials are used.

The intention is not to present a highly technical discussion of fume and dust exposures or detailed information regarding ventilation systems, as such matters are of interest to the professional industrial hygienists and of comparatively little value to safety engineers. This discussion will be limited to the more basic principles of industrial hygiene as they relate to fume and dust exposures, to indicate what control measures are available or used to protect the employee's health, and, to call to your attention operations and materials which are commonly used in the automotive and allied industries, at the same time indicating the generally accepted opinion as to their effect on health.

Many conditions are corrected or improved because of reasons other than their effect upon the health of the employees. Better products, better employee relationship, reduction in maintenance of equipment may be cited as justification for management's decisions for such correction or improvement.

Generally speaking there are two means of entrance of toxic compounds into the human body under industrial conditions, namely, by ingestion or via the respiratory tract through the inhalation of fumes, dusts, mists or gases. Ingestion is of importance if toxic materials which have a systemic effect are used and adequate washing facilities are not provided, or, where the employees are slovenly in their personal habits. Inhalation is considered the most important portal of entry of fumes or dusts and the particle size, therefore, becomes significant in evaluating an exposure. The particles which cause the physiological changes are those which are small enough to remain suspended in the air and not those which immediately fall to the floor. Flying particles, which are of concern to a safety man and for which he advocates the use of goggles, are not of hygienic significance since they are not of respirable size. To judge the seriousness of an exposure by the quantity of detritus adjacent to an operation is often misleading. This is especially true where mechanical ventilation has been provided which will remove the fine material but is inadequate to trap or convey the larger particles.

In evaluating an exposure it is necessary to consider the toxicity of the material, the duration of the exposure, the average concentration of the contaminant with special attention being paid to those operations which produce high concentrations at some phase of an operating cycle, and the measures which have been provided to control the exposure.

Medical records of the individuals subjected to the exposure may be of value if the examinations are thorough and frequent and not of a cursory type. It must be remembered that occupational diseases are slow in development and in some instances lasting in effect. Slow changes may not be detected and the mere fact that cases have not occurred is no definite assurance that exposures to known toxic materials may be ignored.

The determination of the concentration of the toxic material in the air is important in evaluating the exposure. Tests of this type are not only indicative of the degree of contamination but in some instances which operation is the major offender.

The apparatus used in collecting the contaminant and the method used in estimating the amount present in the atmosphere vary with the type of material. Tests of this type are specialized in nature and are beset with many pitfalls which can lead to very erroneous results and conclusions if done by other than experienced personnel.

In a discussion pertaining to toxic materials it is generally necessary to quote permissible concentrations or as it is sometimes expressed — maximum allowable concentrations—permissible limits, or threshold limits. These terms are used extensively by industrial hygienists to indicate concentrations of a substance in the air which are considered compatible with good health. The limit usually applies to exposures of eight hours duration for a prolonged period.

The limits are, for the most part, advisory standards or bench marks which are practical to meet. In general, these limits are derived from three types of evidence all of which have value and limitations.

1. Animals have been exposed at different concentrations and the effects noted.
2. A few experiments have been made on human subjects for short periods of time.
3. Safe limits have been arrived at by measuring the concentrations of substance in the workroom air and correlating this information with results of medical examinations of workmen.

There is no magic connected with these limits and the mere fact that they are exceeded does not necessarily mean that someone will definitely become ill, but there is a good probability that someone will suffer ill effects if the limit is greatly exceeded for a considerable period. There remains much to be learned regarding the toxicity of many substances used in industry, and it is hoped that with more research and study that the answers will be found.

So much for the general picture. Now let's take a look at some specific operations.

Welding—Welding processes most commonly used can be divided into three types, arc, gas, and resistance. The safety measures pertaining to clothing, goggles, and helmets are of common knowledge and therefore, shall not be considered in this discussion.

Arc welding when performed on uncoated steel does not produce a condition which is considered harmful to the welder provided it is accomplished in a comparatively large open area. The fumes which result from welding consist essentially of the oxides of iron and oxides of metals which may comprise the steel or coating of the welding rod. Some investigators have found characteristic markings on chest x-rays of men who have welded under severe conditions for long periods of time. These markings are presumably due to the deposition of iron fumes within the lungs, but it has not been demonstrated that such fumes have caused physical impairment.

A frequently suggested limit for welding fume is 15 milligrams of iron oxide per cubic meter of air. Concentrations of this magnitude existing in the workroom would materially reduce visibility and thereby become a nuisance or an unsafe condition requiring correction.

Welding within confined areas such as tanks, inside machinery or equipment, or in small rooms presents a condition which can be of concern. The concentration of fume is materially higher under these conditions as there is little opportunity for dilution by natural air currents normally present in a large shop. Nitrogen oxides formed by the electric arc when inhaled in sufficient quantities causes fluids to form in the lung—edema—with the resultant failure of the respiratory system. While welding in large open areas these toxic gases are normally not present in sufficient quantities to cause harmful effects. However, when welding is done in confined areas, the nitrogen oxides may reach a concentration which will be harmful.

Gas welding generally is not productive of harmful fumes. There are, however, in brazing two potentially harmful exposures. While boric acid or borates generally are used in

brazing fluxes, some metals require fluxes containing significant quantities of fluoride compounds and fumes from these fluxes have been known to produce significant nasal irritation. Fluorides in general are looked upon with suspicion since they may produce harmful effects upon the bone structure. A limit of 2.5 mg. per cubic meter has been suggested for fluorides; but no standard has been agreed upon. Most industrial hygienists attempt to keep them as low as practicable in order to be absolutely certain that bone damage does not occur among the workers.

Silver solder is one of the more common alloys used in brazing. Solders of this type vary in composition and may in some instances contain cadmium which if volatilized in sufficient quantities is considered to be harmful. At present the suggested limit for cadmium fume in air is 1 milligram per 10 cubic meters of air.

Resistance, spot, or butt welding of plain steel is of no concern from the physiological standpoint. The fumes arising from such operations generally are caused by the volatilized oil which has come upon the metal stock during previous operations or which has been placed upon the metal as a rust preventive.

The preceding discussion of welding operations has been based upon the assumption that the metals being welded are of plain steel. The performance of welding operations, either arc, gas, or resistance, upon metals which have been coated with such toxic materials as lead, cadmium, or mercury may cause harmful exposures. The heat of the flame or of the arc causes volatilization of these metals. Welding or cutting of terne plate or other metals containing significant quantities of lead can result in the volatilization of lead fume, which if inhaled for a sufficient period of time, may result in lead absorption and ultimate poisoning. The cutting or welding of surfaces which have been coated with paint containing lead has caused lead poisoning in the past and will continue to do so unless adequately controlled.

Welding of cadmium plated material was attributed as the cause of illness and even death to a number of individuals during the recent war activity. The reported cases indicated that death occurred in a comparatively short time after the exposure.

Welding of galvanized metal causes the volatillization of the zinc coating. Temporary discomfort associated with metal fume fever may result from such an exposure.

Where warranted the control of welding fumes is generally accomplished by providing a mechanical ventilation system. The type of ventilation used is dependent upon the nature of the welding. When the object to be welded is positioned in a fixture or jig it is possible to obtain effective control of the fumes by the use of a grill side hood, or flexible duct near the source of fume. If the parts are large and it is necessary to weld more than a foot from a fixed point it is difficult to obtain good control of the fume with reasonable air volumes through system using flexible ducts. Since the effective range of most flexible ducts is approximately 8 inches from the duct opening, it is necessary for the welder to move the duct whenever the arc is outside this range. The practical result is that most ducts are normally not moved and the ventilation system does not remove the fumes when liberated. According to reports this type of system has been effectively used in shipyards, for the control of welding fumes in confined areas. In view of this experience it should therefore be a satisfactory means of control for welding fumes in tanks. However, excellent supervision and education is necessary to make such systems effective.

Where the room volume per welder is large, the natural ventilation within the plant is usually sufficient to prevent the accumulation of excessive concentration of fumes from plain steel welding. Circulating fans directed from the side help to dilute the fume which may be concentrated in the breathing zone of the welder.

Another means of control is the use of personal respiratory equipment. Air line respirators and fume respirators have been developed which will provide adequate protection. Some manufacturers of this type of equipment have on the market welders' helmets with facilities for providing fresh air to the wearer. The use of this type of equipment has been limited. Since the welder is already burdened with helmet, goggles, and protective clothing he probably will not be receptive to a respirator. It is usually sufficient in most welding for the employee to wear an ordinary helmet and to arrange the position of the work so as to prevent the concentrated fume from flowing under the helmet.

Dry Grinding—The dust resulting from the

grinding of nontoxic metals which are free of sand is generally considered a nuisance and is not harmful per se. Despite this fact some state laws require griding operations to be ventilated. This requirement has probably been a hold over from the days when sandstone wheels were prevalent and also to prevent the creation of a nuisance condition. Grinding wheels in use in industry have artificial abrasives such as aluminum oxide or silicon carbide. Emery, which is a natural product composed of essentially aluminum and the magnetic oxide of iron, may also be used. A permissible limit of 50 million particles per cubic foot of air for aluminum oxide and silicon carbide was recently accepted by the members of the American Conference of Governmental Industrial Hygienists. Such a limit is liberal and concentrations of such magnitude are normally not encountered.

When lead, silica, or some similar toxic material comes in contact with the grinding wheel the exposure to the abrasive matter may be ignored and the exposure evaluated on the basis of the toxic material. If this latter material is controlled the nuisance will also be eliminated.

Ventilation systems for grinding wheels have been fairly well standardized and generally are satisfactory to prevent a nuisance. Hoods should enclose the wheel as completely as is practicable. Air volumes should be provided which are sufficient to cause an inward flow into the hood when using the smallest wheel. This is especially true where toxic materials are involved.

Wet Grinding—Baffles, hoods, and guards are generally located near wet grinding wheels to prevent dispersion of the liquid used as a coolant. These devices are usually sufficient to control the dust if it is nontoxic in nature. If the dust liberated is toxic, mechanical exhaust ventilation may be required.

Buffing and polishing—The buffing compound applied to wheels used for buffing and polishing vary in composition. Waxes and various types of abrasive are the major components. These materials plus lint and fibers from the wheel are the essential ingredients of the airborne dust. The toxicity is dependent upon the type of abrasive. Generally ventilation is provided so as to improve housekeeping and reduce the number of complaints and not because of the hazard to health.

Machining—Smoke from oily parts is the prevailing source of air contamination at machining operations. Illness has not been attributed to this type of exposure. As is the case with most fumes and dusts of the nuisance variety little is known as to what effect such materials have on already existing physical abnormalities.

Machining operations on steel produce large chips or turnings; consequently, dust is not a problem. Operations involving the machining of high lead alloys have been studied, and significant quantities of airborne lead have not been demonstrated.

Graphite which becomes airborne during the machining of cast iron is not considered to be physiologically significant, and therefore is classified as a nuisance dust. Frequently management considers it advisable to provide ventilation for the machines which are productive of the most dust, as graphite on the clothing and person and surrounding machinery is conducive to many complaints. Ventilation systems for the machining, drilling, and so forth, of cast iron should include hoods located as near the cutters or drills as is practicable. Many of these hoods are in use on production machinery and are doing an excellent job of dust control.

Abrasive Cleaning—Since silica is recognized as the most harmful of mineral dusts, an adequate ventilation system is normally provided at the time of installation of commercially built sand blast equipment. Continuous usage and lack of maintenance result in a breakdown of adequate control. Visible escape of dust is the best evidence that this has occurred and it is advisable to correct such a condition without undue delay.

Employees who are stationed in blast rooms are dependent upon personal respiratory equipment. It is of utmost importance that such devices are of a type which will provide the necessary protection. Devices of this type are of the supplied-air variety, and it is necessary that the air provided be free of harmful contaminants. The air compressors should be located in an area free of contamination otherwise the contaminant will be transmitted to the helmet and the breathing zone of the worker.

Normally, ventilation within the room is provided so as to improve visibility and to help prevent the escape of dust to the surrounding areas not to reduce the concentration of silica dust to a safe level.

Tumblast or rotating table type of sand blast units should be provided with sufficient ventilation to prevent the escape of silica dust. Leakage due to excessive wear should be remedied.

Small sand blast cabinets, where the operator controls the blast nozzles from outside the cabinet, frequently have faulty seals around the doors or the rubber gauntlets are loose or torn. The dust which escapes from the cabinet through these openings is in close proximity to the breathing zone of the employee and in many instances exceeds the permissible limit for silica. This leakage should be corrected and the men should not be required to use respirators.

If the articles being blasted are free of silica or other toxic material, the dust resulting from grit or shot blasting is classified in the nuisance category. It follows that the maintenance of ventilating systems for grit blasting, although desirable, is not always so necessary as for sand blasting.

The use of steel grit or shot in blasting rooms produce excessively high concentrations of dust within the enclosure. It is therefore, necessary to protect the worker within the room. The remarks included in the section devoted to sand blasting rooms are therefore, pertinent when considering rooms in which steel grit or shot are used as the abrasive.

Vapor blasting, a variation of sand blasting, is of comparatively recent development. This procedure involves the use of fine silica and water under pressure. The silica used in vapor blast units varies in size and may even be as small as 1250 mesh (approximately 10 microns). It is generally believed that airborne silica particles below 5 microns are most significant in causing silicosis. It then follows that operations involving the use of silica abrasive whose initial particle size approaches that order of magnitude are more hazardous, and require continual vigilance in maintaining good control. It is, therefore, essential that the vapor blast cabinets be maintained so that leakage of mist does not occur. Good housekeeping is also essential as spillage of the sand and water sludge upon the floor will create a source for dust dissemination when the water evaporates. Likewise, containers of the dried sludge should not be allowed to stand in the factory where they can be influenced by air currents of high velocity.

Practically all industrial plants have operations which involve the use of leading base bearing metal or solder. Babbitt bearing metal containing approximately 75 per cent lead has been encountered. The composition of solder metal is variable and dependent upon the purpose for which it is used, with ordinary soft solder containing a comparatively high percentage of lead.

Assuming that the babbitt or solder in use is one containing a significant amount of lead, the question then arises as to whether or not the employees working with this material will become ill. The answer to such a question could be given by a qualified industrial hygienist after he had seen the operation and considered such factors as the temperature to which the metal is heated, the method of removing excess solder, the length of exposure, and the effectiveness of the control measures provided.

It is a well known fact that lead causes illness if absorbed in excessive amounts, and therefore operations wherein lead is used have received considerable attention and study. Out of this experience certain practices are known to produce excessive exposure whereas other practices have been proved not to be harmful. It is generally conceded that excessive concentrations do not result from operations where solder is applied by means of an electric soldering iron. This is probably due to the small amounts of solder used and the comparatively low heat of the metal. When an iron is used which is heated in a small gas fired furnace, the exposure may be of greater consequence. Solder which remains on the iron coming into contact with the flame or heat is vulnerable for volatilization. Small amounts of solder drop from the iron onto the hot floor of the furnace where it is readily volatilized or oxidized. The oxidized material may become airborne due to disturbances created by the flame or by removing or placing the soldering iron in the furnace. Frequently industrial hygienists recommend that ventilation be provided for heating units of this type thereby removing lead fumes and dust from the environment. This is particularly true in small rooms or where many units are in use.

The atmospheric contamination occasioned by the use of either gas or electrically heated pots containing solder is dependent on a number of factors. With higher temperatures more volatilization will occur and the greater

will be the exposure. With the higher temperature the metal is more readily oxidized to produce a dross consisting of a high percentage of lead oxide. The dross may provide a protective coating to reduce the volatilization of the lead; however, disturbance of this coating will create an exposure. As a safeguard against excessive contamination, pots containing solder or babbitt are usually ventilated. Wherever possible it is advisable to enclose the pot as completely as possible and provide sufficient air volume to overcome the thermal effects of the molten metal. Attempts have been made to use natural draft ventilation systems to control these fumes and in those instances where the ducts were not of sufficient diameter the system was inadequate A preferable method is the use of mechanical systems.

The removal of excess solder with power driven tools, such as grinding wheels, discs, or wire wheels, creates airborne dust which may contaminate large areas of the factory if the operation is extensive. Diligent use of abrasive cloth will also result in excessive concentrations of lead dust. Filing, however, is not productive of small particles and is preferred over the use of power driven tools. If filing is not practicable or feasible it will be necessary to provide some type of mechanical ventilation system for the solder removal operations involving the use of power tools. Since the permissible limit generally accepted for lead is 1.5 milligrams per 10 cubic meters of air (355 cubic feet) it will be necessary to have an effective system to provide adequate control. Engineers experienced in designing ventilation systems to control toxic materials should be consulted, otherwise a costly system might be erected and later discovered to be entirely ineffective. Frequently solder removal operations require the use of portable tools on large objects and a local exhaust system would not be effective, as is the case in the fabrication of automobile bodies. General contamination of the factory with lead dust has been eliminated by enclosing the entire operation in a large booth and exhausting a sufficient quantity of air from the enclosure to insure a constant inward flow of air from the factory into the booth. Under these circumstances no practical amount of air could be removed from the booth to reduce the lead concentration to a safe level, and therefore it is necessary that the men working therein be provided with adequate personal protective devices.

Heat Treating—High temperatures are a frequent source of complaint from employees in heat treat departments but such conditions and their control are not within the subject matter under discussion.

Fumes disseminated from cyanide pots are often associated with cyanides used as fumigants or as the lethal agent in death chambers and supervision as well as the employee becomes apprehensive. Fumes from such a source are irritating and because of this property should be adequately ventilated. The irritant nature of the fume is caused by alkali formed upon decomposition of the cyanide.

Molten lead is sometimes used as a hardening medium for metals. Frequently charcoal or some similar material is placed on the surface of the metal to conserve heat and prevent oxidation. A covering of this type reduces the volatilization of lead while the bath is quiescent, but has no effect while the bath is in use. Adequate ventilation should therefore be provided for baths of this type. As complete an enclosure as is practical for the operation being performed is advisable with air quantities dependent upon the open areas in the hood. To prevent contamination resulting from volatilization of lead accumulating in the combustion chambers the products of combustion from gas fired lead pots should be vented to the outdoors and not be allowed to dissipate into the workroom.

Iron Foundries—The principal ingredients of foundry dusts are silica, sea coal, clays, and parting compounds. The predominant material will be dependent upon which phase of the foundry operation is being studied and what operation is being performed. The control of dust is the major problem, whereas fume is of secondary importance.

A discussion of all the aspects of the industrial hygiene problems in such plants would require a separate treatise. For the present discussion it should be sufficient to state that all obvious sources of dust dispersion should be reduced to a minimum by adequate localized exhaust systems. In a mechanized foundry such places would be sand conditioning and mixing equipment, tumbling mills, shakeouts, core removal and knockout stations, transfer points of dry sand, abrasive blasting operations, and all grinding operations performed on castings containing appreciable quantities of sand.

Maintenance of ventilation equipment is a major item in foundries because of the abrasive action of the dust. It is imperative that a good program be maintained so as to keep the equipment functioning at maximum efficiency.

Because of the heat associated with large scale foundry activities it is a common sight to see pedestal fans or air cooling ducts directed in such a manner as to create cross drafts which interfere with the efficient removal of the dust dispersion. Better discretion in the placement of these fans or ducts will go far in reducing dust concentrations in the areas where they are used.

After the obvious has been corrected, it is advisable that a survey of the foundry be made by an industrial hygienist so that an accurate evaluation of the exposure may be obtained.

Respiratory Protective Devices—As has been stated, the atmospheric concentration of dust and fume and other materials may be reduced to a safe level by adequate exhaust ventilation. In some cases it is possible to correct the condition by substituting a less toxic material. If these measures are not practical respiratory protective devices may be used. They may also prove valuable in giving protection during an emergency or to provide protection for intermittent exposures or to supplement other methods of control. They should, however, not be considered as the desirable means of controlling a health hazard.

Experience has shown that frequently protective devices have been issued which do not provide adequate protection. Upon inquiry information was generally offered that the safety engineer was not too well informed as to what should have been provided.

The U. S. Bureau of Mines at their experimental station in Pittsburgh tests equipment of this type and studies the protection offered to the wearer. If the device is satisfactory in performance, they issue an approval number to the manufacturer which appears on the device as well as the container in which it is received from the manufacturers. The approval granted by the Bureau also stipulates that type of materials for which it is approved.

It has become general practice in the field of industrial hygiene to recommend the use of only those respirators which have been approved by the Bureau. Safety engineers should likewise insist that such devices be procured and acquaint themselves with the type of protection afforded by each device and thereby provide adequate control for the individual wearing the equipment. Some engineers prefer to stock only that type of respirator which will protect against the more harmful dusts or fumes, since a respirator of this type will also give adequate protection for materials of lower toxicity. The advantage of such a procedure has merit as it reduces the types of devices needed in stock and likewise insures the correct device for the more serious exposures.

Metal Cleaning

By THOMAS MOONEY
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The complete finishing of metals by electroplating may include:

1. Cleaning by abrasives.
2. Polishing the base metals.
3. Cleaning with solvents.
4. Cleaning with alkaline solutions.
5. Cleaning with acids often referred to as "Pickling."
6. Metal deposition or electroplating.
7. Buffing the deposits.
8. Lacquering the finished product.

In abrasive cleaning, sand or steel shot is used under pressure. The potential health hazards in this type of cleaning are exposure to dust of a high free silica (SiO_2) content caused by the sand and also to metallic dusts where metals capable of producing toxic dusts are cleaned by shot and sand blasting. Steel shot blasting is a much less severe health hazard than sand blasting; consequently, steel shot abrasive cleaning methods should be used wherever possible.

The maximum allowable concentrations (M.A.C.) for free silica are five million parti-

scratches, before the metal is plated or painted. The principal hazards to health in metal finishing are the dusts of toxic metals such as lead, which are used to fill hollow surfaces when power grinding or disc machines are used to grind them down to a smooth finish, as is often done in automobile finishing.

In operations of this kind, where the lead surface is ground with power tools, the job should be isolated from other adjoining departments and have suction applied to it to remove the fine lead particulate dusts from the area. All workers involved in metal finishing where lead is used and ground with power tools should be required to wear a metal fume respirator approved by the U.S. Bureau of Mines for lead dust, if the concentration of lead in the air is 1.5 milligrams per ten cubic meters of air as determined by test. The writer knows of no lead hazard introduced when finishing lead surfaces by hand filing.

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Control of Solvent Exposures

By E. C. BARNES
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The term "solvent" as used in industry denotes a variety of liquids that are used mainly for the purpose of dissolving some other material. The term is used rather loosely and may include such liquids as water or acids. Although there are many interesting factors involved in the proper control of all types of solvents, perhaps the greatest concern is attached to the organic solvents, and this discussion will be limited to that group of solvents generally referred to as "organic solvents." Most of these solvents are purchased to perform a specific function and they are later thrown away, usually in the form of a vapor. For example, a varnish may be made by dissolving a resin in toluol. The varnish is applied to some piece of equipment and the toluol is then evaporated by placing the equipment in an oven. Or, perhaps it is desired to wash grease from some metal parts. The parts may be wet with the solvent until the grease is removed and they are then allowed to dry. We can almost generalize and say that solvents are purchased for the express purpose of creating solvent vapors. These vapors create hazards which must be controlled.

There are about 200 different organic solvents available in drum or tank car quantities. These solvents are supplied to industry both as a specific chemical compound and also as a mixture of one or more of these chemical compounds. Thousands of these mixtures are supplied to industry. In addition to this group of liquids which is available to industry in large quantities, there are several thousand others which are available in quantities of a few quarts or gallons.

Out of the many millions of gallons involved, the 200 organic solvents which are available in large quantities present the greatest problem of control. At the same time, this group of solvents has been used and studied sufficiently, so that reasonably good technical information and methods of control are available. Many of the several thousand organic solvents used in small quantities are not so well known and adequate technical information may not always be available. They thus present a more difficult problem in control.

In addition to these solvents which are now available, there are probably at least a dozen new organic solvents made available in large quantities each year, and hundreds of new solvents are made available in limited quantities. A continual check on new materials and new processes is therefore advisable to be certain that the use of new solvents will be adequately controlled.

When we speak of controlling solvent exposures, we obviously must include all the hazards associated with the use of the solvent. We must include such elements as fire, explosion, and health hazard. When speaking of control, we may feel the desirability of

establishing some kind of an automatic control which would shut off or reduce the exposure before hazardous conditions are created. It would be nice if we had a thermostat or regulator that would automatically turn off the exposure before any hazard was created.

Automatic controls should obviously be applied wherever they are practical. For example, combustible gas alarms may be used to control the explosion hazard in an oven being used to volatilize solvents. Automatic releases may be installed to actuate fire fighting equipment the moment a fire starts. Unfortunately, we do not have such a gadget which can be attached to one of the workers to indicate when he is over-exposed. Other methods of controlling the human exposures must be utilized, and these will be discussed later. Essentially, control of solvent exposures must be based on prevention of hazardous exposures. In order to prevent these exposures, certain technical information must be available. Equipment and processes must be properly designed. Finally, quantitative measurements must be made to establish the extent of the exposure. Perhaps we should consider these three elements more carefully.

Before giving much consideration to the design of a piece of processing equipment or a manufacturing operation involving organic solvents, a considerable amount of technical information must be available. Such elementary data as the boiling point; vapor pressure, vapor density, flammability, flash point, explosive limits, corrosive action, and last but not least, the Maximum Allowable Concentration and skin irritation properties must be known.

The boiling point of a liquid is of interest because it indicates the temperature at which large quantities of vapor will be given off at ordinary atmospheric pressure. It also serves as a guide in estimating the volatility of a solvent.

The vapor pressure of the liquid at room temperature, and also at any processing temperature, is of importance because it indicates the possible concentrations of solvent vapor that might be present under varying conditions. When the vapor pressure is known, the maximum vapor concentration that will be present under saturated conditions can be calculated.

The vapor density is significant since it indicates whether the vapor is lighter or heavier than air, and in cases where highly concentrated vapors may escape from enclosures, it will be known whether these vapors will tend to flow downward or upward through the air. You will note that I said "concentrated vapors." I should like to emphasize this because there is frequently a misunderstanding in connection with the interpretation of the flow of vapors of varying densities. If there are only a few hundred parts per million of vapor in air, this mixture will not tend to flow upward or downward through the air when it is released, but will rather be carried along with whatever air currents may be present at the point where it is released. You are all familiar with the high school chemistry experiment of pouring carbon dioxide from one beaker into another beaker containing a burning candle and the resultant extinguishment of the flame on the candle. If the carbon dioxide in the first beaker were diluted to a concentration of only a few hundred parts per million of carbon dioxide in air, it would not pour from the first beaker into the second but would be carried away with any air currents and rapidly diffused in the surrounding air. Thus, any interpretation placed upon vapor density must take into consideration only those vapors which have not been diluted appreciably with air or other gases.

It is certainly desirable to know whether a solvent is flammable or non-flammable. If the solvent is non-flammable, no special consideration need be given to the possibility of an explosion or the danger of fire. If the solvent is flammable, however, special consideration must be given to its use so that the possibility of an uncontrolled fire or explosion may not occur. Even though conditions may be established for use of the solvent which minimize the fire or explosion hazard, it is essential that a suitable type of fire fighting equipment be made available in case some accident should occur which would cause the solvent to burn. Fire fighting equipment of a type suitable for the specific solvent involved should be selected. Assuming that the proper fire fighting equipment has been provided, it then becomes necessary to train a sufficient number of persons in its proper use.

Assuming that we are dealing with a flammable solvent, its flash point must be known to properly evaluate the means of protection

ich is required. The flash point of a flammable liquid is the lowest liquid temperature at which enough vapors are given off to form a flammable mixture of vapor in air immediately above the liquid surface. If the liquid is above the flash point temperature, a small flame will ignite vapors from the liquid and they will continue to burn. Below this temperature, a small flame passed over the surface of the liquid will not ignite the vapors.

Where a solvent is constantly maintained at a temperature below its flash point, there is not much chance of it being ignited by sparks or small flame. If, however, the solvent is at a temperature higher than its flash point, any small spark or flame near the surface of the liquid will ignite it and the liquid will burn with increasing intensity. Thus, we see that a solvent whose flash point is above room temperature can be used without much danger of fire or explosion wherever the solvent remains at room temperature. If, however, its flash point is below room temperature, care must be taken to avoid igniting it. Care must also be taken to avoid the mation of explosive mixtures where the nash point is less than room temperature. In general, it can be said that when liquids are maintained at temperatures above their flash point, it is possible that explosive mixtures of the vapor in air will be formed.

The lower explosive limit of a gas or vapor is that concentration of vapor in air, below which an explosion cannot occur even though a source of ignition is present. If we are operating an oven under conditions where explosive concentrations of solvents are present, then it requires only a spark or small flame to cause a shattering explosion. Since it is difficult to be certain that no spark or flame will be present, it seems reasonable that we should always operate this type of equipment in such a way that the solvent vapors will always be well below the lower explosive limit. Then we can be sure that if a spark or flame occurs, there will be no possibility of an explosion. We have felt that it is desirable to maintain a four to one safety factor on such exposures, and therefore we limit the vapor concentrations in ovens or milar pieces of processing equipment to 25 percent of the lower explosive limit. When new equipment is being designed, the amount of solvent vapor to be released can usually be calculated and from this the amount of exhaust ventilation can be established, using the four to one safety factor. After installation of the equipment, actual measurements are made to be certain that the design conditions have been met.

In general, the corrosive action of organic solvents is not very great. However, this factor must be known so that suitable piping and processing equipment can be provided. We can thus be assured that a corroded pipe or piece of equipment will not fail and produce hazardous conditions.

The Maximum Allowable Concentration and skin irritation properties of a solvent are part of the technical information which must be available if we are to satisfactorily control exposures. We do not find these properties listed in the handbooks the same as boiling point, vapor pressure, flash point, etc. They are just as important, however, and must be furnished as a part of the technical information which must be in the hands of people who are developing, designing and operating processing equipment or manufacturing operations involving organic solvents. The Maximum Allowable Concentration for different solvent vapors varies over a wide range—from a few parts per million to thousands of parts per million. It is obvious that a piece of processing equipment involving the use of a highly toxic solvent would be designed quite differently than one using a solvent of low toxicity.

The need for providing engineers and supervisors with all essential technical information regarding solvents has been emphasized. Perhaps it should be re-emphasized. All this information may be very helpful and useful if it is in the files of the safety engineer or the industrial hygiene engineer. However, to be most useful, it must be in the hands of those persons who are actually developing, designing or operating the processes which use these solvents. We have used several methods of supplying such information, which I will describe briefly.

All materials used in our plants are assigned a material number. For each material a 4 x 6 card is written by our Headquarters Engineering Department. On each card they list the following information—

Material Number
Material Name
Caution (A brief statement of precautions to be observed in using this material)
For Use By (Name of plant)
Furnished By (Name of supplier)

Order From Supplier As (Supplier's designation or catalog number)

Characteristics (A brief statement of the properties or engineering characteristics of the material).

Application (A brief statement of where the material is used and its general application).

Specify As (How to specify the material on drawings or other written documents). You will note that the third item on this material card is "caution." Before issuing any of these material cards, the Engineering Department consults the Industrial Hygiene Laboratory and they are furnished with a brief statement of the precautions that should be used for this specific material. These are brief statements such as "do not breathe vapors of this material," or "avoid contact of this material with the skin." This system has two advantages—first, it provides the Industrial Hygiene Laboratory with information about all new or changed materials that are used in the plants; second, a suitable warning as to any hazards can be given. These material cards are distributed to purchasing agents, materials and process engineers, development laboratories, design and engineering departments and all other persons having a definite need for information about materials.

Another method that is used for providing good technical information to the proper persons in the organization is the data which are furnished with our Process Specifications. Any process operation used at any plant is described on a process specification. Each process specification is assigned a specific number, and in general it can be said that each of these process specifications describes in detail any methods to be used in preparing a specific item or product. For example, one process specification may describe in detail the method to be used for insulating armature coils, and another may specify the details of the method of molding resins.

Before issuing or revising any of these process specifications, our Headquarters Engineering Department sends a copy to our Industrial Hygiene Laboratory for approval. It is checked to be certain that wherever hazardous materials are used, a suitable warning regarding the hazards has been included. For a number of years we included certain technical information such a Maximum Allowable Concentration, flash point, explosive limits, etc. in each specification. More recently, we are making reference in the specifications to a Safe Practice Data Sheet. These Safe Practice Data Sheets are provided along with the process specifications so that when a person has a process specification he also has a safe practice data sheet. The Safe Practice Data Sheets list the following information about each material that may involve any hazard—

- Containers and Storage
- Properties
  - Fire
  - Explosion
  - Breathing
  - Swallowing
  - Skin Irritation
- Personal Protective Equipment
- Precautions
- First Aid

We feel that this provides fundamental technical information to all persons who are involved in the design, development or operation of processing equipment.

We have made a number of references to the "engineering design" of equipment or processes involving the use of organic solvents. With complete technical information available, the designer of the equipment is in a good position to take advantage of any special characteristics which a material may have. He can utilize equipment and methods to suit the specific needs of the solvent involved. If he is dealing with a solvent which has a relatively low vapor pressure and also a low order of toxicity, such as kerosene, there may be no need for totally enclosed equipment. If the solvent has a relatively high vapor pressure and a high order of toxicity, such as carbon disulfide, the designer will recognize that totally enclosed equipment is essential, and in addition, local exhaust ventilation will be required wherever vapors might escape. In the second case, a considerable expenditure of money will be necessary for this type of equipment.

It is surprising the number of solvent exposures that can be eliminated by proper design of equipment or shop layout. Of course, if we inherit a piece of equipment, or manufacturing methods have not been originally set up to eliminate the solvent exposures, some means of protection against the exposures must be devised. Such methods as the installation of exhaust ventilating equipment, the use of respirators, or the ap-

lication of hand creams may be indicated. metimes these methods of protection may be satisfactory. In general, however, they require an abnormal amount of supervision.

Wherever solvents are used, it seems essential that some quantitative measurements be made to establish the extent of the exposure. We may have good technical information and good engineering design, but we are never certain that we have attained our goal in controlling the solvent exposure unless the actual exposure has been properly measured. The fire hazard can usually be determined by inspection. If there is any possibility of an explosion hazard, the measurement of vapor concentration by use of one of the readily available combustible gas indicators will determine accurately whether satisfactory control has been established.

Unfortunately, it is a little more difficult to determine the exposure of a person. There are two basic methods of determining the exposure of a person to a solvent. The first is by some measurement or inspection. For ample, we may determine by measurement ne concentration of solvent vapor in the air where the employee works, or an inspection may reveal whether there is any contact of the solvent with the skin of the employee. Another method of determining the true exposure of an employee is by some measurement which indicates the amount of solvent vapor which has been breathed by the employee during his working period. Exposure to benzol, for example, may be determined by a chemical analysis of a urine specimen, to determine the ratio of organic sulfates to total sulfates in the urine. Some recent research work indicates that it will be possible to determine the exposure of an employee to trichlorethylene vapors by a measurement of the trichloracetic acid in urine.

A number of solvents increase the rate of excretion of glucuronic acid in the urine. These methods have not been extensively used, but certainly will find wider application in the future. We have found it very helpful in controlling benzol exposures to determine the sulfate ratios in the urine at periodic intervals. Whenever these determinations indicate an excessive exposure, an investigation is immediately made to determine why such exposure exists and to instigate corrective measures.

I should like to emphasize that these are methods of determining exposure and should be used as such. They may not be related in any way to any harmful effect of the solvent.

The second general method of determining an exposure of an employee to a solvent vapor is by a periodic physical examination. This method depends upon making some specific determination which will give an indication of early effects of the solvent in the body. For example, blood counts, when properly performed, can be used to indicate any early effects from exposure to a number of solvents, such as benzol. Other laboratory tests may be made, depending on the type of injury reaction that may occur in the body from a specific solvent. If we depend upon physical examinations to determine exposure to solvent vapors, they obviously must be done at rather frequent intervals, and the physical examination program must continue indefinitely.

I should like to emphasize the difference between these two general methods of control. By making measurements which indicate the exact extent of any individual person's exposure, we are carrying out a procedure which gives an indication of over-exposure before there is any chance for a harmful reaction to occur in the employee. When we depend solely upon physical examinations to determine these exposures, it is possible to get an indication of over-exposure only after some physiological change has taken place in the body. The desirability of the first procedure is obvious.

Even though we may not wish to utilize the periodic physical examination as a means of controlling our solvent exposures, there is still a need for proper pre-placement and periodic physical examinations. The pre-placement examination can indicate any abnormalities in an employee which later might be interpreted as the result of some solvent exposure. Likewise, certain physiological changes may take place in an employee during his period of employment, even though there has been no harmful exposure. It is desirable to detect these unrelated changes and make them known to the employee so that proper treatment can be instituted and the employee will not have a feeling that perhaps his solvent exposure was a factor.

To summarize briefly, there are a wide variety of organic solvents used in industry in relatively large quantities. From these solvents a tremendous quantity of solvent vapors are liberated. To control exposures to these