



5th
Annual Report

1958

AIR POLLUTION FOUNDATION

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WHAT IS THE FOUNDATION?

It is a nonprofit organization, incorporated November 18, 1953, under the laws of the State of California.

As provided in its By-Laws, the Foundation is operated by a Board of Trustees, who serve without compensation.

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

It is prohibited from using any of its money for the benefit of any individual, or from carrying on lobbying activities.

Contributions to the Foundation are deductible for income tax purposes.

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The President's Message

by
FRED D. FAGG, JR.

One thing we shall always remember about the Air Pollution Foundation is that when it was created in November, 1953, those of us who signed our names to the incorporation papers had no way of knowing how long it might actually take to solve the smog problem.

Now, after just five years, we have an answer: *At the rate we are going, two more years can complete the basic research needed for a final solution.*

It is good news, just in itself, that after only five years we have an answer. The Foundation's scientific research plans were set up initially on a five-year basis, not in the belief that smog could be eliminated in any such brief period, but in the hope that qualified scientists could in five years straighten out the backlog of confusion about smog and be able to calculate how much longer the whole job would take. This our scientific staff has accomplished.

It is doubly good news that our scientific staff now expects (as you will read in the Managing Director's report on the following pages) to have all the needed facts about auto exhaust fully in hand by the end of 1960. Auto exhaust is the last remaining Los Angeles smog mystery requiring basic research; many of us had feared that research alone on smog would take ten years or more, not a mere seven years.

Who is responsible for this cheering news? *The industrial, business, financial and professional firms, the trade associations, and public-spirited individuals who have provided the necessary dollars for the Foundation's work.* Their dollars have not been merely gifts or donations; they have been dollars invested in the future

of Southern California—for we must have clean air restored here to guarantee our economy, our comfort and our well-being.

In Our Darkest Days

The Foundation was created because painful years of rules and regulations had proven ineffective. Smog was mushrooming and threatening to wipe out the precious economic gains Southern California had secured during the preceding quarter century.

It was clear to the Foundation's founders and subscribers that the only pathway back to tolerable air was the scientific pathway, free of politics, demagoguery and special pleading. What was needed was pure research, and more pure research.

We incorporated under State law as a nonprofit research foundation, and launched a nationwide search for the highest caliber scientific staff challenge could buy. We obtained men who have dedicated themselves to ~~the very thing~~ ordinary men seek to avoid—WORKING THEMSELVES OUT OF A JOB. (This is exactly what they are striving to do, as they push relentlessly toward the earliest possible elimination of smog.)

Five Years of Accomplishments

After only five years, our scientific staff has arrived at a point where they can say, "Give us the necessary funds for two more years' intensive work, and we can have the basic research job completed for you."

This is the big accomplishment. But it has been made up of many day-by-day accomplishments in three specific areas of operation: our staff has organized and directed a broad program of basic research, cooperation, and public information.

In the area of basic research, the Foundation's first accomplishment was ironing out the controversies of five years ago, when there was much disagreement and confusion even among technically trained persons.

During this first phase of research (1954-55-56), our staff determined the facts about the meteorology of the Basin in which we live, and found out which pollutants are significant in smog formation and which ones are not. They also produced the scientific facts about the ~~harmful effects of rubbish burning~~ that gave local government the evidence it needed to enact a ban against outmoded backyard incineration.

These findings—all published in the nation's scientific literature for the guidance of other smog workers here and elsewhere—led to the inescapable conclusion

that solution of the smog problem depended upon learning how to control auto exhaust.

During the second phase of basic research (1957-58), all work has been aimed at auto exhaust, and our staff tells us they have now reached the point where a break-through can at last be envisioned. This means they are ready to enter the third and final phase of basic research—a tremendous accomplishment in only five years.

In the area of cooperation with others, the Foundation has brought about a most encouraging coordination of effort among public agencies, private groups and individuals who had been working with little or no liaison prior to the Foundation's establishment. Additionally, still ~~other~~ groups, able to help in solving the auto exhaust problem, have been enlisted by the Foundation in the war against smog.

In the area of public information, the Foundation's earliest accomplishment was quieting mass hysteria by proving to the public-at-large that "something was being done" and that our industrial and business leaders were as interested as the man on the street in getting rid of smog.

Since then, (while continuing to keep the general public properly informed and keeping our contributors and other special publics fully up to date) the Foundation has been able to direct its information program primarily to the technically trained people in industry, education, government and private institutes who are especially qualified to use Foundation findings in helping to solve the auto exhaust puzzles.

In this brief review of what the Foundation has accomplished, ~~is the proof that~~ those who have financed the work can know their dollars have been well invested.

With Victory in Sight

It is as necessary today to complete the job begun five years ago as it was then to start it. The people who are building Southern California are not people who let up. The Foundation is their greatest asset in building this sector of the country.

With their continued full support, pure research can continue. In the emotions-filled war against smog, *pure research is our only avenue to smog control methods based on scientific fact, rather than on political considerations.*

PURPOSE OF THE FOUNDATION

An independent, nonprofit corporation has been established for the following purposes:

- 1. To cooperate with, and to assist in coordinating the efforts of, governmental agencies, educational institutions, specialized research groups, and medical, legal, and other technologists, so that every phase of air pollution shall be the object of careful study and constructive, remedial action.*
- 2. To provide for research on those phases of the problem not already undertaken or completed by other agencies.*
- 3. To inform the public periodically concerning the nature and extent of air pollution, progress made in its elimination, and obstacles to such elimination.*

—from the
"Statement of Policy of the Air Pollution Foundation"



The Managing Director's Report*

by
W. L. FAITH

Five years ago you formed a unique organization, the Air Pollution Foundation, and charged it with finding a solution to the Los Angeles smog problem. You did this because you believed the united effort of private enterprise could succeed where government had faltered.

Today we can prove that your confidence was justified. No longer is the community groping in the dark cavern of abysmal ignorance it was in five years ago. We have found the ascending tunnel leading out of that not-easily-forgotten cavern, and we can now see the small pinpoint of light which we ~~know~~ means clear, tolerable air at the end of this tunnel. There are pitfalls and there are rocks to climb over between us and the full, good, fresh light; but with your sustaining confidence, we shall get there.

I shall not take your time with a step-by-step account of our progress or a listing of the difficulties we have encountered. You are more interested, I am sure, in an account of the present status of the smog problem, e.g., where we stand today, what we must do next, and when we are going to lick this problem.

When air pollution controls were first instigated in Los Angeles they were directed toward the suppression of smoke, dust, and sulfur dioxide. These were the atmospheric contaminants found to be most important in eastern cities and it was

*Prepared for delivery to the Trustees and contributors of the Foundation at the Foundation's Fifth Annual Luncheon Meeting, held at the Statler Hilton Hotel in Los Angeles, November 12, 1958.

only logical that they should be most suspect in the industrial economy that had burgeoned in Southern California.

Later, when Haagen-Smit developed his hydrocarbon theory of smog formation, controls were enacted to reduce hydrocarbon emissions from various refinery operations and storage tanks. In the seven years since Haagen-Smit presented his findings, the phenomena described by him have been subjected to considerable close investigation. Haagen-Smit's basic theory proposed that nitrogen dioxide (NO_2) molecules in the atmosphere became sufficiently activated by sunlight to react with organic compounds (chiefly hydrocarbons) to produce ozone and peroxides. He further suggested that the eye irritation, vegetation damage, and restricted visibility peculiar to Los Angeles smog were caused by the same general reaction. He found that the ozone and oxidant-producing reaction was quite dependent on the ratio of nitrogen dioxide and hydrocarbon initially present. Although all hydrocarbons he investigated reacted to some extent, the most rapid ozone producers were olefins (unsaturated hydrocarbons).

From an air pollution control standpoint, the most logical step, of course, was to catalogue the sources of these newly suspected pollutants, and determine how much was emitted to the atmosphere and the minimum quantities that could be tolerated (the threshold concentration).

Key Pollutants: Sources, Amounts and Threshold Concentrations

Nitrogen oxides, chiefly nitric oxide (NO) and nitrogen dioxide (NO_2) are found in all combustion effluents. Highest concentrations (up to several thousand parts per million) are present in automobile exhaust; effluents from the burning of gas and oil in furnaces and boilers seldom exceed a few hundred parts per million.

Hydrocarbons (the chief organic compounds that reach the air) may be released by evaporation or emitted in combustion effluents as unburned fuel. Evaporation losses occur principally in the storage and handling of gasoline, but little of this is olefinic in character. Auto exhaust is the chief source of unburned hydrocarbons from combustion effluents; *approximately 80 per cent of the total hydrocarbons and 95 per cent of the olefins in the Los Angeles atmosphere come from automobile exhaust.*

The minimum concentrations of hydrocarbons and nitrogen oxides that will combine to form smog are difficult to determine. In the open atmosphere one cannot control the important variables sufficiently well to get a good average sample (the

wind won't stand still; the intensity of sunlight varies, etc.); in the laboratory the experimental scale is such that considerable extrapolation is required. Values of hydrocarbons in the open atmosphere (i.e., unaffected by nearby sources) during heavy smog periods vary from 1 to 3 parts per million (ppm); comparable nitrogen oxide concentrations are 0.3 to 0.6 ppm. However, the smog reaction has usually been going on for some time before these values are obtained; hence, they may be low values.

A clue to the threshold concentration may be the concentration of ozone found in the atmosphere during a heavy smog period. At such times ozone values have ranged from 35 parts per hundred million (pphm) to as high as 90 pphm.

Although there is no well-correlated relationship between ozone concentration and other smog effects, a general relationship exists, so any concentration of hydrocarbon and nitrogen oxides that would produce, say, 35 pphm ozone could be considered the threshold concentration.

How Sunlight Changes Auto Exhaust Into Smog

In an attempt to get more definitive information concerning the relationship between source and smog manifestations, i.e., between cause and effect, we contracted with Stanford Research Institute to build a 500-cu-ft smog chamber where various concentrations of hydrocarbons and nitrogen oxides could be subjected to simulated sunlight and where resulting smog effects (eye irritation, ozone, reduced visibility, etc.) could be measured. Because automobile exhaust is probably the only source of pollution that will produce a mixture of hydrocarbons and nitrogen oxides of sufficient concentration to produce smog, experiments so far have been largely with auto exhaust.

It is interesting to note the changes that take place in the chamber when air polluted with exhaust gases is subjected to simulated sunlight. As an example, let us suppose exhaust gas from an automobile, running through a prescribed operating cycle on a chassis dynamometer, is diluted with purified air so that the hydrocarbon content of the exhaust-polluted air sent to the chamber is about 3 ppm...

If the chamber is kept dark we find that the nitrogen oxide present is in the form of nitric oxide (NO) at a level of, let us say, 1 ppm. The polluted air is not eye-irritating, practically no aerosol may be found, and ozone is nil.

Then we turn on the lights. Almost immediately the nitric oxide starts to

decrease and nitrogen dioxide appears. After about 30 minutes the nitric oxide has been completely converted to nitrogen dioxide and the hydrocarbon concentration has decreased slightly. Then ozone starts to form and builds up to 0.8-0.9 ppm. Eye irritation develops and, depending on several factors, aerosols grow rapidly. Oxidation of the hydrocarbons is further evidenced by the rapid increase in the aldehyde content of the chamber.

Thus it has been demonstrated that auto exhaust in concentrations comparable to those that may be expected in the atmosphere produces ozone, eye irritation, and aerosols similar to that found in Los Angeles smog.

What Is It in Auto Exhaust That Must Be Eliminated?

One of the objectives of the study to date has been to learn the nature and identity of important factors governing smog formation from auto exhaust. Is it a function of engine design? Fuel composition? Amount of sunlight? Or some more subtle variable?

The most important variable uncovered to date has been the ratio of hydrocarbons to nitrogen oxide in the exhaust gases. Unless this ratio is in the range of 1:1 (1 part hydrocarbon to 1 part nitrogen oxide) up to 10:1, no eye irritant, no aerosol, and but little ~~ozone~~ forms.

We have occasionally tested automobiles with the motors in such condition that they did not produce an exhaust mixture in the proper ratio to cause a reaction and thus did not produce smog manifestations. The only problem was to keep them in that condition.

A second set of interesting data was produced when the diluted exhaust in the chamber was measured by gas chromatography before and after irradiation. Apparently the ~~most reactive~~ hydrocarbons, i.e., those that disappear upon irradiation, are the 4-carbon and 5-carbon olefins. Paraffinic hydrocarbons and those aromatics that have been measured react only slowly, if at all. Acetylene and ethylene disappear to some extent; the butenes (4-carbon olefins) and pentenes (5-carbon olefins) and their diolefin homologues react rapidly and totally disappear. Further, a high degree of correlation was found between the amounts of these olefins in the exhaust gas-air mixture and the development of eye irritation. The role of propylene (the 3-carbon olefin) appears to be intermediate between the ethylene (2-carbon) and the 4-carbon and 5-carbon olefins. Higher olefins (6 carbons and above) have not yet been identified, but they appear to be present in much smaller quantities, if at all.

Thus, it appears that the nitrogen oxide-hydrocarbon ratio previously believed to control the smog reaction is a fortuitous happenstance; the controlling ratio is probably the nitrogen oxide to C4-C5 olefin ratio. This concept is being further explored in our study at Stanford Research Institute.

The formation of aerosols by the photolysis of diluted automobile exhaust is apparently related to the olefin content of the exhaust, but a wider range of olefins may be involved than appears to be the case in the reaction to produce eye irritation. The presence of sulfur dioxide also appears to increase the formation of aerosol.

Attempts to produce typical smog damage on plants, particularly on pinto bean plants, endive, and petunias, all failed. It is interesting to note that the only way the so-called typical smog damage to vegetation has been produced experimentally was by addition of ozone to olefins and olefin-containing mixtures. Many believe that exposure time and humidity are controlling variables.

Certain tentative conclusions may be drawn from the work performed to date. Obviously, the major culprit in Los Angeles smog is automobile exhaust. The most obvious control method is to upset the nitrogen oxide-hydrocarbon ratio; specifically, the nitrogen oxide-olefin ratio. One way to do this would be to increase either the nitrogen oxide content or the olefin content of the exhaust, but not both. Conversely, it could also be done by decreasing one or both of the reactants below the threshold level. Since no one would countenance a planned increase in any air contaminant, the answer is some sort of an exhaust device that will eliminate olefins or nitric oxide, or both.

Why Changes in Gasoline Will Not Reduce Smog

From time to time the suggestion has been made that a change in gasoline composition might also solve the problem. This suggestion is based on the thesis that there is a direct relationship between olefins in the fuel and olefins in the exhaust.

It has been found, however, that even nonolefinic gasolines produce sufficient olefins in the exhaust to produce eye irritation and ozone. When the exhaust from nonolefinic fuel was compared with the exhaust from a composite of all Los Angeles gasolines (15% olefins), no difference could be detected in eye irritation and ozone.

Thus, we concluded that changing gasoline composition is not the answer to the problem. So, again it appears that some sort of exhaust device to eliminate either olefins or nitric oxide from exhaust is necessary to solve the Los Angeles problem.

Status of Work on Exhaust Control Devices

Let us look, then, at the status of exhaust control devices that show promise of upsetting this oxides of nitrogen-olefin ratio. In recent months the Foundation has worked very closely with private investigators who are spending their own money on the development of exhaust control devices.

One company has developed a direct-flame afterburner that maintains combustion under all automobile operating conditions. This is the only design we have seen that does this. The Foundation has carried out limited tests with the device in the Stanford Research Institute smog chamber and finds that the unit eliminates eye irritation. The unit is still fairly large, so further engineering development is required. Promise of ultimate success is excellent.

A second company of national stature has developed a catalytic unit that reduces the nitric oxide content of auto exhaust. Limited tests by the Foundation indicate that the unit is based on sound technical principles. Further improvements in efficiency are required.

A third industrial organization has developed a catalytic afterburner that has all the earmarks of becoming an effective, economic, and practical means of controlling auto exhaust gases. The Foundation has tested an experimental model that had been operated for 6,000 miles on a car using leaded gasoline. The unit was highly effective in eliminating eye irritation and aerosol formation. The catalyst becomes effective after the car has been operated for only a few minutes. The device has two other very desirable features in that (1) it muffles engine noise, and (2) stainless steel is not required for the converter housing. Life tests on the catalyst are now under way. We are enthusiastic about the possibilities of this catalytic muffler and believe it represents a real achievement in science and engineering.

We know of half a dozen other devices in various stages of development in both large and small companies, representing an astounding array of some of the best technical minds in the United States—all working on one or more solutions to Los Angeles' smog problem with their own money. Here we have an excellent example of the incentive of the profit motive in a democratic society.

In addition to these industrial-sponsored activities, the Foundation is sponsoring basic research on (1) the development of a means of removing active lead from exhaust gases so as to lengthen catalyst life and (2) a study of the chemical reduction of nitric oxide in exhaust gases.

Some of our recent tests at Stanford Research Institute are pointing the way to other means of solving the auto exhaust-smog problem. As mentioned previously, we have tested two models of two popular makes of cars in such condition that we could not produce eye irritation by irradiation of the exhaust. We do not know how long these particular cars would remain in this condition, because by means of a simple adjustment to simulate changes that take place during normal engine use, we later caused them to produce eye irritation. If this adjustment is so critical, perhaps others are also.

So, in cooperation with the Automobile Manufacturers Association, we are embarking on a test program to study the effect of engine variables on the production of smog. It may be that EVENTUALLY cars can be built that will not produce smog and thus not require special control devices. The possibility is certainly intriguing. But this is the long-range solution.

Redoubled Efforts Needed — Whose Responsibility?

In the meantime we must redouble our efforts to aid industry in the development of effective and economic control devices, and there is a tendency in some quarters to foist this job on the Federal government. Suggestions of this sort are based on the notion that a device that will settle the Los Angeles ~~problem~~ will be equally applicable in other areas. This is a questionable assumption.

The low-inversion, low-wind, intense-sunshine regime necessary to develop eye irritation from auto exhaust seldom occurs in areas other than the West Coast. Any Federal bureau studying auto exhaust would be obliged to study its nationwide aspects and to keep the Los Angeles problem in the proper relationship to the whole.

The most common complaints of citizens, health departments, and air pollution control organizations elsewhere are these three:

1. The visible smoke and disagreeable odor of exhaust, particularly from buses and trucks.
2. The potential hazards of carbon monoxide and nitrogen oxides.
3. The suspicion that auto exhaust contains compounds that may induce lung cancer.

These complaints pose exhaust control problems that are not identical with the auto exhaust problems we are dealing with in our efforts to control photochemical smog (Los Angeles' eye irritation, high ozone concentrations, blurred visibility, plant damage, etc.).

To a moderate extent, of course, the two different sets of problems seem to have two points in common. First, the smoke-odor complaint is mainly a diesel-engine problem, but smoke from either diesels or spark-ignited engines (automobiles) is largely a function of engine condition—and we have said we have occasionally found engines in such a condition that they did not produce a smog-reactive exhaust mixture, but the unknown trick is how to keep them in that condition. Second, carbon monoxide could be eliminated by any afterburner that successfully eliminated all hydrocarbons.

While a successful nitric oxide eliminator would do away with smog as we know it in Los Angeles, such a solution would quiet few air pollution complaints elsewhere because nitric oxide is a factor only in photochemical smog.

Cancer fears have been based on the fact that benzpyrene (a known carcinogen) has been found in auto exhaust smoke. Consequently, smoke elimination should be an adequate solution. On the other hand, how people in coal-burning communities can become excited about benzpyrene in auto exhaust is a puzzle, inasmuch as the benzpyrene concentration in coal smoke is many times that in auto exhaust.

Regardless of the answer to this question, the fact is that the auto exhaust problem in Los Angeles is considerably different from exhaust problems elsewhere. Accordingly, the solution that will finally be accepted in Los Angeles and for the West Coast may not apply in other communities.

We feel quite confident that the automobile exhaust problem will be solved and that smog, as presently known in Los Angeles county, will disappear. Other counties in Southern California will also benefit from auto exhaust control, but not so much as Los Angeles county until their local sources of excessive smoke and dust have been abated. This does not mean that control districts in other counties should blindly adopt the Los Angeles County Air Pollution Control District Rules and Regulations *in toto*. A case in point would be indiscriminate control of hydrocarbon evaporation losses. Unless the vapors in question were highly olefinic they could not partake in the smog reaction.

Similarly, any plans of the Los Angeles County Air Pollution Control District to control solvent emissions should be carefully reviewed. Present indications are that solvent vapors are not sufficiently reactive to form smog, not only because they are nonolefinic but also because they never become mixed with the proper nitrogen oxide concentration. We expect to get further information concerning this reaction in our smog chamber during the next year.

How Much More Basic Research Is Needed?

We estimate that two more years of work initiated and sponsored by the Foundation will complete the basic research phase of the Los Angeles smog problem.

How do we arrive at two years? ~~Our estimate is based on three factors:~~ (1) the questions we know must yet be answered about exhaust reactions in the atmosphere; (2) our experience with the number of experiments usually required to answer such technological questions; (3) an assumption that continued adequate funds will be forthcoming for two more years' intensive effort.

The kind of intensive effort we have in mind will have to be initiated by the Foundation, and paid for by the Foundation, for three specific reasons: (1) there is no other private research organization that is committed to use its resources for solution of the smog problem; (2) there is nowhere in the country any single laboratory or scientific institute that has the total facilities needed to conduct all the work still required—several, perhaps many, will have to be contracted with by us to do specific jobs; (3) no governmental agency has the freedom of action to cut off unproductive work quickly, which is frequently necessary in working toward speedy solution to the smog problem.

We fully believe that two more years of intensive scientific work under Foundation auspices can provide all the essential facts, so that private industry can take over from that point and produce workable, economic controls for auto exhaust and thereby eliminate smog.

I pledge to you our continued objective dedication to solving the Los Angeles smog problem. As spelled out in our original guiding policy, our work will be done "without fear or favor—let the chips fall where they may."

JF

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AIR POLLUTION FOUNDATION

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*Out of print, but available at leading libraries.