

NASA TECHNICAL MEMORANDUM

NASA TM X-62,409

NASA TM X-62,409

CHEMICAL RESEARCH PROJECTS OFFICE FUNCTIONS ACCOMPLISHMENTS PROGRAMS

A. H. Heimbuch and J. A. Parker

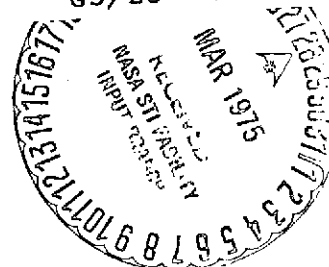
Ames Research Center
Moffett Field, Calif. 94035

(NASA-TM-X-62409) CHEMICAL RESEARCH
PROJECTS OFFICE FUNCTIONS ACCOMPLISHMENTS
PROGRAMS (NASA) 26 p HC \$3.75 CSCL 07A

N75-18324

Unclass
12415

G3/23



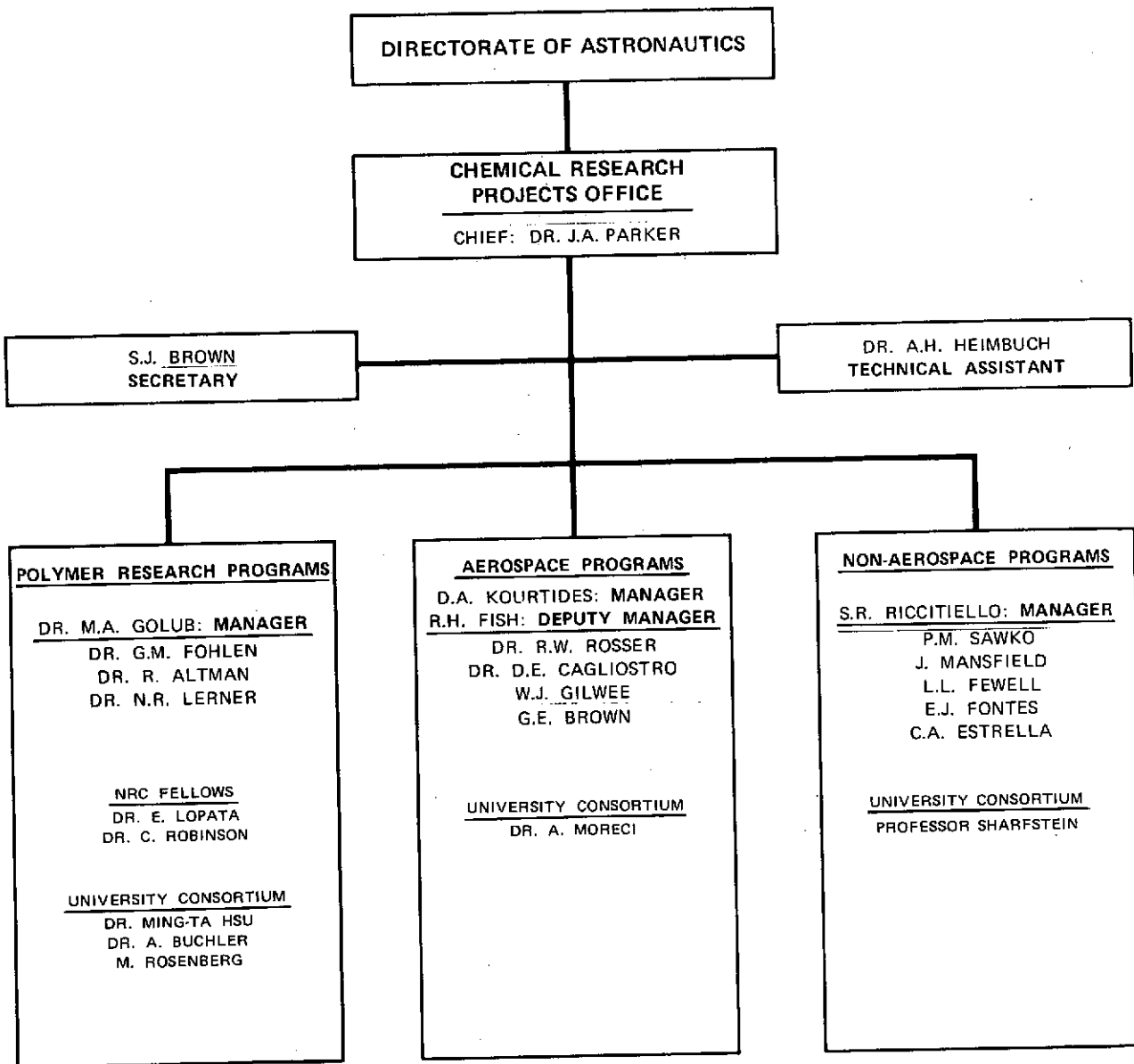
January 1975

TABLE OF CONTENTS

	PAGE
ORGANIZATIONAL CHART	v
MISSION	1
PURPOSE	1
SCOPE	2
ACCOMPLISHMENTS	3
POLYMER RESEARCH AND DEVELOPMENT GROUP	6
ADVANCED MATERIALS DEVELOPMENT GROUP	8
ENGINEERING MATERIALS AND FIRE TEST GROUP	9
PUBLICATIONS	11
PATENTS	16
CONTRACTS AND GRANTS	17
PRESENTATIONS AND SPECIFICATIONS	22

PRECEDING PAGE BLANK NOT FILMED

FUNCTIONAL (LINE) ORGANIZATION



CHEMICAL RESEARCH PROJECTS OFFICE
FUNCTIONS ACCOMPLISHMENTS PROGRAMS

A. H. Heimbuch and J. A. Parker
Ames Research Center

MISSION

The Chemical Research Projects Office conducts basic and applied research in the fields of polymer chemistry, polymeric composites, chemical engineering and biophysical chemistry. Primary objectives are to achieve fire safety and human survivability as they relate to commercial and military aircraft, high-rise buildings, mines and rapid transit transportation. The Office responds to national problems, when possible, by identifying the nonmetallic materials and chemistry needed for the solution of the problem and by participating in the development and application of these materials.

Research and development are therefore performed to develop a strong technological base which supports both the aerospace and domestic needs of the nation. Skills are maintained and developed in the areas of polymer synthesis and characterization, the development and processing of polymeric materials composites, and the basic analytical chemistry and instrumentation needed to support the above activities. A scientific interdisciplinary approach is commonly used in the solution of problems. New and improved materials systems and other fire control systems (e.g., high temperature polymeric foams, composites and fire extinguishing systems) are developed primarily for aerospace applications and can also often be applied to national domestic needs. The Office acts as a liaison between Center scientists and the Engineering community and assures that relevant technology is made available to other NASA Centers, agencies and industry. Before this technology can be transferred, in many cases, bench scale to full-scale tests are conducted of the aircraft systems and sub-systems which have been modified or retrofitted with the Ames' developed materials in order to demonstrate the improvements in performance obtained through the utilization of these materials and fire control measures.

PURPOSE

1. To identify the chemical research and technology required for solutions to problems of national urgency, synchronous with the aeronautics and space effort.

2. To conduct both basic and applied interdisciplinary research on chemical problems, mainly in areas of macromolecular science and fire research.
3. To provide productive liaison with the engineering community and effective transfer of technology to other agencies and industry.

SCOPE

1. Transportation safety in human environments:
 - a. Fire control in vehicles and structures.
 - b. Development of high performance aircraft tire and brake materials.
 - c. Development of high temperature elastomers for fuel tank sealants for advanced supersonic and conventional aircraft.
 - d. Fire extinguishing methods.
 - e. Toxicity studies of fire-retardant materials.
2. Space exploration and advanced aircraft progress:
 - a. Development of advanced aerospace materials.
 - b. Materials for environmental extremes--Entry Thermal Protection.
 - c. Fire-resistant, functional, nonmetallic materials for aircraft applications.
3. Technology utilization for civil applications:
 - a. Utilization of skills in combustion, heat transfer and fluid mechanics to simulate the heating environment associated with accidental liquid propane gas (LPG) fires and application of this characterization to LPG railroad tank cars via a fire test facility.
 - b. Utilization of the technology of high temperature materials development for reentry for application to high temperature friction materials, e.g., automobile brakes.
 - c. The application of high temperature fire resistant materials technology for mine safety; structures and coatings applications in work coordinated with the Bureau of Mines.

- d. Utilization of the technology base developed for aircraft crash-fire survivability for application to fire refuges for high rise dwellings.
- e. Development of microanalytical chemical systems and the application of chemical modeling to biomedical problems, e.g. morphine detector.
- f. Application of the technology base developed for aircraft interior materials to rapid transit systems.
- g. Utilization of computer technology for mapping liquid natural gas spills in inland harbor areas.

ACCOMPLISHMENTS

1. Research Achievements:

- a. Demonstrated that the stable free radicals which are formed during high temperature curing of poly-p-phenylene contribute largely to the long term thermal oxidation of this polymer, and the establishment of the limits of service of organic polymers for high temperature uses.
- b. Characterized the molecular weight distribution of a new class of polyaromatic ethers and found a relation with their heats of reaction.
- c. Demonstration of a structure-properties relationship to increase the Tg by 125° without limiting the mechanical properties when indane is substituted for bisphenol-A in the polycarbonate polymer. The char yield increases, high impact strength and good transparency are maintained and a reduction in flammability is obtained.
- d. It has been found that phenolphthalein can be copolymerized with bisphenol-A to yield a polymer which is processable and with increased char yield and Tg and a much reduced flammability.
- e. The heat penetration of a laser impulse was found to be inversely proportional to the degree of aromaticity in a polymer.
- f. Discovery of new energy transfer process in macromolecules.
- g. Identification of nitro-aromatic amine derivatives as intumescent agents.
- h. Establishment of new techniques and materials for analytical modeling of polymer pyrolysis processes.

- i. Spectroscopic characterization for indole charge transfer process.
- j. Microstructural changes in diene polymers during pyrolysis.
- k. Identification of new thermochemical mechanisms of flame inhibition resulting from spectroscopic studies of hydrogen halides in diffusion flames.
- l. Identification and characterization of silicon carbide as the major char component of the Apollo spacecraft heat shield after entry.
- m. Development of thermally stable polymers from the reaction of N,N' bis(p-nitrophenyl) sulfamide and p-benzoquinone dioxime acid mixtures.
- n. Discovery of the linear correlation of the association constants of 1:1 complexes of methoxy amphetamines and 1,4 dinitrobenzene to the threshold hallucinogenic dose in humans.
- o. Discovery of the effectiveness of gellant polymer-water system (polyacrylamide formulated with suitable scavengers for fuel components) to control hypergolic fires of N_2O_4 and hydrazine.

2. Developments:

- a. Developed a new aircraft tire retread formulation with improved heat build-up and heat blow-out properties.
- b. Developed a new method for screening solid fire extinguishants.
- c. Chemical fire extinguishing systems have been developed for jet engine nacelles while engine is running under high air velocity.
- d. Development of a new class of intumescent coatings, 45B3 and 313, and flexible versions of the same.
- e. Development of high molecular weight perfluoroalkylene ether-heterocyclic polymers as promising high-temperature fuel tank sealants.
- f. Development of a low-density PBI foam for aircraft interiors and fuselage and for general application.
- g. Development of a polyimide foam for thermal insulation and fire resistance.
- h. An instrumental system for comprehensive evaluation of evolved gases, smoke and toxicity of pyrolyzed nonmetallic materials has been developed. (T-4 Facility).

- i. Environmental stabilization of polyurethane baffle foam by the use of coatings.
- j. Development of fire-retardant foams:
 - (1) Semi-rigid urethane (5I).
 - (2) Reinforced urethane (5I-10AQ-B, 5A-43).
 - (3) Semi-rigid isocyanurate.
 - (4) Flexible neoprene modified urethane.
 - (5) Low and high density polybenzimidazole.
 - (6) Low density polyimide.
- k. Development of intumescent fire-retardant formulations: Coatings for structural protection and for thermal-protection of weapons.
- l. Basic parameters for new dangerous drug detector.
- m. Ablative and thermal structures for LEM.
- n. Development of isocyanurate foam-intumescent coating system and concept to increase survivability in aircraft ground crash fires.
- o. Development of low density 5A43 reinforced urethane-composite system to protect Navy aircraft from fires initiated from incendiary projectiles.
- p. Development of new brake lining materials based on high temperature polymeric composites with improved performance characteristics.
- q. Development of non-smoking, fire-resistant foams (polyimide and polybenzimidazole).
- r. Development of fire-resistant, char-forming clear polymers, i.e., phenolphthalein polycarbonate, and cured tetrafunctional epoxy resin for application as windows and canopies for aircraft.
- s. Catalytic conversion of water-hydrocarbon fuel mixture to methane gas using commercially available catalysts.
- t. Development of bismaleimide resin composite structures; development of room temperature cure bismaleimide coatings.
- u. Development of low cost polybenzimidazole prepolymer.
- v. Development of low density polybenzimidazole foam for cryogenic and high temperature insulation applications.

- w. Development of methodology for assessing the toxic threat level of pyrolysis gases produced from aircraft interior materials.

3. Applications:

- a. Development of replica windows for Boeing 737 aircraft with improved impact and fire resistance through the use of a new kind of transparent, laminate, polyaromatic type polymer.
- b. Urethane, void space, ballistic foam (5A-43) developed for use on Navy A-4 aircraft qualified and being used on the Fairchild A-10 fighter aircraft. The same material is also used on the McDonnell Douglas F-15 aircraft for ballistic protection against high velocity fragments.
- c. Application of intumescent coatings and urethane foam to the F-15 Gun System to prevent catastrophic explosions resulting from fire and fire propagation of ignited rounds.
- d. Application of intumescent formulations to explosive devices and missiles to achieve cook-off protection against fires (U.S.N. 500 lb. bombs, Harpoon missile and 20 mm gun pod).
- e. Application of intumescent formulations and urethane foam for thermal protection of the Space Shuttle Vehicle during ascent phase.
- f. Application of bismaleimide laminate-polyimide foam composite structures as fire-resistant bulkheads for crash-fire protection of aircraft.
- g. Application of fire-retardant foams as accoustical insulation for aircraft.
- h. Utilization of Ames fire-resistant materials in the JSC 737 test program.
- i. Development of fire-resistant panels for aircraft interiors consisting of bismaleimide laminate and polybenzimidazole foam (or polyquinoxaline foam).

POLYMER RESEARCH AND DEVELOPMENT GROUP

The activities of this group support the aerospace and non-aerospace programs, and its objectives are specifically established for the purpose of providing a sound technology base.

1. The synthesis and characterization of new and improved polymers include:
 - a. Fire-resistant polymers of the polyphosphazene series (inorganic) for flexible foams, moldings and coatings.
 - b. Transparent and fire-resistant polycarbonates of the bisphenol series (aromatic groups substituted on the pivotal carbon atom) which can be used for aircraft windows, canopies and coatings. The phenolphthalein polycarbonate has also been synthesized and studied.
 - c. Sealants for aircraft fuel tanks include new elastomers such as s-triazine and other heterocyclic linked perfluoroalkylene ethers.
 - d. Elastomers (synthetic rubber) for aircraft tires having higher temperature and stress service involve the study of vinyl polybutadiene and trans polypentenamer.
2. The thermal degradation of polymers and polymeric composite systems is being investigated as related to fires aboard commercial and military aircraft.
 - a. The mechanisms of degradation of fire-resistant polymers are being studied to determine the underlying thermochemistry responsible for flammability, toxicity and smoke formation. The fire-resistant polymers of interest are the polybenzimidazoles, polyquinoxalines, polyphenylenes and polybismaleimides.
 - b. The toxic effects from the gases and smoke which arise from the pyrolysis of polymeric materials are determined for both neat polymers and the total polymeric composite system as used in aircraft structures. Animal assays are used to assess the toxicological effects of the pyrolysis products.
 - c. Chemical fire quenching mechanisms are being studied to develop an understanding of the processes which will lead to the development of dry chemical systems specifically engineered to aircraft engine and interior fires.
3. Fire modeling studies on polymers are performed to determine ignition and quenching processes.
4. The synthesis of polymers via heterogeneous catalysis with very high stereoregularity is being studied with a view toward possible space processing and/or manufacturing applications.
5. The physical chemistry of certain classes of compounds having biological activity and forming charge-transfer complexes has been studied, e.g., indoles and phenylisopropylamines.

ADVANCED MATERIALS DEVELOPMENT GROUP

Formulation, processing and development of polymeric materials and composite systems are provided by this group as model and prototype specimens for chemical and engineering tests. Polymers derived from both NASA aerospace technology and industry are used to develop films, coatings, foams, composites and laminates for a variety of purposes, as listed below. Primarily, material systems are being developed which have greater fire-resistance and thermal insulative properties and a significant decrease in the toxicity of the pyrolysis products.

1. Interior aircraft fuselage panels are being developed which possess improved fire-resistance and insulative properties and decreased toxicity levels of pyrolytic products. These panels will also be used for the lavatories as secondary structures in the aircraft. Low density composites consisting of a honeycomb structure filled with polybenzimidazole foam and laminated on both sides with bismaleimide-glass material is one of the candidates for this purpose.
2. Transparent laminates of epoxy-boroxine and polycarbonates are being developed for use as aircraft windows and canopies. These laminates have greater impact strength and fire-resistance and also much greater laser resistance than materials currently being used.
3. Development work is being performed to make films and coatings from fire-resistant polycarbonates such as the phenolphthalein and fluorene polycarbonates.
4. Internal ballistic foams are being developed from polyphosphazene polymers and external ballistic foams developed from polybenzimidazole.
5. Advanced coatings for cook-off protection of ordnance and missiles in a fire environment are being developed through the use of intumescent materials.
6. New tire treads for aircraft are being developed using vinyl polybutadiene and trans polybutadiene as new elastomers.
7. Work is being performed to develop a carbodiimide foam for fire-resistance as part of a materials system for mine safety application.
8. Drum type brake linings are being developed, with a view toward disc brake pad application, utilizing NASA developed materials. New binder materials being studied are polybismaleimide, branched polyphenylene and polyquinoxaline. Potassium titanate fibers offer advantages over asbestos fibers which are being investigated.
9. New sealant material systems are being developed for aircraft fuel tanks. Formulation and processing parameters are being established for the use of perfluoroalkylene ethers cross-linked with heterocyclic agents such as s-triazines and oxadiazole.

10. Fire-resistant, flexible polyphosphazene-foam is being developed as candidate material for use in aircraft interior furnishings.

ENGINEERING MATERIALS AND FIRE TEST GROUP

The function of this group is to design and perform the appropriate tests on prototype material systems (models) with respect to fire dynamics and retardation, fire safety, thermal protection and toxicology as applied to sub-system models of aircraft. The development of methods and criteria for fire testing is also a function of this group. Also, the physical and mechanical properties of material systems are determined.

1. Work is being conducted to define the operating and testing parameters of a fire test facility to be constructed at Ames. Included will be the definition of the safety requirements, type of heat and fire source for testing, scrubbing of smoke exhaust and other parameters. Design of the facility will permit the testing of various aircraft configurations and components under varying conditions which simulate an aircraft interior or exterior fire.
2. Criteria for large scale fire tests for aircraft secondary structures are being developed. Fire tests will be conducted on lavatories, cargo bays and interior panels and furnishings.
3. Toxicological tests are conducted on new and improved fire-resistant polymers, composites and aircraft sub-systems and the results compared with those obtained from state-of-the-art materials currently used in aircraft interiors which are subjected to the same tests. Smoke and gas samples tested are derived from (a) full-scale fire tests (flaming and smoldering) of complete materials systems, and (b) controlled pyrolytic degradation (aerobic and anaerobic) of neat polymeric materials.
4. Design studies are performed to develop interior fuselage panels which have better fire-resistant properties and produce less smoke and toxic gases than currently used materials. A composite laminate consisting of polyquinoxaline foam in a polybismaleimide honeycomb laminated between two sheets of polybismaleimide-fiberglass has been developed as a candidate panel material.
5. Analytical models to predict fire environments and mechanism of fire inhibition and propagation are being developed.
6. New and improved dry chemical systems for fire quenching are being developed and tested for engine nacelle and cargo bay fires.
7. The analysis of materials applications problems is performed by (a) identification of application requirements and constraints for advanced

aerospace materials, and (b) selection of combinations of key properties required for specific applications.

8. Thermal, mechanical and physical tests are conducted to screen materials (neat polymers, polymeric composites and material systems) developed by the Chemical Research Projects Office. The state-of-the-art commercial materials are tested in a similar manner and the results are compared with those of the NASA-produced materials.

PUBLICATIONS

1. M. Sung and J. A. Parker: "Molecular Complexes Between Methoxyamphetamines and Riboflavin Derivatives." *Z. Naturforsch*, 29 c, 122, (1974).
2. N. R. Lerner: "Free Radicals in Para-Polyphenylene." *Journal of Polymer Science*, October 1974.
3. R. Rosser and J. A. Parker: "Poly-Perfluoroalkylene Ethers - Their Potential as High Temperature Sealants." Publication of Creative Invention Award Symposium by ACS, in press, 1974.
4. M. A. Golub: "Thermal Rearrangements in Polypentenamer and Polyoctenamer." *Polymer Letters*, 12, 295 (1974)
5. M. A. Golub: "Type II Thermal Cyclization in 1,2-Polybutadiene and 3,4-Polyisoprene." *Polymer Letters*, 12, 615 (1974).
6. R. W. Rosser and J. A. Parker: "Fuel Tank Sealants Review." NASA TM X-62,401, December 1974.
7. D. A. Kourtides and J. A. Parker (C. L. Segal - Whittaker Corporation): "Low Density Polybenzimidazole Foams." Proceedings of the Society of Plastic Engineers 32nd Annual Technical Conference, May 13-16, 1974, San Francisco, California.
8. R. J. DePasquale, C. D. Padgett, and R. W. Rosser: "Highly Fluorinated Acetylenes." Submitted to *Journal of Organic Chemistry*.
9. D. E. Cagliostro, E. L. Winkler, and J. A. Parker: "Methanator Fuel Conversion." *International Journal of Atmospheric Environment*, in press.
10. D. E. Cagliostro and E. L. Winkler: "Methanator Fueled Engines for Pollution Control." NASA TM X-62,263, March 1973.
11. P. M. Sawko (and N. Bilow, Hughes Aircraft Company): "Coating Processes for Increasing the Moisture Resistance of Polyurethane Baffle Material." Proceedings of the Society of Plastic Engineers 32nd Annual Technical Conference, May 13-16, 1974, San Francisco, California.
12. D. A. Kourtides, J. A. Parker, and W. J. Gilwee: "Improvements in Fire Safety of Interiors of Wide Body Jets." Proceedings of the 12th Annual Survival and Flight Equipment Association Conference, Las Vegas, Nevada, September 8-12, 1974.

13. A. P. Moreci, J. A. Parker and A. Furst: "A Study of the Effects on Mice of Smoke and Gases from Controlled Fires in Simulated Aircraft Cabins." *Journal of Combustion Toxicology*, in press.
14. E. S. Lopata and S. R. Riccitiello: "The Influence of Extent of Polymerization on the Thermal Behavior of an Epoxy-Based Polyether Resin." *Journal of Applied Polymer Science*, in press.
15. D. E. Cagliostro and S. R. Riccitiello: "Intumescent Coating Modeling." Submitted to *Fire Journal*.
16. D. A. Kourtidis and J. A. Parker: "Effect of Processing Variables on the Thermo Physical Properties of Polybenzimidazole Foams." Submitted to *Journal of Polymer Engineering and Science*.
17. W. Young, J. A. Parker and R. N. Griffin, Jr.: "Toxicity Studies of Freons, Monomers, Catalysts and Pyrolysis Products of Polymers." In-house report.
18. N. R. Lerner and D. E. Cagliostro: "Flame Inhibition by Hydrogen Halides: Some Spectroscopic Measurements." *Journal of Combustion and Flame*, 21, 315 (1973).
19. W. J. Gilwee, R. W. Rosser and J. A. Parker: "High Temperature Resistant Composites from Bismaleimide Resins." *Proceedings of 18th National SAMPE Symposium*, April 1973, Los Angeles, California.
20. M. A. Golub and J. A. Parker: "Polymeric Materials for Unusual Service Conditions." *Applied Polymer Symposium No. 22*, Interscience - Wiley (1973).
21. M. A. Golub and M. Sung: "Thermal Cyclization of 1,2-Polybutadiene and 3,4-Polyisoprene." *Polymer Letters*, 11, 129 (1973).
22. M. Sung and J. A. Parker: "Amphetamines: Correlation of Activity with Stability of Molecular Complexes." *Proceedings of the National Academy of Sciences*, 69, 1346 (1972).
23. P. M. Sawko, E. J. Fontes and S. R. Riccitiello: "Intumescent Coatings for Improved Fuel Fire Protection of Heat Sensitive Articles." *Journal of Paint Technology*, August 1972.
24. M. A. Golub: "Photochemistry of Unsaturated Polymers." NASA TM X-62,201, May 1971; *Pure and Applied Chemistry*, 30, 105 (1972).
25. M. A. Golub and R. J. Gargiulo: "Thermal Degradation of 1,4-Polyisoprene and 1,4-Polybutadiene." *Polymer Letters*, 10, 41 (1972).
26. D. E. Cagliostro, H. Goldstein and J. A. Parker: "Silica Reinforcement and Char Reactions in the Apollo Heat Shield." *Journal of Spacecraft and Rockets (AIAA) No. A4323* (1972).

27. M. Sung and J. A. Parker: "Molecular Complexes of Methoxyindoles with 1,3,5-Trinitrobenzene and Tetracyanoethylene." Proceedings of the National Academy of Sciences, 69, 1196 (1972).
28. G. R. Collins and S. R. Riccitiello: "An Anomalous Reaction of Aceto-4- (or 6-) Nitro-2, 5-Xylides with Hydrochloric Acid." Journal of Organic Chemistry, 37, 3353 (1972).
29. S. R. Riccitiello, G. M. Fohlen and J. A. Parker: "The Thermal Reactions of Bis-(4-nitroanilino)-Sulfone and p-Benzoquinone Dioxime Acid Mixtures." Journal of Polymer Science, A-1,9, 317 (1971).
30. E. L. Winkler and J. A. Parker: "The Molecular Configuration and Pyrolysis Reactions of Phenolic-Novolaks." Journal of Macromolecular Chemistry, July 1971.
31. M. A. Golub: "Photolysis of 1,4-Dichlorobutane Sensitized by Various Aliphatic Ketones." Journal of Physical Chemistry, 75, 1168 (1971).
32. S. R. Riccitiello, R. H. Fish, J. A. Parker and E. J. Gustafson: "Development and Evaluation of Modified Polyisocyanurate Foams for Low-Heating-Rate Thermal Protection." Journal of Cellular Plastics, 7, 91 (1971).
33. J. A. Parker and G. F. D'Alelio: "Ablative Plastics." Marcel Decker, Inc., New York, N. Y., 1971.
34. C. B. Neel and R. H. Fish: "Study of Protection of Passengers in Aircraft Crash Fires." NASA SP-270, May 1971.
35. C. B. Neel, J. A. Parker and R. H. Fish: "Heat Shields for Aircraft: A New Concept to Save Lives in Crash Fires." Astronautics and Aeronautics (AIAA), November 1971.
36. M. A. Golub: "Direct and Sensitized Photolyses of Various Dichlorobutanes." Journal of the American Chemical Society, 92, 2615 (1970).
37. M. A. Golub: "Infrared Absorption Spectra of Deuterated Polyisoprenes." Spectrochimica Acta, 26A, 1883 (1970).
38. G. M. Fohlen, J. A. Parker, S. R. Riccitiello and P. M. Sawko: "Intumescence. An In Situ Approach to Thermal Protection." Proceedings of the NASA Conference on Materials for Improved Fire Safety, May 10, 1970, pp. 12-1-12-20.
39. R. H. Fish: "The Performance of Lightweight Plastic Foams Developed for Fire Safety." Proceedings of the NASA Conference on Materials for Improved Fire Safety, May 10, 1970, pp. 11-1-11-20.

40. A. C. Poshkus and J.A. Parker: "Studies of Nitroaniline-Sulfuric Acid Compositions: Aphrogenic Pyrostats." *Journal of Applied Polymer Science*, 14, 2049 (1970).
41. C. B. Neel, R. N. Griffin, Jr. and J. P. Millard: "Studies Related to Satellite Thermal Control: Measurements of Earth-Reflected Sunlight and Stability of Thermal-Control Coatings." *Solar Physics*, 6, 235 (1969).
42. R. B. Pope, S. R. Riccitiello, J. A. Parker and H. E. Goldstein: "Ablative Thermal Protection at Low Heating Rates." *Materials Journal*, 1, (1969).
43. D. E. Cagliostro, S. R. Riccitiello and J. A. Parker: "A Kinetic Model for the Acid-Catalyzed Decomposition of Delrin." *Journal of Macromolecular Science, Chem.*, A3 (8), 1601 (1969).
44. R. B. Pope, S. R. Riccitiello and J. A. Parker: "Development and Evaluation of a Polyurethane Foam System for Ablative Protection at Low Heating Rates." *Journal of Spacecraft and Rockets*, 6, 506 (1969).
45. J. A. Parker, S. R. Riccitiello, W. J. Gilwee and R. H. Fish: "Development of Polyurethane for Controlling Fuel Fires in Aircraft Structures." *SAMPE Journal*, p. 41, Vol. 5, No. 3, April/May 1969.
46. R. R. Dickey, J. H. Lundell and J. A. Parker: "The Development of Polybenzimidazole Composites as Ablative Heat Shields." *Journal of Macromolecular Science Chemistry*, A3, 753 (1969).
47. J. C. Arvesen, R. N. Griffin, Jr. and B. D. Pearson, Jr.: "Determination of Extraterrestrial Solar Spectrual Irradiance from a Research Aircraft." *Applied Optics*, Vol. 8, No. 11, November 1969.
48. D. A. Kourtides, M. J. Fontes and E. R. Leibfritz: "Molding Procedure for Casting a Variety of Alloys." *NASA-ARC-10358* (1969).
49. M. A. Golub: "Photolysis of 1,4-Dichlorobutane Sensitized by the n, π^* Singlet State of Acetone." *Journal of the American Chemical Society*, 91, 4925 (1969).
50. J. A. Parker, G. M. Fohlen, P. M. Sawko and R. N. Griffin, Jr.: "The Use of Acid Salts, of p-Nitroaniline as a Component of Intumescent Coatings." *SAMPE Journal*, August/September 1968.
51. R. N. Griffin, Jr. and C. W. Beck III: "Description of Ames Research Center Earth Albedo Experiment on OSO-III Spacecraft." *Proceedings of 5th Annual ISA Test Measurement Symposium*, 5, 559 (1968).

52. J. O. Reller, Jr., D. A. Steward and D. A. Kourtides: "Thermal Shock Failure of Shock Tunnel Reservoirs." Proceedings of the Thirteenth Semi-Annual Meeting of the Supersonic Tunnel Association, Ohio State University, Columbus, Ohio, October 3, 1968.
53. R. B. Pope, S. R. Riccitiello and J. A. Parker: "Evaluation of a Polyurethane Foam for Ablative Protection at Low Heating Rates." Journal of Spacecraft and Rockets, 6, 74 (1968).
54. J. A. Parker and E. L. Winkler: "The Effects of Molecular Structure on the Thermochemical Properties of Phenolics and Related Polymers." NASA TR R-276, November 1967.
55. J. A. Parker, C. B. Neel and M. A. Golub: "Development of a Technique for the Correlation of Flight- and Ground-Based Studies of the Ultraviolet Degradation of Polymer Films." Symposium on Thermal Radiation of Solids. NASA Publication SP-55, 381 (1965).
56. M. A. Golub and J. A. Parker: "Comparison of the Ultraviolet and X-Ray Induced Production of Unsaturation and Color in Polyvinyl Chloride." Die Makromolekulare Chemie, 85, 6 (1965).

PATENTS

1. S. R. Riccitiello and J. A. Parker: "Intumescent Composition, Foamed Product Prepared Therewith and Process for Making Same," U. S. Patent 3,819,550, June 25, 1974.
2. J. A. Parker, J. Dimeff and A. H. Heimbuch: "Chromato-Fluorographic Drug Detector," U. S. Patent 3,814,939, June 4, 1974.
3. J. A. Parker and S. R. Riccitiello: "Flexible Fire Retardant Polyisocyanate Modified Neoprene Foam," U. S. Patent 3,772,220, November 13, 1973.
4. S. R. Riccitiello and J. A. Parker: "Intumescent Composition, Foamed Product Prepared Therewith, and Process for Making Same," U. S. Patent 3,730,891, May 1, 1973.
5. R. Rosser: "Polyimide Foam for Thermal Insulation and Fire Protection," U. S. Patent 3,772,216, November 13, 1973.
6. P. M. Sawko: "Polymeric Vehicles as Carriers for Sulfonic Acid Salt of Nitrosubstituted Aromatic Amines," U. S. Patent 3,663,436, May 10, 1972.
7. P. M. Sawko: "Intumescent Paint Containing Nitrile Rubber," U. S. Patent 3,702,841, November 14, 1972.
8. J. A. Parker and G. M. Fohlen: "Intumescent Paints," U. S. Patent No. 3,535,130, October 20, 1970.
9. J. A. Parker and S. R. Riccitiello: "Modified Polyurethane Foams for Fuel Fire," U. S. Patent 3,549,564, December 22, 1970.
10. G. M. Fohlen, J. A. Parker and P. M. Sawko: Patent Disclosure: "Transparent, Fire-Resistant Polymeric Structures," Application No. 437,556, January 1974.
11. R. H. Fish, J. A. Parker and R. Rosser: Patent Disclosure: "Fiber Modified Polyurethane Foam for Ballistic Protection," Application No. 398,885, September 1973.
12. J. Mansfield, S. R. Riccitiello and M. Halberstadt: Patent Disclosure: "Friction Composites Comprising Potassium Titanate Fibers," NASA Case No. ARC-10893-1, July 1974.
13. D. A. Kourtides, J. A. Parker and C. Delano: Patent Disclosure: "Low Density Polybenzimidazole Foams," NASA Case No. ARC-10823, August 1974.

CONTRACTS AND GRANTS

Current:

1. "Optimization of Thermophysical Properties of Polybenzimidazole Foams," Whittaker Corporation, NAS2-8525.
2. "Evaluation of Contemporary Devices for Combustion in Commercial Aircraft," Stanford Research Institute, NAS2-8583.
3. "Analysis of Aircraft Accidents Involving Fires," Stanford Research Institute, NAS2-8535.
4. "Study of Trace Atmospheric Analyzers," Stanford Research Institute, NAS2-8489.
5. "Development of Design Criteria for a Fire Test Facility," University of California, Berkeley, NSG-2026-B.
6. "Chemiluminescence Study of Aircraft Tire Rubber Thermal Degradation," Battelle Memorial Institute, NAS2-8195.
7. "Fabrication and Test of Experimental Auto Brake Lining," Bendix Corp., NAS2-7758.
8. "Design and Fabrication of Fuel Tank Sealant Exposure Apparatus," Boeing Company, NAS2-7341.
9. "Evaluation of Materials and Concepts for Aircraft Fire Protection," Boeing Company, NAS2-7978.
10. "Study to Formulate and Develop an Optimized Intumescent Coating," Hughes Aircraft Co., NAS2-8139.
11. "Preparation, Testing and Delivery of Low Density Polyimide Foam Panels," Monsanto Research Corp., NAS2-8440.
12. "Synthesis of Perfluorinated Polyethers," Peninsula Chemresearch Inc., NAS2-8156.
13. "Development of Baseline Parameters and the Design of Equipment for a Heterogeneous Organic Reaction," Research Triangle Institute, NAS2-8260.
14. "Synthesis of Heterocyclic-Block Perfluorinated Polyethers," Stanford Research Institute, NAS2-8103.
15. "Development of Analytic Fire Models," Systems Science and Software, NAS2-8339.

16. "Large Scale Fire Testing of Aircraft Interior: Construction and Development of Criteria to Represent the Level of Threat," University of California, Berkeley, NSG-2026-A.
17. "Aircraft Tire Development Program Utilizing Vinyl Polybutadiene Elastomer," Thompson Aircraft Tire Corp., NAS2-8229.
18. "Preparation of Linear Hydroxy Terminated Polyphosphazenes," Ultrasystems Inc., NAS2-8469.
19. "Review and Testing of Fire Protective Coatings for Polyurethane Foam," University of California, Berkeley, NAS2-8288.
20. "Synthesis and Characterization of Polycarbonates from Geminally Substituted (Cyclic) Methylene Bis-Phenols," Whittaker Corporation, NAS2-8012.
21. "Synthesis and Development of Low Cost, High Temperature N-Arylene Polybenzimidazole Foam Material," Whittaker Corporation, NAS2-8299.
22. "Preparation of Foam Composite Structures," Whittaker Corporation, NAS2-8189.
23. "Crosslinking and Degradation Mechanisms in Model Sealant Candidates," Ultrasystems Inc., NAS2-7981.
24. "Thermal and Solvent Stable Polymers: Synthesis of Terfunctional Monomers as Potential Crosslinking Agents," Talladega College, NGR 01-7010.
25. "Relative Toxicity of Gases from Pyrolyzed State-of-the-Art Polymers in Experimental Animals," University of San Francisco, NSG-2039.
26. "Pyrolysis and Combustion Products of Nomex, Durette and Tedlar Polymers," University of Utah, NAS2-8244.

Completed:

1. "Analytical Modeling of an Intumescent Coating Thermal Protection System in a JP-5 Fuel Fire Environment," Acurex Corp., NAS2-7709.
2. "Synthesis of Optically Clear Polymeric Materials for High Temperature Windows," Dow Chemical Co., NAS2-6388.
3. "Study of the Hydrolytic Stability Baffle Material," Hughes Aircraft Co., NAS2-7412.
4. "Processing Study to Fabricate a Series of Transparent Laminated and Monolithic Windows for Aircraft," Hughes Aircraft Co., NAS2-7765.

5. "Synthesis of Terephthalonitrile-N-N'-Dioxide," Hughes Aircraft Co., NAS2-7831.
6. "Determination of Possible Relationships Between Spin Concentration and Rate of Oxidation," Stanford Research Institute, NAS2-8027.
7. "Prediction of Service Life of Sealant Materials," Jet Propulsion Laboratory, Task Order No. RD-65, NAS7-100.
8. "Synthesis of Perfluorinated Polyethers," PCR, Inc., NAS2-7331.
9. "Para-polyphenylene and Composites," Rocketdyne Corporation, NAS2-3710.
10. "Polydimethylphosphonitrile Polymers as Thermal Control Coatings," W. R. Grace Company, NAS2-4028.
11. "Study of Vapor Release and Fire Suppression of Encapsulated Fire-Retardant Compounds," Atlantic Research Corporation, NAS2-4988.
12. "Study of Low Density Fire-Retardant Materials," University of Utah, NAS2-5553.
13. "Synthesis and Characterization of Model Polymers for Use in the Investigation of Char Forming Heat Shields," Dow Chemical Company, NAS7-344.
14. "Thermophysical and Chemical Characterization of Charring Ablative Materials," Battelle Memorial Institute, NAS7-342.
15. "Experimental and Analytical Studies of Radiation-Only Pyrolysis of Model Char Forming Polymers," Stanford Research Institute, NAS7-341.
16. "Thermochemical Characterization of Modern Polymers to be Used in the Investigation of Fundamental Ablation Mechanisms of Char-Forming Heat Shields," IITRI, NAS7-343.
17. "Ablation Materials Study," Hughes Aircraft Company, NAS2-2739.
18. "The Kinetics of Reactions of the By-Products of Ablative Materials at High Temperatures and the Rate of Heat Transfer Between Hot Surfaces and Reactive Gases," Stanford Research Institute, NAS7-2739.
19. "A Review of Oxidative Degradations of Certain Heterocyclic Polymers," Stanford Research Institute, NAS2-6464.
20. "Development and Installation of Fire-Retardant Foam," AVCO Corporation, NAS2-6489.
21. "Study to Optimize Gellant Polymer-Water Systems for Control of Hypersonic Fires," Dow Chemical Company, NAS2-6532.

22. "The Synthesis of Monomers for High-Temperature Resistant Polymers," Wartburg College, Grant NGR16-005-001.
23. "Synthesis of Polymers with High Residues at High Temperatures," University of Notre Dame, Grant NGL-15-004-028, NGL-15-004-001.
24. "Formulation and Production of Intumescent Coating Compositions," Hughes Aircraft Company, NAS2-6387.
25. "Material Screening Test Program," Aerotherm Corp., NAS2-5794.
26. "Study for Synthesis of Optically Clear Polymeric Materials for High-Temperature Windows," Dow Chemical Co., NAS2-6388.
27. "Design, Development and Delivery of a Prototype Portable Detector of Morphine in Urine," Whittaker Corp., NAS2-7311.
28. "Development and Evaluation of Room Temperature Curing, Fire-Resistant Coatings Based on Selected Bismaleimides," Battelle Memorial Institute, NASW-1948.
29. "Study of Aircraft Fire Safety: Flame Spreading Across Materials," Princeton University, NAS2-6705.
30. "Characterization of Polybenzimidazole Composite Foams," Whittaker Corp., R and D Division, NAS2-7112.
31. "Study of Oxygen Atom Recombination on Quartz Surfaces," Stanford Research Institute, NAS2-6776.
32. "A Study Involving the Characterization, Synthesis and Production of Polybenzimidazole Prepolymer," ESSO Research and Engineering Co., NAS2-6159.
33. "Theoretical and Experimental Investigation of Ignition and Combustion Mechanisms in Polymer Materials in Both Air and Enriched Atmospheres," Marshall Industries, NASW-1921.
34. "Research on Toxicity of Pyrolysis Products of Foams, Intumescent Coatings and Fluorel," University of Utah, NAS2-6063.
35. "Study to Formulate Intumescent Coating Compositions," Hughes Aircraft Co., NAS2-6349.
36. "Synthesis, Physiochemical and Biological Measurements of a Series of Indole Compounds," University of San Francisco, Grant NGR-05-029-066.
37. "Kinetics of Reaction of the By-Products of Ablative Materials," Stanford Research Institute, NAS7-472.

38. "Fire Protective Materials Application Program," AVCO Corporation, NAS2-5428.
39. "Synthesis of Organic Compounds Containing Nitrogen," Dow Chemical Co., NAS2-4893.
40. "Study and Production of Polybenzimidazole Laminates and Billets," Lockheed Missiles and Space Company, NAS2-5521.
41. "Study to Fabricate Encapsulated Halogen-Containing Compounds," National Cash Register Company, NAS2-4886.
42. "Ablation Testing of PBI," Aerotherm Corporation, NAS2-5794.
43. "Synthesis of Nitro-Aromatic Amine Compounds as Intermediates for Intumescent Coatings and Polymers," Dow Chemical Company, NAS2-4893.
44. "Fire-Retardant Foam Materials Testing Program," Lockheed Aircraft Corporation, NAS2-4815.
45. "Study for Development of Improved Char Forming Heat Shields," Narmco, NAS7-340.
46. "Thermal Control Coatings Systems," Dyna-Therm Corporation, NAS2-3237.

PRESENTATIONS AND SPECIFICATIONS

1. D. A. Kourtides, J. A. Parker and W. J. Gilwee: "Improvements in Fire Safety of Aircraft Interiors of Wide Body Jets." Presented at the 12th Annual Survival and Flight Equipment Association Conference, Las Vegas, Nevada, September 1974.
2. J. A. Parker: "State-of-the-Art Materials." Presented to the Ad Hoc Committee on Fire Aspects of Polymeric Materials, National Materials Advisory Board, National Academy of Sciences, November 1974, to be published.
3. J. A. Parker: "Fire Dynamics in Aerospace Vehicles." Presented at the Symposium on Fire Hazards and Safety, The Polytechnic Institute of New York, November 16, 1974.
4. M. A. Golub: "Thermal Cycloaddition of 1,2-Polybutadiene and 3,4-Polyisoprene." Presented at Western Regional Meeting of the American Chemical Society, San Francisco, Calif., October 16-18, 1974.
5. R. Altman: "Laboratory Evaluation of Dry Chemical Fire Extinguishants." Presented at the Fifteenth International Symposium on Combustion sponsored by the Japanese Section of the Combustion Institute, August 25-31, 1974.
6. R. H. Fish: "Interim Progress Report on Aircraft Canopies," for Joint Technology Coordinating Group Aircraft Survivability, April 1974.
7. M. A. Golub: "Thermal Rearrangements in Unsaturated Polymers." Presented at Gordon Conference on Polymers, Santa Barbara, California, January 1974.
8. M. A. Golub: "Thermal Rearrangements in Polypentenamer and Polyoctenamer." Presented at Western Regional Meeting of the American Chemical Society, San Diego, California, November 1-3, 1973.
9. "Intumescent Coatings as Fire Retardants." NASA-Ames Tech. Support Package ARC-10099.
10. NASA-Ames Research Center Specifications for Fire-Retardant Foams.
11. "Fire Retardant Foams Developed to Support Fuel Fires." NASA-Ames Tech. Support Package 68-10358.
12. J. A. Parker and D. A. Kourtides: "Aerospace Polymers for Public Use." Submitted to the AIAA, 14th Structures, Structural Dynamics and Materials Conference, Williamsburg, Virginia, March 20-22, 1973.

13. R. H. Fish and J. A. Parker: "Relationship of Molecular Structure and Thermochemical Char Yield on the Thermal Properties of Foamed Polymers." Presented at the SAMPE meeting, Los Angeles, California, April 1972.
14. J. A. Parker: "New Fire-Retardant Foams and Intumescent." Presented at the Wesrec Fireproofing and Safety Symposium, Los Angeles, California, May 27, 1972.
15. C. B. Neel and R. H. Fish: "Protection of Aircraft in Ground Crash Fuel Fires." Presented at the Polymer Conference Series, University of Utah, June 25, 1971.
16. M. A. Golub: "Photochemistry of Unsaturated Polymers." Presented at the IUPAC Conference on Chemical Transformations of Polymers, Bratislava, Czechoslovakia, June 1971.
17. J. A. Parker: "Ames-Developed Fire-Retardant Materials." Presented at the AGARD 37th Meeting on Aircraft Fuels, Lubricants and Fire Safety, May 10-14, 1971, The Hague, Netherlands.
18. G. H. Fohlen: "Intumescence: The Use of Some Aromatic Nitrogen Compounds to Provide In Situ Fire Protection." Presented at the American Chemical Society, New Orleans, Louisiana, December 4, 1970.
19. J. A. Parker: "Thermodynamics of the Ignition and Combustion Processes." Apollo 13 Review Board, May 1970.
20. J. A. Parker: Presentation of paper, "NASA Developments in Fire Prevention and Protection," Cocoa Beach, Florida, February 24-25, 1970.
21. J. A. Parker: Lecture on Weapons Cook-Off "Weapons Safety. In Flight." Presented at Second Symposium on Increased Survivability of Aircraft. February 17, 1970.
22. J. A. Parker and A. H. Heimbuch: "The Role of Aerospace Research in Technology Applicable to Criminal Justice." Presented at the California Council of Criminal Justice, Monterey, California, November 20, 1970.
23. J. A. Parker: "Impact in the 70's." Presented at the Washington Industrial Arts Association in Pullman, Washington, March 21, 1970.
24. M. A. Golub: "Direct and Sensitized Photolyses of Various Dichlorobutanes." Presented at the 158th National Meeting of the American Chemical Society, New York, N.Y., September 1969.
25. M. A. Golub: "Photocyclization of 1,2-Polybutadiene and 3,4-Polyisoprene." Presented at the 158th National Meeting of the American Chemical Society, New York, N.Y., September 1969.

26. R. R. Dickey, J. H. Lundell and J. A. Parker: "The Application of Arc-Jet Ablation Tests in the Development of Polybenzimidazole Composites for Heat Shields." Presented at Symposium of the American Chemical Society, Division of Organic Coatings and Plastic Chemistry, San Francisco, California, March 31-April 5, 1968.
27. J. A. Parker: "Low-Density Foams for Fire Protection." Presented at the Gordon Conference, Summer 1968.
28. J. A. Parker: Ablation Materials Symposium, Chairman for the American Chemical Society Conference, April 1968.
29. J. A. Parker, E. L. Winkler, B. H. Miles and F. F. Sonnabend: "The Effects of Molecular Structure on the Thermochemical Properties of Phenolics and Related Polymers." Presented at the American Chemical Society National Meeting, Miami, Florida, April 1967.
30. R. B. Pope and J. A. Parker: "Analysis of Ablation Products and Boundary Layer Chemistry of Ablating Materials with a Mass Spectrometer." Presented at the Third International Symposium on High Temperature Technology, Asilomar, California, September 17-20, 1967.
31. J. A. Parker: "Some Materials Concepts for Thermal Protection Systems." Paper presented at Annual Review of the Systems Command Missile Systems Reentry Program, March 15-17, 1966.
32. J. A. Parker: "Need for Characterization and Process Control of Low Density Composites for Aerospace Application." Presented at 11th National Plastics Exposition and Conference of the Society of Plastics, New York, N. Y., June 8, 1966.
33. E. L. Winkler and J. A. Parker: "Thermal Analysis of Low-Density Char Forming Composites Useful as Ablative Heat Shields." Presented at San Francisco Science Symposium-Thermal Analysis of Polymers, October 16-17, 1966.