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The AIR POLLUTION PROBLEM—

AN APPRAISAL

W. L. FAITH

Managing Director

AIR POLLUTION FOUNDATION

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FOREWORD

The Air Pollution Foundation will have fulfilled its mission early in 1961 and will then disband. The Foundation was organized in 1953 to determine the nature of smog in Los Angeles and to suggest methods by which it could be eliminated. Inasmuch as motor vehicle exhaust has been pinpointed as the sole remaining source of smog in Los Angeles, and the State of California has embarked on its control, the end of the 20-year smog siege is now in sight.

In previous years, the Air Pollution Foundation has presented in its annual report each November a review of its activities during the preceding year. This year, because of the impending dissolution and the issuance of a final report early in 1961, we are presenting an appraisal of the world-wide air pollution problem in lieu of the Annual Report for 1960.

W. L. FAITH
Managing Director

NOVEMBER, 1960

I. DEFINING THE AIR POLLUTION PROBLEM

During the seven years of the Air Pollution Foundation's existence, the staff has been in the unique position of being able to view the air pollution problem from an objective, scientific standpoint. We have been able to do this because, as a nonprofit, independent scientific organization, we were able to avoid the natural bias of governmental or industrial organizations and even that of affected populations.

Although primary emphasis has been placed on the scientific aspects of the Southern California problem, we could not help but become aware of both the differences and similarities between the problem in this area and the multitude of air pollution problems all over the world. Neither could we close our eyes to the many nontechnical aspects of the problem, such as social, economic and political factors. In fact, it is the interaction of all these forces, in addition to the scientific aspects, that makes the problem so complex. Moreover, an acceptable solution can be evolved only after these forces are fully understood.

The purpose of this report is to present the problem in this context in the hope that it will aid those engaged in the preservation of our indispensable air resource. In the discussion that follows, we shall consider the nature and extent of the air pollution problem and the activities of governmental and nongovernmental organizations in the field.

Although many of the social, economic, and political factors discussed are universal problems, emphasis is placed on the situation in the United States. Illustrative examples of the many problems encountered are largely taken from incidents in Southern California.

This report does not present specific remedies for all air pollution problems because each locality has its own unique problem, at least insofar as the relative importance of specific factors is concerned. In the final chapter we present a basic guide to help others avoid the pitfalls that have plagued many communities.

There is one area of knowledge in which we are qualified to make specific recommendations—the area of scientific research. We are convinced that the prerequisite to recognition and sound solution of all air pollution problems is detailed factual knowledge of the physical, chemical, and biological activities of air-borne material. Accordingly, we present, as an appendix to the report, a list of 64 scientific research problems awaiting investigation.

II. THE NATURE OF AIR POLLUTION

A major problem of our times is the tendency of man to pollute the air with waste that is harmful to health and property. The resulting pollution of the atmosphere is particularly bothersome in urban communities, largely because there are so many people discharging wastes, directly or indirectly, into a limited volume of air.

Air pollution is not, however, a new phenomenon. Instances of intense air pollution have occurred occasionally since the beginning of history. Originally, these were natural phenomena, such as dust storms and volcanic eruptions, but man's troubles really began with the discovery of fire. Later, with the advent of the industrial revolution, the smoking factory chimney became a hallmark of civilization. But on those days when the smoke hangs heavily throughout the city, one wonders if civilization can afford the price.

On the other hand, even a congested community is singularly free of smoke on those days when the wind is moderate or the atmosphere has been cleansed by a storm. It is apparent, then, that only a combination of pollutant emissions and a restricted atmosphere creates an air pollution problem.

In *normal* atmospheres, even in crowded communities, smoke is rapidly dissipated upwardly, because the hot gases are lighter than the surrounding air. When the wind is blowing, they are also dispersed horizontally. At times, when an atmospheric temperature inversion* puts a virtual ceiling on upward dispersion of gases and there is little or no wind, the air volume becomes stagnant and soon fills with smoke and fumes.

For several hundred years, the city of London, England, apparently had a monopoly on intense episodes of air pollution, but little was done about it until after the famous disaster of December 1952, in which 4,000 deaths were attributed to smog. Similar episodes resulting in deaths had occurred previously in London (1948); in the Meuse Valley of Belgium (1930); and in Donora, Pennsylvania (1948). Thus, in a few instances, air pollution has killed people.

The problem facing health authorities, however, is not so much the danger of death from very high concentrations of air pollutants as it is whether or not

* An *atmospheric temperature inversion* is a meteorological term that describes a stable atmospheric condition in which little or no vertical movement of the air takes place. In many cases a restricted or stable atmosphere is accompanied by fog. The word "smog" was coined to describe a condition where both smoke and fog are present at the same time. It is now widely used to describe any polluted atmosphere.

continued exposure of large segments of the population to comparatively low concentrations of air pollutants endangers health. At the National Conference on Air Pollution, held in Washington, D.C., in November 1958 under the auspices of the U. S. Public Health Service, considerable discussion was devoted to the health effects of air pollution. Most of the discussion centered around the possible chronic effects of air pollution on bronchitis, asthma, emphysema, lung cancer, and other respiratory and cardiac diseases. Mention was also made of the effects of atomic radiation. It was agreed that the chronic effects of air pollution on health were largely circumstantial and that considerable research was needed to establish a connection between air pollution and chronic disease.

While health effects of air pollution are largely suspicions, nuisance effects and property damage are real. Consequently, these effects have alerted more people to the existence of air pollution than have vague fears of chronic disease.

The chief nuisances are odor; eye, nose, and throat irritations; limited visibility; dustfall; soiling and deterioration of clothing; and similar effects. Some of these are also economic effects, but the chief economic losses are corrosion of metals and other building materials, rubber-cracking, paint-darkening, vegetation damage, and animal losses. The annual cost of air pollution in the United States has been estimated at 4 billion to 7.5 billion dollars.

Pollutants and Their Control

Black smoke is probably our most noticeable air pollutant, but it is not the only important one. In addition to smoke, there are a variety of dusts, fumes, and gases which also pollute the air. Each individual pollutant has specific effects and also a minimum concentration at which the effects are noticed. The problem may be simplified by considering particles* and gases separately.

Particles or Particulate Matter. The chief economic effects of particles are visibility reduction and soiling of surfaces. Health effects are still a subject of controversy. It is generally agreed that very small particles breathed into the lungs are almost entirely exhaled. Comparatively large particles are trapped in the nose

* Particles in the air are usually further classified as *dusts, fumes,* and *mists. Dusts* are solid particles, of natural or industrial origin, usually formed by disintegration of solid masses, such as occurs in rock crushing and cement grinding. *Fumes* are also solid particles, but they are formed by the condensation of vapors, chiefly from chemical and metallurgical sources. *Mists* are liquid particles, which may evolve from vapor condensation, chemical reactions, or by atomization of a liquid. Hence, steam is a mist; so are many crop sprays. Fog is a naturally occurring mist.

and mouth, from whence they may eventually reach the stomach. Certain intermediate sizes may reach the lungs and be retained there. These particles or any gases adsorbed on them may provoke a health problem.

Smoke is a mixture of both particulate matter and gases, which result from the inefficient and incomplete burning of solid, liquid, and gaseous fuels. The solid particles may be either soot or fly ash. Soot, the black carbonaceous constituent of smoke, could be almost completely controlled by use of efficient combustion equipment kept in good condition and properly operated. The fly ash component of the smoke comes from the ash in the fuel, particularly from the burning of bituminous coals and residual oils. Abatement requires some sort of collection equipment, the cost of which varies with the collection efficiency desired.

The sources of atmospheric dust and other particulates are myriad. Some examples are flour milling, cement grinding, rock crushing, rubber tire abrasion, steel making, coal loading, soil tilling, weed pollination, road construction, ore handling, crop spraying, traffic, and ocean spray (salt particles).

A wide variety of abatement methods and collection equipment is available. Both efficiency and cost vary greatly. Experts have pointed out that in the vast majority of cases abatement of particulate matter does not depend upon the development of more engineering knowledge than we now possess. The problem is basically one of economics.

Gases. Gaseous wastes run the gamut of chemical compounds, but by far the most prevalent and annoying are sulfur oxides, hydrogen fluoride, nitrogen oxides, and various components of motor vehicle exhaust.

The chief source of atmospheric sulfur dioxide is the combustion of sulfur-bearing fuels, principally coal and oil; other important sources are smelters and chemical plants. Hydrogen fluoride is evolved largely in metallurgical operations, in fertilizer manufacture (superphosphate), and from ceramic kilns. Oxides of nitrogen are present in all combustion effluents. The chief pollutants in automobile exhaust are carbon monoxide, olefinic hydrocarbons, and nitric oxide. It is the photochemical atmospheric reaction of these last two materials that gives rise to the famous Los Angeles-type smog.

Control of gaseous effluents from chemical and other manufacturing operations is technically possible, although not necessarily cheap. On the other hand, adequate methods for abating sulfur dioxide and nitrogen oxides in power plant effluents,

fluorides from metallurgical and fertilizer plants, and controlling automobile exhaust emissions have not yet been developed.

Closely related to gaseous wastes is the odor problem, which is complicated by the extremely low concentrations of many gases that may be detected by smell. Odors from stacks may be abated reasonably successfully, but control of odors from a large area, e.g., stockyards, lagoons, and dumps, is more difficult.

A problem of very recent origin is that of pollution by radioactive particles and gases. This problem may become more acute as the number of atomic energy installations increases; fortunately, however, there is an awareness of the hazards involved in plants handling radioactive materials and extreme care is taken to prevent emissions of such material to the atmosphere. In the meantime, atmospheric radiation levels will continue to rise, particularly if military weapons testing is resumed.

Control Problems

The foregoing discussion suggests a pertinent question: If adequate controls are available to abate most air pollutants, why are they not used? There may be many reasons, such as nonrecognition of a problem, lack of evidence for cause-and-effect relationship, and the high cost of abatement.

Nonrecognition of an air pollution problem may stem either from ignorance or from fear. Ignorance is an especially common factor in the case of chronic disease or economic loss. Anyone can recognize the soiling of fabrics by soot, the dirt resulting from dustfall, the odor from a rendering plant, or the darkening of a painted surface, but the subtle effects of subliminal concentrations of air contaminants on health may go unrecognized for years. Similarly, the weakening of a structure by corrosion may go unnoticed until it becomes acute. Sometimes the effect is recognized, but the cause is attributed to some factor other than air pollution.

When circumstantial evidence finally points the finger of suspicion at air contamination, two opposing influences based on fear often arise. A highly emotional, sometimes highly vocal, segment of the community becomes afraid of all foreign components of the atmosphere and demands immediate governmental action directed toward all emissions to the atmosphere. More often than not, the cry is taken up by politicians in response to this "will of the people."

Equally important in nonrecognition of an air pollution problem is the industrialist who fears that mob hysteria or political opportunism may result in regulations so oppressive as to be almost confiscatory. His fears thus blind him to his responsibilities. His reaction is often violent and ill-advised, whereas the public usually wants only assurance that a reasonable effort to abate the nuisance will be made.

In those cases where controls are not available, an impasse often results. The public believes either that the alleged polluter knows the answers and withholds them because of the expense involved or that he should initiate a crash program to develop control equipment.* Just who is responsible for the development of suitable control devices is moot. Usually the polluting industry will accept this responsibility, either alone or in cooperation with equipment manufacturers.

When a problem is common to many segments of a given industry, an industry-wide development program may be carried out. Effective programs of this nature have been carried out by the steel industry through the American Iron and Steel Institute and by the petroleum industry through the American Petroleum Institute. This approach works well if the basic problem has been defined and if adequate methods of physical and chemical measurement and analysis are available. In many cases, the basic problem is not well defined. In others, entirely new concepts of measurement must be developed before the problem can even be attacked effectively.** Often a specific industry is not adequately staffed to develop suitable analytical methods or to devise basic control concepts. Unless the industry contracts

* The running battle between Los Angeles politicians and the automobile industry in Detroit over the adequacy of the industry's effort to develop exhaust control devices has been widely reported in the newspapers. In a speech before the National Conference on Air Pollution in 1958, the managing director of the Automobile Manufacturers Association said the industry was spending "about a million dollars a year" on cooperative research. Commenting on this statement, a speaker later in the conference sarcastically remarked it was "about half the cost of one of its (the auto industry's) 15-minute programs on TV."

** Some of the first work done relating automobile exhaust to Los Angeles' smog was by the Los Angeles County Air Pollution Control District. This led to the currently accepted hydrocarbon theory of smog. In cursory follow-up work by the APCD to evaluate the hydrocarbon emissions of internal-combustion engines, it was concluded that 60% of the hydrocarbons emitted to the atmosphere from exhaust was evolved during deceleration. On the basis of these sparse data, the automobile industry undertook a 3-year development program directed toward eliminating hydrocarbons during deceleration. Later, when it was found that the average hydrocarbon emission during deceleration was only 25%, the misdirected development program was abandoned.

One factor contributing to the misleading information was the analytical method used for determining hydrocarbons. Even today, there is controversy over exhaust sampling methods and also the most accurate means of analysis. The Exhaust Analysis Committee of the Coordinating Research Council worked several years evaluating analytical methods for automobile exhaust, but developed only tentative methods of doubtful applicability.

with outside laboratories for such work, it usually remains undone. Eventually, government laboratories attack the problem.

A similar situation exists with respect to research on the *effects* of air pollution. Few industrial organizations are interested in proving they are the cause of public discomfort or the source of a health hazard. By default, the necessary research is carried out in universities and research institutes, usually with government funds.* The scope of this work is usually limited by the interests of the applicant, so much of the necessary research work is carried out directly in government laboratories.

Another facet of the air pollution problem deals with the need for, and the nature of, air pollution control laws. The simplest form of control is the industrial code, under which various industries agree to live up to predetermined standards and then police themselves voluntarily. Suggestions have been made that interested parties evolve a private code, similar to the National Electrical Code sponsored by the National Board of Fire Underwriters. The Pittsburgh Smoke Ordinance is a regulation of this type, developed by private citizens. At any rate, a city or county could adopt such a code by reference. Compliance with the code would then be prima facie evidence that reasonable care was being exercised to prevent air pollution. This reasonable care would presumably be the requirement of the air pollution control statute or ordinance.

Advantages of this type of legislation and self-enforcement would be that (1) the superior engineering and scientific talent of industry would develop the code, (2) the developers of the code could hardly call it arbitrary and unreasonable, and (3) the cost of the necessary governmental control organization would be at a minimum. Without doubt, there are several appealing aspects to this approach to the control of air pollution, but the method has seldom been adopted.

At the government level, the basic means universally available for controlling air pollution are the nuisance laws. The tremendous amount of time required to establish that a nuisance exists has led many municipalities to pass air pollution ordinances. However, inasmuch as air transcends political boundaries, in many cases air pollution control must be passed on to larger governmental units, such as

* The need for extensive government funds for air pollution research was first recognized by Congress in 1955 when it passed Public Law No. 159, commonly known as the Kuchel Bill. The law authorized appropriation of funds up to $25,000,000 over a 5-year period to the U. S. Public Health Service for research and technical assistance in air pollution. In 1959, the law was extended for 4 years.

the county, a special district, or even the state government. Just which approach is most effective is debatable. If the control organization engages in research activities, perhaps the most effective unit is the state. If it involves only inspection and enforcement, the lowest government level is most responsive to the desires of the public. In the formation of special districts, municipalities and unincorporated areas can combine in the attack on air pollution.*

The tendency to make the boundaries of a special district contiguous with county lines partially defeats the purpose of the district. A district covering an area with a common meteorological condition would make more sense. A further confusing factor will arise wherever control of automobile exhaust is sought. Individual city and county ordinances will probably be ineffective in controlling these moving sources of air pollution.

Conclusions

From the previous discussion one may draw the following conclusions concerning the nature of the air pollution problem:

1. Man, individually and through group enterprises, pollutes the atmosphere with a wide variety of wastes in both gaseous and particulate form.

2. Under unfavorable meteorological conditions, these wastes concentrate in the air and cause local nuisances and possibly adverse health effects. In some extreme cases, human deaths have resulted.

3. In most cases, adequate means of control are available.

4. Ignorance and fear play a big role in hindering the installation of effective means of control.

5. Where adequate control methods are not available, research is necessary. Present tendencies are to shift the burden of research to the Federal Government.

6. Control of air pollution requires the establishment of codes, ordinances, regulations, or laws that can be policed. At present, control laws have been enacted on the municipal, county, special district, and state level. Many factors, some not yet evaluated, influence the selection of the most effective level of government for the control agency.

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* The Los Angeles County Air Pollution Control District embraces 71 incorporated cities and many unincorporated communities in Los Angeles County. The Bay Area Air Pollution Control District embraces 6 counties around San Francisco Bay.

III. THE EXTENT OF AIR POLLUTION

In the preceding chapter, emphasis was placed on the *nature* of the air pollution problem, with only casual mention of its extent in time and space. Often one thinks of air pollution as a sporadic event, much like a storm that comes and goes and is worse sometimes than others. It may be difficult to convince one who lives near stockyards or a tannery, or downwind from uncontrolled cement or gypsum factories, or in the vicinity of other offensive industrial installations, that his trouble is not continuous and ever present. Yet, even in these cases a change in wind direction or a thunderstorm creates relief.

Obviously, the nuisance effects of air pollution owe their frequency and severity to the weather. In the long run, however, the weather of an area does not change drastically, so the frequency and severity of air pollution episodes in a given locality will also depend on the types and amounts of pollutants spewed into the air.

A good example of the nuisance type of air pollution on a large scale is Los Angeles' smog. An especially distressing manifestation of this photochemical smog is eye irritation. Supposedly, eye irritation was not noticed until 1942; if it was felt earlier, it was only infrequently. Since 1942 it has increased, until now each year may be expected to bring 150 days of noticeable eye irritation. The weather has not changed. There are still 85 days a year when a combination of strong atmospheric temperature inversion and low wind velocity will produce a greatly restricted air volume and also a goodly number of days when a less restricted atmosphere, but still limited in volume, exists. The continued increase in days of eye irritation may then be laid to increasing automobile traffic, which provides the exhaust gases for the photochemical reaction.

In the same way, this type of smog is being reported more frequently in other areas than it had been, e.g., 20 days per year in San Francisco, 3 or 4 days in New York, and a day or two in Washington and Chicago. Atmospheric conditions in these areas are not so restricted as in Los Angeles, yet with increasing emissions of automobile exhaust, photochemical smog has begun to appear when weather conditions favor atmospheric stagnation.

Another hallmark of the Los Angeles type of smog is typical vegetation damage, in which bronzing and silvering appear on the underside of the leaves of certain plants. This typical smog damage was first noticed in Los Angeles County in 1943. It has gradually increased, and by 1959, according to Prof. John Middleton of the

University of California, it has been found in all but three counties in California. The eminent plant physiologist, Dr. Frits W. Went, has observed that this same type of damage is also increasing in major cities all over the world.

The daily press and professional journals continually report episodes of air pollution, and civic indignation meetings resulting therefrom, in cities all over the world. No longer is air pollution news datelined Los Angeles, London, Pittsburgh, or St. Louis. Recent news articles have carried the names Paris, Hamburg, Moscow, Milan, Tokyo, Christchurch (N. Z.), Oslo, Mexico City, Santiago, Lima, Toronto, Calcutta, and even Durban (So. Africa). Practically no large American city is exempt, although each may have a problem unique to its own location and economy. New York calls its problem "smaze" (smoke + haze); El Paso speaks of "smust" (smoke + dust). A friend of mine defines the problem in the large midwestern city where he resides as "smink." The point is, as cities grow, the ordinary daily activities of a larger population send more pollutants into restricted atmospheres. The weather remains much the same, but the emissions of air pollutants per square mile increase until control laws put on the brakes. Like the incidence of cancer and heart disease, some of the increase in the extent of air pollution may be attributed to better diagnosis, but much of it is certainly real.

Exaggerations and Misconceptions

Better diagnosis and increased publicity have naturally led to a great deal of exaggeration. Many long-time residents of Southern California, embittered because the smog haze often obscures the view of the surrounding mountains, recall when they "could see Catalina Island (35 miles from downtown Los Angeles) every day." This misconception is a function of faulty memory. A study of weather records by Prof. Morris Neiburger of UCLA revealed that, although visibility is worse now, visibility of 35 miles or more at noon occurred only 14 per cent of the time (an average of only one day a week) in the presmog years 1932-37.

Another type of misconception arises from a popular assumption that coincidence implies a cause-and-effect relationship. A crusading group apparently bent on harassing the oil industry in Southern California has widely preached the theory that smog is a result of the use of cracked gasoline. This group asserted that smog was nonexistent until "cat-crackers" were built in Los Angeles County.

Sometimes pretty good scientists are taken in by a combination of sketchy data and wishful thinking. A case in point is an air pollution regulation recently passed

in Los Angeles County restricting the olefin content of gasoline. The case was based on a vague relationship between the olefin content of gasoline and the olefin content of auto exhaust.*

Another fallacy widely accepted in Southern California is the belief that Los Angeles smog is caused by the emissions of a steel mill in San Bernardino County. The mill, which is several miles *east* of the Los Angeles County line, emits a noticeable dust plume, but the plume almost never flows into Los Angeles County because prevailing air movement is from the west. Actually, the Los Angeles County smog cloud flows into San Bernardino County, rather than vice versa.

The same steel mill has been the object of criticism on another count, not yet substantiated. It has been noticed that oranges and other citrus fruit in groves close to the plant are smaller than those in groves farther east. In fact, it has been stated that the size of the fruit gradually increases as one moves east from the mill. This is apparently a fact, but some horticulturists have also pointed out that the soil near the steel mill is only marginal for citrus fruit production and that it improves as one goes east.

The motivation behind these exaggerations is probably exasperation. When air pollution controls were first instigated in Southern California, people believed (or wishfully hoped) that after a few years the problem would be solved. Instead, it has become worse, even though control law after control law has been passed.** It is difficult for many people to believe that invisible exhaust gases from motor vehicles are the culprits causing smog. Their emotions are therefore vented against visible and odorous emissions. This does not mean that all emotional motivations are misdirected; in some cases, it is the only pressure that can move an obtuse plant manager or a dilly-dallying politician to action.

Another factor leading to misconceptions regarding air pollution problems appears to be a general deterioration of public confidence in technical data. This may result from public controversies among scientists on matters of opinion, such as the relationship between cigarette smoking and lung cancer, or it may stem from

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* It is well accepted by scientists in the field that most of the manifestations of Los Angeles smog result from a photochemical reaction between certain olefinic hydrocarbons and oxides of nitrogen. Control of smog by control of gasoline composition is an appealing means of solving the problem, but in the range of practical fuels the olefin content of gasoline bears little relation to the olefin content of the exhaust.

** Few will deny, however, that the problem would have been worse if some of the control laws had not been invoked.

the exposure of misleading advertisements in which scientists supposedly have endorsed proprietary items. Nevertheless, the lack of confidence is real.

In a speech prepared for delivery before the National Air Pollution Conference in 1958, a prominent United States senator said, "Though scientists may scoff, none of us should lightly regard a wave of suggestions that certain types of motor fuels be prohibited by ordinance or regulation." This allusion to scientific opinion was certainly not complimentary to scientists.

Criteria for Clean Air

I have dealt mainly with the nuisance effects of air pollution. A problem of far more concern to many persons is the possible chronic effect on health. The comparatively low concentrations of pollutants that are suspect may be present in the atmosphere over much wider areas and for longer periods of time than the higher concentrations that cause nuisances. Whether the problem is exaggerated or underestimated is an academic consideration, because few data are available.

Although there are some who believe that suspicion is sufficient reason for banning all pollution from the atmosphere, the majority opinion is that the nuisance level should be reduced first, allowing time for the research necessary to relate the type and quantity of pollutants to health effects.

Meanwhile, what criteria should be established for clean air?* This question has been asked many times, but seldom answered. The American Conference of Governmental Industrial Hygienists lists annually the maximum allowable concentrations (MAC) of toxic gases, vapors, and dusts that are considered safe for an 8-hour exposure of healthy persons in industrial environments. Few health authorities believe that these values are acceptable for continual exposure in the outdoor atmosphere, not only because of the time factor but also because the aged, infirm, and very young cannot be expected to withstand as high concentrations as healthy factory workers.

Cases where standards for the outdoor atmosphere have been set are few. Russian hygienists have suggested values for polluted outdoor air, but the values

* There is, of course, no such thing as perfectly clean air, except as a laboratory curiosity. But the term has been so widely used (e.g., the Air Pollution Control Association sponsors an annual "Cleaner Air Week") that it has come to mean air with no ill effects on man and his property. Dr. L. B. Hitchcock suggested the use of the term "tolerable air" to indicate that a satisfactory atmosphere need not be perfectly clean and cited as an analogy the difference between potable water and distilled water.

are so unrealistically low that they are almost worthless. For example, the suggested value for carbon monoxide is 2.0 mg/m³ (1.7 ppm); the value for sulfur dioxide is 0.25 mg/m³ (0.06 ppm). Seldom can we boast of such low values in American atmospheres, whether rural or urban.

Under the alert system established in Los Angeles County in 1955, three levels have been set for each of four gases. The third alert, or emergency level, for carbon monoxide is 300 ppm; nitrogen oxides, 10 ppm; sulfur dioxide, 10 ppm; and ozone, 1.5 ppm. A real anomaly exists between the ozone alert level and the MAC value for factory atmospheres (0.1 ppm). This difference in opinion reflects the state of our knowledge of such things.

In Cincinnati, the Academy of Medicine has proposed outdoor MAC's of 0.1 ppm for ozone and 0.2 ppm for sulfur dioxide.

One of the first sets of official standards for pollutants in the ambient atmosphere is that recently adopted in California. Values have been set for atmospheric "oxidant," carbon monoxide, and sulfur dioxide. Standards for other gases were considered, but were postponed because of the lack of suitable data on the probable long-term effects of the specific pollutants.

Will Air Pollution Increase?

No discussion of the extent of air pollution is complete without consideration of the trend. Can air pollution be expected to increase? Or will it decrease? Industrial air pollution is probably already past its peak. Even in those communities where control laws are nonexistent or not enforced, good industrial public relations dictates the installation of abatement equipment. Considerable research is going on to develop methods for controlling particularly obstinate emissions, and eventually they, too, will come under control. Whether the degree of control that may be expected will be adequate depends on the outcome of health-oriented research.

A different picture unfolds with regard to domestic pollution, or that made by individuals. Single-chamber incinerators, open fires, heating plants, automobiles, and trucks send a variety of wastes into the air. In most cases these emissions are uncontrolled, and the tendency of people to congregate in urban communities puts a load of pollution into the atmosphere that will probably continue to increase until economic and politically palatable means of control are developed.

The effect of a changing technology on the extent of air pollution is more difficult to assess. One can visualize changes in power sources that may have con-

siderable impact on air pollution. Adoption of nuclear power will dramatically decrease pollution from power plants. Any trend to gaseous fuels, either natural gas or gasified coal, will markedly reduce smoke, fly ash, and sulfur dioxide emissions. A much greater impact will be made by changes in the automotive power plant. Gas turbines, free-piston engines, fuel cells, and semidiesel engines all present problems, but fundamentally each has less air pollution potential than the present spark-ignited internal-combustion engine.

Cost of Source Control

Another important aspect of the air pollution problem is the cost of air pollution control. This will vary from the few cents required to repack a valve leaking a volatile solvent to multimillion dollar electrostatic precipitators on open-hearth furnaces. It may be the added cost of a smokeless fuel over one with a great tendency to smoke. It will include the additional taxes required to staff and support an air pollution control agency. In Los Angeles County, for instance, the annual budget of the Air Pollution Control District exceeds three million dollars.

The high cost of controlling domestic air pollution will soon be brought home to the people of California. The Legislature in its most recent session set machinery in motion which will eventually require every gasoline-powered motor vehicle in California to meet predetermined standards for the quantity and type of exhaust gas emissions. It is expected that some sort of exhaust afterburner will be required on every motor vehicle in order to meet public health requirements. If the device adds $100 to the price of a motor vehicle, it will cost $700,000,000 to equip cars currently in use. An additional annual sum of $70,000,000 will be required for new motor vehicles, plus something for maintenance and replacement. Yet Californians believe the abolition of air pollutants from motor vehicle exhaust is worth the cost.

Sympathy should be withheld for those communities which may decide they should require installation of afterburners because "all pollutants are bad." Certainly many communities outside California that have occasional or minor motor vehicle exhaust problems can cure the condition by much less expensive means, e.g., blowby control.

In some instances, control of air pollution may return a profit. As combustion engineers continually point out, smoke indicates a loss of heat, a waste of energy. Accordingly, better combustion not only reduces air pollution but also returns a profit in more efficient utilization of fuel. There is a common misconception, how-

ever, that all industrial controls can result in profit. In most cases, pollution prevention is an additional expense.

Other Air Pollution Abatement Methods

One should realize that control at the source through the use of abatement equipment is only one means of air pollution control. Industrial zoning and meteorological control are two other methods that have received attention. Meteorological control has two facets: (1) intelligent use of the atmosphere for pollution dispersion and (2) treatment of the atmosphere to prevent accumulation of dangerous or annoying amounts of pollutants.

Man has used the atmosphere for centuries as a means of carrying away waste, most of the time successfully. An air pollution problem arises only when the atmosphere is overloaded. In many locations, the atmosphere is perfectly capable of dispersing a pollutant if it is emitted from a sufficiently high stack. Many control officers take a dim view of this means of abatement, because some weather conditions can be visualized in which no stack is tall enough to prevent serious pollution from developing at the ground level.

To remedy this situation, some authorities have suggested that when stable atmospheric conditions are predicted the industrial plant curtail its emissions. In this way the great diluting power of the atmosphere could be utilized most of the time, and the emission could well be restricted when a pollution problem might develop. This method of meteorological control was actually adopted by the Consolidated Mining and Smelting Co. at Trail, B.C., at the suggestion of the international tribunal that investigated the air pollution problem there.

A similar method was recently proposed in Los Angeles County by the Western Oil and Gas Association. Rule 62 of the Los Angeles County Air Pollution Control District prohibits the burning of fuels containing more than a specified amount of sulfur during the seven-month smog season. WOGA suggested that the rule be amended to forbid the burning of such fuels only when a smog siege is predicted for the next day by the APCD. This would allow normal competitive influences to guide the choice of fuel on those days when the atmosphere is capable of dispersing stack gases containing sulfur dioxide.

A related meteorological control method is treatment of the atmosphere, either physically or chemically, to allay the effects of pollution. A variety of recommen-

dations have been made in Los Angeles County to create conditions in the atmosphere that will cause a stable atmosphere to become unstable. This involves either breaking the atmospheric inversion or increasing wind speed, or both. Prof. Neiburger has studied various suggested plans in detail and concluded that the power requirements for most of the proposals are exorbitant.

The Need for Research

Air pollution abatement is no different from any other socio-technological problem—the more information available, the easier it is to solve the problem. The greatest area of ignorance barring the way to a wise solution of the problem is the possible chronic effect of subliminal concentrations of pollutants on people, not only on their general health but also on their comfort and convenience. Mortality and morbidity studies are currently being made by public health authorities, but present results are more confusing than enlightening. Only when these surveys are buttressed with adequate toxicological data can they be properly interpreted. The extent of toxicological research in the realm of practical concentrations of atmospheric pollutants is pitiably small, possibly because of the length of time required to obtain useful results. When one superimposes on this the probable synergistic effects of multiple pollutants, the complexity of the required studies increases.

Even more confusing are the effects of products of atmospheric reactions in which neither the mechanism of reaction nor the identity of the product is known. Yet these are the research studies that will eventually yield the keys to the solution of urban air pollution.

Compared to effects on people, the effects of various air pollutants on vegetation are relatively straightforward. Direct damage is easily assessed, but the determination of the effect of small quantities of pollutants on the *growth* of vegetation, e.g., the size of fruit, requires unending patience and painstaking experimental control, and, at the end, perhaps will yield inconclusive results. Thus, in the areas of studying the effects of air pollution on man, animals, and vegetation, long-term commitments are necessary.

In contrast, studies of economic and social effects, developments of better control methods and better instrumentation, assessment of pollution loads, and meteorological studies appear simple. Apparently they are not so simple as they seem, because several itemized lists of problems in these areas that badly need solutions were presented at the National Conference on Air Pollution in 1958. An expanded list is presented in the Appendix.

Finally, who is going to do this work? Who can secure the needed information? This brings us to a discussion of what is currently being done about air pollution abatement, who is doing it, and barriers to more rapid progress.

IV. GOVERNMENTAL ACTIVITIES

Municipalities

The first point of contact between government and the air pollution problem is at the local or municipal level. Someone complains to the local health department about a nuisance that must be abated, often also accusing a specific source. There is then an investigation and, possibly, legal action. If complaints continue or multiply, some type of air pollution control legislation follows. The local government organization usually consists of a control officer and a few inspectors and is engaged primarily in persuasive activities and enforcement. Research is not done at this level. In a few large municipalities, e.g., New York City, there are many inspectors, a laboratory is available, and perhaps a little research is carried out.

Because municipal boundaries cannot define air movement, there is a trend towards formation of special air pollution control districts that cover a wider area. The best-known organizations of this type are in California. The largest, the Los Angeles County and the Bay Area (San Francisco) control districts, maintain laboratories and have a considerable number of technical employees. The Los Angeles County APCD carries out a broad program of research, public information, air monitoring, plant inspection, and enforcement. Its annual budget exceeds 3 million dollars.

State and Interstate Problems

Eleven states have set up their air pollution control organizations at the state level on the premise that over-all costs would be lower than those of a multiplicity of local or district organizations. Some of these also have small research staffs. In California, where the district has been accepted as the proper local agency, the State has also come into the picture. The 1959 Legislature directed the State Department of Public Health to set standards for allowable concentrations of pollutants in ambient air and in motor vehicle exhaust. The 1960 Legislature set up a Motor Vehicle Pollution Control Board, also in the State Department of Public Health, to test and certify acceptable control devices for motor vehicle exhaust emissions. Upon certification, the devices will be required on nearly all motor vehicles registered in California. The Legislature was motivated by the fact that, although local districts could cope with stationary sources of pollutants, the mobility of the motor vehicle was such that only state-wide control could be effective.

In a few cases, congested areas with a common air pollution problem include sections of more than one state. Loose interstate federations have been formed (e.g., Interstate Sanitation Commission—New York, New Jersey, and Connecticut), but their activities have been limited to assessment of the problem, mainly by air pollution surveys.

There is little doubt that local, state, and interstate governmental organizations have done a yeoman job of combating industrial air pollution. In most cases, staff members have been grossly underpaid and subjected to unwarranted criticism from both industry and the public. A great deal of their effort has been spent in informing the public of their goals and in persuading industry to cooperate. Considerable success has been attained in persuading industry to carry out the research necessary to solve difficult emission problems; in fact, most of the progress in air pollution control to date has been accomplished through this mechanism. Even in Los Angeles, where recent regulations have been quite arbitrary, industrial research has provided the data that resulted in compliance.

The chief problem of small local air pollution control organizations is maintenance of a well-balanced control program. Basically, the chaotic condition at the local level stems from lack of technical information. Air-monitoring and source-testing equipment is expensive. Municipal salaries do not attract the most capable technical personnel. Definitive data on the chronic effects of pollutants are almost nonexistent. Accordingly, there is a tendency to seek federal help to assess the local problem and to recommend necessary controls. An alternate solution might be consolidation of adjacent control districts, but pride in local prerogatives presents a barrier.

Federal Activities

The Federal Government entered the air pollution scene on a large scale with the passage of Public Law 159 in 1955. This law directed the U. S. Public Health Service to conduct and support research on air pollution and to provide technical services to state and local governments and to private agencies. Among its activities have been initiation of research in various governmental facilities, particularly the Taft Sanitary Engineering Center; research grants to universities and research institutes for specific medical, scientific, and engineering studies; temporary assignment of personnel to various state and local agencies and to universities; establishment of training courses for technicians; consultation in several urban air pollution

surveys; establishment of a comprehensive epidemiological survey in Nashville, Tenn., for demonstration purposes; establishment of a National Air Sampling Network for measuring air-borne particulate matter in more than 225 localities; and sponsorship of the National Conference on Air Pollution in Washington, D.C., November 1958. Currently, the Secretary of Health, Education, and Welfare is also seeking permission to hold hearings and to make recommendations concerning local air pollution problems.

One of the problems faced by the U. S. Public Health Service is allocation of research funds to the satisfaction of various communities. Public officials in California press for an all-out attack on automobile exhaust; others want priority placed on emission standards and control of effluents from specific industries; still others want laboratories established in specific localities to study urgent local problems.

This tendency to push all air pollution activities to the federal level is well exemplified by proposals of the National Association of County Officials Air Pollution Committee. At a meeting in San Diego in February 1960, the following proposals, among others, were made: an air pollution division of the U. S. Public Health Service be set up; federal enabling acts for air pollution regulations be enacted; air quality standards be adopted for the entire country; the Federal Government conduct added research into the causes of smog; and that the Federal Government make studies into methods of controlling major sources of air pollution.

Summary of Governmental Activities

In summing up governmental activities in the air pollution field, we can conclude:

1. Local government would like to solve the problem, but does not want to spend much money.

2. There is a dire need for more information as to the magnitude and severity of local air pollution problems.

3. The Federal Government, through the U. S. Public Health Service, is expanding its activities in all areas of air pollution research and in atmospheric monitoring. Demand for greater federal activity is increasing. This is disconcerting to those who believe that federal aid inevitably begets federal control.

V. NONGOVERNMENTAL ACTIVITIES

Activities of individuals and nongovernmental agencies in the abatement of air pollution are many and extremely diverse. They range from political and social pressure to remove all contaminants from the air to defensive research by those who seek to maintain the status quo. Between these extremes, a wide variety of civic-minded citizens, professional associations, and industrial interests are seeking effective solutions to the air pollution problem.

Voluntary Organizations

Civic-improvement committees and clean-air groups represent all segments of the community, all disturbed by the hazards, distress, economic losses, and discomfort attributed to air pollution. Most individuals are truly concerned; some are crusaders, some are misguided fanatics, and a few are outright charlatans. Most of them cooperate with civil authority, and nearly all groups are seeking scientific and medical guidance.

The fact that many groups have been misled is testimony to the need for better information. Even medical groups have been so confused by conflicting opinions that emotional considerations have sometimes governed their recommendations. Many of these citizens' groups have been effective in stirring civil officials and industrial organizations to action and have sustained activity in air pollution abatement. Occasionally, however, overly ambitious groups press their crusades to the point of impairing the economy upon which they depend for a living. Often, ensuing legal action only confuses the issues.

Industrial Corporations

Probably more information of real value in assessing and alleviating the air pollution problem has come from industrial laboratories than from any other source. This is understandable, because our major air pollution problems are of industrial origin. In the laissez-faire industrial economy of 50 years ago, air pollution was considered an inevitable by-product of economic progress. A smoking stack meant jobs, or so it was alleged. Then, when the public became aroused there followed the usual series of actions, which Pendray calls "the air pollution syndrome"—denial, name-calling, and clamming-up—before a real attempt was made to solve the problem.

In the past 15 years the attitude has changed, and notable progress has been made in industrial research to find economic means of abating air pollution. Much has been done by individual companies; a great deal more by trade associations.

Outstanding jobs have been done by the American Petroleum Institute, both in granting research funds to universities and other research laboratories and in cooperating with the Society of Automotive Engineers through their joint organization, the Coordinating Research Council; by the American Iron and Steel Institute through research grants and by coordinating research activities of individual steel companies; by the Manufacturing Chemists' Association through publications, workshops, and conferences; and by the Automobile Manufacturers Association in coordinating the industry's research program. These are but a few that could be mentioned.

Similar activities have taken place at the local and regional level. In Southern California, the Joint Research Council on Power Plant Air Pollution Control spent $1,500,000 in less than two years to study means of abating smoke plumes from oil-fired power plants. The Western Oil and Gas Association has spent more than $3,000,000 in 10 years in sponsored air pollution research.

One result of the industrial cleanup in many areas has been to draw attention to the increasing importance of domestic air pollution from apartment incinerators, motor vehicles, and coal-burning home furnaces. In fact, in some jurisdictions, control of industrial effluents has not markedly affected the over-all quality of the air, because pollutants arose largely from domestic sources.

Unfortunately, industrial research has often not been particularly useful to small industrial plants. Because of the nature of their processes and the relatively high cost of abatement, extremely difficult economic problems arise. These must be solved if small units are to survive. Even research supported by trade associations is often directed to the problems of the large producer and of little value to the small manufacturer.

Two regulations passed recently in Los Angeles County may serve to illustrate the problems faced by small industrial units. One regulation essentially prohibits the burning of residual fuel oil that contains more than 0.5% sulfur. One effect of this rule is to restrict, perhaps to eliminate, the use of low-gravity Southern California crude oil, which can be economically refined only to residual fuel oil. Many of the wells producing this crude are owned by individuals who are at the mercy of the market. A large producer can find other outlets for his crude; if the small operator cannot serve the local market he is doomed.

The other example, also from the petroleum industry, is a regulation that restricts the olefin content of gasoline. Petroleum refining is a complex operation in large refineries and involves multiple units of equipment and a variety of processes. These can be so rearranged and scheduled that even *olefin-free* gasoline can be produced for a few cents per gallon extra cost. A small refiner, on the other

hand, may have to double his capital investment to eliminate even part of the olefins. This would be a real economic burden. Similar cases come to mind in all segments of industry. The economic and social problems involved have not yet received adequate attention.

One proposed method for alleviation of some of the problems that face small manufacturers is a tax credit for costs involved in air pollution abatement. Even this may not be adequate for the cases cited. The solution to these two cases is better technical information as to the need for the basic rules. Both regulations were passed under considerable emotional pressure, which filled the void left by sparse and conflicting technical testimony. The cases may eventually reach the courts.

This brings up one of the difficult areas of air pollution legislation, that of acceptance of scientific testimony. Most regulations are passed by boards at the local level. When adequate data are not available and conflicting scientific opinions must be evaluated, lay control boards become confused. The tendency to assume that scientific personnel employed by industry cannot be objective only compounds the confusion. Part of this feeling undoubtedly arises from antibusiness political alignments. A great need obviously exists for an objective scientific organization whose opinion would be accepted by all parties.

Professional Societies

The growing interest of professional societies in air pollution matters is evident from the number of organizations that have committees devoting time to the subject. Most active are the American Chemical Society, American Meteorological Society, American Institute of Chemical Engineers, American Society for Testing Materials, American Society of Mechanical Engineers, American Industrial Hygiene Association, and the American Public Health Association. The committees of these professional societies serve the needs primarily of their own membership and seldom take part in public discussions of air pollution problems. Their activities are usually restricted to the arrangement of symposia on specific aspects of air pollution and the publication of technical papers.

The ASME, through its Committee on Air Pollution Controls, has also developed a model law for control of smoke and fly ash and is currently revising its recommendations. This committee is also studying the need for a model ordinance for the control of certain gaseous pollutants. Another activity is the semimonthly publication of "Smog News," which carries reproductions of clippings from daily newspapers throughout the United States.

One professional organization, the Air Pollution Control Association, devotes its entire effort to the cause of clean air. It sponsors a national campaign annually,

called "Cleaner Air Week"; publishes a bimonthly journal and a monthly bulletin of abstracts; sponsors an annual meeting; and, through a complex committee structure, it brings industrial representatives and control officers together for professional discussions. With adequate support from industry and government, APCA could well provide the common ground on which the philosophical differences between industry and government could be resolved.

Universities and Colleges

The role of universities and colleges in air pollution is primarily a research function, supported largely through grants from the U.S. Public Health Service and various industrial organizations.

The work is fundamental and is seldom aimed toward the solution of a specific problem, yet the published results of these scientific studies are usually of more lasting value than those from problem-oriented industrial investigations. Occasionally, with industrial support, universities have entered into a broad study of acute local air pollution problems, but their officials usually dislike this type of crash program because of the possibility of political repercussions.

There is also a trend toward including some formal instruction in air pollution subjects in sanitary engineering curricula. Several schools have assignments in air pollution research in their graduate program; others offer short courses of a specialized nature. Support for training scientists in air pollution research has been obtained in some cases from the U. S. Public Health Service. Several technical societies have also banded together in the American Sanitary Engineering Intersociety Board to improve training and practices in sanitary engineering, including air pollution control.

One problem encountered in seeking research grants from the U. S. Public Health Service has been the insistence of the Public Health Service on very low overhead allotments. As a consequence, some schools have not sought these funds.

Research Institutes

For assistance in the solution to pressing air pollution problems, many industries have contracted for investigations by research institutes. In many cases this has been a more satisfactory arrangement than grants to educational institutions. Full-time attention can usually be given to the problem, a greater variety of skills is available, and specific studies can be performed under contract.

Research institutes conducting air pollution studies include Stanford Research

Institute, Armour Research Foundation, Franklin Institute, Battelle Memorial Institute, Southern Research Institute, and Southwest Research Institute. Each has its specialty and has engaged in continuing research over a period of years. Many others have had occasional contracts for air pollution studies in areas related to their specialized skills. These institutes have carried out very little research with Public Health Service funds, chiefly because of overhead provisions previously mentioned.

The Air Pollution Foundation

A unique approach to air pollution research was originated in Los Angeles in 1953 with the formation of the Southern California Air Pollution Foundation. The words "Southern California" in the title were deleted in 1955. The smog problem in Los Angeles in 1953 had become so confused and so rife with emotion and politics that a group of civic-minded business and educational leaders undertook to solve the dilemma. It was generally agreed that the cause of Los Angeles smog was not known and that only independent, objective research could find the answers. Local universities shied away from the problem, because of the highly emotional atmosphere surrounding it. Consequently, the Air Pollution Foundation was formed.

This organization had as its only objective the solution of the Los Angeles smog problem through research and wide dissemination of results and conclusions to the public. Annual budgets were set at one million dollars, which was never reached, for a five-year period. A small technical staff was organized to study the problem and to contract for necessary research in existing laboratories.

The Air Pollution Foundation is currently in its seventh and last year of operation. It has pinpointed the Los Angeles problem as primarily and almost entirely a problem caused by motor vehicle exhaust and has promoted a broad, intensive research program by industry to develop a suitable control device for motor vehicle exhaust. A State law requiring these devices on motor vehicles registered in California recently went into effect. As a result, the goal set by the organizers of the Foundation, elimination of Los Angeles smog, is in sight.

A major problem of the Air Pollution Foundation since its inception has been that it was not truly a foundation in that it had neither an endowment nor a permanent source of funds. Rather, it has been supported by annual contributions of business and industrial interests, chiefly in Southern California. A goodly source of funds was the petroleum industry, so when the Foundation pointed out the importance of nonindustrial sources as the chief smog culprits, several segments of the community, as was inevitable, charged the Foundation with bias and self-interest. To a certain extent these charges and suspicions, not subject to proof one way or the other, diminished the Foundation's effectiveness.

The Role of Communications Media

No discussion of activities in air pollution control would be complete without notice of the activities of newspapers, magazines, television, and radio. Most people obtain their information concerning civic problems through these media. The air pollution problem is no exception. It is obligatory, therefore, that those who guide public opinion make responsible use of these communication media. To do this adequately requires professional skills in preparing releases and conducting press conferences. The subject must be timely and presented in informative and easily understood language.

Reporters and editors cannot, as a rule, differentiate between fact and fancy in highly scientific fields. They must rely on the accuracy and integrity of the informer. But even the best and most authoritative information cannot be interpreted accurately by reporters if it is presented to them in vague, diffuse language with a multitude of qualifying phrases. The various news media need the intelligent cooperation of the information source to keep the public accurately informed.

Conclusions

In reviewing the activities and problems of nongovernmental organizations in abating air pollution, we reach the following conclusions:

1. Civic-improvement committees, clean-air groups, and other voluntary citizens' organizations need technical information and guidance to direct their enthusiasm into effective channels.

2. Research by private industry and trade organizations would be more effective if better coordination could be effected among various organizations. A greater effort should be spent on the problems of small industrial units.

3. Legal controversies and political arguments between industry and government on air pollution matters would be minimized if sound technical and economic information were available and the opinion of neutral, objective authorities were sought.

4. Professional societies should continue their efforts to inform their memberships and the public of the status of air pollution abatement activities and the areas where more scientific information is needed.

5. The air pollution research and training activities of universities, colleges, and research institutes should be encouraged with whatever funds can be made available from both government and private sources.

6. News media offer an effective means of keeping the public informed. The responsibility for the accuracy of the information presented must be shared by the medium and the originator of the information.

VI. SOLVING THE AIR POLLUTION PROBLEM

Any problem as diverse and widespread as the air pollution problem can be attacked in many ways. The only successful attack, however, is one that recognizes certain basic needs and is directed specifically toward meeting those needs. We recognize four needs that must be filled before an air pollution problem can be solved:

1. More information relating the sources of air pollution to effects on people and property. The alternative to obtaining this knowledge is to assume that *all* emissions to the atmosphere are harmful and therefore must be forbidden. This is the approach of the zealot, but an approach that society cannot afford. Only when we know the effects of various types and amounts of pollutants can we proceed *intelligently* against harmful emissions.

2. Development of effective control methods that will not be so expensive as to disrupt the economy of the community. In many cases these means are already available; others defy solution. What should be done in the latter case? In an equitable society there must be a balance of rights and privileges of various sectors of the community for the good of the whole. In extreme cases it could mean actual shutting down of an enterprise emitting dangerous fumes, or relocation of nearby homes. These obviously are extremes and are undesirable. The logical process, and by far the cheaper, is to put our scientific brains to work on the development of economic means of controlling stubborn effluents.

3. Broad dissemination of the facts of air pollution in language readily understood by the public. Any restrictive law or regulation must have public acceptance. Occasionally the public is panicked temporarily by emotional pleas, but wholehearted support is given only to laws that can be understood. Unfortunately, a large majority still do not understand the basic facts of air pollution and its control. Worse yet, there is often a strong tendency to question the motives of those who try to disseminate facts. This hurdle must be overcome.

4. A cooperative approach between business and government toward legislation adequate to protect the public, yet in keeping with the democratic principle of fair play. Usually such cooperation is not difficult to obtain once the facts are known. It will not spring up spontaneously, however. Each locality must devise its own *modus operandi.*

Some of the areas involved in these four needs are highly technical and others

are political, but the problem is no more difficult than many society has already faced and solved. Sufficient research and development efforts are already under way in some areas of interest. Other aspects of the problem are sadly in need of much greater research effort. In addition to the need for information on the chronic effects of various pollutants on health, we need more reliable and sensitive instruments for the measurement of pollutants, both in effluent streams and in the atmosphere; a better knowledge of atmospheric chemical reactions and the meteorological dispersion of pollutants; and, obviously important, the development of economic abatement methods.*

In addition to technical problems, we also have a problem in communications. All too often we find government, industry, and the public separated by a wall of mutual suspicion and distrust, which makes it very difficult to apply sound reasoning to the control or abatement problem. But just as the ignorance factor can be diminished by sound research and an enlightened public information program, this suspicion and distrust can be dissipated by a little compromise and better liaison.

* A list of specific air pollution needs amenable to research is presented in the Appendix.

APPENDIX

Air Pollution Needs Amenable to Research

Biology

1. Mechanism of absorption of both gases and particulates by vegetation.
2. Identification of phytotoxicant responsible for "typical smog damage" to vegetation.
3. Effects of fluorine compounds on growth of citrus fruit.
4. Determination of the mechanism of eye irritation from photochemical smog.
5. Effect of pesticide sprays on wildlife.

Chemistry and Chemical Engineering

1. Methods of recovering large-volume chemical effluents (e.g., nitrogen oxides and ozone) which are difficult to absorb or remove by contact washing.
2. Methods of recovering intermediate concentrations of odorous gases too concentrated to adsorb in odor canisters and too dilute to recover economically.
3. Photochemical stability and physical chemistry of aerosols.
4. Factors affecting the formation of nitric oxide in combustion processes.
5. Extension of analytical methods for atmospheric pollutants to parts-per-billion range.
6. Mechanism of formation of sulfuric acid mist and its removal from the atmosphere.
7. Development of lead-resistant oxidation catalysts for automobile exhaust hydrocarbons.
8. Method of analysis for atmospheric aldehydes.
9. Development of lead-resistant catalysts for decomposition of nitric oxide in automobile exhaust.
10. Method for prevention of nitric oxide formation in flames.
11. Mechanism of the removal of carbon monoxide from the atmosphere.

12. Better methods for the sampling and analysis of complex mixtures in the atmosphere.

13. Determination of the mechanism of photochemical oxidation of organic compounds in the atmosphere.

14. Economic methods for the removal of sulfur compounds from fuels.

15. Development of chemical or physical methods for odor measurement.

Engineering

1. An effective device for the control of motor vehicle exhaust gases.

2. Less expensive high-temperature gas filtration media.

3. Better means for disposal of city demolition debris.

4. Practical methods of controlling discharges from coke ovens.

5. Economic means of controlling emissions from small foundries.

6. Control of fly ash from oil-fired equipment.

7. Methods of reducing sulfur dioxide in combustion effluents.

8. Methods for controlling acid mists and high vapor pressure organic suspensoids.

9. Development of more economic construction for absorption equipment for handling low-contaminant-concentration, high-volume effluent gases.

10. Basic performance characteristics and criteria for spray-type absorbers.

11. Adsorption characteristics of solids for low concentrations of contaminants.

12. Methods of evaluating performance of particulate collection equipment.

13. New methods for handling fine metallurgical fumes at high temperatures.

14. Life studies of fixed and dynamic filters with a wide variety of aerosols.

15. Fundamental studies on graded filter media for low loadings of air contaminants.

16. Development of relationships from particle and equipment parameters, which will enable the reliable prediction of performance from primary dimensions of equipment and rapidly evaluated properties of the particulate material.

17. Establishment of incinerator design criteria.

18. Elimination of odor from diesel exhaust.

19. Effect of engine variables and maintenance practice on motor vehicle exhaust emissions.

20. Method for reducing fluoride content of steel-mill effluents.

21. Simplified means of assessing community air pollution problems.

Medicine

1. Chronic effects of air pollutants on organisms.

2. Relationship of various air contaminants to incidence of respiratory diseases.

3. Determination of maximum allowable concentrations of atmospheric contaminants for 24-hour exposure of the general public.

4. Objective method for measuring atmospheric eye irritation.

5. Synergistic effects of aerosols and gaseous pollutants on living organisms.

6. Synergistic effects of air pollutants and aeroallergens.

7. Relationship between air pollution and the geographical distribution of death and disease.

Meteorology

1. Effects of inversion conditions and topography on dispersion characteristics of the atmosphere.

2. Effects of wind speed and stack-gas velocity on average ground-level concentrations of stack-gas contaminants.

3. Relationship between stack concentrations, as well as emission rates and meteorology, and the short-time or peak-ground-level concentrations of stack-gas contaminants.

4. Atmospheric dispersion characteristics of coarse particulates.
5. Development of means for relating emission concentrations to average atmospheric concentrations.
6. Development of sensitive tracer techniques, with particular reference to tracing air movements in urban areas.
7. Basic criteria for evaluating allowable emission rates in urban areas.
8. Dispersion of exhaust gases from rocket launching.

Physics (and Engineering)

1. Principles of deposition and retention of gaseous and particulate contaminants on surfaces.
2. Determination of fundamental particle dynamics as applied to inertial separation, filtration, and electrostatic properties of particulates.
3. Determination of the properties and behavior of atmospheric aerosols.
4. Development of adequate effluent sampling methods.
5. Basic studies of electrostatic phenomena.
6. Development of inexpensive instruments for continuous atmospheric monitoring.
7. Relationship between various effluents and visibility reduction.
8. Development of analytical techniques and instrumentation for the determination of auto exhaust constituents.

ABOUT THE AIR POLLUTION FOUNDATION

The Air Pollution Foundation is a private, non-profit, scientific research organization, incorporated November 18, 1953, under the laws of the State of California.

It is financed by public-spirited industrial, business, financial, and professional firms; trade associations, and private citizens.

It is operated by a Board of Trustees who, as provided in its By-Laws, serve without compensation.

It is committed to impartial fact finding—without fear or favor—through scientific research.

The Air Pollution Foundation is dedicated to the solution of the smog problem.

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