Engineering and Environmental Sciences Division
Research Triangle Institute
Post Office Box 12194
Research Triangle Park
North Carolina 27709

APPLICATIONS OF AEROSPACE TECHNOLOGY IN AIR POLLUTION CONTROL

Contract No. NASW-1950
RTI No. EU-469

Quarterly Progress Report 1
15 June 1969 to 14 September 1969

Prepared for

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

TABLE OF CONTENTS

ABSTRACT

This report covers the activities of the National Aeronautics and Space Administration (NASA) Technology Application Team (TATeam) located at the Research Triangle Institute (RTI) for the period from 15 June 1969 to 14 September 1969. Activities covered by this report are those directed towards the accomplishment of Tasks g.1.(a) and g.1.(b), Article II, Statement of Work of the Schedule of NASA Contract No. NASW-1950 and related to the transfer of aerospace science and technology to applications in air pollution control. The work reported here was performed by an interdisciplinary team in the Engineering and Environmental Sciences Division (EESD) of RTI. This project is under the general direction of J. N. Brown, Jr., Manager, Systems Engineering Department, EESD, and under the technical direction of J. J. B. Worth, Associate Director, EESD. The major portion of the work reported here was performed by L. F. Ballard, C. E. Decker and D. R. Whitaker. All phases of this project were coordinated with the Technology Utilization Division of NASA and with the National Air Pollution Control Administration in Washington, D. C., Durham, North Carolina, and Cincinnati, Ohio.

During the reporting period, evaluations of 21 computer searches of NASA's aerospace information system were essentially completed. Also, 30 responses to problem statements were received from scientists and engineers at five NASA Field Centers. Evaluations of suggested solutions contained in the responses have begun.

As a result of these activities, two transfers of technology have been accomplished and two potential technology transfers have been documented. Additionally, it is expected that technology that has been identified during the reporting period will, within six months, lead to solutions of approximately 10 problems presently being investigated.

Results of efforts to identify aerospace technology that can be applied to solve or aid in the solution of problems in air pollution control indicate clearly that the best approach to identifying this technology is through direct contact with engineers and scientists at NASA Field Centers. Thus, the efforts of the RTI TATeam are being directed towards establishing improved lines of communications between the TATeam and NASA Field Centers.

1.0 INTRODUCTION

The Technology Utilization Division of the National Aeronautics and Space Administration (NASA) is making extensive and concentrated efforts to apply the scientific and technological knowledge gained in the nation's aerospace programs in order to solve or aid in the solution of problems in the public sector. Many examples of success in this Technology Utilization program are already in evidence.* The study of the general process by which technology and scientific information are transferred across disciplinary and jurisdictional lines and other barriers is a very important part of NASA's Technology Utilization program.

In order to study and develop mechanisms for transferring technology, NASA established three multidisciplinary teams in 1966 to investigate the transfer of aerospace technology to the field of biomedical research and medical practice. These multidisciplinary Biomedical Application 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 more important aspects of the Biomedical Application Team program are (1) the interdisciplinary character of the teams and their ability to selectively draw upon the base of expertise within their parent institutes, (2) the person-to-person contact that is established among individual medical investigators and clinicians at major medical centers and individual scientists and engineers within NASA and the aerospace industry, (3) the team's close contacts with NASA's Regional Dissemination Centers which give rapid computerized access to the aerospace related information base that has been generated in the past ten years, and (4) the rapid and effective communication among the three Biomedical Application Teams concerning specific biomedical problems and items of technology that have been transferred to applications in medicine.

During the preceding three years, approximately 750 technology related problems and requirements in medicine have been investigated by the three Biomedical Application Teams. Relevant scientific and technological information was identified for approximately one-half of these problems. Of these

---

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

cases, approximately one-half have been developed to the stage of technology transfer. Technology transfer here implies that the potentially useful technology identified in this program has actually been applied and used by an individual biomedical researcher.

The success of the Biomedical Application Team program in developing a workable technology transfer methodology and in accomplishing useful transfers of aerospace technology has led NASA to extend the concept of the application team into other areas in the public sector; e.g., application teams are now involved in transferring technology into the fields of air pollution control, water pollution control, mine safety, criminalistics, and transportation. Because of this broader base for technology transfer between aerospace research and development programs and nonaerospace public sector programs, these multidisciplinary teams are referred to as Technology Application Teams (TATeams). NASA has recently established two new TATeams at Stanford Research Institute, Menlo Park, California, and Illinois Institute of Technology Research Institute, Chicago, Illinois.

The objectives of the TATeams are both experimental and operational in nature. The experimental phase of the program involves the investigation of the technology transfer process; the operational phase involves the actual transfer of specific items of technology to solve problems existing in public sector programs and to generate a data base for further study of the technology transfer process on an experimental basis.

The remainder of this report is confined to reporting and evaluating the activities of the RTI TATeam in the specific area of air pollution control.

2.0 SUMMARY

In attempting to transfer aerospace technology to the general area of air pollution control, the RTI TATeam has worked directly with engineers and scientists of the National Air Pollution Control Administration (NAPCA). When the Technology Utilization program in air pollution control was initiated, the methodology and objectives of the TATeam program were discussed in detail by representatives of NASA, NAPCA, and RTI. Guidelines for interaction between the RTI TATeam and individuals at NAPCA were clearly defined at that meeting and have been reported in a previous RTI project report.* Both the technical and organizational scope of the team's activities with NAPCA are discussed in detail in Section 3.0 of this report.

The general methodology that has been employed by the RTI TATeam can be subdivided into four major phases of activity as described below:

1. Problem Identification and Specification
   In meeting with NAPCA scientists and engineers, TATeam members attempt to comprehend not only specific problems and requirements but also how these problems are affecting the progress of research and development in air pollution control. These problems are generally related to instrumentation for measuring specific pollutants, instrumentation for determining the effects of various pollutants, and systems for reducing or removing specific pollutants from the air. Following these discussions, the team prepares problem statements on each specific requirement. These problem statements describe problems in a concise manner using functional and nondisciplinary terminology. They also point up the significance of the problem and the possible benefits should a solution be found.

2. Identification of Relevant Information or Technology
   Two approaches are presently used to obtain information relevant to solving specific problems. The first approach utilizes a

*"Applications of Aerospace Technology in Air Pollution Control," NASA Contract No NASW-1950, Final Report, (June 15, 1968 - June 14, 1969).

computerized information search of NASA's Aerospace Information Bank. This information bank consists of approximately 600,000 documents covering aerospace science and technology world-wide as announced in the Scientific and Technical Aerospace Reports (STAR) and the International Aerospace Abstracts (IAA). Computer information searches are performed collaboratively by members of the RTI team and application engineers at NASA Regional Dissemination Centers such as the Science and Technology Research Center of the North Carolina Board of Science and Technology located in the Research Triangle Park, North Carolina. For those problems for which these computer searches do not provide the information necessary for solutions, air pollution problem statements are circulated within NASA Field Centers and in selected industrial organizations participating in the space program. The purpose of these problem statements is to obtain assistance in solving problems from those individual scientists and engineers who may have relevant expertise, experience, or knowledge to contribute.

3. Evaluation of Potentially Applicable Information or Technology
   When potentially applicable technology or information has been identified, both the TATeam and the NAPCA engineer or scientist who originated the problem evaluate this information in detail. This evaluation includes both a consideration of applicability and any reengineering or further development that must be performed in order to apply the applicable technology.

4. Documentation
   The final phase of activity involves complete and detailed documentation of specific problems, the technology that was applied and how it was applied, and the procedures used for obtaining the relevant information.

Prior to the beginning of the present reporting period,(i.e., June 14, 1969), all of the activities of the RTI TATeam were devoted to problem identification and specification. This work resulted in the identification and specification of 41 specific technology related problems in the area of air pollution control. These problems were discussed in a previous RTI project report.* Of the 41 identified problems, problem statements were prepared on 21 which were selected on the basis of priority from NAPCA's standpoint and the probability of successfully identifying a solution in aerospace technology. Additionally, computer information searches were initiated in an effort to identify information relevant to these 21 problems. As reported previously, these 21 computer searches resulted in approximately 3500 citations.* An initial evaluation of the cited documents indicated that 373 were relevant to the 21 specific problems. During the preceding contract quarter, evaluations of the results of these 21 computer searches were made both by the TATeam and by the problem statement originators at NAPCA. Two technology transfers have resulted from these computer searches. These transfers and some observations concerning the general results of these computer searches are discussed in Sections 4 and 5, respectively.

Also during the preceding contract quarter, initial responses to problem statements circulated at NASA research centers were received. These responses from individual NASA scientists and engineers are discussed in Section 5. So far, responses from the NASA centers have been very encouraging; a number of potential transfers of technology have been identified and are presently being evaluated. The remaining sections of this report contain information on the operational aspects of the activities of the RTI TATeam applicable to the preceding contract quarter. The final section contains recommendations for enhancing the success of the RTI program to transfer technology to problems in air pollution control.

---

*See footnote on page 3.

3.0 INTERFACE BETWEEN THE NATIONAL AIR POLLUTION CONTROL ADMINISTRATION AND THE RTI TECHNOLOGY APPLICATION TEAM

This section contains a brief discussion of the interface that has been established between NAPCA and the NASA TATeam at RTI, both in terms of the organizational extent of the interface and the technical scope of the information exchange across this interface.

The National Air Pollution Control Administration (NAPCA) is composed of three operating bureaus plus six administrative offices reporting through the Deputy Commissioner's Office to the Commissioner, Dr. John Mittleton. Coordination of the activity of the RTI TATeam with the operating bureaus has been effected through the Office of the Assistant Commissioner for Science and Technology, Dr. John Ludwig, and NASA's Office of Technology Utilization, Technology Utilization Division, Mr. Ronald Philips, Director. Mr. R. G. Bivins, Technology Utilization Division, NASA, and Mr. Kay Jones, assistant to Dr. John Ludwig, NAPCA, are directly responsible for coordinating this experimental program in technology utilization.

Of the three operating bureaus in NAPCA, the RTI TATeam is working with the Bureau of Criteria and Standards, Dr. Delbert Barth, Chief, and the Bureau of Engineering and Physical Sciences, Mr. Paul Spaite, Chief. No activities have been initiated at this time with the Bureau of Abatement and Control, Mr. Robert Harris, Chief. Within the Bureau of Criteria and Standards, the activities of the RTI TATeam have been concentrated in the Division of Health Effects Research. Within the Bureau of Engineering and Physical Sciences, the TATeam interface extends across all four divisions--Chemistry and Physics Division, Meteorology Division, Process Control Engineering Division, and the Division of Motor Vehicle Research and Development. When this Technology Utilization program was initiated early in 1969, it was decided jointly by NAPCA, NASA, and the RTI TATeam that these five divisions represented that part of NAPCA having the greater potential for applying aerospace developed technology.

Published objectives of NAPCA reflect the increasing national concern about air pollution control problems. NAPCA's program directed towards achieving these objectives emphasizes public awareness in the following areas:

1. The rapid development of the capability of state and local governments to assure wholesome air for the population in their jurisdictions,
2. The definition and degree of risk associated with pollutants known to cause either harmful effects on health and economics on a broad geographic and population base or extremely harmful effects on a select population, and
3. The operational development of control technology for types of sources or for specific pollutants having major nationwide impact.

The activities of the RTI TATeam have been directed toward technology transfer in the latter two areas, with major emphasis being placed on support of the NAPCA Research and Development (R & D) Program. The NAPCA program is planned so as to provide the requisite base of knowledge for specific, sensitive, precise, or lower cost instrumentation and analytical techniques for all pollutants of major importance. The R & D plan is to provide the operational program with standard methods of sampling and analysis; development of advanced sensors; and the continual studies of laboratory feasibility and developmental studies of new families of instruments.

Of the 41 problem areas identified by the RTI TATeam, 24 are in the area of sensor development, 12 are in support of increasing the requisite base of knowledge, four are in the area of standard method of sampling and analysis, and one is in the general area of information management. Based upon these numbers and NAPCA's stated objectives and plans for achieving these objectives, it is clear that NAPCA has taken a very responsible and serious approach to this experimental technology transfer project. The technological problems under investigation by the RTI TATeam are of national significance in the area of air pollution control.

4.0 PROBLEM STATUS

During the preceding contract quarter, the RTI TATeam has concentrated its efforts on the evaluation of computer research results and on the initial evaluation of responses from NASA Research Centers to specific problem statements. As a result of these activities, the team has accomplished two transfers of technology and has identified two potential technology transfers plus nine additional items of technology which should become potential or completed transfers during the next quarter.

In general, the response from NASA Field Centers to problem statements has been very good. To date we have received 28 responses to specific problem statements. Our evaluations of the results of computer information searches on the other hand have indicated that the searches are not sufficiently up to date concerning NASA R & D programs to allow the team to identify NASA technology that can be applied in air pollution control to the extent that should be possible.

Of the 41 active problems being investigated by the RTI TATeam, 21 received the team's concentrated effort during the preceding quarter. The status of these 21 problems is discussed in the following paragraphs. These discussions include the results of computer searching as well as brief descriptions of specific responses from NASA Research Centers to problem statements circulated. A complete list of the active problems being investigated by the TATeam is attached as Appendix A.

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

Computer search No. 1686 yielded 140 citations. Although Dr. Shy has not completed his evaluation of these search results, he has ordered a total of 22 documents cited in the search bibliography.

A potential solution to this problem has been identified by a response to the problem statement from Mr. Grady Moroman and Dr. James Scow of NASA's Langley Research Center. This response was received both by direct contact from Dr. Scow and through Mr. John Samos, Technology Utilization Officer, Langley Research Center. A potential technology transfer report is included in Appendix B.

The potential solution to this problem involves the application of a coordination tester developed by NASA for performance testing of astronauts. This specific coordination tester has been used by the U.S. Navy for testing performance of submarine personnel. Dr. Scow feels that this testing equipment satisfies all NAPCA's requirements as specified in the problem statement. The significant data base on personnel performance that has been generated through the use of this coordination tester should be of significant additional value to NAPCA.

At the present time the RTI TATeam plans to visit Langley with investigators from NAPCA to discuss and further evaluate the proposed use of NASA's coordination tester for performance testing of automobile drivers. Dr. Scow has indicated that Langley Research Center will consider lending the equipment to NAPCA for further evaluation.

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

No applicable information has been identified through computer searching. It was recently learned that NAPCA is testing a new technique for atmospheric temperature sensing. The technique is at present proprietary and no information is available except that it utilizes molecular absorption and emission of optical energy. If further evaluation indicates that this instrument satisfies NAPCA's requirements, it is likely that the instrument will be made commercially available and the problem will be solved.

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 - J. J. B. Worth

At present, Mr. Hosler has not completed an evaluation of computer search No. 1718. Two responses to problem statement AP-5 have been received through Mr. Harrison Allen, Technology Utilization Officer, Langley Research Center. Mr. Bill Gordon has suggested that technology for measuring radiation emitted by molecules and light scattered from particulate matter may be applicable in investigating the long-term geophysical effects of particulates. Mr. H. B. Probst has suggested that techniques used in the joint NASA/Air Force project "Venus Fly Trap" to collect micrometeorites should be useful. Both suggestions are being followed up at the present time and their general significance to this problem is being discussed with NAPCA personnel.

RTI/AP-21, "Development of Advanced Pollutant Sensor for Ozone"
Mr. Robert K. Stevens, Division of Process Control Engineering
Team Member - Dr. L. F. Ballard

A report cited in the search bibliography which compares a Brewer-Mast, a Regener, and a coulometric instrument for measuring ozone has been used by NAPCA researchers in an ongoing program to develop new instrumentation for ozone measurements. This transfer is documented in Appendix B.

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

Three responses to this problem statement have been obtained to date. Mr. R. J. Schwinehamer of NASA's Marshall Space Flight Center has suggested that although flame ionization detectors do not fulfill NAPCA's requirements for monitoring total hydrocarbons, the cross section ionization detector approach may be satisfactory since it does not require a flame and it has a very high sensitivity. Mr. J. T. Powell, also of NASA's Marshall Space Flight Center, has suggested that the thin-film techniques developed for hydrogen gas detection for NASA can be adapted to hydrocarbon gas detection. This development work was carried out by the General Electric Company for NASA. He further indicates that the thin-film technique will have to be evaluated to determine whether the sensitivity and accuracy requirements of NAPCA can be met. Mr. Benjamin H. Beam of NASA's Ames Research Center has suggested that total hydrocarbons can be monitored using laser technology. He has sent two papers on the detection of hydrocarbons using HeNe laser to the RTI team, which is presently studying them. All three responses to this problem statement are presently being evaluated both by the RTI TATeam and by NAPCA engineers.

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 - Dr. L. F. Ballard

Of the 57 citations in computer search bibliography No. 1707, 10 were requested by the NAPCA investigator. One of these documents contained information that has been of value to engineers of the Division of Process Control Engineering; this is reported as a transfer and is documented in Appendix B.

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

No directly applicable information has been identified in computer search bibliography No. 1712. Evaluation of this bibliography is, however, incomplete at the present time. No potentially applicable technology has been suggested in response to circulation of the problem statement.

RTI/AP-10, 11, 22, 25, 26, 27 and 41, "Development of Advanced Pollutant Sensors for Methane, SO_2, Fluorides, CO_2, Hydrocarbons, CO, and Oxides of Nitrogen"
Mr. Andrew E. O'Keefe and Mr. Robert K. Stevens, Division of Chemistry and Physics
Team Member - Mr. C. E. Decker

These particular problems are being discussed together because the responses to problem statements from NASA Field Centers have been related to all seven requirements. Mr. Robert Naumann and Dr. Tom Edwards of NASA's Marshall Space Flight Center have been involved in the development of mass spectrometer techniques and instrumentation for spacecraft contamination analyses. Techniques for real time gas analysis using small digital computers have been developed. They have suggested that a complete self-contained system that can sample and perform quantitative as well as qualitative analyses on a real time basis is feasible as a result of NASA's R & D programs. These systems could be made to operate in a remote location in an automated mode or, by adaption, in an aircraft. Mr. Russel Oluss of NASA's Kennedy Space Center, who is involved in monitoring hazardous gases in spacecraft, has suggested the use of a modified off-the-shelf spectrometer as a solution to the subject problems. Mr. Oluss stated that at the Kennedy Space Center gases are sampled through a one-quarter inch diameter stainless steel tubing and brought from the top of a launch vehicle to its base where gas monitoring instrumentation is located. The gases are detected automatically and quantitative information telemetered to a site approximately three miles from the launch vehicle. It was felt that techniques employed in this monitoring system would be useful in monitoring gases in stacks. NAPCA engineers concerned with stack monitoring are being identified for discussing these techniques.

The RTI TATeam is working closely with NASA engineers at Marshall Space Flight Center and Kennedy Space Center in further evaluation of the mass spectrometer and automated analysis techniques as a possible solution to NAPCA's gas monitoring requirements. The team plans to visit Marshall Space Flight Center with NAPCA engineers in the near future.

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

Mr. Chester D. Lanzo of NASA's Lewis Research Center has responded to this problem statement. His suggestion was related to a particulate injection system that he has used and which appears to be applicable to the experimental program at NAPCA. Actually, two different injection systems have been used by Mr. Lanzo. One of these employs a glass annulus which allows the particulate-laden gas under study to be accelerated to Mach 1 conditions. The shock wave at the annulus is effective in deglomerating the submicron particles in the gas. The techniques suggested by Mr. Lanzo are presently being evaluated by NAPCA engineers.

In discussions with Mr. Lanzo, techniques for determining the size distributions of submicron particles were considered. These techniques involved both optical and nitrogen absorption approaches. The techniques also appear to be directly applicable to problem RTI/AP-38, "Measuring Techniques for Airborne Particulates." This information is also being evaluated.

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

The information received from Mr. Lanzo at Lewis Research Center and mentioned in the preceding problem status discussion is being evaluated by Mr. Dorsey.

Additionally, information search No. 1746 has resulted in several items of information on instruments and techniques relevant to this problem. One document in particular on the measurement of particle diameters appears to be directly relevant to Mr. Dorsey's experimental program and is reported as a potential transfer in Appendix B.

5.0 CONCLUSIONS AND RECOMMENDATIONS

During the preceding contract quarter, the activities of the RTI TATeam in the area of air pollution control have been directed primarily towards evaluating computer information searches related to 21 problems. These evaluations are essentially complete. As a direct result of these computer searches, two technology transfers have been accomplished and one potential technology transfer has been identified.

During August 1969, problem statements on 21 active problems were circulated through NASA Research Centers. The purpose of this circulation was to solicit assistance from individual NASA scientists and engineers in identifying technology that might provide possible solutions to the problems and requirements specified in the problem statements. To date approximately 30 responses related to specific problems have been received from five NASA Field Centers--Langley Research Center, Lewis Research Center, Marshall Space Flight Center, Ames Research Center, and Kennedy Space Center. The initial evaluations of these responses indicate that approximately 10 may result in transfers of aerospace technology to the field of air pollution control. Most of the information received in response to the circulation of problem statements is very recent and has not yet been published in the open literature or in NASA reports.

Based on the experience of the RTI TATeam in evaluating both the results of computer searches and responses to problem statement circulation, it is concluded that a successful Technology Utilization program in air pollution control must be based on access to recently developed aerospace technology. In the future, the efforts of the TATeam will be directed towards this aim. This will be accomplished in the following ways.

First, the circulation of problem statements will be effected as early in the problem investigation cycle as possible. The computer information search will be used to inform the solicited NASA engineers and scientists of the technology already considered in attempting to solve the specific problems. The computer search will also be used to insure that obvious solutions have not been overlooked.

Second, engineers and scientists involved in R & D related to specific problems and located at NASA Field Centers will be contacted through the Field Center Technology Utilization Officer even though they have not responded to or may not have seen the problem statement. These contacts initiated by the TATeam will be based on information obtained from NASA's project reporting system and Field Center Organizational Directories and on suggestions solicited from Field Center Technology Utilization Officers and other appropriate sources.

6.0 ACTIVITIES FOR THE NEXT QUARTER

During the next contract quarter, the RTI TATeam will direct its activities toward the following specific tasks: (1) Responses to problem statements from NASA Research Centers will be evaluated. More specifically it is expected that this effort will be concentrated on evaluating responses to the following problem statements: RTI/AP-1, 10, 11, 21, 22, 25, 26, 27, 28, 29, 30, 31, 34, 35, 38, and 41. (2) Contacts with individual engineers and scientists at NASA Research Centers will be initiated by the TATeam in order to enhance the flow of information from NASA centers into the area of air pollution control. In particular, emphasis will be placed upon the following specific problems: RTI/AP-23, 33, 34, 38. (3) An initial analysis of the amount of effort required in each phase of the transfer process in the area of air pollution control will be performed. (4) A formal project review will be set up near the end of the next contract quarter. It is planned that representatives of the Office of Science and Technology of NAPCA and the Technology Utilization Division of NASA will be present.

APPENDIX A

ACTIVE PROBLEMS

ACTIVE PROBLEMS

Problem Number	Title
RTI/AP-1*	Human Performance Test
RTI/AP-2*	Remote Temperature Sensing Technique in the Lower 2 Kilometers of the Atmosphere
RTI/AP-3*	Remote Wind Vector Sensing Technique in the Lower 2 Kilometers of the Atmosphere
RTI/AP-4*	Long-Term Geophysical Effects of Carbon Dioxide (CO_2)
RTI/AP-5*	Long-Term Geophysical Effects of Particulates from 0.2 to 0.5 Microns in Size
RTI/AP-6	Odor Classification and Identification
RTI/AP-7	Development of Advanced Pollutant Sensor for Total Oxides of Nitrogen NO_X ($NO + NO_2 + N_2 O_4 + \ldots$)
RTI/AP-8	Development of Advanced Pollutant Sensor for Nitrogen Dioxide
RTI/AP-9	Development of Advanced Pollutant Sensor for Nitric Oxide
RTI/AP-10*	Development of Advanced Pollutant Sensor for Methane
RTI/AP-11*	Development of Advanced Pollutant Sensor for SO_2
RTI/AP-12	Development of Advanced Pollutant Sensor for Arsenic
RTI/AP-13	Development of Advanced Pollutant Sensor for Beryllium
RTI/AP-14	Development of Advanced Pollutant Sensor for Mercury
RTI/AP-15	Development of Advanced Pollutant Sensor for Nickel
RTI/AP-16	Development of Advanced Pollutant Sensor for Ammonia
RTI/AP-17	Development of Advanced Pollutant Sensor for Carcinogens
RTI/AP-18	Development of Advanced Pollutant Sensor for Chlorine
RTI/AP-19	Development of Advanced Pollutant Sensor for Hydrogen Sulfide
RTI/AP-20	Development of Advanced Pollutant Sensor for Vanadium

*Problem Statements have been prepared and circulated to NASA Research Centers.

Problem Number	Title
RTI/AP-21	Development of Advanced Pollutant Sensor for Detection of Ozone
RTI/AP-22*	Development of Advanced Pollutant Sensor for (Br -, Cl -, F -, I -)
RTI/AP-23	Development of Advanced Pollutant Sensor for Lead
RTI/AP-24	Development of Advanced Pollutant Sensor for Reactive Hydrocarbons
RTI/AP-25*	Development of Advanced Pollutant Sensor for Carbon Dioxide
RTI/AP-26*	Development of Advanced Pollutant Sensor for Total Hydrocarbons
RTI/AP-27*	Development of Advanced Pollutant Sensor for Carbon Monoxide
RTI/AP-28*	Adsorption and Absorption Techniques
RTI/AP-29*	Adequate Instrumentation for the Investigation of Flame Chemistry
RTI/AP-30*	Effect on Pollutant Identity and Output of Trace Quantities of Metals
RTI/AP-31*	Analytical Techniques for Trace Metals in Combustion Effluent and Waste Gases from Metal Processing
RTI/AP-32*	Fluidized Bed Combustion Processes
RTI/AP-33*	Working Fluids for Rankine Cycle Engines
RTI/AP-34	Holographic Technique for Measuring Particulate Flux
RTI/AP-35*	Heat Transfer to Small Gasborne Particles
RTI/AP-36	Combustion Chamber Aerodynamics
RTI/AP-37*	Physical Consideration in Optimizing Fuel Air Mixture
RTI/AP-38*	Measuring Techniques for Airborne Particulates
RTI/AP-39*	Gas Exchange Capacity of the Lungs
RTI/AP-40	Development of Advanced Pollutant Sensor for Cadmium
RTI/AP-41	Development of Advanced Pollutant Sensor for Oxides of Nitrogen (NO_X, NO, NO_2)

APPENDIX B

TECHNOLOGY TRANSFER AND POTENTIAL TECHNOLOGY TRANSFER REPORTS

POTENTIAL TRANSFER REPORT

RTI/AP-1

"Automobile Drivers Performance Test"

Dr. Carl Shy
National Air Pollution Control Administration

Team Member - Dr. F. Thomas Wooten

Problem Acquired - April 1969
Elapsed Time - Seven months

Description of Problem

The National Air Pollution Control Administration has a general interest in the effects of air pollutants on large numbers of people. Some 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 satisfactory degree. There is, however, only 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 various types of air pollutants. Carbon monoxide, one of the most common pollutants, can reach a level of 50 ppm on busy freeways. These pollutants are assumed to degrade automobile driver performance, but quantitative tests are needed to determine the degree of degradation. The primary reason for observed effects is that these pollutants cause anoxia (i.e., decreased supply of oxygen to the body); one symptom of anoxia is sleepiness.

A number of performance tests, including autitory discrimination, time estimation, visual line separation, minimum detectable light intensity, and color matching have been used in evaluating driver performance. However, the researcher feels that these tests establish only baseline or resting condition data. Tests are desired that include a stress level during the test where fatigue and boredom are stress factors.

A performance test is needed to determine the effects of air pollutants (CO, O_3, NO, NO_2) on physical ability, alertness, and vigilance of automobile drivers. Inhalation of specific concentrations of pollutants is required during the tests. The test should also allow for the introduction of discrete levels of boredom and fatigue.

Description of Potential Solution

The solution is a complex coordination tester developed by NASA for measuring physiological changes due to toxicity, physiological or psychological stress in long duration, closed environment tests. The unit is a self-paced serial reaction complex coordinator psychomotor performance tester that presents a series of light displays that must be arranged in a particular pattern by four limb controls, one for each hand and foot.

Thus, a test is presented--one new problem being presented after the completion of each answer (serial reaction);each new problem only being presented after the successful completion of the previous one (self-paced); each problem for successful completion involves the correct positioning of all four limb controls (complex coordination); the ability to see the combinations of problem lights and to determine the correct action with the limb controls (psychomotor performance).

Successful Search Method

The potential solution to this problem was identified as a result of circulating the problem statement to NASA Field Centers. Dr. James Scow of NASA's Langley Research Center (LRC), Hampton, Virginia, contacted the RTI Biomedical Application Team through Mr. John Samos, Technology Utilization Officer, LRC, to suggest that the complex coordinator developed for NASA represented a solution.

In addition to the solution obtained from LRC, Dr. Shy is still evaluating the results of computer search No. 1656 performed by the Science and Technology Research Center of the North Carolina Board of Science and Technology--one of NASA's Regional Dissemination Centers. So far 22 documents which are relevant to the problem have been obtained by Dr. Shy.

Benefits to be Derived from Transfer

The Complex Coordinator will enable NAPCA to evaluate quantitatively the effect of the most common air pollutants on the ability of automobile drivers.

This evaluation will determine if air pollutants significantly degrade driver performance and, in turn cause a significant number of highway deaths. The highway death toll is now greater than 50,000 people per year.

TRANSFER REPORT

RTI/AP-28

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

Joshua S. Bowen, NAPCA

Team Member - Dr. L. F. Ballard

Problem Acquired - April 22, 1969
Transfer Made - October 1, 1969
Elapsed Time - Five months

Description of Problem

The potential use of adsorption and absorption techniques for removing pollutants from carrier gas streams has not been fully capitalized. Adsorption is currently used in air pollution control, mainly on relatively small volumes of effluent gas. The use of activated carbon, one of the best adsorbents, is seriously restricted at elevated temperature because it is subject to spontaneous combustion. Adsorption with accompanying chemical reactions by various types of solutions is promising in many areas.

Examples of needed improvements are better adsorbents and adsorbing solutions for specific compounds, and better efficiency from manipulation of temperature, pressure, or contact area (geometry). Specific pollutants of major interest are sulfur compounds, oxides of nitrogen, organics, and oxides of carbon.

Description of Solution

NAPCA engineer, Joshua S. Bowen, is currently conducting a dead-burning test methods program in Cincinnati. A paper by Yoshio Ohno entitled, "The Direct Adsorption of CO_2 by Quicklime," which was included in bibliography No. 1707, was found to be of significant value to this program. Its importance in NAPCA's research is indicated by the following excerpt of a memorandum from D. C. Drehmel to Joshua S. Bowen:

> "In Ohno's experiment, limestone particles 30-40 mm. in size were heated to 930, 1000, 1100, 1200, 1300°C at 60°C/min. Total calcination time was three hours. These samples were exposed to CO_2 at 600°C, 1 atm., 0.3-0.5 liters/min. and the weight was monitored as

a function of exposure time. Ohno found that the adsorption rose rapidly with time and was nearly constant after 20 minutes. At 30 minutes exposure, the adsorption dropped with increasing calcination temperature; the largest drop being for calcination temperatures from 930 to 1100°C. Comparison of these data and data obtained within NAPCA was attempted by setting the absorption for the 1700°F calcine at one hundred percent. The result . . . indicates good agreement between these sources even though the exposure conditions are somewhat dissimilar. The sharp perhaps discontinuous drop at 1900°F is attributed by Ohno to shrinking, melting, and fusing of the crystals, thereby obstructing the penetration of CO_2. This is substantiated by the finding that interior adsorption is much less than exterior adsorption only above 1900°F.

"Ohno concluded that in any event, CaO adsorption of CO_2 provides a means by which the chemical activity of CaO may be measured. It is believed . . . experimental methodology need not be limited to the past method of determining activity on the basis of hydration. This conclusion is of great significance since adsorption of CO_2 by CaO is presently the most promising candidate for a dead-burning test method."

Successful Searching Method

RDC computer search of aerospace literature.

Benefits to be Derived from Transfer

Since adsorption of CO_2 by calcium oxide CaO is presently the most promising candidate for a dead-burning test method, the availability of the work of Yoshio Ohno is of great significance. Agreement of the experimental results that were accomplished independently with those produced in somewhat different circumstances gives added confidence in the current interpretation of research data. The additional conclusions indicate possible shortcuts in present operational techniques. In real terms this transfer has resulted in a savings in time and resources.

TRANSFER REPORT

RTI/AP-21

"Development of Advanced Pollutant Sensor for Ozone"

Robert K. Stevens, NAPCA

Team Member - Dr. J. J. Wortman

Problem Acquired - April 25, 1969
Transfer Made - August 27, 1969
Elapsed Time - Four months

Description of Problem

Ozone is one of the major air pollutants in urban environments. In addition to its generation in the upper atmosphere, it is photochemically produced by the reaction of certain hydrocarbons with nitrogen dioxide in the presence of sunlight. This compound has detrimental effects on plants and materials and is a potential health hazard. An advanced sensor that is specific for ozone and capable of measuring its concentration in ambient air is needed. This information is particularly useful in determining the relationship between smog formation and ozone concentration.

Traditionally, ozone has been measured as total oxidant by the following techniques: (1) spectrophotometric (neutral buffered KI method) and (2) coulometric (Brewer-Mast). Neither of these techniques is specific for ozone. A chemiluminescent technique (Regener) that is more specific for ozone has been used and is currently under development.

The goal of current research is an ozone sensor that is highly specific with a measurement range between 1 ppb and 1 ppm and with a desired accuracy of ± 5 percent.

Description of Solution

In the development of analytical instrumentation, many different techniques must be investigated. Considerable search time and money are devoted to determining the technique that is most desirable for specific application. The literature on ozone included comparisons of a Brewer-Mast, a Regener, and a coulometric instrument. In addition to verifying some of the NAPCA research, the literature included additional comparative data on available instrumentation. Specifically, the document used was A67-13931 in search No. 1756.

Successful Searching Method

Computer search of aerospace literature.

Benefits to be Derived from Transfer

The information obtained in the literature search had immediate value to the NAPCA researchers. Through the provision of additional data and the verification and support of current work, the ozone research effort received added impetus. Additionally, the availability of the document will save this group time and an undetermined amount of money by verification and support of their current research.

POTENTIAL TRANSFER REPORT

RTI/AP-38

"Measuring Techniques for Airborne Particulates"

Mr. James A. Dorsey, NAPCA

Team Member - Dr. L. F. Ballard

Problem Acquired - May 15, 1969
Elapsed Time - Four months

Description of Problem

A rapid technique for measuring the size and concentration of airborne particulates is needed. Originating in a wide variety of industrial and natural processes, this particulate matter is a major air pollution problem. The researcher desires to measure the concentration and size of these particles with sufficient speed to enable control of their emission. *In situ* techniques are preferred, but a rapid procedure for measuring extracted samples would also be of value. Several techniques are currently in use. In one technique a sample of particulate matter is collected on an adhesive surface; the particle size and density are then obtained photographically or by visual inspection under a microscope. Another technique involves collecting particles in a liquid vehicle that is monitored by capacitance changes in a small orifice.

Optical particle analyzers have been developed for limited use and the technology of holographic techniques is expanding rapidly. Although X-ray and beta absorption techniques are available for determining total mass density, present instrumentation is inadequate for monitoring particle diameters over the range of 0.1 to 10 microns with a concentration up to 10^8 per cubic foot.

Potential Solution

Information search No. 1746 in this problem area disclosed several instruments and techniques that satisfied certain parts of the specifications. One document identified an instrument developed at the University of Minnesota that is capable of measuring particle diameters of 0.001 to 10 microns. Loading specifications of 10^8 per cubic foot, however, were not obtained. To achieve the wide range of diameters, the instrument used a combination of three techniques: condensation nuclei, a light scattering counter, and an electrical particle counter. A potential solution to the problem is a combination of a dilution technique with the described instrument to allow for a particle loading of 10^8 per cubic foot.

Successful Searching Method

RDC computer search.