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ABSTRACTS OF AF MATERIALS LABORATORY  
REPORTS JANUARY 1972-DECEMBER 1972

Air Force Materials Laboratory  
Wright-Patterson Air Force Base, Ohio

September 1973

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12

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**AFML-TR-73-143**

**ABSTRACTS OF AF MATERIALS LABORATORY REPORTS  
JANUARY 1972-DECEMBER 1972**

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## FOREWORD

This report was prepared by the Scientific and Technical Information Office (STINFO), Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio (AFML/DO).

Technical reports published by the Air Force Materials Laboratory during the period 1 January 1972 - 31 December 1972 are abstracted herein. Reports on research conducted by Air Force Materials Laboratory personnel as well as that conducted on contract are included.

The abstracts are separated into sections corresponding to the divisions of the laboratory. Indexes provided are: Subject Index, Keyword-Out-of-Context (KWOC) Index, page 109; Investigator Index, page 190; and Contractor Index, page 195.

The access number cited with each abstract provides access to the document itself in the Air Force Materials Laboratory's document collection. The corresponding AD number is also cited. Retention copies of these reports may be requested from DDC, Cameron Station, Alexandria, Virginia 22314.

This technical document has been reviewed and is approved.



Edward Dugger  
Operations Office  
Air Force Materials Laboratory

## ABSTRACT

Technical reports published by the Air Force Materials Laboratory during the period 1 January 1972 - 31 December 1972 are abstracted herein. They are presented in groups corresponding to the divisions of the Laboratory. In addition to the abstract text, the report number, investigator, AFML project monitor, contractor, contract number, AFML project/task number, report date, and access numbers are given. Reports on research conducted by the Air Force Materials Laboratory personnel as well as that conducted on contract are included.

## TABLE OF CONTENTS

	Page
ABSTRACTS OF TECHNICAL REPORTS -----	1
Advanced Development Division (AFML/LC) -----	1
Metals and Ceramics Division (AFML/LL) -----	5
Electromagnetic Materials Division (AFML/LP) -----	30
Manufacturing Technology Division (AFML/LT) -----	49
Nonmetallic Materials Division (AFML/MB) -----	64
Systems Support Division (AFML/MX) -----	99
Technical Services Division (AFML/TU) -----	107
SUBJECT INDEX -----	109
INVESTIGATOR INDEX -----	190
CONTRACTOR INDEX -----	195

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ABSTRACTS OF TECHNICAL REPORTS

ADVANCED DEVELOPMENT DIVISION (AFML/LC)

REPORT NO: AFML-TR-70-58 AD 904 324L  
Volume IV September 1972

ACCESS NO: H-466

TITLE: ADVANCED COMPOSITES DATA FOR AIRCRAFT  
STRUCTURAL DESIGN VOLUME IV: MATERIAL  
AND BASIC ALLOWABLE DEVELOPMENT --  
GRAPHITE/EPOXY

AUTHOR: L. M. Lackman  
CONTRACT NO: F33615-68-C-1489  
CONTRACTOR: North American Rockwell Corp.  
PROJECT MONITOR: R. L. Rapson (AFML/LC), et. al.  
PROJECT NO: 6169CW

ABSTRACT: This volume summarized that portion of the program concerned with the material and basic allowable development of a specific current graphite-filament/epoxy-matrix advanced composite system. The specific system selected is known commercially as Type AS/3002 prepregged by Fiberite Corporation, with the fiber and matrix formulation supplied by Hercules Incorporated, the U. S. licensed distributor of Courtaulds fibers. The main body of this volume comprises the following basic topics: material qualification, specimen fabrication, specimen testing and data reduction, Evaluation of results and generation of design allowables. The test program purpose is to characterize a singular graphite/epoxy system with the data divided into two categories: baseline data and environmental effects data.

REPORT NO: AFML-TR-71-186 AD 893 713L  
Volume I March 1972

ACCESS NO: 67,854

TITLE: ADVANCED COMPOSITE APPLICATIONS FOR  
SPACECRAFT AND MISSILE PHASE I FINAL  
REPORT VOLUME I: STRUCTURAL DEVELOP-  
MENT

AUTHOR: J. D. Forest, et. al.  
CONTRACT NO: F33615-70-C-1442  
CONTRACTOR: Convair Aerospace Div/General Dynamics  
PROJECT MONITOR: R. L. Rapson (AFML/LC)

PROJECT NO:  
ABSTRACT: Four structures of the Orbiting Vehicle One (OV1) Satellite launch support system were selected to serve as representative components for design, analysis, and fabrication development efforts. The OV1 is small, standardized Air Force satellite that is launched on the Atlas missile. The dual satellite launch configuration was selected for study. Trade-offs were made early in the program to compare several materials and design concepts for each component. A materials and processes development program was then conducted to allow the final component design to proceed with confidence. Concurrent with the process development work was a structural element test program. The final designs and analysis of each component were then prepared for construction of the demonstration hardware.

REPORT NO: AFML-TR-71-186 AD 893 715L  
Volume II March 1972  
ACCESS NO: 67,854  
TITLE: ADVANCED COMPOSITE APPLICATIONS FOR  
SPACECRAFT AND MISSILES PHASE I FINAL  
REPORT VOLUME II: MATERIAL DEVELOPMENT  
AUTHOR: J. Hertz, et. al.  
CONTRACT NO: F33615-70-1442  
CONTRACTOR: General Dynamics/Convair  
PROJECT MONITOR: R. L. Rapson (AFML/LC)  
PROJECT NO:  
ABSTRACT: Materials development work included screening of candidate matrix and fiber systems, characterization of several systems, and design allowables and environmental testing of the materials selected for the final hardware components. Screening and characterization mechanical property tests were performed to select advanced composite systems capable of operating for short time (five minutes) over a temperature range of -320 to +350F. Two types of graphite/epoxy were desired, one to exhibit very high modulus for shell stiffeners and stiffness-critical beams. The Courtald's HT-S fiber was selected for high strength applications and the Celanese GY-70 fiber for high modulus applications as a result of the screening tests.

REPORT NO: AFML-TR-71-205 AD 893 368L  
Volume I October 1971  
ACCESS NO: 200,511  
TITLE: ADVANCED COMPOSITE MATERIAL STUDY FOR  
MILLIMETER WAVELENGTH ANTENNAS  
AUTHOR: J. W. Haylett  
CONTRACT NO: F33615-70-C-1390  
CONTRACTOR: Goodyear Aerospace Corporation  
PROJECT MONITOR: R. L. Rapson (AFML/LC)  
PROJECT NO:  
ABSTRACT: The purpose of this program was to conduct a theoretical and experimental exploratory development program to establish the required technology to design, fabricate, and test reliable flightworthy advanced composite, extremely high frequency (ehf) antennas for space systems applications. The selected materials were fabricated into a 30-inch diameter antenna model. The paraboloid was of sandwich-type construction utilizing GFRP laminate face skins and aluminum core. The paraboloid laminate and sandwich were cured on a low coefficient of thermal expansion ceramic mold developed during the program. The finished antenna model tolerance was 0.003 inch RMS. Many antenna rf reflective coatings were evaluated at 34.4, 60 and 90 GHz. Grafoil and flame sprayed aluminum proved to be excellent rf reflectors at all frequencies. Other materials were good at selective frequencies. Feed support tubes 0.5 inch in diameter were fabricated of 75S/4617 and 5Y/4617 material. Tests showed that both materials could result in zero thermal coefficient of expansion along the axis of the tube by controlling the laminate wrap angle and resin content.

REPORT NO: AFML-TR-72-25 AD 894 874L  
ACCESS NO: 68,042 January 1972  
TITLE: DEVELOPMENT OF FABRICATION TECHNIQUES  
FOR BORSIC - ALUMINUM AIRCRAFT STRUCTURES  
AUTHOR: R. G. Cheatham, et. al.  
CONTRACT NO: F33615-70-C-1541  
CONTRACTOR: The Boeing Company  
PROJECT MONITOR: A. W. Davis (AFML/LC), et. al.  
PROJECT NO: 698 CW  
ABSTRACT: The objective of this program was to design, fabricate, and test a subscale wingbox representative of typical aircraft structure, using Borsic-aluminum composite material and employing low pressure bonding techniques. The program was composed of two phases. Phase I consisted of developing fabrication techniques and deriving test data from several proposed design elements representative of details of the final box. Phase II applied the developed fabrication techniques and design data to the final design and fabrication of the wingbox. Test data from the structural tests of the design elements and wingbox as well as material property data for various Borsic-aluminum ply layups were included.

REPORT NO: AFML-TR-72-96 AD 903 260L  
ACCESS NO: 200,911 June 1972  
TITLE: DEVELOPMENT AND DEMONSTRATION OF LOW  
COST BORON FILAMENT FORMATION PROCESS  
AUTHOR: D. K. Kuehl, et. al.  
CONTRACT NO: F33615-71-C-1333  
CONTRACTOR: United Aircraft Corporation  
PROJECT MONITOR: R. M. Neff (AFML/LC)  
PROJECT NO: 6169CW  
ABSTRACT: Under the program described herein, a study was made of three heating methods for a multifilament boron reactor. Components of advanced reactors were designed, fabricated, and tested. Technical feasibility of an RF heated multifilament reactor was demonstrated and a production demonstration of a monofilament AC heated reactor showed the potential for significant price/cost reduction. The study covered DC, AC, and RF heating. DC heated reactors, currently in production, are not easily used or economically useful for multifilament reactors. RF heated reactors, both monofilament and multifilament, although initially erratic in properties, produced very high strength boron under controlled conditions. AC heated reactors, although technically feasible for multifilament operations, promised best short-term cost reduction benefits from monofilament operation. A production demonstration period in which 10 lbs. of 4.0 mil boron was produced on 2 AC reactors gave: 1. Average diameter 4.01 mils,  $\beta$ , 2. Average UTS 539 ksi, 3. Average modulus  $58.8 \times 10^6$  psi, 4. Density 2.59 gm/cc, 5. Average run length with constant speed take-up 24,700 ft/run.

REPORT NO: AFML-TR-72-108 AD 904 039L  
Part III July 1972  
ACCESS NO: 69,126  
TITLE: ADVANCED COMPOSITE ENGINE DEVELOPMENT  
PROGRAM  
AUTHOR: K. G. Boll  
CONTRACT NO: F33615-69-C-1651  
CONTRACTOR: United Aircraft Corp.  
PROJECT MONITOR: W. J. Schulz (AFML/LC)  
PROJECT NO: 6169CW

ABSTRACT: This report deals with the application of advanced composite materials to gas-turbine engine components, and the benefits that can be achieved through their use. The program was divided into the following discrete tasks: Material Screening, Material Design Allowables, First-Stage Fan Blade Development, Third-State Fan Blade Development, Third-State Disk Development, Fan Intermediate Case Development, Three Stage Aero-mechanical Rig Program, Systems Analysis, and Design Guide. Quality assurance techniques used for monitoring boron and graphite fibers and BORSICAL<sup>TM</sup> tape are described, and strength values for these materials are presented. The design, fabrication development, inspection, and testing of F100-PW-100 first-stage boron-polyimide fan blades, third-stage BORSIC<sup>R</sup>-aluminum fan blades, and third-stage boron-polyimide reinforced disks are described. The testing of these components in a three-stage fan aeromechanical rig is discussed.

METALS AND CERAMICS DIVISION (AFML/LL)

REPORT NO: AFML-TR-68-127 AD 840 874  
ACCESS NO: 48,188 August 1968  
TITLE: THE FEASIBILITY OF FORMING A BORON FIBER-  
REINFORCED ALUMINUM COMPOSITE BY A HOT  
EXTRUSION PROCESS

AUTHOR: Capt. W. J. Meyerer

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR:

TASK NO: 735107

ABSTRACT: This study was performed to ascertain the feasibility of forming a boron fiber-reinforced aluminum composite by a hot extrusion process. Post-extrusion examination revealed that fiber break-up was excessive, but the length to diameter ratio for most of the filaments was great enough to effect a stress-transfer. Thus, both modulus and strength values increased as the volume percent fiber in the specimens increased.

REPORT NO: AFML-TR-68-135 AD 841 354  
ACCESS NO: 48,187 August 1968  
TITLE: FABRICATION AND EVALUATION OF BERYLLIUM  
INGOT SHEET ALLOYED WITH COPPER AND  
SILVER

AUTHOR: R. E. Evans, et. al.

CONTRACT NO: AF61052-788

CONTRACTOR: Atomic Weapons Research Establishment

PROJECT MONITOR: K. L. Kojola (AFML/LLP)

TASK NO: 735104

ABSTRACT: Attempts have been made to increase the yield strength of wrought ingot beryllium to a target of 45 kpsi by a combination of warm working and alloying with individual additions of up to w/o copper and up to 10 w/o silver. Metallographic examinations and texture determinations suggest that copper promotes more homogeneous deformation during hot-rolling, which may contribute to the observed improved grain refinement. The latter makes a quantitative comparison of the degree of solution hardening difficult. Constitutional work revealed no discrepancies in the previously published beryllium copper equilibrium diagram over the range investigated.

REPORT NO: AFML-TR-70-202 AD 748 254  
Part V January 1972  
ACCESS NO: 200,524  
TITLE: AN APPLICATION OF FRACTURE CONCEPTS TO THE  
PREDICTION OF CRITICAL LENGTH OF FATIGUE  
CRACKS, PART IV. EXPERIMENTAL DETERMINA-  
TION OF FRACTURE TOUGHNESS AND CRITICAL CRACK  
LENGTH OF 7075-T7351 ALUMINUM ALLOY PLATES  
AUTHOR: S. O. Davis  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: S. O. Davis (AFML/LLN)  
PROJECT NO: 7351  
TASK NO: 735108  
ABSTRACT: The validity of applying fracture mechanics concepts  
for the prediction of critical crack lengths in alloys subjected to tension fatigue  
loading service conditions was experimentally determined. The investigation  
consisted of the following steps: 1. Generation of basic design data yield strength,  
modulus of elasticity, and fracture toughness parameters ( $K_{Ic}$  and  $K_{Ic}$ ) from  
experimental tests of 7075-T7351 aluminum alloy specimens. 2. Utilization of  
the generated data with fracture mechanics concept to a mathematically predict  
critical crack lengths in 7075-T7351 aluminum alloy center-notched specimens  
subjected to axial tension fatigue stresses. 3. Experimental measurement of  
critical crack lengths in 7075-T7351 aluminum alloy specimens tested under the  
fatigue loading conditions used for the mathematical prediction. 4. Comparison  
of experimental results with analytical predictions.

REPORT NO: AFML-TR-70-212 AD 736 774  
Part II July 1971  
ACCESS NO: 200,351  
TITLE: NEW AND REFINED NONDESTRUCTIVE TECHNIQUES  
FOR GRAPHITE BILLETS AND SHAPES  
AUTHOR: A. E. Oaks  
CONTRACT NO: F33615-69-C-1623  
CONTRACTOR: General Electric Company  
PROJECT MONITOR: W. Shelton (AFML/LLN)  
PROJECT NO: 7351  
ABSTRACT: The limits of utility of several advanced NDT approaches  
for detecting small flaws in graphite were evaluated. Of these, focal plane ultra-  
sonic inspection was found to be the most successful in delineating defects down  
to 0.020 to 0.030 in. diameter in ATJ-S and 0.010-in. diameter in AXF-9Q  
graphite. For nearer surface inspection 1 MHz differential eddy current  
techniques can be applied to detect voids down to 0.010 x 0.010 in. For billet  
and part inspection slit radiographic techniques were found to reduce scatter  
and parallax distortion induced image degradation and to achieve 10 to 15  
percent improvements in the film contrast and defect resolution achieved with  
graphite. Tests with delta scan techniques, spectrum analysis and signals,  
acoustic resonance, microwave and thermoelectric techniques were either  
insensitive to flaws and gross structural differences in ATJ-S graphite or were  
affected by background conditions other than flaws and thus excessively difficult  
to interpret.

REPORT NO: AFML-TR-70-213  
Part II August 1971  
ACCESS NO: 200,483  
TITLE: INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS  
AUTHOR: J. S. Evangelides, et. al.  
CONTRACT NO: F33615-69-C-1640  
CONTRACTOR: McDonnell Douglas Astronautics Company - West  
PROJECT MONITOR: W. L. Shelton (AFML/LLN)  
TASK NO: 735109  
PROJECT NO: 7351  
ABSTRACT: Material variations and discrete discontinuities can be encountered in carbon-carbon composites. The object of this program was to identify and evaluate those factors that affect the quality and performance of carbon-carbon composites by nondestructive and destructive test methods. In addition, it was to be determined what correlations existed between the non-destructive test response data and the physical and mechanical property measurements. The general approach was to characterize the precursor materials, apply the nondestructive test techniques to the composites on an in-process basis, determine mechanical and physical properties and determine what relationships may exist between the NDT and property measurements.

REPORT NO: AFML-TR-70-266 AD 743 105  
ACCESS NO: 200,347 October 1971  
TITLE: EDDY CURRENT INSPECTION OF TURBINE BLADES  
AUTHOR: I. R. Kraska, et. al.  
CONTRACT NO: F33615-68-C-1429  
CONTRACTOR: General American Transportation Corporation  
PROJECT MONITOR: H. L. Stevens (AFML/LLN), et. al.  
PROJECT NO: 7351  
TASK NO: 735109  
ABSTRACT: This report presents the results of a program to find a nondestructive field inspection technique which will detect cracks in the leading and trailing edges of jet engine turbine blades. Such an inspection is required because of the presence of cracks causes blade failures and can cause the loss of an engine or entire aircraft. Various nondestructive inspection methods were considered and experimentally evaluated in the laboratory. One was found suitable for field testing. This method which uses eddy currents, is described in detail. The ease of operation speed of inspection of built up rotors, and excellent crack maintenance inspection of turbine blades. It is recommended that several such systems, with appropriate application instructions, be provided to maintenance to allow an extended field evaluation of the technique.

REPORT NO: AFML-TR-71-165 AD 734 761  
ACCESS NO: 200, 353 June 1971  
TITLE: INFRARED DISPERSION ANALYSIS AND OPTICAL  
CONSTANT SPECTRA OF  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> (HEMATITE)  
AUTHOR: C. M. Phillippi, et. al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: C. M. Phillippi (AFML/LPL), et. al.  
PROJECT NO: 7360  
TASK NO: 736005  
ABSTRACT: Infrared reflection spectra of the ordinary and  
extraordinary rays of single crystal ferric oxide in the form of the mineral  
hematite are isolated and measured. Dispersion analyses are performed  
on these spectra and the best fit resonance parameters are identified, along  
with estimated tolerances. Longitudinal optical mode frequencies are  
calculated from these data. Also calculated are: refractive index, extinction  
coefficient, absorption coefficient, and real and imaginary parts of the  
dielectric constant of both rays. These are presented as tabulations between  
4000 and 200 cm<sup>-1</sup>, and as plots between 700 and 200 cm<sup>-1</sup>. Several oxidation  
film spectra from pure iron are illustrated and discussed.

REPORT NO: AFML-TR-71-168 AD 752 251  
ACCESS NO: 200, 348 April 1971  
TITLE: DEVELOPMENT AND APPLICATION OF NON-  
DESTRUCTIVE METHODS FOR PREDICTING  
MECHANICAL PROPERTIES OF ADVANCED  
REINFORCED NONMETALLIC COMPOSITES  
AUTHOR: A. W. Schultz  
CONTRACT NO: F33615-70-C-1526  
CONTRACTOR: Avco Corporation  
PROJECT MONITOR: Capt. L. R. Gulley (AFML/LLN)  
PROJECT NO: 7351  
TASK NO: 735109  
ABSTRACT: A detailed evaluation of the interval velocity, one  
side access technique was conducted and results indicate that it has, at  
its present stage of development a limited usefulness for routinely measuring  
relative values of polar velocity, and hence polar modulus, for many fiber  
reinforced composites including boron/epoxy. Although the usefulness of  
nondestructive modulus measurements for predicting elastic modulus and  
ultimate strength for fiber composites has been confirmed, these studies  
strongly indicate that this capability can be extended to include all fiber  
configurations at any polar orientation.

REPORT NO: AFML-TR-71-172 AD 748 837  
ACCESS NO: 200,832 June 1972  
TITLE: DEVELOPMENT OF PROTECTIVE COATINGS  
FOR COLUMBIUM ALLOY GAS TURBINE BLADES  
AUTHOR: S. Priceman, et. al.  
CONTRACT NO: AF33615-69-C-1613  
CONTRACTOR: Sylvania Electric Products Inc.  
PROJECT MONITOR: N. Geyer (AFML/LLM)  
PROJECT NO: 7312  
TASK NO: 731201  
ABSTRACT: Four developmental cycles of candidate selection, screening test and evaluation were performed on coatings for columbium turbine blade airfoils and root sections. Candidate coatings included numerous fused silicide compositions, silicided sintered underlays, and fused silicides plus glass, ceramic, soft metal, and flame sprayed overlays. The first three developmental cycles employed thermogravimetric analysis, isothermal furnace oxidation tests, and prestrain plus oxidation tests as screening criteria. The airfoil coating selected on the basis of performance in the above tests was a Si-20Fe-40Cr fused silicide with an iron-chromium-aluminum flame sprayed impact resisting overlay. The root coating selected was the same fused silicide coating with an Ag-Al overlay. These two coatings were more definitively and statistically characterized in the fourth cycle on the basis of the same test criteria.

REPORT NO: AFML-TR-71-173 AD 891 810L  
Volume I January 1972  
ACCESS NO: 200,376  
TITLE: COMPARATIVE EVALUATION OF COATED ALLOYS  
FOR TURBINE COMPONENTS OF ADVANCED AIR-  
CRAFT GAS TURBINE ENGINES. VOL. I. SUMMARY  
AND ANALYSIS OF TESTING EVALUATION  
AUTHOR: K. H. Ryan  
CONTRACT NO: F33615-69-C-1615  
CONTRACTOR: General Motors  
PROJECT MONITOR: N. M. Geyer (AFML/LLM)  
PROJECT NO: 7312  
TASK NO: 731201  
ABSTRACT: The purpose of this program was to evaluate the effects of newly developed coatings on modern superalloys. Most of the property tests were conducted on hollow, thin-wall (0.032 in), simulated airfoil test bars. To accomplish this effort, the program was divided into three phases. Phase I - Demonstrate the ability of laboratory tests to correlate with gas turbine engine experience, Phase II - Establish a base line on current state-of-the-art coating/alloy systems, Phase III - Evaluate newly developed coatings on specific alloy substrates. The hot corrosion, oxidation-erosion, and thermal fatigue tests of Phase I showed good correlation with accelerated turbine engine tests and flight service experience.

REPORT NO: AFML-TR-71-185 AD 730 348  
ACCESS NO: 200,318 September 1971  
TITLE: THE EARLY DETECTION OF FATIGUE DAMAGE  
AUTHOR: J. F. Mocre, et. al.  
CONTRACT NO: F33615-68-C-1706  
CONTRACTOR: North American Rockwell Corporation  
PROJECT MONITOR: R. R. Rowand (AFML/LLN), et. al.  
PROJECT NO: ARPA Order 1244  
ABSTRACT: This is the final technical report for a program directed at the development of nondestructive test (NDT) methods for the detection of early fatigue and fracture damage in metals and alloys. The program is based on an interdisciplinary approach designed to interrelate the factors of early fatigue damage with measurable physical phenomena. The program initially concentrated on a comprehensive study of the existing knowledge of fatigue phenomena in metals, and the results of the study are described in terms of fatigue and fatigue-associated phenomena, metallurgical structure, effect of interrelating fatigue phenomena on physical properties, and the availability of appropriate measurement techniques and equipment. Next, the program developed a series of controlled fatigue experiments to measure quantitatively the fatigue effects in selected metal specimens.

REPORT NO: AFML-TR-71-187 AD 746 592  
ACCESS NO: 200,396 October 1971  
TITLE: DEVELOPMENT OF NONDESTRUCTIVE TEST  
TECHNIQUES FOR MULTIDIRECTIONAL FIBER-  
REINFORCED RESIN MATRIX COMPOSITES.  
AUTHOR: J. L. Cook, et. al.  
CONTRACT NO: F33615-69-C-1624  
CONTRACTOR: McDonnell Douglas Astronautics Company  
PROJECT MONITOR: Capt. L. R. Gulley (AFML/LLN)  
PROJECT NO: 7351  
TASK NO: 735109  
ABSTRACT: The second year of effort of a two-year program was devoted to the study of the applicability of nondestructive analysis of the B-stage condition composite, evaluation of cured composite variability, relation of composite mechanical strength to location and severity of weave irregularities, and evaluation of the material elastic constants by means of ultrasonic velocity measurements verified through mechanical load versus strain data. The application of the ultrasonic attenuation C-scan mapping technique did not enable discrete areas of altered impregnation to be clearly detected. Both C-scan attenuation and ultrasonic velocity measurements were indicative of composite variability in the fully cured condition. Application of film radiography indicated that these techniques were feasible for inspection of such surfaces of revolution.

REPORT NO: AFML-TR-71-193 AD 752 317  
ACCESS NO: 200, 996 July 1972  
TITLE: DAMPING IN PORCELAIN ENAMEL COATINGS  
AUTHOR: P. Sridharan, et. al.  
CONTRACT NO: F33615-69-C-1240  
CONTRACTOR: University of Minnesota  
PROJECT MONITOR: J. P. Henderson (AFML/LLN)  
PROJECT NO: 7351  
TASK NO: 735106  
ABSTRACT: Procelain enamels are extensively used as protective and decorative coatings for metal parts. This report describes a study of the damping capability of these coatings at elevated temperatures. A maximum loss coefficient of  $4 \times 10^{-2}$  was observed for a bending specimen of mean thickness 0.09 inches, with a  $5.5 \times 10^{-3}$  inch thick porcelain enamel coating. Experimental data showing the dependence of damping on temperature, coating thickness, and frequency is presented. A method for determining the complex elastic modulus of the coating material is discussed. Results from bending and torsion experiments are compared.

REPORT NO: AFML-TR-71-204 AD 740 584  
ACCESS NO: 200, 420 December 1971  
TITLE: METAL MATRIX COMPOSITE TECHNOLOGY  
AUTHOR: K. G. Kreider, et. al.  
CONTRACT NO: F33615-69-C-1539  
CONTRACTOR: United Aircraft Corporation  
PROJECT MONITOR: Capt. D. Rice (AFML/LLC)  
PROJECT NO: 7341  
TASK NO: 734107  
ABSTRACT: The goals of this program include a critical property evaluation of the best aluminum and titanium alloy matrix boron composite systems available today and improvement of the understanding of fracture in metal matrix composites. This program is intended to develop criteria for material selection and metallurgical processing and to generate data to guide the structural engineer in designing with metal matrix composites. Areas of concentrated studies include: environmental effects, transverse properties, off-axis properties, failure mechanisms of fatigue, notch bending fracture, and notched tensile fracture. The effects of exposing boron aluminum composites to synthetic sea water was similar to that observed with the matrix alloys. High temperature air exposure indicated that BORSIC<sup>®</sup> was more resistant to attack than boron. Thermal cycling studies indicated that boron aluminum composites are durable under severe thermal fluctuations.

REPORT NO: AFML-TR-71-212 AD 753 412  
ACCESS NO: 200, 317 November 1971  
TITLE: WEAR RESISTANT COATINGS FOR TITANIUM  
ALLOYS: FRETTING FATIGUE OF UNCOATED  
Ti-6Al-4V

AUTHOR: R. K. Betts  
CONTRACT NO: F33615-70-C-1537  
CONTRACTOR: General Electric Company  
PROJECT MONITOR: J. J. Crosby (AFML/LLM)  
PROJECT NO: 7312  
TASK NO: 731201

ABSTRACT: Classic fretting fatigue performed in an in-situ manner between surfaces of shot-peened, forged Ti-6Al-4V was found not to affect the run-out stress capability compared to nonfretted specimens in tests at room temperature. However, at 400 F, a slight decrease in the run-out stress was observed, and at 650 F a decrease of 30% resulted from severe surface interaction. At overstress levels of 10,000 psi above the nonfretted run-out stress, fretting reduced the cyclic life capability by two orders of magnitude at room temperature, and 2-1/2 orders at the elevated temperatures. At overstress conditions, a narrow threshold of inexorable fretting fatigue damage occurred between  $10^4$  and  $5 \times 10^4$  cycles. Fluorescent penetrant inspection was capable of revealing cracks in specimens interrupted from fretting after the threshold had been exceeded, which specimens were subsequently tested to fatigue failure with no additional fretting.

REPORT NO: AFML-TR-71-218 AD 747 225  
ACCESS NO: 60, 157 January 1972  
TITLE: DEVELOPMENT OF A NONDESTRUCTIVE TEST-  
ING TECHNIQUE TO DETERMINE FLAW  
CRITICALITY

AUTHOR: C. E. Hartbower, et. al.  
CONTRACT NO: F33615-68-C-1705  
CONTRACTOR: Aerojet Solid Propulsion Company  
PROJECT MONITOR: R. R. Rowand (AFML/LLN), et. al.  
PROJECT NO: 7351  
TASK NO: 735109

ABSTRACT: This report presents the findings of a study to develop a nondestructive testing technique to determine flaw criticality based upon stress-wave emission. The research included an evaluation of various sensors and instrumentation systems, and several materials and material conditions tested to failure in rising load and low-cycle, high-stress-intensity fatigue. The fracture testing utilized a linear-elastic fracture-mechanics approach. Acoustic emission was the basis of the nondestructive inspection technique. The stress-wave analysis technique (SWAT) was shown to be a highly sensitive nondestructive inspection method, capable of detecting growing defects at least an order of magnitude smaller than any other known NDI method and, with a computerized system, capable of locating one or more defects in real time.

REPORT NO: AFML-TR-71-232 AD 751 528  
ACCESS NO: 200,623 March 1972  
TITLE: STRESS CORROSION CRACKING OF TITANIUM  
ALLOYS IN METHANOLIC AND OTHER MEDIA  
AUTHOR: C. M. Chen, et. al.

CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: Dr. H. B. Kirkpatrick (AFML/LLS), et. al.  
PROJECT NO: A01466

ABSTRACT: Results are given of a systematic survey of the stress-corrosion cracking behavior of titanium and certain of its alloys in such environments as pure organic liquids, organic liquid-bromine mixtures, methanol-water-acid mixtures, methanol vapor, and liquid mercury. Stress-corrosion behavior is measured by time-to-failure under static tensile load and by reduction in ultimate elongation under dynamic tension. The effects are described of such variables as water concentration, bromine concentration, applied electrical potential, and strain rate. Depending on the circumstances, mechanical failure appears to be associated with different processes or mechanisms such as anodic dissolution at grain boundaries, hydrogen embrittlement, corrosive reactions between titanium and bromine or methanol, catalytic dehydrogenation of methanol, or stress sorption.

REPORT NO: AFML-TR-71-237 AD 743 107  
ACCESS NO: 68,556 December 1971  
TITLE: JOINING TECHNIQUES FOR FABRICATION OF  
HIGH-TEMPERATURE SUPERALLOY BLADES

AUTHOR: C. G. Nessler  
CONTRACT NO: F33615-70-C-1784  
CONTRACTOR: Pratt and Whitney Aircraft  
PROJECT MONITOR: Dr. G. E. Metzger (AFML/LLM), et. al.  
AFML TASK NO: 735102

ABSTRACT: Three diffusion welding systems were evaluated for applicability to the fabrication of advanced design air-cooled gas turbine blades from split halves. The joining systems evaluated were based upon the use of interlayers to promote and enhance diffusion welding of the directionally solidified superalloy (modification of MARM-200) used for this program. Particular emphasis was placed on increasing the ability of the joining systems to accommodate lack of fit which is a major concern in diffusion welding complex-shaped hollow parts. The three systems, an electroplated nickel-cobalt alloy interlayer, a nickel-cobalt-tungsten-chromium dispersion electroplated interlayer, and thin foil intermediaries were first evaluated on tests specimens using metallography, microprobe analysis, and selective shear testing.

REPORT NO: AFML-TR-71-240 AD 744 845  
ACCESS NO: 200,515 December 1971  
TITLE: MICROSTRUCTURES OF POWDER AND CON-  
VENTIONALLY PROCESSED 7075 ALUMINUM  
AUTHOR: L. A. Jacobson, et. al.

CONTRACT NO:  
CONTRACTOR:  
PROJECT MONITOR: L. A. Jacobson (AFML/LLM)  
PROJECT NO: 7351  
TASK NO: 735105

ABSTRACT: Aluminum alloy powder of the 7075 composition was consolidated by warm upset and trusion. Commercial cast and wrought material was also extruded to serve as a control. Results of varying the length of time at solution treatment temperature indicate that the powder material is far less resistant to recrystallization than the conventional material. Optical and transmission electron microscopy revealed that after identical post-extrusion solution treatments the substructure formed during extrusion throughout the commercial material was stable while the powder material retained substructure only near the edges of the rectangular extrusion and had undergone complete recrystallization toward the center. These results are explained in terms of the presence of a certain particulate constituent and the amount of warm working, both of which appear to influence substructure formation and stability. The results obtained by varying quench rates and employing cold work after solution treatment are compared for the powder and the conventional material.

REPORT NO: AFML-TR-71-241 AD 736 484  
ACCESS NO: 65,316 January 1972  
TITLE: DEVELOPMENT OF POROUS BERYLLIUM  
AUTHOR: S. N. Rosenwasser, et. al.  
CONTRACT NO: F33615-69-C-1606  
CONTRACTOR: McDonnell Douglas Corporation  
PROJECT MONITOR: K. L. Kojola (AFML/LLM)  
PROJECT NO: 7351  
TASK NO: 735104

ABSTRACT: The processing procedures and parameters were developed for the fabrication of uniform controlled permeability porous beryllium billets by cold isostatic pressing and vacuum sintering of fractioned commercial, attritioned powder. Optimized parameters for the production of 1 1/2-in. -diameter billets in the permeability range of  $1 \times 10^{-10}$  in.<sup>2</sup> to  $1_2 \times 10^{-12}$  in.<sup>2</sup> and 3-in. -diameter billets in the permeability range of  $5 \times 10^{-11}$  in.<sup>2</sup> to  $5 \times 10^{-12}$  in.<sup>2</sup> were derived by an iterative experimental procedure. SP-200 grade powder with particle sizes between 74 and 10 microns was selected as the optimum blend, although control of particle size distribution within this range was shown to be necessary for lot-to-lot reproducibility. A press-anneal-repress procedure was developed to obtain uniform billets with permeabilities below  $5 \times 10^{-11}$  in.<sup>2</sup>

REPORT NO: AFML-TR-71-251 AD 743 228  
ACCESS NO: 65, 441 January 1972  
TITLE: CONTINUOUS OXIDE FILAMENT SYNTHESIS  
(CVD)

AUTHOR: P. E. Gruber, et. al.  
CONTRACT NO: F33615-69-C-1501  
CONTRACTOR: Avco Corporation  
PROJECT MONITOR: Capt. R. E. Tressler (AFML/LLS)  
PROJECT NO: 7350  
TASK NO: 735001

ABSTRACT: The program objective was to develop a process suitable for production of continuous aluminum oxide filaments at high rates by chemical vapor deposition. Several processes were investigated including gas phase hydrolysis or oxidation of  $AlCl_3$  and decomposition of organo-aluminum compounds; both high and low pressure deposition regimes as well as immersion in boiling liquid were investigated. Production of alumina filaments by chemical vapor deposition was achieved in some cases producing dense, small grained filaments; however, even the best appearing filaments had low strengths. Substrate breakage caused by chemical attack and mechanical failure was a persistent problem; substrates investigated included W, Pt, Ta, SiC, C, and B. An additional problem resulting from the use of a resistance heated substrate was that the surface temperature drops as the filament grows; nonuniform surface deposit may be caused by the low surface temperature.

REPORT NO: AFML-TR-71-252 AD 752 589  
ACCESS NO: 69, 420 March 1972  
TITLE: SILICON CARBIDE WHISKER-METAL MATRIX  
COMPOSITES

AUTHOR: F. Ordway, et. al.  
CONTRACT NO: F33615-69-C-1187  
CONTRACTOR: Artech Corp.  
PROJECT MONITOR: J. P. Kershaw (AFML/LLS)  
PROJECT NO: 7351  
TASK NO: 735107

ABSTRACT: Aluminum alloy composites reinforced with silicon carbide whiskers were prepared by liquid-phase hot pressing of aligned whisker-powder bodies. Biaxial (X-Y) alignment was obtained by filtering a liquid slurry. Uniaxial alignment was obtained by performing the filtration in a magnetic field, extruding the whisker-powder mixture suspended in solid camphene, or extruding the hot-pressed composite near the matrix melting temperature. The hot extrusion of -SiC composites at a reduction ratio of 13:1 materially impaired the tensile strength through fiber fracture. Camphene extrusion and hot pressing produced the highest strengths. The superior properties of -SiC whiskers could be utilized effectively only by thorough consolidation of a composite essentially free of clusters and non-whisker debris.

REPORT NO: AFML-TR-71-263 AD 739 557  
ACCESS NO: 200, 469 December 1971  
TITLE: A CRACK EXTENDING NON-UNIFORMLY IN AN  
ELASTIC SOLID SUBJECTED TO GENERAL  
LOADING

AUTHOR: L. B. Freund  
CONTRACT NO: F33615-71-C-1308  
CONTRACTOR: Brown University  
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLN)  
AFML TASK NO: 735303

ABSTRACT: The stress intensity factor of a half-plane crack extending non-uniformly in an isotropic elastic solid subjected to general loading is determined. The loading is applied in such a way that a state of plane strain exists, and that crack extension takes place in mode I. The crack tip is initially at rest, and then moves in an arbitrary way in the plane of the crack. In the process of obtaining the stress intensity factor, the complete elastic field is determined for a crack which starts from some initial position, extends at a constant rate for some time, and then suddenly stops.

REPORT NO: AFML-TR-71-272 AD 739 857  
ACCESS NO: 200, 470 December 1971  
TITLE: A NEW MODEL FOR THE DYNAMIC BEHAVIOR  
OF ELASTOMERIC MATERIALS

AUTHOR: Capt. J. L. Edwards, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: Capt. J. L. Edwards (AFML/LLM)  
AFML TASK NO: 735106

ABSTRACT: A mathematical model describing the dynamic behavior of rubber or elastomeric materials has been developed. It is based on Flory's concept of the rotational isometric state model of polymer chains. With a unit step strain applied to the material, each polymer chain is assumed to go from an unrelaxed initial configuration to a fully relaxed equilibrium state at a rate described by a non-linear first-order differential equation. The differential equation is derived by assuming that the relaxation rate is proportional to a probability function, namely, the probability that the elastic and thermal energy present in the chain is greater than or equal to a critical value. This probability function, as a first approximation, is shown to be just the chi-square distribution.

REPORT NO: AFML-TR-71-277 AD 739 876  
ACCESS NO: 200, 471 January 1972  
TITLE: MICROSTRUCTURE AND FATIGUE PROPERTIES  
OF ALUMINUM BASE ALLOYS  
AUTHOR: S. Weissmann  
CONTRACT NO: F33615-70-C-1240  
CONTRACTOR: Rutgers University  
PROJECT MONITOR: Dr. W.H. Reimann (AFML/LLM)  
AFML TASK NO: 735301  
ABSTRACT: The microstructures of Al-3wt.% Cu, Al 2024  
and Al-6.5 at. % Zn alloys were studied as a function of aging tempera-  
ture and time. The interaction of moving dislocations with precipitated  
particles and the generation of dislocation from particle-matrix inter-  
faces were related to flow stress and fatigue life.

REPORT NO: AFML-TR-71-278 AD 892 786L  
ACCESS NO: 200, 472  
TITLE: DEVELOPMENT OF REPAIR AND REPROCESS  
COATINGS FOR AIR-COOLED NICKEL ALLOY  
TURBINES BLADES  
AUTHOR: E. E. Jones, et al.  
CONTRACT NO: F33615-69-C-1662  
CONTRACTOR: TRW Group, Inc.  
PROJECT MONITOR: J. J. Crosby (AFML/LLM)  
AFML TASK NO: 731202  
ABSTRACT: The purpose of this program was to identify,  
develop and characterize coating compositions, processing techniques  
and resulting properties for: (1) repair of localized damage to diffused  
aluminide coatings on nickel base turbine blade alloys and (2) re-  
application of coatings to worn turbine blades during engine overhaul  
(reprocess coating). A multiphased effort was undertaken to develop a  
stripping procedure for removing used aluminide coatings and a coating  
process for reapplying a new coating as well as for use as a repair. A  
comprehensive test program was also conducted to compare the environ-  
mental performance of reprocess and repair coatings and to evaluate  
the effects of the new coatings on the mechanical properties of the sub-  
strate relative to the corresponding properties of the original coatings.

REPORT NO: AFML-TR-72-5 AD 748 361  
ACCESS NO: 200,512 February 1972  
TITLE: EFFECTS OF THERMOMECHANICAL  
TREATMENTS ON ALUMINUM ALLOYS  
AUTHOR: A. W. Sommer, et al.  
CONTRACT NO: F33615-69-C-1422  
CONTRACTOR: North American Rockwell Corporation  
PROJECT MONITOR: J. W. Poynter (AFML/LLS)  
AFML TASK NO: 735301

ABSTRACT: The effects produced by thermomechanical treatments on the mechanical, microstructural, and stress-corrosion-resistance properties of 2024, 7049, and 7075 aluminum alloys have been investigated. These properties are compared with those obtained in the standard commercial tempers. The optimum benefits of thermomechanical processing are obtained when the material has previously been heat-treated to its maximum age-hardenable condition. A thermomechanical response is developed with as little as 5 percent mechanical deformation. The uniformity of this plastic strain throughout the entire mass of the material is a critical factor. This mechanical deformation is carried out at a temperature high enough to develop a homogeneous random distribution of dislocations and to stabilize this configuration by precipitation along a portion of their lengths.

REPORT NO: AFML-TR-72-12 AD 750 556  
ACCESS NO: 200,942 July 1972  
TITLE: PROJECT THEMIS METAL DEFORMATION  
PROCESSING  
AUTHOR: H. Conrad  
CONTRACT NO: F33615-69-C-1027  
CONTRACTOR: University of Kentucky  
PROJECT MONITOR: A. M. Adair (AFML/LLN)  
PROJECT NO: 7912

ABSTRACT: The research tasks underway and the accomplishments during the third year of Project Themis-Metal Deformation Processing at the University of Kentucky are presented. The most significant accomplishments include: Uniaxial tensile tests on titanium indicated that (a) twinning is important in the low temperature deformation kinetics of Ti-50A; (b) the deformation kinetics of Ti-6Al-4V at low temperatures are governed principally by the interstitial solute content. Both single and double maximum type flow patterns were observed for the extrusion of Ti-5Al-2.5Sn, the change from one type to the other occurring at a constant value of the Zener-Hollomon parameter. It was concluded that the type of pattern is determined primarily by the material properties and that the effect of friction is merely to modify this behavior.

REPORT NO: AFML-TR-72-21 AD 747 709  
ACCESS NO: 200, 504 February 1972  
TITLE: CORROSION FATIGUE CRACK PROPAGATION  
IN ALUMINUM ALLOYS: PT. I - EFFECT OF  
CYCLIC STRESS WAVE FORM ON CORROSION  
FATIGUE CRACK PROPAGATION IN Al-Zn-Mg  
ALLOYS

AUTHOR: R. J. Selines, et al.  
CONTRACT NO: F33615-70-C-1785  
CONTRACTOR: Massachusetts Institute of Technology  
PROJECT MONITOR: A. W. Brisbane (AFML/LLN)  
AFML TASK NO: 735303

ABSTRACT: Fatigue crack growth rates of a 7075 type aluminum alloy were measured as a function of environment, frequency, stress wave form, alloy chemistry, and thermomechanical treatment. At low K values (below  $K_{ISCC}$ ), the crack growth rates in a 3.5 per cent sodium chloride solution were ten times greater than those in a reference argon environment. Comparison of the effects of square wave, a negative sawtooth wave, and a positive sawtooth wave at different frequencies indicates that the synergistic interaction with the environment occurs during the loading part of each cycle. Overaging the alloy and limiting the alloy impurity contents results in a reduced corrosion fatigue crack growth rate, but a thermomechanical treatment leading to a grain size refinement increases it.

REPORT NO: AFML-TR-72-21 AD 747 709  
ACCESS NO: 200, 505 February 1972  
TITLE: CORROSION FATIGUE CRACK PROPAGATION  
IN ALUMINUM ALLOYS: PT. II - MECHANISMS  
OF CORROSION FATIGUE CRACK PROPAGATION  
IN Al-Zn-Mg ALLOYS

AUTHOR: R. E. Stoltz, et al.  
CONTRACT NO: F33615-70-C-1785  
CONTRACTOR: Massachusetts Institute of Technology  
PROJECT MONITOR: A. W. Brisbane (AFML/LLN)  
AFML TASK NO: 735303

ABSTRACT: Corrosion fatigue crack propagation tests were performed on commercial 7075 alloys. Testing was done in a 3.5% sodium chloride solution under constant impressed potential and under reversed anodic cathodic conditions. Results indicated that a cathodic potential of -1.400 volts vs. SCE was sufficient to reduce corrosion fatigue crack growth rates to the level observed in dry argon. By alternately impressing anodic and cathodic currents, it was shown that anodic potentials enhance the crystallographic dependence of the fracture mode, resulting in brittle striations, while cathodic potentials results in ductile striations formed by shear.

REPORT NO: AFML-TR-72-28 AD 744 109  
ACCESS NO: 65, 652 January 1972  
TITLE: DEVELOPMENT OF ALLOY FOR CAST AIR-COOLED TURBINE BLADES  
AUTHOR: H. E. Collins, et al.  
CONTRACT NO: F33615-69-C-1661  
CONTRACTOR: TRW Inc.  
PROJECT MONITOR: L. D. Parsons (AFML/LLM)  
AFML TASK NO:

ABSTRACT: The objective of this program was to develop an alloy and to improve processing for cast air-cooled blades used in high performance gas turbines. Emphasis was placed on attainment of optimum properties in thin sections. The program was divided into three phases. Phase I was a screening study where 36 compositions were melted, cast and evaluated on the basis of 1400<sup>o</sup>F tensile, 1800<sup>o</sup>F/20 ksi stress rupture and hot corrosion tests. Phase II was a concurrent study of the effect of section size and processing variables upon the thin section properties of high temperature alloys. Phase III included the characterization of the two most promising alloys from Phase I utilizing the processing results from Phase II.

REPORT NO: AFML-TR-72-37 AD 744 850  
ACCESS NO: 200, 626 March 1972  
TITLE: MATHEMATICAL CALIBRATION OF THE RING TEST WITH BULGE FORMATION  
AUTHOR: V. DePierre, et al.  
CONTRACT NO: F33615-71-C-1163  
CONTRACTOR: Westinghouse Electric Corporation  
PROJECT MONITOR: V. Depierre (AFML/LLS)  
AFML TASK NO: 735108

ABSTRACT: An available mathematical solution of ring compression with bulge formation was utilized to calibrate ring test specimens on the basis of constant interface friction factor,  $m$ . Calibration curves for the 6:3:2 and other ring geometries were obtained by mathematical computation and a method was established for calibrating all ring geometries with bulge formation. Calculated calibration curves of the 6:3:2 ring showed very correlation with experimentally determined interface friction factors,  $m$ . The investigation demonstrated that a valid mathematical solution of ring compression can be utilized for more accurate and less laborious calibration than experimental calibration of ring test specimens.

REPORT NO: AFML-TR-72-38 AD 749 136  
ACCESS NO: 200, 913 August 1972  
TITLE: THE CORRELATION OF NONDESTRUCTIVE  
TEST TECHNIQUES WITH THE FRACTURE  
BEHAVIOR OF ATJ-S GRAPHITE

AUTHOR: W. L. Shelton, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: W. L. Shelton (AFML/LLN), et al.  
AFML TASK NO: 735106

ABSTRACT: Selected specimens of ATJ-S graphite were non-destructively evaluated and tensile tested in gas-bearing test facilities. The nondestructive test methods used on billets, specimen blanks, and finished specimens were visual inspection, alcohol wipe, radiography, and radiographic enhancement techniques. Correlations were made between nondestructive test indications and fracture location and strength. Low density areas were found to be the predominant weakening defect in this graphite. Fractographic examination of the fractured specimens revealed flaws which could be correlated with those flaws detected non-destructively and predicted from Griffith's theory.

REPORT NO: AFML-TR-72-48 AD 745 989  
ACCESS NO: 200, 677 May 1972  
TITLE: METALLURGICAL CONTROL OF FATIGUE  
CRACK GROWTH IN HIGH-STRENGTH  
ALUMINUM ALLOYS

AUTHOR: G. T. Haha, et al.  
CONTRACT NO: F33615-71-C-1107  
CONTRACTOR: Battelle Columbus Laboratories  
PROJECT MONITOR: Dr. W. H. Reimann (AFML/LLM)  
AFML TASK NO: 735106

ABSTRACT: The results of 22 different investigations of cyclic crack growth, principally on the 2024-T3 and 7075-T6 alloys, but including results for unalloyed and other 2-, 5-, 6-, and 7-thousand series alloys, have been examined and compiled with a view to separating metallurgical effects from other factors. The various crack growth measurements show good agreement when the comparisons involve the same R-value, environment and cyclic frequency. Both the 2024-T3 and 7075-T6 alloy can display widely different rates of growth for the same K-value. The highest growth rates are for tests in humid air, the lowest growth rates for tests in dehydrated air with high cyclic frequencies. These extremes point to a moisture assisted corrosion process capable of producing a 20-fold increase in the growth rate at low k-levels. Crack growth rate -K measurements have also been converted into S-N curves for cracked members. These curves illustrate the influence of flaw size, stress range, R and Kc on the cyclic life of the 7075-T6 and 2024-T3 grades.

REPORT NO: AFML-TR-72-50 AD 748 266  
ACCESS NO: 200,680 July 1972  
TITLE: IMPROVEMENT OF THE OXIDATION RESISTANCE  
OF DISPERSION STRENGTHENED NICKEL-  
CHROMIUM ALLOYS

AUTHOR: D.H. Timbres, et al.  
CONTRACT NO: F33615-70-C-1199  
CONTRACTOR: Sherritt Gordon Mines Limited  
PROJECT MONITOR: P. L. Hendricks (AFML/LLM), et al.  
AFML TASK NO: 735103

ABSTRACT: The cyclic dynamic oxidation and hot corrosion behavior at 2000°F (1093°C) and 2200°F (1204°C) of Ni/Cr/ThO<sub>2</sub> alloys modified by additions of 5 w/o aluminum and 0.2 w/o yttrium or 3-5 w/o manganese were measured. Alloys of the composition Ni/16-20Cr/5Al/2ThO<sub>2</sub> exhibited the best oxidation resistance having a smaller weight change and less damage by spalling or erosion than the manganese modified alloys. A thermomechanical procedure has been defined to produce a coarse grain microstructure in the aluminum-modified alloys. The procedure consists of primary working by extrusion followed by secondary working by swaging or rolling. The resulting coarse grained alloys have good stress-rupture strength at 2000°F but the ultimate tensile strength is low. A coarse thoria size resulting during processing of the powder through the consolidation step was believed to have contributed to the low tensile strengths at 2000°F (1093°C).

REPORT NO: AFML-TR-72-52 AD 747 207  
ACCESS NO: 200,687 June 1972  
TITLE: HEAT TREATMENT STUDY OF BETA EXTRUDED  
TITANIUM ALLOY Ti-6Al-6V-2Sn

AUTHOR: R. J. Sajdak, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR:

AFML TASK NO: 735105

ABSTRACT: A linear regression analysis was utilized to analyze mechanical properties data from a statistically designed experiment which maximized the variability in heat treating parameters of a titanium alloy, Ti-6Al-6V-2Sn, beta extruded ribbed panel. Using the results of the linear regression analysis, a computer program was executed to predict mechanical properties. Nine heat treatment cycles were chosen to test the validity of the predicted mechanical properties. Generally, the yield strength and ultimate strength are slightly higher than predicted; and fracture toughness is lower than predicted. Two heat treatment cycles were singled out as yielding superior properties over the other heat treatment cycles investigated.

REPORT NO: AFML-TR-72-62 AD 751 979  
ACCESS NO: 200, 664 May 1972  
TITLE: LONGITUDINAL IMPACT ON A ROD OF RATE-DEPENDENT MATERIAL  
AUTHOR: W. T. C. Li, et al.  
CONTRACT NO: F33615-71-C-1175  
CONTRACTOR: University of Illinois  
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLN)  
AFML TASK NO: 735106  
ABSTRACT: The problem of a semi-infinite rod of rate-dependent material subjected to an axially applied load is considered and an arbitrary number of terms in series expressions are obtained for the velocity, stress and strain distributions in the rod. Several examples are given to illustrate the use of the method of series expansion in comparison with other numerical method.

REPORT NO: AFML-TR-72-68 AD 748 269  
ACCESS NO: 200, 692 March 1972  
TITLE: ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE  
AUTHOR: J. E. Dryer  
CONTRACT NO: F33615-69-C-1026  
CONTRACTOR: The Ohio State University  
PROJECT MONITOR: Dr. H. L. Gegel (AFML/LLS)  
AFML TASK NO: 735302  
ABSTRACT: Experimental and theoretical investigation of the electrical properties of thin films during the nucleation state of film growth were undertaken. It was found that electrostatic forces in the film can significantly influence the film resistance, nucleation rate and island size. Electrode contact effects were also found to have a large effect in measurements taken across narrow films. Experimentally it was found that a number of films investigated exhibited a reversible switching phenomena wherein they underwent a substantial increase in conductivity then persisted to lower voltage and subsequently the film could be converted to its original condition. Previous theories of conduction in discontinuous films were considered and modified to include electrode carrier injection and substrate dielectric polarization.

REPORT NO: AFML-TR-72-84 AD 744 711  
ACCESS NO: 200, 659 May 1972  
TITLE: INVESTIGATIONS TO UNDERSTAND THE  
PLASTIC DEFORMATION AND STRENGTH-  
ENING MECHANISMS OF SOLID SOLUTION  
PHASES OF TITANIUM

AUTHOR: H. Conrad, et al.  
CONTRACT NO: F33615-68-C-1052  
CONTRACTOR: University of Kentucky  
PROJECT MONITOR: Dr. H. L. Gegel (AFML/LLS)  
AFML TASK NO: 735103

ABSTRACT: Static and dynamic strain aging occurs in the intermediate temperature range of 0.3 to 0.45  $T_m$ . At higher temperatures the deformation can be described very well by Weertman's dislocation climb model. Fracture at high temperature appears to be controlled by the same mechanism. The ratio of fatigue limit to yield stress is approximately 0.65, relatively independent of grain size, interstitial content and temperature, suggesting that fatigue is controlled by the same mechanism as plastic flow.

REPORT NO: AFML-TR-72-102 (Pt. II) AD 751 529  
ACCESS NO: 200, 994 August 1972  
TITLE: CORROSION CRACKING OF METALLIC  
MATERIALS. PART II: ACOUSTIC EMISSION -  
EXPERIMENT AND THEORY

AUTHOR: M. G. Fontana, et al.  
CONTRACT NO: F33(615)-69-C-1258  
CONTRACTOR: Ohio State University  
PROJECT MONITOR: Dr. H. B. Kirkpatrick (AFML/LLS)  
AFML TASK NO: 731202

ABSTRACT: The aspects of acoustic emission associated with the theory of the stress waves emitted from cracking and the experimental measurement of the acoustic emission pulses is reported here. In the theoretical phase of the work, a survey of the applicable literature in the area of stress waves from moving cracks is reviewed. Certain simple theoretical arguments pertaining to the energy release from an increment of crack growth are reported. In the experimental phase, an evaluation of a number of ultrasonic nondestructive test transducers from acoustic emission work was carried out and an optimum transducer selected. A complete acoustic emission test system was then constructed and several tests performed by the conclusion of the project.

REPORT NO: AFML-TR-72-103 AD 749 932  
ACCESS NO: 200,934 July 1972  
TITLE: IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS

AUTHOR: T. Hamajima  
CONTRACT NO: AF33615-69-C-1322  
CONTRACTOR: Rutgers University  
PROJECT MONITOR: Dr. S. Fujishiro (AFML/LLS)  
AFML TASK NO: 735302  
ABSTRACT: The mechanical properties of Ti-7 Mo-7 and Ti-7 Mo-16 Al (in atomic per cent) were correlated to the microstructure. The mechanical properties of the alloy with low aluminum content, consisting of a + b phases, were dependent on the size of the a particles. Small a particles functioned as typical hard agents in a dispersion-hardened system and the volume fraction of the particles controlled the ductility. Large a particles behaved like soft incoherent particles, the volume fraction having little effect on the inherent ductility of the alloy. This different behavior could be attributed to the dependence of strain-hardening behavior of a particles on particle size.

REPORT NO: AFML-TR-72-134 AD 752 590  
ACCESS NO: 200,940 July 1972  
TITLE: DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE

AUTHOR: T. J. McDaniel  
CONTRACT NO: F33615-70-C-1337  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: D. I. G. Jones (AFML/LLN)  
AFML TASK NO: 735106  
ABSTRACT: The purpose of this report is to present the results of a theoretical study of the effects of spatially varying curvature on the dynamics of cylindrical panels and stiffened cylindrical shell structures. The first section of the report contains a brief discussion of the general problem area. Following this discussion, the analytical techniques for solving constant curvature cylindrical panels and stiffened cylindrical shell problems by a transfer matrix approach are reviewed. These techniques are found to apply directly to the varying curvature shell analysis provided the transfer matrix for this type of shell can be obtained. An analytical approach to obtaining the transfer matrix for a varying curvature shell is explored. A solution to the transfer matrix for a cylindrical shell with exponentially varying curvature is obtained.

REPORT NO: AFML-TR-72-149 AD 753 706  
ACCESS NO: 201, 100 September 1972  
TITLE: THE TIME DEPENDENT MECHANICAL  
BEHAVIOR OF METAL MATRIX COMPOSITES  
AUTHOR: S. T. Scheirer, et al.  
CONTRACT NO: F33615-71-C-1501  
CONTRACTOR: TRW Inc.  
PROJECT MONITOR: K. D. Shimmin (AFML/LLN)  
AFML TASK NO: 735106

ABSTRACT: A study of tensile properties, fatigue, thermal fatigue, and creep behavior in B-Al and B/SiC-Ti composite materials was performed. Prior studies of small diameter boron reinforced 6061 Al have identified the failure mechanisms for a variety of loading conditions. The use of larger diameter (5.6 mil) boron filaments, having an improved resistance to longitudinal splitting, has been shown to alter the behavior of B-Al in certain important areas. A more extensive study of time dependent and tensile behavior of B/SiC reinforced Ti-6Al-4V was also performed. Because of the substantially higher matrix shear strength, the behavior of Ti matrix composites was shown to be considerably different from that of B-Al. The elimination of the filament-splitting problem through the use of larger diameter boron fibers improved the off-axis tensile properties of B-6061 Al to a point where they are correctly predicted by theory based on matrix shear strength control.

REPORT NO: AFML-TR-72-159 AD 751 980  
ACCESS NO: 200, 935 August 1972  
TITLE: RESEARCH ON DEVELOPMENT AND FABRI-  
CATION OF BORON SUBOXIDE SPECIMENS  
AUTHOR: W. H. Rhodes  
CONTRACT NO: F33615-71-C-1449  
CONTRACTOR: Avco  
PROJECT MONITOR: Dr. R. Ruh (AFML/LLS)  
AFML TASK NO: 735001

ABSTRACT: This work describes the processing of dense boron suboxide by hot pressing. Sound billets, four inches diameter by three-eighths inch thick, were consolidated to a density as high as 99.2 percent of theoretical. Adjustment of process parameters was very critical as incorrect parameters resulted in either low density, excessive decomposition, or cracked billets. Several process modifications were identified that reduced production costs.

REPORT NO: AFML-TR-72-161 AD 752 609  
ACCESS NO: 200, 958 March 1972  
TITLE: GROWTH OF MULTICOMPONENT COMPOSITES  
FROM THE MELT  
AUTHOR: M. D. Rinaldi  
CONTRACT NO: F33615-71-C-1374  
CONTRACTOR: Massachusetts Institute of Technology  
PROJECT MONITOR: Capt. D. A. Rice (AFML/LLS)  
AFML TASK NO:

ABSTRACT: A simple constitutional supercooling analysis is given for predicting interface stability in plane front solidification of ternary alloys containing one, two, or three phases. It is concluded that polyphase composites can be grown from ternary alloys by plane front solidification provided thermal gradient is sufficiently high, growth rate is low, convection is low and kinetic undercooling is small. Calculated examples of conditions required for stability are given for three-phase alloys from the aluminum-rich corner of the Al-Cu-Ni system. It is seen that the most stable compositions (with respect to interface breakdown) lie nearly, but not exactly, on lines of two-fold saturation. Ternary alloys from the Al rich corner of the Al-Cu-Ni system were unidirectionally solidified under a wide variety of growth conditions. Plane front solidification was achieved at sufficiently high thermal gradients and slow growth rates. Conditions necessary to cause planar interface breakdown in both two and three phase alloys compare well to those predicted by a simple constitutional super-cooling criterion.

REPORT NO: AFML-TR-72-171 AD 754 240  
ACCESS NO: 201, 151 September 1972  
TITLE: SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS  
AUTHOR: E. W. Colings, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: H. L. Gegel (AFML/LLS)  
AFML TASK NO: 735302

ABSTRACT: Phase stabilization and solid solution strengthening in titanium alloys are discussed from an electronic viewpoint. Based on the structure dependence of cohesive energy, we rationalize the alpha and beta-stabilization of titanium as produced by alloying with nontransition and transition metals, respectively; and point out that only the addition of alpha-stabilizers will yield significant strengthening effect. The preference of multicomponent alloying, i. e., adding several nontransition metal solutes to titanium or otherwise beta-stabilized alloys, can also be justified from the concept to be described. Correlations between physical and mechanical properties of prototype systems (Ti-Al, Ti-Ga, Ti-Sn, Ti-Al-Ga, Ti-Mo, and Ti-Mo-Fe-Al) are presented to demonstrate the validity of the fundamental approach, which should eventually develop into useful alloy design criteria.

REPORT NO: AFML-TR-72-180 AD 753 711  
ACCESS NO: 201, 153 September 1972  
TITLE: AN INVESTIGATION OF THE MECHANICAL  
PROPERTIES OF SILICON CARBIDE AND  
SAPPHIRE FILAMENTS

AUTHOR: R. L. Crane

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR:

AFML TASK NO: 735107

ABSTRACT: The mechanical properties of SiC and Al<sub>2</sub>O<sub>3</sub> (sapphire) filaments pertinent to the initial design of a metal matrix composite have been documented. The strength contributions of these filaments to a composite were simulated with tensile tests of self-abraded samples. The strength of virgin SiC filament was found to decrease linearly to about 1100°C and exponentially above this temperature. The abraded strength was found to be constant, as a function of temperature, to about 1100°C. The loss of high temperature strength was correlated with the reaction between SiC and the fiber's W core. The strength of single crystal sapphire as a function of temperature was determined for both a- and c-axis filaments. Similar tests were conducted on ruby fiber (Cr<sub>2</sub>O<sub>3</sub> doped sapphire). Ruby fiber was found to be significantly stronger than pure sapphire and insensitive to abrasion about 500°C. The strength of ruby fiber as a function of Cr<sup>+3</sup> content showed that the optimum dopant level has not yet been reached. A filament strength of 250 ksi at 1100°C was predicted for a c-axis fiber with an optimum Cr<sup>+3</sup> concentration. The use of abraded filament strength to predict the in situ fiber strength contribution was found to be valid for Al<sub>2</sub>O<sub>3</sub> reinforced Ti.

REPORT NO: AFML-TR-72-199 AD 750 140  
ACCESS NO: 200, 956 July 1972  
TITLE: RESEARCH ON SYNTHESIS OF HIGH-STRENGTH  
ALUMINUM ALLOYS

AUTHOR: J. D. Boyd

CONTRACT NO: F33615-71-C-1805

CONTRACTOR: Battelle Columbus Laboratories

PROJECT MONITOR: 1st Lt. D. P. Voss (AFML/LLS)

AFML TASK NO: 735302

ABSTRACT: The objective of Task A is to provide increased strength and fracture resistance in aluminum alloys by optimizing the precipitate microstructure. To control the size and distribution of the intermediate precipitates in some high-strength 7000 and 2000 series alloys, several alloy were cast and their precipitate microstructures characterized by microscopy after homogenization treatments at various times and temperatures. Homogenization treatments were selected to produce a fine and a coarse intermediate precipitate. The objective of

**ABSTRACT (cont'd):** Task B is to develop a recrystallized microstructure in wrought high-strength aluminum alloys during hot working. Recrystallization occurred along the grain boundaries in the 2024 alloy only at the highest upset rate (8.8 inch/sec) and the highest temperature (925°F). Preliminary microscopy results indicate that the intermediate precipitate in 2024 may not be stable during hot working.

ELECTROMAGNETIC MATERIALS DIVISION (AFML/LP)

REPORT NO: AFML-TR-68-167 AD , 41 040  
ACCESS NO: 40, 792 August 1968  
TITLE: THE FARADAY EFFECT IN CEROUS  
METAPHOSPHATE GLASS

AUTHOR: C. C. Robinson  
CONTRACT NO: AF 33(615)-5065  
CONTRACTOR: American Optical Corporation  
PROJECT MONITOR: Dr. A.M. Stoffel (AFML/LPE)  
AFML TASK NO: 737103

ABSTRACT: A cerous metaphosphate glass was made with approximately stoichiometric composition and without any detectable quantity of  $Ce^{4+}$ . The theoretical calculations were fitted to the experimental results at  $.4358\mu$  and were found to predict the rotation at the remaining temperatures and wavelengths with an acceptable degree of accuracy. It was pointed out that calculations for a cubic or a tetrahedral site would not agree with the data.

REPORT NO: AFML-TR-68-228 AD 682 999  
ACCESS NO: 44, 555 September 1968  
TITLE: PREPARATION AND CHARACTERIZATION OF  
HIGH QUALITY SINGLE CRYSTAL REFRACTORY  
METAL BORIDES AND CARBIDES

AUTHOR: J. S. Haggerty, et al.  
CONTRACT NO: AF 33(615)-5130  
CONTRACTOR: Arthur D. Little, Inc.  
PROJECT MONITOR: J. R. Fenter (AFML/LPL)  
AFML TASK NO: 735001

ABSTRACT: Reproducible techniques have been developed to produce single crystals of  $HfB_2$ ,  $HfC$ ,  $TaC$ , and  $ZrC$  of a higher quality than had been available previously. The use of ambient furnace pressures up to 20 atmospheres to reduce the loss of volatile constituents by vaporization from the melts, has greatly improved the control of the stoichiometry of the single crystals. The dependence of vaporization rates on ambient pressure is discussed in terms of a mathematical model that was derived. Detailed procedures used for the preparation of the uniform, high-density sintered feed rods, as well as crystal growth synthesis, are presented to eliminate much of the art involved in earlier process techniques.

REPORT NO: AFML-TR-70-121 AD 893 718L  
ACCESS NO: 200, 586 October 1970  
TITLE: PROCEDURES FOR THE PRECISE DETERMINATION OF THERMAL RADIATION PROPERTIES  
AUTHOR: J. C. Richmond, et al.  
CONTRACT NO: D. O. (33-615)-65-1005  
CONTRACTOR: National Bureau of Standards  
PROJECT MONITOR: D. F. Stevison (AFML/LPH)  
AFML TASK NO: 738106

ABSTRACT: The broad objective of this program, which has continued for several years, is to develop equipment and procedures for measuring the important thermal radiation properties of materials, particularly those used in aircraft, missiles, and space vehicles, at temperatures up to the melting points of the most refractory materials. During the period covered by this report the specific objectives were to complete development of the laser-source integrating sphere reflectometer, and to prepare emittance standards for use at temperatures above 1400 K (2000°F). The laser-source integrating sphere reflectometer consisted of (1) a helium-neon laser as a source, capable of operation at 0.6328, 1.15, and 3.39  $\mu$ m; (2) a 35 cm (14 in.) diameter sphere coated with barium sulphate or sodium chloride; (3) a lead sulfide detector; and (4) a radio-frequency generator for heating the sample by induction.

REPORT NO: AFML-TR-71-161 AD 741 846  
ACCESS NO: 200, 530 November 1971  
TITLE: IMPROVING ULTRASONIC TRANSDUCER ASSEMBLIES GENERATING AEROSOLS FOR INSTRUMENTAL TECHNIQUES OF CHEMICAL ANALYSIS  
AUTHOR: L. E. Owen  
CONTRACT NO: F33615-71-C-1132  
CONTRACTOR: Tomorrow Enterprises  
PROJECT MONITOR: F. F. Bentley (AFML/LP)  
AFML TASK NO: 736005

ABSTRACT: A search for surface coatings, which, when applied to the working faces of active piezoelectric transducers, would prevent their destruction by sample solutions containing HF, was unrewarded. Coatings otherwise suitable for fountain type nebulizers could not withstand the great rigor of direct impingement nebulization in which the working surface is only lightly loaded. All failure modes involved loss of coating integrity with subsequent attack of the piezoceramic by the HF.

REPORT NO: AFML-TR-71-165 AD 734 761  
ACCESS NO: 200, 353 June 1971  
TITLE: INFRARED DISPERSION ANALYSIS AND  
OPTICAL CONSTANT SPECTRA OF  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>  
(HEMATITE)

AUTHOR: C. M. Phillippi, et al.

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR: C. M. Phillippi (AFML/LPA), et al.

AFML TASK NO: 736005

ABSTRACT: Infrared reflection spectra of the ordinary and extraordinary rays of single crystal ferric oxide in the form of the mineral hematite are isolated and measured. Dispersion analyses are performed on these spectra and the best fit resonance parameters are identified, along with estimated tolerances. Longitudinal optical mode frequencies are calculated from these data. Also calculated are: refractive index, extinction coefficient, absorption coefficient, and real and imaginary parts of the dielectric constant of both rays. These are presented as tabulations between 4000 and 200 cm<sup>-1</sup>, and as plots between 700 and 200 cm<sup>-1</sup>. Several oxidation film spectra from pure iron are illustrated and discussed.

REPORT NO: AFML-TR-71-224 AD 740 587  
ACCESS NO: 200, 533 December 1971  
TITLE: FLUORINE-19 NUCLEAR MAGNETIC RESONANCE  
AUTHOR: R. O. Ragsdale  
CONTRACT NO: F33615-69-C-1016  
CONTRACTOR: University of Utah  
PROJECT MONITOR: Dr. D. S. Dyer (AFML/LP)

AFML TASK NO: 736702  
ABSTRACT: Several series of diadducts of titanium tetrafluoride were studied with high-resolution fluorine-19 nuclear magnetic resonance spectroscopy. These consisted of studies with aromatic amine oxides, amides and sulfoxides on bases. Missed diadducts of TiF<sub>4</sub> with the aromatic amine oxides and tetramethylurea as a reference base were also investigated. Both basicity and steric interactions were found to affect the <sup>19</sup>F chemical shifts. Some aromatic amine oxide, amide and sulfoxide adducts with tin tetrafluoride were also investigated. Cis and trans isomers were found for all complexes in which the donor molecule was small. With large bulky ligands only the trans isomers were detected. First order spectra for the cis adduct were measured when the donor molecule was a very weak base. Only second order spectra were found for SnF<sub>4</sub>. 2D complexes formed with the relatively strong bases. The <sup>19</sup>F chemical shifts, in contrast to TiF<sub>4</sub> data, were found to be relatively insensitive to the basicity of the donor molecules.

REPORT NO: AFML-TR-71-235 AD 740 588  
ACCESS NO: 200, 514 December 1971  
TITLE: X-RAY DIFFRACTION STUDIES OF THE ROLE  
OF HYDROGEN BONDING IN THE LOW  
TEMPERATURE BEHAVIOR OF MATERIALS

AUTHOR: M. A. Goldschmidt, et al.  
CONTRACT NO: F33615-69-C-1330  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: H. Marcus (AFML/LPH)  
AFML TASK NO: 736005  
ABSTRACT: X-ray diffraction strip chart recordings were  
obtained at 100°K and 300°K for powder samples of urea and seven  
carbohydrates. A combination of known crystallographic data and a  
least squares fit program revealed the temperature dependence of the  
unit cell for urea and three of the carbohydrates. In all cases, a con-  
traction on cooling was observed. While the volume of data produced  
did not justify any positive conclusions, the results did not contradict  
the model of Sklar et al. assigning the entire shrinkage to hydrogen bond  
contraction. The model remains valid for interpretation of infrared data,  
at least until further x-ray data becomes available.

REPORT NO: AFML-TR-71-239 AD 737 314  
ACCESS NO: 200, 352 November 1971  
TITLE: ELECTRON SPIN RESONANCE STUDIES OF  
DEFECTS IN FLUORITES

AUTHOR: G. Wessel  
CONTRACT NO: F33615-69-C-1161  
CONTRACTOR: Syracuse University  
PROJECT MONITOR: W.G. Frederick (AFML/LPE)  
PROJECT NO: 7371  
ABSTRACT: The microwave spectra of calcium-fluoride  
doped with hydrogen as well as with gadolinium have been measured and  
the spin-Hamiltonian constants for the cubic and tetragonal spectra have  
been measured. These measurements were carried out at a frequency  
of about 25 GHz in the ranges of temperature, liquid nitrogen, and liquid  
helium temperature. The microwave spectra of iron doped lead titanate  
have been measured at frequencies between 30 GHz and 75 GHz in the  
temperature range between liquid nitrogen and room temperature. The  
spin-Hamiltonian constants have been determined from the measurements  
and have been related to the relative deformations by the internal electric  
field of this ferroelectric crystal.

REPORT NO: AFML-TR-71-259 AD 743 027  
ACCESS NO: 200, 669 December 1971  
TITLE: THE HUGONIOT OF A SOLID DETERMINED  
BY MEANS OF A VARIATIONAL PRINCIPLE  
AUTHOR: J. F. Heyda  
CONTRACT NO: F33615-70-C-1228  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: G. H. Griffith (AFML/LPH)  
AFML TASK NO: 736006

ABSTRACT: The formulation of the Gruneisen coefficient based on the velocity doubling approximation is used to define a normalized Gruneisen coefficient. A new integral formulation for the free surface velocity is then written in terms of this normalized coefficient. On the assumption that the specific energy of the solid at 0°K is a known function of the specific volume and that the bulk sound speed in the uncompressed state is a known quantity, the Hugoniot of the solid is chosen to be that curve, among a family of curves lying on a Mie-Gruneisen constraint surface, which maximizes the free surface velocity. A differential equation for the resulting Hugoniot is determined and its solution is approximated by the first three terms of a series expansion. This expansion furnished a quadratic expression for the shock velocity in terms of the particle velocity all of whose coefficients are given by formulas involving physically meaningful quantities. Calculations have been found to agree with the experimental data out to 340 kb very closely. A preliminary check for sodium metal are also given.

REPORT NO: AFML-TR-71-262 AD 739 884  
ACCESS NO: 200, 508 February 1972  
TITLE: A MASS SPECTROMETRIC STUDY OF THE  
VAPORIZATION OF CUPROUS IODIDE  
AUTHOR: Capt. T. E. Joyce, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: E. J. Rolinski (AFML/LPH)  
AFML TASK NO: 736001

ABSTRACT: The vaporization of  $\text{CuI}$  was studied using Knudsen effusion-mass spectrometric techniques. The ionic species in the mass spectrum were identified and assigned to the appropriate parent molecules in the equilibrium vapor. Partial pressures for each of the components of the equilibrium vapor were determined as a function of temperature. Second law heats of sublimation were determined and two structural transformations occurring in the solid were characterized. The possibility of a temperature dependent ionization cross section for some of the species is discussed.

REPORT NO: AFML-TR-71-269 AD 745 134  
ACCESS NO: 200, 354 November 1971  
TITLE: DEVELOPMENT OF THIN FILM ALUMINUM  
AUTHOR: C. B. Roberts  
CONTRACT NO: F33615-71-C-1231  
CONTRACTOR: Dow Chemical Company  
PROJECT MONITOR: Capt. R. J. Callahan (AFML/LPH)  
AFML TASK NO: 763303

ABSTRACT: Attempts to coat polyester film with aluminum having resistivities between 10 and 200 ohms per square were not successful utilizing Dow Electroless Aluminization Process. An abrupt change in resistivity appeared at a thickness of approximately 150 Å, and intermediate values between 3 ohms and infinite resistivities could not be obtained. Thicker films (200-300 Å) were anodized to uniformly remove aluminum in an attempt to obtain the desired range of resistivities. Lack of uniformity eliminated them from being tested for admittance values. Exposure to a 100 percent oxygen atmosphere did not increase the resistivity of 200-300 Å thick aluminum coatings. Patterns with 2 to 8 mil wide lines could not be printed on a polyester film web by the present coating methods.

REPORT NO: AFML-TR-71-273 AD 744 847  
ACCESS NO: 200, 509 January 1972  
TITLE: EDREM - A COMPUTER PROGRAM TO IDENTIFY  
LINES IN REPETITIVELY SCANNED DIGITIZED  
SPECTRA

AUTHOR: V. L. Donlan, et al.

CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR:  
AFML TASK NO: 736003

ABSTRACT: Program EDREM (Editing Digitized Experimental Magnetic Resonance Data) is a versatile Fortran IV computer routine for identifying peaks in digitally recorded spectra. In cases when more than one digitized scan of a spectrum is available, EDREM computes the average position and intensity of spectral peaks with a high degree of discrimination against noise and other spurious peaks. In this report, EDREM is described in detail, and as an illustration of the use of EDREM, an analysis of the NMR spectrum of benzoxazole is given.

REPORT NO: AFML-TR-71-279 AD 740 589  
ACCESS NO: 200, 516 November 1971  
TITLE: VIBRATIONAL SPECTRA OF SUBSTITUTED  
CYCLOBUTANE COMPOUNDS

AUTHOR: J. E. Katon, et al.  
CONTRACT NO: F33615-71-C-1021  
CONTRACTOR: Miami University  
PROJECT MONITOR: F. F. Bentley (AFML/LP)  
AFML TASK NO: 736005

ABSTRACT: As a preliminary to the study of group frequencies present in substituted cyclobutanes, the complete vibrational spectra of the model compound cyclobutanecarboxylic acid have been recorded on the crystalline material. A tentative, approximate vibrational assignment has been proposed based on these spectra along with the infrared spectra of the potassium salt, cyclobutanecarboxylic acid-O-d cyclobutanecarboxylli acid-a-d-O-d cyclobutanecarboxylic acid-a-d and previous published results with other simple cyclobutane derivatives. The spectra of crystalline cyclobutanecarboxylic acid can best be interpreted in terms of a hydrogen bonded dimer structure with a center of symmetry. The results of the isotopic studies indicate that there is an unusual amount of vibrational coupling between vibrations of the hydrogen bonded ring system and a number of vibrations of the cyclobutane ring system.

REPORT NO: AFML-TR-71-280 AD 744 107  
ACCESS NO: 200, 507 February 1972  
TITLE: CHEMICAL, STRUCTURAL AND ANALYTICAL  
RESEARCH

AUTHOR: J. E. Katon  
CONTRACT NO: F33615-70-C-7360  
CONTRACTOR: Miami University  
PROJECT MONITOR: F. F. Bentley (AFML/LP)  
AFML TASK NO: 736005

ABSTRACT: This report summarizes the research programs and service functions covering determination of molecular structures, characterization of materials and development and application of analytical techniques of various kinds. The contract also involves various services supplied the Air Force in support of their in-house programs. The major areas of research were in emission spectrometry, mass spectrometry, microchemical analyses, and vibrational spectroscopy. In emission spectrometry studies in electromagnetic arc stabilization were carried out and special techniques for the analysis of cadmium fluoride crystals were developed.

REPORT NO: AFML-TR-71-282 AD 739 885  
ACCESS NO: 200, 482 January 1972  
TITLE: NMR SPECTRAL CHROMATOGRAPHY - A  
POWERFUL NEW TOOL FOR STRUCTURE  
DETERMINATION

AUTHOR: R. E. Rondeau  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: R. E. Rondeau (AFML/LPH), et al.  
AFML TASK NO: 736003

ABSTRACT: A new technique is described which radically simplifies complex nuclear magnetic resonance spectra and markedly increases their information content. Through the use of a unique chemical additive in a sample solution, overlapping spectral peaks are separated, coincidental resonances are dispersed, and the entire spectrum remarkably simplified as a result of induced spectral shifts. The additive is a fluorinated rare earth chelate,  $\text{Eu}(\text{fod})_3$ , which is believed to represent the optimum combination of lanthanide metal and organic ligand for use as a shift reagent. Its effect on an NMR spectrum is to "chromatography" it by causing spectral absorptions to move to different extents along the "spectral chromatogram".

REPORT NO: AFML-TR-72-6 AD 744 108  
ACCESS NO: 200, 473 January 1972  
TITLE: MOLECULAR STRUCTURES STUDIES AND  
OTHER RELATED RESEARCH

AUTHOR: B. L. Fox, et al.  
CONTRACT NO: F33615-69-C-1330  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: H. Marcus (AFML/LPH)  
AFML TASK NO: 736001

ABSTRACT: This report covers four separate work areas. Analyses of selected materials by microbeam probe x-rays was performed. Reference to eight publications and nine technical presentations are included. X-ray diffraction studies of another group of materials were performed. Ketoximes were found to undergo both photochemical rearrangement to amides and cleavage to nitriles. The latter process appears to be analogous to the Norrish Type I cleavage of ketones, and is favored by the presence of -substituents which are capable of stabilizing the intermediate radical. An NMR method for assigning ketoxime stereochemistry was developed in conjunction with the photochemical studies.

REPORT NO: AFML-TR-72-7 AD 739 877  
ACCESS NO: 200, 481 March 1972  
TITLE: EPITAXIAL FILM GROWTH OF BUBBLE  
DOMAIN MATERIALS

AUTHOR: D.M. Heinz, et al.  
CONTRACT NO: F33615-71-C-1055  
CONTRACTOR: North American Rockwell Corporation  
PROJECT MONITOR: H. Garrett (AFML/LPE)  
AFML TASK NO: 737103

ABSTRACT: This program's objective is to improve the compatibility between substrates and films of epitaxially grown magnetic bubble domain materials. The initial effort has been concerned with gallium substituted erbium iron garnet films prepared by chemical vapor deposition. The introductory section of this report contains a discussion of the means by which the requirements for the existence of cylindrical magnetic domains may be met in epitaxial films. The experimental section deals with film and substrate matching, garnet substrate crystal composition determinations, improvements in film deposition control and heat treatment of films. Techniques for characterizing magnetic bubble domain films are reviewed and properties of gallium-substituted erbium iron garnet films are discussed.

REPORT NO: AFML-TR-72-8 AD 741 847  
ACCESS NO: 200, 528 January 1972  
TITLE: MOLECULAR STRUCTURE AND MATERIALS  
CHARACTERIZATION

AUTHOR: W. R. Fearheller, Jr.  
CONTRACT NO: F33615-71-C-1132  
CONTRACTOR: Monsanto Research Corporation  
PROJECT MONITOR: F. F. Bentley (AFML/LP)  
AFML TASK NO: 736005

ABSTRACT: During the contract period research studies have been completed on (1) the infrared and Raman spectra of methyl esters, (2) the thermolytic dissociation of molecules by means of a pyrolysis GLC technique (3) methods to improve transducer assemblies for use in direct impingement ultrasonic nebulizers, and (4) structure and spectra of halogen-containing materials involving Group V Species. A review of the analytical support provided to the Air Force Materials Laboratory is also presented.

REPORT NO: AFML-TR-72-32 AD 746 032  
ACCESS NO: 200,662 June 1972  
TITLE: RESEARCH AND DEVELOPMENT OF YTTRIUM  
ALUMINATE LASERS

AUTHOR: M. J. Weber, et al.  
CONTRACT NO: F33615-71-C-1212  
CONTRACTOR: Raytheon Research Division  
PROJECT MONITOR: V. L. Donlan (AFML/LPL)  
AFML TASK NO: 737101

ABSTRACT: Yttrium orthoaluminate doped with rare earth ions is investigated for use as an optically-pumped laser material. Two laser ions are studied in detail: neodymium ( $\text{Nd}^{3+}$ ) and holmium ( $\text{Ho}^{3+}$ ) sensitized with erbium and thulium. Measurements of optical absorption and emission spectra, fluorescence kinetics, and stimulated emission cross sections are reported. Nd:YA103 laser rods oriented along the three principal crystallographic directions were tested in long-pulse, Q-switched, and cw operation. The laser outputs and efficiencies of Nd:YA103 are compared with those obtained from Nd:YAG in the same operating configuration. Ho:YA102 laser action is investigated at liquid nitrogen temperatures. Long-pulse and Q-switched laser performance is reported for three different rod orientations. To provide information for predicting laser action and performance of other rare-earth ions in YA103, experiments and calculations of radiative transition probabilities of nonradiative decay by multiphonon emission are presented. Sensitization of rare-earth ion fluorescence in YA103 by codoping with chromium to improve the optically pumping efficiency is also surveyed.

REPORT NO: AFML-TR-72-59 AD 749 135  
ACCESS NO: 68,307 April 1972  
TITLE: ROOM TEMPERATURE INJECTION LUMI-  
NESCEANCE IN II-VI SEMICONDUCTORS

AUTHOR: D. I. Kennedy, et al.  
CONTRACT NO: F33615-70-C-1107  
CONTRACTOR: Bowmar Canada Limited  
PROJECT MONITOR: P. M. Hemenger (AFML/LPE)  
AFML TASK NO: 736703

ABSTRACT: Experiments relating to the preparation of hetero-junction structures by the application of close-spaced epitaxial techniques to the vapor deposition of ZnSe films on compatible substrates were also conducted and the potential application of III-V - II-VI alloy crystals to this type of device evaluated. A method was developed to prepare hetero-structures by solution growth, of GaAs and ZnSe, GaP on ZnS, and GaP on SnSe. Limited metallurgical success was achieved but the electrical properties of these structures were not conducive to the development of injection luminescent device structures. Growth of wafers GaInP for application to heterojunction structures was investigated using similar solution growth methods. In the evaluation of the optical properties of heterojunction

ABSTRACT (Cont'd) structures, a high-resolution spectrograph was developed. This instrument was designed to mount on any standard microscope and was used in the determination of the optical absorption edge of areas less than  $10^{-8}$  cm<sup>2</sup>.

REPORT NO: AFML-TR-72-79 AD 753 415  
ACCESS NO: 200, 993 April 1972  
TITLE: EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS

AUTHOR: E. F. Olster, et al.  
CONTRACT NO: F33615-70-C-1570  
CONTRACTOR: Avco Corporation  
PROJECT MONITOR: G. H. Griffith (AFML/LPH)

AFML TASK NO: 736006  
ABSTRACT: The tolerance to ballistic impact of graphite/epoxy and boron/epoxy composites has been investigated. The effects of pre-load, of ply layups, and of projectile velocity have been determined for 30 caliber armor piercing projectiles striking the plate at a 0° obliquity. A limited number of tests were performed on glass/epoxy laminates and on type 6061-T6 aluminum panels. Several tests were conducted using 50 caliber armor piercing projectiles. High speed photography was used to determine the overall ballistic response, as an additional check on projectile velocity, and to determine when crack initiation occurred. The fracture toughness of each type of laminate was determined and both the residual strength (the nominal stress to which a panel which did not fail during perforation can be loaded) and the threshold strength (the lowest preimpact stress which results in failure upon impact) are shown to correlate directly with the toughness.

REPORT NO: AFML-TR-72-83 AD 744 496  
ACCESS NO: 200, 667 May 1972  
TITLE: A FLUORINE-19 NMR STUDY OF SOME FLUOROTITANIUM (IV) COMPLEXES. II.

AUTHOR: R. S. Borden  
CONTRACT NO: F33615-71-C-1197  
CONTRACTOR: Wittenberg University  
PROJECT MONITOR: Dr. D. S. Dyer (AFML/LP)

AFML TASK NO: 736702  
ABSTRACT: Systems involving methylal or TiI<sub>4</sub> gave poorly resolved spectra which apparently resulted from rapid ligand exchange rates for these systems. All other systems produced well resolved spectra which could be interpreted on the bases of pseudo-octahedral structures formed by redistribution processes. Structures involving neutral donor molecules trans to one another were not observed. Most of the possible complexes involving cis oriented donors were present but not in the amounts expected for a randomly ordered system. Structural

**ABSTRACT (Cont'd):** assignments as well as chemical shift and coupling constant data are presented for each observed complex. In the systems involving water, species containing hydroxyl groups could not be detected although hydrolysis was clearly indicated by the formation of a white precipitate. Water was found to be a strong donor capable of displacing either 1,2-dimethoxyethane or tetrahydrofuran to produce mixed donor or diaquo complexes.

**REPORT NO:** AFML-TR-72-99 AD 743 992  
**ACCESS NO:** 200,668 April 1972  
**TITLE:** RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT MAGNET MATERIALS

**AUTHOR:** A.E. Ray, et al.  
**CONTRACT NO:** F33615-70-C-1625  
**CONTRACTOR:** University of Dayton  
**PROJECT MONITOR:** D. Evans (AFML/LPE)  
**AFML TASK NO:** 737103  
**ABSTRACT:** Mixed intermetallic phases of the type  $R_2(Co_{1-x}Fe_x)_{17}$  with R=Ce, Pr, Nd, Sm, Y, and MM (Ce-rich mischmetal) are being studied as potential permanent magnet materials. Except for R = Nd, all show ranges of x in which the crystallographic c-axis is the easy axis of magnetization. These ranges have been more precisely defined and quantitative measurements of the saturation magnetization and crystal anisotropy constants initiated. It is concluded that some of these alloys are indeed promising candidate materials for improved rare earth-cobalt magnets. The composition dependence of selected metallurgical and magnetic properties of phases of the type  $Nd_{1-x}R_xCo_5$ , where R = Ce, Pr, Y are under investigation. Peritectic melting temperatures, lattice constants, Curie temperatures and saturation-magnetization measurements are reported. Single crystals of several of the mixed phases have been prepared and saturation magnetization and room-temperature anisotropy measurements on these have been initiated.

**REPORT NO:** AFML-TR-72-131 AD 902 880L  
**ACCESS NO:** 200,829 August 1972  
**TITLE:** SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS

**AUTHOR:** A. R. Hilton  
**CONTRACT NO:** F33615-71-C-1762  
**CONTRACTOR:** Texas Instruments Incorporated  
**PROJECT MONITOR:** Dr. G. E. Kuhl (AFML/LP)  
**PROJECT NO:** 317J  
**ABSTRACT:** The goal of this program was to grow thick, large-area plates of CdTe using a solution epitaxy method. Solution epitaxy was chosen as the method for growth in the belief that fast reaction rates could be obtained at lower temperatures than those used for

**ABSTRACT (Cont'd):** vapor growth. Operating at a temperature well below the wide existence region found for CdTe would reduce the trouble with impurities and lead to greater control of stoichiometry. Generally, solution epitaxy is a batch process used to grow thin layers. The process as used is rate-limited by diffusion of one constituent through the solution. Mechanical motion of the solution was used in an effort to overcome the batch-type nature of the process. Motion of the solution in the vicinity of the substrate led to extremely irregular layer growth along with spontaneous nucleation and growth of CdTe dendrites and platelets.

**REPORT NO:** AFML-TR-72-138 AD 903 430  
**ACCESS NO:** 69,388 June 1972  
**TITLE:** EPITAXIAL GROWTH AND CHARACTERIZATION OF GaAs ON SPINEL  
**AUTHOR:** C. C. Wang  
**CONTRACT NO:** F33615-70-C-1536  
**CONTRACTOR:** RCA Lab.  
**PROJECT MONITOR:** R. L. Hickmott (AFML/LPE)  
**AFML TASK NO:** 737102

**ABSTRACT:** Research on the epitaxial growth and characterization of GaAs on magnesium aluminate spinel was carried out. Single crystal GaAs films with electron and hole mobilities up to 4000 and 300  $\text{cm}^2/\text{V}\cdot\text{sec}$ , respectively, were successfully grown on spinel substrate using both vapor phase and liquid phase epitaxial techniques. The effect of growth conditions on the layer characteristics were studied in order to achieve optimization of the film properties. The epitaxial GaAs spinel composites were characterized by x-ray diffraction, electron diffraction, electron microscopy, and optical techniques. Information on the crystal-line perfection, epitaxial orientation relationships, surface structures, and optical constants was obtained. The growth of GaP,  $\text{GaAs}_x\text{P}_{1-x}$ , and  $\text{In}_x\text{Ga}_{1-x}\text{As}$  was also explored with encouraging results. Heteroepitaxial Zn-doped thin GaAs degenerate films were successfully grown on various substrates, and the composites are of potential importance for negative electron affinity devices.

**REPORT NO:** AFML-TR-72-140 AD 750 937  
**ACCESS NO:** 201,011 August 1972  
**TITLE:** A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING  $\text{CdF}_2$  WITH  $\text{Ce}^{3+}$  AND  $\text{Gd}^{3+}$  CODOPANTS  
**AUTHOR:** M. A. Bafico, et al.  
**CONTRACT NO:** F33615-71-C-1121  
**CONTRACTOR:** University of Dayton  
**PROJECT MONITOR:** V. L. Donlan (AFML/LPE)  
**AFML TASK NO:** 737101

**ABSTRACT:** Electrical measurements were made on insulating and semiconducting  $\text{Gd}^{3+}:\text{CdF}_2(\text{Ce}^{3+})$  samples. The gadolinium concentration was held at .02 mole percent while the cerium concentrations were .006, .02 and .06 mole percent. Samples were heated at  $520^\circ\text{C}$  in a Cd vapor for 30 minutes and quenched to room temperature. Various electrode metals were studied, including Ag, In, Hg-In alloy and Au. The techniques of applying these electrodes included vacuum deposition, thermal soldering and ultrasonic soldering. Thermal soldering of indium produced the most consistent results. Complex dielectric constants were measured over the frequency range of 50 Hz to 20 MHz. The large real dielectric constants found were attributed to a depletion layer formed within the sample. A voltage dependent capacitance was observed. Only one sample displayed a true metal-insulator-semiconductor (MIS) structure. Bulk resistivities were obtained using a pulse technique. A higher resistivity was found for each higher cerium concentration. Current models for the conversion process and trapping are examined in terms of these results.

REPORT NO: AFML-TR-72-141 AD 749 136  
ACCESS NO: 200,995 August 1972  
TITLE: MEASUREMENT AND ANALYSIS OF THE

FLUORESCENCE DECAY OF  $\text{Gd}^{3+}$  IN  $\text{SrF}_2$   
VERSUS THE CONCENTRATION OF  
CODOPANT  $\text{Ce}^{3+}$

AUTHOR: D.M. Schaeffer, et al.  
CONTRACT NO: F33615-69-C-1172  
CONTRACTOR: University of Dayton  
PROJECT MONITOR: Dr. V. L. Donlan (AFML/LPE)  
AFML TASK NO: 737101

**ABSTRACT:** The fluorescence lifetimes of the  ${}^6\text{P}_{7/2}$  state of  $\text{Gd}^{3+}$  in the assumed monoclinic (GCl) site and in the tetragonal ( $\text{C}_{4v}$ ) site of  $\text{SrF}_2$  for various concentrations of  $\text{Ce}^{3+}$  as a codopant have been studied. Of particular interest was the GCl site which has been shown to arise in the presence of the  $\text{Ce}^{3+}$  codopant. The excitation and decay modes of the two sites were analyzed in terms of the three-level model. Experimental techniques involved using the "boxcar integrator" coupled a logarithmic converter and an analog-to-digital data acquisition system. For the GCl site, strong  $\text{Ce}^{3+}$  5d band absorption at  $2500 \text{ \AA}$  with exchange transfer directly to the  ${}^6\text{P}_{7/2}$  state of  $\text{Gd}^{3+}$  was determined to be the most probable excitation and decay mode. The lifetime of the  ${}^6\text{P}_{7/2}$  to  ${}^8\text{S}_{7/2}$  transition was a constant  $8.8 \pm 0.4$  msec at  $77^\circ\text{K}$  over a  $\text{Ce}^{3+}$  concentration range of 0.001 to 1.0 mole percent with a fixed  $\text{Gd}^{3+}$  concentration of 0.1 mole percent.

REPORT NO: AFML-TR-72-153 AD 748 429  
ACCESS NO: 200,939 August 1972  
TITLE: MAGNETIC STRUCTURE DETERMINATION OF  
RARE EARTH-COBALT-IRON SYSTEMS,  
 $RFe_xCo_{5-x}$  BY NEUTRON DIFFRACTION  
AUTHOR: W. J. James  
CONTRACT NO: F33615-71-C-1332  
CONTRACTOR: University of Missouri-Rolla  
PROJECT MONITOR: Lt. R. D. Hutchens (AFML/LPE)  
AFML TASK NO: 736703

ABSTRACT: Hexagonal intermetallic compounds close to  $R_2M_{17}$  stoichiometry in the Lu-Fe, Th-Ni, Y-Ni, and Er-Co systems have been studied by single crystal x-ray techniques. Additional neutron diffraction studies were made of the Lu-Fe compound. The ideal  $Th_2Ni_{17}$ -type structure, as previously reported for these compounds, was found not to exist. Substitutions on all R rows parallel to the c-axis led to non-stoichiometric compositions, such as  $ThNi_{9.5}$ . The thermal variation of lattice parameters of rare earth-transition metal intermetallic compounds rich in Fe, Co, or Ni in the temperature range 25-900°K was studied. Negative thermal expansion is observed for the iron compounds below their magnetic ordering temperature.

REPORT NO: AFML-TR-72-167 AD 754 958  
ACCESS NO: 201,101 August 1972  
TITLE: EPITAXIAL FILM GROWTH OF BUBBLE  
DOMAIN MATERIALS  
AUTHOR: D. M. Heinz, et al.  
CONTRACT NO: F33615-71-C-1055  
CONTRACTOR: North American Rockwell Corporation  
PROJECT MONITOR: H. Garrett (AFML/LPE)  
AFML TASK NO: 737102

ABSTRACT: This program's objective is to improve the compatibility between substrates and films of epitaxially grown magnetic bubble domain materials. The introductory section of this report contains a discussion of the means by which the requirements for the existence of cylindrical magnetic domains may be met in epitaxial films grown by chemical vapor deposition. The experimental section deals with substrate crystal growth and wafer preparation; chemical vapor deposition and heat treatment of epitaxial films. Techniques for characterizing magnetic bubble domain films are reviewed and properties of gallium-substituted erbium iron garnet films are discussed. Preparation and properties of polycrystalline ceramic samples of substituted ytterbium iron garnet are presented.

REPORT NO: AFML-TR-72-177 AD 753 068  
ACCESS NO: 201,013 July 1972  
TITLE: R AND D ON THE APPLICATION OF POLY-  
CRYSTALLINE ZINC SELENIDE AND CADMIUM  
TELLURIDE TO HIGH ENERGY IR LASER  
WINDOWS

AUTHOR: M. W. Benecke, et al.  
CONTRACT NO: F33615-71-C-1863  
CONTRACTOR: Coors Porcelain Company  
PROJECT MONITOR: J. R. Fenter (AFML/LPL)  
PROJECT NO: 317-J

ABSTRACT: The optical absorption of previously available polycrystalline zinc selenide and cadmium telluride was too extensive to permit the use of these materials in high energy laser windows. The approach used in the program was to make polycrystalline windows by hot-pressing under optimum conditions, making use of starting materials of ordinary purity and stoichiometry which were currently available on a commercial basis. Many ZnSe pressings and a few CdTe pressings were made which possessed essentially theoretical transmittance. Absorption coefficients as low as  $0.023 \text{ cm}^{-1}$  and  $0.33 \text{ cm}^{-1}$  were obtained in ZnSe pressings and CdTe respectively. ZnSe powder from Merck Inc. refined at Coors and CdTe ingots prepared by II-VI, Inc., were the best starting materials. Absorption at  $9 \text{ m}$  was a persistent problem in both materials. Although extensive analytical testing was carried out and optical transmission and electrical measurements were made as appropriate, the mechanisms responsible for the absorption were not fully explained.

REPORT NO: AFML-TR-189 AD 751 545  
ACCESS NO: 201,014 September 1972  
TITLE: DEVELOPMENT ON PROCESS FOR PRODUCING  
CONTINUOUS FINE DIAMETER FILAMENTS OF  
SUPERCONDUCTORS

AUTHOR: J. Economy, et al.  
CONTRACT NO: F33615-71-C-1709  
CONTRACTOR: The Carborundum Company  
PROJECT MONITOR: Dr. M. C. Ohmer (AFML/LPE)  
AFML TASK NO: 737103

ABSTRACT: A process to produce the continuous niobium carbonitride filament yarn from both carbon and boron nitride precursors was developed. The process involved converting chemically the precursor yarns into niobium carbonitrides with niobium pentachloride in the presence of hydrogen and nitrogen. The superconductive filament yarns produced were characterized by their superconducting and mechanical properties and their surface structures. Critical temperatures up to 19 K were observed for the superconductive filaments made by this method. The

ABSTRACT (Cont'd): critical currents of some of the filaments were determined to be  $0.4-1.0 \times 10^5$  amp/cm<sup>2</sup> in zero field. Procedures to prepare filaments with high flexibility and strength were also developed.

REPORT NO: AFML-TR-72-202 AD 750 746  
ACCESS NO: 201, 015 August 1972  
TITLE: RESEARCH AND DEVELOPMENT OF RARE  
EARTH-TRANSITION METAL ALLOYS AS  
PERMANENT-MAGNET MATERIALS  
AUTHOR: A. E. Ray, et al.  
CONTRACT NO: F33615-70-C-1625  
CONTRACTOR: University of Dayton  
PROJECT MONITOR: D. Evans (AFML/LPE)  
AFML TASK NO: 737103

ABSTRACT: The results of thermomagnetic analyses of the  $R_2(\text{Co}_{1-x}\text{Fe}_x)_{17}$  phases with  $R = \text{Ce}, \text{Pr}, \text{Sm}, \text{Y}$ , and MM above room temperature are reported, as well as the results of room temperature saturation magnetization for the phases with  $R = \text{Ce}, \text{Pr}, \text{Nd}, \text{Sm}, \text{and Y}$ . The magnetic transitions observed above the Curie points of the more iron-rich 2-17 phases in the alloys with  $R = \text{Ce}, \text{Sm}, \text{and MM}$  are believed due to the instability of the ternary phases in certain temperature and composition ranges. The room temperatures saturation rise with increasing iron content throughout the easy c-axis composition ranges. The magnitude of the magnetocrystalline anisotropy has been measured on a large number of magnetically aligned powder specimens for the ternary phases with  $R = \text{Ce}, \text{Pr}, \text{Sm}, \text{Y}, \text{and MM}$ . The largest anisotropy is found in the system with  $R = \text{Sm}$ .

REPORT NO: AFML-TR-72-208 AD 904 714L  
ACCESS NO: 201, 098 September 1972  
TITLE: SONIC CASTING OF CdTe FOR HIGH POWER  
IR LASER WINDOWS  
AUTHOR: B. Siegel, et al.  
CONTRACT NO: F33615-71-C-1770  
CONTRACTOR: Tyco Lab., Inc.  
PROJECT MONITOR: Dr. G. E. Kuhl (AFML/LPL)  
PROJECT NO: 317J

ABSTRACT: This report describes the results of an exploratory development program whose primary objective was to demonstrate the feasibility of sonically casting CdTe windows for application in high energy CO<sub>2</sub> laser systems. Initially, the program was to be of eight months duration, but was extended for an additional five months. Within the course of this study effort, equipment was designed, procured, and built, resulting in the capability to vibrate the molten CdTe charge while simultaneously affecting a directional solidification. Initial program goals emphasized the dual material requirements of extremely low optical absorption coefficients at 10.6 (less than .001/cm) and the attainment of

**ABSTRACT (Cont'd):** fine grain sizes to maximize strength. The rationale and methodology used to achieve the goals is described. During the course of the program, the grain size goal was deemphasized and the bulk of the effort was directed toward lowering the absorption at 10.6 .

**REPORT NO:** AFML-TR-72-225 AD 754 951  
**ACCESS NO:** 201,155 September 1972  
**TITLE:** MATERIALS PROCESSING OF RARE EARTH-COBALT PERMANENT MAGNETS  
**AUTHOR:** P.J. Jorgensen, et al.  
**CONTRACT NO:** F33615-70-C-1624  
**CONTRACTOR:** Stanford Research Institute  
**PROJECT MONITOR:** H. Garrett (AFML/LPE)  
**AFML TASK NO:** 737103

**ABSTRACT:** The initial sintering kinetics of stoichiometric  $\text{SmCo}_5$  powder containing a samarium-rich sintering addition (60% Sm plus 40wt% Co) have been investigated as a function of amount of liquid phase, time, temperature, and particle size. The shrinkage as a function of time exhibits the classical three stages of liquid-phase sintering, i. e., rearrangement, solution-precipitation, and solid phase. The rate-controlling step during the solution-precipitation stage corresponds to a phase boundary (solid/liquid) reaction leading to dissolution. Evidence for this conclusion is partially based on the logarithm shrinkage-logarithm time slopes being equal to 1/2 instead of 1/3. A 1/3 slope is predicted by the liquid diffusion-controlled sintering model while the phase boundary sintering model predicts a slope of 1/2. An activation energy of 52.8 kcal/mole was obtained for the temperature dependence, and this also suggests a phase boundary reaction rather than rate control by diffusion in the liquid phase.

**REPORT NO:** AFML-TR-72-227 AD 753 713  
**ACCESS NO:** 69,988 December 1972  
**TITLE:** VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER  
**AUTHOR:** T. A. Milne, et al.  
**CONTRACT NO:** F33615-71-C-1577  
**CONTRACTOR:** Midwest Research Institute  
**PROJECT MONITOR:** P. Dimiduk (AFML/LPH)  
**AFML TASK NO:** 736001

**ABSTRACT:** A brief review of current studies of the vaporization of graphite is presented, followed by a detailed description of our own work. Apparatus improvements are described, which allow heating of all-graphite Knudsen cells to about 3300<sup>o</sup>K in vacuum without significant heating of beam system walls or objectionable outgassing. A continuously operating vacuum viewport and automatic pyrometer system is

**ABSTRACT (Cont'd):** described for temperature monitoring under rapid window darkening vaporization conditions. Preliminary equilibrium ion ratio measurements are presented for the species C<sub>1</sub>-C<sub>7</sub> at temperatures up to 3300°K. Extensive experimental results are presented on the neutral time-of-flight behavior of both carbon and low temperature gaseous species, using both the Nuclide and the Bendix mass spectrometers.

**REPORT NO:** AFML-TR-72-258 AD 905 752L  
**ACCESS NO:** 201, 158 November 1972  
**TITLE:** MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS  
**AUTHOR:** A. L. Gentile, et al.  
**CONTRACT NO:** F33615-71-C-1778  
**CONTRACTOR:** Hughes Research Laboratories  
**PROJECT MONITOR:** G. E. Kuhl (AFML/LP)  
**AFML TASK NO:**

**ABSTRACT:** This program was undertaken to study the feasibility of CdTe for use as a high-power infrared laser window. Although the study began with single crystal CdTe, the mechanical properties of the material indicated that a significant gain in yield strength could be achieved with a polycrystalline body with no apparent loss in optical absorption at 10.6  $\mu$ m. This investigation involved preparation of polycrystalline CdTe as 5 cm diameter ingots by the Modified Bridgman Technique. During the course of this program, polycrystal ingots were grown weighing nearly 1 Kilogram. The modulus of rupture of single crystal CdTe was found to be in excess of 3000 psi, a value much larger than reported up to that time in the literature. A thermal annealing process was established which reproducibly yields low absorption material and is applicable to ingots grown under a variety of conditions. The study led to the fabrication of 5 cm diameter CdTe disks having measured absorption coefficients as low as 0.00089  $\text{cm}^{-1}$  and typically less than 0.002  $\text{cm}^{-1}$ .

MANUFACTURING TECHNOLOGY DIVISION (AFML/LT)

REPORT NO: AFML-TR-71-222 AD 751 531  
ACCESS NO: 67, 933 October 1971  
TITLE: DEVELOPMENT OF A MANUFACTURING METHOD  
FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL  
COMPONENTS OF TITANIUM BY HIGH-FREQUENCY  
RESISTANCE WELDING

AUTHOR: F. A. DeSaw, et al.  
CONTRACT NO: F33615-70-C-1416  
CONTRACTOR: Battelle Memorial Institute  
PROJECT MONITOR: F. R. Miller (AFML/LTN)  
PROJECT NO: 817-9

ABSTRACT: In a previous Air Force program, methods were developed for fabricating titanium tee shapes by high-frequency resistance welding. In the current program, these methods were refined and butt sections and tee sections were fabricated from 0.050, 0.090, and 0.125 inch-thick Ti-6Al-4V strips. The fabrication of multiple-stiffened sections also was demonstrated to be feasible. The tee sections were machined after welding to form fillets of various radii between the stem and flange of the tee section. The static and fatigue properties of the butt and tee sections were evaluated and compared with extruded Ti-6Al-4V tee sections and 7075-T6511 aluminum tee sections. The static and fatigue properties of the welded sections were comparable to those of the Ti-6Al-4V base metal or extruded sections.

REPORT NO: AFML-TR-71-243 AD 892 253L  
ACCESS NO: 200, 424 December 1971  
TITLE: MANUFACTURING METHODS FOR ASSOCIATIVE  
PROCESSOR MEMORY MODULES

AUTHOR: W. S. Tuma  
CONTRACT NO: F33615-70-C-1294  
CONTRACTOR: Goodyear Aerospace Corporation  
PROJECT MONITOR: J. Garrett (AFML/LTE)  
PROJECT NO: 500-0

ABSTRACT: The objective of this program was to advance manufacturing processes and techniques applicable to the production of associative processor (AP) memory modules utilizing plated-wire storage elements for use in mission-oriented associative processors to be used in future Air Force systems. The material covered in this report represents the results of an 18 month effort consisting of design, manufacturing methods, fabrication, and testing. A large segment of this report is devoted to the memory array electronics: wire drivers, strap drivers, response store, and interface logic. Design characteristics, circuit schematics, evaluation results, and photographs of printed circuit board

**ABSTRACT (Cont'd):** assemblies are presented. A section of the report is devoted to the design, construction, and utilization of a fully automated, programmable plated-wire array tester. Electronic design of drivers, sense amp-discriminator circuits, control logic, circuit schematics, hardware and waveform photographs, and a pulse test sequence diagram for the tester are included. The final section summarizes results and conclusions obtained from the work performed on the project.

**REPORT NO:** AFML-TR-71-258 AD 893 765 L  
**ACCESS NO:** 68, 517 April 1972  
**TITLE:** MANUFACTURING METHODS FOR SURFACE INTEGRITY OF MACHINED STRUCTURAL COMPONENTS

**AUTHOR:** W. P. Koster  
**CONTRACT NO:** F33615-70-C-1589  
**CONTRACTOR:** Metcut Research Associates Inc.  
**PROJECT MONITOR:** Capt. R. H. Coe, Jr. (AFML/LTN)  
**PROJECT NO:** 721-0

**ABSTRACT:** A surface integrity evaluation of several iron, titanium and nickel base structural alloys has been completed. Materials investigated include AISI 4340, 4340 Modified, Grade 300 Maraging Steel, Ti-6Al-4V, Ti-6Al-6V-2Sn, Ti-6Al-2Sn-4Zr-2Mo, Inconel 718, AF 95, AF2-1DA, and Rene' 80. For the most part, these alloys were quenched and tempered or solution treated and aged, as appropriate, to put them into the high strength condition typically used for structural purposes. Various grinding procedures caused the largest variation in surface integrity response. Fatigue strengths associated with gentle versus abusive grinding for Ti-6Al-6V-2Sn were 68 versus 10 ksi. Nickel alloys also showed large variations such as 70 versus 20 ksi in the case of gentle versus abusive grinding applied to AF2-1DA.

**REPORT NO:** AFML-TR-71-284 AD 752 555  
**ACCESS NO:** 200, 625 March 1972  
**TITLE:** ABRASION RESISTANCE OF POLYBENZIMIDAZOLE FIBROUS MATERIALS

**AUTHOR:** P. M. Williamson  
**CONTRACT NO:**  
**CONTRACTOR:** INTERNAL  
**PROJECT MONITOR:**  
**PROJECT NO:**

**ABSTRACT:** An improved method of evaluating in the laboratory the simulated wear resistance of both monofilaments and staple yarns is described. Wear resistance is measured as a fraction of strength retained after abrasion against a solid polybenzimidazole bar. The coefficients of variations in wear resistance findings are shown to be compatible with the coefficients of variation in tensile strength data of unabraded control specimens.

REPORT NO: AFML-TR-72-13 AD 745 571  
ACCESS NO: 67, 291 May 1972  
TITLE: MANUFACTURING METHODS FOR HIGH  
PERFORMANCE GRAFTED-POLYETHYLENE  
BATTERY SEPARATORS

AUTHOR: V. D'Agostino, et al.  
CONTRACT NO: F33615-70-C-1193  
CONTRACTOR: R. A. I. Research Corporation  
PROJECT MONITOR: C. Tanis (AFML/LTN)  
PROJECT NO: 396-0

ABSTRACT: The purpose of this program was to develop manufacturing methods, controls equipment, quality controls parameters and processes expressly directed toward the efficient generation of reliable, low cost grated polyethylene separator film for high-performance aircraft alkaline type batteries. To accomplish the above, the program was divided into nine separate tasks. The separation of the manufacturing process into distinct tasks was an outgrowth of a previous development contract wherein the salient steps in the process to prepare the grated membrane were established on a limited scale. Before discussing in detail the establishment of the manufacturing methods the basic procedure for preparing the grafted membrane is outlined to permit an understanding of the sequence necessary to prepare the separator.

REPORT NO: AFML-TR-72-43 AD 894 156L  
ACCESS NO: 46, 253 April 1972  
TITLE: MANUFACTURE OF JET ENGINE THRUST  
BEARINGS BY AUSFORMING

AUTHOR: E. N. Bamberger  
CONTRACT NO: AF 33(615)-1723  
CONTRACTOR: General Electric Company  
PROJECT MONITOR: G. W. Trickett (AFML/LTM)  
PROJECT NO: 127-7

ABSTRACT: Components for medium and large size main shaft jet engine bearings have been manufactured by thermomechanical processing (ausforming) and tested in full-scale bearing tests. A life improvement of about 3 1/2 times has been demonstrated for 75mm bore ball bearings having ausformed inner rings and balls when compared to bearings with standard processed components. The 75mm ausformed rings were produced by high energy rate extrusion, whereas the balls were machined from bar stock thermomechanically worked by standard extrusion processes. Large size bearings (210mm bore), having ausformed inner rings and balls, failed to achieve the expected life improvement. The major problem with the latter is believed to be the variability of the ring rolling process used to produce the inner rings. The large (1.62-inch) diameter balls, made by triaxial redundant working, performed satisfactorily.

REPORT NO: AFML-TR-72-45 (Vol. I) AD 901 874L  
ACCESS NO: 68, 500 July 1972  
TITLE: MANUFACTURING METHODS FOR MERCURY-  
DOPED GERMANIUM INFRARED DETECTOR  
ARRAYS

AUTHOR: W. G. Rae, et al.  
CONTRACT NO: F33615-70-C-1400  
CONTRACTOR: Texas Instruments Incorporated  
PROJECT MONITOR: Lt. T. A. Boynton (AFML/LTE)  
PROJECT NO: 503-9

ABSTRACT: Existing fabrication processes have been improved; new manufacturing methods have been investigated and introduced into the fabrication procedure for multielement mercury-doped germanium arrays. A multimetal electrode structure has been introduced which has allowed the soldering of the larger mercury-doped germanium sliced to the degenerate germanium substrate. Reduction in the value of the  $DBB$  between large inter-electrode spacing and small inter-electrode spacing has been identified as due to a reduction in "effective" quantum efficiency. This effect is very sensitive to the contacting procedure. A realistic production capability has been established. Detector subarrays were tested, utilizing the Automatic Data Acquisition System and the Master Data Reduction System. A procedure has been established. Improved performance of detector elements has been demonstrated, using indium arsenide emitters, noise versus frequency spectra, scanned CW carbon-dioxide laser, and finally, a Q-switched carbon-dioxide laser. Production yields have been analyzed to give an estimated selling price of \$1, 275.00 per subarray.

REPORT NO: AFML-TR-72-49 AD 901 523L  
ACCESS NO: 200, 678 March 1972  
TITLE: LASER WELDING PRECISION MINIATURE  
ASSEMBLIES

AUTHOR: D. Kloepper  
CONTRACT NO: F33615-71-C-1554  
CONTRACTOR: Grumman Aerospace Corporation  
PROJECT MONITOR: F. Miller (AFML/LTM)  
PROJECT NO: 835-1

ABSTRACT: The program objective was to demonstrate laser welding capabilities by fabricating precision miniature null-point calorimeter slugs to be used and/or evaluated by the Air Force Materials Laboratory. Such devices have wide use in measuring heat transfer in high pressure arc heater facilities. The state-of-the-art of null-point calorimeter fabrication and laser welding is reviewed. Parameters for welding 0.0005- to 0.002-inch-diameter chromel/alumel thermocouple wires to thin copper sheets were optimized using appropriate fixturing. 1/16-inch-diameter OFHC copper slugs were drilled with 0.021-inch-diameter flat-bottom holes to extreme tolerances. Ultraminiature sheathed thermocouple assemblies with 0.0008-inch-diameter wires were laser welded to the

**ABSTRACT (Cont'd):** interior of the slug cavity by a melt-through technique. Eight finished calorimeter slugs were delivered to AFML. Advantages of the progress include ease of fabrication, strength and reliability of joint, and cost savings.

**REPORT NO:** AFML-TR-72-53 AD 894 543L  
**ACCESS NO:** 200,627 May 1972  
**TITLE:** MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS

**AUTHOR:** R. D. Nevala, et al.  
**CONTRACT NO:** F33615-70-C-1001  
**CONTRACTOR:** Fairchild Semiconductor Project  
**PROJECT MONITOR:** M. Bailer (AFML/LTE)  
**PROJECT NO:** 500-9

**ABSTRACT:** This report describes the manufacturing and design techniques used to produce BIPOLAR MICROMOSAIC TM Large Scale Integrated (LSI) Circuit Arrays of 100-gate complexity. Major efforts described are concentrated in two areas: circuit design using Computer-aided Design (CAD) techniques and the present processing approach for multilayer interconnects. The BIPOLAR MICROMOSAIC TM design technique has been demonstrated to be an effective tool for producing 100-gate complexity circuits. Such features as computer-aided design for circuit simulation, verification, and CRT layout are demonstrated and are necessary to provide fast, accurate, turn-around time in the design phase. The establishment of a cell library is Key to the Mosaic approach. To ensure logic and design accuracy of each cell, extensive characterization was carried out on Performance Characterization Arrays containing individual cells whose inputs and outputs were available for analysis.

**REPORT NO:** AFML-TR-72-54 AD 893 979L  
**ACCESS NO:** 66,665 May 1972  
**TITLE:** ESTABLISHMENT OF A MANUFACTURING PROCESS FOR INFRARED GLASS WINDOWS

**AUTHOR:** H. C. Hafner  
**CONTRACT NO:** F33615-69-C-1861  
**CONTRACTOR:** Texas Instruments, Inc.  
**PROJECT MONITOR:** L. Kopell (AFML/LTM)  
**PROJECT NO:** 484-9

**ABSTRACT:** A production process was established for manufacturing infrared transmitting windows from a chalcogenide glass having the composition  $\text{Ge}_{33}\text{Se}_{55}\text{As}_{12}$ , Texas Instruments No. 20 glass. A kettle-type reactor capable of reacting 50 pounds of glass in one charge was developed. A casting facility was modified to produce window blanks of the No. 20 glass up to 15.5 x 26.5 x 0.50 inch. Material purification equipment was designed, built, installed, and operated. Conventional optical

ABSTRACT (Cont'd): finishing and antireflection coating techniques for chalcogenide glasses were adapted to the large windows. Thermal tempering capability was expanded to window sizes up to 12 x 24 x 0.5 inch from a 5 x 7 x 0.375-inch size.

REPORT NO: AFML-TR-72-63 AD 894 540L  
ACCESS NO: 200,628 April 1972  
TITLE: FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB  
AUTHOR: B. P. W. Stocker  
CONTRACT NO: F33615-70-C-1327  
CONTRACTOR: Sikorsky Aircraft  
PROJECT MONITOR: G. W. Trickett (AFML/LTM)  
PROJECT NO: 227-9

ABSTRACT: Under contract with the Air Force Materials Laboratory, Sikorsky Aircraft fatigue tested the first large full-scale aircraft structure fabricated of diffusion bonded titanium. This program was very successful in providing evidence of the potential of the diffusion bonding process for large-scale dynamically-loaded titanium structures. The modes of fracture were identical, and the fatigue strength was equal to that previously obtained for a forged structure. Material specimen fatigue tests showed uniform fatigue strength throughout the bonded structure. The candidate structure selected for the program was the rotor hub for the Sikorsky H-53 series helicopter. This hub was the largest titanium aircraft forging in existence, 4.5 in flight is subjected to multi-directional loading, including large vibratory and steady loads.

REPORT NO: AFML-TR-72-77 AD 755 831  
ACCESS NO: 201,145 May 1972  
TITLE: USAF APPLICATIONS OF LIQUID CRYSTAL MATERIALS  
AUTHOR: R. A. Champa  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR:

AFML TASK NO: 736003  
ABSTRACT: The current state-of-the-art in liquid crystals (LC) as electronic, electro-optic and diagnostic materials is examined with emphasis on unique properties and applications to USAF systems. Research in basic physical organic chemistry is suggested to fill gaps in the current knowledge of LCs which have limited their use in the above applications. A point-of-contact list of both DOD and non-government personnel involved in LC research is given together with a short description of the individual work effort.

REPORT NO: AFML-TR-72-81 AD 902 834L  
ACCESS NO: 200, 831 July 1972  
TITLE: MANUFACTURING METHODS FOR SILICON  
SOLAR CELLS WITH INTEGRAL COVERSLEIPS  
AUTHOR: H. Somberg, et al.  
CONTRACT NO: F33615-70-C-1619  
CONTRACTOR: Textron Inc.  
PROJECT MONITOR: M. Bailer (AFML/LTE)  
PROJECT NO: 504-0  
ABSTRACT: A pilot production line employing both an 18 and 42 inch diameter vacuum system was run producing 1600 cells with integral covers up to  $150\mu$  M thickness. Cells with  $50\mu$  M covers yielded ~ 10 percent average efficiency under AMO,  $28^{\circ}\text{C}$ , conditions while  $100\mu$  M covers showed greater than 9 percent efficiency. These cells successfully passed typical space type thermal cycling and high temperature storage tests. The integral cover demonstrated behavior at least equivalent to conventional fused silica covers when subjected to 1 MeV electrons and ultraviolet radiation. Electron beam evaporation techniques were used to rapidly deposit up to  $150\mu$  M thick integral covers. The aluminosilicate glass source material yielded highly transparent ( $> 90$  percent transmission) covers provided the glass was premelted to remove volatile materials and then deposited with a background oxygen pressure of  $\sim 5 \times 10^{-5}$  torr.

REPORT NO: AFML-TR-72-86 AD 901 796L  
ACCESS NO: 67, 370 June 1972  
TITLE: DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS  
AUTHOR: J. V. Peck  
CONTRACT NO: F33615-70-C-1084  
CONTRACTOR: United Aircraft Corporation  
PROJECT MONITOR: J. R. Williamson (AFML/LTM)  
PROJECT NO: 483-9  
ABSTRACT: This program was undertaken to develop a low cost manufacturing process for applying a duplex Cr/Al coating to TD Nickel based on existing coating technology. Several methods of depositing chromium and aluminum were evaluated. These included electroplating, slurry processes, and atmosphere pack. The atmospheric pack cementation process was selected as being the most economical and reliable means of depositing the duplex Cr/Al coating. Other methods such as occluded particle electroplating to deposit a chromium-nickel solid solution layer exhibited considerable promise but required developmental effort outside the scope of this program. Procedures were developed for producing the duplex coating by atmospheric pack cementation on a scale-up production

**ABSTRACT (Cont'd):** basis. The atmospheric pack process could repeatedly produce the desired level of chromium and aluminum. The performance of the atmospheric pack coating was generally comparable to existing commercial coatings but somewhat less than the performance of its vacuum pack predecessor developed by DuPont.

**REPORT NO:** AFML-TR-72-88 AD 901 591L  
**ACCESS NO:** 200,696 July 1972  
**TITLE:** MANUFACTURING PROCESS FOR MOLDED CELL/R/V HEAT SHIELD

**AUTHOR:** W. Bradley, et al.  
**CONTRACT NO:** F33615-72-C-1151  
**CONTRACTOR:** Aerojet Liquid Rocket Company  
**PROJECT MONITOR:** Lt. L. J. Peters, III (AFML/LTN)  
**PROJECT NO:** 399-1

**ABSTRACT:** Intremold III is a three-directional fiber-reinforced composite structure which was conceived and developed by Aerojet-General Corporation. In its cylindrical form, the composite is made of radially oriented cell filler rods supported by filament-wound cell walls. The material can be tailored to fit a wide range of applications by proper selection of materials and structural geometry. The production of Intremold III composites originally required a large amount of hand labor, resulting in a relatively low production rate and high labor costs. A recent program sponsored by AFML had the objective of automating two major steps in the manufacturing process, namely the molding of the radial cell filler rods and the layup of the rods into a cylindrical array suitably for filament winding. A porcupine demonstration cylinder was fabricated as part of the evaluation of the new molding and lay-up facility.

**REPORT NO:** AFML-TR-72-89 AD 745 991  
**ACCESS NO:** 68,041 June 1972  
**TITLE:** EFFECTIVE TOOLING DESIGNS FOR PRODUCTION OF PRECISION FORGINGS

**AUTHOR:** J. R. Becker, et al.  
**CONTRACT NO:** F33615-70-C-1437  
**CONTRACTOR:** Battelle Columbus Laboratories  
**PROJECT MONITOR:** N. E. Klarquist (AFML/LTM)  
**PROJECT NO:** 128-0

**ABSTRACT:** This program was directed toward making available to the aerospace forging industry improved tooling concepts that will permit the forging of high-strength steels and nickel-base superalloys to precision configurations without premature failure of the dies. In previous work in precision forging broken dies often have resulted primarily because standard hot-forging die-design practices were used, i. e., the dies were usually manufactured from one-piece die blocks. The aim of this two-phase program is to demonstrate that nonsymmetric rib and web type configurations can be hot forged to precision dimensions with

**ABSTRACT (Cont'd):** better die life through the use of interference fitted reinforcing components surrounding the die inserts.

**REPORT NO:** AFML-TR-72-98 AD 902 292L  
**ACCESS NO:** 68, 210 May 1972  
**TITLE:** MANUFACTURING METHODS PROGRAM 100 KW,  
KU-BAND POWER AMPLIFIER OPERATING  
INSTRUCTIONS

**AUTHOR:** J. P. Vaszari  
**CONTRACT NO:** F33615-70-C-1384  
**CONTRACTOR:** Hughes Aircraft Company  
**PROJECT MONITOR:** J. I. Meulemans (AFML/LTE)  
**PROJECT NO:** 613-0

**ABSTRACT:** The primary objectives of this program were the development of the manufacturing techniques, controls, and processes of a 100 kW Ku-band amplifier necessary for a production capability of 50 tubes per month. The 838H is a PPM focused, grid controlled, coupled cavity traveling-wave tube. In order to achieve the 838H program's objectives, the program was divided into six phases. During Phase I of the program, a design study was undertaken, and as a result of this design study, a complete preliminary electrical and mechanical design for the 838H was developed, and a detailed production development plan was generated. The major effort during Phase II was implemented of the mechanical and electrical designs. This was accomplished through an experimental fabrication and evaluation program during which two tubes were constructed and tested.

**REPORT NO:** AFML-TR-72-116 AD 906 873L  
**ACCESS NO:** 66, 749 July 1972  
**TITLE:** A MANUFACTURING PROCESS FOR TD COBALT  
NICKEL CHROMIUM SHEET

**AUTHOR:** W. J. Barnett, et al.  
**CONTRACT NO:** F33615-69-C-1876  
**CONTRACTOR:** Fansteel Inc.  
**PROJECT MONITOR:** N. E. Klarquist (AFML/LTM)  
**PROJECT NO:** 200-9

**ABSTRACT:** The original process study was broadened to include three alloy compositions; the original Co-20%Ni-18%Cr-2%ThO<sub>2</sub> and the additional alloys, Co-20%Ni-18%Cr-4%ThO<sub>2</sub> and Co-20%Ni-30%Cr-2%ThO<sub>2</sub>. Definitive processes were established to produce sheet of the three alloys. The original alloy Co-20Ni-18Cr-2ThO<sub>2</sub> was produced in three gauges; 0.020" and 0.050" in sheet sizes of 20" x 48" and 0.075" in a sheet size of 24" x 48". The added alloys were produced only in the two thinner gauges. The width and length goals were met for all alloys and gauges. Process yields of approximately 25% were realized permitting the production of sheet in excess of the goal quantities.

REPORT NO: AFML-TR-72-120 AD 902 943L  
ACCESS NO: 68,553 July 1972  
TITLE: INCREMENTAL STRETCH FORMING  
AUTHOR: T. Renshaw  
CONTRACT NO: F33615-70-C-1522  
CONTRACTOR: Fairchild Industries, Incorporated  
PROJECT MONITOR: J. Williamson (AFML/LTM)  
PROJECT NO: 784-0  
ABSTRACT: The incremental stretch forming concept involves the forming of large titanium aircraft panels to compound curvatures by applying tension to their long direction and traversing a heat source along them while they are strained over a die. The method has inherent economic advantages over alternative forming methods. The objective of this program was to determine the suitability of the method on actual aircraft panels and to define the limits of panel complexity for which it is applicable. Because early feasibility work had shown that contour deviations in the nature of buckles and excessive curvature would commonly result, it was necessary to focus attention on process control parameters by analytical studies before conducting the design and construction of ISF equipment. The model was also the basis for the selection of process control conditions and the development of a forming plan that would make maximum use of the limited number of panels available.

REPORT NO: AFML-TR-72-156 AD 904 032L  
ACCESS NO: 66,918 August 1972  
TITLE: ADAPTATION OF THE CONVEX DRAW DIE TO  
THE PRODUCTION OF AIRCRAFT  
ENGINE RINGS

AUTHOR: J. R. Douglas  
CONTRACT NO: F33615-70-C-1139  
CONTRACTOR: Battelle Memorial Institute  
PROJECT MONITOR: T. S. Felker (AFML/LTM)  
PROJECT NO: 251-9  
ABSTRACT: This manufacturing methods program was aimed at establishing the feasibility of using a convex draw die to fabricate jet engine rings to net dimensions. After a study of several design concepts, a ring forming machine was designed, built, and used in conjunction with a curved convex draw die in studies with rolled and welded T-shaped rings of 7075 aluminum alloy. The studies showed that a T-shaped ring could be drawn through the convex draw die to achieve close dimensional control and good surface finish on the fabricated ring. The results suggest that this new ring forming technique should be applicable to fabricating high-strength materials for actual engine ring investigations of this new technique for fabricating engine rings would be required to establish this method as a viable production process.

REPORT NO: AFML-TR-72-168 AD 905 524  
ACCESS NO: 67,999 July 1972  
TITLE: INDUCTION MELTING AND CASTING OF  
TITANIUM ALLOY AIRCRAFT COMPONENTS

AUTHOR: T. S. Piwonka, et al.  
CONTRACT NO: F33615-70-C-1409  
CONTRACTOR: TRW Inc.  
PROJECT MONITOR: K. L. Love (AFML/LTM)  
PROJECT NO: 164-0

ABSTRACT: Induction melting of titanium alloys using a semi-levitation technique and bottom pouring in a graphite crucible was evaluated for four titanium alloys, Ti-6Al-4V, Ti-6Al-2Sn-4Zr-2Mo, Ti-3Al-8V-6Cr-4Mo-4Zr (Beta C), and Ti-11Mo-4.5Sn-6Zr (Beta III). Precision investment (lost wax) casting molds coated with pyrolytic graphite were used with the melting technique to make castability, tensile specimen and bearing housing segment castings. Castability and tensile properties of the alloys were characterized. Bearing housing segments were subject to porosity, which was extensively studied. Process capabilities and limitations were investigated for induction melting and the pyrolytic graphite coated mold. Properties of castings were determined, and weldability of the four cast alloys evaluated. Effects of the casting process on microstructure were investigated.

REPORT NO: AFML-TR-72-169 AD 906 704L  
ACCESS NO: 65,836 January 1973  
TITLE: MANUFACTURING METHODS FOR ROLL  
DIFFUSION BONDED STIFFENED SKIN  
STRUCTURE

AUTHOR: R. D. Brunken, et al.  
CONTRACT NO: F33615-69-C-1877  
CONTRACTOR: North American Rockwell Corporation  
PROJECT MONITOR: G. Trickett (AFML/LTM)  
PROJECT NO: 9-109a

ABSTRACT: The capability of the roll diffusion bonding process to fabricate large plan area Ti-6Al-4V titanium alloy integrally stiffened skin structure to design tolerances was demonstrated. The dimensional tolerances achieved on two roll bonded panels measuring 35" wide and 222" long is presented and compared to standard aircraft structure design tolerances. Results of base material mechanical property tests, bond joint strength tests, ultrasonic inspection and microscopic examination performed on the panels show the process capable of producing a homogeneous structure with bond strengths equivalent to the base material.

REPORT NO: AFML-TR-72-170 AD 904 689L  
ACCESS NO: 68,516 September 1972  
TITLE: MANUFACTURING METHODS FOR PRODUCTION  
OF HOLLOW-BALL BEARINGS FOR USE IN GAS  
TURBINE ENGINES

AUTHOR: J. R. Potts  
CONTRACT NO: F33615-70-C-1524  
CONTRACTOR: Pratt and Whitney Aircraft  
PROJECT MONITOR: W. Harris (AFML/LTM)  
PROJECT NO: 121-0

ABSTRACT: This report describes a Manufacturing Methods Program to establish techniques for the production of diffusion bonded hollow balls for high speed gas turbine applications. The projected requirements of aircraft gas-turbine engines strongly indicate the need for increased speed capability in mainshaft ball bearings. This need arises from expected increases in engine shaft speed, and from increased shaft diameters to meet anticipated torque and stiffness requirements. Bearings in current engines use solid balls and operate at approximately 1.8 million DN. DN is the product of bearing diameter in millimeters and shaft speed in rpm. A value of 3.0 million DN is representative of future engine requirements. At this DN value, the centrifugal load imposed by a solid ball is approximately three times as great as the load at 1.8 million DN. This, together with the higher ball passing frequency, can be expected to drastically reduce bearing life. Lower weight, hollow balls will significantly reduce the centrifugal loads at high speed and increase bearing life.

REPORT NO: AFML-TR-72-175 AD 904 855L  
ACCESS NO: 201,102 September 1972  
TITLE: MANUFACTURING TECHNIQUES FOR PRODUCTION OF SINGLE CRYSTAL BERYLLIUM OXIDE

AUTHOR: S. B. Austerman, et al.  
CONTRACT NO: F33615-71-C-1530  
CONTRACTOR: North American Rockwell Corporation  
PROJECT MONITOR: E. H. Tarrants (AFML/LTE)  
PROJECT NO: 562-8

ABSTRACT: Methods were developed for production of beryllium oxide (BeO) crystals. The intended application for BeO crystals is in the field of microelectronic devices. The crystals are produced by controlled precipitation from solution in the molten solvent flux, alkali polymolybdate, by the steady-state thermal gradient method. The method developed concentrated primarily on the use of stirred seed plates, at temperatures between 1050 and 1100°C. Slicing, etching, and cleaning methods were developed to provide clean, damage-free seed plates. Mounting structures and seed plate attachment techniques were improved to provide secure mounting, optimum interplate spacing, and streamlined

ABSTRACT (Con't): flux flow over the plate surface. Furnace components were redesigned, and procedural checklists instituted to improve frequency (approaching 100 percent) of successfully-completed crystal growth runs.

REPORT NO: AFML-TR-72-183 AD 904 328L  
ACCESS NO: 67, 884 October 1972  
TITLE: THERMO MECHANICAL WORKING OF ELECTRO-SLAG MELTED M-50 BEARING STEEL  
AUTHOR: E. N. Bamberger  
CONTRACT NO: AF 33(615)-70-C-1234  
CONTRACTOR: General Electric Company  
PROJECT MONITOR: G. W. Trickett (AFML/LTM)  
PROJECT NO: 122-0  
ABSTRACT: A number of electroslag (ESR) melting procedures were investigated with the objective of establishing the thermomechanical working (ausforming) characteristics of M-50 bearing steel produced by this method. The ESR processes evaluated were: Electroslag remelted - Air melted electrode, Electroslag remelted - Vacuum induction melted electrode, Powder-strip electroslag melting, Double electroslag remelted - Vacuum induction melted electrode, Continuous electroslag melting. Rolling contact fatigue testing, heat treat studies and other metallurgical tests were performed on most of these materials utilizing standard heat treat procedures as well as a thermomechanical process. In the latter case, high energy rate forward extrusion using Controlled Energy Flow Forming (CEFF) equipment was employed. Test results showed the ESR M-50 hardened by standard heat treat procedures to have comparable rolling contact fatigue lives to vacuum melted M-50.

REPORT NO: AFML-TR-72-188 AD 905 170  
ACCESS NO: 69, 197 September 1972  
TITLE: ELECTROCHEMICAL MACHINING (ECM)  
VOLUME I - OPTIMIZATION OF PARAMETERS  
AUTHOR: J. A. Cross, et al.  
CONTRACT NO: F33615-71-C-1149  
CONTRACTOR: General Electric Company  
PROJECT MONITOR: Capt. R. Dove (AFML/LTM), et al.  
PROJECT NO: 723-9  
ABSTRACT: The objective of this program was to increase the efficiency of electrochemical machining (ECM) techniques for metal removal and thereby provide methods to decrease manufacturing costs, increase the structural integrity of production parts and extend the utilization of the process. Eight ferrous, nickel, titanium, and cobalt base aerospace structural materials were selected for ECM parameter optimization and machining demonstrations. The optimized parameter were demonstrated as cost effective on one airframe and two aircraft engine components by contour, pocket and side cutting ECM techniques. The final report

**ABSTRACT (Cont'd):** includes supplemental information which provides data on ECM tooling costs, criteria for the selection of electrode materials, data on ECM electrolyte properties, and electrolyte control and clarification information.

**REPORT NO:** AFML-TR-72-188 AD 905 171  
**ACCESS NO:** 69, 197 September 1972  
**TITLE:** ELECTROCHEMICAL MACHINING (ECM) VOL. II -  
DEMONSTRATION OF OPTIMIZED PARAMETERS  
AND PROCESS APPLICATION DATA  
**AUTHOR:** J. A. Cross, et al.  
**CONTRACT NO:** F33615-71-C-1149  
**CONTRACTOR:** General Electric Company  
**PROJECT MONITOR:** Capt. R. A. Dove (AFML/LTN)  
**PROJECT NO:** 723-9

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**REPORT NO:** AFML-TR-72-190  
**ACCESS NO:** 201, 104 October 1972  
**TITLE:** SAPPHIRE MULTIPLE FILAMENT AND LARGE  
PLATE GROWTH PROCESSES  
**AUTHOR:** G. F. Hurley, et al.  
**CONTRACT NO:** F33615-70-C-1471  
**CONTRACTOR:** Tyco Lab., Inc.  
**PROJECT MONITOR:** L. Kopell (AFML/LTN)  
**PROJECT NO:** 345-0

**ABSTRACT:** Progress on concurrent programs to establish manufacturing programs for the growth of single crystal sapphire in two shapes is reported. One process is for the simultaneous growth of 25 high strength continuous sapphire filaments while the other is for the growth of 12 in. x 12 in. transparent sapphire plates. The objective of the first program was to increase the production rate capability and decrease the cost of sapphire filament by designing, building, and operating a multiple filament machine. The successful achievement of these objectives are described, and recommendations for scaleup to further increase production

**ABSTRACT (Cont'd):** capability and to decrease costs are given. Particular advancements in the technology of several components used in the filament process are reported. The objectives of the second program were to develop a system and to establish a manufacturing process for the growth of large sapphire plates.

**REPORT NO:** AFML-TR-72-224 AD 905 282  
**ACCESS NO:** 201, 154 October 1972  
**TITLE:** MANUFACTURING PROCESS FOR THE  
CIRCULAR FABRICATION OF PYROLYZED  
PLASTIC

**AUTHOR:** W. Dittmer, et al.  
**CONTRACT NO:** F33615-72-C-1129  
**CONTRACTOR:** Avco Systems Division  
**PROJECT MONITOR:** P. Pirrung (AFML/LTN)  
**PROJECT NO:** 457-1

**ABSTRACT:** Equipment to fabricate 3D-MOD-3 cylinders has been designed, fabricated, and a cylinder produced and delivered to the AFML. All of the goals of the equipment and the product have been met; a high fabric compaction 72 layers per inch of wall thickness was attained, which resulted in a final cylinder density of 1.60 gm/cc. The program was conducted under five tasks as follows: Task I - Design of circular piercing equipment. Task II - Fabrication of equipment. Task III - Equipment demonstration. Task IV - Fabrication of graphite 3D-MOD-3 cylinder. Task V - Pyrolyzation proceeding of 3D-MOD-3 cylinder.

**REPORT NO:** AFML-TR-72-270 AD 906 698L  
**ACCESS NO:** 68, 211 December 1972  
**TITLE:** ISOTHERMAL FORGING OF TITANIUM ALLOY  
MAIN LANDING GEAR WHEELS AND NOSE  
WHEELS

**AUTHOR:** K.M. Kulfarni, et al.  
**CONTRACT NO:** F33615-67-C-1533  
**CONTRACTOR:** IIT Research Institute  
**PROJECT MONITOR:** G. Trickett (AFML/LTM)  
**PROJECT NO:** 120-0

**ABSTRACT:** This project relates to isothermal forging of complex wheel shaped forgings of a titanium alloy. The three major objectives of the project were (1) to conduct a production run of 12 in. diameter nose wheels, (2) to select an alternate die material less expensive than IN-100, and (3) to produce the die stack for and isothermally forge 22 in. diameter outer main wheel forgings.

NONMETALLIC MATERIALS DIVISION (AFML/MB)

REPORT NO: AFML-TR-64-383 (Pt. VIII) AD 891 898L  
ACCESS NO: 200, 377 December 1971  
TITLE: SYNTHESIS INVOLVING ORGANOMETALLIC  
AND ORGANOMETALLOIDAL COMPOUNDS  
CONTAINING PERFLUORO AND PERCHLORO  
SUBSTITUENTS  
AUTHOR: H. Gilman, et al.  
CONTRACT NO: F33615-71-C-1094  
CONTRACTOR: Iowa State University  
PROJECT MONITOR: Dr. C. Tamborski (AFML/MBP)  
AFML TASK NO: 734201  
ABSTRACT: The purpose of this study is concerned with new  
or improved syntheses of organometallic and organometalloidal compounds  
containing polyfluoro and polychloro substituents. These versatile re-  
agents are to be used for the preparation of thermally stable fluids, lubri-  
cants, etc. The primary objective is to develop convenient and novel  
procedures for the synthesis of perfluoroalkylmetallic types having one  
or more C-M linkages, such as  $CF_3(CF_2)_nM$  and  $M(CF_2)_nM$ .

REPORT NO: AFML-TR-66-161 (Pt. VII) AD 906 351L  
ACCESS NO: 201, 136 April 1972  
TITLE: HIGH STRENGTH, HIGH MODULUS GRAPHITE  
FIBER  
AUTHOR: P. E. McMahon, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: H.M. Ezekiel (AFML/MBE)  
AFML TASK NO: 732001  
ABSTRACT: It is generally recognized that the translation of  
graphite fiber tensile strength into composites is poorer for high modulus  
fiber ( $> 50$  Msi) than for lower modulus counterparts ( $< 50$  Msi). The pur-  
pose of this investigation was to achieve a basic understanding of this  
difference in translation efficiency. The approach taken was to prepare  
fibers at two levels of modulus (70 and 40 Msi) and fully characterize their  
tensile properties and distributions, to evaluate the strengths of composites  
of varying size and shape made with these fibers, and to couple these para-  
meters with various available failure models. Fiber was prepared having  
tensile strengths of 250 and 220 Ksi, respectively, at 70 and 40 Msi  
modulus. Surface treatment of increasing severity was applied to both  
fibers such that five levels of shear strength between 2500 and 10,000 psi  
were prepared. Fiber tensile strength was not altered by surface treat-  
ment, however, composite tensile strength was shown to have a maxi-  
mum value at intermediate shear strengths (ca. 6000-7000 psi) for 70 Msi

**ABSTRACT (Cont'd):** fibers. It was further shown by evaluating impregnated single strands as well as flat and clumped multi-strands that both specimen size and shape influence fiber-to composite strength translation, i. e., increasing the specimen complexity decreases the tensile strength.

**REPORT NO:** AFML-TR-66-334 (Pt. VI) AD 900 495L  
**ACCESS NO:** 200,671 July 1971  
**TITLE:** HIGH STRENGTH-HIGH MODULUS CARBON FIBERS  
**AUTHOR:** R. Bacon  
**CONTRACT NO:** F33615-70-C-1453  
**CONTRACTOR:** Union Carbide Corporation'  
**PROJECT MONITOR:** H.M. Ezekiel (AFML/MBC)  
**AFML TASK NO:** 732001

**ABSTRACT:** Work has been performed to improve the performance of high modulus graphite fibers, in resin-matrix composites, especially with regard to compressive strength. The approaches taken were to alter the fiber size, shape, and internal structure. Several special rayon raw materials, including both round filament and large denier-per-filament types, were processed into high modulus graphite fibers, formed into small unidirectional composite rods, and tested. Although round shape appeared to have no effect on composite properties, the large-diameter fibers showed some promise of improving compressive strength. Laboratory-scale processing of small denier-per-filament rayons was partially successful in that graphite fibers of moderately high (0.76%) breaking strain were produced; however, no evaluation of these fibers in composites was made. The use of unusual graphitization conditions designed to reduce the degree of internal structure order in the fiber was confirmed as an effective means to improve the compressive strength of composites; composite-properties of 13,400 psi shear strength and 130,000 psi compressive strength was achieved with the use of a graphite yarn of 48 million psi Young's modulus.

**REPORT NO:** AFML-TR-67-172 (Pt. II) AD 841 428L  
**ACCESS NO:** 46,420 September 1968  
**TITLE:** THERMALLY STABLE POLYMERIC FIBERS  
**AUTHOR:** E. C. Chenevey, et al.  
**CONTRACT NO:** AF 33(615)-5192  
**CONTRACTOR:** Celanese Research Company  
**PROJECT MONITOR:** W.H. Gloor (AFML/MBC)  
**AFML TASK NO:** 732001

**ABSTRACT:** The raw materials for making benzimidazo-benzophenanthroline (BBB) polymer have been characterized exhaustively. Tetracarboxy-naphthalene (TCN) which can be purified to make acceptable polymer is available from three sources. Laboratory support work related the difficulty principally to the use of a stainless steel reactor.

**ABSTRACT (Cont'd):** Laboratory experiments showed the importance of stirrer speed, heating rate, reaction dilution, and boiling alkaline wash on the tensile properties of the resulting fiber after a standard spinning and drawing routine. The BBB fiber continues to show excellent resistance to deterioration in hot air and light exposure.

**REPORT NO:** AFML-TR-67-270 (Pt. IV) AD 891 876L  
**ACCESS NO:** 200, 374 November 1971  
**TITLE:**

ABLATIVE THERMAL PROTECTION  
COMPOSITES FOR LIFTING VEHICLES

**AUTHOR:** R. A. Taverna, et al.  
**CONTRACT NO:** AF33615-68-C-1410  
**CONTRACTOR:** Avco Corporation  
**PROJECT MONITOR:** H. Materne (AFML/MBC)  
**AFML TASK NO:** 734001

**ABSTRACT:** The objective of this program was to develop, screen, and obtain characterization data of improved materials for the thermal protection of lifting reentry vehicles. Mod 58 HD a leading candidate from Part III of this program was characterized in terms of mechanical and thermal properties. Various density carbon felts made by a spray process were impregnated with resin also as leading edge candidate materials. For afterbody region thermal protection composites were formulated, processed, and ablation tested with carborane siloxane resins, pyrrone resins and phenolic resin with Delrin added as a decomposing filler. Although the ablative performance of these materials showed no improvement over the Mod 58 reference material, there was significant insulation improvement (time to reach backface temperature) for the pyrrone and decomposing filler composites.

**REPORT NO:** AFML-TR-67-368 (Pt. V) AD 904 982  
**ACCESS NO:** 201, 103 December 1971  
**TITLE:**

HIGH TEMPERATURE ELASTOMER NETWORKS  
FROM DIFUNCTIONAL BLOCK POLYMERS

**AUTHOR:** M. Morton, et al.  
**CONTRACT NO:** F33615-69-C-1222  
**CONTRACTOR:** University of Akron  
**PROJECT MONITOR:** Dr. R. C. Evers (AFML/MBP)  
**AFML TASK NO:** 734004

**ABSTRACT:** The reactions of cyclic silane monomers with organolithium initiators were investigated under high vacuum conditions ( $< 10^{-6}$  torr). It was found that at 23°C, 1, 1, 3, 3-tetramethyl-1, 3-disilacyclobutane undergoes no reaction with either ethyl lithium or sec-butyl lithium in benzene. In a more polar medium, such as THF at -78°C, ring-opening does occur, but propagation does not proceed. In benzene at 23°C 1, 1-dimethylsilacyclobutane and 1, 1, 3-trimethylsilacyclobutane undergo a very slow ring-opening reaction with the above-mentioned

**ABSTRACT (Cont'd):** initiators. The rate of ring-opening is increased in tetrahydrofuran at  $-78^{\circ}\text{C}$ . However, there appears to be a metallation side reaction with the silylmethyl groups. Polymerization of 1, 1, 3-trimethylsilacyclobutane in benzene with trace amounts of triethylamine gave polymers having a broad molecular distribution and less than quantitative yield.

**REPORT NO:** AFML-TR-68-131 (Pt. III) AD 903 413L  
**ACCESS NO:** 200, 943 May 1970  
**TITLE:** OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BIS-BENZIMIDAZOBENZOPHENANTHROLINE-DIONE)

**AUTHOR:** R. T. Conley  
**CONTRACT NO:** F33615-68-C-1277  
**CONTRACTOR:** Wright State University  
**PROJECT MONITOR:** Dr. G. F. L. Ehlers (AFML/MBP)  
**AFML TASK NO:**

**ABSTRACT:** This report is based (sections I-IV), in part, upon the recent advances in the literature insofar as the available data pertains to the oxidation of amines and heterocyclic nitrogenous compounds. Since the oxidation of the parent polymers and model compounds related poly(benzimidazole), poly(benzimide) and poly(bis-benzimidazobenzophenanthroline-dione) should reflect, at least in some measure, oxidation of simple monocyclic systems, an attempt has been made to correlate the results of our previous work as reported in AFML-TR-68-131 (Parts I and II) with the available oxidation literature in this area of research. The reported efforts to date in the investigation of oxidation phenomena, as are shown in the report, are quite limited and certainly fragmentary. The correlation of these data to our work, however, seems quite good. The mechanistic proposals contained herein are the basis guidelines for our future research efforts; particularly, experiment design.

**REPORT NO:** AFML-TR-68-131 (Pt. IV) AD 902 837L  
**ACCESS NO:** 200, 423 May 1970  
**TITLE:** THE SYNTHESIS AND THERMOOXIDATIVE DEGRADATION OF POLY(BENZIMIDES) AND RELATED MODEL COMPOUNDS

**AUTHOR:** C. E. Browning, et al.  
**CONTRACT NO:** F33615-68-C-1277  
**CONTRACTOR:** Wright State University  
**PROJECT MONITOR:** G. F. L Ehlers (AFML/MBP)  
**AFML TASK NO:**

**ABSTRACT:** Polyimides belong to a recent class of organic polymers that possess an outstanding resistance to thermal degradation in both inert and oxidative environments. Since the high-temperature stabilities of polyimides are determined by the stabilities of the dianhydride and diamine monomers used in the polymerization, a new monomer,

ABSTRACT (Cont'd): 2, 3, 6, 7-anthraquinonetetracarboxylic dianhydride (ATCDA), was synthesized in an effort to prepare polyimides having improved thermal and oxidative stabilities. Also 2,6-diaminoanthraquinone (DAA) was investigated as to its suitability for incorporation with selected dianhydrides into polyimides possessing improved high-temperature properties. Other monomers used in this investigation included m-phenylenediamine (m-PDA) and 1, 4, 5, 8-naphthalenetetracarboxylic dianhydride (NTDA).

REPORT NO: AFML-TR-68-132 (Pt. I) AD 841 836  
ACCESS NO: 44, 556 September 1968  
TITLE: HIGH TEMPERATURE RESISTANT POLYMERIC COATINGS  
AUTHOR: J. M. Butler, et al.  
CONTRACT NO: F33615-67-C-1383  
CONTRACTOR: Monsanto Research Corporation  
PROJECT MONITOR: R. L. Stout (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: Silicone and organic polymeric coatings systems have been sought with improved resistance to thermoxidative degradation in the 650 to 800°F air environment. The organic polymers remain of interest particularly in unpigmented coatings because of their potentially longer retention of coating extensibility and water impermeability. The greatest improvement has been achieved with a nickel-aluminum primer. Among chemical treatments employed, an HF-HCl-H<sub>3</sub>PO<sub>4</sub> etch showed the best adhesion improvement. The investigation of silicone and organic coating systems is continuing.

REPORT NO: AFML-TR-68-181 (Pt. III) AD 736 772  
ACCESS NO: 200, 466 September 1971  
TITLE: KINETIC ANALYSIS OF THERMOGRAVIMETRY PART III: EXPERIMENTAL MODIFICATIONS  
AUTHOR: I. J. Goldfarb  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: Dr. I. J. Goldfarb (AFML/MBP)  
AFML TASK NO: 734203

ABSTRACT: The experimental apparatus for temperature programmed thermogravimetry has been modified to more effectively obtain kinetic parameters for the degradation of polymers. The thermobalance was modified to incorporate direct sample temperature measurement thereby to minimize temperature measurement errors. An automatic data acquisition system was incorporated into the apparatus and appropriate computer programs to handle the magnetic tape data were written. The modified apparatus has been tested with several polymer systems and it was demonstrated that the use of the magnetic tape data recording system permitted greatly increased output from the thermobalance.

REPORT NO: AFML-TR-68-322 (Pt. III) AD 893 196L  
ACCESS NO: 200,503 February 1972  
TITLE: EFFECT OF ENVIRONMENTAL PRESSURE ON  
THE THERMAL DEGRADATION OF GLASS  
REINFORCED PLASTIC LAMINATES: PT. III:  
INVESTIGATION OF LOW VOID CONTENT  
POLYIMIDE LAMINATES

AUTHOR: D. R. Askins  
CONTRACT NO: F33615-69-C-1385  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: H. S. Schwartz (AFML/MB)  
AFML TASK NO: 734003

ABSTRACT: Low void content glass fabric reinforced polyimide laminates, designated BPI-373, have been aged at 665°F over a range of air pressures from 10 mm Hg to 2280 mm Hg. Weight loss of the laminates was periodically measured during the agings and after prescribed periods the laminates were tested in flexure. The rate of degradation of the laminates, measured as the rate of composite weight loss with exposure time, was found to be quite sensitive to air pressure, although not directly proportional. A mathematical model developed in similar previous studies was employed to describe the laminate degradation behavior here also. A comparison of the degradation behavior and laminate microstructure of the low void content BPI-373 system investigated here and the high void content system investigated earlier is presented.

REPORT NO: AFML-TR-69-164 (Pt. II) AD 891 880L  
ACCESS NO: 65,437 September 1971  
TITLE: ABLATIVE PLASTIC CHARACTERIZATION IN  
ROCKET MOTOR EXHAUST

AUTHOR: S. L. Ostrow, et al.  
CONTRACT NO: F33615-68-C-1421  
CONTRACTOR: Philco-Ford Corporation  
PROJECT MONITOR: P. F. Pirrung (AFML/MBC)  
AFML TASK NO: 734001

ABSTRACT: Advanced materials which utilize newly developed resins, reinforcements, fillers, and construction techniques were exposed to several rocket motor combustion gas environments as nozzle throat inserts. Seven separate tests series were conducted during the performance of this contract which included seventy-eight test firings of sixty-six research specimens. In addition 31 checkruns were accomplished to verify the performance of the various environments, resulting in a total of 109 test firings. The hot gas environments employed were: (1) nitrogen tetroxide ( $N_2O_4$ ) and 50 percent hydrazine/50 percent unsymmetrical dimethylhydrazine (50-50) at both 300 psia chamber pressure and 1000 psia chamber pressure, (2) the exhaust from a high temperature aeronutronic solid propellant rocket motor simulator at chamber pressure levels of 500 psia and 1000 psia.

REPORT NO: AFML-TR-69-326 (Pt. III) AD 902 857L  
ACCESS NO: 200, 833 August 1972  
TITLE: RESEARCH ON SYNTHESIS PROCEDURES FOR  
INTERMEDIATES REQUIRED FOR HIGH  
TEMPERATURE STABLE POLYMERS

AUTHOR: C.C. Chappelow, et al.  
CONTRACT NO: F33615-71-C-1128  
CONTRACTOR: Midwest Research Institute  
PROJECT MONITOR: G. Moore (AFML/MBP)  
AFML TASK NO: 734004  
ABSTRACT: Work is reported on the synthesis and/or characterization of 30 different compounds for use in studies related to the preparation of high-temperature stable polymers. As a result of this effort, 28 synthesized and/or characterized compounds were submitted as 42 individual samples. The number and type of compounds submitted are identified as follows: 2-Perfluore-n-alkyl iodides, 2-Divinyl substituted aromatics, 2-Organodiiodides, 5-Acenaphthene derivatives, 3-Diether linked dicarboxylic acids, 3-Aromatic disulfonamides, 2-Perfluoroalkylene bisphenols, 2-Perfluorophenyl thiols, 1-Ladder polymer, 3-Substituted polyphenyl ethers, 3-Substituted phenyl halides. The 42 samples of the submitted compounds ranged in size from 2.0 to 650.4 g and, in nearly all cases, the purity was at least 99 percent.

REPORT NO: AFML-TR-70-5 (Pt. III) AD 893 621L  
ACCESS NO: 69, 041 March 1972  
TITLE: POLYANTHRAZOLINES AND LADDER  
POLYQUINOXALINES

AUTHOR: J. K. Stille, et al.  
CONTRACT NO: F33615-71-C-1139  
CONTRACTOR: University of Iowa  
PROJECT MONITOR: Dr. F. L. Hedberg (AFML/MBP)  
AFML TASK NO: 734201  
ABSTRACT: The synthesis of ladder polyquinoxalines under a variety of reaction conditions has been continued. An attempt has been made to polymerize 1,2-diketo-5,6-diaminopyracene in situ. Polymerizations of 1,2,6,7-tetraketopyrene with 1,2,4,5-tetraminobenzene and with 1,2,5,6-tetraminoanthraquinone in both m-cresol and polyphosphoric acid are reported. Polymerizations of 1,2,5,6-tetraketoanthracene with 1,2,5,6-tetraminoanthraquinone and with 1,2,5,6-tetraminonaphthalene in m-cresol are discussed. The latter polymerization is also reported with hexamethylphosphoramide and polyphoric acid as the solvents. Results indicate that polymers prepared in polyphosphoric acid have higher molecular weights than the corresponding polymers prepared in m-cresol. The most soluble polymers were those prepared from 1,2,5,6-tetraminoanthraquinone and either of the two tetraketones.

REPORT NO: AFML-TR-70-32 (Pt. III) AD 891 509L  
ACCESS NO: 200, 373 January 1972  
TITLE: EXPLORATORY DEVELOPMENT ON ADVANCED  
FLUIDS AND LUBRICANTS IN EXTREME  
ENVIRONMENTS BY MECHANICAL  
CHARACTERIZATION  
AUTHOR: D. R. Wilson  
CONTRACT NO: F33615-69-C-1236  
CONTRACTOR: Midwest Research Institute  
PROJECT MONITOR: F. C. Brooks (AFML/MBT)  
AFML TASK NO: 734008 and 734303  
ABSTRACT: Six shear/thermal stability pump loop evaluations were conducted in the high-temperature hydraulic circuit. One series of three evaluations was conducted with the phosphate ester fluid MLO-71-37 at 275°F for 32.5 hr., at 300°F for 50 hr., and at 350°F for 13.1 hr. Both the fluid and the piston-type pump were degraded during the 350°F evaluation but were not affected adversely by the lower temperature evaluations. The silicate ester MLO-71-45 was studied in the other series of three evaluations at 300°F for 50 hr., 350°F for 50 hr., and 400°F for 50 hr. Neither the fluid nor the pump was appreciably degraded by use in these evaluation although the pump developed some minor signs of wear during the 400°F evaluation.

REPORT NO: AFML-TR-70-39 (Pt. III) AD 901 279L  
ACCESS NO: 200, 672 March 1972  
TITLE: FUNDAMENTAL STUDIES ON REACTIVE  
OLIGOMERS  
AUTHOR: G. F. D'Alelio  
CONTRACT NO: F33615-69-C-1032  
CONTRACTOR: Notre Dame University  
PROJECT MONITOR: E. F. Arnold (AFML/MBP)  
AFML TASK NO: 734201  
ABSTRACT: A process for the synthesis of high purity 1,3-di (3-aminophenoxy) benzene in improved yields was developed. A series of aromatic, oligomeric polyimides having nitrile, vinyl, acetylene, and maleyl termini of excellent elemental analyses were prepared in very high yields using a new benzene: m-cresol azeotropic technique. The tractability of the oligomers was dependent on the natures of the aromatic dicarboxylic anhydride and aromatic diamine reactants. The thermal stability of the oligomers was high when the oligomers was high when the cabin length was sufficient to contribute a true polyimide character to the product. A large number of dipolar cycloaddition polymers were prepared by reaction of these oligomers with BDNO and BDNI respectively. Most of the derived polymers were tractable in the intermediate stages. Many of the dipolar cycloaddition polymers have high thermal stabilities in nitrogen and in air. The novel styrene-terminated oligomeric polyimides were outstanding materials, particularly in their ability to crosslink, without benefit of the dipole reaction, to afford polymers of high thermal stability.

REPORT NO: AFML-TR-70-72 (Pt. II) AD 893 493L  
ACCESS NO: 200, 521 March 1972  
TITLE: NONFLAMMABLE FABRICS. PART II  
AUTHOR: J. Economy, et al.  
CONTRACT NO: F33615-69-C-1297  
CONTRACTOR: The Carborundum Company  
PROJECT MONITOR: S. Schulman (AFML/MBC)  
AFML TASK NO:

ABSTRACT: A program has been carried out to develop a suitable non-flammable and non-melting fabric based on a fiber consisting of phenolic units crosslinked in a novel manner. Extensive research to improve precursor resins has led to a system with vastly improved spinning performance. This, combined with the development of a new spinning technique and improved equipment has made it possible to fabricate uniform small denier continuous filament yarn. Processes for bleaching and dyeing of KYNOL have been improved. Physical and chemical properties including the viscoelastic properties of the fibers have been further defined. Progress has been made in developing spun yarns and fabrics of KYNOL. Preliminary work on blends and surface treatments has already led to fabrics with drastically increased strength and abrasion resistance with practically no loss in flame resistance, dimensional stability, and smoke evolution.

REPORT NO: AFML-TR-70-94 (Pt. III) AD 903 563  
ACCESS NO: 200, 937 May 1972  
TITLE: IMPROVED RADIATION-STABLE THERMAL CONTROL COATINGS  
AUTHOR: M. Lillywhite  
CONTRACT NO: F33615-71-C-1410  
CONTRACTOR: Martin Marietta Corporation  
PROJECT MONITOR: C. P. Boebel (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: Candidate pigments for thermal control coatings were synthesized by four methods that produced high-purity fine-particle material. These methods were cryochemical, hydrothermal, controlled dehydration synthesis, and oxalate calcination. These methods were used to prepare relatively pure crystals or crystallites whose particles were mainly less than  $5.0\mu$ . The pigment materials synthesized were sphen (CaTiSiO<sub>5</sub>), quartz (SiO<sub>2</sub>), spinel (MgAl<sub>2</sub>O<sub>4</sub>), alumina ( $\alpha$ -Al<sub>2</sub>O<sub>3</sub>), and perovskite (CaTiO<sub>3</sub>). All materials were evaluated in the simulated solar irradiance environment. The best four pigments based on these data (CaTiSiO<sub>5</sub>, CaTiO<sub>3</sub>,  $\alpha$ -Al<sub>2</sub>O<sub>3</sub>, and SiO<sub>2</sub>) were formulated into coatings using a dimethyl silicone binder and a low-speed blending dispersion technique. These coatings were evaluated in a simulated solar environment. Results show that three of the coatings prepared exhibit stability to simulated solar electromagnetic radiation comparable to the ITRI S-13G coating; the CaTiO<sub>3</sub> coating is less stable.

REPORT NO: AFML-TR-70-112 (Pt. II) AD 709 214  
ACCESS NO: 68, 216 June 1971  
TITLE: FRACTURE MECHANICS STUDIES OF  
COMPOSITE SYSTEMS  
AUTHOR: G. C. Sih, et al.  
CONTRACT NO: F33615-69-C-1417  
CONTRACTOR: Lehigh University  
PROJECT MONITOR: Dr. N. J. Pagano (AFML/MBC)  
AFML TASK NO:

ABSTRACT: A combined theoretical and experimental re-  
search program for investigating the application of fracture mechanics  
to composite systems was carried out. Preliminary results are pre-  
sented which include the development of two fiber reinforced composite  
crack models, one with a low-fiber volume fraction and the other a high  
fiber volume fraction, and corresponding experimental data. The quali-  
tative features of the theoretical prediction are in agreement with the  
experimental data indicating that there exists an optimum fiber volume  
fraction for which the composite achieves maximum fracture toughness.  
Tests were performed on uni-directional fiber reinforced composites  
with the crack running parallel to the fibers.

REPORT NO: AFML-TR-71-2 (Pt. II) AD 881 802  
ACCESS NO: 69, 422 August 1972  
TITLE: POLYMER STRUCTURES AND PROPERTIES  
AUTHOR: G. C. Berry  
CONTRACT NO: F33615-70-C-1058  
CONTRACTOR: Mellon Institute  
PROJECT MONITOR: Dr. M. T. Gehatia (AFML/MBP)  
AFML TASK NO: 734004

ABSTRACT: Viscoelastic studies on films of BBB are described.  
These studies are intended to elucidate both the mechanism by which defor-  
mation occurs in BBB and the relation between supramolecular structure  
and deformation. Methods for casting films of BBB from methane sulfonic  
acid for use in the viscoelastic measurements are discussed. It is found  
that certain thermal histories give rises to an insoluble form of BBB. A  
tensile creep apparatus suitable for studies on films in vacuum ( $10^{-4}$  mm  
Hg) over the temperature range -20 to 500°C is described. Creep and  
creep recovery data on two samples of BBB are given. It is found that  
the 'instantaneous' creep deformation is followed by creep in which the  
deformation is proportional to the cube root of time (Andrade Creep).  
Creep recovery is complete, although the rate of recovery is not in ac-  
cord with the laws of linear viscoelasticity.

REPORT NO: AFML-TR-71-13 (Pt. II) AD 891 431L  
ACCESS NO: 200, 346 February 1972  
TITLE: SAPPHIRE FILAMENTS  
AUTHOR: G. F. Hurley, et al.  
CONTRACT NO: F33615-69-C-1369  
CONTRACTOR: Tyco Labs., Inc.  
PROJECT MONITOR: Capt. L. G. Tolley (AFML/MBC), et al.  
AFML TASK NO: 732001

ABSTRACT: The nature of the Edge-Defined Film-Fed (EFG) process and the characteristics of filament grown by EFG were studied in detail. Tungsten was substituted for molybdenum as the material used to form the orifice for filament growth. Tungsten has a higher thermal conductivity and was found to permit filament growth at higher rates. Of greater significance, however, the higher thermal conductivity proved able to prolong the conditions for plane front solidification so that clear filament could be grown at rates up to 1.3 in./min. The latter had strength to 550 KSI, however, were shown possible by flame polishing standard 400 KSI filament. Another possibility for strengthening filament by growing at smaller diameters was attempted. However, filament as small as 4 mil diameter was shown to behave the same as larger filament both with respect to growth characteristics and mechanical properties.

REPORT NO: AFML-TR-71-60 (Pt. II) AD 900 861L  
ACCESS NO: 200, 665 April 1972  
TITLE: THERMAL DEGRADATION OF POLYMERS USING  
MASS SPECTROSCOPY-THERMOGRAVIMETRIC  
ANALYSIS TECHNIQUES  
AUTHOR: A. G. Jackson  
CONTRACT NO: F33615-70-C-1489  
CONTRACTOR: Systems Research Laboratories  
PROJECT MONITOR: Dr. I. J. Goldfarb (AFML/MBP)  
AFML TASK NO: 734004

ABSTRACT: An instrument with capabilities in analyzing evolved gas species and weight loss of a polymer sample has been described. The instrument was built around an existing TGA apparatus by modifying the vacuum system and adding a quadrupole mass spectrometer. Characteristics of the MS-TGA system have been determined. These include details on the total pressure, standard spectra, intensity roll-off, pumping rates and sensitivity. Maintenance of the system has been done to determine the required procedures and schedules for keeping the system in operating condition. Samples of BBB, PBI-M and fabric have been degraded. The resulting data has been reduced to usable form, and analysis of the results has been conducted, leading to identification of major evolved gas species. Advantages of the system are the relative simplicity of the hardware and wide usefulness of the data in characterizing polymers. From the data, suggestions for decomposition schemes are possible, and determination of actual thermal behavior of plastic fabrics can be made.

REPORT NO: AFML-TR-71-61 (Pt. II) AD 893 795L  
ACCESS NO: 200, 513 January 1972  
TITLE: IMPROVED HIGH-TEMPERATURE SOLID  
FILM LUBRICANTS

AUTHOR: V. Hopkins, et al.  
CONTRACT NO: F33615-70-C-1226  
CONTRACTOR: Midwest Research Institute  
PROJECT MONITOR: B. D. McConnell (AFML/MBT)  
AFML TASK NO: 734302

ABSTRACT: The hot-pressed solid lubricant compact work emphasized the development of materials for use at high temperatures in an air environment. The fabric lined bearing work was limited in scope and included some development work with flat bearing systems and the evaluation of two commercially available materials. The solid lubricant technology work was aimed at the development of new technology, and lubricating material systems with the emphasis on self-lubricating composites. The work was related to different schemes of lubrication with solids such as solid lubricant films, solid lubricant compacts, and fiber-reinforced composites. The lubricant evaluation work concentrated on characterizing materials developed on this and earlier programs in addition to aiding in the development of current materials through testing. This has included basic friction and wear studies, the evaluation of solid lubricant compact containing spherical bearings, testing of carbonized phenolic resin samples, and the evaluation of high-temperature compacts. The accelerated testing work is concerned with the approach used, and testing required, to predict long-term performance of solid lubricant materials.

REPORT NO: AFML-TR-71-87 (Pt. VII) AD 893 342L  
ACCESS NO: 200, 506 February 1972  
TITLE: APPROACHES TO LADDER STRUCTURES. VII:  
POLYCONDENSATION OF AROMATIC DIAMINO  
DICARBOXYLIC ACIDS WITH DIMETHYLFORMA-  
MIDE AND PHOSPHORUS PENTOXIDE

AUTHOR: G. A. Loughran  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: G. A. Loughran (AFML/MBP)  
AFML TASK NO: 734004

ABSTRACT: It has been found that a new compound, 6-dimethyl-amino-carbonyl-dibenzo-(b, f) (1, 5)-diazocine-12, (11H)-one, is produced when either anthranilic acid or dibenzo-(b, f) (1, 5)-diazocine-6, 12 (5H, 11H)-dione is heated at 50 to 80°C in solution in dimethylformamide in the presence of a suspension of phosphorus pentoxide. A mechanism involving self condensation of anthranilic acid to dibenzo-(b, f) (1, 5)-diazocine-6, 12 (5H, 11H)-dione followed by reaction with dimethylformamide is proposed.

REPORT NO: AFML-TR-71-97 AD 752 202  
ACCESS NO: 200, 349 December 1971  
TITLE: THE SYNTHESIS AND CHEMISTRY OF FLUORINE-  
CONTAINING BENZENEDIAZOOXIDES  
AUTHOR: J. W. Spence  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: J. W. Spence (AFML/MBE)  
AFML TASK NO: 734005  
ABSTRACT: This report covers the synthesis of fluorine-  
containing benzenediazooxides. Compounds of particular interest are  
tetrafluoro-ortho- and par-benzenediazooxides. Tetrafluoro-ortho- and  
para-benzenediazooxides were synthesized and characterized by infrared  
and nuclear magnetic resonance. Triphenylphosphine,  $\beta$ -naphthol, and  
N, N-dimethylaniline were found to couple with tetrafluoro-para-benze-  
nediazooxide; however, attempts to form derivatives of the tetrafluoro-ortho-  
benzenediazooxide successful. Methoxytrifluoro-1, 4-benzenediazooxide  
was synthesized from 2, 3, 5, 6-tetrafluoro-para-anisidine. The structure  
of this diazooxide and the mechanism of reaction are under investigation.

REPORT NO: AFML-TR-71-114 (Pt. II) AD 901 875 L  
ACCESS NO: 200, 681 April 1972  
TITLE: SYNTHESIS OF PERFLUOROALIPHATIC ETHER  
MONOMERS  
AUTHOR: T. Psarras  
CONTRACT NO: F33615-70-C-1403  
CONTRACTOR: PCR, Incorporated  
PROJECT MONITOR: Dr. R.C. Evers (AFML/MBP)  
PROJECT NO: 7342  
ABSTRACT: Monoester-acyl chlorides were obtained by par-  
tial esterification of hexafluoroglutaryl chloride with methanol and tri-  
fluoroethanol. The monoester-acyl chlorides were converted to the cor-  
responding ester-acyl fluorides by reaction with potassium fluoride in  
diglyme. Substitution of tetraglyme for diglyme as a solvent drastically  
alters the course of the reaction. Monofunctional and difunctional acyl  
fluoride oligomers of HFPO were converted to the corresponding per-  
fluoroiodides by reaction with a slurry of sodium carbonate and iodine in  
diglyme or tetraglyme. The reaction is general for perfluoroalkyl acyl  
halides and anhydrides. Monofunctional and difunctional nitrile oligomers  
of HFPO were converted to the corresponding perfluoroalkyl iminoethers  
by base catalyzed addition of an alcohol. The reaction is general for per-  
fluoroalkyl nitride. Difluorocarbene, generated by thermal decomposition  
of HFPO and trimethyltrifluoromethyltin, did not add to the carbonyl group  
of gentafluorobenzoyl fluoride and perfluoroacetophenone. Hexafluoropro-  
pylene-1, 2-epixulfide was prepared in low yield, by two published routes.

REPORT NO: AFML-TR-71-116 (Pt. VI) AD 736 780  
ACCESS NO: 200, 314 September 1971  
TITLE: STUDIES OF THE BREAKDOWN MECHANISM  
OF POLYMERS  
AUTHOR: G. F. L. Ehlers, et al.

CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: Dr. G. F. L. Ehlers (AFML/MBP)  
AFML TASK NO: 734004

ABSTRACT: The thermal breakdown of three polybenzoxazoles and three polybenzothiazoles was studied in vacuum between 450 and 660<sup>o</sup>C, and two model compounds, corresponding to the two basic polymer systems above, were subjected to flash pyrolysis. The polybenzoxazoles lose most of the oxygen up to 660<sup>o</sup>C as carbon monoxide and carbon dioxide, with the carbon atom of the benzene ring adjacent to the oxygen participating in the reaction. The structure of the residual polymer is possible that of a crosslinked, Schiff base structure, with only one out of six C=N linkages being eliminated as hydrogen cyanide. A polybenzoxazole with a perfluoroaliphatic chain forms hydrogen fluoride (from ring hydrogen) which attacks the quartz vessel and generates large quantities of silicon tetrafluoride. Polybenzothiazoles become highly crosslinked, but are essentially unchanged, after heating of 625<sup>o</sup>C. About one sulfur atom for every five repeat units is removed as hydrogen sulfide, and the benzothiazole ring replaced by a Schiff base linkage.

REPORT NO: AFML-TR-71-143 AD 736 783  
ACCESS NO: 200, 315 October 1971  
TITLE: FURTHER STUDY OF UNIDIRECTIONAL AND  
BIDIRECTIONAL COMPOSITES UNDER  
CYLINDRICAL BENDING

AUTHOR: N. J. Pagano, et al.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: Dr. N. J. Pagano (AFML/MBP)  
AFML TASK NO: 734003

ABSTRACT: The results of elasticity solutions for the response of unidirectional and bidirectional laminates are presented in detail and compared to corresponding results given by classical lamination theory. Laminates under uniformly distributed and concentrated loadings are treated.

REPORT NO: AFML-TR-71-197 AD 893 919L  
ACCESS NO: 200, 522. December 1971  
TITLE: MATERIALS PARAMETERS THAT GOVERN THE  
RAIN EROSION BEHAVIOR OF POLYMERIC COAT-  
INGS AND COMPOSITES AT SUBSONIC VELOCITIES  
G. F. Schmitt, Jr.

AUTHOR:  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: G. F. Schmitt, Jr. (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: Subsonic investigations of polymeric coatings, bulk polymers, and fiber reinforced polymeric composites are described for their erosion behavior and the influence of materials variables on their erosion response. Polymeric coatings such as epoxies, polyesters, and amide-imides are brittle relative to the impinging water droplets with rupture of the film occurring very rapidly. The most resistant coatings such as elastomeric polyurethanes typically show no surface erosion at all but fail at isolated points associated with a breakdown of the composites, underneath the coating. Other elastomeric coatings such as neoprene will gradually erode on the surface by structural failure or tearing within the film; erosion of the composite then follows. The elastomeric coatings protect the surface by pulse attenuation of the impact load and by protecting the composite from the radial out flow of the impinging drop. The modulus of these coatings is related to their performance in a rain environment since it governs the stress level which is transmitted to the substrate.

REPORT NO: AFML-TR-71-200 AD 743 836  
ACCESS NO: 200, 534 June 1971  
TITLE: HEAT TRANSFER AND PRESSURE DISTRIBUTIONS  
ON RE-ENTRY NOSE SHAPES IN THE VKI LONG-  
SHOT HYPERSONIC TUNNEL

AUTHOR: B. E. Richards, et al.  
CONTRACT NO: F61052-70-C-0031  
CONTRACTOR: von Karman Institute for Fluid Dynamics  
PROJECT MONITOR: Dr. M. L. Minges (AFML/MB)  
AFML TASK NO:

ABSTRACT: Heat transfer and pressure distributions have been made on five vehicle nose shapes in the VKI Longshot free piston wind tunnel at  $M=15$  and  $20$ . The flow parameters achieved closely simulate aerodynamic re-entry conditions. The models used in the study were a  $50^\circ - 8^\circ$  biconic configuration, with sharp- and blunt-nosed versions and a sharp-nosed version with a machined roughness, and a hemisphere configuration with a smooth and a sand-blast rough surface. The configurations resemble the stable shapes of turbulent and laminar ablating nose cones. Preliminary comparisons have been made with the state-of-the-art engineering predictions. Some discussion about the state of the boundary layer is included.

REPORT NO: AFML-TR-71-203 AD 894 579L  
ACCESS NO: 200, 619 February 1972  
TITLE: COMPUTATIONAL SCHEME FOR PREDICTING  
RECESSION AND IN-DEPTH HEATING OF A  
TWO-MATERIAL ABLATING SYSTEM  
AUTHOR: J. L. Olinger  
CONTRACT NO: F33615-69-C-1385  
CONTRACTOR: University of Dayton  
PROJECT MONITOR: J. M. Kelble (AFML/MBC)  
PROJECT NO: 7340

ABSTRACT: This report contains the results of a three month working effort to devise a detailed computational scheme for the evaluation of low recession nose tip concepts. It is the first step in devising an overall computational procedure for evaluation of various nose tip designs within the LRNT concept, and of candidate materials for use in such vehicles. The ASTHMA program was chosen, from a survey of existing methods and an evaluation of constructing a new scheme to handle this problem. Although not available as such for use in the two material ablation problem, this program has the capability of handling such a problem. This report contains information on the adaptation of the ASTHMA program to the two material ablation problem and on the results obtained from runs of the revamped program on several material combinations. These runs, although crude at the moment, demonstrate that realistic thermal response, thermal ablation and thermal gradient, results can be obtained. Recommendations for program improvement, updating, and for use as a tool for evaluating materials and design concepts are given.

REPORT NO: AFML-TR-71-231 AD 742 282  
ACCESS NO: 200, 585 January 1972  
TITLE: MICROBUCKLING OF UNIDIRECTIONAL  
COMPOSITES  
AUTHOR: L. B. Greszczuk  
CONTRACT NO: F33615-67-C-1559 and F33615-71-C-1070  
CONTRACTOR: McDonnell-Douglas Astronautics Co.  
PROJECT MONITOR: N. J. Pagano (AFML/MBC)  
AFML TASK NO: 734003

ABSTRACT: A review is presented of the theories of microbuckling of unidirectional composites subjected to compressive loading parallel to fiber direction. The results predicted by the various theories are compared. Large differences in predicted results are shown to exist for microbuckling in the extension mode. In the case of microbuckling in the shear mode, the various theories predict the same results. Nearly perfect (as compared to actual composites) model composites consisting of circular rods in an epoxy matrix are employed to obtain experimental data on failure of unidirectional composites subjected to compressive loading. The constituent materials used in preparation of model composites are characterized for their mechanical properties.

REPORT NO: AFML-TR-71-247 AD 892 801L  
ACCESS NO: 200, 465 November 1971  
TITLE: DEVELOPMENT OF SILICON CARBIDE

WHISKERS

AUTHOR: R. M. Minday  
CONTRACT NO: F33615-71-C-1482  
CONTRACTOR: Esso Research and Engineering Company  
PROJECT MONITOR: W. H. Gloor (AFML/MBC)  
AFML TASK NO: 732001

ABSTRACT: This report describes the progress made on the portion of Esso Research's whisker program supported on a contract with the Air Force Materials Laboratory. The work concerns the development of the processing and handling techniques occurring after the growth of the  $\beta$ -silicon carbide whiskers which are necessary to attain production capabilities for this material. The areas discussed are harvesting the whiskers from the growth substrate, cleaning and classification of the whiskers, mechanical property testing of the whiskers, and preparation and testing of whisker-epoxy composites.

REPORT NO: AFML-TR-71-248 AD 894 544L  
ACCESS NO: 200, 620 December 1971  
TITLE: METAL PIGMENTED THERMAL CONTROL

COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE

AUTHOR: G. E. Stevenson  
CONTRACT NO: F33615-69-C-1385  
CONTRACTOR: University of Dayton  
PROJECT MONITOR: C. P. Boebel (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: The purpose of this program was to develop sprayable paint-type coatings with variable solar absorptance to infrared emittance ratios greater than unity. Exploratory development on coating materials that will yield a fixed a s/e ratio over the range 0.2 e 0.50 is described. A variety of leafing metal pigmented coatings was developed and prepared which gave a s/e ratios greater than unity. The highest ratios were obtained with copper pigmented films after they were oxidized at elevated temperatures. Such specially treated and prepared materials have shown excellent stability to electron and/or ultraviolet irradiation in a simulated space environment and have demonstrated potential for use on future satellite systems.

REPORT NO: AFML-TR-71-256 AD 891 491L  
ACCESS NO: 200, 350 December 1971  
TITLE: EXPLORATORY DEVELOPMENT OF STRUCTURAL  
ADHESIVES HAVING IMPROVED TOUGHNESS  
PROPERTIES

AUTHOR: K. D. Klapprott, et al.  
CONTRACT NO: F33615-71-C-1419  
CONTRACTOR: The Dexter Corporation  
PROJECT MONITOR: T. J. Aponyi (AFML/MBC)  
AFML TASK NO: 734002

ABSTRACT: The contract work has been directed to the improvement of the sandwich peel properties of ADX-639, the adhesive film version of ADX-516 while retaining the strength/temperature characteristics of this material. ADX-639 is the successful result of work on a previous contract to combine the strength/temperature characteristics of existing high temperature adhesives with significantly improved toughness. This was accomplished by the combination of a high glass transition, with respect to sandwich peel strength, part of which would be ascribed to poor flow and core filleting characteristics. Catalysts were found which decreased the reaction temperature of the aromatic amine curing agent, but their use did not lead to development of acceptable elevated temperature adhesive bond strength. Plant equipment has been used to produce adhesive tape having acceptable and reproducible adhesive performance properties.

REPORT NO: AFML-TR-71-260 AD 754 249  
ACCESS NO: 200, 683 March 1972  
TITLE: INTERFACE AND MECHANICS RESEARCH IN  
FIBER REINFORCED COMPOSITES

AUTHOR: H. R. Nara  
CONTRACT NO: F33615-70-C-1016  
CONTRACTOR: Case Western Reserve University  
PROJECT MONITOR: H. S. Schwartz (AFML/MB)  
AFML TASK NO: 734202

ABSTRACT: Experimental and analytical investigations were performed to provide increased understanding of the fundamental behavior of fiber reinforced plastic composites. The research was conducted in a number of discrete tasks which were grouped into three principal categories, namely: materials research, mechanics of composites, and analysis and design of composite structures. In the materials research category, information on the physical and chemical characteristics of graphite fiber surfaces was obtained using gas and liquid adsorption techniques and mass spectrometry. This information provides a new insight into the relationship between graphite fiber surface characteristics and their adhesion to plastic matrices. In an investigation targeted to develop composites having improved fiber-matrix adhesion and higher toughness, graphite fiber-nylon 6 matrix adhesion were prepared by in situ polymerization of nylon in a reaction vessel containing the fibers.

REPORT NO: AFML-TR-71-271 AD 894 598L  
ACCESS NO: 200,624 February 1972  
TITLE: DIRECT FLUORINATION OF ORGANIC COMPOUNDS  
AUTHOR: J. L. Margrave, et al.  
CONTRACT NO: F33615-71-C-1043  
CONTRACTOR: William Marsh Rice University  
PROJECT MONITOR: Dr. C. Tamborski (AFML/MBP)  
AFML TASK NO: 734201

ABSTRACT: The following report contains the results of the work performed on the direct fluorination of a variety of organic compounds and materials. The majority of the compounds studied were acids or acid derivatives such as esters or salts of acids. The compounds studied included: ortho-toluic acid, meta-toluic acid, para-toluic acid, sodium acetate, diglycolic acid, diphenyl ether, 2-ethoxyethylacetate, 3-oxoglutaric acid, 2-oxoglutaric acid, and methoxyacetic acid. These materials have been fluorinated at low concentrations of fluorine and at a variety of temperatures varying from room temperature to  $-78^{\circ}\text{C}$ . Invariably with extremely low fluorine concentrations, the resulting products contained very little fluorinated material as evidenced by their infrared spectra. Under longer reaction times and or higher fluorine concentrations, the materials tended to be degraded into low molecular weight volatiles such as  $\text{CO}_2$  and  $\text{CF}_4$ . In some instances complete charring of starting material was observed. Polyethylene has been surface fluorinated and the kinetics of the process have been studied from 25 to  $50^{\circ}\text{C}$ . The rate was determined as indicated by weight gain as a function of time.

REPORT NO: AFML-TR-71-274 AD 744 106  
ACCESS NO: 200,531 January 1972  
TITLE: THE SHEAR AND THERMAL STRESS BEHAVIOR  
OF A SUPERREFINED MINERAL OIL AND A  
FLUROSILICONE

AUTHOR: F. C. Brooks  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: F. C. Brooks (AFML/MBT)  
AFML TASK NO: 734008

ABSTRACT: Two high temperature hydraulic fluids were characterized as to their shear and thermal stress behavior in the environment of a new small-volume high-temperature evaluation stand. A dewaxed superrefined mineral oil was investigated at 550, 600, 625, and  $700^{\circ}\text{F}$  and exhibited no significant degradation to  $600^{\circ}\text{F}$  in the inerted system environment. A modified fluorosilicone was investigated at  $600^{\circ}\text{F}$  and experienced a significant loss in viscosity after 58 hours of environmental residence. A detailed analysis was made of the results of these characterizations and the results of previous studies with the same fluids in a large volume system from the analysis of these data is shown that, for similar test profiles,

ABSTRACT (Cont'd): the two circuits produce fluid property changes which correlated with the induced environments. Relationships between operational features in the two fluid systems and differences in fluid results are established.

REPORT NO: AFML-TR-71-275 AD 902 930L  
ACCESS NO: 200, 830 December 1971  
TITLE: HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS

AUTHOR: H. M. Ezekiel  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: H. M. Ezekiel (AFML/MBC)  
AFML TASK NO: 732001

ABSTRACT: Experimental homopolymer acrylonitrile (PAN) fibers of two tenacity levels were oxidized in air and then heated directly to graphitization temperatures. The oxidized, low tenacity PAN was graphitized at temperatures from 2500 to 3000°C; resulting fibers had densities from 1.5 to 2.0 g/cm<sup>3</sup> and maximum average tensile properties of 230,000 to 275,000 psi tensile strength and 84 to 103 million psi modulus of elasticity. Similar treatment of the high tenacity PAN at temperatures between 2500 and 2800°C gave fiber densities from 1.8 to 2.1 g/cm<sup>3</sup> and tensile strengths and moduli with average values to at least 300,000 psi and 90 million psi, respectively. For the low tenacity precursor the parameters of graphitization temperature, tension, and speed were investigated to some extent.

REPORT NO: AFML-TR-71-281 AD 903 765L  
ACCESS NO: 200, 914 December 1971  
TITLE: THE DIRECT GRAPHITIZATION OF ACRYLONITRILE COPOLYMER YARNS

AUTHOR: H. M. Ezekiel  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: H. M. Ezekiel (AFML/MBC)  
AFML TASK NO: 732001

ABSTRACT: High strength, high modulus graphite fibers were prepared by heating oxidized acrylonitrile copolymer yarns directly to graphitization temperatures. The comonomer was methyl acrylate in one case and vinyl acetate in the other and was present to only a few percent in each instance. The methyl acrylate-containing polymer was graphitized at temperatures from 2500 to 2920°C to give graphite fibers with tensile strengths from 150,000 to 317,000 psi and moduli from 32 to 64 million psi with densities of 1.58 to 2.01 g/cm<sup>3</sup>. Parameters varied in these experiments included the tension at which the polymeric yarn was wound

**ABSTRACT (Cont'd):** prior to oxidation, the temperature and residence time during graphitization, and the tension applied to the yarn during graphitization. Increased residence time gave higher strengths and moduli but other parameters had only minor effects. Most of the graphite fibers from the acrylate-containing copolymer yarn had moduli from 32 to 45 million psi, and average tensile strengths of these fibers were generally well below 200,000 psi. The stabilization of this polymer appeared to be more difficult than for the acrylate copolymer and the graphitization process for the vinyl acetate copolymer fibers was not investigated in detail.

**REPORT NO:** AFML-TR-72-14 (Pt. I) AD 751 973  
**ACCESS NO:** 200,666 March 1972  
**TITLE:** FIBER FORMING THIOACRYLAMIDE POLYMERS  
FROM POLYACRYLONITRILES

**AUTHOR:** L. G. Picklesimer  
**CONTRACT NO:**  
**CONTRACTOR:** INTERNAL  
**PROJECT MONITOR:** L. G. Picklesimer (AFML/MBC)  
**AFML TASK NO:** 732001

**ABSTRACT:** The cyano moiety of polyacrylonitrile homopolymer and copolymer has been converted to thioamide by the addition of gaseous hydrogen sulfide to solutions of the polymers. In one case, 69% of the cyano moiety was converted to the thioamide. The carbonates of sodium, lithium, and potassium were found to catalyze the addition of hydrogen sulfide by the cyano moiety. The polymer solvent was also found to influence the addition of hydrogen sulfide. In the case of dimethyl sulfoxide, the hydrogen sulfide was reduced without addition unless a catalyst was used.

**REPORT NO:** AFML-TR-72-16 AD 903 565L  
**ACCESS NO:** 200,912 July 1972  
**TITLE:** EVALUATION OF CANDIDATE MATERIALS FOR  
FIRE FIGHTER'S PROXIMITY SUITS

**AUTHOR:** R. M. Stanton  
**CONTRACT NO:**  
**CONTRACTOR:** INTERNAL  
**PROJECT MONITOR:** R. M. Stanton (AFML/MBC)  
**AFML TASK NO:** 732002

**ABSTRACT:** Lightweight protective fabrics are needed for incorporation into fire fighter's proximity suits to provide protection, comfort, and increased mobility to the wearer while fighting liquid fuel (JP-4) fires. Candidate materials which are commercially available are evaluated on the basis of protection from radiant heating exposures and for flammability and mechanical properties. Novatex and Fypro shell fabrics in combination with a neoprene water barrier and a Nomex needle punch felt will provide a high degree of protection and increased comfort and mobility for wearers while fighting liquid fuel fires.

REPORT NO: AFML-TR-72-18  
ACCESS NO: 200,663 May 1972  
TITLE: INTERLAMINAR STRESSES IN COMPOSITE  
LAMINATES  
AUTHOR: R. B. Pipes  
CONTRACT NO: F33615-71-C-1244  
CONTRACTOR: General Dynamics  
PROJECT MONITOR: N. J. Pagano (AFML/MBC)  
AFML TASK NO:

ABSTRACT: The mechanism of load transfer between the layers of a fiber-reinforced composite laminate of finite-width is investigated by methods of classical elasticity. The finite-difference technique was employed to obtain numerical solutions of the governing equations of elasticity. Two modes of interlaminar load transfer are identified. The response of the general laminate is investigated, and the influence and interaction of the two load transfer modes are determined. Variables considered in the study include stacking sequence, laminate geometry, material properties, and fiber orientation. Characteristics of the finite-difference solution procedure are investigated and methods are developed for study of convergence of the numerical solutions. Employing the insight gained by the results of the investigations, expressions for the average interlaminar stresses, as a function of material properties and laminate geometry, are developed for consideration in the design of a finite width laminate subjected to extensional loads.

REPORT NO: AFML-TR-72-23 AD 901 780L  
ACCESS NO: 200,686 May 1972  
TITLE: COUPLING OF EPOXY POLYMERS TO  
GRAPHITE FIBERS  
AUTHOR: R. J. Dauksys  
CONTRACT NO:  
CONTRACTOR:Q INTERNAL  
PROJECT MONITOR: R. J. Duaksys (AFML/MBC)  
AFML TASK NO: 734003

ABSTRACT: The information presented herein suggests that it is possible to induce carbonyl specificity to high modulus graphite fibers with subsequent coupling to the oxirane ring of epoxy matrices via a stannic chloride intermediate. Small quantities of a rayon precursor graphite fiber, approximately 100 mg, were treated in such a fashion and examined as to the bonding capability of fiber to epoxy matrix. The treatment proved successful in some areas: tensile strength of the fibers was negligibly reduced and scanning electron photomicrographs of fractured tensile specimens indicated good resin-reinforcement adhesion. Although the treatment shows a potential for improving composite interlaminar shear strength, disadvantages lie in using highly toxic osmium tetroxide as a component in the wet chemical oxidation process, and presented difficulties involved in scaling the batch process to a continuous in-line operation.

**ABSTRACT (Cont'd):** Based on high magnification scanning electron photomicrographs of as-received high modulus graphite fibers and treated fibers, a hypothesis for graphite fiber surface morphology is presented.

**REPORT NO:** AFML-TR-72-24 AD 893 841L  
**ACCESS NO:** 200,525 January 1972  
**TITLE:** EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, HIGH MODULUS GRAPHITE FILAMENTS

**AUTHOR:** D.G. Flom, et al.  
**CONTRACT NO:** F33615-70-C-1444  
**CONTRACTOR:** General Electric Company  
**PROJECT MONITOR:** W.H. Gloor (AFML/MBC)  
**AFML TASK NO:** 732001

**ABSTRACT:** Exploratory development was conducted leading to high strength, high modulus graphite filaments based on polyacetylene precursors. These polymers have carbon contents greater than 90% and can be converted to high performance filaments in very short processing times. In addition, large diameter filaments can be produced readily. The primary objective to achieve a high elongation-to-break simultaneously with high strength, high modulus, and large diameter. While this combination of properties was not reached in this contract period, strengths were obtained as high as 439,000 psi for small diameter filaments and in the 1-mil diameter range average strengths of 275,000 psi were obtained with one value as high as 324,000 psi. The latter exhibited a modulus of  $47 \times 10^6$  psi, leading to an elongation-to-break of 0.7%. The latter properties were achieved at a graphitization temperature of 2550°C.

**REPORT NO:** AFML-TR-72-30 AD 904 092L  
**ACCESS NO:** 200,957 September 1972  
**TITLE:** INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK

**AUTHOR:** R.M. Heitz, et al.  
**CONTRACT NO:** F33615-71-C-1675  
**CONTRACTOR:** Northrop Corporation  
**PROJECT MONITOR:** T. L. Graham (AFML/MBE)  
**AFML TASK NO:** 313

**ABSTRACT:** The objective of this program was to adapt a newly developed self-sealing integral fuel tank materials system to a C-130 integral wing tank and evaluate its resistance to slosh and vibration damage as well as its protective capabilities against small arms ground gunfire. The selected system consists of a combination of flexible ballistic nylon laminates (corrugated and flat) and precompressed Buna-N closed-cell foam. This system, when installed in a C-130 wing integral fuel tank section, was found to withstand slosh and vibration tests. In firing tests of this system installed in a C-130 wing integral fuel tank section, promising results were obtained. The damage control system

ABSTRACT (Cont'd): proved successful in limiting the damage to the C-130 skin structure. The self-sealing system was successful for many .50 caliber AP and API impacts. When the projectiles hit a rib longitudinally and tumbled immediately behind the tank entry skin structure, large areas of the tank were damaged and sealing was only partially effective.

REPORT NO: AFML-TR-72-31 AD 748 259  
ACCESS NO: 200,706 March 1972  
TITLE: DEFECT EQUILIBRIA IN ALKALINE EARTH  
FLUORIDES CONTAINING RARE EARTH IONS

AUTHOR: A. D. Franklin  
CONTRACT NO: F33615-71-M-5001  
CONTRACTOR: National Bureau of Standards  
PROJECT MONITOR: Dr. V. L. Donlan (AFML/MB)  
AFML TASK NO: 737101

ABSTRACT: The point defects present in  $GdF_3$ -doped  $CaF_2$ , with concentrations ranging from 0.01 to 0.46 mole percent  $GdF_3$ , have been studied using measurements of density, EPR, and dielectric and anelastic relaxation as a function of concentration and annealing temperature in an He + HF atmosphere in the range 500°C to 1100°C. The density measurements showed no dependence upon annealing. The unit cell contents increased in mass with increasing  $GdF_3$  concentration more rapidly than expected on the basis of substitutional  $Gd^{3+}$  and interstitial  $F^-$  ions, and suggest the incorporation of an HF molecule with each  $GdF_3$  unit. The role previously suggested for cation vacancies in the annealing behavior appears untenable in light of these density results. The reorientation kinetics of the pair formed by association of the mobile interstitial  $F^-$  ion with the immobile  $Gd^{3+}$  ion were studied using EPR line-broadening and dielectric relaxation measurements, and some anelastic relaxation measurements were made as well.

REPORT NO: AFML-TR-72-65 (Pt. I) AD 755 932  
ACCESS NO: 201,142 May 1972  
TITLE: TORSIONAL TESTING OF FINE FILAMENTS  
PART I: APPARATUS AND PROCEDURES

AUTHOR: W. H. Gloor  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR:  
AFML TASK NO: 732001

ABSTRACT: A device is described for the torsional testing of small-diameter single fibers. Both shear modulus and damping (internal friction) characteristics of fibers can be determined. The apparatus is suitable for fibers ranging in diameter from a few microns to over one mil. The test procedure is outlined and sample calculation of torsional properties are provided.

REPORT NO: AFML-TR-72-66 AD 903 734L  
ACCESS NO: 200,916 March 1972  
TITLE: LONG LIFE ELASTOMERIC SEALS  
AUTHOR: L. G. Hiltner, et al.  
CONTRACT NO: F33615-71-C-1304  
CONTRACTOR: Parker-Hannifin Corporation  
PROJECT MONITOR: L. M. Peterson (AFML/MBE)  
AFML TASK NO: 734005

ABSTRACT: The purpose of this investigation was to develop a material for long life, high temperature, elastomeric hydraulic seals. The objective was to achieve functional service for 1000 hours at 275°F where present indications were that service life was limited to between 300 and 500 hours. The work was essentially limited to investigating the five most likely polymer classes: nitrile, polyacrylate, fluorocarbon, fluorosilicone, and epichlorohydrin. However, during the course of the investigation the "door was left open" to consider new advanced polymers and new production variations of the five basic polymers. Prescreening tests were conducted on approximately 175 compound formulations including some dynamic tests when appropriate on a bench type "chew" test rig. These "chew" tests proved to be quite valuable.

REPORT NO: AFML-TR-72-67 AD 749 853  
ACCESS NO: 200,688 April 1972  
TITLE: STUDIES OF THE BREAKDOWN MECHANISM OF  
POLYMERS VII. THE THERMAL DECOMPOSITION  
OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES  
G. Ehlers, et al.

AUTHOR:  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR: Dr. G. F. L. Ehlers (AFML/MBP)  
AFML TASK NO: 734004

ABSTRACT: Poly-1, 3-phenylene hydrazide, when heated to 250°C in vacuum, partially undergoes cleavage of the N-N bond to yield isophthalonitrile, water, carbon monoxide, and carbon dioxide. The major part converts to the corresponding polyoxadiazole. Poly-1, 3- and -1, 4-phenylene -2, 5 (1, 3, 4-oxadiazole) decompose essentially in the 450 to 500°C region to yield isophthalonitrile, nitrogen, carbon dioxide, hydrogen cyanide, carbon monoxide, water, ammonia, methane, and hydrogen. The 1, 4-polymer decomposes at a slightly higher temperature than the 1, 3-polymer and forms less gaseous products and more condensate. The oxadiazole ring degrades before the benzene ring. Initial competing reactions seem to be the removal of nitrogen, further degradation of the remaining ether linkage, and the elimination of oxygen with subsequent cleavage of the residual -C=N-N=C- linkage.

REPORT NO: AFML-TR-72-69 AD 752 606  
ACCESS NO: 200,661 April 1972  
TITLE: A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS  
AUTHOR: N.J. Olson  
CONTRACT NO: F33615-69-C-1385  
CONTRACTOR: University of Dayton  
PROJECT MONITOR: J.M. Kelble (AFML/MB)  
AFML TASK NO: 734001

ABSTRACT: This report is an operational description of a quartz tube, tungsten filament lamp bank developed for the characterization of nonmetallic thermal protection materials for high irradiance environments. The quartz lamp bank is a highly versatile apparatus for providing irradiances of up to 60 Cal/cm<sup>2</sup>-sec for various specimen configurations of up to 80 square inches in surface area. The three operational modes consist of: (a) a pre-set irradiance level, (b) precise regulation in a closed-loop network including a sensing radiometer, (c) regulation over a programmed irradiance history. Air jets, a high velocity exhaust and pressurized components are used to avoid lamp overheating and minimize contamination of critical components by pyrolysis gases emanating from irradiated materials. The quartz lamp bank has proven to be adaptable and versatile tool in the exploratory research and development of a variety of nonmetallic thermal protection materials. The classes of characterization materials currently consist of camouflage coatings, fire protection elastomers, and textiles.

REPORT NO: AFML-TR-72-70 AD 905 048  
ACCESS NO: 200,955 October 1972  
TITLE: DEVELOPMENT OF SURFACE TREATMENTS FOR TITANIUM ALLOYS FOR ADHESIVE BONDING  
AUTHOR: G.W. Lively  
CONTRACT NO: F33615-71-C-1104  
CONTRACTOR: LTV Aerospace Corporation  
PROJECT MONITOR: E. A. Arvay (AFML/MBC)  
AFML TASK NO: 734002

ABSTRACT: This report describes the development of an improved surface treatment for titanium alloys for adhesive bonding. Numerous surface treatments including acid etch, anodize, vapor blast, and combinations were investigated. The effect of hostile environments such as salt spray, high humidity, and high temperature on bonded tensile lapshear (including prestress and aged) specimens was evaluated. An epoxy-novalac adhesive was utilized for 350°F environments while a polyimide was evaluated at 600°F. A combination mechanical-chemical treatment was found to offer the best surface for bonding titanium alloys. By combining a reactive solution with a conventional vapor blast, intermittent contamination or reoxidation of the cleaned titanium surface was reduced significantly. The treated titanium surfaces were examined with the scanning electron

ABSTRACT (Cont'd): microscope and various topographies correlated to strength values of bonded specimens. Evaporation rate analysis was also utilized. No detrimental effects to the metallurgical properties of the titanium were found. There was no reduction in fatigue strength or ductility and no increase in absorbed hydrogen.

REPORT NO: AFML-TR-72-71 AD 753 414  
ACCESS NO: 201, 143 June 1972  
TITLE: NOVEL BENZOBISTRIAZOLOPHENATHROLINE  
POLYMERS  
AUTHOR: R. C. Evers

CONTRACT NO:  
CONTRACTOR: INTERNAL

PROJECT MONITOR:

AFML TASK NO: 734004

ABSTRACT: Novel, high molecular weight benzobistriazolo-phenanthroline polymers were prepared by the polycondensation of 1, 4, 5, 8-naphthalene tetracarboxylic acid with iso- of tere-phthaldihydrazidine dihydrochloride in polyphosphoric acid. Inherent viscosities in the range of 1.33 to 2.51 were recorded. Tough, transparent films of these polymers could be cast from methane sulfonic acid. Onset of polymer breakdown during thermogravimetric analysis in an air atmosphere occurred at 450°C.

REPORT NO: AFML-TR-72-72 AD 901 949L  
ACCESS NO: 200, 689 June 1972  
TITLE: EXPLORATORY DEVELOPMENT ON FORMATION  
OF HIGH STRENGTH, HIGH MODULUS BORON  
NITRIDE CONTINUOUS FILAMENT YARNS

AUTHOR: R. Y. Lin, et al.  
CONTRACT NO: F33615-71-C-1377  
CONTRACTOR: The Carborundum Company  
PROJECT MONITOR: S. Schulman (AFML/MBC)

AFML TASK NO:

ABSTRACT: A process to produce the high strength, high modulus continuous boron nitride multifilament was developed. The process consists of three fundamental steps; fiber drawing, nitriding and hot stretching. The important process parameters in each step were studied and optimized. The highest average tensile strength and modulus observed thus far are  $171 \times 10^3$  psi and  $40 \times 10^6$  psi respectively. A complete line of fiber characterization techniques were established and the correlation between fiber structure and properties was also made.

REPORT NO: AFML-TR-72-73 AD 746 034  
ACCESS NO: 200,660 June 1972  
TITLE: PERFORMANCE OF BALL BEARINGS IN AIR  
AND VACUUM WITH NO ADDED LUBRICATION

AUTHOR: K. R. Mecklenburg  
CONTRACT NO: F33615-69-C-1236  
CONTRACTOR: Midwest Research Institute  
PROJECT MONITOR: F. C. Brooks (AFML/MBT)  
AFML TASK NO:

ABSTRACT: Forty-one experiments on six different designs of size 204 ball bearings were conducted. The results of these experiments, operating time and frictional torque values determined by coast-down times, are presented for various test atmospheres, loads, and speeds. The experimental approach is outlined and the different test apparatus are described. The distinctive design features of the production-type ball bearings are identified. Even though no lubrication was applied to any of these bearings, several of the specimens ran satisfactorily for over 10,000 hr at speeds of 1,790 and 3,600 rpm with light axial loads of 7 lb nominal. One specimen continues to operate in a vacuum environment after 45,600 hr at 1,790 rpm.

REPORT NO: AFML-TR-72-75 AD 903 906L  
ACCESS NO: 200,991 March 1972  
TITLE: THERMOOXIDATION STUDIES OF THE QUINOXALINE SYSTEM AND CERTAIN BENZIMIDAZOLE COPOLYMER SYSTEMS PART I: INITIAL STUDIES ON THE MECHANISM OF THERMOOXIDATION OF THE QUINOXALINE SYSTEM

AUTHOR: R. T. Conley, et al.  
CONTRACT NO: F33615-68-C-1277  
CONTRACTOR: Wright State University  
PROJECT MONITOR: G. F. L. Ehlers (AFML/MBP)  
AFML TASK NO:

ABSTRACT: A number of model compounds related to the polyquinoxaline system have been synthesized and subjected to solution and pyrolytic oxidation. The pyrolytic oxidation of the model compounds at temperatures between 450 and 500°C reduced benzonitrile, the oxides of carbon and cyanogen. Controlled solution oxidation of phenylquinoxaline model compounds produced the related pyrazinedicarboxylic acids. Subsequent pyrolytic oxidation of the pyrazinedicarboxylic acid (the product of solution oxidation) yielded benzonitrile, carbon dioxide, cyanogen and the parent, phenylpyrazine. The results parallel those obtained in our previous studies with the benzimidazole system and are discussed in terms of an initial oxygenation mechanism for thermal oxidation of the quinoxaline system. Dramatic evidence for thermal oxidation intermediates oxygenated at the carbocyclic ring is presented by product isolation and spectral data.

REPORT NO: AFML-TR-72-85 AD 900 517L  
ACCESS NO: 200,670 May 1972  
TITLE: SUPERSONIC RAIN AND SAND EROSION  
RESEARCH: CHARACTERIZATION AND  
DEVELOPMENT OF EROSION RESISTANT  
MATERIALS

AUTHOR: W.F. Adler, et al.  
CONTRACT NO: F33615-71-C-1219  
CONTRACTOR: Bell Aerospace Company  
PROJECT MONITOR: G.F. Schmitt (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: Development and evaluation of electro-deposited, sprayed and diffusion coatings capable of providing erosion protection for titanium compressor and fan blades on gas turbine engines were carried out. Recently developed hard coatings of carbides and borides exhibited sand erosion resistance 2.5 - 5 times that of uncoated titanium. Results are outlined comparative erosion characteristics of thermoplastic polymers that might be used as coatings and might possess satisfactory rain erosion resistance. Correlation of the physical and mechanical properties of these polymers with erosion resistance, are discussed. The mechanism of erosion damage caused by plastic deformation and progressive fracture is discussed in detail. The erosion process occurring by these two methods considers ductile pitting, abrasion, polishing fatigue, tearing, and brittle fracture.

REPORT NO: AFML-TR-72-92 (Pt. I) AD 901 745L  
ACCESS NO: 200,690 June 1972  
TITLE: HIGH TEMPERATURE ELASTOMER  
REINFORCING MATERIALS

AUTHOR: E.F. Abrams, et al.  
CONTRACT NO: F33615-71-C-1431  
CONTRACTOR: General Technologies Corporation  
PROJECT MONITOR: J.K. Sieron (AFML/MBE)  
AFML TASK NO: 734005

ABSTRACT: Improved techniques for making polycrystalline fibers for fluoroelastomer reinforcement were developed. Magnesium oxide fibers were made with purity greater than 99.7 percent. Fiber diameters were varied from 5 miles to 30 mils by changing spinnerette orifice size and extrusion pressure. Fibers as small as 2 mils diameter were made smaller than 2 mils diameter could not be preformed because of the rheological properties of the spinning solution. The effect of additions of lithium salts during fiber preparation of act as sintering aids was also investigated in detail. Results have shown that the lithium salts are removed by evaporation during sintering of the fibers and that the lithium salt additions assist formation of larger and more dense crystallites in the fibers. Several methods for preparation of CaF<sub>2</sub> fibers were studied.

**ABSTRACT (Cont'd):** None of the approaches attempted met with success because of the limited solubility of CaF<sub>2</sub>. A high temperature process for preparation of MgO fibers from a melt was briefly investigated.

**REPORT NO:** AFML-TR-72-93 AD 906 546L  
**ACCESS NO:** 201, 146 December 1972  
**TITLE:** SYNTHESIS OF SELECTED PERFLUOROALKYL-SUBSTITUTED POLYPHENYL ETHERS  
**AUTHOR:** C. E. Snyder, Jr.

**CONTRACT NO:**  
**CONTRACTOR:** INTERNAL  
**PROJECT MONITOR:**

**AFML TASK NO:** 734008

**ABSTRACT:** This report discusses the synthesis and physical properties of perfluoroalkyl substituted three-, four-, and five-phenyl ethers. The synthetic routes are shown and the fluid properties of the derivatives are compared to those of the unsubstituted derivatives. It was found that the low temperature properties of three of the derivatives prepared were improved over those of the five-ring polyphenylether (5P4E) which is the best one in this class of materials for high temperature fluid applications.

**REPORT NO:** AFML-TR-72-105 AD 901 710L  
**ACCESS NO:** 69, 428 June 1972  
**TITLE:** KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS

**AUTHOR:** H. L. Friedman, et al.  
**CONTRACT NO:** F33615-71-C-1108  
**CONTRACTOR:** General Electric Company  
**PROJECT MONITOR:** Dr. I. J. Goldfarb (AFML/MBP)  
**AFML TASK NO:** 734203

**ABSTRACT:** Research using mass spectrometric thermal analysis to study the thermal degradation of various polymers has now been completed. An improved data processing system was developed, which was based on the use of analog magnetic tape, followed by computations with a hybrid computer system. MTA experimental were carried out for polyquinoxaline for bis benzimidazo benzophenathroline ladder copolymers with quinoxaline, anthraquinone and dibenzofuran. The results were compared with each other and with earlier data.

REPORT NO: AFML-TR-72-106 AD 748 790  
ACCESS NO: 200,709 June 1972  
TITLE: A MODEL FOR RAIN EROSION OF  
HOMOGENEOUS MATERIALS

AUTHOR: G. S. Springer, et al.  
CONTRACT NO: F33615-71-C-1572  
CONTRACTOR: University of Michigan  
PROJECT MONITOR: G. F. Schmitt, Jr. (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: The behavior of homogeneous materials subjected to repeated impingements of liquid droplets is investigated. Based on fatigue theorems, a model is presented for describing both the incubation period  $n_i$  (i. e., the time elapsed before the mass loss of the material becomes appreciable), and the mass loss past the incubation period  $m$ . The parameters are established which govern the length of the incubation period and the subsequent mass loss rate, and simple algebraic expressions are developed relating  $n_i$  and  $m$  to the properties of the impinging droplets and the material. The limits of applicability of the model are also established. The results obtained are compared to available experimental data. Reasonable agreement is found between the present results and the data, indicating that the model developed can be used to estimate the incubation period and the mass loss of the material.

REPORT NO: AFML-TR-72-136 AD 903 875L  
ACCESS NO: 200,961 August 1972  
TITLE: SYNTHESIS AND EVALUATION OF POLY-  
FUNCTIONAL PERFLUOROHYPOFLUORITES

AUTHOR: B. N. Hamon  
CONTRACT NO: F33615-70-C-1739  
CONTRACTOR: PCR, Inc.  
PROJECT MONITOR: J. K. Sieron (AFML/MBE)  
AFML TASK NO: 734005

ABSTRACT: The purpose of this program was to develop stable difluoroxyperfluorinated cross-linking agents for the vulcanization of perfluoro-elastomers, for potential use as seals and sealants on advanced aircraft and missile systems. Several methods were investigated for the preparation of high boiling fluoroxy terminated perfluoroethers and perfluoroalkanes for evaluation as cross-linking agents. In particular, cesium fluoride catalyzed fluorination of acid fluoride terminated perfluoroethers and perfluoroalkanes was investigated in detail. The conversions of the fluoride groups to fluoroxy groups were found to be low (less than 25 percent) in almost every case investigated. The highest conversions were obtained when the fluorinations were carried out on the preformed cesium alkoxide salt of the acid fluoride in the presence of catalytic amounts of elemental iodine.

REPORT NO: AFML-TR-72-143 AD 906 438L  
ACCESS NO: 201, 149 October 1972  
TITLE: THERMAL OXIDATION-POLYMERIC COATING  
TREATMENTS OF HIGH MODULUS GRAPHITE  
FIBERS

AUTHOR: R. J. Dauksys

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR:

AFML TASK NO: 734003

ABSTRACT: The interfacial bond between polyvinyl alcohol (PVA) and water-sized high modulus graphite fibers and an epoxy matrix was improved by thermal oxidation of the fiber surface by a propane-generated flame followed by application of various types of thermoplastic coatings and subsequent impregnation with the epoxy resin solution. This approach was followed in an attempt to obtain a "ductile" zone at the fiber-matrix interface. The mechanical property results indicated that improvement in composite interlaminar shear strength was attained without apparent loss of fiber strength (compared to composites fabricated with the same types of yarn, but untreated). Also, scanning electron microscopy was utilized to obtain photomicrographs of treated fibers and fractured composites.

REPORT NO: AFML-TR-72-144 AD 752 221  
ACCESS NO: 200, 936 July 1972  
TITLE: ANALYTICAL MODELING OF SUBSONIC  
PARTICLE EROSION

AUTHOR: W. F. Adler

CONTRACT NO: F33615-71-C-1528

CONTRACTOR: Bell Aerospace Company

PROJECT MONITOR: G. F. Schmitt, Jr. (AFML/MBE)

AFML TASK NO: 734202

ABSTRACT: An analytical approach to particle erosion of solid surfaces in developed based on a model of erosion pit used to introduce the kinematic and material parameters into this general statistical formulation of erosion processes. In order to minimize the number of unknown factors in the initial development of a predictive erosion theory, the particular case of solid spherical particles impacting directly on the plane surface of an elastic half-space is investigated. Erosion tests were conducted on the AFML-Bell erosion apparatus in conjunction with the modeling studies. The erosion mechanisms in fused silica have been identified when eroded by multiple impacts of spherical glass beads. The erosion process for 2.8 mil beads impacting at 200 fps was found to differ from the sequence of erosion mechanisms associated with 11 mil beads at the same velocity. The observed erosion mechanisms could be correlated with the measured erosion rates.

REPORT NO: AFML-TR-72-145 AD 750 793  
ACCESS NO: 200, 938 August 1972  
TITLE: RAIN EROSION CHARACTERISTICS OF THERMAL  
PROTECTION SYSTEM MATERIALS AT SUB-  
SONIC VELOCITIES

AUTHOR: N. E. Wahl  
CONTRACT NO: F33615-71-C-1219  
CONTRACTOR: Bell Aerospace Company  
PROJECT MONITOR: G. F. Schmitt (AFML/MBE)  
AFML TASK NO: 734007

ABSTRACT: The relative rain erosion resistance of low density thermal protection materials for the space shuttle were evaluated at velocities of 200, 350 and 410 miles per hour, angles of attack of 10, 20, 40 and 90 degrees and rainfall intensities of 1/4, 1/2 and 1 inch per hour on the AFML-Bell rotating arm rain erosion tests apparatus. The program was sponsored and all materials provided by NASA-Manned Spacecraft Center.

REPORT NO: AFML-TR-72-146 AD 903 797L  
ACCESS NO: 200, 959 August 1972  
TITLE: EXPLORATORY DEVELOPMENT OF HIGH  
TEMPERATURE RESINS FOR STRUCTURAL  
LAMINATES AND ADHESIVES

AUTHOR: W. P. Fitzgerald, Jr.  
CONTRACT NO: F33615-71-C-1544  
CONTRACTOR: Whittaker Corporation  
PROJECT MONITOR: T. J. Aponyi (AFML/MBC)  
AFML TASK NO: 734003

ABSTRACT: The polyimidazoquinazoline, PIQ, heterocyclic resin system has been investigated as a high-temperature support resin, and to a limited extent, as a structural adhesive, in several trifunctional and difunctional modifications. Marked improvements in ring-closure efficiency, providing an integral cyclized structure, have been realized through the use of a streamlined cure-postcure schedule which has included a short term final exposure to temperatures exceeding 950<sup>o</sup>F (the approximately glass-transition temperature of the system) preferably at 975<sup>o</sup>F. Low-void, high-perfection laminates have been fabricated with Modmor-II unidirectional reinforcement whose flexural properties equal or exceed the levels of capability of conventional high-performance support resin systems. Further, when a 100 percent trifunctionally-curing system was used (AF-R-530 triazine centered crosslink), in conjunction with the streamlined cure-postcure, a singular level of high-temperature thermomechanical performance has been realized in Modmor-II-unidirectionally reinforced laminates.

REPORT NO: AFML-TR-72-150 AD 905 485  
ACCESS NO: 201,110 August 1972  
TITLE: THE CHARACTERIZATION OF AROMATIC  
POLYAMIDE POLYMERS

AUTHOR: H. A. Wells, et al.

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR: J. Ross (AFML/MBC)

AFML TASK NO: 736005

ABSTRACT: In the last few years the Air Force Materials Laboratory has been evaluating fiber and fabric samples made of aromatic polyamides. This report discusses the analytical methods used to analyze and characterize the polymeric materials. The major portion of the report involves the use of two techniques; internal reflection spectroscopy and spectroscopy of pyrolyzates. The two techniques proved to be very effective in the analysis of the polymeric samples. A number of infrared spectra are given to show how each polymeric material can be differentiated.

REPORT NO: AFML-TR-72-211 AD 907 589  
ACCESS NO: 201,111 September 1972  
TITLE: HIGH STRENGTH, HIGH TEMPERATURE  
POLYMERIC FIBERS

AUTHOR: W. P. Fitzgerald, Jr., et al.

CONTRACT NO: F33615-71-C-1435

CONTRACTOR: Whittaker Corporation

PROJECT MONITOR: W. H. Gloor (AFML/MBC)

PROJECT NO: 7320

ABSTRACT: The subject program has been concerned with the synthesis of specifically ordered heterocyclic polymer systems for evaluation as high tenacity fiber candidates. Specifically sought in the performance spectrum of successful fibers was a high level of mechanical properties, high energy absorption (work-to-break), and high temperature performance. The primary structural criteria for polymer order are: chain growth which describes a straight line; the absence of bulky pendant groups; capability for approaching a planar structure; and interchain bonding. These structural features, which are primarily responsible for providing enhanced thermal and mechanical capability relative to non-oriented counterparts, at the same time render the polymer system highly intractible. Hence, specialized solvent systems and dissolution techniques are required for wet spinnability.

REPORT NO: AFML-TR-72-229 (Pt. I) AD 906 659L  
ACCESS NO: 201, 157 September 1972  
TITLE: DEVELOPMENT OF HIGH TEMPERATURE  
FUNCTIONAL FLUIDS

AUTHOR: R. Anderson, et al.  
CONTRACT NO: F33615-71-C-1406  
CONTRACTOR: PCR, Inc.  
PROJECT MONITOR: C. Snyder (AFML/MBT)  
AFML TASK NO: 734008

ABSTRACT: A series of 1, 3, 5-monotriazines with perfluoroalkylether side chains derived from oligomers of tetrafluoroethylene oxide was prepared. These triazines show dramatically improved low temperature properties in comparison with similar molecular weight triazines derived from hexafluoropropylene oxide (HFPO). Mono-triazines containing side chains derived from both tetrafluoroethylene oxide and HFPO were prepared and their physical properties determined. A series of HFPO-derived dumbbell triazines with connecting groups derived from oxalyl fluoride was prepared. These triazines have lower viscosities and pour points than dumbbell triazines with connecting groups derived from hexafluoroglutaryl fluoride. Trichloro-1, 2, 4-triazine was prepared and its reaction with perfluorovinyl ethers and potassium fluoride was investigated.

SYSTEMS SUPPORT DIVISION (AFML/MX)

REPORT NO: AFML-TR-68-163 (Vol. I) AD 841 847  
ACCESS NO: 48, 186 September 1968  
TITLE: TENSILE PROPERTIES AND FRACTURE  
TOUGHNESS OF 6Al-4V TITANIUM  
AUTHOR: C. E. Hartbower, et al.  
CONTRACT NO: F33615-67-C-1358  
CONTRACTOR: Aerojet-General Corporation  
PROJECT MONITOR: S. O. Davis (AFML/MXE), et al.  
AFML TASK NO: 738106  
ABSTRACT: Phase of a MIL-HDBK data collection has been completed to provide room- and elevated-temperature-tensile and fracture-toughness data on 6Al-4V titanium at a 0.2% offset yield strength of approximately 160 ksi. The material was from second-stage Minuteman rocket-motor cases. The uniaxial tensile-data means were determined for each temperature and plots of percent-of-room temperature tensile-properties versus temperature were constructed for input to MIL-HDBK-5. Based on all of the 540 tests, treated as a non-normal distribution, the A-basis value was 30.6 and the B-basis value was 35.2 ksi-in. 1/2.

REPORT NO: AFML-TR-70-266 AD 743 105  
ACCESS NO: 200, 347 October 1971  
TITLE: EDDY CURRENT INSPECTION OF TURBINE  
BLADES  
AUTHOR: I. R. Kraska, et al.  
CONTRACT NO: F33615-68-C-1429  
CONTRACTOR: General American Transportation Corporation  
PROJECT MONITOR: E. W. McKelvey (AFML/MXA), et al.  
AFML TASK NO: 735109  
ABSTRACT: This report presents the results of a program to find a nondestructive field inspection technique which will detect crackskin in the leading and trailing edges of jet engine turbine blades. Such an inspection is required because of the presence of cracks causes blades failures and can cause the loss of an engine or entire aircraft. Various nondestructive inspection methods were considered and experimentally evaluated in the laboratory. One was found suitable for field testing. This method which uses eddy currents, is described in detail. The ease of operation speed of inspection of built up rotors, and excellent crack detection sensitivity of the eddy current system make it attractive for field maintenance inspection of turbine blades. It is recommended that several such systems, with appropriate application instructions, be provided to maintenance to allow an extended field evaluation of the technique.

REPORT NO: AFML-TR-70-307 (Vol. II) AD 901 697L  
ACCESS NO: 68, 856 June 1972  
TITLE: EROSION MECHANISMS AND IMPROVEMENT  
OF GRAPHITIC MATERIALS VOL. II. HYPER-  
THERMAL EROSION TESTS AND SURFACE  
ROUGHNESS CHARACTERIZATION

AUTHOR: K. M. Kratsch, et al.  
CONTRACT NO: F33615-69-C-1631  
CONTRACTOR: McDonnell Douglas Astronautics Company  
PROJECT MONITOR: C. A. Pratt (AFML/MXS)  
PROJECT NO: 7381

ABSTRACT: This document presents high-pressure ablation data and post test model surface characterization results for nine bulk polycrystalline graphites. The ablation data span stagnation pressure range from 5 to 170 atm. Ablation data are also presented for the AVCO MOD III carbon-carbon material. Axial recession data are presented from a composite of high quality movie film data and oscillograph traces of the test model ablation compensator, designed to maintain the ablation test specimen in a constant-pressure test rhombus. The recession data are correlated with model shape change. Test facility uncertainties including freestream turbulence, enthalpy spike, and arc radiation are considered in the data reduction. The reduced data scatter and general trends in material response evidenced by the recession data suggest that high quality recession data can be obtained and may be used to validate analytical models for the thermochemical and thermomechanical response of candidate materials. Correlation of the graphite microroughness measured from the post test models is presented and correlated with the material microstructural characteristics.

REPORT NO: AFML-TR-71-244 AD 743 311  
ACCESS NO: 200, 682 February 1972  
TITLE: CLADDINGS OF SUPERIOR CORROSION RESISTANCE  
FOR HIGH STRENGTH ALUMINUM ALLOYS

AUTHOR: F. H. Meyer, Jr.  
CONTRACT NO:  
CONTRACTOR: INTERNAL  
PROJECT MONITOR:

AFML TASK NO: 738107

ABSTRACT: This technical report summarizes the results of an evaluation of the corrosion performance of various experimental claddings on 7075-T6 aluminum alloys in certain natural environments for periods of up to 24 months. Claddings tested were 1199, 5457, 7004, 7472, 7072, and 7039 aluminum alloys. The superiority of 1199 and 5457 alloy cladding from the corrosion standpoint in tropical, and semi-tropical and temperature climates was confirmed. Corrosion related blistering of the clad layer indicate some modification of composition of 1199 and 5457

ABSTRACT (Cont'd): alloys might be desirable for long-term corrosion performance. Alloys 7004 and 7472 also were found to be superior to 7072 cladding from the corrosion standpoint but not equal to 1199 and 5457 alloys.

REPORT NO: AFML-TR-71-253 AD 739 204  
ACCESS NO: 200, 356 December 1971  
TITLE: MULTIAXIAL BEHAVIOR OF ATJ-S GRAPHITE  
AUTHOR: J. Jortner  
CONTRACT NO: F33615-71-C-1143  
CONTRACTOR: McDonnell Douglas Astronautics Company  
PROJECT MONITOR: Lt. J. R. Koenig (AFML/MXS)  
AFML TASK NO: 738102

ABSTRACT: An experimental program to explore the fracture and stress-strain behavior of ATJ-S graphite under uniaxial, biaxial, and triaxial stresses is described. The program included the development of triaxial test techniques based on simultaneous pressurization and axial loading of solid and hollow cylindrical specimens. The experimental results include biaxial data obtained by simultaneous internal pressurization and axial loading of hollow cylindrical specimens at room temperature and 200°F; uniaxial tensile and compressive data obtained at room temperature in the with-grain and across-grain directions, and also at some off-axis angles; strains measured during hydrostatic pressurization to 20,000 psi at room temperature; and triaxial data obtained by simultaneous external pressurization and axial loading of solid cylindrical specimens at room temperature.

REPORT NO: AFML-TR-72-1 AD 748 257  
ACCESS NO: 200, 526 February 1972  
TITLE: FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES

AUTHOR: R. E. Jones  
CONTRACT NO: F33615-71-C-1054  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: D. C. Watson (AFML/MXE)  
AFML TASK NO: 738106

ABSTRACT: Tensile, fracture toughness, and crack growth properties of 7175-T736 aluminum alloy die forging were investigated at various temperatures from -65°F to 350°F. Room temperature tensile and fracture toughness data was compared to similar properties for wrought 7075 products. The 7175 appears to be a better alloy. Fatigue crack growth rates at room temperature were similar to 7075-T6 and 7075-T7352 crack growth data in the literature. Crack growth rates increased with increasing temperature from room temperature to 350°F. Crack growth rates below room temperature were probably affected by condensation of moisture at the crack tip and results were inconsistent.

REPORT NO: AFML-TR-72-2 AD 740 878  
ACCESS NO: 200, 527 February 1972  
TITLE: MECHANICAL PROPERTIES OF 7049-T73 AND  
7049-T76 ALUMINUM ALLOY EXTRUSIONS AT  
SEVERAL TEMPERATURES

AUTHOR: R. E. Jones  
CONTRACT NO: F33615-71-C-1054  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: D. C. Watson (AFML/MXE)  
AFML TASK NO: 738106

ABSTRACT: The mechanical properties of (1) a 7049-T73 bar extrusion, (2) a 7049-T73 integrally stiffened extrusion, and (3) a 7049-T76 bar extrusion were evaluated. The evaluation encompassed tensile, fracture toughness, axial fatigue, stress corrosion, and fatigue crack growth testing at several temperatures from  $-65^{\circ}\text{F}$  to  $500^{\circ}\text{F}$ . The tensile properties of the integrally stiffened extrusion were comparable to 7075-T651 extrusion properties in the bar were superior to the 7075-T651 properties. The -T73 bar and T73 integrally stiffened extrusions had superior axial fatigue properties when compared with 7075-T651 extruded panel data in the literature. Failure did not occur in time-to-failure stress corrosion tests using either constant immersion precracked specimen or alternate immersion smooth specimen. The crack growth rate in -T73 bar was similar to that of 7075-T7352 hand forging and 7075-T6 sheet in the literature.

REPORT NO: AFML-TR-72-4 AD 746 288  
ACCESS NO: 200, 584 April 1972  
TITLE: EXPLORATORY DEVELOPMENT OF PROTOTYPE  
MISSILE FUSELAGES

AUTHOR: E. P. Lowe, et al.  
CONTRACT NO: F33615-69-C-1657  
CONTRACTOR: Hughes Aircraft Company  
PROJECT MONITOR: E. J. Morrissey (AFML/MXE)  
AFML TASK NO: 738101

ABSTRACT: A practicable, molded-plastic, missile fuselage concept was successfully developed by the Hughes Aircraft Company utilizing a unique "Quadrant Molding Process". The primary objective of the development was demonstration of the feasibility of producing such a missile fuselage with inexpensive, glass, fiber-reinforced, composite materials with fabrication methods capable of high production at a low cost. All final test objectives were met or exceeded, except the  $270^{\circ}\text{F}$  wing tests. Eight fuselages were produced, delivered to the Air Force Materials Lab, and tested structurally by the Air Force Flight Dynamics Lab.

REPORT NO: AFML-TR-72-9 AD 743 976  
ACCESS NO: 200, 529 February 1972  
TITLE: DETERMINATION OF THERMOPHYSICAL  
PROPERTIES AT HIGH TEMPERATURES BY  
DIRECT HEATING METHODS

AUTHOR: R. E. Taylor  
CONTRACT NO: F33(615)-71-C-1012  
CONTRACTOR: Purdue University  
PROJECT MONITOR: Dr. M. L. Minges (AFML/MXS), et al.  
AFML TASK NO: 738102

ABSTRACT: Modifications to the direct heating apparatus to permit measurement of the thermophysical properties of shorter samples and of samples of anisotropic materials are discussed. Also the measurement of thermal linear expansion using the multiproperty apparatus is described and data are presented for a standard copper sample. Thermophysical property data are cast tungsten and for MOD-3 carbon to about 2500 K are given. These properties include the electrical resistivity, hemispherical total emittance, normal spectral emittance, and thermal conductivity for both materials, Lorenz function for tungsten and thermal linear expansion for MOD-3 carbon. Some data on Thornel 50 and Morgantite II fibers are also presented. A brief analysis of digital data acquisition systems for the laboratory and a description of the system purchased by TPRC are included.

REPORT NO: AFML-TR-72-20 AD 746 343  
ACCESS NO: 200, 679 January 1972  
TITLE: FATIGUE-CRACK PROPAGATION IN D6AC STEEL  
PLATE FOR SEVERAL FLIGHT LOADING PRO-  
FILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS

AUTHOR: C. E. Fedderson  
CONTRACT NO: F33615-71-C-1054  
CONTRACTOR: Battelle Columbus Laboratories  
PROJECT MONITOR: C. L. Harmsworth (AFML/MXE)  
AFML TASK NO: 738106

ABSTRACT: The objective of this experimental program was to obtain an independent evaluation of the fatigue-crack propagation characteristics of D6AC steel for the F-111 aircraft under specific flight loading spectra. The program also included selected studies of constant amplitude fatigue-crack propagation and crack growth retardation under the influence of single overloads. It was determined that fatigue-crack propagation specimens evaluated under spectra with peak loads exceeding one-half of the tensile yield strength of the material sustained significantly longer lifetimes than under spectra wherein the peak loads were significantly below this stress level. An upper limit to this beneficial behavior was not established. It was noted that the distribution of the peak loads were also a significant factor in retarding crack growth.

REPORT NO: AFML-TR-72-95 AD 903 501  
ACCESS NO: 200,915 June 1972  
TITLE: EVALUATION OF MATERIALS APPLICABLE  
TO AEROSPACE SYSTEMS

AUTHOR: D. A. Gerdeman, et al.  
CONTRACT NO: F33615-71-C-1054  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: A. Olevitch (AFML/MXE)  
AFML TASK NO: 738102

ABSTRACT: This report describes the materials evaluations and related efforts completed under contract to the Air Force Materials Laboratory. It is divided into three sections: properties of metals, non-metallic materials evaluation, and other efforts related to materials evaluation. The first section describes programs which involved the evaluation of the mechanical properties of metal alloys. The crack growth properties of D6AC steel were determined and actual components constructed of D6AC and 4340 were fatigue tested. The tensile, crack growth, and fracture toughness properties of roll-extruded HP 9-4-25 were determined as a function of degree of roll-reduction. The second section describes the evaluation of nonmetallic materials. One program discussed involves the storage life of elastomeric fuel tank sealants. Thirty-three materials manufactured by five different companies are involved in this 24 month program. The hydrolytic stability of several potting compounds was also determined.

REPORT NO: AFML-TR-72-117 AD 751 551  
ACCESS NO: 200,708 August 1972  
TITLE: DESIGN CRITERIA TRANSPARENT POLY-  
CARBONATE PLASTIC SHEET

AUTHOR: R. S. Hassard  
CONTRACT NO: F33615-71-C-1465  
CONTRACTOR: Goodyear Aerospace Corporation  
PROJECT MONITOR: R. E. Wittman (AFML/MXE)  
AFML TASK NO: 738108

ABSTRACT: This report is a collection of data obtained from tests performed within the program for determining design criteria for transparent polycarbonate sheet. Included in the appendices is an outline of the complete test program, and five tentative specifications developed for use in polycarbonate testing. The test program deals primarily with the properties of monolithic transparent polycarbonate sheet but also takes cognizance of abrasive resist ve coatings and acrylic cladding as a means of improving the over-all properties of polycarbonate glazing.

REPORT NO: AFML-TR-72-160 (Vol. I) AD 904 361L  
ACCESS NO: 201, 097 July 1972  
TITLE: THERMAL AND MECHANICAL PROPERTIES OF  
ADVANCED HEATSHIELD RESINOUS (CP) AND  
CARBONACEOUS (CC) COMPOSITES VOLUME I:  
TESTS METHODS, COMPARATIVE DATA,  
RECOMMENDED INPUTS AND ANALYSIS

AUTHOR: J. K. Legg, et al.  
CONTRACT NO: F33615-69-C-1796  
CONTRACTOR: Southern Research Institute  
PROJECT MONITOR: Capt. J. T. Tesson (AFML/MXS)  
AFML TASK NO: 738102

ABSTRACT: This document presents the results of a mechanical and thermal property screening program for resinous (CP) and carbonaceous (CC) matrix composites (19 total) which are candidate materials for advanced heatshield application. Volume I presents a summary of all the results with a discussion of the test methods and comparisons of the CP's and CC's. In the CP group of materials, different classes of materials were represented ranging from low compliance (linear stress-strain behavior) to high compliance (bilinear stress-strain behavior) materials. Materials 15 (AVCO ORTH 3D CQP), 14 (AVCO ORTH 3D Carbon Polyimide), and 6 (Whittaker Narcomwrap CP) were similar, low compliance materials. Also, Materials 1 (Aerojet Intremold CP), 3 (MDAC Resep FMI CP), and 4 (GE FMI CP) were similar, high compliance materials. Materials 11 (AVCO ORTH 3D QP) and 10 (AVCO TW R6300) were standards. The CC materials were individually different and indeed were made so that the different critical properties for a heat shield application were different.

REPORT NO: AFML-TR-72-173 AD 753 709  
ACCESS NO: 201, 152 September 1972  
TITLE: ENGINEERING DESIGN DATA FOR ALUMINUM  
ALLOY 7475 IN THE T761 AND T61 CONDITION

AUTHOR: R. R. Cervay  
CONTRACT NO: F33615-71-C-1054  
CONTRACTOR: University of Dayton Research Institute  
PROJECT MONITOR: D. Watson (AFML/MXE)  
AFML TASK NO: 738106

ABSTRACT: Tensile, exfoliation, fatigue, and fatigue crack growth properties were determined for a new aluminum sheet alloy, 7475, in two heat treated conditions. (T761 and T61). The tensile properties of the T61 sheet were superior to those for the T761 sheet. The fatigue crack growth properties were the same from heat treatment to heat treatment and were unaffected by crack orientation in the plate. Conventional notched and unnotched fatigue data showed in the 7475 alloy had superior fatigue resistance compared to presently-in-use aluminum alloys. The exfoliation properties of the T761 sheet were slightly superior to those of the T61 heat treatment.

REPORT NO: AFML-TR-72-196 (Vol. I) AD 755 407  
ACCESS NO: 201,123 September 1972  
TITLE: ENGINEERING DATA ON NEW AEROSPACE  
STRUCTURAL MATERIALS

AUTHOR: O. L. Deel, et al.  
CONTRACT NO: F33615-71-C-1262  
CONTRACTOR: Battelle Columbus Laboratories  
PROJECT MONITOR: C. Harmsworth (AFML/MXE)  
AFML TASK NO: 738106

ABSTRACT: The major objectives of this research program were to evaluate newly developed materials of interest to the Air Force for potential weapons system usage, and then to provide "data sheet" type presentations of engineering data for these materials. The effort covered in this report has concentrated on 17-4 PH (H900) ESR bar, Udimet 710 forged bar, 7050-T7E56 hand forging, 2214-T351 plate, and Ti-6Al-4V (DBHT) diffusion bonded component. The properties investigated include tension, compression, shear, bend, impact, fracture toughness, fatigue, creep and stress-rupture, and stress corrosion at selected temperatures.

TECHNICAL SERVICES DIVISION (AFML/TU)

REPORT NO: AFML-TR-72-147 AD 750 938  
ACCESS NO: 201,012 August 1972  
TITLE: THE DETERMINATION OF CERIUM AND  
GADOLINIUM IN  $\text{CaF}_2$ ,  $\text{CdF}_2$  AND  $\text{SrF}_2$  SINGLE  
CRYSTALS BY EMISSION SPECTROGRAPH  
AUTHOR: L. L. Roush  
CONTRACT NO: F33615-72-C-1040  
CONTRACTOR: Miami University  
PROJECT MONITOR: F. F. Bentley (AFML/TUA)  
AFML TASK NO: 736005  
ABSTRACT: This method fills the need for quantitative deter-  
mination of low concentration levels of cerium and gadolinium in fluoride-  
base single-crystals. The sensitivity and producibility attained will  
enable correlation of optical, electrical, and energy transfer data with  
observed concentration levels. A minimum of sample handling is neces-  
sary. A complete consumption burn is utilized with six replicates to  
achieve sensitivities of 0.01 percent for gadolinium and 0.033 percent  
for cerium in a fluoride-graphite matrix.

REPORT NO: AFML-TR-72-214 AD 749 942  
ACCESS NO: 201,099 October 1972  
TITLE: INFRARED STUDIES WITH SPECIAL REFERENCE  
TO THE LONGER WAVELENGTH REGION, AND  
PHOTOELECTRON SPECTROSCOPY  
AUTHOR: H. W. Tompson  
CONTRACT NO: F61052-69-C-0013  
CONTRACTOR: University of Oxford  
PROJECT MONITOR: F. F. Bentley (AFML/TUA)  
AFML TASK NO: 736702  
ABSTRACT: Photoelectron and infrared spectroscopy were  
applied to problems of molecular structure and reactivity and were studied  
as possible means of chemical analyses. The photoelectron spectra of a  
large number of molecules were measured in the 0-21 eV range. Ioniza-  
tion potentials were assigned in most cases to specific molecular orbitals.  
Shifts of particular energy levels in related series of molecules were  
interpreted in terms of inductive and conjugative effects. Some of the  
ionization potentials were correlated with variations in chemical reactivity.  
The photoelectron spectrometer was modified to measure ionization po-  
tentials to low volatility compounds at temperatures up to 300°C. Infrared  
measurements in the 5000 - 10  $\text{cm}^{-1}$  range were directed at systems in-  
volving hydrogen bonding in the gaseous phase with some studies of hydro-  
gen bonding equilibria in an inert solvent. The use of the fine structure  
of vibration-rotation bands to determine molecular constants was  
considered.

## SUBJECT INDEX

The subject index is presented as a Keyword-Out-of-Context (KWOC) index. Each significant title word is displayed in alphabetic order to the left of the page. The full title is displayed in the middle of the page. The right-hand column shows the access number and page number in the report on which the abstract itself appears.

KWOC ENTRY	TITLE	ACCESS NO./ PAGE NO.
ABLATING	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN- DEPTH HEATING OF A TWO- MATERIAL ABLATING SYSTEM	200619/079
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.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
COMPUTATIONAL	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN- DEPTH HEATING OF A TWO- MATERIAL ABLATING SYSTEM	200619/079

SUBJECT INDEX  
(BY TITLE KEYWORD)

ABLATING	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200619/079
ABLATIVE	ABLATIVE THERMAL PROTECTION COMPOSITES FOR LIFTING VEHICLES	200374/066
ABLATIVE	ABLATIVE PLASTIC CHARACTERIZATION IN ROCKET MOTOR EXHAUST	065437/069
ABRASION	ABRASION RESISTANCE OF POLYBENZIMIDAZOLE FIBROUS MATERIALS	200625/050
ABSORPTANCE	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
ACIDS	APPROACHES TO LADDER STRUCTURES. VIII. POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
ACOUSTIC	CORROSION CRACKING OF METALLIC MATERIALS. PART II: ACOUSTIC EMISSION-EXPERIMENT AND THEORY	200994/024
ACRYLONITRILE	THE DIRECT GRAPHITIZATION OF ACRYLONITRILE COPOLYMER YARNS	200914/083
ACRYLONITRILE	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
ADAPTATION	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	066918/058
ADHESIVE	DEVELOPMENT OF SURFACE TREATMENTS FOR TITANIUM ALLOYS FOR ADHESIVE BONDING	200955/089
ADHESIVES	EXPLORATORY DEVELOPMENT OF STRUCTURAL ADHESIVES HAVING IMPROVED TOUGHNESS PROPERTIES	200350/081
ADHESIVES	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL LAMINATES AND ADHESIVES	200959/096

AEROSOLS	IMPROVING ULTRASONIC TRANSDUCER ASSEMBLIES GENERATING AEROSOLS FOR INSTRUMENTAL TECHNIQUES OF CHEMICAL ANALYSIS	200530/031
AEROSPACE	ENGINEERING DATA ON NEW AEROSPACE STRUCTURAL MATERIALS	201123/106
AEROSPACE	EVALUATION OF MATERIALS APPLICABLE TO AEROSPACE SYSTEMS	200915/104
AIR	FATIGUE-CRACK PROPAGATION IN 06AC STEEL PLATE FOR SEVEPAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
AIR	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200650/091
AIRCRAFT	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
AIRCRAFT	DEVELOPMENT OF FABRICATION TECHNIQUES FOR RORSIC - ALUMINUM AIRCRAFT STRUCTURES	068042/003
AIRCRAFT	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H466/001
AIRCRAFT	COMPARATIVE EVALUATION OF COATED ALLOYS FOR TURBINE COMPONENTS OF ADVANCED AIRCRAFT GAS TURBINE ENGINES. VOL. I	200376/009
AIRCRAFT	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	066918/058
AIRCRAFT	INDUCTION MELTING AND CASTING OF TITANIUM ALLOY AIRCRAFT COMPONENTS	067999/059
AIR-COOLED	DEVELOPMENT OF ALLOY FOR CAST AIR-COOLED TURBINE BLADES	065652/020
AIR-COOLED	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	200472/017
ALKALINE	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/097

ALLOWABLE	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H466/001
ALUMINATE	RESEARCH AND DEVELOPMENT OF YTTRIUM ALUMINATE LASERS	200552/039
ALUMINUM	RESEARCH ON SYNTHESIS OF HIGH-STRENGTH ALUMINUM ALLOYS	200956/028
ALUMINUM	DEVELOPMENT OF THIN FILM ALUMINUM	200354/035
ALUMINUM	DEVELOPMENT OF FABRICATION TECHNIQUES FOR BORSIC - ALUMINUM AIRCRAFT STRUCTURES	068042/003
ALUMINUM	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	048198/005
ALUMINUM	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200677/021
ALUMINUM	MICROSTRUCTURE AND FATIGUE PROPERTIES OF ALUMINUM BASE ALLOYS	200471/017
ALUMINUM	MICROSTRUCTURES OF POWDER AND CONVENTIONALLY PROCESSED 7075 ALUMINUM	200515/014
ALUMINUM	EFFECTS OF THERMOMECHANICAL TREATMENTS ON ALUMINUM ALLOYS	200512/018
ALUMINUM	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
ALUMINUM	CLADDINGS OF SUPERIOR CORROSION RESISTANCE FOR HIGH STRENGTH ALUMINUM ALLOYS	200582/100
ALUMINUM	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
ALUMINUM	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102

ALUMINUM	ENGINEERING DESIGN DATA FOR ALUMINUM ALLOY 7475 IN THE T761 AND T61 CONDITION	201152/105
ALUMINUM	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. I	200504/019
AL-7N-MG	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
AMPLIFIER	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	058210/057
ANALYTICAL	CHEMICAL, STRUCTURAL AND ANALYTICAL RESEARCH	200507/036
ANALYTICAL	ANALYTICAL MODELING OF SUBSONIC PARTICLE EROSION	200936/095
ANTENNAS	ADVANCED COMPOSITE MATERIAL STUDY FOR MILLIMETER WAVELENGTH ANTENNAS	200511/002
APPLICABLE	EVALUATION OF MATERIALS APPLICABLE TO AEROSPACE SYSTEMS	200915/104
APPLICATION	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
APPLICATION	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
APPLICATION	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
APPLICATION	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
APPLICATION	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/062

APPLICATIONS	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILES PHASE I FINAL REPORT VOLUME II: MATERIAL DEVELOPMENT	067854/002
APPLICATIONS	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILE PHASE I FINAL REPORT VOLUME I: STRUCTURAL DEVELOPMENT	067854/001
APPLICATIONS	USAF APPLICATIONS OF LIQUID CRYSTAL MATERIALS	201145/054
APPROACHES	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
AROMATIC	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
AROMATIC	THE CHARACTERIZATION OF AROMATIC POLYAMIDE POLYMERS	201110/097
ARRAYS	MANUFACTURING METHODS FOR MERCURY-DOPED GERMANIUM INFRARED DETECTOR ARRAYS	068500/052
ASSOCIATIVE	MANUFACTURING METHODS FOR ASSOCIATIVE PROCESSOR MEMORY MODULES	200424/049
ATJ-S	THE CORRELATION OF NONDESTRUCTIVE TEST TECHNIQUES WITH THE FRACTURE BEHAVIOR OF ATJ-S GRAPHITE	200913/021
ATJ-S	MULTIAXIAL BEHAVIOR OF ATJ-S GRAPHITE	200356/101
AUSFORMING	MANUFACTURE OF JET ENGINE THRUST BEARINGS BY AUSFORMING	046253/051
A5D	THERMOOXIDATION STUDIES OF THE QUINOXALINE SYSTEM A5D CERTAIN BENZIMIDAZOLE COPOLYMER SYSTEMS PART I	200991/091
A-FE203	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-FE203 (HEMATITE)	200353/032
A-FE203	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-FE203 (HEMATITE)	200353/008

BALL	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200660/091
BALLISTICS	EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS	200993/040
BANK	A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS	200661/089
BASE	MICROSTRUCTURE AND FATIGUE PROPERTIES OF ALUMINUM BASE ALLOYS	200471/017
BASIC	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H466/001
BATTERY	MANUFACTURING METHODS FOR HIGH PERFORMANCE GRAFTED-POLYETHYLENE BATTERY SEPARATORS	067291/051
BEARING	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067384/051
BEARINGS	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200660/091
BEARINGS	MANUFACTURING METHODS FOR PRODUCTION OF HOLLOW-BALL BEARINGS FOR USE IN GAS TURBINE ENGINES	068516/060
BEARINGS	MANUFACTURE OF JET ENGINE THRUST BEARINGS BY AUSFORMING	046253/051
BENDING	FURTHER STUDY OF UNIDIRECTIONAL AND BIDIRECTIONAL COMPOSITES UNDER CYLINDRICAL BENDING	200315/077
BENZENEDIAZOXI	THE SYNTHESIS AND CHEMISTRY OF FLUORINE-CONTAINING BENZENEDIAZOXIDES	200349/076
BENZIMIDAZOLE	THERMOXIDATION STUDIES OF THE QUINOXALINE SYSTEM AND CERTAIN BENZIMIDAZOLE COPOLYMER SYSTEMS PART I	200991/091
BENZOBISTRIAZOL	NOVEL BENZOBISTRIAZOLOPHENATHROLINE POLYMERS	201143/090

BERYLLIUM	FABRICATION AND EVALUATION OF BERYLLIUM INGOT SHEET ALLOYED WITH COPPER AND SILVER	048197/005
BERYLLIUM	DEVELOPMENT OF POROUS BERYLLIUM	055316/014
BERYLLIUM	MANUFACTURING TECHNIQUES FOR PRODUCTION OF SINGLE CRYSTAL BERYLLIUM OXIDE	201102/060
BETA	HEAT TREATMENT STUDY OF BETA EXTRUDED TITANIUM ALLOY TI-3AL-6V-2SN	200687/022
BETA	IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS	200934/025
BIDIRECTIONAL	FURTHER STUDY OF UNIDIRECTIONAL AND BIDIRECTIONAL COMPOSITES UNDER CYLINDRICAL BENDING	200315/077
BILLETS	NEW AND REFINED NONDESTRUCTIVE TECHNIQUES FOR GRAPHITE BILLETS AND SHAPES	200351/006
BIPOLAR	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
BLADES	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/007
BLADES	DEVELOPMENT OF ALLOY FOR CAST AIR-COOLED TURBINE BLADES	065552/020
BLADES	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	200472/017
BLADES	DEVELOPMENT OF PROTECTIVE COATINGS FOR COLUMBIUM ALLOY GAS TURBINE BLADES	200932/009
BLADES	JOINING TECHNIQUES FOR FABRICATION OF HIGH-TEMPERATURE SUPERALLOY BLADES	069556/013
BLADES	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/099
BLOCK	HIGH TEMPERATURE ELASTOMER NETWORKS FROM DIFUNCTIONAL BLOCK POLYMERS	201103/066
BONDED	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
BONDED	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054

BONDING	X-RAY DIFFRACTION STUDIES OF THE ROLE OF HYDROGEN BONDING IN THE LOW TEMPERATURE BEHAVIOR OF MATERIALS	200514/033
BONDING	DEVELOPMENT OF SURFACE TREATMENTS FOR TITANIUM ALLOYS FOR ADHESIVE BONDING	200955/089
BORIDES	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
BORON	RESEARCH ON DEVELOPMENT AND FABRICATION OF BORON SUBOXIDE SPECIMENS	200935/026
BORON	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	048188/005
BORON	DEVELOPMENT AND DEMONSTRATION OF LOW COST BORON FILAMENT FORMATION PROCESS	200911/003
BORON	EXPLOATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
BORSIC	DEVELOPMENT OF FABRICATION TECHNIQUES FOR BORSIC - ALUMINUM AIRCRAFT STRUCTURES	068042/003
BREAKDOWN	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200688/088
BREAKDOWN	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS	200314/077
BRIDGMAN	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
BUBBLE	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	201101/044
BUBBLE	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	200431/038
BULGE	MATHEMATICAL CALIBRATION OF THE RING TEST WITH BULGE FORMATION	200626/020

CADMIUM	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
CADMIUM	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200929/041
CADMIUM	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201138/048
CAF2	THE DETERMINATION OF CERIUM AND GADOLINIUM IN CAF2, CDF2 AND SRF2 SINGLE CRYSTALS BY EMISSION SPECTROGRAPH	201012/107
CALIBRATION	MATHEMATICAL CALIBRATION OF THE RING TEST WITH BULGE FORMATION	200626/020
CANDIDATE	EVALUATION OF CANDIDATE MATERIALS FOR FIRE FIGHTER'S PROXIMITY SUITS	200912/084
CARBIDE	AN INVESTIGATION OF THE MECHANICAL PROPERTIES OF SILICON CARBIDE AND SAPPHIRE FILAMENTS	201153/028
CARBIDE	SILICON CARBIDE WHISKER-METAL MATRIX COMPOSITES	069420/015
CARBIDE	DEVELOPMENT OF SILICON CARBIDE WHISKEYS	200465/080
CARBIDES	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
CARBON	HIGH STRENGTH-HIGH MODULUS CARBON FIBERS	200671/065
CARBONACEOUS	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
CARBON-CARBON	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007
CAST	DEVELOPMENT OF ALLOY FOR CAST AIR-COOLED TURBINE BLADES	065552/020

CASTING	SONIC CASTING OF COTE FOR HIGH POWER IR LASER WINDOWS	201098/046
CASTING	INDUCTION MELTING AND CASTING OF TITANIUM ALLOY AIRCRAFT COMPONENTS	067999/059
CDF2	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING CDF2 WITH CE3+ AND GD3+ CODOPANTS	201011/042
CDF2	THE DETERMINATION OF CERIUM AND GADOLINIUM IN CAF2, CDF2 AND SRF2 SINGLE CRYSTALS BY EMISSION SPECTROGRAPH	201012/107
COTE	SONIC CASTING OF COTE FOR HIGH POWER IR LASER WINDOWS	201098/046
CELLS	MANUFACTURING METHODS FOR SILICON SOLAR CELLS WITH INTEGRAL COVERSLEIPS	200831/055
CELL/R/V	MANUFACTURING PROCESS FOR MOLDED CELL/R/V HEAT SHIELD	200696/056
CERIUM	THE DETERMINATION OF CERIUM AND GADOLINIUM IN CAF2, CDF2 AND SRF2 SINGLE CRYSTALS BY EMISSION SPECTROGRAPH	201012/107
CEROUS	THE FARADAY EFFECT IN CEROUS METAPHOSPHATE GLASS	040792/030
CE3	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF GD3+ IN SRF2 VERSUS THE CONCENTRATION OF CODOPANT CE3+	200995/043
CE3	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING CDF2 WITH CE3+ AND GD3+ CODOPANTS	201011/042
CHARACTERISTICS	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
CHARACTERIZATIO	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
CHARACTERIZATIO	EPITAXIAL GROWTH AND CHARACTERIZATION OF GAAS ON SPINEL	059388/042

CHARACTERIZATIO	MOLECULAR STRUCTURE AND MATERIALS CHARACTERIZATION	200528/038
CHARACTERIZATIO	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERTHERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
CHARACTERIZATIO	A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS	200651/089
CHARACTERIZATIO	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200670/092
CHARACTERIZATIO	THE CHARACTERIZATION OF AROMATIC POLYAMIDE POLYMERS	201110/097
CHARACTERIZATIO	EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION	200373/071
CHARACTERIZATIO	ABLATIVE PLASTIC CHARACTERIZATION IN POCKET MOTOR EXHAUST	065437/069
CHEMISTRY	THE SYNTHESIS AND CHEMISTRY OF FLUORINE-CONTAINING BENZENEDIAZOXIDES	200349/076
CHROMATOGRAPHY	NMR SPECTRAL CHROMATOGRAPHY - A POWERFUL NEW TOOL FOR STRUCTURE DETERMINATION	200482/037
CHROMIUM	A MANUFACTURING PROCESS FOR TD COBALT NICKEL CHROMIUM SHEET	066749/057
CIRCUITS	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
CIRCULAR	MANUFACTURING PROCESS FOR THE CIRCULAR FABRICATION OF PYROLYZED PLASTIC	201154/063
GLADDINGS	GLADDINGS OF SUPERIOR CORROSION RESISTANCE FOR HIGH STRENGTH ALUMINUM ALLOYS	200692/100
COATED	COMPARATIVE EVALUATION OF COATED ALLOYS FOR TURBINE COMPONENTS OF ADVANCED AIRCRAFT GAS TURBINE ENGINES. VOL. I	200376/009
COATING	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095

COATINGS	DAMPING IN PORCELAIN ENAMEL COATINGS	200996/011
COATINGS	DEVELOPMENT OF PROTECTIVE COATINGS FOR COLUMBIUM ALLOY GAS TURBINE BLADES	200832/009
COATINGS	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	200472/017
COATINGS	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-6AL-4V	200317/012
COATINGS	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
COATINGS	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
COATINGS	IMPROVED RADIATION-STABLE THERMAL CONTROL COATINGS	200937/072
COATINGS	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
COATINGS	HIGH TEMPERATURE RESISTANT POLYMERIC COATINGS	044556/068
COBALT	A MANUFACTURING PROCESS FOR TD COBALT NICKEL CHROMIUM SHEET	066749/057
CODOPANT	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF $Gd^{3+}$ IN $SrF_2$ VERSUS THE CONCENTRATION OF CODOPANT $Ce^{3+}$	200995/043
CODOPANTS	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING $CdF_2$ WITH $Ce^{3+}$ AND $Gd^{3+}$ CODOPANTS	201011/042
COLUMBIUM	DEVELOPMENT OF PROTECTIVE COATINGS FOR COLUMBIUM ALLOY GAS TURBINE BLADES	200832/009
COMPLEXES	A FLUORINE-19 NMR STUDY OF SOME FLUOROTITANIUM (IV) COMPLEXES. II.	200557/040

COMPOSITE	EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS	200993/040
COMPOSITE	METAL MATRIX COMPOSITE TECHNOLOGY	200420/011
COMPOSITE	ADVANCED COMPOSITE ENGINE DEVELOPMENT PROGRAM	069126/004
COMPOSITE	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	043188/005
COMPOSITE	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILES PHASE I FINAL REPORT VOLUME II: MATERIAL DEVELOPMENT	067854/002
COMPOSITE	ADVANCED COMPOSITE MATERIAL STUDY FOR MILLIMETER WAVELENGTH ANTENNAS	200511/002
COMPOSITE	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILE PHASE I FINAL REPORT VOLUME I: STRUCTURAL DEVELOPMENT	067854/001
COMPOSITE	INTERLAMINAR STRESSES IN COMPOSITE LAMINATES	200663/085
COMPOSITE	FRACTURE MECHANICS STUDIES OF COMPOSITE SYSTEMS	068216/073
COMPOSITES	GROWTH OF MULTICOMPONENT COMPOSITES FROM THE MELT	200958/027
COMPOSITES	THE TIME DEPENDENT MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES	201100/026
COMPOSITES	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	004466/001
COMPOSITES	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
COMPOSITES	SILICON CARBIDE WHISKER-METAL MATRIX COMPOSITES	069420/015

COMPOSITES	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007
COMPOSITES	DEVELOPMENT OF NONDESTRUCTIVE TEST TECHNIQUES FOR MULTIDIRECTIONAL FIBER-REINFORCED RESIN MATRIX COMPOSITES	200396/010
COMPOSITES	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
COMPOSITES	MICROBUCKLING OF UNIDIRECTIONAL COMPOSITES	200585/079
COMPOSITES	FURTHER STUDY OF UNIDIRECTIONAL AND BIDIRECTIONAL COMPOSITES UNDER CYLINDRICAL BENDING	200315/077
COMPOSITES	MATERIALS PARAMETERS THAT GOVERN THE EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
COMPOSITES	INTERFACE AND MECHANICS RESEARCH IN FIBER REINFORCED COMPOSITES	200683/081
COMPOSITES	ABLATIVE THERMAL PROTECTION COMPOSITES FOR LIFTING VEHICLES	200374/066
COMPOUNDS	VIBRATIONAL SPECTRA OF SUBSTITUTED CYCLOBUTANE COMPOUNDS	200516/036
COMPOUNDS	DIRECT FLUORINATION OF ORGANIC COMPOUNDS	200624/082
COMPOUNDS	OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BISBENZIMIDAZOBENZOPHENANTHROLINE-DION F)	200943/067
COMPOUNDS	THE SYNTHESIS AND THERMOOXIDATIVE DEGRADATION OF POLY(BENZIMIDES) AND RELATED MODEL COMPOUNDS	200423/067
COMPOUNDS	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064

COMPUTATIONAL	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200519/079
COMPUTER	EDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
CONCENTRATION	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF $Gd^{3+}$ IN $SrF_2$ VERSUS THE CONCENTRATION OF CODOPANT $Ce^{3+}$	200995/043
CONCEPTS	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
CONDITION	ENGINEERING DESIGN DATA FOR ALUMINUM ALLOY 7475 IN THE T761 AND T61 CONDITION	201152/105
CONDUCTION	ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE	200692/023
CONSTANT	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF $\alpha$ - $Fe_2O_3$ (HEMATITE)	200353/032
CONSTANT	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF $\alpha$ - $Fe_2O_3$ (HEMATITE)	200353/008
CONTAINING	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
CONTAINING	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
CONTINUOUS	DEVELOPMENT ON PROCESS FOR PRODUCING CONTINUOUS FINE DIAMETER FILAMENTS OF SUPERCONDUCTORS	201014/045
CONTINUOUS	CONTINUOUS OXIDE FILAMENT SYNTHESIS (CVD)	065441/015
CONTINUOUS	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
CONTINUOUS	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093

CONTROL	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200677/021
CONTROL	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
CONTROL	IMPROVED RADIATION-STABLE THERMAL CONTROL COATINGS	200937/072
CONVENTIONALLY	MICROSTRUCTURES OF POWDER AND CONVENTIONALLY PROCESSED 7075 ALUMINUM	200515/014
CONVEX	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	066918/058
COPOLYMER	THERMOOXIDATION STUDIES OF THE QUINOXALINE SYSTEM AND CERTAIN BENZIMIDAZOLE COPOLYMER SYSTEMS PART I	200991/091
COPOLYMER	THE DIRECT GRAPHITIZATION OF ACRYLONITRILE COPOLYMER YARNS	200914/083
COPPER	FABRICATION AND EVALUATION OF BERYLLIUM INGOT SHEET ALLOYED WITH COPPER AND SILVER	048137/005
CORRELATION	THE CORRELATION OF NONDESTRUCTIVE TEST TECHNIQUES WITH THE FRACTURE BEHAVIOR OF ATJ-S GRAPHITE	200913/021
CORROSION	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
CORROSION	STRESS CORROSION CRACKING OF TITANIUM ALLOYS IN METHANOLIC AND OTHER MEDIA	200623/013
CORROSION	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
CORROSION	CORROSION CRACKING OF METALLIC MATERIALS. PART II: ACOUSTIC EMISSION-EXPERIMENT AND THEORY	200994/024
CORROSION	CLADDINGS OF SUPERIOR CORROSION RESISTANCE FOR HIGH STRENGTH ALUMINUM ALLOYS	200582/100

CORROSION	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. I	200504/019
COST	DEVELOPMENT AND DEMONSTRATION OF LOW COST BORON FILAMENT FORMATION PROCESS	200911/003
COUPLING	COUPLING OF EPOXY POLYMERS TO GRAPHITE FIBERS	200636/085
COVERSLIPS	MANUFACTURING METHODS FOR SILICON SOLAR CELLS WITH INTEGRAL COVERSLIPS	200831/055
CRACK	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
CRACK	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200469/016
CRACK	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200577/021
CRACK	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
CRACK	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. I	200504/019
CRACK	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
CRACKING	CORROSION CRACKING OF METALLIC MATERIALS. PART II: ACOUSTIC EMISSION-EXPERIMENT AND THEORY	200994/024
CRACKING	STRESS CORROSION CRACKING OF TITANIUM ALLOYS IN METHANOLIC AND OTHER MEDIA	200623/013
CRACKS	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
CRITERIA	DESIGN CRITERIA TRANSPARENT POLYCARBONATE PLASTIC SHEET	200708/104

CRITICAL	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
CRITICALITY	DEVELOPMENT OF A NONDESTRUCTIVE TESTING TECHNIQUE TO DETERMINE FLAW CRITICALITY	060157/012
CRYSTAL	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041
CRYSTAL	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
CRYSTAL	USAF APPLICATIONS OF LIQUID CRYSTAL MATERIALS	201145/054
CRYSTAL	MANUFACTURING TECHNIQUES FOR PRODUCTION OF SINGLE CRYSTAL BERYLLIUM OXIDE	201102/060
CRYSTALS	THE DETERMINATION OF CERIUM AND GADOLINIUM IN $CaF_2$ , $CdF_2$ AND $SrF_2$ SINGLE CRYSTALS BY EMISSION SPECTROGRAPH	201012/107
CUPROUS	A MASS SPECTROMETRIC STUDY OF THE VAPORIZATION OF CUPROUS IODIDE	200508/034
CURRENT	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/007
CURRENT	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/099
CURVATURE	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025
CYCLOBUTANE	VIBRATIONAL SPECTRA OF SUBSTITUTED CYCLOBUTANE COMPOUNDS	200516/036
CYLINDRICAL	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025
CYLINDRICAL	FURTHER STUDY OF UNIDIRECTIONAL AND BIDIRECTIONAL COMPOSITES UNDER CYLINDRICAL BENDING	200315/077
C-130	INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK	200957/086

DAMAGE	EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS	200993/040
DAMAGE	THE EARLY DETECTION OF FATIGUE DAMAGE	200318/010
DAMPING	DAMPING IN PORCELAIN ENAMEL COATINGS	200996/011
DECAY	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF $G03+$ IN $SrF_2$ VERSUS THE CONCENTRATION OF $COOPANT\ CE3+$	200995/043
DECOMPOSITION	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200688/088
DEFECT	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
DEFECTS	ELECTRON SPIN RESONANCE STUDIES OF DEFECTS IN FLUORITES	200352/033
DEFORMATION	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
DEFORMATION	PROJECT THEMIS METAL DEFORMATION PROCESSING	200942/018
DEGRADATION	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
DEGRADATION	THERMAL DEGRADATION OF POLYMERS USING MASS SPECTROSCOPY-THERMOGRAVIMETRIC ANALYSIS TECHNIQUES	200565/074
DEGRADATION	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
DEGRADATION	THE SYNTHESIS AND THERMOOXIDATIVE DEGRADATION OF POLY(BENZIMIDES) AND RELATED MODEL COMPOUNDS	200423/067
DEMONSTRATION	DEVELOPMENT AND DEMONSTRATION OF LOW COST FIBER FILAMENT FORMATION PROCESS	200911/003

DEMONSTRATION	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/062
DEPENDENT	THE TIME DEPENDENT MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES	201100/026
DESIGN	SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS	201151/027
DESIGN	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H466/001
DESIGN	ENGINEERING DESIGN DATA FOR ALUMINUM ALLOY 7475 IN THE T761 AND T61 CONDITION	201152/105
DESIGN	DESIGN CRITERIA TRANSPARENT POLYCARBONATE PLASTIC SHEET	200708/104
DESIGNS	EFFECTIVE TOOLING DESIGNS FOR PRODUCTION OF PRECISION FORGINGS	068041/056
DETECTION	THE EARLY DETECTION OF FATIGUE DAMAGE	200318/010
DETECTOR	MANUFACTURING METHODS FOR MERCURY-DOPED GERMANIUM INFRARED DETECTOR ARRAYS	068500/052
DIAMETER	DEVELOPMENT ON PROCESS FOR PRODUCING CONTINUOUS FINE DIAMETER FILAMENTS OF SUPERCONDUCTORS	201014/045
DIAMINO	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
DICARBOXYLIC	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
DIE	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	066918/058
DIFFRACTION	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, REFCO5-X BY NEUTRON DIFFRACTION	200939/044

DIFFRACTION	X-RAY DIFFRACTION STUDIES OF THE ROLE OF HYDROGEN BONDING IN THE LOW TEMPERATURE BEHAVIOR OF MATERIALS	200514/033
DIFFUSION	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
DIFFUSION	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054
DIFUNCTIONAL	HIGH TEMPERATURE ELASTOMER NETWORKS FROM DIFUNCTIONAL BLOCK POLYMERS	201193/066
DIGITIZED	FOREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
DIMETHYLFORMAMI	APPROACHES TO LADDER STRUCTURES. VIII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
DISCONTINUOUS	ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE	200692/023
DISPERSION	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF $\alpha$ -FE <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/032
DISPERSION	IMPROVEMENT OF THE OXIDATION RESISTANCE OF DISPERSION STRENGTHENED NICKEL-CHROMIUM ALLOYS	200680/022
DISPERSION	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF $\alpha$ -FE <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/008
DISPERSION	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
DISPERSION-HARD	IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS	200934/025
DISTRIBUCTIONS	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
DOMAIN	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	200481/038

DOMAIN	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	201101/044
DRAW	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	056918/058
DRY	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
DYNAMIC	A NEW MODEL FOR THE DYNAMIC BEHAVIOR OF ELASTOMERIC MATERIALS	200470/016
DYNAMICS	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025
D6AC	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
EARLY	THE EARLY DETECTION OF FATIGUE DAMAGE	200318/010
EARTH	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
EARTH	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
EARTH-COBALT	MATERIALS PROCESSING OF RARE EARTH-COBALT PERMANENT MAGNETS	201155/047
EARTH-COBALT-IR	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, RFEXC05-X BY NEUTRON DIFFRACTION	200939/044
EARTH-TRANSITIO	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT MAGNET MATERIALS	200558/041
EARTH-TRANSITIO	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT-MAGNET MATERIALS	201015/046
EDDY	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/007
EDDY	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/099

EDREM	EDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
ELASTIC	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200469/016
ELASTOMER	HIGH TEMPERATURE ELASTOMER REINFORCING MATERIALS	200690/092
ELASTOMER	HIGH TEMPERATURE ELASTOMER NETWORKS FROM DIFUNCTIONAL BLOCK POLYMERS	201103/066
ELASTOMERIC	A NEW MODEL FOR THE DYNAMIC BEHAVIOR OF ELASTOMERIC MATERIALS	200470/016
ELASTOMERIC	LONG LIFE ELASTOMERIC SEALS	200916/088
ELECTRICAL	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING $\text{COF}_2$ WITH $\text{Ce}^{3+}$ AND $\text{Gd}^{3+}$ CODOPANTS	201011/042
ELECTRICAL	ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE	200692/023
ELECTROCHEMICAL	ELECTROCHEMICAL MACHINING (ECM) VOLUME I - OPTIMIZATION OF PARAMETERS	069197/061
ELECTROCHEMICAL	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/062
ELECTRON	ELECTRON SPIN RESONANCE STUDIES OF DEFECTS IN FLUORITES	200352/033
ELECTROSLAG	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067884/061
EMISSION	THE DETERMINATION OF CERIUM AND GADOLINIUM IN $\text{CaF}_2$ , $\text{COF}_2$ AND $\text{SrF}_2$ SINGLE CRYSTALS BY EMISSION SPECTROGRAPH	201012/107
EMISSION-EXPERI	CORROSION CRACKING OF METALLIC MATERIALS. PART II: ACOUSTIC EMISSION-EXPERIMENT AND THEORY	200934/024
EMITTANCE	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/090

ENAMEL	DAMPING IN PORCELAIN ENAMEL COATINGS	200996/011
ENERGY	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
ENERGY	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041
ENGINE	ADVANCED COMPOSITE ENGINE DEVELOPMENT PROGRAM	069126/004
ENGINE	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	066918/058
ENGINE	MANUFACTURE OF JET ENGINE THRUST BEARINGS BY AUSFORMING	046253/051
ENGINES	COMPARATIVE EVALUATION OF COATED ALLOYS FOR TURBINE COMPONENTS OF ADVANCED AIRCRAFT GAS TURBINE ENGINES. VOL. I	200376/009
ENGINES	MANUFACTURING METHODS FOR PRODUCTION OF HOLLOW-BALL BEARINGS FOR USE IN GAS TURBINE ENGINES	068516/060
ENVIRONMENTAL	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
ENVIRONMENTS	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
ENVIRONMENTS	EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION	200373/071
EPITAXIAL	EPITAXIAL GROWTH AND CHARACTERIZATION OF GaAs ON SPINEL	069388/042
EPITAXIAL	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	201101/044
EPITAXIAL	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	200481/038
EPOXY	COUPLING OF EPOXY POLYMERS TO GRAPHITE FIBERS	200686/085

EQUILIBRIA	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
EROSION	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERThERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
EROSION	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERThERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
EROSION	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200670/092
EROSION	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
EROSION	ANALYTICAL MODELING OF SUBSONIC PARTICLE EROSION	200936/095
EROSION	A MODEL FOR RAIN EROSION OF HOMOGENEOUS MATERIALS	200709/094
EROSION	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200670/092
EROSION	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
ESTABLISHMENT	ESTABLISHMENT OF A MANUFACTURING PROCESS FOR INFRARED GLASS WINDOWS	066655/053
ETHER	SYNTHESIS OF PERFLUOROALIPHATIC ETHER MONOMERS	200681/075
ETHERS	SYNTHESIS OF SELECTED PERFLUOROALKYL-SUBSTITUTED POLYPHENYL ETHERS	201146/093
EXHAUST	ABLATIVE PLASTIC CHARACTERIZATION IN ROCKET MOTOR EXHAUST	065437/069

EXPERIMENTAL	KINETIC ANALYSIS OF THERMOGRAVIMETRY PART III: EXPERIMENTAL MODIFICATIONS	200466/068
EXPLORATORY	EXPLORATORY DEVELOPMENT OF PROTOTYPE MISSILE FUSELAGES	200584/102
EXPLORATORY	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL LAMINATES AND ADHESIVES	200959/096
EXPLORATORY	EXPLORATORY DEVELOPMENT OF STRUCTURAL ADHESIVES HAVING IMPROVED TOUGHNESS PROPERTIES	200350/081
EXPLORATORY	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
EXPLORATORY	EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, HIGH MODULUS GRAPHITE FILAMENTS	200525/085
EXPLORATORY	EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION	200373/071
EXTENDING	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200459/016
EXTRUDED	HEAT TREATMENT STUDY OF BETA EXTRUDED TITANIUM ALLOY TI-6AL-6V-2SN	200687/022
EXTRUSION	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	048188/005
EXTRUSIONS	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102
FABRICATION	RESEARCH ON DEVELOPMENT AND FABRICATION OF BORON SUBOXIDE SPECIMENS	200935/026
FABRICATION	FABRICATION AND EVALUATION OF BERYLLIUM INGOT SHEET ALLOYED WITH COPPER AND SILVER	048187/005
FABRICATION	DEVELOPMENT OF FABRICATION TECHNIQUES FOR BORSIC - ALUMINUM AIRCRAFT STRUCTURES	068042/003

FABRICATION	JOINING TECHNIQUES FOR FABRICATION OF HIGH-TEMPERATURE SUPERALLOY BLADES	068556/013
FABRICATION	MANUFACTURING PROCESS FOR THE CIRCULAR FABRICATION OF PYROLYZED PLASTIC	201154/063
FABRICS	NONFLAMMABLE FABRICS. PART II	200521/072
FAILURE	EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS	200993/040
FARADAY	THE FARADAY EFFECT IN CEROUS METAPHOSPHATE GLASS	040792/030
FATIGUE	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS; FRETTING FATIGUE OF UNCOATED TI-6AL-4V	2003177/012
FATIGUE	THE EARLY DETECTION OF FATIGUE DAMAGE	200318/010
FATIGUE	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200677/021
FATIGUE	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS; PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
FATIGUE	MICROSTRUCTURE AND FATIGUE PROPERTIES OF ALUMINUM BASE ALLOYS	200471/017
FATIGUE	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS; PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
FATIGUE	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
FATIGUE	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
FATIGUE	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS; PART. I	200504/019

FATIGUE	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054
FATIGUE-CRACK	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
FEASIBILITY	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	048188/005
FIBER	INTERFACE AND MECHANICS RESEARCH IN FIBER REINFORCED COMPOSITES	200683/081
FIBER	FIBER FORMING THIOACRYLAMIDE POLYMERS FROM POLYACRYLONITRILES	200666/084
FIBER	HIGH STRENGTH, HIGH MODULUS GRAPHITE FIBER	201136/064
FIBERS	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
FIBERS	HIGH STRENGTH, HIGH TEMPERATURE POLYMERIC FIBERS	201111/097
FIBERS	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095
FIBERS	COUPLING OF EPOXY POLYMERS TO GRAPHITE FIBERS	200686/085
FIBERS	THERMALLY STABLE POLYMERIC FIBERS	046420/065
FIBERS	HIGH STRENGTH-HIGH MODULUS CARBON FIBERS	200671/065
FIBER-REINFORCE	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	048188/005
FIBER-REINFORCE	DEVELOPMENT OF NONDESTRUCTIVE TEST TECHNIQUES FOR MULTIDIRECTIONAL FIBER-REINFORCED RESIN MATRIX COMPOSITES	200396/010
FIBROUS	ABRASION RESISTANCE OF POLYBENZIMIDAZOLE FIBROUS MATERIALS	200625/050
FIGHTER'S	EVALUATION OF CANDIDATE MATERIALS FOR FIRE FIGHTER'S PROXIMITY SUITS	200912/084

FILAMENT	DEVELOPMENT AND DEMONSTRATION OF LOW COST BORON FILAMENT FORMATION PROCESS	200911/003
FILAMENT	CONTINUOUS OXIDE FILAMENT SYNTHESIS (CVD)	065441/015
FILAMENT	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
FILAMENT	SAPPHIRE MULTIPLE FILAMENT AND LARGE PLATE GROWTH PROCESSES	201104/062
FILAMENTS	DEVELOPMENT ON PROCESS FOR PRODUCING CONTINUOUS FINE DIAMETER FILAMENTS OF SUPERCONDUCTORS	201014/045
FILAMENTS	AN INVESTIGATION OF THE MECHANICAL PROPERTIES OF SILICON CARBIDE AND SAPPHIRE FILAMENTS	201153/028
FILAMENTS	EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, HIGH MODULUS GRAPHITE FILAMENTS	200525/086
FILAMENTS	TORSIONAL TESTING OF FINE FILAMENTS PART I: APPARATUS AND PROCEDURES	201142/087
FILAMENTS	SAPPHIRE FILAMENTS	200346/074
FILM	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	200481/038
FILM	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	201101/044
FILM	DEVELOPMENT OF THIN FILM ALUMINUM	200354/035
FILM	IMPROVED HIGH-TEMPERATURE SOLID FILM LUBRICANTS	200513/075
FILMS	ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE	200692/023
FIRE	EVALUATION OF CANDIDATE MATERIALS FOR FIRE FIGHTER'S PROXIMITY SUITS	200912/084
FLAW	DEVELOPMENT OF A NONDESTRUCTIVE TESTING TECHNIQUE TO DETERMINE FLAW CRITICALITY	060157/012

FLIGHT	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
FLUIDS	DEVELOPMENT OF HIGH TEMPERATURE FUNCTIONAL FLUIDS	201157/098
FLUIDS	EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION	200373/071
FLUORESCENCE	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF G03+ IN SRF2 VERSUS THE CONCENTRATION OF CODOPANT CE3+	200995/043
FLUORIDES	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
FLUORINATION	DIRECT FLUORINATION OF ORGANIC COMPOUNDS	200624/082
FLUORINE-CONTAINING	THE SYNTHESIS AND CHEMISTRY OF FLUORINE-CONTAINING BENZENEDIAZOXIDES	200349/076
FLUORINE-19	A FLUORINE-19 NMR STUDY OF SOME FLUOROTITANIUM (IV) COMPLEXES. II.	200657/040
FLUORINE-19	FLUORINE-19 NUCLEAR MAGNETIC RESONANCE	200533/032
FLUORITES	ELECTRON SPIN RESONANCE STUDIES OF DEFECTS IN FLUORITES	200352/033
FLUOROSILICONE	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUOROSILICONE	200531/082
FLUOROTITANIUM	A FLUORINE-19 NMR STUDY OF SOME FLUOROTITANIUM (IV) COMPLEXES. II.	200657/040
FORGING	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
FORGING	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
FORGINGS	EFFECTIVE TOOLING DESIGNS FOR PRODUCTION OF PRECISION FORGINGS	068041/056

FORMATION	DEVELOPMENT AND DEMONSTRATION OF LOW COST BORON FILAMENT FORMATION PROCESS	200911/003
FORMATION	MATHEMATICAL CALIBRATION OF THE RING TEST WITH BULGE FORMATION	200626/020
FORMATION	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
FORMING	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	043188/005
FORMING	FIBER FORMING THIOACRYLAMIDE POLYMERS FROM POLYACRYLONITRILES	200656/084
FORMING	INCREMENTAL STRETCH FORMING	068553/058
FRACTURE	THE CORRELATION OF NONDESTRUCTIVE TEST TECHNIQUES WITH THE FRACTURE BEHAVIOR OF ATJ-S GRAPHITE	200913/021
FRACTURE	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
FRACTURE	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
FRACTURE	TENSILE PROPERTIES AND FRACTURE TOUGHNESS OF 6AL-4V TITANIUM	048186/099
FRACTURE	FRACTURE MECHANICS STUDIES OF COMPOSITE SYSTEMS	068216/073
FRETTING	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-6AL-4V	200317/012
FUEL	FATIGUE-CRACK PROPAGATION IN D5AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
FUEL	INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK	200957/086

FULL-SCALE	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054
FUNCTIONAL	DEVELOPMENT OF HIGH TEMPERATURE FUNCTIONAL FLUIDS	201157/098
FUNDAMENTAL	SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS	201151/027
FUNDAMENTAL	FUNDAMENTAL STUDIES ON REACTIVE OLIGOMERS	200672/071
FURTHER	FURTHER STUDY OF UNIDIRECTIONAL AND BIDIRECTIONAL COMPOSITES UNDER CYLINDRICAL BENDING	200315/077
FUSELAGES	EXPLORATORY DEVELOPMENT OF PROTOTYPE MISSILE FUSELAGES	200584/102
GAAS	EPITAXIAL GROWTH AND CHARACTERIZATION OF GAAS ON SPINEL	069388/042
GADOLINIUM	THE DETERMINATION OF CERIUM AND GADOLINIUM IN $CaF_2$ , $CeF_2$ AND $SrF_2$ SINGLE CRYSTALS BY EMISSION SPECTROGRAPHY	201012/107
GAS	DEVELOPMENT OF PROTECTIVE COATINGS FOR COLUMBIUM ALLOY GAS TURBINE BLADES	200832/009
GAS	COMPARATIVE EVALUATION OF COATED ALLOYS FOR TURBINE COMPONENTS OF ADVANCED AIRCRAFT GAS TURBINE ENGINES. VOL. I	200376/009
GAS	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
GAS	MANUFACTURING METHODS FOR PRODUCTION OF HOLLOW-BALL BEARINGS FOR USE IN GAS TURBINE ENGINES	068516/060
GD3	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING $CeF_2$ WITH $Ce^{3+}$ AND $GD^{3+}$ CODOPANTS	201011/042
GD3	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF $GD^{3+}$ IN $SrF_2$ VERSUS THE CONCENTRATION OF CODOPANT $Ce^{3+}$	200995/043

GEAR	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
GENERAL	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200459/016
GENERATING	IMPROVING ULTRASONIC TRANSDUCER ASSEMBLIES GENERATING AEROSOLS FOR INSTRUMENTAL TECHNIQUES OF CHEMICAL ANALYSIS	200530/031
GERMANIUM	MANUFACTURING METHODS FOR MERCURY-DOPPED GERMANIUM INFRARED DETECTOR ARRAYS	068500/052
GLASS	THE FARADAY EFFECT IN CEROUS METAPHOSPHATE GLASS	040792/030
GLASS	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
GLASS	ESTABLISHMENT OF A MANUFACTURING PROCESS FOR INFRARED GLASS WINDOWS	066655/053
GOVERN	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
GRAFTED-POLYETH	MANUFACTURING METHODS FOR HIGH PERFORMANCE GRAFTED-POLYETHYLENE BATTERY SEPARATORS	067291/051
GRAPHITE	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	069988/047
GRAPHITE	THE CORRELATION OF NONDESTRUCTIVE TEST TECHNIQUES WITH THE FRACTURE BEHAVIOR OF ATJ-S GRAPHITE	200913/021
GRAPHITE	NEW AND REFINED NONDESTRUCTIVE TECHNIQUES FOR GRAPHITE BILLETS AND SHAPES	200351/006
GRAPHITE	MULTIAXIAL BEHAVIOR OF ATJ-S GRAPHITE	200356/101
GRAPHITE	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
GRAPHITE	EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, HIGH MODULUS GRAPHITE FILAMENTS	200525/086

GRAPHITE	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095
GRAPHITE	COUPLING OF EPOXY POLYMERS TO GRAPHITE FIBERS	200636/085
GRAPHITE	HIGH STRENGTH, HIGH MODULUS GRAPHITE FIBER	201136/064
GRAPHITE/EPOXY	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H466/001
GRAPHITIC	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERTHERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
GRAPHITIZATION	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
GRAPHITIZATION	THE DIRECT GRAPHITIZATION OF ACRYLONITRILE COPOLYMER YARNS	200914/083
GROWTH	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
GROWTH	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	200481/038
GROWTH	GROWTH OF MULTICOMPONENT COMPOSITES FROM THE MELT	200958/027
GROWTH	EPITAXIAL GROWTH AND CHARACTERIZATION OF GaAs ON SPINEL	069388/042
GROWTH	EPITAXIAL FILM GROWTH OF BUBBLE DOMAIN MATERIALS	201101/044
GROWTH	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200677/021
GROWTH	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101

GROWTH	SAPPHIRE MULTIPLE FILAMENT AND LARGE PLATE GROWTH PROCESSES	201104/062
HAVING	EXPLORATORY DEVELOPMENT OF STRUCTURAL ADHESIVES HAVING IMPROVED TOUGHNESS PROPERTIES	200350/081
HEAT	HEAT TREATMENT STUDY OF BETA EXTRUDED TITANIUM ALLOY TI-6AL-6V-2SN	200587/022
HEAT	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
HEAT	MANUFACTURING PROCESS FOR MOLDED CELL/R/V HEAT SHIELD	200696/056
HEATING	DETERMINATION OF THERMOPHYSICAL PROPERTIES AT HIGH TEMPERATURES BY DIRECT HEATING METHODS	200529/103
HEATING	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200519/079
HEATSHIELD	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CR) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
HELICOPTER	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054
HIGH-FREQUENCY	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
HIGH-STRENGTH	RESEARCH ON SYNTHESIS OF HIGH-STRENGTH ALUMINUM ALLOYS	200956/028
HIGH-STRENGTH	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200677/021
HIGH-TEMPERATUR	JOINING TECHNIQUES FOR FABRICATION OF HIGH-TEMPERATURE SUPERALLOY BLADES	068556/013
HIGH-TEMPERATUR	IMPROVED HIGH-TEMPERATURE SOLID FILM LUBRICANTS	200513/075

HOLLOW-BALL	MANUFACTURING METHODS FOR PRODUCTION OF HOLLOW-BALL BEARINGS FOR USE IN GAS TURBINE ENGINES	068516/060
HOMOGENEOUS	A MODEL FOR RAIN EROSION OF HOMOGENEOUS MATERIALS	200709/094
HOMOPOLYMER	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
HOT	THE FEASIBILITY OF FORMING A BORON FIBER-REINFORCED ALUMINUM COMPOSITE BY A HOT EXTRUSION PROCESS	048188/005
HUB	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054
HUGONIOT	THE HUGONIOT OF A SOLID DETERMINED BY MEANS OF A VARIATIONAL PRINCIPLE	200669/034
HYDROGEN	X-RAY DIFFRACTION STUDIES OF THE ROLE OF HYDROGEN BONDING IN THE LOW TEMPERATURE BEHAVIOR OF MATERIALS	200514/033
HYPERSONIC	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
HYPERTHERMAL	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERTHERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
IDENTIFY	EDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
II-VI	ROOM TEMPERATURE INJECTION LUMINESCENCE IN II-VI SEMICONDUCTORS	068307/039
IMPACT	LONGITUDINAL IMPACT ON A ROD OF RATE-DEPENDENT MATERIAL	200654/023
IMPORTANCE	IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS	200934/025
INCREMENTAL	INCREMENTAL STRETCH FORMING	068553/058

INDUCTION	INDUCTION MELTING AND CASTING OF TITANIUM ALLOY AIRCRAFT COMPONENTS	067999/059
INFRARED	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/032
INFRARED	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
INFRARED	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/008
INFRARED	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201099/107
INFRARED	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
INFRARED	ESTABLISHMENT OF A MANUFACTURING PROCESS FOR INFRARED GLASS WINDOWS	065565/053
INFRARED	MANUFACTURING METHODS FOR MERCURY-DOPED GERMANIUM INFRARED DETECTOR ARRAYS	068500/052
INGOT	FABRICATION AND EVALUATION OF BERYLLIUM INGOT SHEET ALLOYED WITH COPPER AND SILVER	049187/005
INJECTION	ROOM TEMPERATURE INJECTION LUMINESCENCE IN II-VI SEMICONDUCTORS	068307/039
INSPECTION	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/007
INSPECTION	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/099
INSTALLATION	INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK	200957/086
INSTRUCTIONS	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	068210/057
INSTRUMENTAL	IMPROVING ULTRASONIC TRANSDUCER ASSEMBLIES GENERATING AEROSOLS FOR INSTRUMENTAL TECHNIQUES OF CHEMICAL ANALYSIS	200530/031

INSULATING	ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE	200692/023
INTEGRAL	INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK	200957/086
INTEGRAL	MANUFACTURING METHODS FOR SILICON SOLAR CELLS WITH INTEGRAL COVERSLEIPS	200831/055
INTEGRATED	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
INTEGRITY	MANUFACTURING METHODS FOR SURFACE INTEGRITY OF MACHINED STRUCTURAL COMPONENTS	068517/050
INTERFACE	INTERFACE AND MECHANICS RESEARCH IN FIBER REINFORCED COMPOSITES	200693/081
INTERLAMINAR	INTERLAMINAR STRESSES IN COMPOSITE LAMINATES	200653/085
INTERMEDIATES	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070
INVOLVING	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
IN-DEPTH	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200619/079
IODIDE	A MASS SPECTROMETRIC STUDY OF THE VAPORIZATION OF CUPROUS IODIDE	200508/034
IONS	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
IR	SONIC CASTING OF CdTe FOR HIGH POWER IR LASER WINDOWS	201098/046
IR	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
IR	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041

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ISOTHERMAL	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
IV	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H456/001
JET	MANUFACTURE OF JET ENGINE THRUST BEARINGS BY AUSFORMING	046253/051
JOINING	JOINING TECHNIQUES FOR FABRICATION OF HIGH-TEMPERATURE SUPERALLOY BLADES	068556/013
JP-4	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
KINETIC	KINETIC ANALYSIS OF THERMOGRAVIMETRY PART III: EXPERIMENTAL MODIFICATIONS	200466/058
KINETICS	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	069988/047
KINETICS	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
KU-BAND	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	068210/057
KW	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	068210/057
LADDER	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
LADDER	POLYANTHRAZOLINES AND LADDER POLYQUINOXALINES	069041/070
LAMINATES	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069

LAMINATES	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL LAMINATES AND ADHESIVES	200959/096
LAMINATES	INTERLAMINAR STRESSES IN COMPOSITE LAMINATES	200663/085
LAMP	A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS	200661/089
LANDING	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
LARGE	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
LARGE	SAPPHIRE MULTIPLE FILAMENT AND LARGE PLATE GROWTH PROCESSES	201104/062
LASER	SONIC CASTING OF COTE FOR HIGH POWER IR LASER WINDOWS	201098/046
LASER	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
LASER	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
LASER	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041
LASER	LASER WELDING PRECISION MINIATURE ASSEMBLIES	200678/052
LASERS	RESEARCH AND DEVELOPMENT OF YTTRIUM ALUMINATE LASERS	200552/039
LENGTH	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
LIFE	LONG LIFE ELASTOMERIC SEALS	200916/089
LIFTING	ABLATIVE THERMAL PROTECTION COMPOSITE FOR LIFTING VEHICLES	200374/066

LINES	LDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
LIQUID	USAF APPLICATIONS OF LIQUID CRYSTAL MATERIALS	201145/054
LOADING	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200469/016
LOADING	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVEPAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
LONGER	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201099/107
LONGITUDINAL	LONGITUDINAL IMPACT ON A ROD OF RATE-DEPENDENT MATERIAL	200664/023
LONG-SHOT	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
LUBRICANTS	IMPROVED HIGH-TEMPERATURE SOLID FILM LUBRICANTS	200513/075
LUBRICANTS	EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION	200373/071
LUBRICATION	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200650/091
LUMINESCENCE	ROOM TEMPERATURE INJECTION LUMINESCENCE IN II-VI SEMICONDUCTORS	068307/039
MACHINED	MANUFACTURING METHODS FOR SURFACE INTEGRITY OF MACHINED STRUCTURAL COMPONENTS	069517/050
MACHINING	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/062
MACHINING	ELECTROCHEMICAL MACHINING (ECM) VOLUME I - OPTIMIZATION OF PARAMETERS	069197/061

MAGNET	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT MAGNET MATERIALS	200658/041
MAGNETIC	FLUORINE-19 NUCLEAR MAGNETIC RESONANCE	200533/032
MAGNETIC	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, RFEXC05-X BY NEUTRON DIFFRACTION	200939/044
MAGNETS	MATERIALS PROCESSING OF RARE EARTH-COBALT PERMANENT MAGNETS	201155/047
MAIN	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054
MAIN	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
MANUFACTURE	MANUFACTURE OF JET ENGINE THRUST BEARINGS BY AUSFORMING	046253/051
MANUFACTURING	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
MANUFACTURING	MANUFACTURING METHODS FOR ASSOCIATIVE PROCESSOR MEMORY MODULES	200424/049
MANUFACTURING	MANUFACTURING METHODS FOR SURFACE INTEGRITY OF MACHINED STRUCTURAL COMPONENTS	068517/050
MANUFACTURING	MANUFACTURING METHODS FOR HIGH PERFORMANCE GRAFTED-POLYETHYLENE BATTERY SEPARATORS	057291/051
MANUFACTURING	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
MANUFACTURING	MANUFACTURING METHODS FOR MERCURY-DOPED GERMANIUM INFRARED DETECTOR ARRAYS	068500/052
MANUFACTURING	MANUFACTURING PROCESS FOR THE CIRCULAR FABRICATION OF PYROLYZED PLASTIC	201154/063
MANUFACTURING	A MANUFACTURING PROCESS FOR TD COBALT NICKEL CHROMIUM SHEET	066749/057

MANUFACTURING	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	068210/057
MANUFACTURING	MANUFACTURING METHODS FOR PRODUCTION OF HOLLOW-BALL BEARINGS FOR USE IN GAS TURBINE ENGINES	068516/060
MANUFACTURING	MANUFACTURING TECHNIQUES FOR PRODUCTION OF SINGLE CRYSTAL BERYLLIUM OXIDE	201102/060
MANUFACTURING	MANUFACTURING PROCESS FOR MOLDED CELL/R/V HEAT SHIELD	200696/056
MANUFACTURING	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
MANUFACTURING	MANUFACTURING METHODS FOR SILICON SOLAR CELLS WITH INTEGRAL COVERSLIPS	200831/055
MANUFACTURING	ESTABLISHMENT OF A MANUFACTURING PROCESS FOR INFRARED GLASS WINDOWS	066655/053
MASS	A MASS SPECTROMETRIC STUDY OF THE VAPORIZATION OF CUPROUS IODIDE	200508/034
MASS	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	069988/047
MASS	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
MASS	THERMAL DEGRADATION OF POLYMERS USING MASS SPECTROSCOPY-THERMOGRAVIMETRIC ANALYSIS TECHNIQUES	200665/074
MATHEMATICAL	MATHEMATICAL CALIBRATION OF THE RING TEST WITH BULGE FORMATION	200626/020
MATRIX	THE TIME DEPENDENT MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES	201100/026

MATRIX	DEVELOPMENT OF NONDESTRUCTIVE TEST TECHNIQUES FOR MULTIDIRECTIONAL FIBER-REINFORCED RESIN MATRIX COMPOSITES	200396/010
MATRIX	SILICON CARBIDE WHISKER-METAL MATRIX COMPOSITES	069420/015
MATRIX	METAL MATRIX COMPOSITE TECHNOLOGY	200420/011
MEASUREMENTS	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007
MECHANICAL	THE TIME DEPENDENT MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES	201100/026
MECHANICAL	AN INVESTIGATION OF THE MECHANICAL PROPERTIES OF SILICON CARBIDE AND SAPPHIRE FILAMENTS	201153/028
MECHANICAL	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
MECHANICAL	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102
MECHANICAL	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
MECHANICAL	EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION	200373/071
MECHANICAL	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067884/061
MECHANICS	INTERFACE AND MECHANICS RESEARCH IN FIBER REINFORCED COMPOSITES	200683/081
MECHANICS	FRACTURE MECHANICS STUDIES OF COMPOSITE SYSTEMS	068216/073

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MECHANISM	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLLES	200688/088
MECHANISM	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS	200314/077
MECHANISMS	EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS	200993/040
MECHANISMS	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
MECHANISMS	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
MECHANISMS	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERTHERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
MECHANISMS	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
MEDIA	STRESS CORROSION CRACKING OF TITANIUM ALLOYS IN METHANOLIC AND OTHER MEDIA	200623/013
MELT	GROWTH OF MULTICOMPONENT COMPOSITES FROM THE MELT	200958/027
MELTED	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067884/061
MELTING	INDUCTION MELTING AND CASTING OF TITANIUM ALLOY AIRCRAFT COMPONENTS	067999/059
MEMORY	MANUFACTURING METHODS FOR ASSOCIATIVE PROCESSOR MEMORY MODULES	200424/049
MERCURY-DOPED	MANUFACTURING METHODS FOR MERCURY-DOPED GERMANIUM INFRARED DETECTOR ARRAYS	068500/052

METALLIC	CORROSION CRACKING OF METALLIC MATERIALS. PART II: ACOUSTIC EMISSION-EXPERIMENT AND THEORY	200994/024
METALLURGICAL	METALLURGICAL CONTROL OF FATIGUE CRACK GROWTH IN HIGH-STRENGTH ALUMINUM ALLOYS	200677/021
METAPHOSPHATE	THE FARADAY EFFECT IN CEROUS METAPHOSPHATE GLASS	640792/030
METHANOLIC	STRESS CORROSION CRACKING OF TITANIUM ALLOYS IN METHANOLIC AND OTHER MEDIA	200623/013
MICROBUCKLING	MICROBUCKLING OF UNIDIRECTIONAL COMPOSITES	200585/079
MICROMOSAIC	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
MICROSTRUCTURE	MICROSTRUCTURE AND FATIGUE PROPERTIES OF ALUMINUM BASE ALLOYS	200471/017
MICROSTRUCTURES	MICROSTRUCTURES OF POWDER AND CONVENTIONALLY PROCESSED 7075 ALUMINUM	200515/014
MILLIMETER	ADVANCED COMPOSITE MATERIAL STUDY FOR MILLIMETER WAVELENGTH ANTENNAS	200511/002
MINERAL	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUROSILICONE	200531/082
MINIATURE	LASER WELDING PRECISION MINIATURE ASSEMBLIES	200678/052
MISSILE	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILE PHASE I FINAL REPORT VOLUME I: STRUCTURAL DEVELOPMENT	067854/001
MISSILE	EXPLORATORY DEVELOPMENT OF PROTOTYPE MISSILE FUSELAGES	200584/102
MISSILES	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILES PHASE I FINAL REPORT VOLUME II: MATERIAL DEVELOPMENT	057854/002
MODE	IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS	200934/025

MODIFICATIONS	KINETIC ANALYSIS OF THERMOGRAVIMETRY PART III: EXPERIMENTAL MODIFICATIONS	200466/068
MODIFIED	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
MODULES	MANUFACTURING METHODS FOR ASSOCIATIVE PROCESSOR MEMORY MODULES	200424/049
MODULUS	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095
MODULUS	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
MODULUS	EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, HIGH MODULUS GRAPHITE FILAMENTS	200525/086
MODULUS	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
MODULUS	HIGH STRENGTH, HIGH MODULUS GRAPHITE FIBER	201136/064
MODULUS	HIGH STRENGTH-HIGH MODULUS CARBON FIBERS	200571/065
MOLDED	MANUFACTURING PROCESS FOR MOLDED CELL/R/V HEAT SHIELD	200596/056
MOLECULAR	MOLECULAR STRUCTURE AND MATERIALS CHARACTERIZATION	200528/038
MOLECULAR	MOLECULAR STRUCTURES STUDIES AND OTHER RELATED RESEARCH	200473/037
MONOMERS	SYNTHESIS OF PERFLUOROALIPHATIC ETHER MONOMERS	200681/076
MOTOR	ABLATIVE PLASTIC CHARACTERIZATION IN ROCKET MOTOR EXHAUST	065437/069
MULTIAXIAL	MULTIAXIAL BEHAVIOR OF ATJ-S GRAPHITE	200356/101
MULTICOMPONENT	GROWTH OF MULTICOMPONENT COMPOSITES FROM THE MELT	200958/027

MULTIDIRECTIONAL	DEVELOPMENT OF NONDESTRUCTIVE TEST TECHNIQUES FOR MULTIDIRECTIONAL FIBER-REINFORCED RESIN MATRIX COMPOSITES	200396/010
MULTIPLE	SAPPHIRE MULTIPLE FILAMENT AND LARGE PLATE GROWTH PROCESSES	201104/062
MANUFACTURING	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
M-50	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067894/061
NETWORKS	HIGH TEMPERATURE ELASTOMER NETWORKS FROM DIFUNCTIONAL BLOCK POLYMERS	201103/066
NEUTRON	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, REXCO5-X BY NEUTRON DIFFRACTION	200939/044
NICKEL	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	203472/017
NICKEL	A MANUFACTURING PROCESS FOR TD COBALT NICKEL CHROMIUM SHEET	066749/057
NICKEL-CHROMIUM	IMPROVEMENT OF THE OXIDATION RESISTANCE OF DISPERSION STRENGTHENED NICKEL-CHROMIUM ALLOYS	200680/022
NITRIDE	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
NMR	A FLUORINE-19 NMR STUDY OF SOME FLUOROTITANIUM (IV) COMPLEXES. II.	200357/040
NMR	NMR SPECTRAL CHROMATOGRAPHY - A POWERFUL NEW TOOL FOR STRUCTURE DETERMINATION	200482/037
NO	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200630/091
NONDESTRUCTIVE	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008

NONDESTRUCTIVE	DEVELOPMENT OF A NONDESTRUCTIVE TESTING TECHNIQUE TO DETERMINE FLAW CRITICALITY	060157/012
NONDESTRUCTIVE	THE CORRELATION OF NONDESTRUCTIVE TEST TECHNIQUES WITH THE FRACTURE BEHAVIOR OF ATJ-S GRAPHITE	200913/021
NONDESTRUCTIVE	DEVELOPMENT OF NONDESTRUCTIVE TEST TECHNIQUES FOR MULTIDIRECTIONAL FIBER-REINFORCED RESIN MATRIX COMPOSITES	200396/010
NONDESTRUCTIVE	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007
NONDESTRUCTIVE	NEW AND REFINED NONDESTRUCTIVE TECHNIQUES FOR GRAPHITE BILLETS AND SHAPES	200351/006
NONFLAMMABLE	NONFLAMMABLE FABRICS. PART II	200521/072
NONMETALLIC	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
NON-UNIFORMLY	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200469/016
NOSE	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
NOSE	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
NOVEL	NOVEL BENZOBISTRIAZOLOPHENATHROLINE POLYMERS	201143/090
NUCLEAR	FLUORINE-19 NUCLEAR MAGNETIC RESONANCE	200533/032
OIL	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUROSILICONE	200531/082
OLIGOMERS	FUNDAMENTAL STUDIES ON REACTIVE OLIGOMERS	200672/071

OPERATING	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	069210/057
OPTICAL	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/032
OPTICAL	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/008
OPTIMIZATION	ELECTROCHEMICAL MACHINING (ECM) VOLUME I - OPTIMIZATION OF PARAMETERS	069197/061
OPTIMIZED	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/062
ORGANIC	DIRECT FLUORINATION OF ORGANIC COMPOUNDS	200624/082
ORGANOMETALLIC	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
ORGANOMETALLOID	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
OXIDATION	IMPROVEMENT OF THE OXIDATION RESISTANCE OF DISPERSION STRENGTHENED NICKEL-CHROMIUM ALLOYS	200680/022
OXIDATION	OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BISBENZIMIDAZOBENZOPHENANTHROLINE-DIONE)	200943/067
OXIDATION-POLYM	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095
OXIDE	CONTINUOUS OXIDE FILAMENT SYNTHESIS (CVD)	069441/015
OXIDE	MANUFACTURING TECHNIQUES FOR PRODUCTION OF SINGLE CRYSTAL BERYLLIUM OXIDE	201102/060
PARAMETERS	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/076

PARAMETERS	ELECTROCHEMICAL MACHINING (ECM) VOLUME I - OPTIMIZATION OF PARAMETERS	069197/051
PARAMETERS	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/052
PARTICLE	ANALYTICAL MODELING OF SUBSONIC PARTICLE EROSION	200936/095
PENTOXIDE	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
PERCHLORO	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
PERFLUORO	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
PERFLUOROALIPHA	SYNTHESIS OF PERFLUOROALIPHATIC ETHER MONOMERS	200681/076
PERFLUOROALKYL-	SYNTHESIS OF SELECTED PERFLUOROALKYL-SUBSTITUTED POLYPHENYL ETHERS	201146/093
PERFLUOROHYPOFL	SYNTHESIS AND EVALUATION OF POLY-FUNCTIONAL PERFLUOROHYPOFLUORITES	200951/094
PERFORMANCE	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200650/091
PERFORMANCE	MANUFACTURING METHODS FOR HIGH PERFORMANCE GRAFTED-POLYETHYLENE BATTERY SEPARATORS	067291/051
PERMANENT	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT MAGNET MATERIALS	200658/041
PERMANENT	MATERIALS PROCESSING OF RARE EARTH-COBALT PERMANENT MAGNETS	201155/047
PERMANENT-MAGNET	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT-MAGNET MATERIALS	201015/046

PHASE	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILES PHASE I FINAL REPORT VOLUME II: MATERIAL DEVELOPMENT	067854/002
PHASE	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILE PHASE I FINAL REPORT VOLUME I: STRUCTURAL DEVELOPMENT	067854/001
PHASES	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
PHOSPHORUS	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
PHOTOELECTRON	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201099/107
PIGMENTED	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
PLASTIC	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
PLASTIC	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
PLASTIC	DESIGN CRITERIA TRANSPARENT POLYCARBONATE PLASTIC SHEET	200708/104
PLASTIC	ABLATIVE PLASTIC CHARACTERIZATION IN ROCKET MOTOR EXHAUST	065437/069
PLASTIC	MANUFACTURING PROCESS FOR THE CIRCULAR FABRICATION OF PYROLYZED PLASTIC	201154/063
PLATE	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
PLATE	SAPPHIRE MULTIPLE FILAMENT AND LARGE PLATE GROWTH PROCESSES	201104/062

POLYACRYLONITRI	FIBER FORMING THIOACRYLAMIDE POLYMERS FROM POLYACRYLONITRILES	200666/084
POLYAMIDE	THE CHARACTERIZATION OF AROMATIC POLYAMIDE POLYMERS	201110/097
POLYANTHRAZOLIN	POLYANTHRAZOLINES AND LADDER POLYQUINOXALINES	069041/070
POLYBENZIMIDAZO	ABRASION RESISTANCE OF POLYBENZIMIDAZOLE FIBROUS MATERIALS	200625/050
POLYCARBONATE	DESIGN CRITERIA TRANSPARENT POLYCARBONATE PLASTIC SHEET	200708/104
POLYCONDENSATIO	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
POLYCRYSTALLINE	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
POLYHYDRAZIDE	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200688/088
POLYMER	POLYMER STRUCTURES AND PROPERTIES	069422/073
POLYMERIC	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
POLYMERIC	HIGH STRENGTH, HIGH TEMPERATURE POLYMERIC FIBERS	201111/097
POLYMERIC	HIGH TEMPERATURE RESISTANT POLYMERIC COATINGS	044556/068
POLYMERIC	THERMALLY STABLE POLYMERIC FIBERS	046420/065
POLYMERS	THERMAL DEGRADATION OF POLYMERS USING MASS SPECTROSCOPY-THERMOGRAVIMETRIC ANALYSIS TECHNIQUES	200655/074
POLYMERS	FIBER FORMING THIOACRYLAMIDE POLYMERS FROM POLYACRYLONITRILES	200536/084



POLYMERS	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS	200314/077
POLYMERS	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
POLYMERS	THE CHARACTERIZATION OF AROMATIC POLYAMIDE POLYMERS	201110/097
POLYMERS	COUPLING OF EPOXY POLYMERS TO GRAPHITE FIBERS	200636/085
POLYMERS	NOVEL BENZOBISTRIAZOLOPHENATHROLINE POLYMERS	201143/090
POLYMERS	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200688/088
POLYMERS	HIGH TEMPERATURE ELASTOMER NETWORKS FROM DIFUNCTIONAL BLOCK POLYMERS	201103/066
POLYMERS	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070
POLYMERS	OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BISBENZIMIDAZOBENZOPHENANTHROLINE-DION E)	200943/067
POLYOXADIAZOLES	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200688/088
POLYPHENYL	SYNTHESIS OF SELECTED PERFLUOROALKYL-SUBSTITUTED POLYPHENYL ETHERS	201146/093
POLYQUINOXALINE	POLYANTHRAZOLINES AND LADDER POLYQUINOXALINES	069041/070
POLY-FUNCTIONAL	SYNTHESIS AND EVALUATION OF POLY-FUNCTIONAL PERFLUOROHYPOFLUORITES	200961/094

POLY(BENZIMIDAZ	OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BISBENZIMIDAZOBENZOPHENANTHROLINE-DION E)	200943/067
POLY(BENZIMIDE	OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BISBENZIMIDAZOBENZOPHENANTHROLINE-DION E)	200943/067
POLY(BENZIMIDES	THE SYNTHESIS AND THERMOOXIDATIVE DEGRADATION OF POLY(BENZIMIDES) AND RELATED MODEL COMPOUNDS	200423/067
POLY(BISBENZIMI	OXIDATION STUDIES OF MODEL COMPOUNDS AND POLYMERS RELATED TO POLY(BENZIMIDAZOLE) POLY(BENZIMIDE) AND POLY(BISBENZIMIDAZOBENZOPHENANTHROLINE-DION E)	200943/067
PORCELAIN	DAMPING IN PORCELAIN ENAMEL COATINGS	200996/011
POROUS	DEVELOPMENT OF POROUS BERYLLIUM	065316/014
POWDER	MICROSTRUCTURES OF POWDER AND CONVENTIONALLY PROCESSED 7075 ALUMINUM	200515/014
POWER	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
POWER	SONIC CASTING OF CDTE FOR HIGH POWER IR LASER WINDOWS	201098/046
POWER	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	068210/057
POWERFUL	NMR SPECTRAL CHROMATOGRAPHY - A POWERFUL NEW TOOL FOR STRUCTURE DETERMINATION	200482/037
PRECISE	PROCEDURES FOR THE PRECISE DETERMINATION OF THERMAL RADIATION PROPERTIES	200586/031
PRECISION	EFFECTIVE TOOLING DESIGNS FOR PRODUCTION OF PRECISION FORGINGS	068041/056

PRECISION	LASER WELDING PRECISION MINIATURE ASSEMBLIES	200578/052
PRECURSORS	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
PREDICTING	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
PREDICTING	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200619/079
PREDICTION	AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PART 2	200524/006
PRELIMINARY	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING $\text{CdF}_2$ WITH $\text{Ce}^{3+}$ AND $\text{Gd}^{3+}$ CODOPANTS	201011/042
PRESSURE	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	059988/047
PRESSURE	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
PRESSURE	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
PROCEDURES	PROCEDURES FOR THE PRECISE DETERMINATION OF THERMAL RADIATION PROPERTIES	200586/031
PROCEDURES	TORSIONAL TESTING OF FINE FILAMENTS PART I: APPARATUS AND PROCEDURES	201142/087
PROCEDURES	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070
PROFILES	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103

PROJECT	PROJECT THEMIS METAL DEFORMATION PROCESSING	200942/018
PROPAGATION	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
PROPAGATION	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. II - MECHANISMS OF CORROSION FATIGUE CRACK PROPAGATION IN AL-ZN-MG ALLOYS	200505/019
PROPAGATION	CORROSION FATIGUE CRACK PROPAGATION IN ALUMINUM ALLOYS: PART. I	200504/019
PROPAGATION	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVEPAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
PROPERTIES	PROCEDURES FOR THE PRECISE DETERMINATION OF THERMAL RADIATION PROPERTIES	200586/031
PROPERTIES	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING CDF <sub>2</sub> WITH CE <sub>3+</sub> AND GD <sub>3+</sub> CODOPANTS	201011/042
PROPERTIES	AN INVESTIGATION OF THE MECHANICAL PROPERTIES OF SILICON CARBIDE AND SAPPHIRE FILAMENTS	201153/028
PROPERTIES	MICROSTRUCTURE AND FATIGUE PROPERTIES OF ALUMINUM BASE ALLOYS	200471/017
PROPERTIES	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
PROPERTIES	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007
PROPERTIES	DETERMINATION OF THERMOPHYSICAL PROPERTIES AT HIGH TEMPERATURES BY DIRECT HEATING METHODS	200529/103

PROPERTIES	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
PROPERTIES	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102
PROPERTIES	TENSILE PROPERTIES AND FRACTURE TOUGHNESS OF 5AL-4V TITANIUM	048186/099
PROPERTIES	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
PROPERTIES	EXPLORATORY DEVELOPMENT OF STRUCTURAL ADHESIVES HAVING IMPROVED TOUGHNESS PROPERTIES	200350/081
PROPERTIES	POLYMER STRUCTURES AND PROPERTIES	069422/073
PROTECTION	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
PROTECTION	ABLATIVE THERMAL PROTECTION COMPOSITES FOR LIFTING VEHICLES	200374/056
PROTECTIVE	DEVELOPMENT OF PROTECTIVE COATINGS FOR COLUMBIUM ALLOY GAS TURBINE BLADES	200832/009
PROTECTIVE	A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS	200651/089
PROTECTIVE	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
PROTOTYPE	EXPLORATORY DEVELOPMENT OF PROTOTYPE MISSILE FUSELAGES	200584/102
PROXIMITY	EVALUATION OF CANDIDATE MATERIALS FOR FIRE FIGHTER'S PROXIMITY SUITS	200912/084
PT	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069

PYROLYZED	MANUFACTURING PROCESS FOR THE CIRCULAR FABRICATION OF PYROLYZED PLASTIC	201154/063
QUALITY	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
QUARTZ	A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS	200651/089
QUINOXALINE	THERMOOXIDATION STUDIES OF THE QUINOXALINE SYSTEM AND CERTAIN BENZIMIDAZOLE COPOLYMER SYSTEMS PART I	200991/091
RADIATION	PROCEDURES FOR THE PRECISE DETERMINATION OF THERMAL RADIATION PROPERTIES	200586/031
RADIATION-STABLE	IMPROVED RADIATION-STABLE THERMAL CONTROL COATINGS	200937/072
RAIN	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
RAIN	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200670/092
RAIN	A MODEL FOR RAIN EROSION OF HOMOGENEOUS MATERIALS	200709/094
RAIN	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
RARE	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, RFeXCO <sub>5</sub> -X BY NEUTRON DIFFRACTION	200939/044
RARE	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT MAGNET MATERIALS	200668/041
RARE	MATERIALS PROCESSING OF RARE EARTH-COBALT PERMANENT MAGNETS	201155/047
RARE	RESEARCH AND DEVELOPMENT OF RARE EARTH-TRANSITION METAL ALLOYS AS PERMANENT-MAGNET MATERIALS	201015/046

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RARE	DEFECT EQUILIBRIA IN ALKALINE EARTH FLUORIDES CONTAINING RARE EARTH IONS	200706/087
RATE-DEPENDENT	LONGITUDINAL IMPACT ON A ROD OF RATE-DEPENDENT MATERIAL	200654/023
RATIOS	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
REACTIVE	FUNDAMENTAL STUDIES ON REACTIVE OLIGOMERS	200672/071
RECESSION	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200619/079
REFINED	NEW AND REFINED NONDESTRUCTIVE TECHNIQUES FOR GRAPHITE BILLETS AND SHAPES	200351/006
REFRACTORY	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
REGION	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201099/107
REINFORCED	DEVELOPMENT AND APPLICATION OF NONDESTRUCTIVE METHODS FOR PREDICTING MECHANICAL PROPERTIES OF ADVANCED REINFORCED NONMETALLIC COMPOSITES	200348/008
REINFORCED	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
REINFORCED	INTERFACE AND MECHANICS RESEARCH IN FIBER REINFORCED COMPOSITES	200683/081
REINFORCING	HIGH TEMPERATURE ELASTOMER REINFORCING MATERIALS	200690/092
RELATIONSHIP	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007

REPAIR	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	200472/017
REPETITIVELY	EDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
REPROCESS	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	200472/017
REQUIRED	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070
RESIN	DEVELOPMENT OF NONDESTRUCTIVE TEST TECHNIQUES FOR MULTIDIRECTIONAL FIBER-REINFORCED RESIN MATRIX COMPOSITES	200396/010
RESINOUS	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
RESINS	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL LAMINATES AND ADHESIVES	200959/096
RESISTANCE	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
RESISTANCE	ABRASION RESISTANCE OF POLYBENZIMIDAZOLE FIBROUS MATERIALS	200625/050
RESISTANCE	EVALUATION OF BALLISTIC DAMAGE RESISTANCE AND FAILURE MECHANISMS OF COMPOSITE MATERIALS	200993/040
RESISTANCE	IMPROVEMENT OF THE OXIDATION RESISTANCE OF DISPERSION STRENGTHENED NICKEL-CHROMIUM ALLOYS	200680/022
RESISTANCE	CLADDINGS OF SUPERIOR CORROSION RESISTANCE FOR HIGH STRENGTH ALUMINUM ALLOYS	200682/100

RESISTANT	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-5AL-4V	200317/012
RESISTANT	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200570/092
RESISTANT	HIGH TEMPERATURE RESISTANT POLYMERIC COATINGS	044556/068
RESONANCE	ELECTRON SPIN RESONANCE STUDIES OF DEFECTS IN FLUORITES	200352/033
RESONANCE	FLUORINE-19 NUCLEAR MAGNETIC RESONANCE	200533/032
RE-ENTRY	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
RFEXC05-X	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, RFEXC05-X BY NEUTRON DIFFRACTION	200939/044
RING	MATHEMATICAL CALIBRATION OF THE RING TEST WITH BULGE FORMATION	200626/020
RINGS	ADAPTATION OF THE CONVEX DRAW DIE TO THE PRODUCTION OF AIRCRAFT ENGINE RINGS	066918/058
ROCKET	ABLATIVE PLASTIC CHARACTERIZATION IN ROCKET MOTOR EXHAUST	065437/069
ROD	LONGITUDINAL IMPACT ON A ROD OF RATE-DEPENDENT MATERIAL	200654/023
ROLE	X-RAY DIFFRACTION STUDIES OF THE ROLE OF HYDROGEN BONDING IN THE LOW TEMPERATURE BEHAVIOR OF MATERIALS	200514/033
ROLL	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
ROOM	ROOM TEMPERATURE INJECTION LUMINESCENCE IN II-VI SEMICONDUCTORS	069307/039
ROTOR	FULL-SCALE FATIGUE TEST OF A DIFFUSION BONDED HELICOPTER MAIN ROTOR HUB	200628/054

ROUGHNESS	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERTHERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	058856/100
SAND	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200670/092
SAPPHIRE	AN INVESTIGATION OF THE MECHANICAL PROPERTIES OF SILICON CARBIDE AND SAPPHIRE FILAMENTS	201153/028
SAPPHIRE	SAPPHIRE FILAMENTS	200346/074
SAPPHIRE	SAPPHIRE MULTIPLE FILAMENT AND LARGE PLATE GROWTH PROCESSES	201104/062
SCALE	MANUFACTURING METHODS FOR BIPOLAR MICROMOSAIC LARGE SCALE INTEGRATED CIRCUITS	200627/053
SCANNED	EDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
SCHEME	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200619/079
SEALS	LONG LIFE ELASTOMERIC SEALS	200916/088
SELENIDE	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
SELF-SEALING	INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK	200957/086
SEMICONDUCTING	A PRELIMINARY STUDY OF THE ELECTRICAL PROPERTIES OF SEMICONDUCTING $CdF_2$ WITH $Ce^{3+}$ AND $Gd^{3+}$ CODOPANTS	201011/042
SEMICONDUCTORS	ROOM TEMPERATURE INJECTION LUMINESCENCE IN II-VI SEMICONDUCTORS	058307/039
SEPARATORS	MANUFACTURING METHODS FOR HIGH PERFORMANCE GRAFTED-POLYETHYLENE BATTERY SEPARATORS	057231/051

SEVERAL	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
SEVERAL	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
SEVERAL	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102
SHAPES	NEW AND REFINED NONDESTRUCTIVE TECHNIQUES FOR GRAPHITE BILLETS AND SHAPES	200351/006
SHAPES	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
SHEAR	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUROSILICONE	200531/082
SHEET	FABRICATION AND EVALUATION OF BERYLLIUM INGOT SHEET ALLOYED WITH COPPER AND SILVER	048197/005
SHEET	DESIGN CRITERIA TRANSPARENT POLYCARBONATE PLASTIC SHEET	200708/104
SHEET	A MANUFACTURING PROCESS FOR TD COBALT NICKEL CHROMIUM SHEET	066749/057
SHELLS	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025
SHIELD	MANUFACTURING PROCESS FOR MOLDED CELL/R/V HEAT SHIELD	200696/056
SILICON	AN INVESTIGATION OF THE MECHANICAL PROPERTIES OF SILICON CARBIDE AND SAPPHIRE FILAMENTS	201153/028
SILICON	SILICON CARBIDE WHISKER-METAL MATRIX COMPOSITES	069420/015
SILICON	DEVELOPMENT OF SILICON CARBIDE WHISKERS	200465/080
SILICON	MANUFACTURING METHODS FOR SILICON SOLAR CELLS WITH INTEGRAL COVERS LIPS	200831/055

SILVER	FABRICATION AND EVALUATION OF BERYLLIUM INGOT SHEET ALLOYED WITH COPPER AND SILVER	049197/005
SINGLE	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041
SINGLE	PREPARATION AND CHARACTERIZATION OF HIGH QUALITY SINGLE CRYSTAL REFRACTORY METAL BORIDES AND CARBIDES	044555/030
SINGLE	THE DETERMINATION OF CERIUM AND GADOLINIUM IN CaF <sub>2</sub> , CeF <sub>2</sub> AND SrF <sub>2</sub> SINGLE CRYSTALS BY EMISSION SPECTROGRAPH	201012/107
SINGLE	MANUFACTURING TECHNIQUES FOR PRODUCTION OF SINGLE CRYSTAL BERYLLIUM OXIDE	201102/060
SKIN	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
SLIP	IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS	200934/025
SOLAR	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200620/080
SOLAR	MANUFACTURING METHODS FOR SILICON SOLAR CELLS WITH INTEGRAL COVERSIPS	200831/055
SOLID	THE HUGONIOT OF A SOLID DETERMINED BY MEANS OF A VARIATIONAL PRINCIPLE	200659/034
SOLID	SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS	201151/027
SOLID	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
SOLID	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200469/016
SOLID	IMPROVED HIGH-TEMPERATURE SOLID FILM LUBRICANTS	200513/075
SOLUTION	SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS	201151/027

SOLUTION	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
SONIC	SONIC CASTING OF CDTE FOR HIGH POWER IR LASER WINDOWS	201038/046
SPACECRAFT	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILES PHASE I FINAL REPORT VOLUME II: MATERIAL DEVELOPMENT	067854/002
SPACECRAFT	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILE PHASE I FINAL REPORT VOLUME I: STRUCTURAL DEVELOPMENT	067854/001
SPATIALLY	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025
SPECIAL	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201039/107
SPECIMENS	RESEARCH ON DEVELOPMENT AND FABRICATION OF BORON SUBOXIDE SPECIMENS	200935/026
SPECTRA	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe2O3 (HEMATITE)	200353/032
SPECTRA	EDREM - A COMPUTER PROGRAM TO IDENTIFY LINES IN REPETITIVELY SCANNED DIGITIZED SPECTRA	200509/035
SPECTRA	VIBRATIONAL SPECTRA OF SUBSTITUTED CYCLOBUTANE COMPOUNDS	200516/036
SPECTRA	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe2O3 (HEMATITE)	200353/008
SPECTRAL	NMR SPECTRAL CHROMATOGRAPHY - A POWERFUL NEW TOOL FOR STRUCTURE DETERMINATION	200482/037
SPECTROGRAPH	THE DETERMINATION OF CERIUM AND GADOLINIUM IN CaF2, CdF2 AND SrF2 SINGLE CRYSTALS BY EMISSION SPECTROGRAPHY	201012/107
SPECTROMETER	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	069988/047

SPECTROMETRIC	A MASS SPECTROMETRIC STUDY OF THE VAPORIZATION OF CUPROUS IODIDE	200508/034
SPECTROMETRY	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
SPECTROSCOPY	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201099/107
SPECTROSCOPY-TH	THERMAL DEGRADATION OF POLYMERS USING MASS SPECTROSCOPY-THERMOGRAVIMETRIC ANALYSIS TECHNIQUES	200655/074
SPIN	ELECTRON SPIN RESONANCE STUDIES OF DEFECTS IN FLUORITES	200352/033
SPINEL	EPITAXIAL GROWTH AND CHARACTERIZATION OF GaAs ON SPINEL	069388/042
SRF2	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF $Gd^{3+}$ IN $SRF_2$ VERSUS THE CONCENTRATION OF CO-DOPANT $Ce^{3+}$	200995/043
SRF2	THE DETERMINATION OF CERIUM AND GADOLINIUM IN $CaF_2$ , $GdF_2$ AND $SRF_2$ SINGLE CRYSTALS BY EMISSION SPECTROGRAPHY	201012/107
STABILIZED	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
STABLE	THERMALLY STABLE POLYMERIC FIBERS	046420/065
STABLE	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070
STEEL	FATIGUE-CRACK PROPAGATION IN D6AC STEEL PLATE FOR SEVERAL FLIGHT LOADING PROFILES IN DRY AIR AND JP-4 FUEL ENVIRONMENTS	200679/103
STEEL	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067884/061
STIFFENED	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025

STIFFENED	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
STRENGTH	CLADDINGS OF SUPERIOR CORROSION RESISTANCE FOR HIGH STRENGTH ALUMINUM ALLOYS	200692/100
STRENGTH	HIGH STRENGTH, HIGH TEMPERATURE POLYMERIC FIBERS	201111/097
STRENGTH	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200689/090
STRENGTH	EXPLORATORY DEVELOPMENT OF HIGH STRENGTH, HIGH MODULUS GRAPHITE FILAMENTS	200525/086
STRENGTH	HIGH MODULUS, HIGH STRENGTH GRAPHITE FIBERS BY DIRECT GRAPHITIZATION OF STABILIZED ACRYLONITRILE HOMOPOLYMER PRECURSORS	200830/083
STRENGTH	HIGH STRENGTH, HIGH MODULUS GRAPHITE FIBER	201136/064
STRENGTHENED	IMPROVEMENT OF THE OXIDATION RESISTANCE OF DISPERSION STRENGTHENED NICKEL-CHROMIUM ALLOYS	200680/022
STRENGTHENED	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
STRENGTHENING	SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS	201151/027
STRENGTHENING	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
STRENGTH-HIGH	HIGH STRENGTH-HIGH MODULUS CARBON FIBERS	200671/065
STRESS	STRESS CORROSION CRACKING OF TITANIUM ALLOYS IN METHANOLIC AND OTHER MEDIA	200623/013
STRESS	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUOROSILICONE	200531/082
STRESSES	INTERLAMINAR STRESSES IN COMPOSITE LAMINATES	200663/085

STRETCH	INCREMENTAL STRETCH FORMING	068553/058
STRUCTURAL	CHEMICAL, STRUCTURAL AND ANALYTICAL RESEARCH	200507/036
STRUCTURAL	MANUFACTURING METHODS FOR SURFACE INTEGRITY OF MACHINED STRUCTURAL COMPONENTS	068517/050
STRUCTURAL	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
STRUCTURAL	ADVANCED COMPOSITES DATA FOR AIRCRAFT STRUCTURAL DESIGN VOLUME IV: MATERIAL AND BASIC ALLOWABLE DEVELOPMENT - GRAPHITE/EPOXY	00H466/001
STRUCTURAL	ADVANCED COMPOSITE APPLICATIONS FOR SPACECRAFT AND MISSILE PHASE I FINAL REPORT VOLUME I: STRUCTURAL DEVELOPMENT	067854/001
STRUCTURAL	EXPLORATORY DEVELOPMENT OF STRUCTURAL ADHESIVES HAVING IMPROVED TOUGHNESS PROPERTIES	200350/081
STRUCTURAL	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL LAMINATES AND ADHESIVES	200959/096
STRUCTURAL	ENGINEERING DATA ON NEW AEROSPACE STRUCTURAL MATERIALS	201123/106
STRUCTURE	MOLECULAR STRUCTURE AND MATERIALS CHARACTERIZATION	200528/038
STRUCTURE	NMR SPECTRAL CHROMATOGRAPHY - A POWERFUL NEW TOOL FOR STRUCTURE DETERMINATION	200482/037
STRUCTURE	MAGNETIC STRUCTURE DETERMINATION OF RARE EARTH-COBALT-IRON SYSTEMS, REXC05-X BY NEUTRON DIFFRACTION	200939/044
STRUCTURE	MANUFACTURING METHODS FOR ROLL DIFFUSION BONDED STIFFENED SKIN STRUCTURE	065836/059
STRUCTURES	MOLECULAR STRUCTURES STUDIES AND OTHER RELATED RESEARCH	200473/037

STRUCTURES	DEVELOPMENT OF FABRICATION TECHNIQUES FOR BORSIC - ALUMINUM AIRCRAFT STRUCTURES	068042/003
STRUCTURES	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
STRUCTURES	POLYMER STRUCTURES AND PROPERTIES	069422/073
SUBJECTED	A CRACK EXTENDING NON-UNIFORMLY IN AN ELASTIC SOLID SUBJECTED TO GENERAL LOADING	200469/016
SUBOXIDE	RESEARCH ON DEVELOPMENT AND FABRICATION OF BORON SUBOXIDE SPECIMENS	200935/026
SUBSONIC	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
SUBSONIC	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
SUBSONIC	ANALYTICAL MODELING OF SUBSONIC PARTICLE EROSION	200936/095
SUBSTITUENTS	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/064
SUBSTITUTED	VIBRATIONAL SPECTRA OF SUBSTITUTED CYCLOBUTANE COMPOUNDS	200516/036
SUBSTRATE	ELECTRICAL CONDUCTION IN DISCONTINUOUS FILMS ON AN INSULATING SUBSTRATE	200692/023
SUITS	EVALUATION OF CANDIDATE MATERIALS FOR FIRE FIGHTER'S PROXIMITY SUITS	200912/084
SUPERALLOY	JOINING TECHNIQUES FOR FABRICATION OF HIGH-TEMPERATURE SUPERALLOY BLADES	068556/013
SUPERCONDUCTORS	DEVELOPMENT ON PROCESS FOR PRODUCING CONTINUOUS FINE DIAMETER FILAMENTS OF SUPERCONDUCTORS	201014/045
SUPERIOR	CLADDINGS OF SUPERIOR CORROSION RESISTANCE FOR HIGH STRENGTH ALUMINUM ALLOYS	200692/100

SUPERREFINED	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUROSILICONE	200531/082
SUPERSONIC	SUPERSONIC RAIN AND SAND EROSION RESEARCH: CHARACTERIZATION AND DEVELOPMENT OF EROSION RESISTANT MATERIALS	200670/092
SURFACE	MANUFACTURING METHODS FOR SURFACE INTEGRITY OF MACHINED STRUCTURAL COMPONENTS	068517/050
SURFACE	DEVELOPMENT OF SURFACE TREATMENTS FOR TITANIUM ALLOYS FOR ADHESIVE BONDING	200955/089
SURFACE	EROSION MECHANISMS AND IMPROVEMENT OF GRAPHITIC MATERIALS VOL. II. HYPERTHERMAL EROSION TESTS AND SURFACE ROUGHNESS CHARACTERIZATION	068856/100
SYNTHESIS	RESEARCH ON SYNTHESIS OF HIGH-STRENGTH ALUMINUM ALLOYS	200956/028
SYNTHESIS	CONTINUOUS OXIDE FILAMENT SYNTHESIS (CVD)	065441/015
SYNTHESIS	SYNTHESIS OF PERFLUOROALIPHATIC ETHER MONOMERS	200691/076
SYNTHESIS	SYNTHESIS AND EVALUATION OF POLY-FUNCTIONAL PERFLUOROHYPOFLUORITES	200961/094
SYNTHESIS	SYNTHESIS OF SELECTED PERFLUOROALKYL-SUBSTITUTED POLYPHENYL ETHERS	201146/093
SYNTHESIS	THE SYNTHESIS AND CHEMISTRY OF FLUORINE-CONTAINING BENZENEDIAZOXIDES	200349/076
SYNTHESIS	SYNTHESIS INVOLVING ORGANOMETALLIC AND ORGANOMETALLOIDAL COMPOUNDS CONTAINING PERFLUORO AND PERCHLORO SUBSTITUENTS	200377/054
SYNTHESIS	THE SYNTHESIS AND THERMOOXIDATIVE DEGRADATION OF POLY(BENZIMIDES) AND RELATED MODEL COMPOUNDS	200423/067
SYNTHESIS	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070

TANK	INSTALLATION OF A SELF-SEALING MATERIALS SYSTEM IN A C-130 INTEGRAL FUEL TANK	200957/086
TD	A MANUFACTURING PROCESS FOR TD COBALT NICKEL CHROMIUM SHEET	066749/057
TECHNOLOGY	METAL MATRIX COMPOSITE TECHNOLOGY	200420/011
TELLURIDE	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
TELLURIDE	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041
TELLURIDE	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
TEMPERATURE	ROOM TEMPERATURE INJECTION LUMINESCENCE IN II-VI SEMICONDUCTORS	068307/039
TEMPERATURE	X-RAY DIFFRACTION STUDIES OF THE ROLE OF HYDROGEN BONDING IN THE LOW TEMPERATURE BEHAVIOR OF MATERIALS	200514/033
TEMPERATURE	HIGH TEMPERATURE ELASTOMER REINFORCING MATERIALS	200690/092
TEMPERATURE	EXPLORATORY DEVELOPMENT OF HIGH TEMPERATURE RESINS FOR STRUCTURAL LAMINATES AND ADHESIVES	200959/096
TEMPERATURE	HIGH STRENGTH, HIGH TEMPERATURE POLYMERIC FIBERS	201111/097
TEMPERATURE	DEVELOPMENT OF HIGH TEMPERATURE FUNCTIONAL FLUIDS	201157/098
TEMPERATURE	HIGH TEMPERATURE ELASTOMER NETWORKS FROM DIFUNCTIONAL BLOCK POLYMERS	201103/066
TEMPERATURE	RESEARCH ON SYNTHESIS PROCEDURES FOR INTERMEDIATES REQUIRED FOR HIGH TEMPERATURE STABLE POLYMERS	200833/070
TEMPERATURE	HIGH TEMPERATURE RESISTANT POLYMERIC COATINGS	044556/058

TEMPERATURES	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102
TEMPERATURES	DETERMINATION OF THERMOPHYSICAL PROPERTIES AT HIGH TEMPERATURES BY DIRECT HEATING METHODS	200529/103
TEMPERATURES	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
TENSILE	TENSILE PROPERTIES AND FRACTURE TOUGHNESS OF 6AL-4V TITANIUM	048186/099
THEIR	INVESTIGATION OF THE PROPERTIES OF CARBON-CARBON COMPOSITES AND THEIR RELATIONSHIP TO NONDESTRUCTIVE TEST MEASUREMENTS	200483/007
THEMIS	PROJECT THEMIS METAL DEFORMATION PROCESSING	200942/018
THERMAL	PROCEDURES FOR THE PRECISE DETERMINATION OF THERMAL RADIATION PROPERTIES	200586/031
THERMAL	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CR) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
THERMAL	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
THERMAL	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095
THERMAL	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
THERMAL	METAL PIGMENTED THERMAL CONTROL COATINGS WITH HIGH RATIOS OF SOLAR ABSORPTANCE TO INFRARED EMITTANCE	200520/080
THERMAL	THE SHEAR AND THERMAL STRESS BEHAVIOR OF A SUPERREFINED MINERAL OIL AND A FLUOROSILICONE	200531/082

THERMAL	THERMAL DEGRADATION OF POLYMERS USING MASS SPECTROSCOPY-THERMOGRAVIMETRIC ANALYSIS TECHNIQUES	200555/074
THERMAL	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200638/088
THERMAL	EFFECT OF ENVIRONMENTAL PRESSURE ON THE THERMAL DEGRADATION OF GLASS REINFORCED PLASTIC LAMINATES: PT. III	200503/069
THERMAL	ABLATIVE THERMAL PROTECTION COMPOSITES FOR LIFTING VEHICLES	200374/066
THERMAL	IMPROVED RADIATION-STABLE THERMAL CONTROL COATINGS	200937/072
THERMALLY	A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS	200551/089
THERMALLY	THERMALLY STABLE POLYMERIC FIBERS	045420/065
THERMO	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BEARING STEEL	067884/061
THERMODYNAMICS	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	069988/047
THERMOGRAVIMETR	KINETIC ANALYSIS OF THERMOGRAVIMETRY PART III: EXPERIMENTAL MODIFICATIONS	200466/068
THERMOMECHANICA	EFFECTS OF THERMOMECHANICAL TREATMENTS ON ALUMINUM ALLOYS	2005127018
THERMOOXIDATION	THERMOOXIDATION STUDIES OF THE QUINOXALINE SYSTEM AND CERTAIN BENZIMIDAZOLE COPOLYMER SYSTEMS PART I	200991/091
THERMOOXIDATIVE	THE SYNTHESIS AND THERMOOXIDATIVE DEGRADATION OF POLY(BENZIMIDES) AND RELATED MODEL COMPOUNDS	200423/067
THERMOPHYSICAL	DETERMINATION OF THERMOPHYSICAL PROPERTIES AT HIGH TEMPERATURES BY DIRECT HEATING METHODS	200529/103
THIN	DEVELOPMENT OF THIN FILM ALUMINUM	200354/035

THIOACRYLAMIDE	FIBER FORMING THIOACRYLAMIDE POLYMERS FROM POLYACRYLONITRILES	200666/084
THORIA	DEVELOPMENT OF PRODUCTION MANUFACTURING TECHNIQUES FOR APPLICATION OF PROTECTIVE COATINGS TO THORIA DISPERSION STRENGTHENED ALLOYS	067370/055
THRUST	MANUFACTURE OF JET ENGINE THRUST BEARINGS BY AUSFORMING	046253/051
TIME	THE TIME DEPENDENT MECHANICAL BEHAVIOR OF METAL MATRIX COMPOSITES	201100/026
TIME-OF-FLIGHT	KINETICS AND MECHANISMS OF THERMAL DEGRADATION OF POLYMERS USING TIME-OF-FLIGHT MASS SPECTROMETRY FOR CONTINUOUS GAS ANALYSIS	069428/093
TITANIUM	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
TITANIUM	SOLID SOLUTION STRENGTHENING AND FUNDAMENTAL DESIGN OF TITANIUM ALLOYS	201151/027
TITANIUM	HEAT TREATMENT STUDY OF BETA EXTRUDED TITANIUM ALLOY TI-6AL-6V-2SN	200687/022
TITANIUM	STRESS CORROSION CRACKING OF TITANIUM ALLOYS IN METHANOLIC AND OTHER MEDIA	200623/013
TITANIUM	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-6AL-4V	200317/012
TITANIUM	IMPORTANCE OF SLIP MODE FOR DISPERSION-HARDENED BETA TITANIUM ALLOYS	200934/025
TITANIUM	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200659/024
TITANIUM	DEVELOPMENT OF SURFACE TREATMENTS FOR TITANIUM ALLOYS FOR ADHESIVE BONDING	200955/089
TITANIUM	TENSILE PROPERTIES AND FRACTURE TOUGHNESS OF 6AL-4V TITANIUM	048186/099

TITANIUM	INDUCTION MELTING AND CASTING OF TITANIUM ALLOY AIRCRAFT COMPONENTS	067999/059
TITANIUM	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
TI-6AL-4V	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-6AL-4V	200317/012
TI-6AL-6V-2SN	HEAT TREATMENT STUDY OF BETA EXTRUDED TITANIUM ALLOY TI-6AL-6V-2SN	200687/022
TOOL	NMR SPECTRAL CHROMATOGRAPHY - A POWERFUL NEW TOOL FOR STRUCTURE DETERMINATION	200432/037
TOOLING	EFFECTIVE TOOLING DESIGNS FOR PRODUCTION OF PRECISION FORGINGS	068041/056
TORSIONAL	TORSIONAL TESTING OF FINE FILAMENTS PART I: APPARATUS AND PROCEDURES	201142/087
TOUGHNESS	EXPLORATORY DEVELOPMENT OF STRUCTURAL ADHESIVES HAVING IMPROVED TOUGHNESS PROPERTIES	200350/081
TOUGHNESS	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
TOUGHNESS	TENSILE PROPERTIES AND FRACTURE TOUGHNESS OF 6AL-4V TITANIUM	048186/099
TRANSDUCER	IMPROVING ULTRASONIC TRANSDUCER ASSEMBLIES GENERATING AEROSOLS FOR INSTRUMENTAL TECHNIQUES OF CHEMICAL ANALYSIS	200530/031
TRANSFER	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
TRANSPARENT	DESIGN CRITERIA TRANSPARENT POLYCARBONATE PLASTIC SHEET	200708/104
TREATMENT	HEAT TREATMENT STUDY OF BETA EXTRUDED TITANIUM ALLOY TI-6AL-6V-2SN	200687/022
TREATMENTS	EFFECTS OF THERMOMECHANICAL TREATMENTS ON ALUMINUM ALLOYS	200512/018

TREATMENTS	DEVELOPMENT OF SURFACE TREATMENTS FOR TITANIUM ALLOYS FOR ADHESIVE BONDING	200955/089
TREATMENTS	THERMAL OXIDATION-POLYMERIC COATING TREATMENTS OF HIGH MODULUS GRAPHITE FIBERS	201149/095
TUNNEL	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
TURBINE	DEVELOPMENT OF ALLOY FOR CAST AIR-COOLED TURBINE BLADES	065652/020
TURBINE	DEVELOPMENT OF PROTECTIVE COATINGS FOR COLUMBIUM ALLOY GAS TURBINE BLADES	200832/009
TURBINE	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/007
TURBINE	EDDY CURRENT INSPECTION OF TURBINE BLADES	200347/099
TURBINE	COMPARATIVE EVALUATION OF COATED ALLOYS FOR TURBINE COMPONENTS OF ADVANCED AIRCRAFT GAS TURBINE ENGINES. VOL. I	200376/009
TURBINE	COMPARATIVE EVALUATION OF COATED ALLOYS FOR TURBINE COMPONENTS OF ADVANCED AIRCRAFT GAS TURBINE ENGINES. VOL. I	200376/009
TURBINE	MANUFACTURING METHODS FOR PRODUCTION OF HOLLOW-BALL BEARINGS FOR USE IN GAS TURBINE ENGINES	068516/060
TURBINES	DEVELOPMENT OF REPAIR AND REPROCESS COATINGS FOR AIR-COOLED NICKEL ALLOY TURBINES BLADES	200472/017
TWO-MATERIAL	COMPUTATIONAL SCHEME FOR PREDICTING RECESSION AND IN-DEPTH HEATING OF A TWO-MATERIAL ABLATING SYSTEM	200619/079
T61	ENGINEERING DESIGN DATA FOR ALUMINUM ALLOY 7475 IN THE T761 AND T61 CONDITION	201152/105
T761	ENGINEERING DESIGN DATA FOR ALUMINUM ALLOY 7475 IN THE T761 AND T61 CONDITION	201152/105
ULTRASONIC	IMPROVING ULTRASONIC TRANSDUCER ASSEMBLIES GENERATING AEROSOLS FOR INSTRUMENTAL TECHNIQUES OF CHEMICAL ANALYSIS	200530/031

UNCOATED	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-6AL-4V	200317/012
UNDERSTAND	INVESTIGATIONS TO UNDERSTAND THE PLASTIC DEFORMATION AND STRENGTHENING MECHANISMS OF SOLID SOLUTION PHASES OF TITANIUM	200559/024
UNIDIRECTIONAL	FURTHER STUDY OF UNIDIRECTIONAL AND BIDIRECTIONAL COMPOSITES UNDER CYLINDRICAL BENDING	200315/077
UNIDIRECTIONAL	MICROBUCKLING OF UNIDIRECTIONAL COMPOSITES	200585/079
USAF	USAF APPLICATIONS OF LIQUID CRYSTAL MATERIALS	201145/054
VACUUM	PERFORMANCE OF BALL BEARINGS IN AIR AND VACUUM WITH NO ADDED LUBRICATION	200660/091
VAPORIZATION	A MASS SPECTROMETRIC STUDY OF THE VAPORIZATION OF CUPROUS IODIDE	200508/034
VAPORIZATION	VAPORIZATION KINETICS AND THERMODYNAMICS OF GRAPHITE USING THE HIGH PRESSURE MASS SPECTROMETER	069988/047
VARIATIONAL	THE HUGONIOT OF A SOLID DETERMINED BY MEANS OF A VARIATIONAL PRINCIPLE	200569/034
VARYING	DYNAMICS OF STIFFENED CYLINDRICAL SHELLS WITH SPATIALLY VARYING CURVATURE	200940/025
VEHICLES	ABLATIVE THERMAL PROTECTION COMPOSITES FOR LIFTING VEHICLES	200374/066
VELOCITIES	MATERIALS PARAMETERS THAT GOVERN THE RAIN EROSION BEHAVIOR OF POLYMERIC COATINGS AND COMPOSITES AT SUBSONIC VELOCITIES	200522/078
VELOCITIES	RAIN EROSION CHARACTERISTICS OF THERMAL PROTECTION SYSTEM MATERIALS AT SUBSONIC VELOCITIES	200938/096
VERSUS	MEASUREMENT AND ANALYSIS OF THE FLUORESCENCE DECAY OF GD <sup>3+</sup> IN SRF <sub>2</sub> VERSUS THE CONCENTRATION OF CDDPANT CE <sup>3+</sup>	200995/043

VIBRATIONAL	VIBRATIONAL SPECTRA OF SUBSTITUTED CYCLOBUTANE COMPOUNDS	200516/036
VII	APPROACHES TO LADDER STRUCTURES. VII: POLYCONDENSATION OF AROMATIC DIAMINO DICARBOXYLIC ACIDS WITH DIMETHYLFORMAMIDE AND PHOSPHORUS PENTOXIDE	200506/075
VII	STUDIES OF THE BREAKDOWN MECHANISM OF POLYMERS VII. THE THERMAL DECOMPOSITION OF A POLYHYDRAZIDE AND OF POLYOXADIAZOLES	200588/088
VKI	HEAT TRANSFER AND PRESSURE DISTRIBUTIONS OF RE-ENTRY NOSE SHAPES IN THE VKI LONG-SHOT HYPERSONIC TUNNEL	200534/078
WAVELENGTH	ADVANCED COMPOSITE MATERIAL STUDY FOR MILLIMETER WAVELENGTH ANTENNAS	200511/002
WAVELENGTH	INFRARED STUDIES WITH SPECIAL REFERENCE TO THE LONGER WAVELENGTH REGION, AND PHOTOELECTRON SPECTROSCOPY	201099/107
WEAR	WEAR RESISTANT COATINGS FOR TITANIUM ALLOYS: FRETTING FATIGUE OF UNCOATED TI-6AL-4V	200317/012
WELDING	DEVELOPMENT OF A MANUFACTURING METHOD FOR THE PRODUCTION OF AIRCRAFT STRUCTURAL COMPONENTS OF TITANIUM BY HIGH-FREQUENCY RESISTANCE WELDING	067933/049
WELDING	LASER WELDING PRECISION MINIATURE ASSEMBLIES	200678/052
WHEELS	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
WHEELS	ISOTHERMAL FORGING OF TITANIUM ALLOY MAIN LANDING GEAR WHEELS AND NOSE WHEELS	068211/063
WHISKERS	DEVELOPMENT OF SILICON CARBIDE WHISKERS	200455/080
WHISKER-METAL	SILICON CARBIDE WHISKER-METAL MATRIX COMPOSITES	069420/015
WINDOWS	SONIC CASTING OF COTE FOR HIGH POWER IR LASER WINDOWS	201098/046

WINDOWS	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
WINDOWS	MODIFIED BRIDGMAN TECHNIQUES GROWTH OF CADMIUM TELLURIDE FOR HIGH POWER INFRARED LASER WINDOWS	201158/048
WINDOWS	SINGLE CRYSTAL CADMIUM TELLURIDE HIGH ENERGY IR LASER WINDOWS	200829/041
WINDOWS	ESTABLISHMENT OF A MANUFACTURING PROCESS FOR INFRARED GLASS WINDOWS	066665/053
WORKING	THERMO MECHANICAL WORKING OF ELECTROSLAG MELTED M-50 BE. RING STEEL	067894/061
X-RAY	X-RAY DIFFRACTION STUDIES OF THE ROLE OF HYDROGEN BONDING IN THE LOW TEMPERATURE BEHAVIOR OF MATERIALS	200514/033
YARNS	EXPLORATORY DEVELOPMENT ON FORMATION OF HIGH STRENGTH, HIGH MODULUS BORON NITRIDE CONTINUOUS FILAMENT YARNS	200589/090
YARNS	THE DIRECT GRAPHITIZATION OF ACRYLONITRILE COPOLYMER YARNS	200914/083
YTTRIUM	RESEARCH AND DEVELOPMENT OF YTTRIUM ALUMINATE LASERS	200662/039
ZINC	R AND D ON THE APPLICATION OF POLYCRYSTALLINE ZINC SELENIDE AND CADMIUM TELLURIDE TO HIGH ENERGY IR LASER WINDOWS	201013/045
100	MANUFACTURING METHODS PROGRAM 100 KW, KU-BAND POWER AMPLIFIER OPERATING INSTRUCTIONS	068210/057
6AL-4V	TENSILE PROPERTIES AND FRACTURE TOUGHNESS OF 6AL-4V TITANIUM	043186/099
7049-T73	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102
7049-T76	MECHANICAL PROPERTIES OF 7049-T73 AND 7049-T76 ALUMINUM ALLOY EXTRUSIONS AT SEVERAL TEMPERATURES	200527/102

7075	MICROSTRUCTURES OF POWDER AND CONVENTIONALLY PROCESSED 7075 ALUMINUM	200515/014
7175-T736	FRACTURE TOUGHNESS AND FATIGUE CRACK GROWTH PROPERTIES OF 7175-T736 ALUMINUM ALLOY FORGING AT SEVERAL TEMPERATURES	200526/101
7475	ENGINEERING DESIGN DATA FOR ALUMINUM ALLOY 7475 IN THE T761 AND T61 CONDITION	201152/105
(CC)	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
(CP)	THERMAL AND MECHANICAL PROPERTIES OF ADVANCED HEATSHIELD RESINOUS (CP) AND CARBONACEOUS (CC) COMPOSITES VOLUME I	201097/105
(CVD)	CONTINUOUS OXIDE FILAMENT SYNTHESIS (CVD)	065441/015
(ECM)	ELECTROCHEMICAL MACHINING (ECM) VOLUME I - OPTIMIZATION OF PARAMETERS	069197/061
(ECM)	ELECTROCHEMICAL MACHINING (ECM) VOL. II - DEMONSTRATION OF OPTIMIZED PARAMETERS AND PROCESS APPLICATION DATA	069197/062
(HEMATITE)	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/032
(HEMATITE)	INFRARED DISPERSION ANALYSIS AND OPTICAL CONSTANT SPECTRA OF A-Fe <sub>2</sub> O <sub>3</sub> (HEMATITE)	200353/008
(IV)	A FLUORINE-19 NMR STUDY OF SOME FLUOROTITANIUM (IV) COMPLEXES. II.	200667/040

## INVESTIGATOR INDEX

	Page
Abrams, E. F. -----	92
Adler, W. F. -----	92, 95
Anderson, R. -----	98
Askins, D. R. -----	69
Austerman, S. B. -----	60
Bacon, R. -----	65
Bafico, M. A. -----	42
Bamberger, E. N. -----	51, 61
Barnett, W. J. -----	57
Becker, J. R. -----	56
Berry, G. C. -----	73
Boll, K. G. -----	4
Borden, R. S. -----	40
Boyd, J. D. -----	28
Bradley, W. -----	56
Brooks, F. C. -----	82
Browning, C. E. -----	67
Brunken, R. D. -----	59
Butler, J. M. -----	68
Callahan, R. J. -----	35
Cervay, R. R. -----	105
Champa, R. A. -----	54
Chappelow, C. C. -----	70
Cheatham, R. G. -----	3
Chen, C. M. -----	13
Chenevey, E. C. -----	65
Colings, E. W. -----	27
Collins, H. E. -----	20
Conley, R. T. -----	67, 91
Conrad, H. -----	18, 24
Crane, R. L. -----	28
Crosby, J. J. -----	12
Cross, J. A. -----	61, 62
D'Agostino, V. -----	51
D'Alelio, G. F. -----	71
Dauksys, R. J. -----	85, 95
Davis, S. O. -----	6
Deel, O. L. -----	106
Depierre, V. -----	20
DeSaw, F. A. -----	49

INVESTIGATOR INDEX (Continued)

	Page
Dittmer, W. -----	63
Donlan, V. L. -----	35
Douglas, J. R. -----	58
Dryer, J. R. -----	23
Economy, J. -----	72
Edwards, J. L. -----	16
Ehlers, G. F. L. -----	77, 88
Evangelides, J. S. -----	7
Evans, R. E. -----	5
Evers, R. C. -----	90
Ezekiel, H. M. -----	83
Feairheller, W. R., Jr. -----	38
Fedderson, C. E. -----	103
Fenter, J. R. -----	45
Fitzgerald, W. P., Jr. -----	96, 97
Flom, D. G. -----	86
Fontana, M. G. -----	24
Forest, J. D. -----	1
Fox, B. L. -----	37
Franklin, A. D. -----	87
Freund, L. B. -----	16
Friedman, H. L. -----	93
Garrett, H. -----	44
Gentile, A. L. -----	48
Gerdeman, D. A. -----	104
Gilman, H. -----	64
Gloor, W. H. -----	87
Goldfarb, I. J. -----	68
Goldschmidt, M. A. -----	33
Greszczuk, L. B. -----	79
Gruber, P. E. -----	15
Gulley, L. R. -----	10
Hafner, H. C. -----	53
Haggarty, J. S. -----	30
Haha, G. T. -----	21
Hamajima, T. -----	25
Hamon, B. N. -----	94
Hartbower, C. E. -----	99
Hassard, R. S. -----	104

INVESTIGATOR INDEX (Continued)

	Page
Haylett, J. W. -----	2
Heinz, D.M. -----	38
Heitz, R.M. -----	86
Henderson, J. P. -----	11
Hertz, J. -----	2
Heyda, J. F. -----	34
Hiltner, L. G. -----	88
Hilton, A. R. -----	41
Hopkins, V. -----	75
Hurley, G. F. -----	62, 74
Hutchens, R. D. -----	44
Jackson, A. G. -----	74
Jacobson, L. A. -----	14
Jones, E. E. -----	17
Jones, R. E. -----	101, 102
Jorgensen, P. J. -----	47
Jortner, J. -----	101
Joyce, T. E. -----	34
Katon, J. E. -----	36
Kennedy, D. I. -----	39
Klapprott, K. D. -----	81
Klopper, D. -----	52
Kojola, K. L. -----	14
Koster, W. P. -----	50
Kraska, I. R. -----	7, 99
Kratsch, K. M. -----	100
Kuehl, D. K. -----	3
Kulfarni, K. M. -----	63
Lackman, L. M. -----	1
Legg, J. K. -----	105
Li, W. T. C. -----	23
Lillywhite, M. -----	72
Lin, R. Y. -----	90
Lively, G. W. -----	89
Loughran, G. A. -----	75
Lowe, E. P. -----	102
Margrave, J. L. -----	82
McDaniel, T. J. -----	25
McMahon, P. E. -----	64

## INVESTIGATOR INDEX (Continued)

	Page
Mecklenburg, K. R. -----	91
Meyer, F.H., Jr. -----	100
Meyerer, W.J. -----	5
Milne, T.A. -----	47
Minday, R.M. -----	80
Morton, M. -----	66
Nessler, C.G. -----	13
Nevala, R.D. -----	53
Oaks, A.E. -----	6
Ohmer, M.C. -----	45
Olinger, J.L. -----	79
Olson, N.J. -----	89
Olster, E.F. -----	40
Ordway, F. -----	15
Ostrow, S.L. -----	69
Owen, L.E. -----	31
Pagano, N.J. -----	77
Peck, J.V. -----	55
Phillippi, C.M. -----	8, 32
Picklesimer, L.G. -----	84
Pipes, R.B. -----	85
Piwonka, T.S. -----	59
Potts, J.R. -----	60
Priceman, S. -----	9
Psarras, T. -----	76
Rae, W.G. -----	52
Ragsdale, R.D. -----	32
Ray, A.E. -----	41, 46
Renshaw, T. -----	58
Rhodes, W.H. -----	26
Rice, D. -----	11
Richards, B.E. -----	78
Richmond, J.C. -----	31
Rinaldi, M.D. -----	27
Robinson, C.C. -----	30
Rondeau, R.E. -----	37
Roush, L.L. -----	107
Roward, R.R. -----	10, 12
Ryan, K.H. -----	9

## INVESTIGATOR INDEX (Continued)

	Page
Sajdak, J. R. -----	22
Schaeffer, D. M. -----	43
Scheirer, S. T. -----	26
Schmitt, G. F., Jr. -----	78
Schultz, A. W. -----	8
Schwartz, H. S. -----	81
Selines, R. J. -----	19
Shelton, W. L. -----	21
Siegel, B. -----	46
Sih, G. C. -----	73
Snyder, C. E., Jr. -----	93
Somberg, H. -----	55
Sommer, A. W. -----	18
Spence, J. W. -----	76
Springer, G. S. -----	94
Stanton, R. M. -----	84
Stevenson, G. E. -----	80
Stille, J. K. -----	70
Stocker, B. P. W. -----	54
Stoltz, R. E. -----	19
Taverna, R. A. -----	66
Taylor, R. E. -----	103
Timbres, D. H. -----	22
Tompson, H. W. -----	107
Tuma, W. S. -----	49
Vaszari, J. P. -----	57
Wahl, N. E. -----	96
Wang, C. C. -----	42
Weber, M. J. -----	39
Weissmann, S. -----	17
Wells, H. A. -----	97
Wessel, G. -----	33
Williamson, P. M. -----	50
Wilson, D. R. -----	71

## CONTRACTOR INDEX

	Page
Aerojet-General Corporation -----	99
Aerojet Liquid Rocket Company -----	56
Aerojet Solid Propulsion Company -----	12
American Optical Corporation -----	30
Artech Corporation -----	15
Arthur D. Little, Incorporated -----	30
Atomic Weapons Research Establishment -----	5
Avco Corporation ----- 8, 15, 26, 40,	66
Avco Systems Division -----	63
Battelle Columbus Laboratories ----- 21, 28, 56, 103, 106	106
Battelle Memorial Institute -----	49, 58
Bell Aerospace Company ----- 92, 95,	96
Boeing Company -----	3
Bowmar Canada Limited -----	39
Brown University -----	16
Case Western Reserve University -----	81
Celanese Research Company -----	65
Coors Porcelain Company -----	45
Dow Chemical Company -----	35
Esso Research and Engineering Company -----	80
Fairchild Industries, Incorporated -----	58
Fairchild Semiconductor Project -----	53
Fansteel Incorporated -----	57
General American Transportation Corporation -----	7, 99
General Dynamics Corporation -----	85
General Dynamics/Convair -----	1, 2
General Electric Company ----- 6, 12, 51, 61, 62, 86,	93
General Motors Corporation -----	9
General Technologies Corporation -----	92
Goodyear Aerospace Corporation ----- 2, 49,	104
Grumman Aerospace Corporation -----	52
Hughes Aircraft Company -----	57, 102
Hughes Research Laboratories -----	48
IIT Research Institute -----	63
Iowa State University -----	64

CONTRACTOR INDEX (Continued)

	Page
Lehigh University -----	73
LTV Aerospace Corporation -----	89
Martin Marietta Corporation -----	72
Massachusetts Institute of Technology -----	19, 27
McDonnell Douglas Astronautics Company -----	7, 10, 79, 100, 101
McDonnell Douglas Corporation -----	14
Mellon Institute -----	73
Metcut Research Associates Incorporated -----	50
Miami University -----	36, 107
Midwest Research Institute -----	47, 70, 71, 75, 91
Monsanto Research Corporation -----	38, 69
National Bureau of Standards -----	31, 87
North American Rockwell Corporation -----	1, 10, 18, 38, 44, 59, 60
Northrop Corporation -----	86
Notre Dame University -----	71
Ohio State University -----	23, 24
Parker-Hannifin Corporation -----	88
PCR, Incorporated -----	76, 94, 98
Philco-Ford Corporation -----	69
Pratt and Whitney Aircraft -----	13, 60
Purdue University -----	103
RAI Research Corporation -----	51
Raytheon Research Division -----	39
RCA Lab. -----	42
Rutgers University -----	17, 25
Sherritt Gordon Mines Limited -----	22
Sikorsky Aircraft -----	54
Southern Research Institute -----	105
Stanford Research Institute -----	47
Sylvania Electric Products Incorporated -----	9
Syracuse University -----	33
Systems Research Laboratories -----	74
Texas Instruments Incorporated -----	41, 52, 53
Textron Incorporated -----	55
The Carborundum Company -----	45, 72, 90
The Dexter Corporation -----	81

CONTRACTOR INDEX (Continued)

	Page
Tomorrow Enterprises -----	31
TRW Group, Incorporated -----	17
TRW, Incorporated -----	20, 26, 59
Tyco Lab., Incorporated -----	46, 62, 74
Union Carbide Corporation -----	65
United Aircraft Corporation -----	3, 4, 11, 55
University of Akron -----	66
University of Dayton -----	41, 42, 43, 46, 79, 80, 89
University of Dayton Research Institute -----	25, 33, 34, 37, 69 101, 102, 104, 105
University of Illinois -----	23
University of Iowa -----	70
University of Kentucky -----	18, 24
University of Michigan -----	94
University of Minnesota -----	11
University of Missouri-Rolla -----	44
University of Oxford -----	107
University of Utah -----	32
Von Karman Institute for Fluid Dynamics -----	78
Westinghouse Electric Corporation -----	20
Whittaker Corporation -----	96, 97
William Marsh Rice University -----	82
Wittenberg University -----	40
Wright State University -----	67, 91