R T I

R E S E A R C H T R I A N G L E I N S T I T U T E

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Engineering and Environmental Sciences Division
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APPLICATIONS OF AEROSPACE TECHNOLOGY IN AIR POLLUTION CONTROL

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Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

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PREFACE

This report covers the activities of the NASA Technology Application Team located at the Research Triangle Institute during the period from 15 June 1968 to 14 June 1969. Activities covered by this report are those directed toward the accomplishment of Tasks G-2a and G-2b of Article II of the Statement of Work of NASA Contract No. NSR-34-004-056 and which relate to the transfer of aerospace technology to applications in air pollution control. The accomplishment of other tasks specified in the aforementioned contract are reported separately. The work reported here was performed by an interdisciplinary team in the Engineering and Environmental Sciences Division of the Research Triangle Institute under the general direction of Dr. J. N. Brown, Jr. and the technical direction of J. J. B. Worth. Other RTI staff members who participated significantly in this work are Dr. J. J. Wortman, C. E. Decker, R. C. Haws, Dr. L. A. Ripperton, Dr. L. F. Ballard, R. L. Beadles, Dr. F. T. Wooten, Ernest Harrison, and Dr. J. C. Orcutt. All phases of this project were coordinated closely with the Technology Utilization Division of NASA in Washington, D.C., and the National Air Pollution Control Administration located in Washington, D. C., Durham, North Carolina, and Cincinatti, Ohio.

This report presents the results of the activities in the area of air pollution control of the NASA Technology Application Team of the Research Triangle Institute during the contract period from 15 June 1968 to 14 June 1969. (The bulk of these activities were conducted during the period beginning December 1968.) This work is part of a feasibility program to determine the effectiveness of technology transfer methodology developed in NASA's Biomedical Application Team program in transferring aerospace-generated technology to non-aerospace problems and requirements. Functionally, the RTI Technology Application Team has served as an interface between the information and technology resources of the National Aeronautics and Space Administration and the National Air Pollution Control Administration.

During the reporting period, a formal inter-agency agreement was made between NASA and NAPCA for this technology utilization feasibility study. The Application Team at RTI, in working with NAPCA, has identified 41 specific technology-related problems and requirements existing in programs of the National Air Pollution Control Administration. Problem abstracts were prepared on 21 of these problems and computer information searches have been completed on 18 of these 21 problems. Information judged to be relevant was identified in 16 of the 18 completed computer searches.

Members of the RTI Technology Application Team have interfaced directly with engineers and scientists of all four divisions of the Bureau of Engineering and Physical Sciences and of one division of the Bureau of Criteria and Standards of the National Air Pollution Control Administration. The problems and requirements which have been investigated involve meteorological instrumentation, the effects of gaseous and particulate pollutants, detection instrumentation for both gaseous and particulate pollutants, process control for the elimination of pollutants, and chemical and thermal properties of pollutants.

A preliminary analysis of the program indicates (1) aerospace-generated technology is clearly relevant to problems and requirements in air pollution control; (2) the Technology Application Team methodology can be effectively applied as a catalytic information and technology interface between NASA and NAPCA; and, (3) the person-to-person contact inherent in the Technology Application Team methodology must be stressed in all phases of the technology transfer process as well as in the identification and specification of specific problems.

1.0 INTRODUCTION AND SUMMARY

The Technology Utilization Division of the National Aeronautics and Space Administration is making extensive efforts to transfer the scientific and technological results of the nation's aerospace programs to applications in the non-aerospace related industrial, educational, and governmental sectors of the United States.* There are at present many examples of success in this Technology Utilization Program. The study of the general process by which technology and scientific information are transferred across disciplinary lines is equally as important as actually transferring specific items of technology in NASA's Technology Utilization Program. In their effort to study and develop mechanisms for transferring technology, NASA has established three multidisciplinary teams to investigate the transfer of aerospace technology into the field of biomedical research and medical practice. These multidisciplinary or perhaps more appropriately interdisciplinary teams are located at the Research Triangle Institute, Research Triangle Park, North Carolina; the Midwest Research Institute, Kansas City, Missouri; and the Southwest Research Institute, San Antonio, Texas. The most important aspects of the activities of these technology application teams are the person-to-person contact which is established with individual medical investigators and clinicians at major medical centers and with individual scientists and engineers within NASA and aerospace industries; the team's close contacts with NASA's Regional Dissemination Centers which give rapid computerized access to the vast amount of aerospace related

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*National Aeronautics and Space Administration, 1968, "Useful Technology from Space Research", U. S. Government Printing Office, Washington, D. C., 20402.

information which has been generated in the past ten years; and the rapid and effective communication between the teams concerning specific medical problems and items of technology which have been found to be of value in medicine. The success which has been realized by these teams both in developing a technology transfer methodology and in accomplishing items of technology transfer has led NASA to extend the activities of these teams into other areas. As examples, the teams are now involved in transferring technology into the fields of air pollution control, water pollution control, and law enforcement communications. This report is confined specifically to reporting the activities of the RTI Technology Application Team in attempting to transfer aerospace technology into the field of air pollution control.

In this program, the objectives of the teams are both experimental and operational in nature. The experimental phase of the program involves an investigation of the technology transfer process and the operational phase involves the actual transfer of specific items of technology to assist in solving problems and meeting requirements in air pollution control and to generate a data base for further study of the technology transfer process on an experimental basis.

The general methodology employed by the Technology Application Team can be subdivided into four major phases of activity: (1) problem identification and specification; (2) identification of relevant information or technology; (3) evaluation of potentially applicable information or technology; and, (4) documentation of specific applications or "technology transfers" and the manner in which these technology transfers are accomplished. Problem identification and specification is initiated by discussions between members of the Technology Application Team and individual engineers and scientists involved in work in the area of air pollution control. Members of the application team attempt to understand fully the nature of the problems and requirements, and, in addition, how these problems are affecting the progress of research and development in instrumentation for measuring specific pollutants, instrumentation for measuring the effects of various pollutants, and systems for reducing or removing specific pollutants from air which is dumped directly into the atmosphere.

Following these discussions the team identifies very specific technology-related problems and prepares air pollution problem abstracts on each specific requirement. These problem abstracts describe problems in a concise manner using functional and nondisciplinary terminology. They also describe the significance of the problem and the benefits which would likely be realized if a solution can be found.

The next phase involves the identification of relevant information and technology. There are at present two approaches to obtaining this information. The first approach involves conducting a computerized information search of NASA's aerospace information bank. This information bank consists of the entries in the abstract journals known as Scientific and Technical Aerospace Reports (STAR) and International Aerospace Abstracts (IAA) which together cover the aerospace-related scientific and technical literature world-wide. Computer information searches are performed collaboratively by members of the Technology Application Team and applications engineers at NASA Regional Dissemination Centers such as the Science and Technology Research Center located in the Research Triangle Park, North Carolina. In cases where the computer searches do not provide all the information necessary for a solution to a problem, specific air pollution problem abstracts are disseminated through the Technology Utilization Division of NASA to NASA Research Centers and industrial organizations participating in the space program. The purpose of these abstracts is to solicit assistance in solving problems from individual scientists and engineers who may have relevant expertise or experience to contribute.

The third step in the transfer process involves an evaluation of information which appears to be relevant to the solution of specific problems. Both the application team and the problem originator involved in air pollution research and development are involved in this evaluation.

The final phase of activity involves a complete and detailed documentation of specific problems, the technology which was applied and how it was applied, as well as a description of how the relevant information was obtained. Where adaptive engineering or re-engineering is required to meet a specific user need, the final phase includes recommendations or assessments regarding the additional efforts or costs which will be required. This documentation is required both for further study of the technology transfer process, as well as for wide dissemination of the information to individuals and groups concerned with the control of air pollution.

In extending the Technology Application Team program beyond the field of biomedicine to include air pollution control, the basic methodology has not been changed. Instead of working with medical researchers and clinicians, the team works directly with engineers and scientists involved in air pollution control research and development. Specifically, the RTI Technology Application Team has interacted directly with engineers and scientists of the National Air

Pollution Control Administration. Thus, the RTI application team is acting as an information and technology interface between NASA and the National Air Pollution Control Administration (NAPCA) and a catalyst among the various sources of information involved in the technology transfer process. When this program was initiated, the methodology and objectives were discussed in detail by representatives of NASA, NAPCA, and RTI. Both the technical and organizational scope of the team's activities within NAPCA are discussed in detail in Section 2.0 of this report.

The remaining sections of this report contain a brief history of the RTI applications team's experience in the area of air pollution control. Specific problems which have been identified and the action taken on each problem is described in detail. The present status of the entire program is reviewed briefly and conclusions and recommendations for continued activity in this area of technology utilization are presented.

2.0 GENERAL NAPCA PROBLEM AREAS

The initial working conference between RTI and the National Air Pollution Control Administration was held with Dr. John Ludwig, NAPCA Assistant Commissioner for Science and Technology, on December 6, 1968. The purpose of the meeting was to brief the NAPCA Headquarters staff on the methodology and general objectives of the NASA Technology Application Teams. Mr. Roy Bivins, NASA Technology Utilization Division, and Dr. Jim Brown, RTI, presented the background information on the NASA Technology Program. The meeting resulted in an official exchange of inter-agency correspondence and the establishment of a formal agreement to proceed with an experimental technology transfer program whose aim is to apply existing aerospace technology to solve or help solve problems in the area of air pollution control.

On February 5, 1969, Mr. Ron Philips, Director, NASA Technology Utilization Division was invited to participate in a NAPCA general staff meeting to outline the objectives and purposes of the NASA technology utilization program. The meeting provided a technical background and baseline departure from which the RTI Technology Application Team, together with NAPCA and NASA, was to operate. Following the aforementioned meetings, Dr. Ludwig's office, with assistance from RTI, proceeded to draft a list of potential problem areas for consideration.

The NAPCA organizational structure (Fig. 1) is basically divided into three technically oriented bureaus encompassing a total of ten (10) working divisions. With the concurrence of Dr. Ludwig, RTI personnel made technical contacts in all of the divisions to offer assistance in the definition and

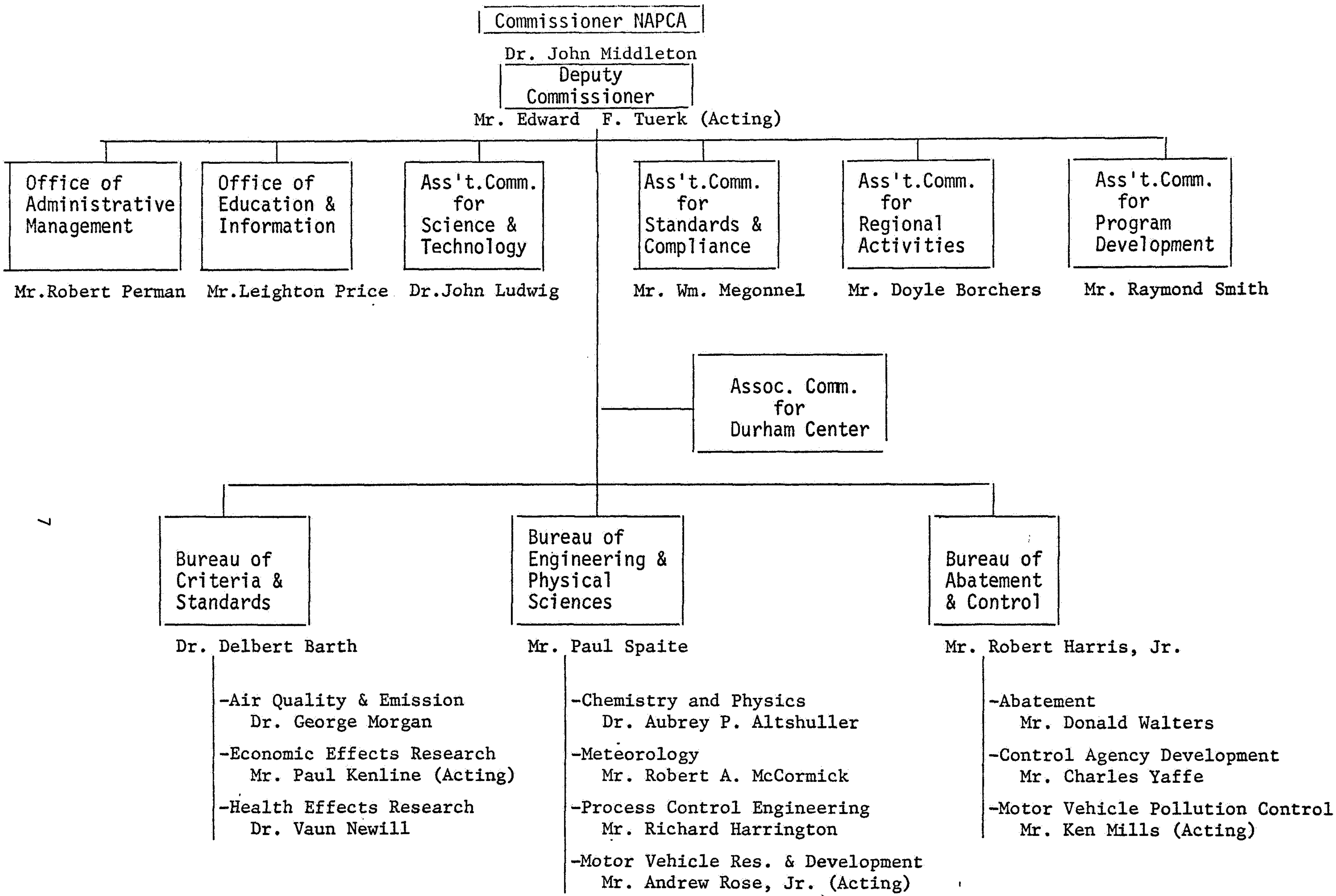

Fig. 1 National Air Pollution Control Administration

selection of applicable problem areas. A NAPCA listing of potential problem areas was submitted through internal NAPCA administrative channels to Dr. Ludwig's office for final review and compilation.

The technical response of the operational NAPCA divisions was one of excellent cooperation and enthusiasm. All of the NAPCA technical divisions responded to the invitation to submit problem areas.

The office of the Assistant Commissioner for Science and Technology prepared a listing of twelve (12) problem areas for the Technology Application Team's consideration. The following list of problem areas was officially transmitted from NAPCA to Mr. Ron Philips, Director, NASA Technology Utilization Division,in a letter dated March 21, 1969:

> "The following list of projects are submitted for search by the RTI as a part of NASA's Technology Utilization Program. The appropriate Division and Bureau within NAPCA for follow-on contact are given following the problem description.
>
> (1) A dose response relationship between air pollution exposure and human performance may be most efficiently demonstrated under test conditions of maximum physiological workloads. Methods are needed to produce such measurable workloads on components of the 1) central nervous system, 2) respiratory system, 3) cardiovascular system, and 4) neuromuscular system. With such tools the effects of a wide number of pollutants could be evaluated. --Division of Health Effects Research, Bureau of Standards & Criteria
>
> (2) Development of advanced pollutant sensors for trace elements and compounds. Automated instrumentation will be needed for some 30 pollutants over the next 5 to 10 years. --Division of Chemistry & Physics, Bureau of Engineering & Physical Sciences
>
> (3) Development of remote sensing techniques for wind velocity and temperature both in the vertical and horizontal dimensions. --Division of Meteorology, Bureau of Engineering & Physical Sciences

(4) Development of alternate working fluids for Rankine cycle power systems which will overcome the inherent problems of corrosion and lubrication normally associated with water. --Division of Motor Vehicle Research and Development, Bureau of Engineering & Physical Sciences

(5) A clear understanding and definition of pollutant removal and transformation mechanisms in the atmosphere is needed. Such a need is basic to determining the importance of air pollution relative to long term geophysical effects. --Division of Meteorology, Bureau of Engineering & Physical Sciences

(6) Generally speaking most air pollution control systems involve mass transfer of the pollutant between two phases. The development of new gas-liquid, gas-solid, liquid-solid contacting systems is needed for a host of pollutants including SO_x, NO_x, reactive hydrocarbon, odorants and particulates, etc. -- Division of Process Control Engineering, Bureau of Engineering & Physical Sciences

(7) Insufficient information is known about odor detection mechanisms. A great number of air pollution problems involve odors from paper mills, food processing plants, the petrochemical industry, transportation, etc. The classification and identification of odorants in extremely low concentrations have not been sufficiently developed. --Division of Chemistry & Physics, Bureau of Engineering & Physical Sciences and Division of Health Effects Research, Bureau of Criteria & Standards

(8) One of the major naturally occurring pollutant classes impinging on man's health is pollen. Current techniques for classifying and quantitating pollens are slow and cumbersome. A study to be undertaken in the very near future involves the ambient detection of ragweed pollen. The development of a rapid and specific measurement technique for this species is needed. --Division of Health Effects Research, Bureau of Criteria & Standards

(9) A better understanding of combustion as it relates to air pollution is needed. Current research knowledge on combustion which was developed for space applications may have spin-off. --Division of Process Control Engineering, Bureau of Engineering & Physical Sciences

(10) A measurement technique is needed for determining the trace metal emissions from fossil-fuel combustion, incinerators and metal processing plants. --Division of Process Control Engineering, Bureau of Engineering & Physical Sciences

(11) The gas exchange capacity as it develops from birth to maturity is not known. To study the effects of environmental factors on this growth, the exchange capacity of the lung through the first eight years of age needs to be measured. Knowledge of this function in other age groups may have bearing on this problem. --Division of Health Effects Research, Bureau of Criteria & Standards

(12) In order to evaluate the performance of various particulate control devices, standardized aerosol generating and measurement techniques must be developed. The generation system should be capable of loadings of 10^2 to 10^4 gm/min with a size range of 1 to 10 microns. The detection scheme should be capable of monitoring particle concentrations up to 10^8 part/ft^3 in gas streams moving at rates up to 120 ft/sec and temperature up to 400°F. --Division of Process Control Engineering, Bureau of Engineering & Physical Sciences"

With the coordination of the NAPCA Office of Science and Technology, the RTI Technology Application Team established a working relationship with the following NAPCA divisions: Division of Health Effects Research, Division of Chemistry and Physics, Division of Meteorology, Division of Motor Vehicle Research and Development and Division of Process Control Engineering. Personal contacts were made at each of the divisional chief levels prior to the establishment of any working relationships.

The Technology Application Team, working within the administrative structure of the designated NAPCA divisions, was able to define in detail a total of forty-one (41) specific problems within the twelve (12) NAPCA general problem areas. Because of limited resources for this project, the initial list of forty-one problems was reduced to a total of twenty-one (21) problem abstracts selected jointly by NAPCA, RTI, and NASA on the basis of NAPCA priorities and constraints of the aerospace information resources. The remaining group of twenty problems will be reconsidered at a later period in this technology transfer program. A complete listing of these forty-one (41) problems and their status are presented in Table 1, Section 4.0.

3.0 PROBLEM ABSTRACTS

At the present time, the RTI Technology Application Team has completed 21 problem abstracts in the area of air pollution control. These specific problems were selected for immediate action on the basis of the probable relevance of aerospace technology to potential solutions and of their significance from the standpoint of NAPCA's overall objectives and program priorities.

Each of the problem abstracts contains the following elements. First, the problem is stated very briefly. This is followed by background information which places the problem within the proper context and restates the problem in both functional and nondisciplinary language. (It is highly important that this discussion be understandable by engineers and scientists from a broad spectrum of disciplines.) Finally, physical and operational constraints and specifications are given. Only those constraints and specifications which are absolutely essential are included. A strong attempt is made not to limit the technological approach which can be taken in solving specific problems.

The status of all problems for which an abstract has been prepared as well as those problems which have been rejected or are still in the identification phase is given in Section 4.0.

Problem Abstract

RTI/AP-1
April 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Automobile Drivers Performance Tests"

Problem Description

A performance test of sufficient sensitivity is needed to quantify the effects of various air pollutants (CO, O_3, NO, NO_2) on the ability of automobile drivers.

Background

The researcher has a general interest in the effects of air pollutants on large numbers of people. Aome of the major pollutants of interest are carbon monoxide (CO), ozone (O_3), and the oxides of nitrogen (NO, NO_2). The effect of these pollutants on the human chemical physiology has been measured to a degree that satisfies the researcher. However, he is not satisfied with the limited knowledge of the effects of pollutants on human performance.

One of the performance functions that affects nearly every person in this country relates to automobile driving. The automobile driver is exposed to varying types of air pollutants, and carbon monoxide is one of the most common. Carbon monoxide can reach a level of 50 ppm on busy freeways. The pollutants of interest are assumed to affect driver performance but tests are needed to precisely determine the effect. The reason for the effect is that the pollutants of interest cause anoxia (i.e. absence of oxygen). For example, one symptom of anoxia is sleepiness.

A number of performance tests have been used in evaluating driver performance. These include hearing discrimination, time estimation, visual line separation, minium detectable light intensity, and color matching. However, the researcher feels that these tests are baseline or resting condition tests. Tests are desired that include a stress level during the test where fatigue and boredom are stress factors. These tests will be performed with various levels of air pollutants as the independent variables.

Requirements and Constraints

Concepts are desired for evoking and measuring responses which are related to automobile driver performance and which can be used in a test to be developed. Alertness and vigilance tests would be valuable. Inhalation of the air pollutants of interest is required during the tests. The test should also allow various levels of boredom and fatigue to exist during the tests.

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Problem Abstract

RTI/AP-2
April 1969

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by

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"Remote Temperature Sensing Technique for the Lower Two Kilometers of the Atmosphere"

Problem Description

A remote, non-immersion, sensing technique is needed for measuring changes of temperature with height in the lower two (2) kilometers of the atmosphere.

Discussion

A requirement of the National Air Pollution Control Administration (NAPCA) is to provide each Air Quality Control Region a quick means of obtaining atmospheric stability information in the lower atmosphere, specifically, the region from the earth's surface to 1½ to 2 kilometers. The stability can be depicted by the vertical profile of a temperature versus height curve. The stability in the lower atmosphere is one of the controlling factors in the buildup of air pollution concentrations. During periods of atmospheric stability, i.e., when the temperature is not decreasing with height,pollutants are trapped within the layer and concentrations build up. Ambient temperature within the stability layer is not as important as the change of temperature with height.

Current ground-based temperature sensing techniques require that the sensor be placed in the parcel of air being measured, e.g., by a balloon or a fixed tower.

A solution to this problem would permit NAPCA to better satisfy its responsibilities under the National Clean Air Act. All air pollution monitoring stations and meteorological stations are potential users of such a remote sensing technique.

Constraints and Specifications

The temperature sensing technique should have the following specific characteristics:

1. Be portable and ground-based, although infrequent calibration by aircraft would be acceptable, e.g., 30-day interval.
2. Measure by indirect means, i.e., non-immersion.
3. The system shall operate on an unattended on-call basis, with a response time of one hour or less.

4. Relative accuracy of the temperature-height profile should be on the order of ± .1° C/100 meters below the mixing height, i.e., top of the stable layer.

5. Vertical resolution below the mixing height is on the order of ± 50 meters.

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Problem Abstract

RTI/AP-3
April 1969

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"Remote Wind Vector Sensing Technique for the Lower Two Kilometers of the Atmosphere"

Problem Description

A remote, non-immersion, sensing technique is needed for measuring wind vectors and their fluctuations in the lower two (2) kilometers of the atmosphere. The interest is on mixing and ventilation in this layer.

Discussion

A requirement of the National Air Pollution Control Administration (NAPCA) is to provide each Air Quality Control Region with a quick response method of obtaining wind vector data in the lower atmosphere, specifically, the region from the earth's surface to 1½ to 2 kilometers. These data will facilitate the estimation of mixing and ventilation in the lower atmosphere.

One of the larger factors in the buildup of air pollution concentrations is the lack of mixing and ventilation in the lower atmosphere. A sensing technique to measure x, y, z components of the wind vectors and their fluctuations is desired. The interest is in mesoscale features, i.e., to characterize tens of minutes to an hour in time and one to one hundred (1-100) kilometers in the horizontal plane.

A solution to this problem would permit NAPCA to better satisfy its responsibilities under the National Clean Air Act. All air pollution monitoring stations and meteorological stations are potential users of such a remote sensing technique.

Constraints and Specifications

1. Be portable and ground-based, although infrequent calibration by aircraft would be acceptable, e.g., 30-day interval.
2. Measure by indirect means, i.e., non-immersion.
3. The system shall operate on an unattended on-call basis with a response time of one hour or less.
4. The sensor shall provide data on the x, y, z components of the wind and their fluctuations.

5. The interest is mesoscale, in order to characterize tens of minutes to an hour in time, one to one hundred (1-100) kilometers in horizontal space, and vertically from the surface to two (2) kilometers.

6. Required accuracies are on the order of ± 10% of the mean wind vector.

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Problem Abstract

RTI/AP-4
May 1969

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Long Term Geophysical Effects of Carbon Dioxide (CO_2)"

Problem Description

A better understanding and definition is needed of the residence times, sources, sinks, and concentration levels of carbon dioxide (CO_2) in the atmosphere.

Discussion

An understanding of the long term global effects of air pollution on the climate and mankind is one of the highest priority problems being investigated by the National Air Pollution Control Administration (NAPCA). The need for an understanding and definition of pollutant removal and transformation mechanisms in the atmosphere is basic to determining the importance of air pollution related to long term geophysical effects. Although many gases are of interest, carbon dioxide will be investigated first. The long term objective of NAPCA is a complete demography of population and air pollution.

CO_2 characteristics of interest include: Natural sinks and sources, background concentration levels, half-life time, mean residence time, and continuous build up rates, if applicable. Radiation effects, transmissivity, weather modification effects, and nucleation are also to be considered.

Constraints and Specifications

Global accuracies of an order of magnitude or better are suggested.

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Problem Abstract

RTI/AP-5
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
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"Long Term Geophysical Effects of Particulates in the 0.2 to 0.5 Micron Size Range"

Problem Description

A better understanding and definition is needed of the residence times, sources, sinks, number of particles and density of particulates in the atmosphere.

Discussion

An understanding of the long term global effects of air pollution on the climate and mankind is one of the highest priority problems being investigated by the National Air Pollution Control Administration (NAPCA). Information is needed on the radiation effects, transmissivity, weather modification effects, nucleation, mean residence times, natural sinks, and sources of particulates in the atmosphere. Natural aerosols or volcanic dust are possibilities for study.

An answer to these problems would give NAPCA, and other investigators a potential to determine long term effects of air pollution on climate.

Constraints and Specifications

1. Emphasis is on particulates in the 0.2 to 0.5 micron size range.

2. Limits of detection of ± 50% in number of particles and their density.

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Problem Abstract

RTI/AP-10
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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"Development of Advanced Pollutant Sensor for Methane"

Problem Description

An advanced sensor which is capable of measuring methane (CH_4) in urban environments is needed.

Background

Methane is one of the naturally occurring background constituents in the atmosphere. Although methane is relatively non-reactive and does not undergo photochemical reactions, it is important to be able to measure the amount of methane in urban environments, so that the concentration of reactive hydrocarbons in the atmosphere can be determined (i.e., total hydrocarbons minus methane equals reactive hydrocarbons). These reactive hydrocarbon take part in the formation of "photochemical smog", which is the classical terminology for an air pollution system characterized by photochemical reactions between oxides of nitrogen and many organics in the presence of sunlight.

Presently, a gas chromatographic technique is used for determining CH_4 in ambient air; however, it would be desirable to develop new techniques or improve existing techniques as far as sensitivity and accuracy.

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Problem Abstract

RTI/AP-11
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

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"Development of Advanced Pollutant Sensor for Sulfur Dioxide"

Problem Description

There is a need for an advanced sulfur dioxide (SO_2) analyzer which is capable of measuring SO_2 in the atmosphere as well as in stack effluents.

Background

Sulfur dioxide is produced by the combustion of sulfur-containing fuels, such as coal and oil, sulfuric acid plants, in metallurgical processes involving ores containing sulfur, and in incineration of solid waste. The major effects of SO_2 at concentrations normally found in the atmosphere (pphm range) are damage to plant and materials, visibility reduction, and irritation of the upper respiratory tack of man.

Present techniques for measuring sulfur dioxide include spectrophotometric (West-Gaeke Method), conductrometric, flame photometric, and process gas chromatographic. Measurement techniques for SO_2 in ambient air appear to be adequate; however, there is a great need for better remote sensing systems. Both direct measurements techniques as well as remote sensing devices are needed for the establishment of and enforcement of abatement criteria and for source testing.

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Problem Abstract

RTI/AP-22
May 1969

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"Development of Advanced Pollutant Sensor for Fluoride"

Problem Description

An advanced sensor which is capable of measuring fluoride in urban environments and in stack gases is needed.

Background

Considerable interest has been directed toward the determination of fluoride in ambient air and stack gases. Fluoride, which has been shown to be detrimental to vegetation and animals, is emitted into the environment from various industrial processes, such as phosphate fertilizer production, aluminum reduction, and metal smelting processes. Ambient fluoride damages sensitive plants and is harmful to animals that have eaten contaminated forage. The concentration of fluoride in ambient air is usually too low to cause damage by inhalation.

Traditionally, fluoride has been determined volumetrically, conductimetrically, potentiometrically, complexometrically, gravimetrically, and colorimetrically. However, all of these techniques have been manual and none of them have been adapted to an automated system and lack specificity. An analyzer which is capable of measuring fluoride in urban envrionments and in stack gases is needed to provide information necessary for developing criteria for abatement activities.

Requirements and Constraints

The requirements for a fluoride sensor are that it be a specific, real time analyzer capable of measuring fluoride in ambient air and stack gas. Measurements of fluoride concentrations in the range 1 ppb to 1000 ppm with an accuracy of $\pm$ 5% are desirable.

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Problem Abstract

RTI/AP-25
May 1969

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"Development of Advanced Pollutant Sensors for Carbon Dioxide"

Problem Description

An advanced sensor which is capable of measuring carbon dioxide (CO_2) in urban environments and in stack effluents is needed.

Background

Carbon dioxide is not normally considered an air pollutant because the uncontaminated atmosphere has a concentration of approximately 300 ppm, it is essential for animal and plant life, and a concentration of at least 5000 ppm in air is necessary to adversely affect man's respiration. However, world-wide atmospheric concentrations of CO_2 have been rising steadily since the mid-19th century due to increased combustion of fossil fuel. Carbon dioxide has an undesirable effect causing deterioration of building stone, such as limestone and plays an important role in the heat balance of the earth. The levels of CO_2 in the atmosphere needs to be known to determine long term changes in the geophysical levels of CO_2.

Presently, non-dispersive infrared and gas chromatographic techniques are used to measure CO_2 in ambient air in part per million concentrations, while less sensitive techniques (i.e., gravimetric, volumetric) are used in source testing. Improvements in both accuracy and flexibility are necessary.

Requirements and Constraints

An improved real time analyzer capable of measuring CO_2 in ambient air and stack gases is needed. The range of interest is 1-3000 ppm in ambient air and 0.1 to 25 percent in stack gases with a desired accuracy of $\pm$ 5%. Present infrared instrumentation has an accuracy of $\pm$ 20% and has a limited range.

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Problem Abstract

RTI/AP-26
May 1969

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"Development of Advanced Pollutant Sensors for Total Hydrocarbons"

Problem Description

An advanced sensor which is capable of measuring the concentration of total hydrocarbons in ambient air, auto exhaust, and incinerator effluents is needed.

Background

Total hydrocarbons are defined as methane plus C_2-C_6 organics and comprise 95 to 99% of the hydrocarbons in the atmosphere. Hydrocarbons, excluding methane, are emitted to the atmosphere during the incomplete combustion of all fuels (including rubbish, agriculture waste); however, automobile exhaust is the major source. The C_2 to C_6 hydrocarbons react chemically with nitrogen dioxide in the presence of sunlight to produce "photochemical pollutants" (i.e., ozone, peroxy-acetyl nitrate, aldehydes) which can cause eye irritation, plant damage, visibility restricting aerosols, and deterioration of materials. The knowledge of the concentration of total hydrocarbons in the atmosphere is useful in determining pollution due to automobiles and incineration, evaluation of smog control devices, and prediction of smog episodes.

Presently, a flame ionization detector and a gas chromatographic technique have been used to determine total hydrocarbons in the above environments; however, a lack of knowledge about flame chemistry and inadequaticies of sample introduction to the flame have impaired progress in this area.

Requirements and Constraints

The requirements for an advanced analyzer are that it be able to measure THC in the range 1-10 ppm and have an accuracy of $\pm$ 0.1 ppm. It would be desirable to develop a new system for counting carbon atoms.

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Problem Abstract

RTI/AP-27
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Development of Advanced Pollutant Sensors for Carbon Monoxide"

Problem Description

An advanced sensor which is capable of measuring carbon monoxide (CO) in urban environments, auto exhaust, and stack effluents is needed.

Background

Carbon monoxide is one of the major air pollutants in urban environments, and is emitted in auto exhaust and from incomplete combustion of carbonaceous materials. Carbon monoxide is a poisonous inhalant, and exists in concentrations higher than any other toxic gaseous air pollutant in urban environments. The effect of CO is to deprive body tissue of necessary oxygen, due to its strong affinity for hemoglobin. An instrument is needed which is capable of measuring the concentration of CO in the above environments in order to permit the determination of the general distribution of CO in the atmosphere, the level of exposure to individuals in urban environments, and the evaluation of smog control devices.

Presently, carbon monoxide in the parts per million level is determined using non-dispersive infrared and gas chromatographic techniques; however, these techniques require expensive equipment and the sensitivity is less than desirable.

Requirements and Constraints

A real time analyzer capable of measuring CO in ambient air (0-25 ppm), auto exhaust (1-300 ppm), and stack gas (1-3000 ppm) is needed. An accuracy of $\pm$ 5% is desirable for measuring CO in the above environments.

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Problem Abstract

RTI/AP-28
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Research Triangle Institute
Technology Application Team

"Improvement in Adsorption and Absorption Techniques for Removing Pollutants from Carrier Gas Streams Could be Beneficial to Air Pollution Control"

Problem Description

Improvement is needed in adsorption and absorption techniques for removing pollutants from carrier gas streams and could be beneficial to air pollution control.

Background

Currently adsorption is used in air pollution control mainly on relatively small volumes of effluent gas. A serious restriction on the use of activated carbon, one of the best of the adsorbants, is that at elevated temperature, it is subject to spontaneous combustion. Absorption, with accompanying chemical reaction, by various types of solutions is promising in many areas.

Better adsorbants and absorbing solutions for specific compounds than are now being used, and better efficiency from manipulation of temperature, pressure or contact time (geometry) are examples of improvements that could be of value. Specific types or specific pollutants of greatest interest are oxides of sulfur, oxides of nitrogen organics and oxides of carbon.

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Problem Abstract

RTI/AP-29
May 1969

Prepared for

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Research Triangle Institute
Technology Application Team

"Instrumentation for the Investigation of Flame Chemistry"

Problem Description

Better instrumentation for the investigation of flame chemistry is needed by the National Air Pollution Control Administration.

Background

The study of flame chemistry is complicated by a number of factors, among them being the elevated temperatures and the extreme rapidity of the reactions involved. A knowledge of the chain reactions involved and the free radicals produced can suggest a point of attack on the combustion process which may reduce the production of undesirable combustion products.

Requirements and Constraints

The instruments should be designed to measure the flames content *in situ*. Extracted smaples do not have the same chemical characteristic (e.g., no free radicals, etc.) as *in situ* flame content.

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Problem Abstract

RTI/AP-30
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Effect of Trace Quantities of Metals, and Impurities on Pollutant Identity and Output in Combustion"

Problem Description

Knowledge of the effect of trace quantities of metals, other additives and impurities on the identity and output of pollutants in combustion effluent is needed.

Background

The National Air Pollution Control Administration is investigating the effect of fuel additives on combustion effluent. Principally, they are utilizing various metal carbonyls. General information about the behavior of various additives in combustion chemistry might be of value in aiding NAPCA in its investigation. Specific information regarding the effect of fuel additive on production of the oxides of nitrogen, the size and type of particulate matter, and the kinds and quantities of organic compounds in the exhaust effluent would be of even more value.

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Problem Abstract

RTI/AP-31
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Technology Application Team

"Analytical Techniques for the Trace Metals in Combustion Effluent and Waste Gases from Metal Processing, Both in Collected Particles and *in situ*"

Problem Description

Analytical techniques for the trace metals in combustion effluent and waste gases from metal processing, both in collected particles and *in situ* are needed.

Background

NAPCA is investigating metallic air pollutants and is, in general, dissatisfied with currently available analytical techniques. The official NAPCA priority of interest in these substances is:

1st Priority	2nd Priority	3rd Priority
Arsenic	Berium	Iron
Asbestos	Chromium	Manganese
Beryllium	Vanadium	Selenium
Cadmium		Zinc
Mercury		
Nickel		

These substances will be found in the particulate (probably solid only) phase of various combustion effluents. *In situ* analysis would be highly desirable, but analysis of the collected material is the current role.

Constraints and Specifications

The limit of detectability desired is $\pm$ 0.1% of the collected particulate matter. The accuracy desired is $\pm$ 10%. Time of analysis is not currently a factor. NAPCA needs to know the form of the samples needed for a given type of analysis.

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Problem Abstract

RTI/AP-32
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Fluidized Bed Combustion Processes"

Problem Description

An efficient combustion process is needed which will minimize the emission of NO_x and SO_x to the atmosphere. There is a possibility that solid materials, perhaps with both adsorptive or catalytic properties, can be used in a fluidized state to assist in the combustion of liquid, solid or gaseous fuels and at the same time provide NO_x reduction and SO_x adsorbtion.

Background

The researcher is interested in developing a combustion process, if need be, from existing principles and information, or by adapting other processes to this application. He has information which leads him to believe that finely divided solid particles having suitable surface and chemical properties could serve as a combustion vehicle in the fluidized state.

To the end of devising such a process, information is required in the following general areas:

1) Fluidized bed combustion processes.
2) Catalytic and adsorptive properties of solid materials having high thermal stability.
3) Fluid mechanics of fluidized beds as applied to combustion efficiency.
4) Atomization and combustion of liquid fuels (conventional fuels only).
5) Composition of combustion gases.
6) Steam generation using fluidized bed combustion processes.
7) Adsorption and reactions of NO_x and SO_x on solid surfaces.

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Problem Abstract

RTI/AP-33
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Research Triangle Institute
Technology Application Team

"Working Fluids for Rankine Cycle Engines"

Problem Description

A working fluid is needed which is optimized for use in a Rankine cycle propulsion system for passenger vehicles.

Background

The Motor Vehicle Research and Development Division of the National Air Pollution Control Administration is responsible for developing inherently low-emission vehicles to meet future air pollution standards. An approach to meeting this requirement is the development of low pollution propulsion systems based on the Rankine cycle. The identification and development of suitable working fluids for use in such an engine is a critical area of concern, since many of the design parameters of the engine depend directly on the physical characteristics of the working fluid.

Fluids which are stable at high temperature enable the design of Rankine engines with high thermal efficiencies. For example, an increase in peak cycle temperature from 600° F to 800° F translates to an overall thermal efficiency gain of approximately thirty percent in a Rankine cycle engine. A related problem is the typically skewed shape of the temperature-entropy (T-S) diagrams, which limits the actual Rankine efficiency to about half the Carnot efficiency. A given working fluid with nearly parallel vertical sides on the T-S diagram in the temperature range of interest could equal or exceed the efficiency of a higher temperature fluid with less favorable temperature-entropy characteristics, since the nearly parallel-vertical characteristics allow the Rankine efficiency to approach the Carnot efficiency.

The alternatives to finding a Rankine cycle fluid with better T-S characteristics include solving the freezing problem with water and using a liquid metal such as mercury as the working fluid. Because of its abundance and excellent thermal stability, water should still be considered for advanced systems if freezing and lubrication problems can be eased. Since the intended application is passenger vehicles both private and public, the required quantities of engines virtually excludes liquid metals on a cost and availability basis.

Requirements and Constraints

The working fluid should be chemically stable to at least 600° F. Temperature of fusion should be no higher than the minimum temperature automobiles encounter, roughly -40°F. The fluid must be self-lubricating or compatible with appropriate lubricants.

Because of the gain in thermal efficiency with increased peak cycle temperature, a fluid suitable for extended use (2,000 hours) at high temperatures is particularly attractive. Good heat transfer properties and minimum fouling of critical heat transfer surfaces during vehicle life are required. The fluid should present a minimum safety and waste disposal problem.

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Problem Abstract

RTI/AP-35
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Heat Transfer to Small Gas Borne Particles"

Problem Description

A description is needed of the heat transfer from a hot gas to small particles passing through the gas with a short residence time.

Background

The researcher is seeking a broad understanding of the combustion process as it relates to air pollution. A depth of understanding of the fundamentals of combustion is needed including fuel mixing, temperature profiles and factors which determine the products of combustion. Particle characteristics which are expected to be important in the heat transfer process are size, shape, and surface quality. Particles may be composed of organic material, metals and metal oxides, oil or dust.

The temperature of certain materials involved in combustion is critical in the determination of by-products which are achieved. Having an understanding of the heat transfer to small particles can be very helpful in determining burner design and injection procedures to control the air pollution products of combustion.

Requirements and Constraints

The temperature of primary interest is between 1600 and 2000^{o}F. The particle residence time in the hot gas region is less than 1/2 second.

For more information contact

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Problem Abstract

RTI/AP-37
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Physical Consideration in Optimizing Fuel Air Mixture"

Problem Description

Burner design criteria are needed which optimize the fuel air mixture with respect to air pollution products.

Background

The researcher desires an understanding of combustion processes such as drop-wise combustion. Hardware design criteria for maxium combustion efficiency may not be consistent with the aims of air pollution. However, a knowledge of combustion chamber design and the physical characteristics during combustion may be useful in the design of systems having different optimization criteria. Of particular interest are the aerosol generation characteristics of the fuel injection system. Additional information is desired concerning the effects of organometallic compounds or other fuel additives.

Requirements and Constraints

Fuels of interest are low grades ranging from kerosene to heavy oils. Gas temperatures of interest are between 1600 and 2000°F.

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Problem Abstract

RTI/AP-38
May 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Measuring Techniques for Airborne Particulates"

Problem Description

A rapid technique for measuring the size and concentration of airborne particulates is needed.

Background

Particulate matter which originate in a wide variety of industrial and natural processes is a major air pollution problem. The researcher desires to measure the concentration and size of these particles rapidly in order to control their emission. In-situ techiques are preferred but a rapid procedure for measuring extracted smaples would also be of value.

Two techniques are commonly used at the present time. In the first, a sample of particulate matter is collected on an adhesive surface. The particle size and density are then obtained by visual inspection under a microscope. Another technique involves collecting particles in a liquid carrier which is monitored by a Coulter counter.

A measurement technique which identifies the shape of particles would be a distinct advantage but this is not a prime requisite.

Requirements and Constraints

Particle diameters of concern lie in the range of 0.1 to 10 microns. Particle concentrations up to 10^8 ft^{-3} are of concern. The gas stream has a velocity between 20 ft/sec and 120 ft/sec. The gas temperature is less than 400^oF.

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Problem Abstract

RTI/AP-39
May 1969

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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"Gas Exchange Capacity of the Lungs"

Problem Description

A method of measuring the gas exchange capacity of the lungs as they develop from birth to maturity, particularly from birth to approximately eight years is desired.

Background

The gas exchange capacity or diffusion capacity of the lungs can be defined as the number of milliliters of a gas at standard temperature and pressure diffusing across the pulmonary membrane per minute per millimeter of mercury of partial pressure difference between alveolar air and pulmonary capillary blood. The gas exchange capacity of the lungs as they develop from birth to approximately eight years of age has not been determined. It is desired to know what effects, if any, environmental factors have on the development of gas exchange capacity especially in the first eight years. In order to determine the effects of environmental factors on gas exchange capacity during these developmental years, it is necessary to measure the gas exchange capacity of the lungs of children living in various environments as they develop.

Several techniques have beendeveloped to measure gas exchange capacity. Each method has its limitations. The CO method, from which several techniques have been developed, is perhaps the most widely used. The CO method is based on the premise that if Pco is kept below several percent of an atmosphere, the capacity of the hemoglobin in the blood is great enough to bind all the CO that crosses the pulmonary membrane. This permits the assumption that Pco in the capillaries is zero and the gas exchange capacity, or diffusing capacity D_L, of the lung can be expressed:

$$D_L = \frac{\text{CO uptake in ml/min}}{\text{Alveolar Pco in mm Hg}}$$

All the CO methods are relatively difficult to use, especially on children. In addition, they involve various approximations or additional measurements which would be desirable to eliminate. For example, the various methods generally require at least one of the following: (a) alveolar Pco is estimated, (2) dead space volume is assumed or independently measured, (c) alveolar volume is measured independently, (d) alveolar ventilation is measured or estimated independently, (e) Pco in arterial blood is measured.

Requirements and Constraints

An accurate, simple method of measuring the gas exchange capacity of lungs suitable for use on children is required. It is desirable that the measurement be sufficiently easy to perform so that it can be used in a screening program and can be administered by relatively untrained personnel.

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Problem Abstract

RTI/AP-41
July 1969

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

by

Research Triangle Institute
Technology Application Team

"Development of Advanced Pollutant Sensor for Measuring Oxides of Nitrogen"

Problem Description

An instrument or technique is needed for measuring specifically the concentration of NO, NO_2, or total oxides of nitrogen in air.

Background

Oxides of nitrogen (NO_x) which include NO, NO_2, N_2O_4, etc., are important sources of pollutants in urban environments, auto exhaust, and stack effluents. There are no good instruments or techniques available for monitoring either NO or NO_2. A compromise has been to measure the total oxides of nitrogen in the above environments. The availability of such a sensor or sensors would permit the development of criteria for abatement activities, evaluation of smog control devices, and the prediction of smog episodes.

Nitric oxide (NO) is measured indirectly using a wet-chemichal method of analysis (Saltzman), where NO is oxidized to nitrogen dioxide (NO_2) and determined spectrophotometrically. However, this method of analysis is unsatisfactory due to variations in conversion efficiency encounter when NO is oxidized to NO_2 using a chromic acid scrubber and objects to the indirect approach.

Possible techniques for measuring total oxides of nitrogen include spectroscopic, flame emission, electrochemical and gas phase reaction systems. These techniques lack refinement and have not been adapted to such environments as in-stack monitoring.

Requirements and Constraints

The requirements for the nitric oxide sensor are that it be specific, and capable of measuring NO in urban air, auto exhaust, and stack effluents. Measurements of NO concentrations in the range, 0.01 - 1000 ppm, are desirable. It would also be desirable, although not required, if the accuracy of the device were better than ± 5%.

The requirements for a nitrogen dioxide sensor are that it be specific to NO_2 and insensitive to other constituents in urban air, auto exhaust, and stack effluents. It should be capable of responding on a real time basis. The range of interest is .01 - 1000 ppm. An accuracy of ± 5% or better is desirable, but not required for all applications. A method of in-stack analysis would also be desirable.

A real time analyzer capable of measuring total oxides of nitrogen in urban environments, auto exhaust, and stack effluents is needed. The range of interest is 0.01 to 1000 ppm. The desired accuracy $\pm$ 5% or better, although not required for all applications.

For more information contact

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4.0 PROBLEM STATUS SUMMARY

In this section, the status of action being taken on all problems which have been discussed by the RTI Technology Application Team with individuals within the National Air Pollution Control Administration is presented in Table 1. Table 1 contains the following information: (1) problem number and title, problem originator within NAPCA, and the responsible application team contact; (2) the date of the initial contact with the problem originator which is the beginning of the problem identification phase and the date the problem abstract is complete which is the end of the problem identification and specification phase; (3) the dates of the initiation of information searches and the acceptance of problem abstracts by NASA for dissemination within NASA Research Centers are included and represent significant land marks in the second phase of the technology transfer process -- i.e. search for relevant information or technology (at the date of this report, the problem abstracts have not yet been formally submitted to NASA for acceptance); (4) the date at which evaluations of potentially applicable technology is completed; (5) the date a problem is closed -- problems generally are closed when a technology transfer has been accomplished or when it is judged that further activity directed toward obtaining a solution is not warranted; and, (6) date of completion of all documentation associated with the specific problem.

The forms used in Table 1 have been used by the RTI Technology Application Team in generating a master problem file. This file contains the present status of all problems under investigation in the biomedical

Table 1. **Problem Status.** Master Problem File

NASA/RTI Technology Application Team (4/69-1)

User Institution or Agency: NATIONAL AIR POLLUTION CONTROL ADMINISTRATION Code: RTI/AP

Sample:

Problem Number, Title, Researcher, Team Contact

Date of first Contact	Problem Abstract Complete	Information search initiated	Problem Abstract accepted	Pot. Solution Eval. Complete	Problem Closed (Date/Code)	Documentation Complete
RTI/AP-1, Human Performance Test, Dr. Carl Shy, Dr. F. T. Wooten						
April 21, 1969	April 1969	April 22, 1969				
RTI/AP-2, Remote Temperature Sensing Technique in the Lower 2 Kilometers of the Atmosphere, Mr. Charles Hosler, Mr. Richard C. Haws						
April 23, 1969	April 1969	No Results				
RTI/AP-3, Remote Wind Vector Sensing Technique in the Lower 2 Kilometers of the Atmosphere, Mr. Charles Hosler, Mr. Richard C. Haws						
April 23, 1969	April 1969	May 2, 1969				
RTI/AP-4, Long Term Geophysical Effects of Carbon Dioxide (CO_2), Mr. Charles Hosler, Mr. Richard C. Haws						
April 29, 1969	May 1969	May 23, 1969				
RTI/AP-5, Long Term Geophysical Effects of Particulates from -2 to .5 Microns in Size, Mr. Charles Hosler, Mr. Richard C. Haws						
April 29, 1969	May 1969	May 23, 1969				
RTI/AP-6, Odor Classification and Identification, Messrs. Andy O'Keefe & Bob Stevens, Mr. Clifford Decker						
April 25, 1969					June 1969/J	
RTI/AP-7, Development of Advanced Pollutant Sensor for Total Oxides of Nitrogen NO_x ($NO + NO_2 + N_2O_4 +$ ____), Mr. Andy O'Keefe Mr. Bob Stevens, Mr. C. Decker/Dr. J. J. Wortman						
April 25, 1969					June 1969/J	

Table 1. Problem Status (Continued). Master Problem File

NASA/RTI Technology Application Team (4/69-1)

User Institution or Agency: NATIONAL AIR POLLUTION CONTROL ADMINISTRATION Code: RTI/AP

Sample:

Problem Number, Title, Researcher, Team Contact

Date of first Contact	Problem Abstract Complete	Information search initiated	Problem Abstract accepted	Pot. Solution Eval. Complete	Problem Closed (Date/Code)	Documentation Complete
RTI/AP-8, Development of Advanced Pollutant Sensor for Nitrogen Dioxide, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969					June 1969/J	
RTI/AP-9, Development of Advanced Pollutant Sensor for Nitric Oxide, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969					June 1969/J	
RTI/AP-10, Development of Advanced Pollutant Sensor for Methane, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969	May 1969					
RTI/AP-11, Development of Advanced Pollutant Sensor for SO_2, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969	May 1969					
RTI/AP-12, Development of Advanced Pollutant Sensor for Arsenic, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-13, Development of Advanced Pollutant Sensor for Beryllium, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-14, Development of Advanced Pollutant Sensor for Mercury, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						

Table 1. Problem Status (Continued). Master Problem File

(4/69-1)

NASA/RTI Technology Application Team

User Institution or Agency: NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

Code: RTI/AP

Sample:

Problem Number, Title, Researcher, Team Contact						
Date of first Contact	Problem Abstract Complete	Information search initiated	Problem Abstract accepted	Pot. Solution Eval. Complete	Problem Closed (Date/Code)	Documentation Complete
RTI/AP-15, Development of Advanced Pollutant Sensor for Nickel, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-16, Development of Advanced Pollutant Sensor for Ammonia, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-17, Development of Advanced Pollutant Sensor for Carcinogens, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-18, Development of Advanced Pollutant Sensor for Chlorine (including HCl), O'Keefe/Stevens, Decker/ Wortman						
April 25, 1969						
RTI/AP-19, Development of Advanced Pollutant Sensor for Hydrogen Sulfide , O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-20, Development of Advanced Pollutant Sensor for Vanadium, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-21, Development of Advanced Pollutant Sensor for Detection of Ozone , O'Keefe/Stevens, Decker/Wortman						
April 25, 1969		June 25, 1969				

Table 1. **Problem Status (Continued).** Master Problem File

NASA/RTI Technology Application Team (4/69-1)

User Institution or Agency: NATIONAL AIR POLLUTION CONTROL ADMINISTRATION Code: RTI/AP

Sample:

Date of first Contact	Problem Abstract Complete	Information search initiated	Problem Abstract accepted	Pot. Solution Eval. Complete	Problem Closed (Date/Code)	Documentation Complete
Problem Number, Title, Researcher, Team Contact						
RTI/AP-22, Development of Advanced Pollutant Sensor for (Br −, ce −, F −, I −), O'Keefe/Stevens, Decker/Wortman						
April 25, 1969	May 1969	June 25, 1969				
RTI/AP-23, Development of Advanced Pollutant Sensor for Lead, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-24, Development of Advanced Pollutant Sensor for Reactive Hydrocarbons, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969						
RTI/AP-25, Development of Advanced Pollutant Sensor for Carbon Dioxide , O'Keefe/Stevens, Decker/Wortman						
April 25, 1969	May 1969	June 24, 1969				
RTI/AP-26, Development of Advanced Pollutant Sensor for Total Hydrocarbons , O'Keefe/Stevens, Decker/Wortman						
April 25, 1969	May 1969	June 25, 1969				
RTI/AP-27, Development of Advanced Pollutant Sensor for Carbon Monoxide , O'Keefe/Stevens, Decker/Wortman						
April 25, 1969	May 1969	June 25, 1969				
RTI/AP-28, Adsorption and Absorption Techniques..., Joshua Bowen, Dr. Lyman Ripperton						
April 22, 1969	May 1969	May 16, 1969				

Table 1. Problem Status (Continued). Master Problem File

NASA/RTI Technology Application Team (4/69-1)

User Institution or Agency: NATIONAL AIR POLLUTION CONTROL ADMINISTRATION Code: RTI/AP

Sample:

Problem Number, Title, Researcher, Team Contact

Date of first Contact	Problem Abstract Complete	Information search initiated	Problem Abstract accepted	Pot. Solution Eval. Complete	Problem Closed (Date/Code)	Documentation Complete
RTI/AP-29, Adequate Instrumentation for the Investigation of Flame Chemistry, John H. Wasser, Lyman Ripperton						
April 22, 1969	May 1969	May 21, 1969				
RTI/AP-30, Effect on Pollutant Identity and Output of Trace Quantities of Metals, J. Wasser, Ripperton						
April 22, 1969	May 1969					
RTI/AP-31, Analytical Techniques for Trace Metals in Combustion Effluent and Waste Gases from Metal Processing..., Jim Dorsey, Ripperton						
April 22, 1969	May 1969	May 21, 1969				
RTI/AP-32, Fluidized Bed Combustion Processes, John H. Wasser, John Orcutt						
May 12, 1969	May 1969	May 14, 1969				
RTI/AP-33, Working Fluids for Rankine Cycle Engines, David Dawson/Ray F. Machacek, Robert Beadles						
May 12, 1969	May 1969	May 13, 1969				
RTI/AP-34, Holographic Technique for Measuring Particulate Flux, James Dorsey, Robert Beadles						
May 12, 1969						
RTI/AP-35, Heat Transfer to Small Gas Borne Particles, John Wasser, Dr. L. F. Ballard						
May 15, 1969	May 1969	June 5, 1969				

Table 1. **Problem Status (Continued).** Master Problem File

(4/69-1)

NASA/RTI Technology Application Team

User Institution or Agency: NATIONAL AIR POLLUTION CONTROL ADMINISTRATION Code: RTI/AP

Sample:

Date of first Contact	Problem Abstract Complete	Information search initiated	Problem Abstract accepted	Pot. Solution Eval. Complete	Problem Closed (Date/Code)	Documentation Complete
Problem Number, Title, Researcher, Team Contact						
RTI/AP-36, Combustion Chamber Aerodynamics, Wasser, Ballard						
May 15, 1969						
RTI/AP-37, Physical Consideration in Optimizing Fuel Air Mixture, Wasser, Ballard						
May 15, 1969	May 1969					
RTI/AP-38, Measuring Techniques for Airborne Particulates, Dorsey, Ballard						
May 15, 1969	May 1969	June 10, 1969				
RTI/AP-39, Gas Exchange Capacity of the Lungs, Carl Shy, Ernest Harrison						
May 26, 1969	May 1969					
RTI/AP-40, Development of Advanced Pollutant Sensor for Cadmium, O'Keefe/Stevens, Decker/Wortman						
April 25, 1969		June 25, 1969				
RTI/AP-41, Development of Advanced Pollutant Sensor for Oxides of Nitrogen (NO_x, NO, NO_2), O'Keefe/Stevens, Decker/Wortman						
July 2, 1969		June 25, 1969				

field and law enforcement communications, as well as air pollution control. The code used under problem closed in Table 1 is explained in Table 2. This particular code was designed specifically for the biomedical field and as a result some of the reasons for closing problems may not be appropriate for the areas of air pollution control and law enforcement.

The Technology Application Team methodology for problem identification is based on a technical exchange between RTI team personnel trained in air pollution research and development and the NAPCA technical investigators. For the preparation of the abstracts, conferences were held with NAPCA divisional personnel in Durham, N. C.; Cincinnati, Ohio; and Ann Arbor, Michigan. The initial technical conferences were completed in April 1969. The April conferences resulted in the detailed list of forty-one (41) problems. During the months of April and May, twenty-one (21) problems were selected and draft problem abstracts were written and reviewed with the initiating NAPCA investigators. The technology application team coordinated the draft problem abstracts with NASA's Technology Utilization Division and proceeded to implement the individual information searches.

The status of the twenty-one (21) problems for which abstracts have been prepared as follows:

RTI/AP-1, "Automobile Drivers Performance Tests"
Dr. Carl M. Shy, Division of Health Effects Research
Team Member - F. T. Wooten

The first contact was made on April 17, 1969 with the initial meeting including Dr. Vaun Newell, Dr. Carl Shy, and Dr. Bill Balridge. The search was started on April 22nd and was delivered to Dr. Shy on April 29th. A follow-up conference with Dr. Shy on May 23rd indicated he had not yet read the search but indicated his continued interest. The search produced 140 abstracts and the search was judged to be useful.

TABLE 2

Code for Problem Closure

A	—	Transfer Accomplished.
B	—	Researcher has no further interest in the problem.
C	—	Researcher has found his own solution.
D	—	As a result of personnel transfer in the institutions, the problem has either been closed or transferred to another institution along with the investigator and has been given a new number.
E	—	No present or foreseeable future NASA technology applicable.
H	—	Satisfactory solution identified by team and verified by researcher, but transfer cannot be completed by researcher for reasons of economy or lack of resources temporarily to implement findings.
I	—	Problem as originally stated was too broad or general.
J	—	Problem is too difficult; i.e., the problem as given to the Technology Application Team is presently the focus of large expenditures of money research, and developmental effort making the likelihood of success by the team too low to warrant its expenditure of effort worthwhile.
K	—	Problem priority, e.g., Cost/Benefits ratio, team resources available, researcher's resources and enthusiasm, etc, compared to these aspects on other problems too low.

RTI/AP-2, "Remote Temperature Sensing Technique for the Lower Two Kilometers of the Atmosphere"
Mr. Charles R. Hosler, Division of Meteorology
Team Member - R. C. Haws

Problem abstract has been written and a copy mailed to Mr. Hosler on May 12, 1969 requesting his comments. A computer search was made but yielded only one "hit". Another computer search was made with additional search terms and yielded only three "hits", none of which suggests a solution to the problem. The output from the second search was mailed to Mr. Hosler on June 27, 1969.

RTI/AP-3, "Remote Wind Vector Sensing Technique for the Lower Two Kilometers of the Atmosphere"
Mr. Charles R. Hosler, Division of Meteorology
Team Member - R. C. Haws

The problem abstract has been written and a copy mailed to Mr. Hosler on May 12, 1969 requesting his comments. A computer search was made and the output mailed to Mr. Hosler on May 12, 1969. The search yielded 110 "hits".

RTI/AP-4, "Long Term Geophysical Effects of Carbon Dioxide (CO_2)"
Mr. Charles R. Hosler, Division of Meteorology
Team Member - R. C. Haws

The problem abstract has been written and a copy mailed to Mr. Hosler on May 12, 1969 requesting his comments. A computer search was made which yielded 87 "hits" and the output was mailed to Mr. Hosler on June 27, 1969.

RTI/AP-5, "Long Term Geophysical Effects of Particulates in the 0.2 to 0.5 Micron Size Range"
Mr. Charles R. Hosler, Division of Meteorology
Team Member - R. C. Haws

The problem abstract has been written and a copy mailed to Mr. Hosler on May 12, 1969. A computer search was made which yielded 197 "hits" and the output was mailed to Mr. Hosler on June 27, 1969.

RTI/AP-10, "Development of Advanced Sensor for Methane"
Dr. Robert K. Stevens, Division of Chemistry and Physics
Team Member - J. J. Wortman

A selective sensor for measuring methane in urban environments is needed. Andrew O'Keefe and Robert Stevens, Division of Chemistry and Physics were contacted about this problem on April 25, 1969. A computer search was initiated on June 10, 1969 but sifting articles of value from the references related to methane is proving to be difficult. Since it is a naturally occurring constituent of the atmosphere, it frequently occurs in reports where the primary emphasis is on other gases. Literature on the explosion hazard of methane in closed environments is also a source of information. It is anticipated that a good technology transfer can be made with additional effort.

RTI/AP-11, "Development of Advanced Sensor for Sulfur Dioxide"
Mr. Andrew E. O'Keefe, Division of Chemistry and Physics
Team Member - J. J. Wortman

The first contact was made on April 25, 1969 with Andrew O'Keefe and Dr. Stevens. This meeting determined the need for a more reliable and economical sulfur dioxide analyzer for the atmosphere and stack effluents. A computer search was initiated on June 10, 1969. The results of the search are not complete.

RTI/AP-22, "Development of Advanced Pollutant Sensors for Fluoride"
Mr. Andrew E. O'Keefe, Division of Chemistry and Physics
Team Member - J. J. Wortman

The first contact was made with Andrew O'Keefe and Dr. Stevens on April 25, 1969. A need was determined for a sensor capable of measuring fluoride in stack gases and urban environments. A computer search was initiated on June 10, 1969. Completion on June 27, 1969 indicated 3 "hits". These documents have been ordered.

RTI/AP-25, "Development of Advanced Pollutant Sensors for Carbon Dioxide"
Dr. Robert K. Stevens, Division of Chemistry and Physics
Team Member - J. J. Wortman

The first contact was made with Andrew O'Keefe and Dr. Stevens on April 25, 1969. A need was determined for the development of an advanced sensor for measuring carbon dioxide in stack effluents and urban environments.

A computer search was initiated on June 10, 1969 and completed by July 2, 1969. From the list of 46 "hits", 17 documents were ordered which may be useful to air pollution research.

RTI/AP-26, "Development of Advanced Pollutant Sensors for Total Hydrocarbons"
Mr. Andrew E. O'Keefe, Division of Chemistry and Physics
Team Member - J. J. Wortman

The initial contact was made with Andrew O'Keefe and Dr. Stevens on April 25, 1969. A need was determined for a sensor which is capable of measuring total hydrocarbon concentration in ambient air, auto exhaust, and incinerator effluents. A computer search was initiated on June 10, 1969. The search was completed on June 27, 1969 with 17 "hits". Thirteen (13) research articles have been ordered.

RTI/AP-27, "Development of Advanced Pollutant Sensors for Carbon Monoxide"
Dr. Robert K. Stevens, Division of Chemistry and Physics
Team Member - J. J. Wortman

The first contact was made with Andrew O'Keefe and Dr. Stevens on April 25, 1969. A need was determined to develop sensors capable of measuring the concentration of carbon monoxide in urban environments, auto exhausts, and stack effluents. A computer search was begun on June 10, 1969 and completed on June 27, 1969. From a total of 7 "hits", 4 documents have been ordered.

RTI/AP-28, "Improvement in Adsorption and Absorption Techniques for Removing Pollutants from Carrier Gas Streams"
Mr. Joshua S. Bowen, Division of Process Control Engineering
Team Member - L. A. Ripperton

The problem abstract was approved and the search was initiated on May 21, 1969. The search produced a total of 52 abstracts, of which nine were judged applicable to the problem. The search has been forwarded to NAPCA for their review.

RTI/AP-29, "Instrumentation for the Investigation of Flame Chemistry"
Mr. John H. Wasser, Jr., Division of Process Control Engineering
Team Member - L. A. Ripperton

The literature search was initiated on May 26, 1969 and the computer run produced a total of 180 abstracts, of which 82 were judged applicable.

Mr. Wasser has received the search data and indicated his interests and a possible delay in his being able to quickly asses the value of all 82 abstracts.

RTI/AP-30, "Effects of Trace Quantities of Metals, and Impurities
on Pollutant Identity and Output in Combustion"
Mr. James A. Dorsey, Division of Process Control Engineering
Team Member - L. A. Ripperton

The problem abstract was reviewed with Mr. Dorsey on May 21st and the literature search was initiated on May 26, 1969. The computer search produced 74 abstracts, of which 18 were considered applicable. The results of the data search were transmitted to NAPCA on June 11, 1969.

RTI/AP-31 " Analytical Techniques for The Trace Metals in Combustion
Effluent and Waste Gases from Metal Processing"
Mr. James A. Dorsey, Division of Process Control Engineering
Team Member - L. A. Ripperton

The problem abstract was reviewed with Mr. Dorsey on May 21st and the literature search was combined with AP-30 and initiated on May 26, 1969. The search produced 4 applicable abstracts which were forwarded to NAPCA on June 11, 1969.

RTI/AP-32, "Fluidized Bed Combustion Processes"
Mr. John H. Wasser, Jr., Division of Process Control Engineering
Team Member - J. C. Orcutt

Two computer searches were made in May, 1969 to retrieve information relevant to the titled problem. The search on fluidized beds and related combustion processes with additional key words citing nitrogen and sulfur oxides, catalysts and adsorption produced 71 abstracts and the second search for information on conventional fuel combustion with key words citing nitrogen and sulfur oxides, analyses of products of combustion and fuel gases produced 134 abstracts.

Item-by-item reading of the abstracts from the searches reveals no information of direct application to the subject problem. The search on fluidized beds was deficient in that most abstracts cited work of no relevance or else publications of a general or survey nature. A second source of material may be obtained in the general literature on fluidization beginning with the books by Kunii and Levenspiel (Fluidization Engineering, Wiley, New York, (1969)) and Davidson and Harrison (Fluidization Particles, Cambridge U. Press, (1963)).

Four abstracts were retrieved which had a connection to the problem of fluidized beds. Of these, only one suggests a remote connection with the reactivity of NO and a solid catalyst (zeolite ion exchange resin). In the second search, a total of 134 abstracts were reviewed and only one was considered directly applicable.

RTI/AP-33, "Working Fluids for Rankine Cycle Engines"
Mr. Raymond Machacek, Division of Motor Vehicle Research and Development
Team Member - R. L. Beadles

The problem abstract was approved and the information search initiated on May 13, 1969. The information search did not produce any relevant data potentially applicable to the problem. The Technology Application Team has developed a list of 7 contractor and government agencies which are suggested organizations who may be able to suggest solutions if the problem abstracts were sent to them.

RTI/AP-35, "Heat Transfer to Small Gas Borne Particles"
Mr. John H. Wasser, Jr., Division of Process Control Engineering
Team Member - L. F. Ballard

This problem was formulated during a meeting with Jack Wasser, Division of Process Control Engineering on April 29, 1969. It relates to the need for a practical description of the heat transfer to small particles under transient temperature conditions. The computer search was started on May 20, 1969 and completed June 12, 1969 with 91 "hits" being obtained. Documents are being ordered for about 25 articles which appear to be applicable. Several of these cover research with contraints which concide with the present problem. It is anticipated that this effort will result in a successful technology transfer.

RTI/AP-37, "Physical Considerations in Optimizing Fuel-Air Mixtures"
Mr. John H. Wasser, Jr., Division of Process Control Engineering
Team Member - L. F. Ballard

This problem relates to the need for developing burner design criteria which optimize the fuel-air mixture with respect to various air pollution products. Jack Wasser, Division of Process Control Engineering was visited on April 29, 1969 concerning this research area. The computer search was initiated on May 20, 1969. A large amount of work in this area has been done through NASA with different and varied emphasis. A delay is being encountered in identifying the potentially applicable information within the exceptionally large amount of data pertinent to NAPCA's needs.

RTI/AP-38, "Measuring Techniques for Airborne Particulates"
Mr. James A. Dorsey, Division of Process Control Engineering
Team Member - L. F. Ballard

This problem relates to the need for a rapid technique for measuring the size and concentration of airborne particulates. In-situ techniques are preferable but rapid techniques for analyzing extracted samples are also of value. A group discussion on this subject was held with Jim Dorsey, Division of Process Control Engineering and several members of his group on April 29, 1969. The computer search was begun on May 20, 1969 and completed June 12, 1969 with 94 "hits". A review of the abstracts revealed several articles which were directly applicable to the problem. About 25 documents are being ordered for transfer. Many of these documents concern holographic techniques which are of interest to Mr. Don Phelps, NAPCA who attended the initial discussion on April 29, 1969.

RTI/AP-41, "Development of Advanced Pollutant Sensors for Measuring Oxides of Nitrogen"
Dr. Robert K. Stevens, Division of Chemistry and Physics
Team Member - J. J. Wortman

NO_x, NO, NO_2, N_2O_4 etc. are significant pollutants in most auto exhausts, stack effluents, and urban environments. Sensors for specifically measuring these nitrogen compounds on a real-time basis are needed. This problem was discussed during a visit with Andrew O'Keefe and Robert Stevens, Division of Chemistry and Physics on April 25, 1969.

An information search was initiated on June 10, 1969 and has resulted in 4 abstracts of potential transfer applicability. The documents have been ordered and the information transmitted to NAPCA.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The NASA Technology Application Team at the Research Triangle Institute has been applying the technology transfer methodology developed in NASA's Biomedical Application Team program in the area of air pollution control for twelve months. However, the first four months of this period were devoted to planning and to establishing necessary inter-agency contacts between NASA's Technology Utilization Division and the Office of the Assistant Commissioner for Science and Technology of the National Air Pollution Control Administration. An additional four months were devoted to the establishment of a formal inter-agency agreement to proceed with a technology transfer feasibility program. The final four months of the reporting period were devoted to establishment of individual contacts between members of the RTI application team and investigators at the National Air Pollution Control Administration. During this period of activity, the Application Team has been able to form a number of conclusions concerning the transfer of aerospace technology to air pollution control as well as recommendations for continuing this program.

It is significant that the Application Team has been able to efficiently and effectively integrate eight additional members of the Research Triangle Institute's staff into its operation in a very short time period. These individuals were selected on the basis of their competence and experience in technical fields related to air pollution control. Working with full-time staff of the existing Biomedical Application Team, these individuals were able to successfully carry out the functions of problem identification and specification, problem abstract preparation and computer search of the NASA Aerospace Information Bank. It is concluded that individuals can be used effectively in the technology utilization process on a part-time, rapid-response basis. Coordination and management of such a program, however, is more critical than when the individuals involved devote their entire effort to the program. The management techniques used in the Biomedical Application Team program have been found very effective in coordinating the efforts directed toward technology utilization in air pollution control.

As a result of the Application Team's activities, ten of the twelve problem areas defined by NAPCA and discussed in Section 2.0 have been judged appropriate for technology transfer investigations. These ten problem areas have been broken down into 41 specific problems and requirements. Problem identification and specification and the preparation of problem abstracts has been completed on 21 of these problems and four of the forty-one have been closed for reasons given in Section 4.0. It is felt that there is a relatively high probability of finding solutions in aerospace technology for the 37 problems which are at the present time active. This can be supported partially by the results of computer searching which has been accomplished to date. Of the 21 computer searches which have been performed approximately 3,500 citations were obtained. This number was reduced to 1368 citations or hits by screening at the Science and Technology Research Center. Of these, 373 have been identified as relevant to specific problems through an initial evaluation by Technology Application Team members. Only two of the searches have yielded zero relevant information. As three of the searches have not been completed,this gives an average of approximately 23 documents per problem for the 16 searches which have yielded relevant information. It is concluded that there is good potential for the transfer of aerospace-generated technology to problems and requirements existing in air pollution control. It is recommended that activity be continued on the 21 problems for which problem abstracts have been prepared and that action be continued on the remainder of active problems, as well as additional problems which may be identified as a result of contacts already made within NAPCA.

The response of individual engineers and scientists within NAPCA has been both enthusiastic and very cooperative throughout the problem identification and specification phase of our activity. We have found, however, that these individuals,who generally hold key positions within NAPCA and have considerable administrative responsibilities,are not able to respond rapidly in the evaluation of search results and the approval of problem abstracts. We intend to recommend in the future that these tasks be given to individuals with less administrative responsibility within NAPCA. Additionally, we are directing members of the Technology Application Team to increase the frequency of contacts with problem originators during those phases of our work which involve evaluation of search results, problem abstract responses and potential solutions. The person-to-person contact aspect of the Application Team methodology cannot be dropped following the completion of problem identification. Rather, it must be continued throughout the entire process.

Finally, it is recommended that representatives of the RTI Technology Application Team and of NASA's Technology Utilization Division, together, brief Dr. Ludwig and his staff of the Office of the Assistant Commissioner for Science and Technology of NAPCA on the progress of our feasibility study program in the very near future to insure that all three parties be aware of both progress and operational problems at all times.