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DEAN OF FACULTY

UNITED STATES AIR FORCE ACADEMY, COLORADO

Annual Research Progress Report No. 10

JULY 1975

COVERING PERIOD

1 JULY 1974 - 30 JUNE 1975

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This is the fourth published Annual Research Progress Report; the editions previous to 1972 were published as Semi-Annual Progress Reports. Further information desired on any project may be obtained by writing to the department listed for the principal investigator, USAF Academy, Colorado 80840.

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use the emulator because of its program tracing and dumping features. All programming and testing of the emulator will be completed during the fall semester of 1975.

C. Department of Chemistry

1. High Energy Density Electrochemical Cells

Principal Investigators: Lieutenant Colonel Lowell A. King, Captain John K. Erbacher, and 1st Lt Charles L. Hussey, Frank J. Seiler Research Laboratory (AFSC), and Lieutenant Colonel David W. Seegmiller and Major Armand A. Fannin, Jr., Department of Chemistry

Sponsored by the Frank J. Seiler Research Laboratory, Air Force Systems Command (AFSC)

Work during this reporting period has focused primarily in the following three general areas: (1) physical property measurements on the aluminum chloride/sodium chloride and aluminum chloride/sodium chloride/potassium chloride systems, (2) pelletized aluminum chloride/alkali metal chloride electrolyte batteries, and (3) mathematical analysis of various physical property data.

In the area of physical property measurements, the phase diagram for the $AlCl_3/NaCl/KCl$ has been determined. This investigation has led to the possibility of compounding very low melting ($100^{\circ}C$), very low vapor pressure electrolytes. In support of the thermal battery project, work is continuing in the area of measuring the heat of fusion of various electrolyte compositions. This data is essential for design of batteries using chloroaluminate electrolytes.

Research was done and is continuing on pelletized aluminum chloride thermal batteries and has been extended to the investigation

of alternative means of employing chlorine gas as the active cathode material. The inconvenience of precharging the battery cell to generate chlorine gas in the cathode compartment has been eliminated by employing a catholyte consisting of $NaAlCl_4$ electrolyte, strong oxidant, and graphite. Chlorine gas is generated in situ through oxidation of the melt. Nineteen oxidizing agents have been examined with constant current coulometry to assess their value as cathode materials. Four of these have been found suitable for use in aluminum chloride pelletized thermal batteries: CrO_3, $KMnO_4$, MnO_2, and $CaCrO_4$. Patent applications covering the use of these materials are currently in progress. A variety of melts other than the standard 50 mole % $AlCl_3$-NaCl have been tested as electrolytes: 60-40 mole % $AlCl_3$-NaCl, 50-40-10 mole % and 59-32.2-8.8 mole % $AlCl_3$-NaCl-KCl ternary melts. A technical report covering this work is in the final stages of completion.

The mathematical analysis of the physical property data has included the reduction of $AlCl_3$ vapor pressure data over a large density range below 300°C. The parameters for several equations of state, formulated from that of van der Waals' and its modifications, have been evaluated for $AlCl_3$. From these equations of state, the pressure and density of $AlCl_3$ vapor can be predicted to within 2% at all useful temperatures. This information will be used to predict vapor pressures and concentration changes of sodium chloroaluminate electrolytes.

Work is in progress on surface fitting in multivariate systems for reduction of data involving pressure, temperature, volume, and

composition. Least squares techniques are applied simultaneously to all variables to minimize the distance to the surface.

A system was developed for temperature measurement based on the use of inexpensive platinum resistance elements. The calibration of these elements is performed by fitting resistance data for the element to similar data for an Air Force Reference Standard Thermometer. Standard Callender equation parameters are obtained using a Wang 720C programable calculator. An accuracy of .01K on the 1968 International Practical Temperature Scale is obtained. This innovation allows simultaneous use of thermometers with .01K accuracy in several locations without the expense of multiple Reference Standard Thermometers.

Publications

"Densities of Liquid Aluminum Chloride-Sodium Chloride Mixtures. I. Single Phase Liquid Region," Armand A. Fannin, Jr., Fred C. Kibler, Jr., Lowell A. King, and David W. Seegmiller. J. Chem. Eng. Data 19, 266 (1974). (Also published as Seiler Research Lab TR-74-0020 with data tables.)

FJSRL (NC) Technical Memorandum TM 75-1, January 1975, "Calibration of Platinum Resistance Elements," Armand A. Fannin, Jr., Fred C. Kibler, Jr., and Lowell A. King

FJSRL (NC) Technical Memorandum TM 75-2, February 1975, "Calibration Program for Platinum Resistance Elements," Armand A. Fannin, Jr., and Lowell A. King

2. Chemiluminescent Gas Phase Reactions

Principal Investigators: Captain William E. McDermott and Major John T. Viola, Department of Chemistry pfcf

Associate Investigators: Captain Scott A. Shackelford, Frank J. Seiler Research Laboratory (AFSC), and Cadet David A. Ferguson

Sponsored by the Air Force Weapons Laboratory (AFSC) and the Frank J. Seiler Research Laboratory (AFSC).

New or improved lasers operating in the visible or near-infrared have potential applications to the Air Force. Work this reporting period has concentrated in two areas: the characterization of a heterogenous reaction producing singlet molecular oxygen developed in this laboratory and the investigation of an XeF_2-fueled HF laser.

The heterogeneous reaction between gaseous Cl_2 and a saturated solution of NaOH and H_2O_2 to produce gaseous singlet oxygan ($O_2(^1\Delta g)$) has been studied spectrophotometrically verifying the evolution of singlet oxygen. The kinetics of the solvation of Cl_2 (gas) on an NaOH solution has been measured in terms of the probability of gas phase removal per wall collision. In this study, a simple recording manometer was developed to follow the decrease in pressure in the reacting system.

The XeF_2-fueled HF laser investigation has centered on construction of a flash photolysis laser system and its characterization using a known, kinetically simple laser mixture (Cl_2-HBr).

D. Department of Civil Engineering, Engineering Mechanics, and Materials

1. Automated Finite Element Mesh Generator

Principal Investigator: Major Richard H. Danhof, Department of Civil Engineering, Engineering Mechanics, and Materials

Sponsored by the Air Force Flight Dynamics Laboratory, Air Force Systems Command (AFSC)

The finite element method has gained widespread acceptance in recent years among both the industrial and governmental technical communities. Using this method of analysis, however, involves the preparation of a great deal of input data, especially if the problems are complex.

4. The Validity of Various Measures in Predicting Pilot Training Performance

Principal Investigators: Majors J. M. Koonce and D. C. Prather, Department of Life and Behavioral Sciences

Sponsored by the Frank J. Seiler Research Laboratory (AFSC)

This study is arranged in two phases to determine the validity of certain performance measures in predicting pilot training success. The first phase will use a digit-canceling side-task along with a basic two-dimensional tracking task for the prediction of Air Force Academy cadet performance in T-41 aircraft training. The second phase will investigate the use of performance in a General Aviation Trainer Flight Simulator (GAT-1) while responding to a side-task as predictors of T-41 performance. All measures will be retained for correlation with the cadets' subsequent performance at Undergraduate Pilot Training (T-37 and T-38 aircraft).

5. The Use of Biofeedback Techniques in Stress Management Training

Principal Investigators: Captains R. G. Eggleston and K. E. Parker, Department of Life and Behavioral Sciences

Sponsored by Frank J. Seiler Reserach Laboratory (AFSC)

The purpose of this study is to examine the possible uses of muscle relaxation training through biofeedback techniques as a stress manager. The principal concern has been to develop a program which will aid the student in overcoming stress anxiety associated with both the preparation and taking of college course achievement examinations. A preliminary program including an audio tape series on muscle relaxation and biofeedback training has been developed and is currently being evaluated. Final results of this study will be available by 30 June 1976.

6. Lipids and Lipoproteins in USAF Academy Cadets

Principal Investigator: Major E. L. Arnold, Department of Life and Behavioral Sciences

Sponsored by the Aerospace Medical Division/RDOP (AFSC)

This is a continuing project to obtain data on blood serum lipid and lipoprotein levels in order to evaluate what changes are attributable to natural maturation, to diet, and to the environment (social pressure, exercise, altitude, etc.) of USAF Academy cadets during their four years at the Academy and two years following graduation.

Blood samples have been periodically collected from cadets in the Class of 1976 for analyses of serum lipids, lipoproteins, and related factors. Less frequently, estimates have been obtained on lean body mass for correlation with the lipid data. Estimates have also been made periodically of caloric intake, of the composition of the diet, and of the degree of emotional stress experienced by the subjects of the study.

Publications and Presentations

Clark, D. A., Arnold, E. L., Foulds, E. L., Brown, D. M., Eastmead, D. R., and Parry, E. M., 1975, "Serum Urate and Cholesterol Levels in Air Force Academy Cadets," Aviation, Space and Environmental Medicine. (In press.)

7. Determination of Parameters for a Model of Environmental Quality for USAF Installations

Principal Investigators, Captains L. J. Biever, A. L. Young, and M. A. Thomas, ~~and G. R. Coulter~~, Department of Life and Behavioral Sciences

Sponsored by Frank J. Seiler Research Laboratory (AFSC)

This project was initiated in February, 1975. The objective of this study has been to identify those physical, chemical, and biological

parameters that will determine environmental quality on USAF installations. Using the Air Force Academy as a study area, methodology is being developed for collecting, organizing, storing, and analyzing environmental data produced as the result of the activities of on-base military agencies and nonmilitary organizations such as the U. S. Soil Conservation Service, U. S. Forest Service, Colorado State Fish and Game Department, and local academic institutions. Data collected will be incorporated into a model which will identify environmental deficiencies and predict environmental degradation. The use of such a model could result in a more efficient management of funds and manpower while improving base environmental quality.

8. Radiochemical and Fluorescent Bioassay of TCDD and 2,4,5-T Herbicide

Principal Investigator: Captain James Cupello, Department of Life and Behavioral Sciences

Associate Investigator: Captain A. L. Young, Department of Life and Behavioral Sciences

The Environmental Protection Agency currently limits the commercial use of 2,4,5-T herbicide due to the lack of environmental data on the highly teratogenic (birth-deforming) contaminant TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) found in all 2,4,5-T formulations. The consequence of such a use limitation directly affects the fate of a large USAF surplus inventory of Herbicide Orange (a 2,4,5-T formulation).

Although TCDD occurs in all 2,4,5-T formulations, its presence is measured only in parts per million of concentrated herbicide. When 2,4,5-T formulations are applied in shrub control programs, the

concentration of TCDD introduced into the environment is in parts per trillion. Analytical techniques available for following the fate of TCDD in the environment lack sensitivity and specificity. This study has been initiated to determine whether radiochemical and fluorescent techniques can be used in detecting environmental concentrations of TCDD in biological systems.

9. Lead as an Indicator of Environmental Quality in Airport Environs

Principal Investigators: Major C. E. Thalken, Lieutenant Colonel L. R. Klinestiver, and Captain A. L. Young, Department of Life and Behavioral Sciences

Sponsored by Frank J. Seiler Research Laboratory (AFSC)

Many airports, e.g., Peterson Field, Colorado Springs, Colorado, have a long history of use by both reciprocating and jet aircraft, yet no data are available as to concentrations of pollutants generated by aircraft engines, e.g., lead. Nevertheless, the Air Installation Compatibility Use Zones (AICUZ) of many airports, including Peterson Field, are routinely used for agricultural activities. Concentrations of lead in vegetation, soils, or animals are not known in these environments. As more stringent environmental qualities are applied by state and federal agencies, it will become more essential that the Air Force be able to monitor exposure of environmental pollutants to the environ on and around air installations. This study has been initiated to determine concentrations of lead in the environment immediately surrounding Peterson Field.

10. Disposal of Herbicide Orange by Soil Incorporation and Biodegradation

Principal Investigators: Captain A. L. Young and Major E. L. Arnold, Department of Life and Behavioral Sciences

Associate Investigators: Lieutenant Colonel W. E. Ward, Major C. E. Thalken, and Captain W. J. Cairney, Department of Life and Behavioral Sciences

Sponsored by Air Force Logistics Command/DS

Soil incorporation and biodegradation have been selected as alternate methods for the disposal of USAF inventories of Herbicide Orange. The soil incorporation method is based on the premise that high concentrations of phenoxy herbicide and the toxic contaminant TCDD will be degraded to innocuous products by the combined action of soil microorganisms and soil chemical hydrolysis.

Field plots established in 1972 in Florida, Kansas, and Utah, following incorporation of Herbicide Orange at rates of up to 4,000 pounds active ingredient per acre, have been closely monitored for chemical degradation, potential off-site movement, and ecological effects. Data have indicated rapid degradation of herbicides--greater than 95% of concentrations of 40,000 ppm in two years. Moreover, detailed examination of microbial populations indicated significant increases in fungi, bacteria, and actinomyctes for all treatment plots. No adverse ecological damage has been noted to the surrounding biota of each test site. Similar data were obtained for TCDD.

Publication

Young, A. L., Arnold, E. L., Thalken, C. E., Ward, W. E., and Cairney, W.J., 1975, "Soil Incorporation/Biodegradation of Herbicide Orange: Concepts, Methodology, and Field Results," USAF Academy Technical Report (In preparation).

Presentations

Young, A. L., Thalken, C. E., Ward, W. E., Arnold, E. L., and Cairney, W.J., 1974, Air Force research on ecological effects of herbicide application, Proceedings of the Region VIII Pesticide Disposal Conference, U. S. Environmental Protection Agency, Denver, Colorado, April 4-6, 1973.

Young, A. L., Arnold, E. L., and Wachinski, A. M., 1974, Field studies on the soil persistence and movement of 2,4-D, 2,4,5-T, and TCDD. Presentation to the Weed Science Society of America, 13 February 1974, Las Vegas, Nevada, Abstract No. 226.

11. Ecological Studies on a Herbicide-Equipment Test Area (TA C-52A), Eglin AFB Reservation, Florida

Principal Investigators: Captain A. L. Young, Lieutenant Colonel W. E. Ward, and Majors C. E. Thalken and L. G. Cockerham, Department of Life and Behavioral Sciences

Sponsored by Air Force Logistics Command/DS and Air Force Systems Command/SDWC

For the past four years, ecological studies have been conducted on Test Area C-52A, Eglin AFB Reservation, Florida--a one square mile area used in the testing of aerial defoliation spray equipment from 1962 through 1970. Because massive quantities of herbicides (346,117 pounds) were applied to this area, a unique opportunity existed to document the ecological consequences associated with repetitive use of phenoxy herbicides (e.g., Herbicide Orange) and the effects of the toxic contaminant TCDD.

Data have been obtained on the floral, faunal, and microbial communities. Rapid invasion (ecological succession) of vegetation, insect, and animal population has occurred on the test area in the period from 1970 to 1974. No gross or histological evidences of teratogenesis or toxicity have been found in 173 adults or fetuses of beach mice (Peromyscus

polionotus) inhabiting treated or control field sites. No adverse effects to aquatic ecosystems have been detected.

Publications

Young, A. L., Editor and Principal Investigator, 1974, "Ecological Studies on a Herbicide-Equipment Test Area (TA C-52A) Eglin AFB Reservation, Florida," AFATL-TR-74-12, Air Force Armament Laboratory, Eglin AFB, Florida.

Young, A. L., Thalken, C. E., Ward, W. E., and Cairney, W. J., 1974, "The Ecological Consequences of Massive Quantities of 2,4-D and 2,4,5-T Herbicides," Congressional Record S2425-2442, 28 February 1974.

Young, A. L., Thalken, C. E., and Ward, W. E., 1975, "Studies on the Ecological Impact of Repetitive Aerial Applications of Herbicides on the Ecosystem of Test Area C-52A, Eglin AFB, Florida," AFATL Technical Report, Air Force Armament Laboratory, Eglin AFB, Florida (In press).

Presentations

Young, A. L., Thalken, C. E., Ward, W. E., and Cairney, W. J., 1974, "The Ecological Consequences of Massive Quantities of 2,4-D and 2,4,5-T Herbicides - Summary of a Five-Year Study," presentation to the Weed Science Society of America, 14 February 1974, Las Vegas, Nevada.

Young, A. L., Thalken, C. E., Ward, W. E., Arnold, E. L., and Cairney, W. J., 1974, "Air Force Research on Ecological Effects of Herbicide Application," Proceedings of the Region VIII Pesticide Disposal Conference, U. S. Environmental Protection Agency, Denver, Colorado, April 4-6 1973.

Thalken, C. E., Ward, W. E., and Young, A. L., "Absence of TCDD Toxicity to Rodent Populations Following Massive Field Applications of 2,4,5-T Herbicide," presentation to the American Veterinary Medical Association, 112th Annual Meeting, Anaheim, California, 16 July 1975.

12. Ultrastructural Studies of Liver Tissue from TCDD-Exposed Beach Mice (Peromyscus polionotus)

Principal Investigators: Major L. G. Cockerham and Captain A. L. Young, Department of Life and Behavior

Sponsored by Air Force Logistics Command/DS

In support of research on the biological effects of animals exposed to TCDD (a toxic contaminant contained in USAF surplus inventories

of Herbicide Orange), ultrastructural studies were initiated on beach mice, Peromyscus polionotus, collected from a herbicide-equipment testing range (Test Area C-52-A, Eglin AFB, Florida). Liver tissue from 30 mice (from the test and a control area) were examined with an electron microscope for possible ultrastructural changes in mitochondria and smooth and rough endoplasmic reticulum. Similar data were collected from 22 mice brought from the field into the laboratory and exposed to 30 days of external dusting with alumina gel (with or without 2.5 ppb TCDD).

G. Department of Physics

1. Lasers, Unstable Resonators

Principal Investigators: Major John J. Armstrong and Captain Harald O. Dogliani, Department of Physics

Associate Investigators: Cadets Kevin W. Smith and Dan W. Chapman, Class of '75

Sponsored by the Frank J. Seiler Research Laboratory, Air Force Systems Command (AFSC), and the Air Force Weapons Laboratory, Kirtland AFB, New Mexico

This research is being performed for the Optics Technology Branch of the Laser Division, Air Force Weapons Laboratory, at Kirtland AFB. The research involves investigation of negative branch unstable resonators using a high-power CO_2 laser. Theoretically, negative branch unstable resonators have certain advantages over positive branch unstable resonators. In particular, negative branch unstable resonators are not as susceptible to spherical distortion and mirror misalignment. At the same time, they have the disadvantages of being more susceptible to