

Industrial Fumes, Gases and Vapors

THURSDAY MORNING SESSION

October 14, 1937

The meeting was called to order by Voyta Wrabetz, Chairman, Industrial Commission

of Wisconsin, Madison, who presided and introduced the speakers.

Injurious Effects of Metal Fumes and How to Prevent Them

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The inhalation of metal fumes is a common cause of illness among certain occupational groups. Two very different systemic reactions may result from breathing air containing particulate metal or metal compounds: (a) metal fume fever, an acute, transitory, non-fatal disease causing slight or temporary disability; (b) systemic metal poisoning, mild, severe, or even fatal in its effect. The same occupational exposure may produce both reactions, metal fume fever developing following the worker's early exposure, chronic systemic poisoning developing later as a result of prolonged exposure.

We may consider metal fumes as solid particles generated by condensation from metal in a gaseous state. Condensation is usually accompanied by oxidation.

There are two chief physical characteristics of metal fumes which bear a direct relationship to the ease with which they may be absorbed: (a) The solid particles are much finer than atmospheric dust, probably averaging less than .5 micron in diameter; (b) they tend to flocculate and settle out of the air as dust. The finer the solid particles suspended in the air, the longer the time required for them to settle out. Many of the coarser dust particles in the air are trapped in the upper respiratory tract and by the ciliated cells lining the trachea and bronchi, while the finer particles may be carried to the terminal air spaces of the lungs. Here they are taken up by the phago-

cytic cells and are eliminated chiefly by way of the blood and lymph.

Sayers and his associates¹ found that only about 15 per cent of inhaled particulate matter, such as lead dust from automobile exhaust gas, was retained in the lungs, the remainder passing out with the exhaled air. Drinker and his associates² and Brown³ made quantitative measurements of fumes retained in the lungs. They found a direct relationship between the percentage of fumes retained and the size of the particle and the density of the fumes breathed. They also showed that slow deep breathing increased the reaction resulting from inhaling zinc fumes. Such breathing should increase the percentage of particulate matter retained.

Hazardous Processes

For convenience we may place the more common occupational environments which are likely to afford a harmful exposure to metal fumes in three large groups:

1. Smelting of ores and refining of metals.
2. Employment at processes handling molten metal such as molding, cutting, and welding operations.
3. Salvage and cleaning operations, including the burning of metals or metal covered objects, especially by means of acetylene torch or electric arc.

In the first class, the ores or metals processed provide the source for the generation

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of fumes. Such operations are usually permanent and exposures tend to be more constant, although as a rule the greatest amount of fumes is generated during tapping operations.

Likewise, in the molding processes the molten metal is the source of metal fumes. In welding, cutting, and salvage operations, the metal fumes may originate from metal products processed, coated surfaces of the metals, fluxes used, or from the coating or core of the electrode used.

These latter operations may provide exposure to a greater variety of toxic metals, but as a rule such exposures are to lesser concentrations. Exposure usually is less regular since the operations vary from time to time both as to extent and raw materials used.

Atmospheric Concentrations

Data relative to the minimum concentrations of metal fumes which will produce metal fume fever are limited. It is believed by some that, except in case of the super-sensitive individual, metal fume fevers can be avoided by keeping atmospheric concentrations below 10 milligrams per cubic meter of air. Drinker and his associates⁴ suggest 15 milligrams per cubic meter as a safe limit where workers are exposed to the fumes of zinc oxide, provided the fumes of such impurities as lead, cadmium, and arsenic are not also present in harmful amounts.

Our knowledge of safe limits from the viewpoint of chronic metal poisoning is likewise meager. Prolonged exposure to lead concentrations in the air breathed should be kept below 1.5 milligrams per 10 cubic meters of air.⁵ In the study of chronic mercurialism among fur cutters⁶ it was found that cases developed after prolonged exposure to atmospheric concentrations varying from .6 to 7.2 milligrams of mercury per 10 cubic meters of air.

Less than 5 per cent of those exposed to concentrations which did not exceed 2 milligrams per 10 cubic meters of air developed symptoms of chronic mercurialism, and all cases that developed under such exposure were mild. Canavan and his associates⁷ reported upon a case of chronic manganese poisoning which developed following exposure to manganese dust, where the concentration in the atmosphere was from 10 to 20 milligrams per cubic meter of air, 9 to 12 per cent of which was manganese.

Metal Fume Fever

A strict interpretation of the term "metal fume fever" does not place it in the class of conditions termed "metal poisoning." The reaction set up in the body is not directly attributable to the toxic metal, or dependent upon the inherent toxicity of the metal particles inhaled. The superficial action of the finely divided metal destroys the tissues, and the absorption of these altered body proteins affects the individual much the same as typhoid inoculation or the injection of other foreign proteins.

Metal fume fever has long been recognized as an industrial disease. Other terms commonly applied to the condition are: "Brass founders' ague," "brass chills," "zinc fever," or "zinc chills," "spelter shakes," etc. Formerly it was thought due to the poisonous effects of zinc and zinc alloys. Various workers in the past quarter century have shown, however, that it may be produced by the fumes of metals other than zinc; notably, copper, magnesium, manganese, and probably lead. Koelsch⁸ in 1923 reported upon the occurrence of metal fume fever among employees in a copper rolling mill.

Investigation showed the men to be working under conditions which caused them to breathe air containing heavy concentrations of copper dust. The symptoms resembled "brass founders' ague." In his report he quotes Kissalt⁹ as showing that mercury, nickel, and probably other heavy metals when inhaled in vaporized form caused symptoms similar to those of "brass founders' ague."

Drinker and his associates¹⁰ in 1927 reported that men experimentally exposed to fumes of magnesium developed the classical symptoms of metal fume fever.

Clinical Picture of Metal Fume Fever

The clinical manifestations of metal fume fever are as follows: At the end of the day, or 2 to 12 hours following exposure to metal fumes, the individual notices a dryness of the throat in addition to the metallic taste which most workers commonly experience during exposure. A feeling of tightness of the chest, varying with the exposure, usually indicates the severity of chills and fever which are to follow. In mild cases the individual may not be aware of any fever and may complain only of a chilly sensation, followed by sweating and general weakness.

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Exposure to extreme cold may hasten the onset of fever and chills, but as a rule the worker awakens from sleep with a high temperature and chills, which are quite similar to the chills and fever experienced in attacks of malaria. After they have developed, nothing in the way of extra covers or hot baths appears to affect these chills. Toward the end of the attack the individual sweats profusely and is left with a feeling of marked weakness. In the majority of cases some weakness is still felt the next day. It is commonly believed that hot baths and hot drinks of tea or lemonade may succeed in partially aborting the attacks, if taken at the first sign of respiratory difficulty such as a dry throat or tight sensation in the chest. Drinker and his co-workers⁴ by their experimental work were unable to show that even excessive "sweating" of an individual 2 to 4 hours after exposure altered the reactions in any manner.

Examination of the blood of workers suffering from metal fume fever shows a gradual increase in the polymorphonuclear leukocytes which begins toward the end of the attack and persists for some time after the fever has disappeared. This increase in white blood cells appears to have a direct bearing upon the degree of temporary immunity established.

This probably accounts for another characteristic clinical observation. The workers are most likely to be affected after a vacation period. More cases develop after a holiday or on the first day of the week, after an absence of one or two days from exposure. The condition is found more frequently affecting new employees or old employees returning to work after a prolonged absence from exposure.

As a rule, gastrointestinal disturbances are seldom complained of except in cases where exposure has been to fumes of substances affecting the digestive system. For instance, it is well known that zinc coated metals contain other toxic metals as impurities. The welding and cutting of these release the toxic substances together with the fumes from the zinc, as well as fumes from certain fluxes which are used.

We have no conclusive evidence regarding chronic effects produced by repeated exposure to zinc fumes. A study of workers in brass foundries⁵ showed that the group experiencing attacks of metal fume fever were in somewhat poorer physical condition than

were those who did not develop fever and chills. Theoretically, those experiencing irregular exposures and complaining of repeated attacks of fever and chills which leave them in a generally weakened condition would, in a measure, develop lessened resistance to acute and chronic infection.

Detailed information regarding the pathology of metal fume fever is not available. A search of the literature at hand fails to show any record of death from metal fume fever, uncomplicated. The illness is of such a transitory nature that most of our knowledge regarding blood changes is the result of experimental work and isolated case reports.

In view of the fact that zinc is relatively nontoxic, and of the conclusions expressed by Drinker and Fairhall⁶ regarding the hygienic position of zinc, it is difficult to show why chronic illness should result from exposures producing simple metal fume fever. It would seem, however, that in consideration of the recent work showing the role played by zinc in the treatment of diabetes with insulin, possibly some investigation should be made to determine if exposure to metal fumes capable of producing metal fume fever may not affect the endocrine system, especially in persons with some metabolic disturbances, such as potential diabetes or thyroid dysfunction.

Differential Diagnosis

Metal fume fever may sometimes be overlooked, unless the physician considers occupational environment. The condition may simulate attacks of grippe or bronchitis; or, if in a malarial region it may be mistaken for a fresh attack or a relapse from a former attack of malaria. Careful study of the blood will aid in diagnosis; those suffering with grippe or bronchitis seldom show the increase in white cells usually found present in persons suffering from metal fume fever, while those with malaria usually show the organisms present in their blood. The duration of symptoms is usually less in the case of metal fume fever.

However, it is not uncommon to find persistent rales upon examination of the chest several days after an attack. However, in persons with grippe or bronchitis, these rales are usually associated with a slight elevation in temperature, which is not found persisting in metal fume fever, uncomplicated. Massive exposure producing metal

fume fever may be followed by attacks of bronchial pneumonia, as a result of pulmonary irritation and infective organisms commonly present in the respiratory tract.

Metal particles are not the only injurious substance present in fumes generated by some industrial processes. The use of an acetylene torch in a space with poor ventilation has resulted in incomplete combustion of the gas and the liberation of carbon monoxide gas.

Doig and McLaughlin²² reported upon an illness affecting welders of galvanized metal, using an electric arc. The men complained of lung irritation so severe that their sputum was often blood-tinged. Investigation showed this to be caused by excessive concentrations of nitrous fumes generated by the processes. X-ray examination of the chests of several in this group, who had been employed for many years, showed changes thought due either to the prolonged irritation caused by nitrous fumes, or possibly to the fumes of silica inhaled. The electrodes used were silica-coated.

Chronic Poisoning by Metal Fumes

It is generally recognized that the most serious exposures to toxic metals in industry occur in occupations where the worker breathes air contaminated with these poisonous substances. It is true systemic poisoning by metals may develop in an acute or sub-acute form, as a result of massive exposure. However, the vast majority of such cases are chronic, caused by frequent and prolonged exposure which leads to an accumulation of the toxic metal in the body. Poisons entering the body by way of the lungs, to be eliminated must be taken up by the blood and lymph. When present in the blood, they are carried to all parts of the body.

Poisons taken in by way of the mouth may not be absorbed but be passed out with the feces. If absorbed, it may be trapped in the liver and returned to the intestinal tract in the bile, and eliminated with the feces. Some, it is true, may be transferred by the blood to distant organs. Most heavy metals and their salts are true protoplasmic poisons. Some, such as iron and zinc, are more common constituents of body tissue. The action of these toxic metals is generally cumulative and no immunity, temporary or permanent, may be established if exposure is to sufficient concentrations.

Because of the fact that metals are usually

toxic, the possibility of poisoning from inhaling fumes generated in the processing of any metal should always be given consideration. While zinc itself may be relatively nontoxic, it is seldom used in industry in a form free from toxic substances, such as lead, arsenic, selenium, cadmium, and many others.

Following the initial attack of metal fume fever, because of the temporary immunity which they develop, workers may continue under conditions which caused the attack and not suffer a recurrence. It must be borne in mind that these very conditions may afford exposure to other toxic metals which have cumulative effects and later lead to a chronic poisoning. If atmospheric concentrations of the fumes are kept below those capable of producing metal fume fever in the new worker, the chances of chronic poisoning by the toxic metals present as impurities are definitely reduced.

On the other hand, however, these impurities may be present in amounts sufficient to lead to chronic illnesses later, although the concentration of fumes has never produced metal fume fever.

Clinical Picture of Chronic Poisoning by Metal Fumes

The symptoms produced by poisoning from metal fumes will vary. Some metals affect chiefly the nervous system, others the lining of the blood capillaries, while others exert most characteristic injury upon the blood-forming organs.

Generally speaking, the clinical picture of metal fume fever, regardless of the metal responsible, varies only in severity, while that of metal poisoning per se varies with the particular metal fume inhaled and with the degree of exposure. For example, massive doses of lead fumes inhaled may produce such acute conditions as lead encephalitis and severe gastrointestinal complications; while continued exposure to smaller concentrations will cause such chronic changes as anemia, lead palsy, and chronic nephritis.

Exposure to heavy concentrations of mercury vapor leads to acute nephritis, salivation, and diarrhea, while the more common industrial exposures to but slight concentrations will eventually produce the typical mercury tremor and psychic changes characteristic of chronic mercurialism. Strictly

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speaking, there are no signs or symptoms of poisoning from metals which can not be due to other causes. For this reason diagnosis is always a matter of differential diagnosis and metal poisoning can only be established by careful consideration of all factors, including occupational history, medical history, clinical and laboratory findings.

While laboratory findings are a very important factor in diagnosis, they can not be relied upon as the sole evidence necessary.

Prevention of Metal Fume Poisoning

While the responsibility of controlling health hazards associated with exposure to fumes of toxic metals rests primarily upon the employer, effective elimination of such hazards can only be secured by the wholehearted cooperation of employers, employees, the State, and other regulatory inspection agencies. Three fundamentals contribute most to actual prevention. They are: Good housekeeping, supported by engineering control of hazardous processes, and intelligent medical supervision.

Good Housekeeping

We think of good housekeeping as applying to clean floors and work benches; materials, tools, and processes arranged and maintained in good order; adequate lighting, and no overcrowding of work places by men and materials. All these will do much to lessen the concentration of toxic fumes in the atmosphere, but seldom is the control of processes so effective that some fumes do not escape into the general air of the workroom. From here they may be inhaled, or may contaminate the bodies and clothes of the workers. So general workroom ventilation is a factor in good housekeeping.

The provision of adequate washing facilities is a prerequisite. Under certain conditions lockers and showers for workers are necessary for the safe operation of many processes.

As a rule sweeping and cleaning should be done after regular working hours. Not only can a more thorough job be accomplished, but what is more important, other workers will not be subjected to any increase in atmospheric contaminants occasioned by cleaning methods. If vacuum or wet methods are used, accumulated dust is more effectively and safely removed.

Engineering Control

It has been found practical to exhaust, locally, most processes generating metal fumes so that the toxic fume is trapped at its source and does not gain entrance to the workroom atmosphere. This is done by means of hoods or enclosed processes. Special hazardous processes can usually be isolated in the plant, thereby making potential exposure of all employees unnecessary.

Both local exhaust and enclosed methods are more effective if special attention is given to general workroom ventilation. Disposal of fumes trapped by enclosed processes and local exhaust or isolation methods requires that attention be given that such wastes do not contaminate the air drawn into the work places by general ventilation.

Medical Control

Adequate medical supervision entails special care in the placement of workers, and should not be aimed at the selection of only super-men, since it is practical to make work places safe for the average man. Individuals with serious kidney, respiratory, or other systemic diseases should not be placed where they may be exposed even to minimum concentrations of toxic fumes.

Where processes are known to be potentially hazardous, an important check on the efficiency of engineering control is gained through regular periodic examination of workers. By this practice, in many instances, not only will evidence of absorption be detected before serious injury has resulted, but an opportunity is afforded to correct control measures so effectively that the workers showing early signs of absorption may safely continue at their regular jobs. Routine records of illness should be kept.

Any abnormal rate of absenteeism due to illness among an occupational group, regardless of the diagnosis reported, should call for special investigation to determine if there are any environmental conditions aggravating the primary illness.

Personal Protective Equipment

If proper attention is given to the three fundamentals mentioned—good housekeeping, medical and engineering control—only specific and unusual emergency exposure will call for the provision of personal protective equipment.

The masks or respirators provided work-

ers who must necessarily be exposed to metal fumes should be of special construction and adapted to the processes and materials used. The United State Bureau of Mines¹⁴ has, after testing, approved certain types of masks for workers exposed to specific metal fumes.

No filter type of respirator capable of protection against toxic metal fumes has been submitted for approval. While two or three filter type respirators have been approved for protection against lead dust, the use of which may in a small way reduce the hazard of fumes, they cannot be relied upon for full protection. Filter type respirators approved for protection against nuisance and pneumoconiosis-producing dusts will not protect the user from toxic fumes.

Several of the hose-line or positive pressure type masks have been approved, but there are certain limitations to their application which make them impractical for use in some kinds of work.

Substitution

In a vast majority of cases, resort to substitution is an impractical method of eliminating health hazards due to metal fumes. The raw materials used usually have special application. Furthermore, substitution is often a dangerous practice, even though it is practical. Instances may be cited where the substituted product has proven equally as dangerous as the one it replaced, the only difference being that less was known at the time concerning its toxic properties.

Electroplating Fumes and Vapors and Their Elimination

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The industrial physician is responsible for the health of all employees in his plant, in so far as their health may be affected by their occupations and their environment. Consequently he must be familiar with the various jobs and conditions under which the men work to know definitely the associated health hazards. He must work closely with the safety, maintenance, chemical and purchasing departments to keep himself in-

formed on changes in methods and materials that may influence those hazards.

Thus fortified, the physician occupies a strategic position in the hospital, as the employee invariably comes to him first with complaints which he may associate with his work or which are of a nature that would warrant an investigation which may lead to the discovery of an unhealthy condition.

One of the processes which may be sus-

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pected of involving a health hazard is the electro disposition of metal. In preparing metal for plating as well as during the plating operation, and in the treatment of salvage material after plating, a number of chemicals are used, such as solvents, acids, alkalis, metals and salts, and many toxic and offensive fumes and vapors are liberated. While it is true our prime interest concerns the injurious fumes and vapors, we must also interest ourselves in the non-injurious offensive types, since they may affect the worker's mental attitude, giving rise to dissatisfaction which in turn may result in inefficient work.

Poison is commonly introduced into the body by three routes, ingestion through the mouth, absorption through the skin or inhalation through the lungs. In electroplating our greatest hazard lies in the respiratory route; the ingestion and absorption routes are of lesser importance.

Fumes and vapors, such as heavy acids, may enter the respiratory tract as fine spray and produce local reactions in the nose, throat and lungs, while others such as hydrocyanic acid pass through the lungs without producing any local symptoms and enter the blood stream.

Skin absorption is important in connection with the coal tar derivatives, benzene, toluene and xylene and the petroleum derivatives as carbon tetrachloride and trichlorethylene. Since these are all volatile, poisoning may occur by inhalation as well as by absorption.

Ingestion Is Rare

Ingestion of poison by mouth occurs rarely and is usually the result of a definite accident. However, in the lead electroplating industry, rigid precautions must be taken to prevent the ingestion of lead salts that may have been deposited on the clothing and body of men while working around the plating tanks.

In general in all electrolytic processes irrespective of the constituents of the bath only two gases are liberated, oxygen at the anode and hydrogen at the cathode. Since the anode efficiency is always high and the cathode efficiency relatively lower, and the further fact that the gases are liberated in the relation of two hydrogen to one oxygen, the gas from the anode is negligible compared with that at the cathode.

The amount of oxygen and hydrogen liberated, as such, is of no consequence as a

hazard, but out of their properties as gases arises one of our greatest problems in the control of electroplating fumes and vapors. As the gas is liberated, it forms tiny bubbles in the solution which rise above the surface and break, throwing a fine spray or mist of bath solution into the air above the tanks which may be inhaled by the workers. Consequently to understand and evaluate our hazards we must know the bath constituents in all electrolytic processes.

The materials coming to the plating room usually have a film of oil or grease on them which must be removed and the surface treated before they are placed in the plating solutions. This is accomplished by dipping the parts in a degreasing solution such as xylene or placing them in a vapor bath as trichlorethylene. Usually this operation is carried out in open tanks, and as bath solvents are highly volatile, some of their fumes escape and contaminate the room air.

Xylene though less toxic than benzene and toluene has some narcotic action on the central nervous system. Trichlorethylene is the most commonly used degreaser, and is capable of producing general narcosis. Workers at the tanks complain of giddiness and occasionally lose consciousness, but few deaths have been reported. Trichlorethylene, also has an important characteristic that must be borne in mind—workers have been known to become addicted to its use.

Because of the highly volatile nature of these solvents it is impractical to attempt exhausting the tanks. We found we could eliminate the xylene with its hazards by installing closed tank systems of trichlorethylene washing and vaporizing, passing the parts through the spray and vapor chambers on conveyors. This also eliminated our trichlorethylene hazard and the penetrating, sweet smelling, sickening odor in the plating rooms which had been a source of complaint and concern to the workmen.

Carbon tetrachloride is used in some operations, but its use should be discouraged because of its extreme toxicity.

Following the degreasing process the parts are washed in a strong hot caustic solution to remove organic particles of dirt. This washing is more effective if an electric current is passed through the solution, which by the bombardment of hydrogen gas on the part at the cathode produces a scrubbing effect. Since the aim of the electrolysis in

this process is to produce gas, and none of the current is used to deposit metal, a large amount of gas as hydrogen and oxygen is liberated and considerable bath solution is atomized into the air. The solution being composed of strong alkalis is very irritating to the respiratory tract, and the tanks should be exhausted.

In some cases other operations are required before plating, such as pickling and bright dipping. The pickling bath contains weak solutions of hydro-chloric or sulphuric acid and some nascent hydrogen is generated. Since iron, steel, zinc, copper and lead may contain arsenic as an impurity there is always danger of hydrogen arsenide gas being formed from time to time. This is a powerful hemolytic poison and early symptoms of poison appear soon after the gas is inhaled. All pickling tanks should be exhausted.

In the bright dipping of brass a concentrated solution of sulphuric and nitric acid is used, and large amounts of nitrous oxide or nitrogen dioxide fumes are liberated when the parts are placed in the solution. The oxide of nitrogen has a strong local action on the respiratory tract and may produce serious lung damage. It is unfortunate that that gas is not very asphyxiating; the worker may continue to inhale it without experiencing anything more serious than a choking sensation until some hours later.

Poisonous Salts Used

In the actual plating solutions we deal with poisonous salts of sodium, copper, zinc, nickel, cadmium, gold etc. The cyanide compounds are our greatest concern because of their high toxicity. Plating room workers should be instructed as to the dangers involved in the handling of the various compounds and solutions, and the possibilities of the formation of hydrocyanic acid gas in accidentally mixing acid and cyanide solutions or promiscuously slopping these solutions on the floors or spilling them into stagnant drain pipes.

In the electrolytic process the hydrogen gas bubbling out of the solution will atomize these compounds in the air, and the tanks must be adequately exhausted. It is probable that some cyanogen gas is mechanically thrown out of the solution by the hydrogen gas and undoubtedly minute amounts of hydrocyanic acid are formed. However, the tendency of the cyanogen is to return to the solution, so that the hydrocyanic acid formed

is negligible and does not represent a hazard compared with the copper sodium cyanide that is sprayed into the air. Small amounts of hydrocyanic acid are readily assimilated in the body as sulphocyanides and excreted in the urine.

Chrome is usually the finishing plate in automobile hardware, and in its deposition we use a concentrated solution of chromic acid and a very weak solution of sulphuric acid. Since the efficiency of the chrome bath at the cathode is only about 15 per cent, 85 per cent of the current is used in the generation of hydrogen gas, with a resultant active spraying of the solution. Exhaustion of these tanks must be efficient to prevent air pollution. Chromic acid is relatively non-toxic. Its effects on the body are readily recognized, and probably for that reason it has held too important a part in the literature on toxicology. It may produce ulcers on the skin where concentrated solutions have contacted, but outside of their slow healing properties these are of little consequence. If not exhausted properly it produces in workers erosions of the nasal septum which frequently go on to produce permanent perforations which are annoying but do not predispose to any disfiguration or health problem. Like nickel in susceptible individuals, it produces dermatosis which invariably clears up on removal of the person from work in the sensitizing materials.

In the process of stripping salvage parts for re-working, concentrated alkalis are used to remove chrome, and concentrated sulphuric acid to remove nickel, copper and zinc; or an electrolytic bath of sodium nitrate can be used to remove all the deposited metals. The tanks in all these operations must be exhausted.

The elimination of fumes and vapors in the plating rooms is for the most part the concern of the maintenance engineer.

However, the chemist may eliminate them by changes in methods or solutions, designed to stop their production, and the safety engineer may eliminate them from contact with the workmen by the introduction of hoods, masks, gloves, etc. Probably in the future factories will be air conditioned, and our problems of air pollution will be minimized.

When we analyze the problem of ventilating the plating rooms, we are confronted with many difficulties. Exhaust systems of individual tanks designed by rule of thumb to operate with one hundred per cent effi-

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ciency, if other things are equal, may fall far below the expected figure because of air movements produced by surrounding exhausts. This is especially true of an induced system operating near a direct system. I have seen an induced system actually functioning as an intake air shaft in an air bound room, and the substance it was supposedly exhausting was being drawn into the room air as a contaminant.

Other conditions tend to unbalance a well constructed system, such as open windows, doors, skylights, all of which produce air currents that may divert fumes and vapors from the tanks as they pass to the various exhaust hoods in the room. While room temperature, humidity, barometric pressure, and outside air velocities, likewise influence the exhaust system efficiency.

Remove Fumes at Source

The cardinal rule, of course, is to design the system to remove the fumes and vapors at their point of origin. In electroplating tanks the American Standards Association has recommended that this point be from six to eight inches above the solution level, so that the spray from the breaking gas bubbles may be collected. It further recommends that the point be not more than three feet in height from the level at which the operator is standing to draw off the fumes before they reach his breathing zone. Overhead hoods and exhausts may prevent fumes from entering the room air, but they are of little value to the worker standing at the tank. Tanks should be as narrow as possible and should be vented on both of the long sides, to aid in efficient exhaust of the solution area.

Too frequently we satisfy ourselves that our plating rooms are safe for employees to work in, because we have complied with all state rules and regulations relating to the removal of fumes and vapors, and because state inspectors pass favorably on our systems after their casual survey. We walk through the plating room using our noses to detect the presence of fumes and place our hands against the exhaust hood to determine the efficiency of the systems. While it is true our five senses are valuable in the detection of hazards, it is folly to rely on them to the exclusion of the more scientific means at our disposal. Pitot tubes, anemometers, manometers, and swinging vane velocity meters are available to test air velocities and determine the air volume the various ducts are carry-

ing, and regular periodic checks should be made with these several times a year or as often as indicated.

In the final analysis we are not interested merely in exhausting a tank or a room but rather in the air pollution. Our chief concern is what is in the air we are breathing, and if the contaminant is injurious to health, how much of it is present. A quantitative chemical analysis of the air is the only way to determine this.

We have introduced in our plating rooms several machines for collecting air samples, as designed by the Bureau of Mines and the United States Public Health Service. This method essentially consists of drawing air through a solution in a collecting bottle at a fixed rate, the air passing through an impinger tube so designed that its velocity is increased to about 200 miles an hour. As it strikes the bottom of the bottle or baffle, the air is broken up into minute bubbles, which facilitates absorption in the collecting solutions. By using different solutions or a series of solutions, the suspected solid, liquid or gaseous pollutant is extracted from the tested air, and a chemist makes his analysis.

A complete air analysis is not necessary, as this would entail a very lengthy and difficult problem. Knowing what fumes and vapors are formed from the known constituents of the bath, our interest lies in the harmful ones that may be present in the air and not in the small immeasurable amounts of harmless chemical combinations that may be formed.

To obtain as representative a test as possible, the collecting bottle is placed at face level near the operator, and air is drawn through the solution during the entire period he is working. The total air volume that has passed through the collecting solution is roughly equivalent to the amount of air that would pass through the lungs of an average man during the same period.

Long-Time Studies Made

At some key points in the plating room we are installing air analysis equipment which is to be run continuously, and determinations are to be made on 24-hour collections or more frequently if indicated. By this procedure we are able to make more detailed studies of our hazards at fixed points over a long period of time and attempt to find and control conditions in the room that produce fluctuations in our air pollution.

Along the same line of health research we have formed a health hazard committee, composed of representatives of the safety, chemical, medical and maintenance departments, whose duties are to discover, discuss and correct unhealthy working conditions. The safety man observes, the chemist determines, the physician interprets, and the maintenance engineer eliminates the hazard.

This method of approach has worked out well, the general discussion invariably contributing to a better understanding of problems and a more rapid solution. This is especially true in regard to our plating rooms, where we are dealing with highly technical processes, the intricacies of which are thoroughly understood only by the chemist.

There are no reputable industries whose management, even in the absence of state compensation laws, would ask their employees to engage in work that we as physicians find injurious to health; and there are no dusts, fumes, or vapor hazards in industry that cannot be controlled by a competent engineer, if he knows what results he is to obtain.

The use of masks, hoods and respirators in the plating rooms is an admission of defeat by the chemist and engineer. Workers invariably cheat at intervals, if forced to wear a cumbersome hot hood or respirator throughout the day, and during these periods they are subjected to the hazards the apparatus was designed to control. We should consider these only as emergency measures.

Until such a time as the industrial hygienist and toxicologist determines for us definite safe limits of various poisons in the air in which an unprotected man may work, we must follow an uncharted course with caution, ever being on the alert for signs and symptoms that may lead to the discovery of new health hazards and the establishment of safe standards. The scientific study of processes in our plant by the chemical, ventilating and safety engineers co-ordinating with the physician may assist materially in determining standards of safety in handling of toxic substances; for the toxicologist sets his standard on the basis of the symptoms or pathology produced by a known quantity of substance administered.

Any standard we set up as safe will not necessarily mean that no man will exhibit symptoms while working within it. As long as any toxic material is in the air, certain susceptible or sensitized persons will manifest symptoms, just as individuals in other walks of life are sensitized to pollens in the air, foodstuffs, drugs and local irritants to the skin.

We cannot hope to correct this condition, but we can control it by removing the susceptible person to work in other departments. By analyzing our air, establishing reasonable standards and keeping our polluting substances within these standards we can at least be assured that our workers are not being exposed to quantities of toxic substance that may produce serious damage to their health.

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