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Control of Environmental Industrial Hazards

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THE HEALTH hazards in industry which, if uncontrolled, may cause occupational illnesses and discomfort, are many and varied. The more common ones may be divided conveniently into seven groups as follows: (1) Atmospheric contaminants (dusts, fumes, mists, gases, vapors and smokes); (2) Heat, cold, high humidity and rapid temperature changes; (3) Radiant energy other than heat; (4) Faulty illumination; (5) Noise; (6) Unsanitary conditions; (7) Fatigue.

All of these factors are capable of control by sound engineering to such degree as to render them innocuous to the industrial worker. It follows then that engineering is the first line of defense in the control of ill health and discomfort of industrial workers.

Fortunately for the engineering profession, the human being is a miraculous organism and can stand considerable mistreatment without showing illness or even discomfort. For this reason, noise, radiant energy, atmospheric contaminants, fatigue, etc., need not be completely eliminated, they need merely to be controlled within certain limits. These limits have been fairly well defined for most of the factors included in the foregoing list, and serve as bench marks for the engineers.

Of the groups listed in the first paragraph, the atmospheric contaminant group is the most important one. Because of its importance and the keen interest taken by labor and management, the engineering control of industrial atmospheric sanitation will be discussed in detail. No further reference will be made to the other health hazards, not because they are unimportant, but because of time limitations.

Engineering Control of Atmospheric Contaminants

THE OBJECTIVE in controlling dusts, fumes, mists, smokes, gases and vapors is to prevent the amount in the air breathed by the workers from exceeding safe limits commonly called maximal allowable concentrations. They are not truly maximal allowable concentrations, but are the amounts which all but the unusually susceptible workers can endure day in and day out without producing significant effects on their well-being. These concentrations vary from material to material, some being relatively harmful and others being almost innocuous. Knowledge of the safe limits of the materials in question and how the amounts in the air can be measured is important to the engineer in addition to ways and means of reducing the concentrations.

Engineering measures for preventing the inhalation of excessively contaminated air have been discussed by many authors, and there are about as many different classifications of these methods as there are papers on the subject. The principles expounded, however, are always essentially the same. They may be divided conveniently into three main groups as follows, depending upon the avenue of approach:

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1. Eliminating the sources of contamination or reducing the amount: (a) Design, alteration, and maintenance of buildings and equipment; (b) Substitution of less toxic materials; (c) Process or operation changes; (d) Housekeeping.

2. Prevention of contaminant dispersion: (a) Segregation of hazardous processes; (b) Enclosing the hazardous processes; (c) Wet methods; (d) Local exhaust ventilation; (e) Equipment maintenance; (f) Worker education; (g) Housekeeping.

3. Protecting the worker: (a) Equipment alteration; (b) General ventilation; (c) Respirators; (d) Worker education.

The control of an atmospheric health hazard is rarely accomplished by a single measure; it usually involves the use of a combination of methods.

Eliminating the Source of Contamination

OBVIOUSLY, the most successful approach to the problem of industrial atmospheric sanitation lies in *the design or alteration of plant and equipment* so that the control features are engineered into the structure and machinery. Factories constructed without due consideration to keeping the air clean, and existing plants, preclude the most efficient use of engineering-control knowledge. Much control equipment, installed on "unprepared" machinery even if carefully planned, is makeshift at best and has all the features of the proverbial "sore thumb."

Probably the most important single avenue to better atmospheric sanitation lies in the education of manufacturers of industrial equipment and machinery so that at least the basic elements of control equipment are included as an integral part of each machine which is known to produce or disperse dusts, fumes, smokes, mists, gases, or vapors. Some action in this connection is in progress, but the surface is only being scratched. Some new plants are being laid out with the atmospheric-sanitation problem in mind. Also a few industries which are undertaking industrial hygiene on a long-term basis are slowly mechanizing and modernizing their existing plants to increase production, eliminate arduous labor, and reduce atmospheric pollution. Fully as important as the original design of any piece of equipment is its maintenance. Deterioration, wear, corrosion, abrasion, and shock result in inefficient operation unless maintenance is good. In the smaller industry, maintenance is too frequently left to the user of the equipment. This is not a satisfactory procedure. All maintenance work should be made the responsibility of one man or one department.

A very effective method of control is *the substitution of nontoxic for toxic materials.* The application of this method is very limited in scope because of the basic requirements on which materials are usually selected. It should, however, always receive due consideration since it is both effective and usually inexpensive. Yet, for this very reason, the engineer or chemist must guard against overdoing substitution. It is generally agreed that any material, be it ever so harmful, can be handled safely if properly engineered. This feeling has been verified in practice by the experience of the atomic-bomb plants and the military explosives manufacturing and loading plants.

As substitution of less-toxic materials frequently runs counter to quality control in production it must be recommended with caution, particularly since other methods are available for the adequate control of hazards. Examples of successful substitution of less-toxic materials are the replacement of steel grit for sand in abrasive blasting; artificial abrasive grinding and polishing wheels for sandstone wheels; nonsilica parting compounds for siliceous compounds in foundries; petroleum naphtha or toluol for benzol in the lacquer, ink, and rubber cement industries; Stoddard solvent for carbon tetrachloride, in dry cleaning (special equipment is usually required to comply with fire regulations); quartz-free or low-quartz minerals for sand under mine locomotives; and relatively insoluble lead compounds for lead oxide in paints and ceramic glazes.

A change in the process can sometimes be used to eliminate or control a health hazard. Such change frequently involves major changes in other parts of the production line, and this control measure is therefore very limited in scope. Examples are controlling the temperature and speed of chemical reactions so that the rate of mist, gas, or vapor production is decreased; welding, crimping, riveting, or otherwise

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More can be done by *good housekeeping* to eliminate sources of contamination, particularly dusts and fumes, than is commonly realized. In dusty industries or workrooms where dust is continuously settling on all surfaces which approach the horizontal, and collecting on vertical surfaces, good housekeeping in the form of vacuum cleaning, wet washing, and sometimes brushing prevents the material from being redispersed into the air.

The amount of dustiness which is contributed to the air of dusty industries by the continual redissemination of the settled material is sometimes more than 50% of the total dust concentration. Yet this dust can be prevented from getting into the air very readily by constant cleaning. Painting the walls a light color, improving the illumination, and oiling or wetting the floors are effective in promoting good housekeeping. While good housekeeping alone is seldom sufficient to control existing hazards, experience has shown that the housekeeping in most plants is a good index of the industrial hygiene program.

Prevention of Contaminant Dispersion

MANY INDUSTRIES have operations which produce considerable atmospheric contamination but which require the immediate attention of only a relatively small number of workers. If located indiscriminately throughout the plant or if conducted at certain times, such operations may expose many other workers to a needless amount of atmospheric contamination. By *segregating or isolating these operations*, only those few workers engaged there will be exposed to the hazard, and they may be protected by means of respirators. Also the segregation or bunching of hazardous operations aids materially in the effective application of local exhaust ventilation or other control measures.

The usefulness of this measure is so obvious that examples are scarcely needed. Blasting in mines at the end of the shift so that the gases and dusts will have settled or dissipated by the time the workers return, sweeping and cleaning at night when other workers are not on the job, shaking out foundry castings at night when most workers are off the job, and locating the plating or degreasing tanks in separate rooms are common examples.

Enclosing an operation might be considered an extreme form of isolation. The contaminant or contaminated air is prevented from reaching the breathing zone of any workers except in rare instances when one or two men may be exposed within the enclosure. It is superior to segregation or isolation since it acts nearer the source of contamination. In one instance the simple expedient of attaching a loose cover for the containers being filled to the end of a canvas discharge chute from a gyratory screen reduced the dust concentration in the screen room by well over 50%. In another instance a toxic and highly explosive material was transferred from 50 pound to five pound containers in a complete enclosure. The large cans were mounted on a frame in the top of a home-made enclosing device, and after closing the door the contents were dropped into a hopper by rotating the handle. Measured quantities were then dropped into small cans through a dust-tight corrugated hose. Two slide gates served to close and open the top and bottom of the measuring device. Hence by closing the lower gate and opening the upper one the material from the hopper filled the section between the slides which served as the measuring device. By closing the upper slide and opening the lower one the measured quantity of material was charged into the small container. This arrangement reduced the atmospheric concentration of the toxic material from a harmful level to almost nothing.

Process enclosure has been found particularly successful at abrasive-blasting operations, such as barrel and cabinet types of equipment which operate on the batch basis. The equipment is closed tight during the cleaning operation and is open only for charging and discharging after the abrasive blasting has been discontinued. This method of control does not find wide application except in conjunction with local exhaust ventilation which will be discussed later.

Wetting dust with water or other liquids is probably the oldest method of control. It was practiced in the pottery industry in Great Britain as early as 1713. Wet drilling and water sprays have been widely employed in mining operations in recent years. The use of water sprays in quarrying operations also has been reported recently. Substantial reductions in the dust concentration have been reported as wet-grinding operations, and as wet-drilling operations in mining, but even then the atmospheric concentrations were still greatly in excess of the maximal allowable concentration.

The effectiveness of wet methods for dust control depends upon two factors—wetting the dust, and proper disposal of the wetted dust. Some dusts are hard to wet and unless wetted will not be captured. Even if the dust is wetted satisfactorily, it is necessary to collect and dispose of the wetted material before the liquid evaporates and the dust is again redispersed by air currents, walking, or blasting. In certain mines, for example, the dust from the wet-drilling operations settles out as the water flows away, and collects also as water droplets on the walls from where it is readily redispersed. Even though wetting of the dust must be recommended with discretion, it has been found an effective dust control aid in rock drilling, blasting, crushing, screening, materials transfer, foundry shakeout, core knockout, and abrasive blasting, and the addition of moisture to molding sand decreases greatly any amount of dust produced while making molds.

Local exhaust ventilation is probably the most important single method of preventing industrial atmospheric pollution. Yet the principles involved and the bases for adequate design are so poorly understood that a large percentage of the installations made in recent years are unsatisfactory or inefficient. The design of good local exhaust systems is a specialty requiring knowledge not normally possessed by any engineering group including ventilating engineers, unless they have received special training in this field. This is neither the time nor the place, however, to discuss the details of this most important subject; they have been covered adequately elsewhere.[1,2,3] Suffice it to mention briefly the method of operation and to cite a few examples of operations at which local exhaust systems are used.

Local exhaust systems function by removing the contaminant or grossly contaminated air as close as practicable to the point where it is released or generated. This is done by producing air currents in the area of contaminant escape of such direction and magnitude as to carry the highly contaminated air into the exhaust hood which is located as close as possible to, or around, the source of contamination. The more nearly the hood encloses the source of contamination, or the closer it can be located to the source of contamination, the smaller will be the required exhaust rate to capture the contaminant effectively. Hood shape and location are of the utmost importance and deserve considerable study and head-scratching on the part of the designer. In addition to the hood, a local exhaust system includes piping or ductwork, an exhauster (usually a centrifugal fan), and usually a collector. The contaminated air is moved through the piping to the collector and the filtered air is then discharged to the outside of the exhauster. The design of the hood and piping, and the selection of collectors and exhausters are complete studies in themselves and will not be covered here.

Examples of the satisfactory use of local exhaust systems are numerous. Some are welding; granite surfacing; pickling and plating tanks; wood working equipment; grinders; buffers and polishers; and spray painting booths.

Like all other types of equipment, that are employed to control health hazards they require *constant checking and maintenance*. It should be included with other equipment in the cleaning and maintenance schedule. Dust collectors, fans and in many instances ductwork require periodic cleaning to obtain satisfactory operation. Bent hoods and leaky or damaged ductwork and enclosures should be repaired promptly. Blast gates and dampers, if used, should be locked in position, but even then they need constant watching to see that the setting is not altered by the workers and that the balance of the system is not thereby disturbed. Only too frequently management invests substantial capital in good control equipment and then, either through complacency or lack of understanding proceeds to forget all about it until faced with a case or epidemic of occupational illnesses. The answer, and the only way to protect their investment, is periodic checking and maintenance just as is done with production equipment.

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foolproof. Much depends on the attitude of the worker. A cooperative, interested, and well-trained worker can accomplish much with any control equipment, whereas the indifferent, lackadaisical, untrained worker produces the maximal amount of atmospheric contamination with any control device.

The solution lies in the *education of the worker.* This is an unending task and becomes very discouraging if labor turnover is high. Nevertheless it is the key to the really successful operation of atmospheric sanitation equipment. As a rule, the labor turnover will be much less if the working conditions are good. Therefore, proper education of the worker is the first step in a chain of events which lead to a satisfactory educational program. To be successful the education of the worker must begin the day he is employed. If he is permitted to begin his work without proper instruction in the performance of his tasks he will form faulty habits of operation which require much effort to undo. On the other hand the educational program must not cease as soon as the worker has been trained in the correct procedure of doing his job. It must be continued throughout his period of employment to keep him on his toes and to prevent him from falling into a faulty routine. Examples of what can be accomplished in atmospheric sanitation by worker education are unnecessary—they are quite obvious. Any operation (whether it be provided with control equipment or not) which produces or releases an atmospheric contaminant can be done, and should be done, in a manner which results in the escape of as little material as possible into the workroom air.

Good housekeeping will serve to prevent the dispersion of atmospheric contaminants. However, it is considerably more important in eliminating sources of contamination as was discussed previously in that connection.

Protecting the Worker

MOST INDUSTRIAL machinery or equipment which produces or releases harmful contaminants can be *engineered either in the original design or by alteration of existing installations* to decrease the worker's exposure. In many instances, however, the reduction of exposure is not sufficient to eliminate the hazard, and other control measures are needed. Yet there are some operations where the principle may be applied to render the worker's exposure harmless. Examples are the use of mirrors and/or extensions on operating handles to permit the worker to stand clear of the escaping contaminant; arranging all hot processes so that the operator stands beside rather than above the process; and locating a fan diagonally to the rear and to the side of the worker to blow the relatively clean workroom air through his breathing zone and to carry the highly concentrated contaminant from the operation he is doing away from him, or locating the terminal of a supply duct between the operator and the source of contamination to blow the contaminated air away.

General ventilation is second in importance only to local exhaust ventilation. It is particularly well adapted to certain contaminants and to certain sources of contamination but is unsatisfactory for others. Unlike local exhaust ventilation, it does not prevent the contaminant from escaping into the general workroom air, it merely dilutes the contaminated air of a given room or building with sufficient clean air to keep the concentration of contaminant in the room air from building up to a harmful level. Like local exhaust ventilation, general ventilation is misused a great deal by people who do not understand the fundamental principles of contaminant control. Major sources of contamination, especially if near to workers, cannot be controlled effectively by general ventilation; the dilution rate required to effect a safe concentration in the workers' breathing zones is so great as to be prohibitive. Minor and scattered sources of relatively harmless contaminants, on the other hand, may be controlled effectively and economically by general ventilation.

The subject of atmospheric sanitation through general ventilation is a very large and complex one. For further information on it, the reader is referred to treatises on the subject of which there are many.[1,4,5]

Respiratory protective devices have a distinct place in the field of occupational disease control. That they are a last line of defense can hardly be denied. Nevertheless, where they should be used, how they should be selected, and how they should be used and maintained is not understood adequately by some of the people whose responsibility it is to select them and supervise their use and care. Each and everyone assigned this responsibility should study some of the literature on this subject.[1,6,7,8] Examples of places where respirators may be used satisfactorily are spray painting; abrasive blasting; cutting metal coated with lead paints by means of oxyacetylene torches; welding; handling dusty materials; clean-out operations; shaking out operations in foundries; and housekeeping or other cleaning and sweeping.

The *education of the worker* for his protection is fully as important as to prevent the creation of unnecessary dust, fumes, mist, gases, or vapors. He must be told which contaminants are harmful and sold on the idea of avoiding the higher concentrations. Careful and continuous education is necessary to get workers in the habit of standing upwind of all operations which produce or release considerable material, such as spray painting, welding, cleanout and other maintenance operations, and handling bulk materials; also to keep his face as far from the point of operation as possible, or out of the line of throw or movement of the contaminant.

Examples of Results Obtained

IN CONCLUSION, I should like to cite one or two examples of the results achieved in decreasing occupational diseases through engineering. After all, "the proof of the pudding is in the eating."

In the gold mines of South Africa, dust concentrations averaged about 150 mg/m^3 before a program of control was begun and the reported incidence of miners phthisis was about 30%. About seven years after the dust control program was started the atmospheric dust level had been reduced to about 5 mg/m^3. The incidence of miners phthisis began falling about nine years after the dust control program was started and reached a level of about 2% approximately seven years after the dust level had been reduced to 5 mg/m^3. In this instance, the incidence of illness had been reduced from about 30% to 2% by reducing the atmospheric dust content from 150 mg/m^3 to 5 mg/m^3.[9]

An effective industrial hygiene program was launched in the government-owned explosives manufacturing and loading plants late in 1942—about one year after Pearl Harbor. The atmospheric concentrations of TNT were on the ascent at that time and continued to increase until about April, 1943 when they began to decline, the decline continuing until the close of the war. Periodic medical reports from these plants show that the incidence of lost-time cases because of TNT poisoning, of mild TNT poisoning cases, and of medical transfer from TNT exposure paralleled the atmospheric dust and fume levels very closely. The figures in this instance are somewhat as follows.

The peak concentration of TNT was about 2.7 mg/m^3 in April 1943 and the peak incidence of lost-time, mild, and medical transfer cases was about 21, 640, and 450, respectively, in terms of cases per thousand man years of exposed employees. The peaks of the cases occurred about July, 1943. By the end of 1944 the average atmospheric TNT concentration had been reduced to about 1.0 mg/m^3 and the corresponding incidence of TNT cases was 1, 80, and 85.[10] Engineering measures alone, of course, were not responsible for this entire reduction. The personal hygiene program, and the periodic medical examinations contributed substantially.

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Pollution and Controls in Industry

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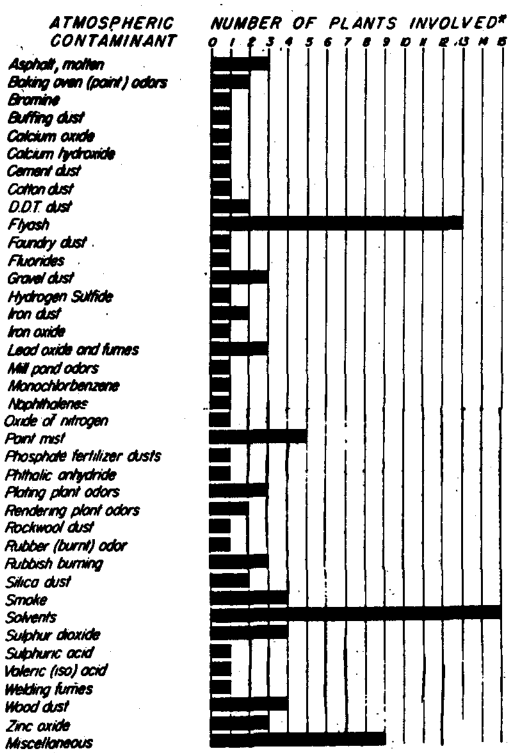
You have heard lectures and discussions mostly on the general principles and theories involved in the control of air contaminants. In my discussion, I am going to stress the other side—the practical application of these principles and theories. A government agency such as ours is in an extremely favorable position to make this type of presentation because we are directly involved with the pollution problem from the time the initial complaint is received to the time when a study is conducted to evaluate the collection equipment installed.

Whether the contaminant be fly ash, alpha-napthoquinone, or odors from a nearby rendering plant or millpond, we are eventually called in to investigate. These investigations can be initiated by the irate housewife who is disturbed by sulphide odors, or the plant manager who maintains that dust from a nearby abrasive reclaiming plant is ruining the bearings in his expensive machinery.

Actual legal authority on these problems rests squarely with local governmental units. In the Michigan Department of Health, we can act in an advisory capacity only. Many of the air pollution cases we are asked to investigate come from local governments who do not have the technicians and the equipment to work on the cases or because the local officials are reluctant to act, fearing that the company will suspend operation in their town. They would rather have the state take the brunt of this burden. In all cases, we make every effort to be of assistance to the local authorities, to the people of the community, and to the industry involved.

The year-to-year increase in the number of requests received for service on air pollution problems, from six in 1940 to nearly a hundred in 1949, indicates the prominence of air pollution in our everyday life. Many of the plants at fault are probably not of sufficient size to afford to spend a great deal of money on contaminant control. Despite the fact that we are not backed by a specific statute and are rarely able to show that the concentrations of the atmospheric contaminants are toxic rather than a serious nuisance, we have found that most industries will consider a practical approach in eliminating the air pollution problem arising from their plant. One of the most successful methods we have of working out a satisfactory solution is to get both the citizens and the management of the industry together. In this manner, management realizes the extent of the nuisance, and the people of the community realize the practical difficulties facing the management in eliminating it.

Investigations by the Michigan Department of Health have turned up a wide variety of contaminants (Fig. 1), and some are very difficult to control. In some in-



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When faced with the problem of collection, there are four things to be considered: first, the selection of the method or collector which is suitable for the job; second, the initial cost of the equipment and installation—and whether this cost is justifiable considering the extent of the nuisance; third, the maintenance on the equipment (a big item with many collectors), and whether it is within an acceptable range or requires frequent expensive replacements and high maintenance costs; and fourth, whether disposal of the collected material is difficult or costly. The following case histories demonstrate that these considerations are extremely important factors in every air pollution problem.

Case No. I

AIR pollution problems involving odors are often extremely difficult to cope with. One of the biggest problems is the elimination of odors. Our sense of smell is often an excellent method of chemical analysis; its delicacy is often greater than any chemical analysis we can run in the laboratory. There are many materials which we can smell long before the concentrations are high enough to enable us to run a chemical determination. Since odors may be due to these minute concentrations of gases and particulate matter, they are extremely hard and often almost impossible to eliminate from the air.

Inasmuch as rendering operations are practically a necessity in all good-sized communities, this case will serve to summarize some of the difficulties we have had with them in several of the cities of the state. The complaints concerned obnoxious stenches which permeated the residential areas near the rendering plant. Upon investigation it was observed that the operating techniques in most of the departments were unsatisfactory, and that a good deal of the odor could be eliminated by improved sanitation and work methods. Several recommendations concerning housekeeping and sanitation procedures were made, including the following:

1. That the sanitation and housekeeping be well planned to include all operations. and that one or two individuals be delegated the responsibility of carrying out the program.
2. That an ample supply of steam and hot water be provided for cleaning and rinsing purposes.
3. That the building receive a thorough initial cleaning, and that certain structural changes be made, such as re-surfacing floors with an impervious material.
4. That a central wash station be provided for all containers and a storage space provided for all clean containers.
5. That materials coming into the plant which were not to be used immediately be stored in properly enclosed containers.
6. That a driveway be constructed of impervious material which could be flushed off.

In addition, local exhaust ventilation for certain operations was recommended.

Shortly after our study of the operations, a group of citizens and the city filed a suit asking that an injunction be issued to restrain the company from polluting the atmosphere with offensive odors. In court, the company stated that in an effort to abate the stenches and smells emanating from the plant, they were acting upon our recommendations. In addition to our recommendations, they had installed two modern cookers; a modernized, used cooker; a new septic tank; a condenser water tank; an additional sewer, and an ozone generator. They had enclosed the elevator shaft with steel, entirely segregating it; purchased an additional boiler, and agreed to construct a new driveway. The driveway was to be of concrete or other comparable material, and was to be made non-absorbent. The court found that the nuisance did exist and had existed for a long time, and stated that the plaintiffs were entitled to the relief sought by them. The company was ordered to wholly abate the nuisance within 30 days; with additional time, if necessary, to complete the installation of the new boiler. The complaints of the residents, the legal action taken and the efforts made by the company to eliminate the odors have helped a great deal to minimize the amount of atmospheric pollution taking place.

Since the completion of the previously mentioned work, there have been no further complaints to the court. It is our opinion that the ozone generators mask the

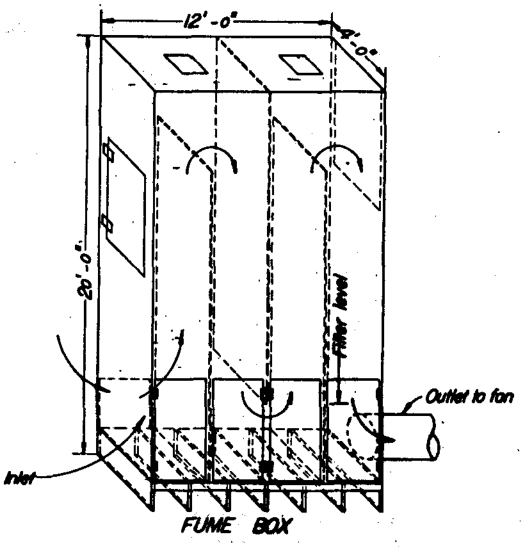

Fig. 2.

odors for the plant employees but do not affect the odors emanating from the plant. It is obvious that effective sanitation and housekeeping programs have to be maintained if the odors from rendering plants are to be minimized.

Case No. 2

Now let us consider a plant producing phthalic anhydride. I have selected this plant because it is a good illustration of practically all the four considerations in selecting a collector which I have outlined.

The plant is large and centrally located in a residential district. The neighborhood is contaminated by a strong pungent odor as well as small quantities of particulate matter. The problem of collecting the annoying stack effluents which are given off by 14 stacks is difficult, and is further hampered by the pyroligenous acids which are produced and can result in explosions and fires. Correspondence with manufacturers of phthalic anhydride and with industrial hygiene units in this country indicates that the same difficulties of collection exist everywhere.

In an attempt to solve these problems, a committee was formed of members of the chemical engineering department of a nearby university, outside engineering consultants, representatives of the company, and several of our engineers. The first attempt to control the contaminant was with the use of steam jets in the tall stacks with the thought that the addition of steam might result in satisfactory collection. It was found that the steam did not help and, in fact, increased the nuisance to the neighborhood. Following this, a standard commercial wet collector was tried and also found unsatisfactory.

While this was being done, the properties of the material were studied and it was found that the contaminant had a tendency to seed and adhere to the ductwork or any other material it contacted. An experimental, box-like duct (Fig. 2) was built. The thought was that a large portion of the material going through the tortuous passage would seed sufficiently and adhere

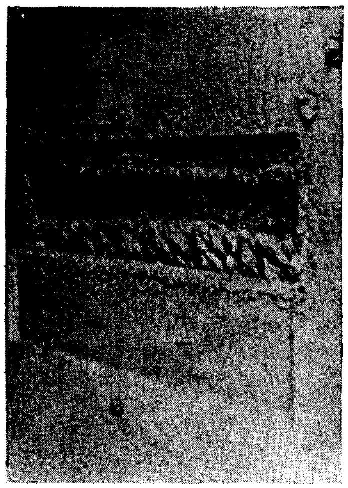
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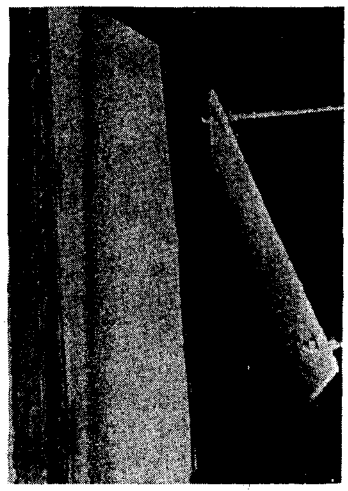
Fig. 4.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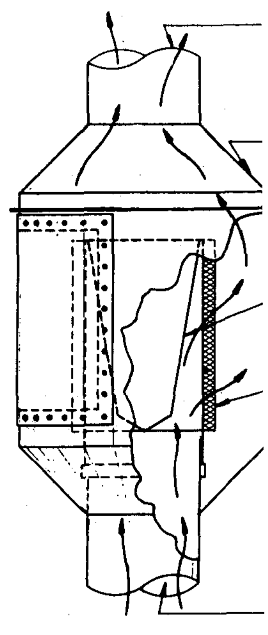
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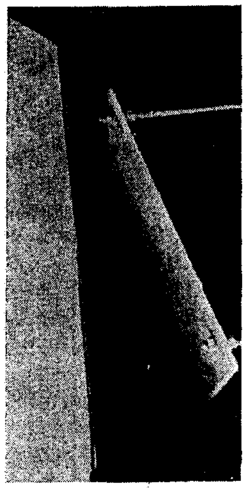

Fig. 5.

to the baffles, thereby minimizing the amount of objectionable material given off. Although large amounts of the material were collected, the odor did not seem to be lessened appreciably. Following this failure at collection, an attempt was made to condense the vapors on a water-cooled, stainless steel wall. However, it was found that the material would not adhere to the wet surface, nor was enough vapor condensed to solve the problem.

A good many things were tried with this box, such as using orifices to increase the velocity in order to impinge the material on a plate. As shown by Figs. 3, 4 and 5, this method removed much of the material but, as previously brought out, did not decrease the odor.

Following months of work on these collectors, a special high pressure fog unit was installed and appeared to work unusually well. However, much water was required and it was found that the water coming from the first section of the collector had a pH of slightly over two and the cost of neutralizing this to allow for disposal was prohibitive.

By this time, sufficient work had been carried on in experimental laboratories to lead us to believe that the strong odor was caused by a by-product, alpha-naphthoquinone, and that concentrations as low as 1 ppm would be objectionable.

Some time after this fog unit was dismantled, the company was approached by two men who had developed a catalyst for burning organic matter from stack effluents. They had had very good success with this catalyst in eliminating odors from wire baking ovens and, judging from previous installations, the system would be reasonably inexpensive to install. Fig. 6 shows the type of system that had been used on the gases from the baking oven. The company decided to try an experimental unit, and a system which might possibly work was designed. Experiments in the laboratory with the catalyst showed that a high temperature would be required. Subsequent work with the unit proved that 400°C was the minimum temperature at which the catalyst would operate. Previous trials had proved that the ducts would clog unless arrangements were made to keep them open, and so a counter-flow system was designed to keep the ducts warm with the thought that the heat from the catalyst would hold the material in the vapor state.

An experimental unit was installed, using a gas flame to increase the air temperature sufficiently for operation of the catalyst. It was found that a good deal of work was

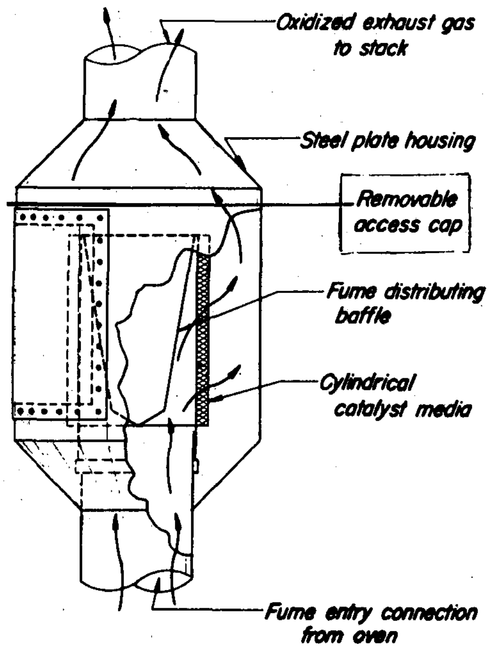

Fig. 6.

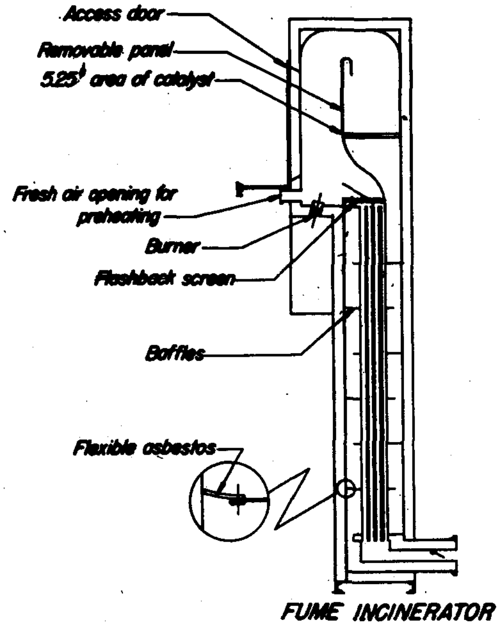

Fig. 7.

necessary to achieve an even temperature and even distribution of air through these catalysts. When this was accomplished and all of the leaks were finally stopped (this was very difficult because of the high experimental temperatures), the system operated quite satisfactorily.

At the present time, work is going forward on the design of a unit which can be installed to control the contaminant from each of the 14 stacks. Fig. 7 gives an idea of the size and complexity of the piece of apparatus to eliminate odors from this plant in comparison to the very simple catalytic arrangement used in another plant with a different material.

Regarding this air pollution problem, I should like to emphasize the desire on the part of the offending company to find a solution of the problem which will be economical and satisfactory to the residents of the community. Practically all reasonable approaches were tried. One method appeared to be satisfactory, but this produced a water pollution problem almost as great as the air pollution problem.

I should also like to bring out here that one of our greatest difficulties results from the fact that it is almost impossible to use a system developed for one operation on another operation in a different plant without many major and often expensive changes.

Case No. 3

A COMMON atmospheric contaminant is fly ash. Practically every city and village is confronted with this problem. I have selected one fly ash problem from our files because it brings out a point that may be of interest.

The plant is situated in a community of 9000 people and employs about 120 workers. When the plant was built for war purposes the citizens were elated because it gave a big industrial boost to the community. Now there are some citizens who wonder whether their elation was not somewhat premature.

Throughout the war, the plant worked on a round-the-clock basis with no complaints from the people of the community, but after it was taken over by a private company, the local city officials began receiving complaints. The principal complaint was due to fly ash. The people of the community were of the opinion that there had been a collector used when the plant was operated for the government and also that the powerhouse was operated more efficiently and gave off no fly ash.

In making our investigation, we found several reasons for the complaints. One was that the plant had been built along the water's edge to take advantage of dock facilities and, unfortunately, the major part of the city was on a bluff overlooking the plant. Most of the houses of the community are actually higher than the top of the stack of the plant. Like many war plants, this one was designed for a specific operation which utilized the flue gases for a carbonization process. The flue gases required scrubbing which, while consuming a great deal of power, was justified by the fact that the gases would be re-used. In peacetime operations, the carbonization process could not be used and the company could not economically justify the use of such a scrubber. Contrary to the belief of some citizens, the power plant is being operated more efficiently now than ever before. Fly ash collectors are in use, but, like all collectors, they are not 100% effective, and some escaping fly ash settles on the residences nearby.

At the present time, an addition to the stack is being planned and will undoubtedly be built when weather permits. It will be interesting to see whether the addition of this extra height will eliminate the complaints, or will simply deposit the fly ash on residences a little farther out. It appears to us that proper installation of electrostatic precipitation might be more justifiable than a gamble on high stacks for dilution purposes.

Case No. 4

THE collection of air contaminants in the manufacture of calcium carbide is almost as important a problem as the manufacture of carbide itself. In our investigations into the manufacture of carbide by one large concern, we found that this was a universal problem among the carbide manufacturers. While much work has been done and many engineering organizations have attempted to solve this problem, we believe that contaminant control will not be satisfactory with present collecting devices unless manufacturing procedures are improved.

Calcium carbide is manufactured in the electric furnace by fusing a mixture of lime and coke. The yield from this reaction varies a great deal depending upon the quality of the coal and lime used. The gases and much of the particulate residue from the reaction are removed from the electric furnace by exhaust fans. The particulate matter taken off from this reaction can run over 100 tons per day. Now if the efficiency of a collector installed to remove this particulate matter from the air runs as high as 96%—and this figure would be high for any collector—it would leave four tons of this material to be thrown into the open air and over the community. If you disperse this four tons of residue into the atmosphere, you can understand that it would do a fairly good job in covering the community in 24 hours. This is the actual problem in controlling air pollution created by a carbide plant. While this air pollution is not a health hazard but a nuisance, it reaches extremely annoying proportions. It is particularly damaging to the painted surfaces of houses and, in some instances, it ruins the finish on automobiles, furniture, etc.

In our work with this particular plant, we collected air samples throughout the plant and in the surrounding neighborhood. The results of the study are shown in Fig. 8. The management, in attempting to alleviate this air pollution, had installed Cottrell precipitators in the stack. The reasons for selecting electrostatic precipitation as a means of collection were: first, experience has shown that electrostatic precipitation, in most cases, works satisfactorily on particulate matter, and, second, the company owned a share of the water rights and produced its own power in that community.

On our investigation, we found that there were several limiting factors in attaining complete success in the collection of the material.

We discovered that the dust-laden flue gases were cooled and moistened by a bank of water sprays before entering the precipitator units. The efficiency of the precipitator varied considerably, owing to the fluctuation in temperature and humidity of the flue gases. Another factor controlling the success of these precipitators was the company's limited water rights. While what power they produced was cheap, production required the greater portion and the remainder was insufficient for constant successful precipitator operation.

DATA SHEET

A. Neighborhood Air Samples

Location	Dust Count Million Particles Per Cubic Foot of Air	Dust Wt. $Mg/10M^3$ of air	$Ca(OH)_2$ Wt. $Mg/10M^3$ of Air	% $Ca(OH)_2$ in Sample
Street No. 1	0.326	5.5	0.74	13.4
Street No. 2	0.415	7.4	1.11	15.0

Dust Analyses

B. Settled Dust in Plant		Dust from Exhaust Stack below Cottrell	
Water	0.8%	Water	1.3%
Loss on ignition (carbon)	24.1%	Loss on Ignition (carbon)	[illegible].3%
Total silica	1.7%	Total silica	1.9%
Ca as $Ca(OH)_2$	67.1%	Ca as $Ca(OH)_2$	69.6%
Fe as FeS	7.2%	Fe as FeS	7.3%

C. Dust Loading of Stack Effluent

Location	Total Weight Dry Dust Grains per Cubic Foot of Air
Cottrell Set No. 1	
Sample No. 1	0.093
2	0.102
3	0.055
4	0.107
5	0.029
6	0.161
7	0.122
Average	0.0956

Rated volume = 150,000 CFM

$$\frac{0.0956 \times 150{,}000 \times 60 \times 24}{7{,}000} = 2{,}950 \text{ pounds dust per day from Set No. 1}$$

Note: No data for Set No. 2 but results should be comparable to Cottrell Set No. 1

Fig. 8.
Carbide Chemical Manufacture

We recommended that the company install automatic current and voltage controls; that local exhaust ventilation at the furnaces be improved, and that other collectors be installed between each furnace and the precipitator. But every recommendation requiring an increase in the amount of power used, whether for wet collection or additional electrical precipitation, brought the reply that the power consumption could not be increased at the time and that all available power was necessary to produce an amount of carbide to justify the existence of the plant.

In addition to the various aspects of the problem just mentioned, the fact that the company is the largest single plant in the area, employing about 500 people makes its existence necessary if economic stability is to be maintained in the city. While it might be possible for the residents to take legal action against the company, in view of the important place the industry occupies in the community it is doubtful if such action is wise.

The situation I have just outlined is not unusual. Every collector installation has its limiting factors, and you can determine from the account I have given that these can be extremely perplexing.

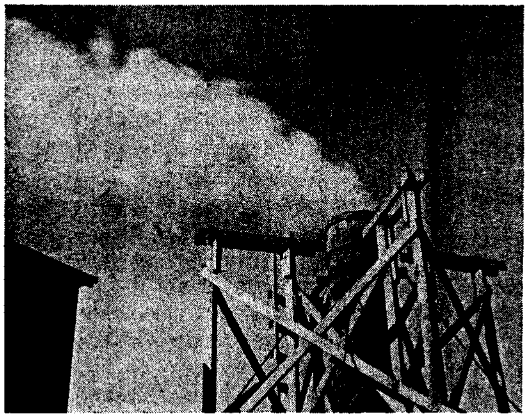

Fig. 9.

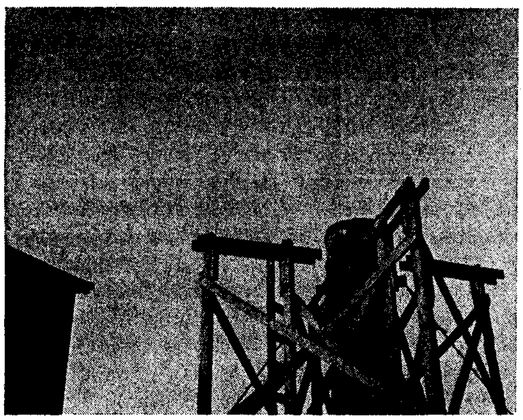

Fig. 10.

Case No. 5

FROM inquiries we have received from all over the country, the control of air contaminants from chemical fertilizer plants is of interest to many engineers and communities. For that reason, I have selected a chemical fertilizer plant in which I believe we have been quite successful. The usual air contaminant from the phosphate fertilizer plant is due to the dust and vapors given off during the mixing of sulfuric acid with calcium phosphate, resulting in excessive pollution of the atmosphere with phosphate, fluoride and sulphate dust and silicic acid.

The equipment used by the company for controlling the materials given off during the mixing consisted of a wooden paddle type blower which sucked the gases and solid materials from the mixing process up a tall wooden scrubbing tower. Several haphazardly-placed water sprays were used in an attempt to effect water scrubbing and collections of the materials given off.

As a result of our investigation, the company, in attempting to determine what equipment would be suitable for complete collection of the contaminants, had high-pressure fog spray equipment installed and requested that we conduct test runs for determining its effectiveness. The installation was very effective and the results of our tests are shown in Figs. 9 and 10. Visual observance of the stack during operation of the process with the high-pressure fog spray collection equipment both on and off indicated satisfactory collection as shown.

After a period of use during which the fog spray equipment was satisfactory, the company gradually cut down on the water pressure used and finally reached the point where it was considered wise to discontinue the use of a high-pressure pump and install in its place an ordinary pump capable of delivering pressure up to 120 pounds per square inch. No further complaints about the mixing process have been received. However, we recently received complaints concerning a dusty material which was contaminating the neighborhood, and upon investigation we found that a great deal of dust was being liberated by the natural draft ventilators during the mixing of a high nitrate composition fertilizer. It was suggested to the company that bag type collectors be used for collecting this dust. No follow-up investigation has been made, and no additional information is available.

It appeared from our work on this plant that the fog spray method of collection is very well adapted for fertilizer plants of this type, providing, of course, the effluent can be satisfactorily disposed of. Another fertilizer plant which has been constructed since, with fog filters installed, has proved satisfactory.

Case No. 6

THE next case is that of a manufacturer of asphaltic base sound-deadening coatings. The contaminant involved is once again odors. The plant is located in a city of approximately 2400, and employs about 85 people. Neighborhood residents complained of the foul-smelling stack effluent given off during the processing of flux oils. The process, known in the trade as "blowing asphalt," consists of blowing air

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through molten asphaltic flux oil which is maintained at a temperature of about 500°F.

During the process, certain volatile compounds are formed and the lighter portions of the flux oil itself may be distilled off, owing to the elevated temperature.

Requests for information concerning control of the "blowing" process were answered by two large oil companies who supply the company in question with their flux oils. One suggested the use of an electrostatic precipitator or "routing the vapors through a furnace where all hydrocarbon particles are burned, giving off a normal stack gas." The other suggested condensing the vapors into a liquid or washing them with water "by which means the greater part of the more volatile portions are knocked down in the form of a liquid." A third inquiry to the author of an article on petroleum base protective coatings brought the reply that he knew of no completely successful method of controlling the stack effluent but thought that it could be successfully collected if passed through "at least two stages of water spray."

The company did not believe that it could consider the costly electrostatic precipitator installation and, because of the highly inflammable nature of the process, ruled out furnace burning of the stack gases. At our suggestion it was decided to try a high-pressure water spray process, and a nearby manufacturer provided the company with a pilot model so that test runs could be made. Although it could easily be seen from the draining water effluent that much oily type material was being collected, the fog spray process did not completely eliminate the foul-smelling white smoky material which went through the collector and out of the stacks. Fig. 11 is a data sheet covering our fog spray test findings. Although additional test runs with a larger capacity water spray unit might have proved more effective, no further work has been carried out.

The problem of collecting the contaminant remains unsolved, but the company plans to continue the search for a suitable collection apparatus and has informed the city council that it will shut down the blowing operations whenever the prevailing winds result in contamination of the neighborhood.

DATA SHEET

A. Fog Spray Collection of Effluent from Flux Oil Blowing Process

1. Supplementary data

Run No. 1 30 nozzles on, full air flow

Run No. 2 12 nozzles on, cut-down air flow

Run No. 3 30 nozzles on, cut-down air flow

Run No.	Pump Pressure (Lb. per sq. inch)	Flux Oil Tank Temp. (°F)	Water Flow Rate Gal./Min.	Collector Inlet Temp. (°F)	Collector Outlet Temp. (°F)	Airflow Inlet (cfm)	Airflow Outlet (cfm)
1	440	520	21.4	450	230	700	622
2	450	520	10.0	458	90	245	212
3	450	520	21.4	—	—	245	212

2. Collection Efficiencies

Run No.	pH		Material Collected		Efficiency of Collection (%)
	Inlet	Outlet	Inlet (Grams per cu. ft.)	Outlet (Grams Per cu. ft.)	
1	slightly acid	—	0.49	—	—
1A	slightly acid	neutral	1.86	0.17	91
1B	slightly acid	neutral	1.18	0.17	86
2A	slightly acid	neutral	0.94	0.15	84
3A	slightly acid	slightly acid	0.44	0.20	55
3B	slightly acid	slightly acid	1.89	0.24	87

Fig. 11.
Asphaltic Base Coatings

Case No. 7

WE WERE requested by a city health department to investigate numerous complaints concerning hydrogen sulphide odors. Stack samples collected during the mixing of sulphur with hot purified lard oil indicated high concentrations of hydrogen sulphide.

The gases emanating from the mixing process were passed through beds of limestone and water in an attempt to collect the hydrogen sulphide. Our study indicated that the collection procedure was ineffective. Knowing of no process which would successfully eliminate the hydrogen sulphide, the company had installed a high-pressure fog spray collection unit so that test runs could be made. The results of our study on this unit are shown in Fig. 12. Ordinary water was used as the spray medium, and the collection of the hydrogen sulphide was unsuccessful.

In an effort to decrease the amount of hydrogen sulphide given off, the company decreased the reaction temperature and increased the reaction time. No follow-up study has been conducted since this modification of the manufacturing process, but we plan to evaluate the new procedure as soon as possible.

At the time of the test runs using the fog spray collector, it was suggested that an alkali solution in place of plain water also be

DATA SHEET

A. Fog spray installation for collecting mixing tank effluent gases

1. H_2S concentrations (Inlet and Outlet)

Sample No.	H_2S Concentrations (milligrams per cubic foot)		Collection Efficiency (%)
	Inlet	Outlet	
1	186	140	24.8
2	490	415	15.3
3	800	775	3.1

2. Air movement data

	Inlet	Outlet
Duct diameter (inches)	6	7
Duct area (square feet)	0.196	0.267
Air velocity (feet per minute)	2865	2110
Air volume (cubic feet per minute)	562	563

B. Note: Collecting medium: water

Fig. 12.
Oil and Grease Company

used for testing purposes, but such a run was not made.

Case No. 8

COMPLAINTS were received from citizens living near a chemical company engaged in the manufacture of pharmaceuticals. During part of the processing, atmospheric pollution with bromine took place and caused disturbance throughout the neighborhood. The complaint was investigated and it was learned that the pollution disturbance resulted during the warm weather months only.

In order to eliminate the annoyance, the company agreed to compound the materials involving the use of bromine during the winter months. No further complaints have been received.

Case No. 9

COMPLAINTS were received from the people residing near a small chemical plant engaged in the manufacture of iso-valeric acid. It was learned that the company was considering a new location but its capital was limited. Unable to relocate because of lack of funds, the company was forced to abandon the contract for the manufacture of iso-valeric acid.

Conclusion

WE BELIEVE these case histories may serve to bring out the importance of the four considerations previously mentioned; namely, the selection of a suitable method or collector, cost of the equipment and installation, maintenance of the equipment, and disposal of the collected material. They also show that there is no cut-and-dried method of controlling the contaminants involved in the term air pollution. At the present time it is our belief that, in many cases similar to the phthalic plant mentioned, even the plant operators do not know what their problem is. We hear a good deal about smoke and fly ash elimination, possibly because we know more about how to eliminate them than most of the other contaminants found. Obviously, the lack of knowledge is the biggest handicap in the control of odors.

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present.[1,2]