

Final report / Air Pollution Foundation

Air Pollution Foundation.

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Final Report

AIR POLLUTION
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UNIVERSITY OF CALIFORNIA
INSTITUTE OF TRANSPORTATION
AND TRAFFIC ENGINEERING

1961



Foreword

IT WOULD BE most satisfying if the final report of the Air Pollution Foundation could be called a final report on Los Angeles smog. Such is not the case.

As spelled out in the first brochure issued by the Foundation's Board of Trustees in late 1953, the "sole reason for the existence of the Air Pollution Foundation is to shorten the time it will take to eliminate smog." We believe we have accomplished this task. We have helped supply the facts which have shown that the only remaining cause of Los Angeles smog is motor vehicle exhaust. We have been instrumental in getting private industry to develop suitable exhaust control devices and in convincing California's legislators of the need for a state-wide motor vehicle pollution control law. But the final report on smog will not be written until adequate exhaust control will have become a reality.

Because the Air Pollution Foundation has been a unique social experiment, this report is primarily a history of the Foundation and its accomplishments. Like any other historical episode, the Foundation's efforts must be viewed in relationship to what others did prior to its inception, the activities of others during its existence, and what others may do after it is dissolved. Accordingly, we have tried to make this report an abbreviated history of the Los Angeles smog problem, with emphasis on the part played by the Foundation in assessing the problem and developing a solution.

For those of us who were privileged to take part in the Foundation's activities, it was an interesting and rewarding experience. Our success or failure can be evaluated in true perspective only by posterity. Regardless, however, of the final judgment to be rendered, credit must be given to the business and civic leaders of Southern California who conceived the idea of the Foundation and followed through with financial support. These are men of the same mold as those who solved the water and harbor problems of Los Angeles and made Southern California great. If our present and future leaders will attack their civic responsibilities with similar courage and vigor, the future of Southern California, both spiritually and materially, is assured.

W. L. FAITH

San Marino, California
April 1, 1961

Final Report

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AIR POLLUTION FOUNDATION

2556 MISSION STREET

SAN MARINO, CALIFORNIA

MAY, 1961

1542-1953 THE PAST IS PROLOGUE

THE FIRST REFERENCE to air pollution in the Los Angeles Basin is attributed to the Spanish explorer, Juan Rodriguez Cabrillo. In 1542, after observing the smoke made by Indians burning brush, he called San Pedro Bay the "Bay of Smokes." The atmospheric condition that contributed to the accumulation of smoke was the combination of low wind speed and the intense atmospheric temperature inversion that was typical of late summer and early fall days in the Southern California coastal plain.

As weather conditions of a locality do not change markedly over a period of a few centuries, we should not have been surprised 400 years later, when the population of the Los Angeles Basin had reached 3 million, to see an intense air pollution problem develop.

In the interim, although there must have been many days when atmospheric visibility was restricted, there were not a sufficient number to cause much comment. Tropical haze (dust, pollen, fibers, salt particles), common even in subtropical areas, was not at all unusual and was accepted as a natural phenomenon, in the same way early morning fogs are accepted along the coast.

Man-Made Air Pollution

Occasionally, when an activity of man resulted in a polluted atmosphere, the populace called for remedial measures. An article published in the Los Angeles Herald, Saturday, January 17, 1903, is apropos. Portions of the article follow.

"Frequently last week former Pittsburghers who were on Spring Street were given a strong reminder of home; it is not likely that any others of the hundreds of people who thronged the busy thoroughfare found anything in the atmospheric conditions that recalled a single pleasant incident or period of their lives. One afternoon during the week a darkness suddenly spread over the street; in shops and stores from Third to Fifth streets electric lights were turned on; people peered in wonder through the blackness, unable to distinguish objects only a few feet from them. Some thought it an eclipse of the sun, a few thought that a heavy fog had settled over the city, but soon all knew the truth, that it was smoke that obscured the sun and drove out daylight from the street, smutted their faces and soiled their linen. It was like meeting a railroad train in a tunnel."...

"Several weeks ago a petition was filed with the City Clerk protesting against the local smoke nuisance. It recited that the amount of smudge carried in the output of the big flues of a number of local hotels and bakeries was so great that it had become a menace to public health as well as public nuisance. This petition went the way of many others addressed to the old city council. It was read in the council chamber and referred to the committee on legislation, and that was the last ever heard of it."

The Beginnings of Smog

So Los Angeles marched on to its rendezvous with smog. By 1940, periods of polluted air were becoming noticeable more frequently and with greater intensity. By this time the population of the Los Angeles Basin, as noted before, had reached nearly 3 million. But with the onset of World War II, more pressing problems arose, and air pollution problems were subordinated to the war effort. During this period, however, widespread complaints concerning atmospheric eye irritation became common, particularly in the East Los Angeles area. Most of the complaints were traced to an oil-gas plant that had been converted to a butadiene manufacturing operation. Vapors released from an open condenser were highly irritating to the eyes and spread over a wide area when the atmosphere was stagnant. Even after the condenser was replaced with a closed condenser (and later, after the plant had been dismantled) complaints about intense eye irritation continued.

Apparently during the early 1940's, eye irritation became generally noticeable, even though a direct source was eliminated. Thus, more and more people became cognizant of eye-irritating smog. By 1944, extensive crop damage in the Basin was caused by smog, and, by 1945, public tempers shortened and stayed that way. Smog had come to Los Angeles.

Early Control Activity

In 1945, Stephen W. Royce, president and manager of the Huntington Hotel in Pasadena, asked Gen. Amos Thomas to join his staff, with the sole assignment of finding out what smog was and what could be done about it. In the same year, the Los Angeles Times brought Prof. Raymond R. Tucker, who had spearheaded the St. Louis cleanup, to Los Angeles for a study that required several weeks.

Concurrently, the Board of Supervisors of the County of Los Angeles made the County Health Officer its Director of Air Pollution Control, who, in turn, appointed Dr. I. E. Deutch as County Air Pollution Engineer. The City of Los Angeles also set up a Bureau of Air Pollution Control in the City Health Department.

Unfortunately, regulations subsequently adopted by the two governmental groups were not the same. Both dealt mainly with smoke abatement, but even then it was realized that the Los Angeles problem was more complex than just black smoke.

By the spring of 1946, it became apparent that an all-embracing air pollution control district was preferable to the nonuniform codes of many municipalities and the county.

A draft of a proposed Air Pollution Control Act was prepared by County Counsel Harold W. Kennedy for submission to the California Legislature. The draft was then approved by the County Board of Supervisors and the Citizens' Smog Advisory Committee, headed by William M. Jeffers. Some industrial opposition to the bill developed and, for a time, threatened its passage. However, after a meeting of Gen. Thomas, Mr. Jeffers, and Mr. Kennedy with industrial officials,* opposition was withdrawn and the bill was passed.

*This meeting is reported in an excellent review, entitled "The History, Legal and Administrative Aspects of Air Pollution Control in the County of Los Angeles," by Harold W. Kennedy, May 9, 1954.

The Air Pollution Control District

The Los Angeles County Air Pollution Control District (APCD) was activated on October 14, 1947. Dr. Louis C. McCabe was appointed Air Pollution Control Officer and, in early 1948, the air pollution personnel of the City Health Department were transferred to the APCD.

During the next six years, a great deal of progress was made in controlling industrial effluents, but in spite of this, smog conditions became worse.

Major regulations put into effect during this period were:

- I. Definition of air contaminants
- II. Permits to construct and operate equipment that may emit air contaminants must be obtained from the APCD.
- III. Establishment of permit fees
- IV. Prohibitions:
 - Rule 50. Smoke abatement (includes opacity definition)
 - Rule 51. Effluents that create nuisances
 - Rule 52. Particulate matter limitations
 - Rule 53. Sulfur dioxide and combustion contaminants
 - Rule 54. Dust and fumes (limited according to process weight)
 - Rule 56. Storage of petroleum products
- V. Hearing Board Procedures
- VI. Orchard or citrus grove heaters

Because smog abatement was not noticeable as a result of these regulations, public disappointment grew into intensive criticism of the APCD, fanned by speeches and "Letters to the Editor" by the overzealous, by fanatics, and even by well-meaning citizens who were led to exasperation by the turn of events.

Considerable venom was directed toward petroleum refiners, who had yet to live down their short-lived opposition to the passage of the law setting up the APCD. Refineries were accused of dumping pollutants into the atmosphere under the black of night; the APCD was accused of not enforcing the law.

By the fall of 1953, charges and countercharges reached a crescendo. Cities blamed the County, the County blamed the State, the State blamed the cities, and the merry-go-round continued. At a meeting of a group of University of California scientists in Riverside in November, it was suggested that unless the smog problem could be solved, "parts of Southern California may have to be evacuated." In late October, Governor Knight had appointed a blue-ribbon committee of scientists to study the problem and to report their recommendations to him at a conference to be held early in December.

A five-day siege of smog in late October and early November brought the confusion to a head. The vice-mayor of Pasadena said the city "may sue all Southern California oil refineries." He also asked the Governor to declare Southern California an emergency area and to quarantine every producer of air pollutants causing smog.

On the fifth day of the smog siege, downtown office workers were reported to have "walked off the job in droves." The acting postmaster complained that the smog was making it difficult for him to breathe and was reported to have collapsed at his desk. A prominent physician said that anyone who could get out of town should do so at once. The Los Angeles Daily News asked the question: "How many more Black Mondays must we have before those to whom we have delegated enforcement powers and who say these powers are sufficient to do the necessary enforcement are going to give us a demonstration?"

The Air Pollution Foundation is Formed

It was in this environment that the Air Pollution Foundation was organized. Agreement to organize was reached at a meeting of more than 75 businessmen, industrialists, civic leaders, churchmen and government officials at the Ambassador Hotel on November 2, 1953.

Chairman of the meeting, Asa V. Call, president of Pacific Mutual Life Insurance Co., said: "As of today, smog is the most serious matter that faces the area (Southern California). A number of groups have been going in different directions. Maybe they can be controlled and maybe they can't . . . This should be a program carried out over a period of several years without fear or favor. If we can come up with the answer and somebody gets hurt, that's too bad. If no one gets hurt, so much the better."

The Foundation was officially incorporated under the laws of California as a non-profit research organization on November 16, 1953. Its first officers were:

Chairman: Fred D. Fagg, Jr., *President, University of Southern California*

Vice Chairman: Stephen W. Royce, *President and Manager, Huntington Hotel, Pasadena*

Treasurer: James E. Shelton, *President, Security-First National Bank*

Secretary: Leroy Garrett, *Musick, Peeler & Garrett*

Committees on Finance, Research, and Personnel were established to get the Foundation going. Several policies were adopted to guide the activities of the Foundation. These were:

What the Foundation Proposes To Do:

1. To assemble a competent technical staff to organize and direct a broad program of cooperation, research, and public information.
2. To determine, record, and publish what has been accomplished to date by all agencies dealing with the Southern California problem.

3. To determine what remains to be done and to employ experts—through the device of research or service contracts—who will provide information and advice for the shaping of future policies and action.

4. To collect information as to what other municipal areas have done, and are doing, under similar circumstances.

5. To provide and maintain a library of materials pertinent to the subject of air pollution.

6. To consult with, exchange information with, and to suggest to governmental and private agencies those research activities, enforcement methods, or other matters, which have not yet been conducted or tried and which seem to offer promise of air pollution abatement—so that the efforts of all groups and individuals may be coordinated properly.

7. To publish current information—by the most appropriate means—on all phases of air pollution and its abatement.

What the Foundation Does NOT Propose To Do:

1. It will not duplicate services already rendered by governmental or private agencies.

2. It will not conduct research activities directly—unless it appears clear that no existing agency can conduct them as advantageously.

3. It will not expend funds entrusted to it for the construction or equipping of Foundation laboratories that will duplicate facilities already available.

4. It will not hold public hearings for the purpose of receiving complaints, or in any way to substitute for governmental agencies now charged with responsibility for certain phases of the air pollution problem.

5. It will not offer any immediate or ready solution for a very complicated, long-range problem.

A further implied policy was listed in a brochure used in the solicitation of funds for the Foundation under the question: “How long will the Foundation exist?” “Current research plans are on a 5-year basis. When the answers have been found, the Foundation will close shop—because it is self-liquidating.”

These policies have guided the activities of the staff throughout the Foundation’s existence.

Beckman Committee Report

A final event of importance in 1953 was the second session of the Governor’s Air Pollution Control Conference, held on December 5 in Los Angeles. The Special Committee on Air Pollution, appointed earlier and chaired by Dr. Arnold O. Beckman, presented its report. The committee recommended that the following measures be put into effect and that dates for conformance be promptly established by the APCD:

1. All open skimming ponds, separators, sumps, and sewers associated with the production and refining of petroleum shall be prohibited.
2. Gasoline transfers involving mobile carriers shall be prohibited unless satisfactory means are provided for preventing escape of vapors to the atmosphere.
3. The problem of spillage and loss of volatile hydrocarbons at filling stations shall receive immediate attention, to the end that suitable equipment and procedures for controlling this source of air pollution are put into use at an early date.
4. The feasibility of reducing or relocating existing facilities and curtailing future expansion of air-polluting industries, such as petroleum refining, shall be actively investigated.
5. Enforceable regulations for the control of obviously offensive fumes from automotive exhaust shall be immediately established and enforced.
6. Large motor vehicles, particularly buses and trucks, shall be required to use liquefied petroleum gas or equally satisfactory means for abating noxious exhaust fumes as rapidly as possible.
7. Systems for the collection and disposal of all combustible rubbish shall be established promptly and local burning shall thereafter be prohibited.

As will be seen later, these recommendations were not completely acceptable to the public, but they served as a framework for the initial activities of the Foundation's staff.

1954

FOUNDATION RESEARCH PROGRAM INITIATED

THE YEAR 1954 was understandably a hectic one for the Foundation. A staff had to be formed; headquarters had to be set up; the nature of the smog problem in Southern California had to be appraised; and an aggressive research program had to be developed and put under way.

The Technical Staff

The newly appointed president and managing director of the Foundation, Dr. Lauren B. Hitchcock, reported for duty on February 1, 1954. On March 15, headquarters were opened at 704 South Spring Street, Los Angeles. By the end of May, key staff members had been selected.

The scientific team which was to carry the brunt of developing and directing the Foundation's research program during its first three years were, in addition to Dr. Hitchcock:

W. L. Faith, *chief engineer and deputy director*
Morris Neiburger, *chief meteorologist*
N. A. Renzetti, *chief physicist*
L. H. Rogers, *chief chemist*

Other key positions filled were public information officer, Burt Leiper; business manager, Robert S. Weatherly; and librarian, Mrs. Mary Ann Jordan.

The officers and members of the Board of Trustees performed yeoman duty in getting the Foundation under way. A finance committee under the chairmanship of Edward W. Carter, president, Broadway-Hale Stores, Inc., raised funds from business and industry for the first year's program. A research committee, headed by Dr. Lee A. DuBridge, president of California Institute of Technology, worked closely with the scientific team of the Foundation in developing the research program.

The most important contribution of the Trustees was their constant insistence on objective, independent action by the staff. Thus, from its inception, the Foundation was committed to "impartial fact-finding, without fear or favor. Let the chips fall where they may." This admonition was so strong that no contributor ever asked the Foundation's staff to alter or soft-pedal any of its conclusions or to direct its research activities away from sensitive areas. There were no sacred cows.

Getting Under Way

The obvious prerequisite to a sound research program was a profound understanding of the nature of the smog problem in the Los Angeles Basin. Conferences were held with everyone purporting to have a knowledge of the facts. Especially valuable was the cooperation and counsel of the Los Angeles County Air Pollution Control District, Stanford Research Institute, various citizens' committees, and government bureaus. We soon became aware of strong differences of opinion among scientists

working on the problem, and especially of misconceptions of a certain segment of the population. In the latter case, we solicited the help and cooperation of the press, radio, and TV in the development of a sound public information program. Our findings and programs were widely reported. The press did an excellent job of proclaiming our objectivity and suggesting patience on the part of the public. The smog committee of Kiwanis International was of especial help in informing the public, particularly opinion leaders, of the technical nature of the problem and the need for moral support of the Foundation. Over a period of three years, a Kiwanis speakers' bureau, armed with information supplied by the Foundation, carried the story of the air pollution problem in Los Angeles directly to the public.

The Beginnings of an Understanding

After many conferences, both formal and informal, we were able to start differentiating fact from opinion and separating likely theories from wishful thinking and emotional hopes. We were subjected to harebrained schemes and fanciful flights of imagination, but we gave everyone a chance to propound his panacea.

In June, we published our first scientific report, summarizing available data on the *Meteorology of the Los Angeles Basin*, by Neiburger and Edinger. We were especially fortunate in having Prof. Neiburger on our staff, inasmuch as he was the only staff member with previous experience in Los Angeles smog studies.

Our library was another source of useful information. From the very beginning, we collected pertinent reprints and manuscripts dealing with the Los Angeles smog problem. The staffs of Stanford Research Institute and the Los Angeles County Air Pollution Control District were particularly helpful and made copies of their valuable collections available to us. Another source of highly useful information was Prof. A. J. Haagen-Smit of Caltech, who was unstinting with his time.

As a result of intensive library research and many conferences, we were able to sort out the areas of agreement and disagreement with respect to Dr. Haagen-Smit's theory of photochemical smog and the relative contribution of various sources to atmospheric smog formers. Our Report No. 2, "*Combustion and Smog*," by W. L. Faith, pointed out these areas of disagreement.

By July, 1954, we were in a position to envision a research program. It was obvious that Los Angeles smog resulted from restricted air movement in the Los Angeles Basin and a variety of emissions related to the daily activities of a rapidly increasing population. (In retrospect, this statement doesn't seem to show much progress, but at the time it was the only statement upon which experts would agree.)

The Initial Research Program

To proceed beyond this point we needed answers to several questions.

1. Were the methods of computing air mass movements by use of surface-wind measurement (as used by Neiburger and Edinger) sufficiently accurate to define the relative contribution of various sources of pollutants?

To answer this question, an air tracer study was devised in which a fluorescent pigment (zinc-cadmium sulfide powder) was released from various points of interest and recollected at sampling stations spread along a 25-mile arc downwind from the point of release. This study was financed by the Los Angeles County APCD through

a research contract with the Foundation. The dispersal and sampling was carried out by the Ralph M. Parsons Co., with personnel supplied by the APCD.

2. Was it a fact that visibility in the Los Angeles Basin had grown progressively poorer since the early 1930's?

This information was needed to determine if controls put into effect in the late 1940's had affected visibility in the Basin. The study was to be carried out under the direction of Dr. Neiburger in conjunction with the U. S. Weather Bureau and the IBM Corporation Service Bureau.

3. Were any of the many proposals for eliminating smog by meteorological modification of the atmosphere suitable for use in Los Angeles?

This study was undertaken by Dr. Neiburger. His very interesting report, published in *Science*, October 4, 1957, pp. 637-645, showed that the power requirements for atmospheric modification were exorbitant and prohibitive.

4. Could some of the objections by capable scientists to Haagen-Smit's theory of photochemical smog formation be resolved by extension of his studies by an independent laboratory?

Confirmatory studies were delegated under contract to the Armour Research Foundation, Chicago, Illinois. Dr. Haagen-Smit cooperated fully with the investigation. As a result, his keen insight concerning the photochemical formation of smog was corroborated.

Two related studies of atmospheric photochemistry were also initiated. One was a critical examination of the literature of atmospheric chemistry by Professors P. A. Leighton and W. A. Perkins of Stanford University. Another was a laboratory study of the detailed mechanism of smog formation by Stanford Research Institute at its Southern California Laboratories in South Pasadena.

5. What was the nature of the atmosphere in the Los Angeles Basin during smog sieges? What was the relationship between oxidant values and other manifestations of smog? How were the manifestations of smog distributed in severity and time throughout the entire Basin?

To answer these questions, an Aerometric Survey of the Los Angeles Basin was carried out from August to November, 1954. It was the most ambitious survey heretofore attempted in the air pollution field. A substantial portion of the study was supported by the Los Angeles County APCD through contracts with the Air Pollution Foundation. The Department of Water and Power, City of Los Angeles, also assisted in the work through a service contract. The total cost of the survey was in excess of \$400,000 and involved the services of 305 persons on a full- or part-time basis for a total of over 9,000 man-days. Over 100,000 individual measurements were made.

In conjunction with the survey, a contract was also made with Mr. Neil Goedhard of the School of Public Administration of the University of Southern California to bring the general statistical data of the Los Angeles Basin up-to-date.

6. What are the present and future emissions of hydrocarbons from the refineries and oil fields of Los Angeles County?

This was an area of considerable controversy and emotional indignation. We believed it would be in the public interest to make an independent audit of refinery emissions, so a contract was placed with the Southwest Research Institute, San Antonio, Texas, to make the study. The various petroleum refiners cooperated wholeheartedly.

7. What new techniques can be utilized to allow more precise and sensitive measurements of air pollutants?

In preparing for our aerometric survey, we became aware of an appalling lack of adequate instrumentation for atmospheric measurements. Under the guidance of our chief physicist, Dr. N. A. Renzetti, we undertook a search for modern instruments that might be adapted to air pollution studies.

Subsequently we contracted with Borman Engineering Co., North Hollywood, California, to build an ultraviolet spectrometer suitable for determination of atmospheric ozone. We also arranged with the National Bureau of Standards to release Mr. Ralph Stair to study the ultraviolet spectra of the sun, as viewed through the atmospheric smog layer in Pasadena. This was done every day during the month of October.

A second survey was made during November by Prof. D. M. Gates of the University of Denver, using an infrared spectrometer.

A preliminary study of a variety of other instruments was also started.

Evaluation of Sources and Their Control

Although the questions listed in the foregoing were believed amenable to direct research investigations, there were two important sources of pollutants about which more information was deemed necessary before embarking on expensive research contracts. One of these was motor vehicle exhaust; the other was rubbish disposal by incineration.

Motor Vehicle Exhaust

To learn more about motor vehicle exhaust, we arranged a "Conference on Vehicle Combustion Products and Other Emissions," which was held in Pasadena, California, on August 19, 20, and 21. A group of 60 experts, representing the automobile industry, the oil industry, universities, and governmental organizations, attended. Sessions were held on composition and analysis of auto exhaust gases; composition and analysis of diesel exhaust gases; effect of fuel composition, fuel additives, and lubricating oil additives; automotive engineering design and exhaust control devices; and chemical reactions in polluted atmospheres.

Important conclusions of the conference were:

1. Automobile exhaust is a serious contributor to Los Angeles smog.
2. More data were required on the composition of motor vehicle exhaust. A prerequisite was better methods of analysis.
3. Fuel modification would probably be of only limited value in ameliorating smog.
4. Further work on afterburners was desirable.

As a direct result of the conference, several projects on automobile exhaust were activated. A contract was given to Midwest Research Institute, Kansas City, Missouri, to determine the effect of automobile exhaust composition on the various manifestations of smog.

Two projects were placed at Southwest Research Institute, San Antonio, Texas. One was for a critical evaluation of a catalytic muffler developed by Dr. Eugene Houdry of Oxy-Catalyst, Inc. This was the only exhaust afterburner device that was available in a suitable prototype.

The second project initiated at Southwest Research Institute was an economic feasibility study of various stop-gap methods that had been proposed to alleviate probable smog effects from motor vehicle exhaust.

Rubbish Disposal and Incineration

To learn more about incinerator emissions and alternate methods of rubbish disposal, a Conference on Incineration, Refuse Disposal, and Air Pollution was held in Pasadena, California, on December 3 and 4, 1954. Participants included sanitary engineers; government administrators in the fields of sewage and sanitation on municipal, state, and Federal levels; academic personnel; and various other specialists in the field of air pollution control.

Principal recommendations and conclusions adopted by the conferees were:

1. The combustion of rubbish in household and backyard incinerators has the twofold detrimental effect of distillation of a large proportion of the material and the production and discharge to the air of particulate materials capable of forming extensive and persistent aerosols which aggravate air pollution. Household and backyard-type incinerators and open rubbish fires should be recognized as unsatisfactory solutions of the community refuse disposal problem in the Los Angeles metropolitan area.
2. Combustion of rubbish in the municipal or industrial incinerator, which leads to the discharge into the atmosphere of an unsatisfactory stack effluent, is indefensible.
3. Since the sanitary landfill method of refuse disposal has been shown to be economical and acceptable from the standpoint of public health, and since it creates no air pollution problems, this method should be given immediate consideration for the disposal of rubbish in the Los Angeles metropolitan area.

A full discussion of the conference proceedings was published in Air Pollution Foundation Report No. 3.

Studies by the Foundation staff prior to the conference indicated that the composition of effluent gases from backyard incinerators was fragmentary and conflicting. Accordingly, a project was placed at Battelle Memorial Institute, Columbus, Ohio, to evaluate the amount and type of effluents that were emitted from a typical backyard incinerator.

1955 ACCELERATED RESEARCH ACTIVITY

THE YEAR 1955 was one of intensive research activity. The staff had to supervise the many research contracts made in 1954, evaluate the data obtained, and arrange for publication of the results. Ten technical reports were issued, including the report of the incineration conference already mentioned; the *First Technical Progress Report*, issued in March; and the *Second Technical Progress Report*, issued in November.

Progress can be illustrated best by a brief review of the other seven technical reports issued.

Report No. 5. *Hydrocarbon Losses from the Petroleum Industry in Los Angeles County*, by Southwest Research Institute.

The audit of petroleum refinery hydrocarbon losses showed a value of 250 tons per day, about midway between the estimates of the Los Angeles County APCD and the Western Oil and Gas Association. It was obvious that the methods of estimation used by the three groups affected the results. This, in itself, was useful information and paved the way for a later cooperative approach between the APCD and WOGA.

Report No. 6. *Basic Statistics of the Los Angeles Basin*, by Neil Goedhard.

Data obtained were useful in delineating the limits of the Los Angeles Basin and predicting trends for motor vehicle exhaust emissions. The Basin limits were later adopted by the APCD in conjunction with the smog alert system.

Report No. 7. *Tracer Tests of Trajectories Computed from Observed Winds*, by M. Neiburger.

The results of this study indicated that the method of computing the movement of air masses from the direction and speed of surface winds, although not exact, gave reasonably accurate results. It was also concluded that better calibration of the existing wind station network was advisable and that more surface stations, in addition to a few upper wind measurements, would improve trajectory computations. The recommendations were adopted by the APCD.

Report No. 8. *Field Evaluation of Houdry Catalytic Exhaust Converters*, by Southwest Research Institute.

The most valuable result of this study was the establishment of techniques suitable for the evaluation of exhaust control devices. Three types of catalytic mufflers were tested—two types for vehicles using unleaded gasoline and one for those using leaded gasoline. The “leaded muffler” and the “intermediate white muffler” (for unleaded gasoline) both failed before reaching 5,000 miles of operation. The other muffler, for unleaded gasoline, was still reducing the hydrocarbon content of exhaust gases satisfactorily when the test was discontinued at 10,000 miles. Chief conclusion

was that "the Houdry catalytic muffler in its present embodiment is not sufficiently rugged and long-lived for use as a partial solution to the Los Angeles smog problem." The Oxy-Cat converter that was found suitable for use on vehicles using non-leaded gasoline was not considered seriously for practical reasons, including high sensitivity of the catalyst, which would lead to almost complete loss of activity if accidentally exposed to lead-containing exhaust gases.

Report No. 9. *An Aerometric Survey of the Los Angeles Basin, August-November, 1954*, N. A. Renzetti, Editor.

The final report of this comprehensive cooperative effort, as indicated in the preceding chapter, was a virtual gold mine of technical information concerning the nature of smog in Los Angeles. The general conclusions drawn from the study are worthy of repetition:

This survey established with reasonable precision the distribution in space and time of the various manifestations of smog and of the contaminants that may be the principal contributors throughout the Los Angeles Basin.

It established on a statistically sound basis relationships, or the lack thereof, among the various air pollutants and manifestations of smog.

It established certain base lines for concentration of pollutants and severities of smog manifestation by which future changes or progress can be gauged and trends, if any, toward toxic levels can be estimated.

It established the influence of incinerators as a contributor to smog.

It confirmed the importance of photochemical reactions in the formation of smog.

It provided additional evidence that the sources of smog are widespread throughout the Basin and not limited to certain local or small areas.

Many specific conclusions were also drawn, and the data obtained are still being studied in light of more recent atmospheric analyses.

One recommendation of note that resulted from the study was the following: "In order to monitor the distribution and trend of pollution in the Los Angeles Basin and to maintain a check on the possibility of development of dangerous concentrations, a minimum of fourteen stations should be established in the Los Angeles Basin."

Subsequently, the APCD established such a network. Since then, it has been improved greatly and now serves as the basis for the County's smog alert system. Some of the equipment used in the survey is still in use for monitoring the atmosphere in various parts of California.

In retrospect, one can see that the aerometric survey of 1954 was one of the most valuable contributions that the Foundation made in the battle against smog. If the Foundation had done nothing else, it would have merited its existence by this one project.

Report No. 10. *Feasibility of Control Methods for Automobile Exhaust*, by Southwest Research Institute.

Shortly after the Foundation was formed. it was apparent to the staff that there was a need for the evaluation of a great many proposals for the alleviation of smog from motor vehicle exhaust by what were called "simple" methods of control. Among the proposals that were examined for technical and economic feasibility by Southwest Research Institute were:

1. That all automobiles, trucks, and buses be required to use liquefied petroleum gas as a fuel in place of gasoline.
2. That only public service buses be required to use LP gas as fuel in place of gasoline.
3. That alcohol or alcohol-gasoline blends be used in place of gasoline.
4. That the "Houdry white gas muffler" be installed on all cars and that, in order for the muffler to be effective, all motor vehicles be required to use nonleaded (white) gasoline.

Actually none of these proposals was found feasible for reasons well spelled out in the report.

Report No. 11. *Visibility Trend in Los Angeles*, by M. Neiburger.

If this study of Weather Bureau records in 1932 did nothing else, it showed that "human memory is a weak and uncertain instrument." Long-time residents of Los Angeles still assert: "In the old days you could see Catalina at noon every day." But the records don't bear them out. One day in seven is a more nearly accurate statement. This is important, because it sets a base line for improvement in atmospheric visibility. Even when smog is gone. fog and haze will still limit visibility when the air is stagnant.

Atmospheric Photochemistry

While the staff supervised the work being done under Foundation contracts, it also had the responsibility of following closely pertinent research work going on in other laboratories spread throughout the United States. Of particular value were the studies on atmospheric photochemistry being done by Haagen-Smit in conjunction with the APCD and by Stephens and others at the Franklin Institute. These studies were closely correlated with related work under Foundation auspices in the large sunlit greenhouse at Midwest Research Institute and in the newly constructed smog chamber at Stanford Research Institute.

In fact, without fully realizing it at the time, the construction of the SRI smog chamber was a major contribution to the unraveling of the mystery of atmospheric photooxidation of hydrocarbons to produce smog.

Studies in the chamber during 1955 demonstrated the need for sunlight to produce ozone and the atmospheric eye irritant that plagued Los Angeles.

Important Conferences

One way of keeping advised of important findings was by bringing together experts in the field to discuss their findings. Accordingly, the Foundation joined with SRI, the Air Pollution Control Association. and the three local universities to sponsor the

Third National Air Pollution Symposium in Pasadena on April 18, 19, 20, 1955. The proceedings of the symposium have been widely published and will not be further discussed here. The Foundation took advantage of this gathering of scientists to sponsor a conference on aerosols on April 20 and 21. It had become apparent that the size and composition of the aerosol component of smog, its sources, and the mechanism of its formation were largely unknown but important factors in the chemistry and physics of smog. This conference was a great help to the staff in defining its research program. As a consequence, the Foundation entered into a contract with Berkeley Research Products, Albany, California, to develop and manufacture an aerosol counter for determination of the size distribution of aerosols. The 10-channel counter proved to be a highly useful piece of equipment when used in conjunction with the smog chamber at SRI.

Technical Advisory Committee Is Formed

The great surge in air pollution research in 1955 presented a twofold problem to the staff. It was necessary to keep advised of a great many activities throughout the world. Further, the Foundation's Board of Trustees insisted that we carry out only necessary studies that others were not able or willing to do with funds from other sources.

Accordingly, a Technical Advisory Committee was formed to counsel the scientific staff. The committee was composed of civic-minded scientists (see Appendix for list of names) who served the Foundation without remuneration until 1958 when the committee was disbanded.

Pasadena Air Monitoring—1955

As a result of recommendations of the Technical Advisory Committee, a follow-up of the 1954 aerometric survey, but on a considerably reduced scale, was undertaken in the Pasadena area, July-November, 1955. Objectives of the survey were (1) determination of the relationship between atmospheric oxidant and ozone measurements; (2) determination of the relationship between the oxidant precursor in early morning air and the severity of smog later in the day; (3) determination of the relationship between the hydrocarbon content of early morning air and the severity of smog later; and (4) determination of whether the relationship among oxides of nitrogen, oxidant precursor, and oxidant observed in laboratory experiments manifests itself in the smog atmosphere.

The results of these studies were of primary value later in setting up experiments in the SRI smog chamber and evaluating the resulting data.

Composition of Automobile Exhaust

Although air pollution scientists were still trying to learn the basic facts about the formation of photochemical smog, automotive engineers were busy trying to determine the nature of automobile exhaust emissions and the effect of engine variables on the amount and type of emissions.

The Automobile Manufacturers Association had undertaken to study exhaust emissions and their relationship to Los Angeles smog in late 1953. During 1954, the Coordinating Research Council (a joint venture of the Society of Automotive Engi-

neers and the American Petroleum Institute) formed a Group on Composition of Exhaust Gases under its Coordinating Fuel and Equipment Research Committee. The group was further divided into a Sampling and Analysis Panel, a Variables Panel, a Literature Survey Panel, and a Field Survey Panel. As a result of the activities of these panels, the exhaust gases of hundreds of automobiles were analyzed under a variety of conditions, particularly for hydrocarbons. Membership of Coordinating Research Council panels was traditionally limited to industrial members, but in 1955 a member of the Foundation staff was invited to join the Literature Survey Panel. In this way, the Foundation was continually apprised of valuable data.

Public Information Activities

Despite the obvious need for technical data, public clamor that something be done at once could not be ignored. The Board of Trustees of the Foundation deemed it wise for the Foundation to engage in a public information program to advise the public of research activities and of the need for regulations based on facts rather than whimsey.

The public still remembered a particularly intense siege of smog in the fall of 1954, during which time Governor Knight was called to Los Angeles "to do something about it." A new Air Pollution Control Officer, Mr. S. Smith Griswold, took office in late 1954 and the APCD began its greatest period of growth, particularly in its research activities. The State Legislature increased appropriations to the State Department of Public Health to continue activity initiated by Gov. Knight in October, 1954.

Under the sponsorship of Senator Kuchel, the Congress of the United States passed Public Law 159, an air pollution control law authorizing the U. S. Public Health Service to carry out a research and training program in the field of air pollution.

In Los Angeles County, the smog alert system went into effect in June, 1955. This emergency regulation, Regulation VII, was designed to prevent the excessive buildup of air contaminants and to avoid any possibility of a catastrophe caused by them. The air pollution control officer was empowered to set limits for important toxic air pollutants and to develop plans to limit emissions in the Los Angeles Basin whenever alert levels were exceeded. This might entail enforced shutdown of industrial plants or cessation of traffic.

The pollutants and levels chosen for the alert system were as follows (in parts per million of air):

	<i>First Alert</i>	<i>Second Alert</i>	<i>Third Alert</i>
Carbon monoxide	100	200	300
Nitrogen oxides	3	5	10
Sulfur oxides	3	5	10
Ozone	0.5	1.0	1.5

First Alert: Close approach to maximum allowable concentration for the population at large. Still safe but approaching a point where preventive action is required.

Second Alert: Air contamination level at which a health menace exists in a preliminary stage.

Third Alert: Air contamination level at which a dangerous health menace exists.

Just after the alert system went into effect, the worst smog in Los Angeles' history was experienced (September 13) when the oxidant value reached 0.90 parts per million (ppm). The need for a sound public information program was obvious.

In this vein, the Foundation, in 1955, published 10 technical reports, as mentioned previously, and distributed them widely. A monthly newsletter was initiated. Two speakers' bureaus, one developed by Kiwanis International's 110 clubs in the Los Angeles Basin and one formed by business and industrial supporters of the Foundation, were kept active. Sound motion pictures and color slide collections were made available to these groups as visual aids. The annual meeting of the Foundation was held in conjunction with the Southern California Conference on the Elimination of Air Pollution arranged by the California State Chamber of Commerce in cooperation with the APCD and the Foundation.

Status of the Smog Problem—December, 1955

By the end of the year, the Foundation could state the following major conclusions:

1. There was little likelihood that any practical changes in the meteorology or topography of the Los Angeles Basin would be effective in reducing smog.
2. Control of the effluents from the back-yard burning of rubbish could well be accomplished by banning this archaic practice.
3. No effective method of reducing hydrocarbon emissions from the exhaust of internal-combustion engines was available.
4. No methods were available for the control of oxides of nitrogen from combustion effluents.

In its *Second Technical Progress Report* (Report No. 12), the Foundation posed the following questions:

1. Will a 50 per cent reduction in hydrocarbon emissions from automobile exhaust markedly reduce the frequency or severity of smog attacks? If not, is 70 per cent required? 90 per cent?
2. Concurrently with a reduction in atmospheric hydrocarbons, will reduction of oxides of nitrogen be necessary?
3. How may extremely fine aerosol emissions, presently uncontrollable, be controlled?

In support of the third question, the following statement was made: "The opinion of medical authorities as to the probable health hazards of very fine aerosols is sufficient reason for seeking a method of control. Furthermore, the high correlation between the aerosol content of the atmosphere and eye irritation found in our aerometric survey lends support to the need for more information and, possibly, control. Further information should also be sought as to the nature and amount of aerosol emissions in automobile exhaust."

1956 FILLING IN THE GAPS

AS WE ENTERED the year 1956, we found that our studies had to be correlated even more with burgeoning research programs of other groups. Examples of important studies under way elsewhere were:

Los Angeles County APCD	Air monitoring (continuous); inventory of pollution sources; meteorological studies
APCD and Automobile Manufacturers Association	Average Los Angeles traffic pattern
APCD and Coordinating Research Council	Composition of automobile exhaust
Franklin Institute (for the American Petroleum Institute)	Infrared studies of smog-forming reactions
Southern California Joint Research Council on Power Plant Emissions	Power-plant emissions
University of California, Berkeley, and University of Southern California	Particulate matter in automobile exhaust
University of California, Riverside	Plant damage by smog
U. S. Public Health Service and California Dept. Public Health	Health studies
U. S. Public Health Service and U. S. Bureau of Mines	Incinerator design

The great increase in governmental research on the national, state, and local level was a giant step forward in the battle against smog in Los Angeles. The role of the Foundation became one of filling in the gaps in research programs. As will be seen later, we tended to concentrate more and more on atmospheric chemistry and the role of motor vehicle exhaust.

Foundation Reports

During 1956, the Foundation published four more reports on studies made primarily the year before.

Report No. 13. *Wind Trajectory Studies of the Movement of Polluted Air in the Los Angeles Basin*, by Morris Neiburger, N. A. Renzetti, and Rita Tice.

During this study, more than 1,000 trajectories, or wind paths, were calculated, tracing the movements of air-borne pollution to affected areas in the Los Angeles Basin. The conclusions were striking.

On nearly one-half of the days when substantial smog was measured in the downtown station, the air had come over the San Gabriel Mountains; about one-fourth of the time the air entered the Basin across the West Coast. In neither case did these

wind streams pass near refineries. The fact that most trajectories passed over regions of heavy traffic, but not over industrial plants, helped the indictment of vehicular exhaust as a major contributor to smog.

Report No. 14. *Solar Radiation, Absorption Rates, and Photochemical Primary Processes in Urban Air*, by P. A. Leighton and W. A. Perkins.

This report was an outstanding scientific achievement, not only as a thorough and systematic analysis but as a pioneering study of the application of photochemical principles to an urban air pollution problem. For the first time, all pertinent knowledge in the broad field of photochemistry was collated and critically examined for its relevance to the formation of smog. Although the report dealt mainly with primary photochemical processes, it brought out many areas of ignorance that would have to be filled in before adequate knowledge of atmospheric chemical reactions would be attained. As a consequence, Dr. Leighton was also commissioned to prepare a report on secondary photochemical processes, which was published in 1958. The two reports have served as a virtual "Bible" for research scientists in this field.

Report No. 15. *Proceedings of the Conference on Chemical Reactions in Urban Atmospheres*, L. H. Rogers, Editor.

About the time Dr. Leighton completed Report No. 14, it was deemed advisable to bring together experts in the field of atmospheric photochemistry, with the objective of improving the general understanding of the phenomena involved. With the assistance of the National Science Foundation and the American Petroleum Institute, 40 leading authorities attended the meeting in Los Angeles on February 2 and 3, 1956. The printed proceedings were distributed widely to public and university libraries.

Report No. 16. *Analysis of Air Near Heavy Traffic Arteries*, by N. A. Renzetti.

One of the many anomalies of the Los Angeles smog problem was the disproportionately low values of hydrocarbons and nitrogen oxides often found during intense smog periods. A possible explanation was that these smog-forming substances had been at higher concentrations some time earlier in the day, had reacted to form oxidant and to give these other effects, and that the concentrations of these smog-formers had thereby become reduced.

Accordingly, the Foundation contracted with the Truesdail Laboratories to collect air samples within 75 feet of heavily traveled traffic arteries. Air samples were collected from September 4 to October 2, 1956, and analyzed for carbon monoxide, carbon dioxide, and hydrocarbons. As expected, concentrations were considerably higher than those found at monitoring stations. The concentration ranges found were later used to guide auto exhaust studies in the smog chambers at Stanford Research Institute and Midwest Research Institute.

Motor Vehicle Exhaust Studies

Studies of the photochemical reactions of diluted automobile exhaust in the smog chambers at SRI and Midwest Research Institute were continued at a high rate of effort during 1956. The first results were not finally reported until 1957 and will be

discussed in the next chapter. Nevertheless it became apparent early that irradiation of exhaust gases at experienced atmospheric concentrations could account for all the manifestations of smog found in Los Angeles.

Members of the Automobile Manufacturers Association Vehicle Combustion Products Subcommittee inspected both installations in May and personally experienced eye irritation. Preliminary data were also presented to the subcommittee at a meeting in Detroit in August. The subcommittee accepted the conclusion that motor vehicle exhaust did, in fact, produce smog and further agreed that it was a "major" contributor to smog. They reserved judgment on whether it was the principal source of smog until additional data became available.

Incinerator Studies

Although public opinion appeared to have crystallized in 1955 in favor of ending the disposal of combustible rubbish by burning, particularly in single-chamber incinerators, it was still uncertain when this desirable goal would be reached. The County Board of Supervisors had banned single-chamber incinerators, effective October 1, 1957, but controversy continued over collection and disposal methods and could have made enforcement impractical at that time.

The diagnosis of incinerator effluents as important contributors to Los Angeles' smog was confirmed by the Foundation project completed at Battelle Memorial Institute during 1956. Over a one-year period, a single-chamber incinerator was operated under scientific control on combustible refuse representative of that burned in Los Angeles. Exclusive of carbon dioxide, carbon monoxide, and fly ash, 82 to 407 pounds of organic compounds were found in the combustion gases per ton of refuse burned. No doubt remained as to the pollution potential of rubbish burning in single-chamber incinerators. The complete data were published by the investigators in the Journal of the Air Pollution Control Association. It is interesting to note that several years later these data were used in indicting single-chamber incinerators in the San Francisco Bay Area.

Instrument Development

Work continued in 1956 on the evaluation and comparison of various analytical instruments for measuring low concentrations of contaminants in the atmosphere. Among the instruments studied were infrared spectrometers for hydrocarbons, a continuous instrument for nitrogen oxides, potassium iodide and ferrous thiocyanate methods for oxidant, the Ehmert ozone analyzer, a modified O'Konski particle counter, and the Goetz particle collector.

Technical Audit of Foundation Program

In the spring of 1956 it was suggested by trustees of the Foundation that an independent evaluation of the Foundation, its value to the community, and its methods of operation should be made as a guide to the trustees for future procedure.

The committee selected was as follows: John K. Northrup (former president of Northrup Aircraft, Inc.), engineering consultant, chairman; Jerome K. Doolan, consultant, Bechtel Corporation; Robert D. Fisher, financial vice president, University

of Southern California; Frederick A. Lindvall, dean of engineering, California Institute of Technology; and Wm. G. Young, dean, Division of Physical Sciences, UCLA.

The committee presented its final report to the Board of Trustees in October. Basically, the committee approved the policies and operating procedures of the Foundation. Several recommendations for changes in procedure were made. These were later modified and adopted by the Board of Trustees.

The sanction of staff activities by a committee of such outstanding men was a great source of confidence to the staff.

Importance of Automobile Exhaust

As 1956 drew to an end, it became apparent to the Foundation that motor vehicles were the principal contributors to smog in Los Angeles. The following statement of the case is taken from the *President's Report, 1956*.

The evidence supporting the conclusion that motor vehicles are the principal contributors to smog is as follows:

1. Over one-half of our total air pollution comes from motor vehicles.
2. Three-fourths of the hydrocarbons in the air come from motor vehicles.
3. Two-thirds of the oxides of nitrogen come from motor vehicles.
4. Nitrogen dioxide, together with hydrocarbons and their derivatives, are the principal smog-forming air contaminants. In the presence of sunshine these materials react to form ozone. No other method of forming significant amounts of ozone in the lower atmosphere is known.
5. Typical smog damage to vegetation has been duplicated by subjecting plants to a mixture of ozone and hydrocarbons in amounts similar to those found in the Los Angeles atmosphere on smoggy days.
6. Scientific studies show that the only material in the air that is both capable of absorbing energy from sunlight and present in amounts sufficient to cause observed smog effects, is nitrogen dioxide.
7. Tests in large chambers have demonstrated that auto exhaust, in quantities similar to those in the Los Angeles atmosphere, produces oxidant and eye irritation when subjected to sunlight.
8. A study of wind trajectories in the Los Angeles Basin shows that air masses high in ozone values and eye irritation in downtown Los Angeles and in Pasadena nearly always passed over heavy traffic areas and in many cases did not pass over any other major pollutant source.
9. Scientific experiments have also shown that oxides of nitrogen at very low concentrations will react with hydrocarbons to form an aerosol capable of restricting visibility, even in the absence of sunlight.
10. A major portion of the carbon dioxide in our air derives from fossil fuels, i.e., petroleum.
11. A major portion of the carbonaceous particulate matter in our air is of fossil origin.

Dr. Hitchcock Resigns

In November, 1956, Dr. L. B. Hitchcock, president and managing director of the Foundation since its inception, resigned to return to private consulting work. He had done a remarkable job in organizing the Foundation staff and guiding the Foundation's activities during its first three years. He was succeeded as managing director by W. L. Faith. The presidency of the Foundation was combined with the chairmanship of the Board of Trustees.

1957 EMPHASIS ON AUTO EXHAUST

IT HAD BEEN decided in 1956 that the future program of the Foundation would be directed almost completely to a study of motor vehicle exhaust and its control. This was divided into two types of work: (1) determining the nature of the automobile exhaust-smog reaction and (2) how automobile exhaust could be controlled adequately and economically. Four technical reports, in addition to the *Third Technical Progress Report* (Report No. 17), were published.

Report No. 18. *Eye Irritation from Irradiated Auto Exhaust*, by E. A. Schuck.

This was the first comprehensive report of the studies in the smog chamber at Stanford Research Institute that had commenced early in 1955. The comparatively long period between inception and first publication of results was occasioned by the exploratory nature of the work and the need for the accurate calibration of the chamber, the measuring instruments, and the human eye irritation panel. Further, variations difficult to control in automobile engine operation and in the response of individuals to eye irritation made many experiments necessary in order to draw statistically valid results.

Two series of experiments were conducted. In the first series, the concentration of the exhaust in the controlled atmosphere was varied, as was also the residence time of the mixtures in the chamber. Eye irritation was determined for both irradiated and nonirradiated mixtures. In the second series, the irradiation and residence time were held constant and the proportions of three of the types of exhaust—idling, acceleration, cruising—were also held constant. The proportion of deceleration exhaust was varied.

Chief values of the published results were the demonstration of the smog-forming tendency of exhaust under a variety of conditions, the apparent importance of hydrocarbon-oxides of nitrogen ratio, and a preliminary understanding of the nature of the photochemical reaction.

Report No. 19. *Reactions of Auto Exhaust in Sunlight*, by F. V. Morriss and Calvin Bolze, Midwest Research Institute.

In this study carried out in comparatively large chambers subjected to direct sunlight, the chambers were charged with varied proportions of automobile exhaust, two different hydrocarbons, nitric oxide, and nitrogen dioxide. Oxidant formation and eye irritation were measured. The experimental pattern was statistically designed to yield maximum information.

From a study of statistically significant effects that were found, the following conclusions may be drawn:

1. Automobile exhaust, irradiated in concentrations similar to those found in the atmosphere of Los Angeles, produces both the oxidant and eye irritant manifestations of Los Angeles smog.
2. In these experiments, eye irritation increased as hydrocarbon level increased.
3. In a similar fashion, oxidant values increased as hydrocarbon level increased.
4. At hydrocarbon levels greater than those measured in the atmosphere, but at nitrogen oxide levels that have actually been experienced, oxidant formation was suppressed as hydrocarbon concentration increased. Eye irritation, however, continued to increase at these high levels, and this lack of correlation may be worthy of note.
5. Some factor in automobile exhaust makes it a more potent smog-former than the two pure hydrocarbons studied in combination with exhaust.
6. The role of the nitrogen oxides in smog formation is complex, and may be dependent on type and structure of the organic compound with which it reacts, as well as the ratio of concentrations.

At the time these results were published, many of the correlations could not be explained. In the light of recent information from other laboratories, the data are plausible.

Report No. 20. *Catalytic Decomposition of Nitric Oxide*, by Charles H. Riesz, Fred L. Morritz, and Karl D. Franson, Armour Research Foundation.

In order to arouse interest in research on the control of oxides of nitrogen, a member of the staff presented a paper* before the annual meeting of the American Institute of Chemical Engineers in 1956. Interest of Armour Research Foundation was evoked and a contract was let to study catalytic methods of eliminating nitric oxide from gas mixtures. A laboratory method was developed in which charcoal activated with potassium carbonate caused appreciable decomposition of nitric oxide. Unfortunately, this method was not practicable in the presence of oxygen-containing exhaust gases.

Report No. 21. *Automobile Exhaust and Smog Formation*, by W. L. Faith, N. A. Renzetti, and L. H. Rogers.

This was a staff report of the great amount of work that had been carried out on the subject, particularly during the past several years. The report covered: (1) the relationship of automobile exhaust to smog, (2) the internal-combustion engine, (3) nature of auto exhaust, (4) atmospheric analyses, (5) analytical methods and testing procedures, (6) control methods for exhaust, and (7) legal and enforcement problems.

Some of the material in Chapter 6, "Control Methods for Auto Exhaust," bears repetition here. Considerable information on the control of hydrocarbons from motor vehicles during the deceleration portion of the driving cycle had been developed by the automobile industry. As a result, several fuel cutoff devices, throttle retarders,

*Faith, W. L., "Nitrogen Oxides—A Challenge to Chemical Engineers," *Chem. Eng. Progr.* 52, 342-4 (1956).

and vacuum-controlled throttle openers were thoroughly tested by the industry. Efficiencies of 80 per cent were reported, but when it was found that the total contribution of the deceleration phase was less than 25 per cent, interest in this approach flagged.

One direct-flame afterburner had been developed by Clayton Manufacturing Company and had been tested on a bus engine by the Air Pollution Control District. The unit was found to be highly effective in burning exhaust hydrocarbons during idling and deceleration, but did not sustain a flame during acceleration and cruising.

This latter problem led the Foundation to initiate a study at Atlantic Research Corporation, Alexandria, Va., to determine the limiting conditions under which a flame could be supported in automobile exhaust gas mixtures. The report will be discussed in the next chapter.

The Search for Catalysts

An intriguing method of removing hydrocarbons from motor vehicle exhaust gases was by catalytic oxidation. This method is sometimes referred to as "flameless combustion," and it is essentially a method of burning organic materials at temperatures below those that will support a flame. This may be done by carrying out the oxidation in the presence of certain specially prepared minerals called "oxidation catalysts." Such a catalyst was the basis for the Oxy-Cat converter discussed previously.

Late in 1956, the Foundation had proposed specifications for a catalyst suitable for oxidizing exhaust hydrocarbons and had publicized the list. Even today, these specifications, listed below, are pertinent.

1. It should convert at least 90 per cent of the organics into carbon dioxide and water.
2. It should ignite at a relatively low temperature. (Some catalysts take 7-10 minutes to warm up.)
3. It must operate effectively under a wide variety of conditions. Hydrocarbon content of exhaust varies tremendously, depending on whether the car is accelerating, decelerating, cruising, or idling.
4. It has to be inert to lead, sulfur, barium, calcium, and phosphates with which it would come into contact.
5. It should operate effectively at a temperature low enough to allow use of mild steel housing.
6. It should retain effectiveness for at least 10,000 miles of car operation, regardless of the condition of the car.
7. Catalyst replacement should be cheap (less than \$10) and easily made.
8. The catalyst should not be adversely affected if flooded with gasoline or water.
9. It should not be fouled by partly burned lube oil. Ideally, it should also convert this into carbon dioxide and water.
10. It should preferably resist coating by molten-lead salts. But if not, the coating should spall off at high temperatures.
11. It should, preferably, not oxidize nitrogen.

In March, 1957, the Foundation, in cooperation with the Los Angeles County APCD, sponsored a two-day conference on "Catalytic Decomposition of Vehicular Exhaust Gases." Consensus of the group of experts who attended the meeting was that the major catalyst problem facing them was the anomaly of high catalyst activity at low temperatures and stability at elevated temperatures, particularly in the presence of lead compounds. Perhaps the most important result of the conference was the increased research activity in industrial laboratories where catalyst know-how was available.

By the end of the year, several promising preliminary reports on exhaust catalysts were published. At the "Third Southern California Conference on Elimination of Air Pollution" (again sponsored by the State Chamber of Commerce in conjunction with the Foundation and others), a General Motors spokesman reported promising results in a 10,000-mile test run with a catalytic converter attached to an automobile using leaded gasoline. Earlier, personnel of the Ford Motor Company had also reported good results with a different type of catalyst.

Plans for the Future

By the end of 1957, the Foundation had further delineated the areas of motor vehicle exhaust research in which it would concentrate its efforts.

On the recommendation of its Technical Advisory Committee, the research program was to be concentrated on two problems that so far had defied solution: (1) determination of the relative importance of engine and fuel variables and specific exhaust components on the formation of smog, and (2) development of scientific principles upon which effective exhaust control devices could be based.

1958 YEAR OF CONTROVERSY

ALTHOUGH 1958 was marked by two controversies in which the Foundation became involved (about which more later), it was also a year of considerable technical advance. Again, the nature of these advances can best be illustrated by discussion of the Foundation reports published during the year.

Report No. 23. *“Eye Irritation from Solar Radiation of Organic Compounds and Nitrogen Dioxide*, by E. E. Harton, Jr., and C. C. Bolze, Midwest Research Institute.

This was the second report of the group working under Foundation auspices in the two sunlit glasshouses at Midwest Research Institute. Previous work had shown differences in the chemical activity of automobile exhaust, a saturated hydrocarbon, and an olefinic hydrocarbon. Accordingly, a series of statistically designed experiments on the photochemical reaction between oxides of nitrogen and a great many specific hydrocarbons and other organic compounds was carried out. Major conclusions were:

1. Olefins produced more eye irritation than paraffins, and they produced more oxidant. The same was true for branched-chain olefins as compared with straight-chain olefins. Location of the double bond in olefins also appeared to influence eye irritation, but not oxidant formation.
2. Various commercial solvents produced little, if any, eye irritation.
3. In general, there was no correlation between eye irritation values and oxidant values.

In addition, a variety of anomalies were encountered that indicated the complexities of reactions that might be encountered in the atmosphere.

Report No. 24. *Photochemical Secondary Reactions in Urban Air*, by Philip A. Leighton and W. A. Perkins.

This was the second of two learned dissertations on atmospheric photochemistry prepared by Leighton and Perkins for the Foundation. The report was another scientific milestone in unraveling the complexities of photochemical smog, and, like the authors' first report (Report No. 14), it will serve for many years as a basic foundation for research in the field.

Report No. 25. *Combustibility of Simulated Automobile Exhaust Gases*, by Bernard Greifer and Raymond Friedman, Atlantic Research Corporation, Alexandria, Va.

One attractive means of controlling the smog-forming characteristics of automobile exhaust was the complete combustion, by direct flame, of the hydrocarbons in the exhaust gases. Unfortunately, this method of attack had not been successful because of the difficulties of burning the low-level concentrations found during acceleration and cruising. Because Atlantic Research Corporation had considerable experience in complex combustion problems, they were awarded a contract to determine the limit-

ing conditions under which exhaust hydrocarbons could be expected to maintain a flame. The report of their laboratory studies showed that combustion could be maintained if the gases entering the afterburner were heated to certain minimum temperatures suitable to the concentration of combustibles in the stream. The report gave considerable impetus to the development of practical afterburners.

Report No. 26. *Air Pollution Effects of Irradiated Automobile Exhaust as Related to Fuel Composition*, by E. A. Schuck and H. W. Ford, Stanford Research Institute, and E. R. Stephens, Franklin Institute.

Over a period of several years, reports from the Los Angeles County APCD had suggested that smog could be controlled by modification of the composition of gasoline used in the Los Angeles Basin. Examination of the laboratory methods used in the APCD's studies indicated that its procedures and equipment may have been inadequate for definite conclusions to be drawn.

A broad-scale study was therefore developed to study the influence of both fuel and engine variables on the production of photochemical smog. The smog chamber at Stanford Research Institute was particularly well suited to this study. The investigators were aided considerably by personnel and equipment from Franklin Institute who were under contract with the American Petroleum Institute.

The study showed that under some engine operating conditions, certain smog manifestations, particularly eye irritation, were related to fuel composition. More important, however, it was shown that in the range of practical fuels and the type of engine operation usually encountered, the effect of fuel composition was negligible.

During the course of the investigation, several new analytical tools were adapted to the study. This was a very rewarding experience, because it opened up new avenues of following the photochemical smog reaction in the chamber with even lower concentrations of contaminants than had been previously allowable.

One entirely unexpected result of the study was the finding that aerosol formation in the chamber was a function of the sulfur content of the gasoline. This result again opened up an entirely new field for investigation.

Exhaust Control Developments

During 1958, considerable progress was made by industrial concerns in the development of practical devices for the control of hydrocarbons in exhaust gases.

Thompson Ramo Wooldridge developed a direct-flame afterburner that involved use of a combination combustion chamber and heat exchanger. A prototype of the unit was tested briefly by the Foundation in the smog chamber at SRI. During the test, hydrocarbons and carbon monoxide were reduced by 90 per cent. Irradiation of the treated exhaust did not produce eye irritation.

A similar test was made of a catalytic converter developed by Ford Motor Company. Here, again, hydrocarbons were reduced to such levels that smog manifestations did not develop when treated exhaust was irradiated in the smog chamber.

Performance tests on three different catalytic converters were published by General Motors personnel, but no smog chamber tests were made.

Improved Maintenance

Ever since the motor vehicle had been suspected of contributing to the smog problem, suggestions had been made that relief from smog could be obtained by better

maintenance practices. The problem was brought into sharp focus late in 1956 when the Coordinating Research Council carried out an extensive survey of the exhaust emissions of several hundred automobiles in the Los Angeles area. To nearly everyone's amazement, the hydrocarbon and carbon monoxide emissions were several times higher than those that previously had been measured in Detroit. Actually, the emissions were so high, few automotive engineers believed engines could be in such poor condition. In 1958, results of exhaustive tests by Chrysler Corporation engineers became available. They showed unequivocally that high emissions of the type found in the survey could be attributed either to poor carburetor adjustment or to a faulty electrical system, or both. Major conclusions of the study were (1) Los Angeles area automobiles were in much poorer condition than those in other areas and (2) proper maintenance could reduce exhaust emissions by 60 per cent. Unfortunately, practical means of enforcing good maintenance are not available.

Controversies with the Los Angeles County APCD

The APCD Budget. When the Air Pollution Foundation was formed in 1953, the budget of the APCD (fiscal year 1953-54) was \$1,010,000. By the fiscal year ending June 30, 1958, the annual budget had reached \$4,067,000.

In March, 1958, the Air Pollution Control Officer asked the Foundation for comments on the proposed budget of \$3,800,000 for 1958-59. This was not unusual. In 1955, a similar request had been made when the Foundation was requested to comment on specific contemplated research projects. On that occasion, the Foundation supported the District, because it believed the proposed research program was well conceived and proper.

Review of the projects proposed for 1958-59 disclosed several projects that were duplicates of studies already completed elsewhere or which showed little promise of contributing to the solution of the smog problem. It was therefore recommended that the budget be reduced by \$650,000. Neither the Air Pollution Control Officer nor the County Board of Supervisors agreed with our suggestions and the budget was adopted essentially as proposed. During the budget hearings before the Board, the Foundation was accused of bias, self-interest, and of being "an oil company-supported institution." Obviously, this controversy produced strained relations between the Foundation and some County officials.

Relations became even more strained later in 1958 during the hearings on Rule 62.

Rule 62. In October, the APCD proposed an addition to the APCD Rules and Regulations directed toward the control of the sulfur content of fuels. The proposed rule was worded in such a way as to prohibit the burning of fuel oil in the District between May 1 and October 31 of any year.

Hearings were held by the Board of Supervisors for two days late in October. The hearings were marred by a high emotional pitch, misstatements, half-truths, and a general aura of confusion. As a consequence, the Foundation recommended to the Board of Supervisors that the hearings be recessed until January, 1959, to allow the Foundation to study available data and to prepare a factual report on the subject.

On October 30, the Foundation was requested to supply any pertinent data it might have or develop before November 13. This was an inadequate amount of time, but the Board was told a report would be sent them prior to January 15, 1959. The report

was filed with the Board January 13, despite the fact that Rule 62 was adopted in the interim (November 13, 1958).

In preparing the report, the staff evaluated all pertinent literature on Los Angeles smog and District data on emissions of contaminants from fuel-oil burning and data on the atmospheric concentrations of sulfur dioxide for the period 1953-58. Dr. Moyer D. Thomas of SRI was engaged to evaluate District data on vegetation damage. North American Weather Consultants, Santa Barbara, California, was selected to determine the likelihood of the occurrence of meteorological conditions that could lead to an air pollution catastrophe in Los Angeles and to determine the relationship between sulfur dioxide emissions and visibility.

The report submitted to the Board of Supervisors showed there was no scientific basis for Rule 62. Obviously, there must have been political reasons for the rule.

Federal Government Activities

The Federal Government entered the air pollution scene on a large scale with the passage of Public Law 159 in 1955. The 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. Authorization was granted for appropriation of funds up to \$25,000,000 over a five-year period. As a result, research was initiated in various governmental facilities, and particularly at the Taft Sanitary Engineering Center, Cincinnati, Ohio. Research grants were made to universities and research institutes for specific medical, scientific, and engineering studies. Scientific personnel were assigned, on a loan basis, to various state and local agencies and to universities; training courses were established for technicians. In addition, a National Air Sampling Network for measuring air-borne particulate matter was established, with stations in 225 communities.

In November, 1958, the U. S. Public Health Service sponsored a National Conference on Air Pollution in Washington, D. C. Purpose of the conference was to assess the atmospheric pollution problem in the United States in all its social, political, and scientific aspects. The proceedings of the conference were published as Public Health Service Publication No. 654; it still serves as an excellent resume of the state of our knowledge of air pollution matters as of that date.

The increasing activity of the Federal Government was one factor that contributed to the slackening of general activities on the part of the Foundation and concentration on the motor vehicle exhaust problem. As Federal research projects increased, the Foundation could focus its attention almost completely on the unique factors of Los Angeles smog.

We were thus able to decrease our staff in an orderly manner and to prepare for the day when others could take over our research and public information programs.

Dr. L. H. Rogers, chief chemist for the Foundation since its inception, resigned in late 1958. We were fortunate to be able to replace him, on a part-time consulting basis, with Dr. Philip A. Leighton. By this time, we had already curtailed our public information activities by gradually reducing our public information staff.

1959

STATE ATTACKS AUTO EXHAUST PROBLEM

AT THE END OF 1958, we estimated that two more years of work by the Foundation would complete the basic research phase of the Los Angeles smog problem. We expected that in two more years we could provide sufficient essential facts to allow private industry to produce workable, economic controls for automobile exhaust and thereby have a means of eliminating Los Angeles smog. We hoped that concurrent development in the legislative field and in industrial laboratories would accent the accumulation of basic information and help us achieve our goal. We were not disappointed.

Legislative Advances

It had become obvious at the end of 1958 that the control of motor vehicle exhaust was a bigger problem than could be handled at the county level, so Los Angeles' air pollution officials and our State legislators took their case to Sacramento.

They explained to Governor Brown and to various legislative committees that county control of heavy intercounty traffic would be an almost impossible task. Representatives from other areas, principally the Bay Area and the Central Valleys, pointed out that smog from motor vehicle exhaust was gradually building up in many California communities.

Some wanted a law to force the installation of control devices not yet invented, but the Legislature turned this down. Three laws were passed, however, which greatly accelerated the drive toward adequate control.

Assemblyman William B. Rumford and others introduced an act directing the State Director of Public Health to develop and publish standards for the quality of air in California. The act stated:

"The standards shall be so developed as to reflect the relationship between the intensity and composition of air pollution and the health, illness, including irritation to the senses, and death of human beings, as well as damage to vegetation and interference with visibility."

A second law, the Rees-Richards Act, further instructed the State Director of Public Health to:

"... determine by February 1, 1960, the maximum allowable standards of emissions of exhaust contaminants from motor vehicles which are compatible with the preservation of public health including the prevention of irritation to the senses."

The third part of the package was an act directing the State Department of Motor Vehicles to study the problem of motor vehicle inspection.

In pursuance of these directives, the State Director of Public Health on December 4, 1959, recommended certain air quality standards and motor vehicle standards to the California State Board of Public Health. The recommendations were subsequently adopted. The importance of the standards is such that they are outlined here.

CALIFORNIA STANDARDS FOR AMBIENT AIR QUALITY

Reasons for each standard are shown in *italics*

POLLUTANT	“ADVERSE” LEVEL	“SERIOUS” LEVEL	“EMER- GENCY” LEVEL
	Level at which there will be sensory irritation, vegetation damage, reduction in visibility, or similar effects	Level at which there will be alteration of bodily function or which is likely to lead to chronic disease	Level at which it is likely that acute sickness or death in sensitive groups of persons will occur
Oxidant Ozone Nitrogen Dioxide Hydrocarbons Photochemical Aerosols	“Oxidant Index” 0.15 ppm for 1 hr by the potassium iodide method (<i>eye irritation, plant damage, and visibility reduction</i>)	No standard set	No standard set
Sulfur Dioxide	1 ppm for 1 hr or 0.3 ppm for 8 hrs (<i>plant damage</i>)	5 ppm for 1 hr (<i>bronchoconstriction in human subjects</i>)	10 ppm for 1 hr (<i>severe distress in human subjects</i>)
Carbon Monoxide	No standard set	30 ppm for 8 hrs or 120 ppm for 1 hr (<i>interference with oxygen transport by blood</i>)	No standard set
Particulates	Sufficient to reduce visibility to less than 3 miles when relative humidity is less than 70%	No standard set	No standard set

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CALIFORNIA STANDARDS FOR MOTOR VEHICLE EXHAUST

Hydrocarbons*	275 parts per million by volume as hexane (0.165 mole per cent carbon atoms)
Carbon Monoxide**	1.5 per cent by volume

*Calculated on the basis that an over-all 80% reduction is needed.

**Calculated on the basis that an over-all 60% reduction is needed.

The standards refer to a composite sample representing an average driving cycle. Exhaust gas concentrations shall be adjusted to a dry exhaust volume containing 15% by volume of carbon dioxide plus carbon monoxide.

Hydrocarbons are defined as the organic constituents of vehicle exhaust, as measured by a hexane-sensitized nondispersive infrared analyzer or by an equivalent method. Carbon monoxide shall be measured by a nondispersive infrared analyzer or an equivalent method.

Industrial Advances

No completely satisfactory control device for automobile exhaust was developed during 1959, but the industrial effort to produce such a device was intensified. Work continued on the three devices previously mentioned, the Thompson Ramo Wooldrige afterburner, the Houdry catalytic muffler, and the Ford Motor Company's catalytic muffler.

General industrial activity in the field intensified so much that the Foundation engaged a New York consultant, Dr. John G. Dean, to follow these activities, particularly in the eastern part of the United States. Dr. Dean was particularly fitted to this assignment, not only because he was a competent and experienced chemist and metallurgist, but he was also an expert on catalysis.

He, and other members of the staff during 1959, visited 25 industrial laboratories developing catalysts or catalyst components specifically for exhaust control. Six of these concerns, and at least five others, were also working on direct-flame afterburners. Many of the developments in these laboratories were more advanced than those which had been publicized. As a consequence, we were confident that at least three effective devices would be developed by the end of 1960.

The program was set back somewhat, however, when the State Department of Public Health included carbon monoxide as one of the elements to be controlled in motor vehicle exhaust. Prior to this time, we had proceeded on the theory that only the olefinic hydrocarbons needed to be controlled in order to eliminate smog. Carbon monoxide, although a dangerous air pollutant in high concentrations, was known not to take part in the atmospheric photochemical reaction that produced Los Angeles' smog.

A few so-called low-temperature catalysts that had been developed to remove olefins selectively from exhaust had to be discarded. Fortunately, high-temperature catalysts and direct-flame afterburners burned carbon monoxide as well as hydrocarbons.

Basic Research Advances

Practically all the basic research work sponsored by the Foundation in 1959 was centered around the smog chamber at Stanford Research Institute. The only other project of importance was one at Franklin Research Institute. Results of the two projects were published during the year as Reports 28 and 29.

Report No. 28. *Elimination of Oxides of Nitrogen from Automobile Exhaust*, by Francis R. Taylor, Franklin Institute, Philadelphia.

The objective of the study was to find means of eliminating nitric oxide from motor vehicle exhaust. This method of controlling smog formation has one very appealing aspect; i.e., the probable chemical reactions by which nitric oxide can be destroyed do not liberate heat and do not require the addition of air, as does hydrocarbon oxidation.

The results of the study were highly encouraging. It was found that various chromium-containing catalysts would speed up the reaction between NO and CO, NO and hydrogen, and straight decomposition of nitric oxide to the point where almost complete elimination of nitric oxide could be attained at relatively moderate temperatures and at gas flow rates that are encountered at high automotive speeds.

An unexpected dividend accrued when it was found that the same catalyst would also catalyze the oxidation of olefins, without affecting the elimination of nitric oxide, if small amounts of air were carefully added.

This work was carried out only on a laboratory-bench scale and had to be confirmed in an automotive laboratory.

Report No. 29. *Photooxidation of Hydrocarbons in Mixtures Containing Oxides of Nitrogen and Sulfur Dioxide*, by E. A. Schuck and G. J. Doyle, Stanford Research Institute.

This was the third extensive report of the group working under Foundation auspices at Stanford Research Institute.

In previous studies, the group had shown that the only way one could reproduce typical smog symptoms in the laboratory was by irradiation of motor vehicle exhaust. They had also shown that gasoline composition was not an important factor in production of smog. Chromatographic analysis of exhaust hydrocarbons during irradiation indicated marked variations in the rate at which various exhaust hydrocarbons partake in the smog reaction. For 1959, therefore, it was decided to study the role of individual hydrocarbon species in the smog-producing reactions.

A wide variety of olefinic, paraffinic, aromatic, and heterocyclic hydrocarbons were reacted with nitrogen dioxide in the smog chamber in the presence of simulated sunlight. The rate of disappearance of the hydrocarbon was monitored; the air mass was analyzed for various reaction products; and the irradiated mixture was tested for eye irritation. Simultaneously with these studies, the formation of aerosols from similar reactions in the presence of sulfur dioxide was studied in small reaction flasks.

The results of these experiments were enlightening and of considerable practical significance. Major results and conclusions were:

1. Olefinic hydrocarbons were the only species which reacted fast enough to account for smog formation.
2. Only those olefins that yield formaldehyde or acrolein by initial oxidation produced noticeable eye irritation. Indications are therefore that the eye irritants in smog are chiefly formaldehyde and acrolein. Other minor irritants may also be present.
3. All olefins yielded ozone on photooxidation. Certain branched-chain paraffins also produced ozone, but so slowly that this reaction is probably not important in the atmosphere.
4. A visibility-blurring aerosol was produced by irradiation of olefin-nitrogen dioxide mixtures, but only when small amounts of sulfur dioxide were present. Even with sulfur dioxide present, irradiation of paraffin-NO₂ and aromatic-NO₂ mixtures did not produce an aerosol.
5. Several common industrial solvents were also studied to determine their participation in the smog-forming reaction. They were found to be unreactive.

The practical significance of this work is apparent. If only olefinic hydrocarbons were responsible for smog symptoms, this would be the only class of hydrocarbons that need be removed from motor vehicle exhaust gases.

Fortunately, olefinic hydrocarbons are much more susceptible to oxidation (burning) than other types of hydrocarbons and thus can be readily removed by catalytic means. Preferential oxidation of olefins in exhaust gases will result in much less heat liberation (something to be desired) than if all the combustibles were burned. Further, the reaction may be initiated at a lower energy level (also something worth striving for). Recognition of these factors will probably result in simplified exhaust afterburners.

As mentioned previously, however, this finding became academic, at least as far as California is concerned, when carbon monoxide limitations were placed on motor vehicle exhaust emissions.

Other Laboratories

Basic research on photochemical smog continued at several other laboratories throughout the United States and Canada. One of the functions of the Foundation staff was to keep continually advised of important results elsewhere and correlate them with the studies at SRI. This liaison was a specific charge of our chemical consultant, Dr. P. A. Leighton, and our chief physicist, Dr. N. A. Renzetti. Although Dr. Renzetti left the full-time staff in September, he remained a part-time consultant of the Foundation through 1960.

Specific photochemical research studies of importance that were followed closely were those of Calvert and co-workers at Ohio State University, Cvetanovic in Canada, and several workers at Franklin Institute. Their reports threw considerable light on the mechanism of photochemical reactions in polluted atmospheres.

Another study of considerable value was an extensive set of experiments by Darley and coworkers at the University of California at Riverside on the plant-damaging and eye-irritating effects of ozone-hydrocarbon mixtures. Their results were of considerable value in interpreting the data from the SRI smog chamber.

Fuel Composition

Research studies at SRI during 1958, and published in Report No. 26, convinced us that the influence of fuel composition on the production of smog by motor vehicle exhaust was of a low order of importance. In our studies at SRI, we had found that fuels of very high olefinic content ($> 50\%$) produced somewhat more reactive exhaust hydrocarbons than fuels of lower olefin content. On the other hand, fuels in common use rarely contained as much as 25 per cent olefins. Below this level, we could not distinguish one fuel from another insofar as smog formation from exhaust gases was concerned. We concluded that regulation of the composition of automotive fuels was an unpromising approach to the problem of urban air pollution.

For several years, however, the Los Angeles County Air Pollution Control District had theorized that reduction of the olefin content of gasoline would decrease the incidence and severity of smog. Accordingly, in June, the District proposed Rule 63, which would restrict the olefin content of gasoline sold in Los Angeles County. After a study of the experimental procedures used by the District, and a review of the data obtained, the Foundation concluded that the proposed rule was not based on scientific facts and would result only in higher gasoline prices and no diminution of smog. The Board of Supervisors was so informed.

No other opposition developed, so despite the fact that District data supporting the rule were of doubtful significance, the rule was passed. The rule limited gasoline sold in Los Angeles County to a 30 bromine number (approximately 15 per cent olefins) after June 30, 1960, and to a 20 bromine number (approximately 10 per cent olefins) after December 31, 1961. The Board of Supervisors did recognize the tenuous basis for the rule and adopted a resolution calling for an intensified research effort to determine whether the values selected should be raised or lowered.

Subsequently, the U. S. Bureau of Mines published several papers reporting studies of the relationship between the olefin content of fuel and the olefin content of exhaust gases. One of the conclusions is:

“More precisely, the majority of experimental data from this laboratory shows a slight trend toward *decreased olefin emissions* with *higher olefinic* content of the fuel.”

Nevertheless, the rule has not yet been rescinded.

Only One More Year Required

At the Annual Meeting of the Foundation's Board of Trustees on November 12, 1959, Fred D. Fagg, Jr., in “The President's Message,” said:

“After six productive years of pioneering activities by the Foundation, completion of the scientific work necessary for an economic end to our smog problem is now within one year's reach.

“This represents high accomplishment. Obviously, the basic research conducted by the Foundation is principally responsible. But the Foundation has also provided technical leadership and has welded noteworthy cooperation among public agencies, private groups, and individuals working on various aspects of air pollution. And through its public information activities, the Foundation has won the confidence of opinion leaders and important support for the thesis that *given time and the necessary funds, science and engineering will eliminate smog.*

“Now we have reached the time when the original plan for the Foundation is near fulfillment. Our scientific staff advises that, granted sufficient finances, the remaining research required for a workable and satisfactory solution to the smog problem will be completed by the end of 1960.

“The Board of Trustees is confident that the reaction of the Southern California business community to this unequivocal declaration will be that any job so vital to all who live and work here, and which CAN be completed in one more year, SHOULD AND MUST be completed in that time. Delay would be indefensible.

“Accordingly, the Foundation’s Trustees have decided that 1960 shall be the final year for which we will raise operational funds and that the Foundation shall be dissolved thereafter upon conclusion of the staff’s work.

“During the liquidation period—the early months of 1961, for which no additional financing will be required—the Foundation will interpret and sum up its final year’s findings, thus completing the scientific solution to the intricate smog problem, and publish its concluding reports for the guidance of those in private industry and government whose obligation it will be to make full and proper use of the solution in bringing about the actual end of smog. When the Foundation removes itself from the scene, it will be with the knowledge that its intended role in betterment of the public welfare has been discharged.”

1960 FINAL YEAR OF RESEARCH

WITH THE KNOWLEDGE that 1960 would be our final year of operation, plans had to be made for an orderly demise. We therefore set the following goals:

1. Establishment of research projects *jointly* with other sponsors, who would be able to support continuing projects at least to some degree after the Foundation was dissolved.
2. Publication of summary articles that would outline progress to date and point out areas of knowledge where further investigations were needed.
3. Continued liaison with industrial laboratories and government for the purpose of accelerating the motor vehicle pollution control program.
4. Liquidation of the assets of the Foundation early in 1961 and dissolution of the corporation.

Of the several research programs supported in 1960, two were of such a nature and scope as to result in technical progress reports. These were:

Report No. 31. *A Progress Report on the Photochemistry of Polluted Atmospheres*, by E. A. Schuck, George J. Doyle, and Noboru Endow, Stanford Research Institute.

This project, which was a continuation of studies made for us by Stanford Research Institute since 1955, was supported jointly by the Foundation and the U. S. Public Health Service through a National Institutes of Health grant to SRI. The report presented further information concerning the nature of the photochemical smog reaction, particularly with regard to eye irritation and haze formation. Previous work had shown that the major products of the photooxidation were produced by rupture of the double bond in the reacting olefin. In certain cases, however, products appeared which could not be accounted for by simple bond rupture. Results of the current project showed how secondary photooxidation of initial products could account for a portion of the final products. It was further shown that part of the olefin oxidation could be effected by alkyl nitrites, which were identified among the minor products of olefin photooxidation. At the present time, the eye irritants in the atmosphere appear to be formaldehyde and peroxyacyl nitrates, and possibly acrolein.

It was also conclusively demonstrated that eye irritation from motor vehicle exhaust irradiation could be controlled by reduction of exhaust olefins. Indications were that oxides of nitrogen control would not be nearly so effective, inasmuch as very small amounts of nitrogen oxides (0.1 ppm) could oxidize a sufficient amount of olefin in the atmosphere to produce noticeable eye irritation.

Further work was also done on the role of sulfur dioxide in the production of the photochemical aerosol, one of the hallmarks of Los Angeles smog. No other nucleiformers tested (sodium chloride, sodium carbonate, and lead chloride) produced

photochemical aerosols. On the other hand, extremely small quantities of sulfur dioxide (in the order of 0.01 ppm) were sufficient to initiate nuclei formation.

Considerably more research appears to be necessary to elucidate the photochemical atmospheric reaction. It was heartening, therefore, to learn that further support will be given this project by the National Institutes of Health. To further aid this work, the Foundation in December donated to SRI all the equipment it owned that was being used on the project, together with a cash grant of \$50,000.

Report No. 32. *Total Hydrocarbon Emissions from Automobiles*, by Paul R. Lepisto, *et al.*, Southwest Research Institute, San Antonio, Texas.

In January, 1960, General Motors engineers reported data showing that in some cases hydrocarbon emissions in crankcase blowby gases were of the same order of magnitude as those emitted in the exhaust. This was subsequently corroborated by workers at the U. S. Public Health Service Taft Sanitary Engineering Center in Cincinnati. Attention was also called by other groups to evaporation losses from carburetors and fuel tanks.

Speculation as to the relative magnitudes of these various automotive sources of hydrocarbons led the Foundation to contract with Southwest Research Institute to measure the total hydrocarbon emission from a selected group of automobiles. It was hoped that such a study would place the various emissions in proper perspective.

Five different cars were examined. They were in various conditions of maintenance, equipped with different types of carburetors, and operated in different traffic patterns, using fuels similar to those sold in Los Angeles. Results indicated that 70.2% of the hydrocarbons emitted were in the exhaust gases; 24.0%, in crankcase blowby; less than 0.1%, carburetor running losses; 2.8% by tank fuel evaporation; and 2.9% by fuel evaporation from the carburetor during hot soak, *i.e.*, during standing after the vehicle had been in operation. It was concluded that both exhaust and blowby hydrocarbons would have to be controlled to eliminate smog, but that the other emissions were too small to be of significance.

Other Research Projects

Several smaller research programs were also supported during 1960. Generally, these were meant to clarify minor points or to initiate longer range projects that could be carried on by others after dissolution of the Foundation. The chief projects were:

Development of an Instrument for Measuring SO₂. For several years, the Atomic Energy Commission's Office of Isotopes Development had been sponsoring a research project at Tracerlab, Inc., Waltham, Mass., to develop an ozone-monitoring instrument based on radio-isotope analysis. The work had resulted in a device based on a reaction between ozone and a clathrate compound containing the radioisotope, krypton-85. Under proper conditions, ozone reacted with the clathrate and liberated krypton-85, which could be measured by an instrument similar to a Geiger counter.

In the course of this study, Tracerlab found that a similar reaction might be made suitable for the analysis of atmospheric sulfur dioxide. Development of a simple atmospheric monitoring device for sulfur dioxide, particularly one which did not require the use of solutions, had been on the Foundation's agenda for some time. However, because of the difficulty of the study, the necessary development could not

possibly be completed before the Foundation would be dissolved. Accordingly, we made an agreement with the Atomic Energy Commission whereby we would support the study for the last six months of 1960 if the AEC would support the work after that time, depending, of course, on the progress made in the meantime.

Results obtained in 1960 were recently published in our *Seventh Technical Progress Report* (Report No. 33). Although many difficulties remain, the six-month study indicated the approach was promising. Consequently, the study is presently being supported by the Atomic Energy Commission.

Development of an Olefin-Measuring Instrument. Early in 1960, attention of the Foundation was called to a laboratory procedure for the measurement of olefins by Dr. S. W. Nicksic of California Research Corporation while working in the laboratories of the Los Angeles County APCD.

The process developed (a bromination procedure) appeared to be adaptable to a simple, inexpensive, portable instrument, which was very badly needed both for measurement of atmospheric olefins and for the measurement of olefins in motor vehicle exhaust. The Foundation therefore sought agreement with Dr. Nicksic and the APCD to allow us to contract for the manufacture of two instruments based on the bromination technique. As a result, a contract was let to Mast Development Co., Inc., Davenport, Iowa, to modify the process and to adapt it to two instruments, one to monitor low concentrations of olefins in air, the other to measure the comparatively higher concentrations in motor vehicle exhaust.

Two commercial prototype instruments which show considerable promise of being useful were manufactured. The atmospheric unit was donated to the California State Department of Public Health for field trials. The other unit was donated to the Taft Sanitary Engineering Center of the U. S. Public Health Service for evaluation as an exhaust measuring device. Greater detail was published in our Report No. 33.

Air Monitoring for Suspected Eye Irritants. The studies at SRI and those conducted at the University of California at Riverside indicated that the principal eye irritants in Los Angeles smog were formaldehyde, acrolein, and peroxyacyl nitrate (PAN). Excellent correlations between the concentrations of these three materials and eye irritation had been obtained in laboratory studies. However, because of the many differences that had been noticed between laboratory atmospheres and the ambient air, it was believed wise to attempt to measure the concentrations of suspected irritants in the actual atmosphere and to correlate these concentrations with eye irritation reported by panels of people for the same atmosphere.

Accordingly, the Foundation (through Truesdail Laboratories) and the APCD entered into a joint study in which concentrations were measured at certain morning hours at 434 South San Pedro Street, Los Angeles, and in the afternoon at 820 Mission Street, South Pasadena. Eye irritation was also measured once each day at each location (at the midpoint of the sampling schedule). The study was conducted five days each week between July 5 and November 18, 1960.

Generally speaking, the data obtained neither corroborated nor invalidated the theory. A great many anomalies were encountered, such as incidences of eye irritation when aldehydes were not found in the atmosphere. It is believed that a combination of analytical difficulties and variable factors affecting eye irritation measurement in the ambient air contributed to the scatter of the data. One cannot, however,

discard the possibility that some mechanism other than the formaldehyde-acrolein theory must also be operating in the ambient atmosphere.

Development of Catalyst for Nitrogen Oxide Control. Previous work at Franklin Institute had indicated that chromite catalysts were effective in the removal of nitric oxide from simulated automobile exhaust gases passed over the catalyst at a constant rate. Accordingly, a project was placed with Scott Research Laboratories, Perkasio, Pa., to test these catalysts on automobile exhaust.

Generally, it was found that with excess air added to the exhaust gases, nitric oxide was not eliminated but that hydrocarbons and carbon monoxide were oxidized; only in the absence of added air was nitric oxide removed by the catalyst. This leads one to believe that a system could be devised for removing all three contaminants (NO, CO, and hydrocarbons) from exhaust gases. Further studies will, however, be required.

Grants-in-Aid for Air Pollution Research

Besides the previously mentioned grant made to SRI, two other grants were made during 1960. In December, a grant of \$10,000 was made to the University of Southern California for general studies on the air pollution problem. In August, a grant of \$11,200 had been made to the University of California at Riverside to aid their studies on vegetation damage. Several other grants of both cash and equipment had been made to UCR over a period of years. By far the most effective work done on the relationship of air pollution to vegetation was that carried out and published by UCR scientists. The various gifts made to them by the Foundation probably represented the most effective utilization of funds of any the Foundation spent. This statement in no way detracts from the excellent work done by others with Foundation grants, notably UCLA and Caltech.

Public Information Activities

For several years the Foundation had been asked repeatedly for a brief dissertation describing air pollution in general and smog in particular for use by high school students. Accordingly, a 20-page pamphlet titled "Air Pollution and Smog" was prepared by Don Kirby, Foundation Public Information Officer, in May. Approximately 18,000 copies were distributed by the Foundation and by the Los Angeles County APCD.

A second brochure, "The Air Pollution Problem—An Appraisal," by W. L. Faith, Managing Director (36 pp) was released in November. Requests for this brochure were so many that 50,000 copies were eventually printed.

The Air Pollution Foundation Newsletter was published bimonthly for the third successive year. The final issue was sent out in December. Although the Newsletter had a circulation (nonpaid) of only 2500, we believe it served a worthwhile function in keeping opinion leaders apprised of current air pollution problems and developments in Los Angeles.

Motor Vehicle Pollution Control

The greatest development of the year 1960 was the passage of the California Motor Vehicle Pollution Control Bill (AB 17) by the Legislature in April. This was a

necessary step if Los Angeles and other parts of California were ever to solve the smog problem.

Basically, the bill provided for the Governor to appoint a 13-man Motor Vehicle Pollution Control Board, which would be delegated to issue certificates of approval for motor vehicle pollution control devices which after testing were found to operate within the standards set by the California State Board of Health, and which would meet other criteria adopted by the Board.

One year after certification of at least two devices, no new motor vehicle may be registered in California unless it is equipped with a certified device, nor may any used motor vehicle upon transfer of ownership be registered unless and until it is equipped with a certified device. Certain "smog-free" areas could be exempt by due process of law from the provision referring to used cars either listed in the above or in the following statements.

After the second December 31 that follows certification, no used commercial vehicle shall be registered unless it is equipped with a certified device, whether the vehicle is sold or kept by its owners.

After the third December 31, the law is extended to cover all remaining vehicles, except those that may be exempt by the Board. It is expected that exemption will be granted to diesel engines, motorcycles, farm machines, and other classifications for which devices are either unnecessary or not available.

The Board was appointed in May and got to work in July. By the end of the year it had established an office in Los Angeles, hired an administrative officer and some staff, held five meetings in different parts of California, contracted for the services of a testing laboratory, prepared and distributed application blanks for submission of devices for test, and announced its willingness to begin testing.

A great many policy decisions had to be made before the Board could expect to receive devices for testing. Among the important decisions made were the following:

1. The Board would test devices in well-defined steps. Step I testing would be chiefly to determine if a device met the standards adopted by the State Board of Health with regard to hydrocarbon and carbon monoxide emissions.
2. The Board adopted a policy statement regarding its ultimate intention to control blowby or crankcase emissions. This decision was occasioned by three events.
 - a. Research findings by several groups that crankcase blowby amounted to a significant percentage of total hydrocarbon emissions from motor vehicles.
 - b. Adoption of a standard for motor vehicle crankcase vent emissions by the State Board of Public Health in December (allowable emission of 0.15 per cent of supplied fuel at specified modes of operation).
 - c. The availability of crankcase blowby control devices, as shown by voluntary installation on all 1961 model automobiles sold in California by American motor car manufacturers.
3. The Board adopted a policy that criteria for device certification, in addition to public health standards, would be established and would include life (not less than 1 year), warm-up time, effect of abusive driving, odor, noise, safety, and similar factors "to the best interests of the buying public."

Motor Vehicle Pollution Control Device Development. Although no devices had been offered the Board by the end of the year, many companies were known to have reached a point in design and development where only a knowledge of final criteria and standard test procedure precluded submission of devices for test.

The Foundation was kept advised by many manufacturers of their progress, and interpreted for them the almost daily procession of events related to the motor vehicle pollution problem.

Two general types of exhaust control devices (direct flame and catalytic) appeared to be ready for testing. Most of the direct-flame afterburners took advantage of heat conservation by use of internal heat exchangers; others required the addition of a small amount of fuel to sustain a flame under all operating conditions. Catalyst manufacturers had apparently overcome the problem of catalyst deactivation by deposition of lead salts (from the antiknock fluid in the gasoline). High temperature deactivation had been surmounted by internal design. Both types of devices appeared competitive. Price range was expected to be in the neighborhood of \$75-125.

Announcement of Plans to Dissolve Foundation

In December, the Foundation formally announced plans for its liquidation early in 1961, subject to the approval of the Superior Court. Under the plan submitted to the Court, any residual assets of the Foundation at the time of its dissolution will be donated to Caltech for additional research work in the field of air pollution.

In releasing the news of dissolution to the press, the Foundation said:

Inasmuch as we know that motor vehicle exhaust is the sole remaining source of smog in Los Angeles, and the State of California has embarked upon its control, the end of the 20-year smog siege is now in sight.

By the time the Foundation closes its doors, all the basic scientific research will be completed, and the technical reports published, to enable engineering to carry out its function of constantly improving, year by year, the efficiency of present-day prototypes of automobile exhaust control devices that will eventually make Los Angeles-type smog only a memory.

1961 DISSOLUTION—AND BEYOND

THE ACTIVITIES of the Foundation during the first part of 1961 were primarily of the nature of an orderly liquidation. Reports had to be written, assets converted largely to cash (exceptions are the library and certain air-monitoring instruments which could be utilized by Caltech as is), and outstanding debts had to be paid. Extra copies of Foundation reports and reprints were distributed to those who could best use them.

Dissolution now awaits the final hearing on the liquidation procedure which has been set by the Superior Court for May 24, 1961.

The Future in Los Angeles

Now that the cause of eye-irritating smog (motor vehicle exhaust) is known, and the State of California has set up means for its control, what does the future hold for Los Angeles? Will the State Board do a thorough job and require control devices on all motor vehicles, or will so many exemptions be made that smog will be only slightly alleviated?

One can only resort to conjecture, but close affiliation with the Motor Vehicle Pollution Control Board can only impress one as to the dedication of its members to do the necessary job and to do it in the best interests of the entire community. As with all public activities, political considerations may at times take precedence over technical factors, but these are not expected to be major stumbling blocks. The public is determined to put an end to the smog menace, so the Board will have plenty of support. Probably the greatest delay will be in equipping very old automobiles, but they will have to be controlled if smog is to be eliminated. If all goes as expected, the area should be truly "smog-free" by the summer of 1968.

In the meantime, there will be concentrated efforts to reduce even further the remaining emissions from stationary sources. Some of the proposals will undoubtedly be capricious if one is to judge from recent Rules 62 and 63. This problem of more and more control based on suspicion or a supposed need to show official concern poses economic problems that can only result in great harm to the community if officials fail to consider economics. One can make the air over Los Angeles as "pure" as that over the High Sierras, but in so doing the community could be destroyed. On the other hand, one can have reasonably clean air and a thriving community as well, if the equities are considered in the development of air pollution legislation.

The one difficult problem to be overcome not only in Los Angeles, but elsewhere, is the hiatus in our knowledge relating human health to air contaminants. This can be solved only by research, and probably research at the Federal level or supported largely with Federal funds. The misguided hypochondriacs who seize every opportunity to harass the economy by shouting for more control of everything (but with-

out evidence of need) are doing themselves a disservice. The same amount of energy well directed could give considerable impetus to securing adequate funds for medical research.

This does not mean that some laws may not have to be tightened, and occasionally new ones written. It only means that a reasonable need for control must exist before a control law is activated. Only high-grade research can show what is reasonable and what is not. It must then be made available to officialdom in language easy to understand. The press, radio, and TV have some responsibility here. Controversy may increase readers, listeners, and viewers, but in matters as ubiquitous as air pollution, the thoughtful editorial greatly outweighs the controversial headline.

Another factor that must be considered is the changing modes of American communities. Plants locate in a given place and control their emissions accordingly. But as people move closer to the plant, more stringent control becomes necessary. This means more stringent laws.

All of these factors will become more important in Los Angeles. But basically the smog problem will be resolved only as the control of automotive exhaust is effected. Any added controls on stationary sources will produce unnecessary economic problems until the results of health-oriented research dictates otherwise. In the final analysis, however, of the basic problems facing Los Angeles, i.e., air, water, transportation, and communications, the first to be solved may well be air.

APPENDIX

OFFICERS OF THE FOUNDATION (1953-1961)

1953-1954

Fred D. Fagg, Jr., <i>Chairman, Board of Trustees</i>	James E. Shelton, <i>Treasurer</i>
Stephen W. Royce, <i>Vice Chairman</i>	Leroy A. Garrett, <i>Secretary</i>
Lauren B. Hitchcock, <i>President</i>	Robert S. Weatherly, <i>Asst. Treasurer</i>

1955

Raymond B. Allen, <i>Chairman, Board of Trustees</i>	James E. Shelton, <i>Treasurer</i>
Arnold O. Beckman, <i>Vice Chairman</i>	Gerald G. Kelly, <i>Secretary</i>
Lauren B. Hitchcock, <i>President</i>	Robert S. Weatherly, <i>Asst. Treasurer</i>
W. L. Faith, <i>Vice President</i>	Murray S. Marvin, <i>Asst. Secretary</i>

1956

Lee A. DuBridge, <i>Chairman, Board of Trustees</i>	W. L. Faith, <i>Vice President</i>
Walter Braunschweiger, <i>Vice Chairman</i>	James E. Shelton, <i>Treasurer</i>
Lauren B. Hitchcock, <i>President</i>	Gerald G. Kelly, <i>Secretary</i>
	James B. Russell, <i>Asst. Treasurer</i>
	Murray S. Marvin, <i>Asst. Secretary</i>

1957

A. J. Gock, <i>President and Chairman, Board of Trustees</i>	Gerald G. Kelly, <i>Secretary</i>
J. Howard Edgerton, <i>Vice President</i>	Robert L. Hunt, <i>Asst. Treasurer</i>
Frank L. King, <i>Treasurer</i>	Murray S. Marvin, <i>Asst. Secretary</i>

1958

Fred D. Fagg, Jr., <i>President and Chairman, Board of Trustees</i>	Gerald G. Kelly, <i>Secretary</i>
F. M. Banks, <i>Vice President</i>	Robert L. Hunt, <i>Asst. Treasurer</i>
Frank L. King, <i>Treasurer</i>	Murray S. Marvin, <i>Asst. Secretary</i>

1959-1961

Fred D. Fagg, Jr., <i>President and Chairman, Board of Trustees</i>	Gerald G. Kelly, <i>Secretary</i>
F. M. Banks, <i>Vice President</i>	Robert L. Hunt, <i>Asst. Treasurer</i>
Harry M. Bardt, <i>Treasurer</i>	Murray S. Marvin, <i>Asst. Secretary</i>

BOARD OF TRUSTEES (1954-1961)

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Chancellor, University of California at Los Angeles
1954-1958

LEE A. DuBRIDGE
President, California Institute of Technology
1954-1961

J. L. ATWOOD
President, North American Aviation, Inc.
1955-1961

J. HOWARD EDGERTON
President, California Federal Savings
1955-1961

F. M. BANKS
President, Southern California Gas Company
1954-1961

FRED D. FAGG, JR.
President Emeritus, University of Southern California
1954-1961

1954-1961
HARRY M. BARDT
Executive Vice President, Bank of America
1958-1961

LEONARD K. FIRESTONE
President, Firestone Tire & Rubber Company of California
1955-1961

WELTON D. BECKET
President, Welton Becket and Associates
1957-1961

J. S. FLUOR
President, The Fluor Corporation, Ltd.
1958-1961

GARNER A. BECKETT
Honorary Chairman of the Board, American Cement Corporation
1955-1961

Y. FRANK FREEMAN
Vice President, Paramount Pictures Corporation
1955-1961

ARNOLD O. BECKMAN
President, Beckman Instruments, Inc.
1954-1961

A. J. GOCK
Director, Bank of America
1955-1961

MILO W. BEKINS
President, Bekins Van & Storage Company
1955

BEN P. GRIFFITH
President, Griffith Company
1955-1961

WALTER BRAUNSCHWEIGER
Bank of America
1954-1961

ROY M. HAGEN
President, California Consumers Corporation
1954-1956

ASA V. CALL
Chairman, Pacific Mutual Life Insurance Company
1954-1961

CHARLES F. KETTERING
Research Consultant and Director, General Motors Research Staff
1955-1956

EDWARD W. CARTER
President, Broadway-Hale Stores, Inc.
1954-1961

FRANK KING
Chairman of the Board, California Bank
1957-1961

TERRELL C. DRINKWATER
President, Western Air Lines, Inc.
1956-1961

VERN O. KNUDSEN
University of California at Los Angeles
1959-1961

E. J. LOEBBECKE
President, Title Insurance and Trust Company
1959-1961

STEPHEN W. ROYCE
President and Manager,
Huntington-Sheraton Hotel, Pasadena
1954-1961

O. F. MARSAL
Plant Manager, M-E-L Division, Ford Motor Co.
1957-1958

D. J. RUSSELL
President, Southern Pacific Company
1955-1961

H. C. McCLELLAN
President, Old Colony Paint & Chemical Company
1955-1956

J. PHILIP SAMPSON, M.D.
Past President, Los Angeles County
Medical Association
1955-1956

JOHN A. McCONE
President, Joshua Hendy Corporation
1954-1957

JAMES E. SHELTON
Chairman of the Board,
Security-First National Bank
1954-1961

STANDISH L. MITCHELL
General Manager, Automobile Club of
Southern California
1955-1956

REESE H. TAYLOR
Chairman of the Board,
Union Oil Company of California
1954-1961

HARVEY S. MUDD
President, Cyprus Mines Corporation
1954

NORMAN P. THOMPSON
Executive Vice President,
Automobile Club of Southern California
1956-1961

WILLIAM C. MULLENDORE
Southern California Edison Company
1954-1961

FORD J. TWAITS
Ford J. Twaits Co.
1955-1956

KENNETH T. NORRIS
President, Norris-Thermador Corporation
1955-1957

ARTHUR J. WILL
Los Angeles
1958-1960

FRED B. ORTMAN
Associate Director, Stanford Research Institute
1954-1961

P. G. WINNETT
Chairman of the Board, Bullock's, Inc.
1954-1957

ALDEN G. ROACH
President, Columbia-Geneva Steel Division,
United States Steel Corporation
1954-1956

JAMES C. ZEDER
Vice President, Chrysler Corporation
1955-1958

EDWARD C. ROSENOW, JR., M.D.
Executive Director, Los Angeles County
Medical Association
1957-1958

TECHNICAL ADVISORY COMMITTEE (1955-1957)

DR. FRANCIS E. BLACET
*Dean, Division of Physical Sciences,
University of California at Los Angeles*

CHARLES A. JONES
*Executive Secretary, Smoke and Fumes
Committee, American Petroleum Institute*

DR. LESLIE A. CHAMBERS
*Director of Research, Los Angeles County,
Air Pollution Control District*

DR. PETER KYROPOULOS
*Executive in Charge of Technical Development,
General Motors Styling*

WILLIAM H. CLAUSSEN
*Executive Secretary, Smoke and Fumes Committee,
American Petroleum Institute*

DR. JOHN T. MIDDLETON
*Chairman, Dept. of Plant Pathology,
University of California at Riverside*

DR. ARIE J. HAAGEN-SMIT
*Professor of Bio-Organic Chemistry,
California Institute of Technology*

DR. LAWRENCE M. RICHARDS
*Assistant Manager of Research and Development,
Richfield Oil Corporation*

CHARLES M. HEINEN
*Vice Chairman, Vehicle Combustion Products
Subcommittee, Automobile Manufacturers Association*

DR. WILLIAM G. YOUNG
*Vice Chancellor, University of California
at Los Angeles*

PROFESSIONAL AND BUSINESS STAFF

LAUREN B. HITCHCOCK
*Managing Director
1954-1956*

DONALD L. KIRBY
*Assistant Information Officer
1955-1956
Public Information Officer
1957-1960*

W. L. FAITH
*Deputy Director and Chief Engineer
1954-1956
Managing Director
1957-1961*

MacKENZIE WASSON
*Public Information Assistant
1955-1956*

M. NEIBURGER
*Senior Meteorologist
1954-1955*

MARY ANN JORDEN
*Librarian
1955-1957*

N. A. RENZETTI
*Senior Physicist
1954-1958
Consulting Physicist
1959-1961*

JAMES B. RUSSELL
*Business Manager
1956*

L. H. ROGERS
*Senior Chemist
1954-1958*

ROBERT L. HUNT
*Business Manager
1957-1961*

BURT LEIPER
*Public Information Officer
1954-1956*

JOHN G. DEAN
*Consulting Chemist
1959-1960*

ROBERT S. WEATHERLY
*Business Manager
1954-1955*

PHILIP A. LEIGHTON
*Consulting Chemist
1959-1960*

CONTRIBUTORS
TO
AIR POLLUTION FOUNDATION

(Numbers in parentheses refer to number of years contribution was made)

- | | |
|---|---|
| Aerogel-General Corporation (5) | Bowers Manufacturing Co., Inc. (2) |
| Allison and Rible (3) | Braun, C. F., and Company (5) |
| Alloy Steel and Metals Company (6) | Briles Manufacturing (1) |
| American Airlines (6) | Broadway Department Stores (7) |
| American Cyanamid Company (1) | Brock, M. J., & Sons, Inc. (5) |
| American Meter Company, Inc. (4) | Bullock's, Inc. (7) |
| American Pipe and Construction Co. (4) | |
| American Potash & Chemical Corporation (7) | California Cotton Oil Corporation (5) |
| Apex Steel Corporation, Ltd. (5) | California Hardware Company (3) |
| Associated Brick Manufacturers of So. Calif. (3) | California Portland Cement Company (5) |
| Atchison, Topeka and Santa Fe Railway (7) | Cannon, James H., Foundation (5) |
| Automobile Club of Southern California (2) | Capital Research & Management Company (4) |
| Automobile Manufacturers Association (7) | Carnation Company (5) |
| Avery Label Co., a Division of Avery Adhesive Products, Inc. (5) | Coldwell, Banker & Company (5) |
| | Continental Can Company, Inc. (5) |
| Baker Oil Tools, Inc. (4) | Convair (Pomona) (3) |
| Barker Bros. Corporation (7) | Cooper Precision Products (1) |
| Barr Lumber Company (2) | Coulter's (4) |
| Bauer, J. A., Pottery Company (1) | Crown Zellerbach Foundation (2) |
| Baxter, Don, Inc. (5) | Curtin, Mrs. Thomas E. (1) |
| Bechtel Corporation (7) | |
| Becket, Welton, and Associates (1) | Davies, Keusder & Brown (1) |
| Bendix, The, Corporation | deMille, Cecil B., Trust (4) |
| Beneficial Management Corporation of America (4) | Desmond's, Inc. (5) |
| Bethlehem Steel Company, Inc. (4) | Disney, Walt, Productions (4) |
| Beverly Hills Hotel (1) | Doheny, Mrs. Edward L. (3) |
| Bohemian Distributing Company (5) | Douglas Aircraft Company (4) |
| | du Pont de Nemours, E. I., & Company, Inc. (7) |
| | |
| | Eastern Columbia (1) |
| | Escherich Bros., Inc. (2) |

Ethyl Corporation (7)
 Farmers Insurance Group (5)
 Fibreboard Paper Products Corporation (1)
 Firestone Tire & Rubber Company of California (6)
 Flintridge China Company (2)
 Fluor Corporation, Ltd., The (7)
 Frantz, McConnell & Seymour (3)

Garrett Corporation (2)
 General Telephone Company of California (5)
 Gibraltar Savings & Loan Assn. of Beverly Hills (1)
 Gilfillan Bros., Inc. (2)
 Gladding, McBean & Company (7)
 Goodrich, The B. F., Company (6)
 Goodyear Tire & Rubber Company, The (6)
 Gough Industries, Inc. (3)
 Graybar Electric Company, Inc. (6)
 Great Atlantic & Pacific Tea Company, The (2)
 Great Lakes Carbon Corporation (4)
 Griffith Company (6)
 Gruen, Victor, Associates (4)

Haggarty's (1)
 Hansen-Lynn Company, Inc. (1)
 Haskins & Sells (5)
 Helms Bakeries (5)
 Hoffman Electronics Corporation (4)
 Hollywood Turf Club (1)
 Hughes Aircraft Company (5)

Hycon Manufacturing Company (2)
 Hydril Company (2)
 Hydro-Aire, Inc. (1)

Industrial Indemnity Company (6)
 International Business Machines Corporation (5)
 Investors Savings and Loan Association (2)

Jeffries Banknote Company (3)
 Johns-Manville Corporation (2)
 Jorgensen, Earle M., Co. (4)
 Kaiser Steel Corporation (2)
 Kay-Brunner Steel Products, Inc. (2)
 Kiewit, Peter, Sons' Co. (3)
 Kirk, Morris P., & Son, Inc. (5)
 Kwikset Locks, Inc. (1)

Leisure, Werden & Terry Agency (1)
 Lever Brothers Company (5)
 Litton Industries (1)
 Lockheed Aircraft Corporation (7)

Los Angeles Clearing House Association (7)
 Bank of America
 California Bank
 Canadian Bank of Commerce (California)
 Citizens National Bank
 First Western Bank & Trust Company
 Security-First National Bank of L. A.
 Union Bank

Los Angeles Newspaper Publishers Association (3)
 Los Angeles Turf Club, Inc. (5)

Lyon Van & Storage Company (1)
Maas, A. R., Chemical Co. (2)
Matson Navigation Company (5)
May Company (7)
Mayfair Markets (1)
McKee, Robert E., General Contractor, Inc. (3)
Menasco Manufacturing Company (1)
Metropolitan Coach Lines (2)
Monolith Portland Cement Company (1)
Mosaic Tile Company, The (2)
Moviola Manufacturing Company (5)

National Tank & Manufacturing Co., Inc. (1)
Newbery Electric Corporation (4)
Norris-Thermador Corporation (5)
North American Aviation, Inc. (7)
Northrop Corporation (6)

O'Keefe & Merritt Co. (2)
O'Melveny & Myers (3)
Orange County Ceramic Tile Mfg. Co. (1)
Overton, Lyman & Prince (1)

Pacific Airmotive Corporation (1)
Pacific Clay Products (3)
Pacific Enameling and Plating Company (1)
Pacific Indemnity Company (5)
Pacific Mutual Life Insurance Company (5)
Pacific Pipeline Construction Company (4)
Pacific Pumps, Inc. (3)

Pacific Telephone and Telegraph Company (7)
Pacific Tile & Porcelain Company (6)
Packard Bell Electronics (2)
Parsons, Ralph M., Company, The (4)
Pasadena Federal Savings & Loan Association (3)
Peck, C. L. (3)
Phillips Poultry Company (1)
Pomona Tile Manufacturing Co. (6)
Productol Company (2)
Prudential Insurance Company of America, The (5)

Radioplane Division, Northrup Corporation (4)
Ralphs Grocery Company (2)
Redondo Tile Company, Ltd. (1)
Republic Supply Company of California, The (5)
Rexall Drug and Chemical Company (5)
Riverside Cement Company (5)
Riverside Steel Construction (7)
Grayson Controls, Division Robertshaw-Fulton Controls Company (5)
Robinson, J. W., Co. (7)
Rowan, R. A., & Co. (7)

Schlitz, Jos., Brewing Company (1)
Sears, Roebuck and Co. (7)
Silverwoods (3)
Southern California Edison Company (7)
Southern California Gas Company (7)

Southern California Poultry Company (3)
Southern California Ready Mixed Concrete Assn. & Southern California Rock Products Association (5)
Southern Counties Gas Company of California (7)
Southern Pacific Company (7)
Southern Pipe (7)
Southwest Steel Rolling Mills (4)
Southwestern Portland Cement Company (5)
Sprague Engineering Corporation (4)
Spring Street Realty Company (5)
Staats, William R., & Co. (5)
Standard Federal Savings & Loan Association (4)
Starnes, Walter, Company (1)
State Mutual Savings and Loan Association (5)
Stauffer Chemical Company (6)
Sunkist Growers (1)
Sutro & Co. (1)

Taywood Steel Products, Inc. (1)
Thompson Ramo Wooldridge, Inc. (5)
Thrifty Drug Stores Co., Inc. (2)
Title Insurance and Trust Company (5)
Transco Products, Inc. (6)
Trans World Airlines (1)
Trousdale Construction Company (1)
Twaits-Wittenberg Co. (1)

Union Carbide Chemicals Company (2)
Union Federal Savings and Loan Association (4)

United Air Lines (7)
United Concrete Pipe Corporation (6)
United States Borax & Chemical Corporation (5)
United States Lime Products Division, The Flintkote Company (1)
United States Rubber Company (6)
United States Steel Corporation (3)
Universal Cast Iron Manufacturing Co. (1)
Universal Consolidated Oil Company (5)
Utility Appliance Corporation (1)

Van Camp Sea Food Company (1)
Van de Kamp's Holland Dutch Bakers (4)
Vernon Kilns (1)
Virtue Bros. Mfg. Co. (2)
Voit, W. J., Rubber Corporation (5)
Volker, William, & Company (1)
Von's Grocery Co. (1)

Wayne Manufacturing Company (1)
Weber Aircraft Corporation (2)
Western Electric Co., Inc. (1)
Western Geophysical Company of America (5)
Western Oil and Gas Association (7)
Western Precipitation Division, Joy Manufacturing Company (4)
Whelan Drug Company, Inc. (1)

X-Ray Products Corporation (1)
Zinsco Electrical Products (1)

FINANCIAL STATEMENT

	1953-54	1955	1956	1957 ²	1958	1959	1960
RECEIPTS							
Contributions	\$774,465	\$ 552,885	\$331,143	\$497,373	\$420,205	\$390,360	\$182,490
Collections ¹	123,596	191,863					
Interest	978	1,242	5,604	7,471	6,974	9,034	12,832
Royalties and Sale of Equipment				1,440	4,400	1,504	1,252
Carry over from previous year		291,989	319,707	170,547	279,289	310,457	368,215
TOTAL INCOME	<u>\$899,039</u>	<u>\$1,037,979</u>	<u>\$656,454</u>	<u>\$676,831</u>	<u>\$710,868</u>	<u>\$711,355</u>	<u>\$564,789</u>
EXPENDITURES							
Research Programs							
Services by outside research organizations	\$377,004	\$ 399,892	\$229,552	\$226,577	\$240,635	\$188,829	\$268,886
Internal	122,010	149,787	134,151	105,009	103,385	97,936	91,378
Public Information	not separated	68,847	42,953	29,864	25,003	25,522	27,456
General and Administrative	108,036	99,746	79,251	36,092	31,388	30,853	30,299
TOTAL EXPENSE	<u>\$607,050</u>	<u>\$ 718,272</u>	<u>\$485,907</u>	<u>\$397,542</u>	<u>\$400,411</u>	<u>\$343,140</u>	<u>\$418,019</u>
ACCRUED NET ASSETS	<u>\$291,989</u>	<u>\$ 319,707</u>	<u>\$170,547</u>	<u>\$279,289</u>	<u>\$310,457</u>	<u>\$368,215</u>	<u>\$146,770³</u>

¹For specific studies (principally from L. A. County APCD).

²Change in distribution of expenditures.

³This sum will be used for operations and liquidation expenditures during first 5 months of 1961. Any excess will be donated to Cal Tech for air pollution research.

TECHNICAL REPORTS*
published by the
AIR POLLUTION FOUNDATION

- No. 1 "Meteorology of the Los Angeles Basin"
M. Neiburger and J. C. Edinger, 99 pp., April, 1954.
- No. 2 "Combustion and Smog"
W. L. Faith, 63 pp., September, 1954.
- No. 3 "Conference on Incineration, Rubbish Disposal, and Air Pollution"
Francis R. Bowerman, ed., 52 pp., January, 1955.
- No. 4 "First Technical Progress Report"
W. L. Faith, L. B. Hitchcock, M. Neiburger, N. A. Renzetti, L. H. Rogers;
89 pp., March, 1955.
- No. 5 "Hydrocarbon Losses from the Petroleum Industry in Los Angeles County"
Southwest Research Institute, 22 pp., November, 1954.
- No. 6 "Basic Statistics of the Los Angeles Area"
Neil Goedhard, 74 pp., January, 1955.
- No. 7 "Tracer Tests of Trajectories Computed from Observed Winds"
M. Neiburger, 59 pp., April, 1955.
- No. 8 "Field Evaluation of Houdry Catalytic Exhaust Converters"
Southwest Research Institute, 77 pp., June, 1955.
- No. 9 "An Aerometric Survey of the Los Angeles Basin, August-November, 1954"
N. A. Renzetti, ed., 334 pp., July, 1955.
- No. 10 "Feasibility of Control Methods for Automobile Exhaust"
Southwest Research Institute, 63 pp., August, 1955.
- No. 11 "Visibility Trend in Los Angeles"
M. Neiburger, 45 pp., September, 1955.
- No. 12 "Second Technical Progress Report"
W. L. Faith, L. B. Hitchcock, M. Neiburger, N. A. Renzetti, L. H. Rogers;
143 pp., November, 1955.
- No. 13 "Wind Trajectory Studies of the Movement of Polluted Air in the Los Angeles Basin"
M. Neiburger, N. A. Renzetti, R. Tice; 74 pp., April, 1956.
- No. 14 "Solar Radiation, Absorption Rates, and Photochemical Primary Processes in Urban Air"
Philip A. Leighton and William A. Perkins, 130 pp., March, 1956.

*All reports are out-of-print, but are available in public and university libraries throughout the United States.

- No. 15 "Proceedings of the Conference on Chemical Reactions in Urban Atmospheres"
L. H. Rogers, ed., 135 pp., November, 1956.
- No. 16 "Analysis of Air Near Heavy Traffic Arteries"
N. A. Renzetti, 28 pp., December, 1956.
- No. 17 "Third Technical Progress Report"
W. L. Faith, N. A. Renzetti, L. H. Rogers; 110 pp., March, 1957.
- No. 18 "Eye Irritation from Irradiated Auto Exhaust"
E. A. Schuck, 85 pp., March, 1957.
- No. 19 "Reactions of Auto Exhaust in Sunlight"
F. V. Morriss and Calvin Bolze, 71 pp., March, 1957.
- No. 20 "Catalytic Decomposition of Nitric Oxide"
Charles H. Riesz, Fred L. Morritz, and Karl D. Franson, 22 pp., May, 1957.
- No. 21 "Automobile Exhaust and Smog Formation"
W. L. Faith, N. A. Renzetti, and L. H. Rogers, 103 pp., October, 1957.
- No. 22 "Fourth Technical Progress Report"
W. L. Faith, N. A. Renzetti, L. H. Rogers; 91 pp., March, 1958.
- No. 23 "Eye Irritation from Solar Radiation of Organic Compounds and Nitrogen Dioxide"
Erskine E. Harton, Jr., and Calvin C. Bolze, 61 pp., April, 1958.
- No. 24 "Photochemical Secondary Reactions in Urban Air"
Philip A. Leighton and William A. Perkins, 212 pp., August, 1958.
- No. 25 "Combustibility of Simulated Automobile Exhaust Gases"
Bernard Greifer and Raymond Friedman, 36 pp., September, 1958.
- No. 26 "Air Pollution Effects of Irradiated Automobile Exhaust as Related to Fuel Composition"
E. A. Schuck, H. W. Ford, and E. R. Stepehns, 991 pp., October, 1958.
- No. 27 "Fifth Technical Progress Report"
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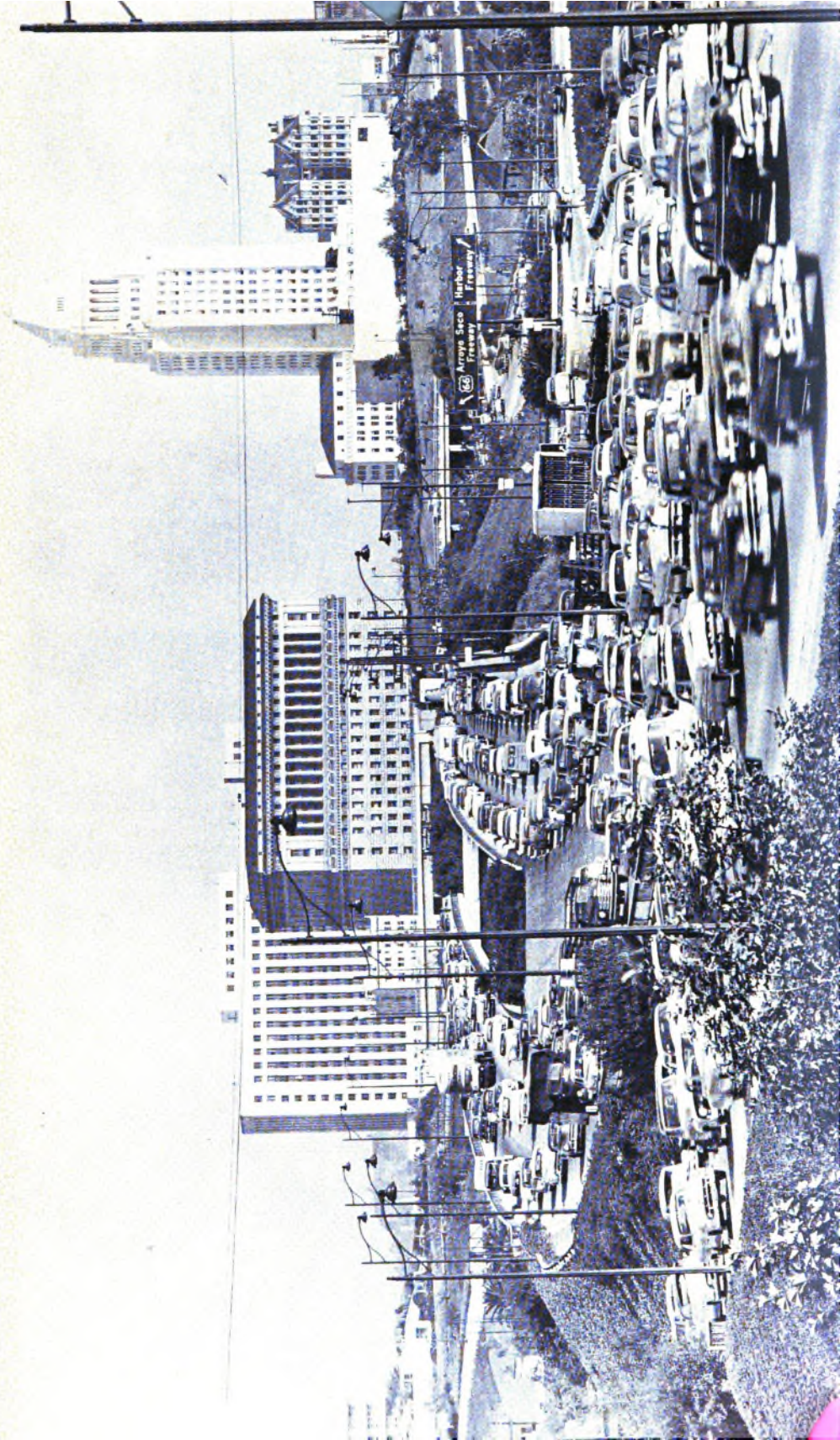
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