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AFML-TR-72-157

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**ABSTRACTS OF
AF MATERIALS LABORATORY REPORTS
JANUARY 1971 - DECEMBER 1971**

TECHNICAL REPORT AFML-TR-72-157

SEPTEMBER 1972

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AFML-TR-72-157

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AF MATERIALS LABORATORY REPORTS
JANUARY 1971 - DECEMBER 1971**

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FOREWORD

This report was prepared by the Materials Information Branch, Materials Support Division, Air Force Materials Laboratory, Wright-Patterson AFB, Ohio.

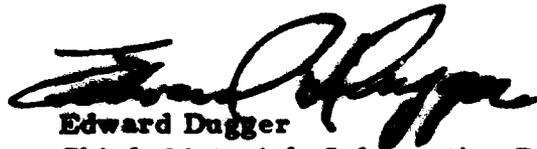
Technical reports received and published by the Air Force Materials Laboratory during the period 1 January 1971 - 31 December 1971 are abstracted herein. Some technical reports in this document carry an earlier date than January 1, 1971. They are included because they were missed in previous editions. Reports on research conducted by Air Force Materials Laboratory personnel as well as that conducted on contract are included.

The body of abstracts is divided into sections corresponding to the divisions of the laboratory. An index listing specific as well as general subject matter included in each report starts on page 137. The access number cited with each abstract provides access to the document itself in the AF Materials Laboratory's Document File. Two or more subjects may be coordinated in this index to reduce the number of abstracts to be reviewed when a combination of subjects is required for an article to be pertinent. Retention copies of these reports may be requested from DDC, Cameron Station, Alexandria, Virginia 22314.

Investigator Index begins on page 158 and Contractor Index on page 164.

This document is a continuation of documentation carried under WADC-TR-53-373, AFML-TR-65-228, AFML-TR-67-13, and AFML-TR-67-13, Supplement I, AFML-TR-68-215, AFML-TR-69-160, AFML-TR-70-163, and AFML-TR-71-107.

This technical report has been reviewed and is approved.



Edward Dugger
Chief, Materials Information Branch
Materials Support Division
AF Materials Laboratory

ABSTRACT

Technical reports received and published by the Air Force Materials Laboratory during the period 1 January 1971 - 31 December 1971 are abstracted herein and indexed by divisions of the laboratory, technical and subject matter, investigator, AFML project monitor and contractor. Reports on research conducted by the Air Force Materials Laboratory personnel as well as that conducted on contract are included.

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ABSTRACTS OF TECHNICAL REPORTS
MATERIALS SUPPORT DIVISION (AFML/LA)

ACCESS NO: 68,739 AD 880 151
REPORT NO: AFML-TR-70-105 November 1970
TITLE: HYDROLYTIC STABILITY OF POTTING COM-
POUNDS FOR ELECTRICAL CONNECTORS

AUTHOR: P. A. House
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: P. A. House (AFML/LAE)
AFML TASK NO: 738106

ABSTRACT: This report describes an extensive evaluation of elastomeric potting compounds for their ability to withstand long-term exposure to high temperature and humidities. This work was initiated as a result of the reversion of potting compounds in the electrical connectors on the F-4 in which the compounds softened and liquefied. Materials tested included polyurethanes, epoxies, silicones, and polysulfides. Coatings and tubing were tested in addition to the potting compounds. This effort involved the establishment of more severe humidity-temperature tests than were previously used in military specifications. The results of testing many specification and non-specification compounds to the more severe conditions are included.

ACCESS NO: 90,536 AD 880 152L
REPORT NO: AFML-TR-70-105 November 1970
Supplement I
TITLE: CODE IDENTIFICATION FOR AFML-TR-70-105
HYDROLYTIC STABILITY OF POTTING
COMPOUNDS FOR ELECTRICAL CONNECTORS
AUTHOR: P. A. House

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: P. A. House (AFML/LAE)
AFML TASK NO: 738106

ABSTRACT: The basic AFML-TR-70-105 report describes an extensive evaluation of elastomeric potting compounds for their ability to withstand long-term exposure to high temperature and humidities. This work initiated as a result of the reversion of potting compounds in the electrical connectors on the F-4 in which the compounds softened and liquefied. Materials tested included polyurethanes, epoxies, silicones, and polysulfides. Coatings and tubing were tested in addition to the potting compounds. This effort involved the establishment of more severe humidity-temperature tests than were previously used in military specifications. The results of testing many specification and non-specification compounds to the more severe conditions are included.

ACCESS NO: 69,042 AD 882 745
REPORT NO: AFML-TR-70-241 February 1971
TITLE: ADHESIVE BONDED DOUBLER FOR H-3
HELICOPTER BLADE SPAR
AUTHOR: T. J. Reinhart, Jr.

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: T. J. Reinhart, Jr. (AFML/LAE)
AFML TASK NO: 738101 and 738108

ABSTRACT: An in-house program has been initiated in order to demonstrate the feasibility of the use of an adhesive bonded, structural doubler to provide a field fix solution to the problem of crack formation in the rivet holes of the tip of the CH/HH-3C main rotor spar. The program is being conducted in the following phases; (1) Doubler Design and Analysis, (2) Subscale Specimen Testing, (3) Stub Blade Fatigue Testing, (4) Whirl Tower Blade Testing, and (5) Field Installation Kit. The program is designed to demonstrate the effectiveness and reliability of an adhesive bonded doubler in the elimination of crack formation and growth due to stress concentration in a metallic substructure. It is to develop quantitative design information to enable optimization of the doubler and to develop methods for the field application of doublers to the H-3 spar.

ACCESS NO: 68,857 AD 720 239
REPORT NO: AFML-TR-70-246 December 1970
TITLE: APPLICATION OF PHOTOCHROMIC COATINGS
FOR NONDESTRUCTIVE INSPECTION

AUTHOR: S. Allinikov
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: S. Allinikov (AFML/LAE)
AFML TASK NO: 738101

ABSTRACT: The application of a photochromic compound to provide a nondestructive inspection (NDI) technique for aerospace materials and structures is discussed. The photochromic compound, incorporated into a paint formulation, is converted from a white to a bright violet color upon a brief irradiation from an ultraviolet source. The colored paint surface is then heated by any suitable means, such as a hot air blower. Heat serves to bleach the paint to the original white color. Defects are disclosed because heat conductivity at the defect site is different from that of the rest of the area under inspection. The defect thus appears as a colored or white area dependent upon the nature of the defect and originating direction of the heat source.

ACCESS NO: 45,808 AD 664 827
REPORT NO: AFML-TR-70-259 November 1970
TITLE: STRESS-CORROSION AND CORROSION-FATIGUE
SUSCEPTIBILITY OF HIGH-STRENGTH ALUMINUM
ALLOYS

AUTHOR: G. E. Nordmark, et al.
CONTRACT NO: F33615-67-C-1922
CONTRACTOR: Aluminum Company of America
PROJECT MONITOR: H. W. Zoeller (AFML/LAA)
AFML TASK NO: 738107

ABSTRACT: The "stress-corrosion-fatigue" performance of several high strength-aluminum alloys was investigated by tests of hydraulic cylinders and other types of specimens. Specimens were prepared from forgings and forging stock of alloys 2014-T6, 7075-T6-7075-T73, 7079-T6, and X7080-T7 and from premium castings of alloy CH70-T7. The alternating internal pressure loading of the cylinders at frequencies between 0.15 and 20 cpm in corrosive environment included hold times at load of as much as 5.4 minutes. Corrosive environment was provided by a warm salt fog at 12 hour intervals.

ACCESS NO: 65,788 AD 724 592
REPORT NO: AFML-TR-70-286 December 1970
TITLE: THERMOPHYSICAL PROPERTIES AT HIGH
TEMPERATURES MEASURED BY DIRECT
HEATING METHODS

AUTHOR: R. E. Taylor
CONTRACT NO: F33615-70-C-1012
CONTRACTOR: Purdue University
PROJECT MONITOR: Dr. M. L. Minges (AFML/LAS), et al.
AFML TASK NO: 738106

ABSTRACT: An analysis of direct heating methods, in which the sample is heated by passing an electric current through it, is presented. These methods are used for measuring thermophysical properties at high temperatures. It was demonstrated that mathematical approximations severely limit the applicability and accuracy of the techniques described in the literature. However, new techniques developed under the present program do not employ severe mathematical approximations and correctly include temperature-dependent properties. Thus the new techniques are significantly more accurate and orders of magnitude more flexible than the previous techniques.

ACCESS NO: 68, 775 AD 880 648
REPORT NO: AFML-TR-70-288 December 1970
TITLE: EVALUATION AND APPLICATION OF MATERIALS
FOR UNUSUAL AEROSPACE SYSTEMS
AUTHOR: D. A. Gerdeman, et al.
CONTRACT NO: F33615-69-C-1471
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: A. Olevitch (AFML/LAE)
AFML TASK NO: 738108
ABSTRACT: This report is divided into three sections: properties of metals, nonmetallic materials evaluation, and other materials evaluation related efforts. The first section describes four program which involved the evaluation of the mechanical properties of metal alloys. The second section describes the evaluation of nonmetallic materials. Included are the results of fuel tank sealant evaluation tests. Three additional areas of support are described in the last section. Included are the details and capabilities of a newly-established compatibility test facility.

ACCESS NO: 68, 860 AD 720 828
REPORT NO: AFML-TR-70-291 January 1971
TITLE: MECHANICAL PROPERTY EVALUATION OF
BETA FORGED Ti-6Al-4V
AUTHOR: G. J. Petrak
CONTRACT NO: F33615-69-C-1471
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: D. C. Watson (AFML/LAE)
AFML TASK NO: 738106
ABSTRACT: The mechanical properties of forged Ti-6Al-4V forged in the conventional manner and at temperatures above the alpha-beta/beta transus were investigated. Tensile, fatigue, stress rupture, and fracture properties of the optimum beta-forged material were determined. It was shown that the material forged in the beta range exhibits superior room temperature fracture and fatigue properties while the other mechanical properties are not affected. At 600 F the fatigue, stress rupture, and tensile properties of the conventional forged and beta forged material are the same.

ACCESS NO: 07, 072 AD 721 676
REPORT NO: AFML-TR-70-297 February 1971
TITLE: USING ACCELERATED HYDROLYTIC REVERSION
DATA TO PREDICT SERVICE LIFE OF
ELASTOMERIC POTTING COMPOUNDS

AUTHOR: Dr. G. L. Welch, et al.
CONTRACT NO: F33615-67-C-1559
CONTRACTOR: Weber State College
PROJECT MONITOR: P. A. House (AFML/LAE)
AFML TASK NO: 738103
ABSTRACT: A method is proposed for estimating the service life to two specific potting compounds based upon reversion data obtained at high temperatures and various humidities at each temperature. Reversion was followed using the change in durometer hardness with time. This method separates the effect of the water vapor concentration from the effects of the temperature on the rate of reversion. Knowing the vapor pressure of water at each temperature, and using the Arrhenius equation to extrapolate the data obtained, a reversion time can be calculated for any desired combinations of temperature and relative humidity, including cyclic operating conditions where temperature and humidity follow a regular cycle.

ACCESS NO: 49, 449 AD 882 626
REPORT NO: AFML-TR-70-299 AD 882 627
TITLE: Volumes I & II February 1971
DESIGN/ANALYSIS METHODS FOR ADVANCED
COMPOSITE STRUCTURES

AUTHOR: R. L. Foye, et al.
CONTRACT NO: F33615-68-C-1199
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: W. J. Iller (AFML/LAA), et al.
PROJECT NO: 8M 29240/6169CW
ABSTRACT: Hardware preliminary design with composites differs from conventional sheet metal design primarily in the fact that fiber orientation angles and ply stacking sequence must enter into consideration. To efficiently utilize these newer materials there should be some logic whereby these new design parameters may be selected so as to best satisfy the design requirements. Three prerequisites to the development of this logic are the means for adequately predicting the stiffness, static strength, and fatigue life of an arbitrary laminate. This program has investigated all three of these areas. Improvements in stiffness and strength prediction methods were obtained through the application of nonlinear micro/macro-mechanics. An initial effort at observing and characterizing boron-epoxy laminate fatigue behavior was also undertaken.

ACCESS NO: 68,856 **AD 881 223**
REPORT NO: AFML-TR-70-307 **January 1971**
Volume I
TITLE: EROSION MECHANISMS AND IMPROVEMENT
OF GRAPHITIC MATERIALS VOLUME I:
GRAPHITE SELECTION AND CHARACTERIZATION
AUTHOR: K. M. Kratsch, et al.
CONTRACT NO: F33615-69-C-1631
CONTRACTOR: McDonnell Douglas Astronautics Company
PROJECT MONITOR: C. A. Pratt (AFML/LAS), et al.
AFML TASK NO: 738102
ABSTRACT: This document describes the content of the Air Force Material Laboratory's exploratory development program (EDP) that is aimed at assessing compositional influences of graphites on ablation behavior in hyperthermal reentry environments. The EDP is directed toward a detail study of material composition variables which have an important influence on the high-temperature erosion of graphitic materials. Pursuant to this major program objective, extensive efforts were expended to characterize the detailed compositional variations in a broad class of graphites which may be important in identifying erosion mechanisms. These efforts involved the performance of a number of characterization experiments, paced by the analysis development required to interpret the data obtained in terms of material compositional variables.

ACCESS NO: 68,888 **AD 882 120L**
REPORT NO: AFML-TR-70-310 **January 1971**
TITLE: DEVELOPMENT OF FRACTURE TOUGHNESS
PROPERTIES OF D6-AC STEEL FOR F-111
APPLICATIONS
AUTHOR: J. N. Masters, et al.
CONTRACT NO: F33615-70-C-310
CONTRACTOR: Boeing Company
PROJECT MONITOR: C. L. Harmsworth (AFML/LAE)
AFML TASK NO: 738106
ABSTRACT: Surface flawed, D6-AC steel, specimens were tested to spot check and supplement fracture and flaw growth rate data obtained from other type specimens used in life prediction of F-111 aircraft structure. Sustained load tests were run in distilled water at 35 F, 75 F, and 175 F and in dry air at room temperature. Cyclic loading was conducted over a range of temperatures from -40 F to 175 F in dry air, distilled water, JP-4 fuel, 2-1/2% NaCl solution, and 50% relative humidity air. Other parameters considered were flaw shape (a/2c ratio), stress level, stress ratio, and frequency. Fracture toughness values obtained from surface flawed specimens were higher than those obtained from compact tension specimens. Relative effects of environment and testing parameters on flaw growth rates compared favorably in most cases for surface flawed specimens and compact tension specimens.

ACCESS NO: 200,199 **AD 890 142L**
REPORT NO: AFML-TR-71-57 **June 1971**
TITLE: REINFORCED CARBON-CARBON COMPOSITES
FOR ADVANCED REENTRY VEHICLE
APPLICATIONS

AUTHOR: L. E. McAllister, et al.
CONTRACT NO: F33615-69-C-1758
CONTRACTOR: Avco Corporation
PROJECT MONITOR: C. A. Pratt (AFML/LAS), et al.
PROJECT NO: 698 CW

ABSTRACT: The objective of the program was to fabricate 3D carbon/carbon composites in cylindrical and block configurations for evaluation by the Air Force. A 3D orthogonal carbon-carbon cylinder (9 inch O.D. x 24 inch long x 0.5 inch thickness) was fabricated for mechanical, thermal, dynamic response and ablative tests on the Air Force Advanced Heat Shield Program (AHP). The cylinder was processed using the Avco "molded slat" technique to a density of 1.65 gms/cm³ using multiple impregnation/carbonization/graphitization steps. Radiographs and photomicrographs of the finished cylinder show a uniform good quality material. Seven 3-D pierced fabric carbon/carbon (Mod 3) billets were fabricated for evaluation and characterization by AFML.

ACCESS NO: H-665 **AD 723 309**
REPORT NO: AFML-TR-71-64 **March 1971**
TITLE: CONTINUING SYSTEMATIC PROGRAM ON
TABLES OF THERMOPHYSICAL PROPERTIES
OF MATERIALS

AUTHOR: C. Y. Ho
CONTRACT NO: F33615-68-C-1229
CONTRACTOR: Purdue University
PROJECT MONITOR: J. H. Charlesworth (AFML/LAM)
AFML TASK NO: 897502

ABSTRACT: The work reported on consists of both data tables projects and scientific documentation efforts. The data tables projects are on the thermal conductivity, specific heat, thermal radiative properties (emittance, reflectance, absorptance, transmittance), thermal diffusivity, and thermal linear and volumetric expansion of elements, ferrous and non-ferrous alloys, intermetallic, semiconducting and nonmetallic compounds, cermets, ceramics, mixtures, composites, systems, polymers, etc., and on the thermal conductivity, specific heat, and viscosity of fluids and fluid mixtures.

ACCESS NO: 69, 925 AD 731 813
REPORT NO: AFML-TR-71-74 July 1971
TITLE: BASELINE SOLUTIONS FOR THE SMOOTH
WALL THERMOCHEMICAL ABLATION RESPONSE
OF GRAPHITE AND CARBON PHENOLIC
AUTHOR: R. A. Rindal, et al.
CONTRACT NO: F33615-69-C-1626
CONTRACTOR: Aerotherm Corporation
PROJECT MONITOR: Dr. M. L. Minges (AFML/LAS)
AFML TASK NO: 738102
ABSTRACT: Recently acquired high pressure ablation data for
graphite and carbon phenolic are analyzed with the objective of establishing
the magnitude of discrepancies between measured ablation rates and smooth-
wall "thermochemical only" predictions. Data were obtained under the
SAMSO sponsored Thermal Protection Program and are believed of sufficient
quality to reach meaningful conclusions with respect to the magnitude of
ablation enhancement resulting from the combined effects of rough-wall and
mechanical erosion phenomena.

ACCESS NO: 69, 565 AD 728 648
REPORT NO: AFML-TR-71-82 March 1971
TITLE: THE INITIATION AND GROWTH OF FATIGUE
CRACKS IN FILAMENT-REINFORCED
ALUMINUM ALLOYS
AUTHOR: J. R. Hancock
CONTRACT NO: F33615-70-C-1284
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: Dr. W. Reimann (AFML/LAM)
AFML TASK NO: 735301
ABSTRACT: The low-cycle fatigue behavior of filamentary
composites of 1235 aluminumberyllium, 6061 aluminum-beryllium, and
7075 aluminum-boron were compared. The effects of the strength and
ductility of the filaments and matrix, and the role of interfaces on fatigue
hardening, and on fatigue-crack initiation and growth-were evaluated to
develop guidelines for the design of fatigue-resistant composites. Generally,
brittle filaments, a ductile matrix, weak interfacial bonds, and a large
modulus difference between constituents were the factors which lead to
greater fatigue resistance in filament-reinforced metals. The observed
modes of fatigue-crack growth confirmed the theoretical predictions of the
effects of stress distribution at a crack tip at an interface, and extended
the applicability of these predictions to filamentary composites.

ACCESS NO: 67,012
REPORT NO: AFML-TR-71-153 June 1971
TITLE: THERMOMECHANICAL EROSION OF ABLATIVE
PLASTIC COMPOSITES
AUTHOR: V. Dicristina, et al.
CONTRACT NO: F33615-69-C-1650
CONTRACTOR: Avco Corporation
PROJECT MONITOR: Dr. M. L. Minges (AFML/LAS)
AFML TASK NO: 734001

ABSTRACT: An analytical technique has been developed to predict the thermomechanical erosion of plastic composite materials for reentry nosetip application. The method presented requires empirically derived material property data which has been obtained for reverse chevron carbon phenolic from a series of 50 MW arc tests. The method has been used to predict the ablation behavior of similar materials in other test environments and is shown to be in reasonable agreement with the measured data.

ACCESS NO: 69,639 AD 736 470
REPORT NO: AFML-TR-71-160 July 1971
TITLE: MULTIAXIAL BEHAVIOR OF ATJ-S GRAPHITE
AUTHOR: J. Jortner
CONTRACT NO: F33615-71-C-1143
CONTRACTOR: McDonnell Douglas Astronautics Company-West
PROJECT MONITOR: Lt. J. R. Koenig (AFML/LAS)
AFML TASK NO: 738102

ABSTRACT: A program to explore the behavior of ATJ-S graphite under multiaxial stress states is described. The program includes biaxial tests, off-axis uniaxial tests, and the development of a triaxial test capability. The first phase of the program is to conduct fracture tests on specimens of ATJ-S graphite under biaxial stress states at room temperature and 2000° F at low strain rates (approximately 10-2/min). The biaxial tests consist of simultaneous axial loading and internal pressurization of hollow cylindrical specimens. The biaxial stress-states investigated include combinations of across-grain tension with with-grain tension, and across-grain compression with with-grain tension.

ACCESS NO: 200,140 AD 733 731
REPORT NO: AFML-TR-71-198 October 1971
TITLE: PROPERTIES OF RE-ENTRY MATERIALS
AUTHOR: S. A. Bortz
CONTRACT NO: F33615-69-C-1454
CONTRACTOR: IIT Research Institute
PROJECT MONITOR: Capt. J. T. Tesson (AFML/LAS)
AFML TASK NO: 738102

ABSTRACT: The work performed on this program consisted of the generation of engineering data for REST 6300, a two dimensionally of the elevated temperature properties of FEP Teflon, and the preliminary flexure and compression testing of a pierced fabric composite. The REST 6300 was pre-charred before testing to eliminate char variations during testing. Four Zones of material were investigated: virgin material, Zone III char which was heat treated to 1200°F, Zone II char which was heat treated to 2500°F, and Zone I char which was heat treated to 4000°F. Each of the four zones was fully characterized for density, composition using powder x-ray analysis, and for microstructure using the light microscope and the scanning electron microscope.

ADVANCED COMPOSITES DIVISION (AFML/LC)

ACCESS NO: 48,894 AD 883 433
REPORT NO: AFML-TR-70-231 AD 883 075
Volumes I & II December 1970
TITLE: ADVANCED COMPOSITE WING STRUCTURES
AUTHOR: R. N. Hadcock
CONTRACT NO: F33615-68-C-1301
CONTRACTOR: Grumman Aerospace Corporation
PROJECT MONITOR: H. A. Wood (AFML/LC)
PROJECT NO: 6169CW
ABSTRACT: The primary objective of this program was to develop technology for design and fabrication of boron-epoxy structures for highly loaded wings of advanced fighter attack type aircraft. Design tension, compression and shear strength and average stiffness as well as fatigue strength, creep behavior, strength of bolted and bonded joints and thermal properties of the 0/+45/90 family of boron-epoxy laminates were generated. Analysis and optimization techniques were developed for unstiffened plates, sheet-stiffened panels and honeycomb sandwich panels. Detailed design, analysis and test programs of elemental subcomponent and component test specimens were conducted to verify the design approach, manufacturing feasibility and structural integrity of the selected wing design. The results of these studies, which include failure analyses, are summarized and pertinent conclusions are delineated for the various areas of composite technology.

ACCESS NO: 68,920 AD 881 935
REPORT NO: AFML-TR-70-261 December 1970
TITLE: ADVANCED DEVELOPMENT OF BORON COMPOSITE WING STRUCTURAL COMPONENTS
AUTHOR: J. L. Leonhardt, et al.
CONTRACT NO: F33615-70-C-1263
CONTRACTOR: General Dynamics
PROJECT MONITOR: L. G. Kelly (AFML/LC)
PROJECT NO: 6169CW
ABSTRACT: The testing conducted in a predevelopment effort to determine feasibility of boron wing primary structure is reported in this document. Concepts of spar design, spar attachment to wing covering, and cover skin attachment to wing root structure were investigated. The scale of work progressed from basic data coupon-type specimens to full-scale box beam specimens simulating a bay of primary structure at the root of a multi-cell wing box. Loads and geometry were derived from the movable portion of the F-111 wing. Feasibility of one or more concepts for each of the major joints of a conventional multi-spar wing were demonstrated successfully.

ACCESS NO: 69,519 **AD 886 332L**
REPORT NO: AFML-TR-70-293 **April 1971**
TITLE: BORON HORIZONTAL TAIL FLIGHT TEST
QUALIFICATION PROGRAM

AUTHOR: J. R. Blacklock, et al.
CONTRACT NO: F33615-69-C-1126
CONTRACTOR: General Dynamics
PROJECT MONITOR: L. G. Kelly (AFML/LC)
PROJECT NO: 6169CW

ABSTRACT: This document contains the engineering, tooling, manufacturing, and quality assurance data generated during the design and fabrication of a set of F-111A horizontal stabilizers from the advanced composite material of boron epoxy. Several analyses and tests were performed to qualify and substantiate the horizontal tails for flight test. Those included a stress analysis, materials allowables test program, a finite element joint analysis, a dynamic analysis including a flutter analysis, and a thermal analysis. In addition, a static test was performed to 103 percent of ultimate load under the application of HT-4 condition. Static beam tests were conducted to validate the secondary joints of the leading edge (127 percent of ultimate load), and the tip (111 percent of ultimate load).

ACCESS NO: 49,781 **AD 889 334L**
REPORT NO: AFML-TR-71-29 **August 1971**
Volume III

TITLE: BORON/EPOXY WING SKINS F-100D AIRCRAFT
STRUCTURAL DESIGN AND ANALYSIS

AUTHOR: C. L. Stotler, et al.
CONTRACT NO: F33615-69-C-1445
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: L. G. Kelly (AFML/LC)
PROJECT NO: 6169CW

ABSTRACT: This document constitutes the final report on the structural analysis and design conducted under Contract F33615-69-C-1445, entitled "Boron Epoxy Wing Skins". This program concerned the design and fabrication of boron composite laminate skins to replace the upper and lower structural covers of the F-100D wing, accepting all the functional design requirements, constraints, and structural loads of the original design. This report presents the final design of these boron-epoxy wing skins and the material properties and structural analysis upon which it was based. First, the design itself is discussed accompanied by representation drawings is relegated to Appendix A.

ACCESS NO: 65,439 AD 888 183
REPORT NO: AFML-TR-71-41 June 1971
TITLE: ADVANCED COMPOSITE TECHNOLOGY FUSE-
LAGE PROGRAM - PHASE I
AUTHOR: F. O. Olson, et al.
CONTRACT NO: F33615-69-C-1494
CONTRACTOR: General Dynamics
PROJECT MONITOR: L. G. Kelly (AFML/LC)
PROJECT NO: 6169CW

ABSTRACT: This report describes the design, analysis, and testing of a full-scale section of F-111 aft fuselage centerbody made from advanced composite materials. A 160-inch-long test component was fabricated and tested to destruction. Composite material systems of graphite-epoxy, boron-epoxy, boron-aluminum, and glass-epoxy were employed. Maximum use of composites was maintained throughout the structure, with both skins and substructures being treated. Static test of the part included loading in bending with simultaneous application of internal pressure. The component sustained 130 percent of design ultimate load. Deflection gauge and strain gauge data showed excellent agreement with analytical results.

ACCESS NO: 68,382 AD 884 965L
REPORT NO: AFML-TR-71-91 May 1971
TITLE: DEVELOPMENT OF HIGH TEMPERATURE
POLYIMIDE SYSTEMS FOR HIGH PERFORMANCE
AIRCRAFT STRUCTURAL APPLICATIONS
AUTHOR: R. D. Johnson, et al.
CONTRACT NO: F33615-70-C-1547
CONTRACTOR: Northrop Corporation
PROJECT MONITOR: R. M. Neff (AFML/LC)
PROJECT NO: 6169CW

ABSTRACT: The Fusible Film Process was demonstrated successfully in producing high-quality boron-polyimide broadgoods, 24 inches wide by 88 inches long, both with and without a 104 glass scrim. The properties of the Skybond 704 film forming resin and the boron reinforcement were characterized. The scrim improved the handleability of the prepreg, reduced the width shrinkage to less than 1% in over staging and increased the transverse tensile and flexure properties of laminates at room temperature and 550 F substantially. Excellent composition control was achieved in the prepreg and maintained in the laminates. Low void contents were achieved by oven staging the prepreg to a nominal 3 1/2 w/o volatiles prior to consolidation. Void contents of 2 plus 1% were achieved in laminates made without scrim by consolidation at 450 F for 3 hours at 100 psig.

ACCESS NO: 65,217 AD 889 934L
REPORT NO: AFML-TR-71-194 AD 889 935L
Volumes I & II November 1971
TITLE: EVALUATION OF ENVIRONMENTAL AND
SERVICE CONDITIONS ON FILAMENTARY
REINFORCED COMPOSITE STRUCTURAL
JOINTS AND ATTACHMENTS
AUTHOR: R. W. Gehring
CONTRACT NO: F33615-69-C-1436
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: G. Husman (AFML/LC)
PROJECT NO: 6169CW

ABSTRACT: This volume is Volume I of two volumes and describes the program, specimens used, and results to evaluate pinned mechanically fastened joints, single overlap, double overlap, and scarfed bonded joints under typical service conditions represented by the fatigue and environmental portions of the program. A nonlinear discrete element method of analysis is presented for the theoretical analysis of bonded joints where the shear stress-strain curves of the adhesive systems are represented by a piecewise linear approximation. Example in the use of the method are shown as compared to bonded specimen data. Results of all three phases of the program are summarized in this volume through the use of summary curves, tables, and charts. These summary curves, for the most part represent the design curves for pinned and bonded joints.

METALS AND CERAMICS DIVISION (AFML/LL)

ACCESS NO: 69,062 **AD 882 615**
REPORT NO: AFML-TR-67-167 **February 1971**

TITLE: Part IV
RESEARCH ON EXPLORATORY DEVELOPMENT OF NONDESTRUCTIVE METHODS FOR CRACK DETECTION

AUTHOR: R. Schroeer, et al.
CONTRACT NO: F33615-70-C-1112
CONTRACTOR: Arvin Systems, Inc.
PROJECT MONITOR: Lt. J. Bohlen (AFML/LLN)
AFML TASK NO: 735109

ABSTRACT: Results of a research study devoted to the exploratory development of a non-destructive method for crack detection are reported in this document. The method investigated is based upon the Acoustic Impact Technique (AIT) which analyzes the vibrations induced in test specimens by mechanical pulses. Specimens of 6061-T6 aluminum and D6ac steel were fatigued while their acoustic impact responses were measured in order to correlate their AIT responses with the beginning and growth of cracks. In several instances the beginning of subsurface defects that could only be verified by metallographic examination were indicated by the AIT measurements. Inconsistencies in some AIT fatigue measurements cannot be explained at present; additional and expanded studies would definitely be necessary.

ACCESS NO: 65,055 **AD 884 140**
REPORT NO: AFML-TR-69-67 **May 1971**

TITLE: Volume IV
IMPROVED GRAPHITE MATERIALS FOR RE-ENTRY VEHICLES

AUTHOR: E. R. Stover
CONTRACT NO: F33615-68-C-1283
CONTRACTOR: General Electric Company
PROJECT MONITOR: J. D. Latva (AFML/LLM)
AFML TASK NO: 735002

ABSTRACT: Several types of carbon-carbon composites have been developed, in which either high or low modulus carbon fiber bundles extend continuously in several directions in three dimensions. Ablation screening tests at 90 atm. stagnation pressure have shown that 3-directional reinforced graphites, having a high proportion of fibers in the axial direction can have ablation rates similar to ATJ-S with proper matrix processing. Fine-textured, cubic, 7-directional-reinforced composites have shown performance similar to 3-directional samples with similar processing.

ACCESS NO: 69, 330 AD 885 295
REPORT NO: AFML-TR-69-84 April 1971
TITLE: Part V
STABILITY CHARACTERIZATION OF REFRACTORY MATERIALS UNDER HIGH VELOCITY ATMOSPHERIC FLIGHT CONDITIONS PART V: ADDITIONAL STUDIES

AUTHOR: L. Kaufman, et al.
CONTRACT NO: AF33615-3859
CONTRACTOR: ManLabs Inc.
PROJECT MONITOR: J. R. Fenter (AFML/LLM)
AFML TASK NO: 735002, 735001, 731201
ABSTRACT: The oxidation of refractory borides, graphites and JT composites, hypereutectic carbide-graphite composites, refractory metals, coated refractory metals over the extensive spectrum of environmental conditions encountered during reentry or high velocity atmospheric flight, as well as those employed in furnace tests was studied. Elucidation of the relationship between hot gas/cold wall (HG/CW) surface effects in terms of heat and mass transfer rates at high temperature was a principal goal. Spectral emittance measurements at 0.65 microns were carried out under high velocity CG/HW conditions at one atmosphere for R512E/Cb752(G-22), R512C/Ta-T222(G-23), W+Zr+Cu(G-20), and ZrB₂+SiC+C(A-10)M₂.

ACCESS NO: SA-278 AD 692 109
REPORT NO: AFML-TR-69-192 June 1969
TITLE: A REVIEW OF THE DISCONTINUITY IN THE S/N CURVE

AUTHOR: M. Bily
CONTRACT NO: F61052-68-C-0027
CONTRACTOR: University of Southampton
PROJECT MONITOR: W. J. Trapp (AFML/LLD)
AFML TASK NO: 735106
ABSTRACT: This review outlines the discontinuities reported for a wide variety of materials. It is suggested that there are four basically different types of discontinuities in S/N curves, related to various phenomena. Correlation of the dynamical yield point with the discontinuity is established in large number of instances.

ACCESS NO: 69,567 AD 886 984
REPORT NO: AFML-TR-70-54 June 1971

TITLE: Part II
CERAMIC MATRIX COMPOSITES AS ARMOR MATERIALS

AUTHOR: D. R. Johnson, et al.
CONTRACT NO: F33615-69C-1659
CONTRACTOR: The Franklin Institute Research Lab.
PROJECT MONITOR: J. R. Fenter (AFML/LLM)
AFML TASK NO: 735001

ABSTRACT: Specimens of nichrome wire mesh reinforced, titania doped alumina and spinel have been fabricated by pressure calcintering and ballistically tested. The samples were right circular cylinders, 4" diameter x 1/4-3/4" thick. Photographs of ballistically tested samples, illustrating the types of fracture incurred, are given. A six months feasibility study of these and other composites is reviewed. Microstructural examination shows no degradation of the wire reinforcement or the matrix materials during fabrication. Sapphire fibers and whiskers did not significantly enhance the properties of the spinel and alumina matrices; the sapphire whiskers were dissolved in the matrix materials during fabrication.

ACCESS NO: 69,293 AD 884 994
REPORT NO: AFML-TR-70-169 April 1971
TITLE: A QUANTITATIVE EVALUATION OF TEST METHODS FOR BRITTLE MATERIALS

AUTHOR: C. D. Pears, et al.
CONTRACT NO: AF33615-3265
CONTRACTOR: Southern Research Institute
PROJECT MONITOR: G. R. Atkins (AFML/LLD)
AFML TASK NO: 735003

ABSTRACT: Testing of a higher fired A-11 blank revealed that density was increased and average strength was reduced. Surface voids, which were detected, (and probably subsurface voids) could account for a portion of the reduction in strength. Non-parametric statistical studies indicated a positive correlation between strength and fired density and negative correlations between strength and minimum fired thickness and between strength and cone angle. Characterization studies generated additional data for correlation and improved techniques for ceramographic preparation. Deep-lapping techniques were investigated to determine if they could be used to remove surface material (as much as 5 mils) without creating subsurface damage. The effects of refiring on the material surface structure were also investigated.

ACCESS NO: 68, 889 AD 719 757
REPORT NO: AFML-TR-70-202 January 1971

Part I

TITLE: AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PT. I: A REVIEW OF PERTINENT ASPECTS OF FRACTURE-(DEVELOPMENT OF RELEVANT CONCEPTS OF LINEAR ELASTIC FRACTURE MECHANICS)

AUTHOR: S. O. Davis

CONTRACT NO:

CONTRACTOR:

INTERNAL

PROJECT MONITOR:

S. O. Davis (AFML/LLN)

AFML TASK NO:

735108

ABSTRACT:

The purpose of this report is to synthesize technological concepts of fracture by making a historical review of the literature from 1913 up to the present time. The pertinent aspects of fracture and the development of relevant concepts of linear elastic fracture mechanics derivatives were delineated and summarized for the prediction of the critical length of fatigue cracks. The pertinent aspects of fracture consisted of the synthesis of Ingliss, Griffith, Orowan, Irwin, and Westergaard's relevant theoretical concepts. It also delineates Boyle's analytical and experimental results of the Westergaard-Irwin theoretical compliance of through-the-thickness centrally cracked plate and sheet for the determination of plane-strain (K_{Ic}) and plane-stress (K_{Ic}) fracture toughness stress-intensity parameter of high strength alloys.

ACCESS NO: 69, 299 AD 725 028
REPORT NO: AFML-TR-70-202 April 1971

Part II

TITLE: AN APPLICATION OF FRACTURE CONCEPTS TO THE PREDICTION OF CRITICAL LENGTH OF FATIGUE CRACKS. PT. II: A REVIEW OF PERTINENT ASPECTS OF FRACTURE (THEORETICAL AND ANALYTICAL ASPECTS OF FATIGUE OF METALS)

AUTHOR: S. O. Davis

CONTRACT NO:

CONTRACTOR:

INTERNAL

PROJECT MONITOR:

S. O. Davis (AFML/LLN)

AFML TASK NO:

735108

ABSTRACT:

This part of the report presents a technical documentary historical review of pertinent theoretical and analytical aspects of fatigue failure and its relationship to fracture mechanics. The review covers the period 1829 to 1970. Fatigue failure, i. e., fracture without gross plastic deformation under repeated application of stress below the proportional limit, has been recognized for at least 138 years. Despite numerous investigations on the subject, there is no available theory for correlating the many variables affecting fatigue failure and for successfully predicting failure.

ACCESS NO: 69,298 AD 725 752
REPORT NO: AFML-TR-70-202 April 1971
TITLE: Part III
AN APPLICATION OF FRACTURE CONCEPTS
TO THE PREDICTION OF CRITICAL LENGTH
OF FATIGUE CRACKS. PT. III: A UNIFIED
THEORY FOR FRACTURE OF METAL AND
ALLOYS
AUTHOR: S. O. Davis
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: S. O. Davis (AFML/LLN)
AFML TASK NO: 735108

ABSTRACT: A thermodynamic energy approach is used to develop a unified theory of fracture relative to mechanical response of metals and alloys as a function of the atomic, and metallurgical structures and the phenomenological aggregate levels collectively. Fracture (stable cracking) and fracture dynamics (unstable cracking) are correlated in terms of the theory based upon the process of energy transformation and in terms of mechanical and thermal energy of the First Law of Thermodynamics: JQ-W-JE12. The theory serves as a rational foundation for analysis of experimental studies of fracture and fatigue crack propagation to be reported in Parts IV and V.

ACCESS NO: 69,129 AD 723 285
REPORT NO: AFML-TR-70-202 March 1971
TITLE: Part IV
AN APPLICATION OF FRACTURE CONCEPTS TO
THE PREDICTION OF CRITICAL LENGTH OF FA-
TIGUE CRACKS PART IV: FRACTURE MECHANICS
ANALYSES FOR PREDICTION OF CRITICAL LENGTHS
AND VELOCITIES OF FATIGUE CRACKS IN 7075-
T7351 ALUMINUM ALLOY
AUTHOR: S. O. Davis

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: S. O. Davis (AFML/LLN)
AFML TASK NO: 735108
ABSTRACT: The Irwin fracture criteria and Boyle mechanical compliance analysis were used to predict critical crack lengths of stable fatigue cracks in aluminum alloy (7070-T7351) plates. The Boyd hypothesis was also used to predict the velocity of unstable cracks in these plates. These predictions were compared with experimental results to be reported in the final part (Part V) of this technical report.

ACCESS NO: 69,125 AD 883 046
REPORT NO: AFML-TR-70-208 December 1970
TITLE: DEVELOPMENT OF IMPROVED COATINGS FOR
NICKEL-AND COBALT-BASE ALLOYS

AUTHOR: J. F. Nejedlik
CONTRACT NO: F33615-68-C-1628
CONTRACTOR: TRW Inc.
PROJECT MONITOR: N. M. Geyer (AFML/LLP)
AFML TASK NO: 731201

ABSTRACT: The purpose of this study was to develop and upgrade aluminum containing coating systems for the protection of nickel and cobalt alloys used in gas turbine hot section components. A comprehensive investigation of modifying elements was undertaken and correlated with hot corrosion resistance and diffusional stability under blade and vane cycle conditions (1950° and 2200° F peak temperatures, respectively). The modifying elements and combinations evaluated were Co, Mn, Cr, Ta, Fe, Mg, Si, Y, Cr-Mn, Co-Cr and Fe-Cr. The influence of the modified coatings on mechanical properties, stress-oxidation, impact and thermal shock of the superalloys was also determined.

ACCESS NO: 68,986 AD 881 707
REPORT NO: AFML-TR-70-212 February 1970
TITLE: NEW AND REFINED NONDESTRUCTIVE TECH-
NIQUES 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)
AFML TASK NO: 735109

ABSTRACT: This report summarizes effort to develop more sensitive techniques for detecting and evaluating flaws in graphite. It was concluded that the potential areas of improvement in the state-of-the-art lay both in the interrogative and interpretative aspects of NDT. In regard to improved interrogative techniques particular emphasis was placed upon developing a better understanding and control of ultrasonic focused pulse echo inspection techniques to provide maximum response to small defects and the demonstration of the feasibility of delta scan ultrasonic inspection for ATJ-S and AXF-9Q grades of graphite. In the area of interpretation, primary emphasis was on improved techniques for delineation of small X-ray images and the application of signal processing techniques for analyzing the ultrasonic responses received from various types of defects in graphite. Results have defined the limitations of conventional pulse echo testing and demonstrated the basic feasibility of delta inspection for graphite inspection.

ACCESS NO: 68,853 AD 881 239
REPORT NO: AFML-TR-70-213 January 1971
TITLE: INVESTIGATION OF THE PROPERTIES OF
CARBON COMPOSITES AND THEIR RELATION-
SHIP TO NONDESTRUCTIVE TEST MEASURE-
MENTS

AUTHOR: J. S. Evangelides et al.
CONTRACT NO: F33615-69-C-1640
CONTRACTOR: McDonnell Douglas Astronautics Company
PROJECT MONITOR: W. L. Shelton (AFML/LLN)
AFML TASK NO: 735109
ABSTRACT: Material variations and discrete discontinuities can be encountered in carbon-carbon composites. This requires that those variations that affect the quality and performance of the composite be identified and characterized. The approach to this problem was to characterize the precursor materials and apply nondestructive analysis and mechanical testing to the carbon-carbon materials after various processing steps to assist in identifying and characterizing these properties that affect the performance of uni- and multidirectional carbon-carbon composites. A number of different types of defects were intentionally introduced into the composites during the processing steps to assist in determining the effect of defects on the composite properties.

ACCESS NO: 69,124 AD 883 597
REPORT NO: AFML-TR-70-217 December 1970
TITLE: THE EMITTANCE OF REFRACTORY METAL
COATINGS

AUTHOR: K. O. Bartsch, et al.
CONTRACT NO: F33615-69-C-1618
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: N. Geyer (AFML/LLP)
AFML TASK NO: 731201
ABSTRACT: Current activity related to the emittance of coated refractory metals was reviewed to update a similar survey made under a previous contract. The review disclosed new hypersonic vehicles environments of significance to emittance measurement techniques. Under the experimental part of the program new total spectral emittance data were gathered for the Cr-Ti-Si, W-3, and Si-20Cr-20Fe systems at 2700° F to 2800° F, and at 5 and 100 Torr. Total and spectral normal emittance measurements were made of the Si-20Ti-10Mo coating on Ta-222 at 2000° F to 2800° F at pressures from 0.01 to 760 Torr.

ACCESS NO: 69,157 AD 883 978
REPORT NO: AFML-TR-70-239 February 1971
TITLE: DEVELOPMENT OF NONDESTRUCTIVE TEST
TECHNIQUES FOR MULTIDIRECTIONAL FIBER-
REINFORCED RESIN MATRIX COMPOSITES

AUTHOR: J. L. Cook
CONTRACT NO: F33615-69-C-1624
CONTRACTOR: McDonnell Douglas Astronautics Company
PROJECT MONITOR: Capt. L. R. Gulley (AFML/LLN)
AFML TASK NO: 735109

ABSTRACT: The first year of effort on a two year duration program was designed to nondestructively evaluate as-woven multidirectional quartz yarn reinforcement material processed through impregnation and cure cycles, and make preliminary nondestructive assessment of the cured composite materials. Both film and television imaging X-ray techniques were employed on both the as-woven reinforcement and the impregnated and cured composite. Neutron radiography with doped and undoped cured composite specimens was conducted and evaluated as compared to conventional X-ray radiography. The cured composite was also evaluated using sound velocity through the thickness, ultrasonic pulse-echo techniques, and ultrasonic through transmission attenuation C-scan mapping. The results of the first year's effort indicate significant advancement in the application of current state-of-the-art nondestructive techniques.

ACCESS NO: 69,289 AD 884 516
REPORT NO: AFML-TR-70-255 March 1971
TITLE: AHP CYLINDER FABRICATION - LTV CARBON-
CARBON COMPOSITE

AUTHOR: B. A. Forcht
CONTRACT NO: F33615-69-C-1783
CONTRACTOR: LTV Aerospace Corporation
PROJECT MONITOR: J. D. Latva (AFML/LLM)
PROJECT NO: 698CW

ABSTRACT: Work effort was devoted to the fabrication of two 9 inch diameter, 15 inch long cylinders with a 1/2 inch wall. Based on the results of the preceding carbon-carbon investigation, the R-120 phenolic, WCA graphite cloth system with four furfuryl alcohol impregnations and pyrolyzation steps was used. Flat panels were processed with the cylinders and characterized by mechanical and physical testing. These cylinders exhibited improved fabrication in the preceding carbon-carbon investigation. One cylinder and test specimen, machined from the second cylinder, were forwarded to the Air Force for testing in the joint SAMSO/AFML/Aerospace screening task of the SAMSO Advanced Heatshield Program (AHP).

ACCESS NO: 69,156 **AD 883 389**
REPORT NO: AFML-TR-70-260 **November 1970**
TITLE: DEFECT INTERACTION AND METALLURGICAL
PROCESS SIMULATION IN METALS AND ALLOYS
AUTHOR: J. R. Beeler, Jr.
CONTRACT NO: F33615-68-C-1012
CONTRACTOR: North Carolina State University
PROJECT MONITOR: Dr. H. L. Gegel (AFML/LLS)
AFML TASK NO: 735302
ABSTRACT: Computer experiments were used to study short-range order processes which proceed via the vacancy diffusion mechanism in an AB alloy with an A2 structure disordered state and a B2 superlattice perfectly ordered state. This was done by simulating vacancy migration in an initially disordered alloy on a jump-by-jump basis at temperatures slightly above the critical temperature for long-range order. Four different fully kinetic models were used. Point defect characteristics in an hcp structure were studied using the quasi-dynamic computer experiment method.

ACCESS NO: 68,952 **AD 882 269**
REPORT NO: AFML-TR-70-272 **February 1971**
TITLE: EVALUATION OF A RELIABILITY ANALYSIS
APPROACH TO FATIGUE LIFE VARIABILITY OF
AIRCRAFT STRUCTURES USING C-130 IN-
SERVICE OPERATIONAL DATA
AUTHOR: C. S. Sarphie, Jr., et al.
CONTRACT NO: F33615-70-C-1252
CONTRACTOR: Lockheed-Georgia Company
PROJECT MONITOR: R. C. Donat (AFML/LLD)
AFML TASK NO: 146704, 735106
ABSTRACT: An analytical program to evaluate a probabilistic analysis approach to the prediction of aircraft structural fatigue endurance using data obtained from the C-130 Structural Integrity Program has been completed. This report is the final report of this program. The proposed method is applied to three fatigue sensitive areas of the C-130 center wing using test results from C-130 B and E wing full scale fatigue tests. The results of this analysis are then correlated with service experience data from the Air Force's fleet of C-130 B and E transport aircraft. In addition, this data is also used to consider the applicability of the basic distributions and parameters selected for the proposed method.

ACCESS NO: 69,206 AD 884 111
REPORT NO: AFML-TR-70-283 March 1971
TITLE: PREPARATION OF AN OMNIWEAVE-REINFORCED
CARBON/CARBON CYLINDER AS A CANDIDATE
FOR EVALUATION IN THE ADVANCED HEAT
SHIELD SCREENING PROGRAM

AUTHOR: E. R. Stover, et al.
CONTRACT NO: F33615-68-C-1283
CONTRACTOR: General Electric Company
PROJECT MONITOR: J. D. Latva (AFML/LLM)
AFML TASK NO: 735002
ABSTRACT: Details of fabrication and process history, NDT
characterization and preliminary flexure test data are presented for the first
"4-D*" Omniweave C/C cylinder material fabricated by GE-RESA. Although
packing faults in the weave, resulting from the experimental nature of the
initial fabrication, created areas in which ID tolerances were not obtained,
satisfactory material and machined specimens sufficient for the test pro-
gram were delivered.

ACCESS NO: 69,287 AD 725 750
REPORT NO: AFML-TR-70-311 March 1971
TITLE: SOME OBSERVATIONS PERTAINING TO SIMPLE
FRACTURE TOUGHNESS SCREENING TESTS
FOR TITANIUM

AUTHOR: T. M. F. Ronald, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: P. L. Hendricks (AFML/LLP)
AFML TASK NO: 735105
ABSTRACT: While the K_{Ic} value of a material is a very useful
measurement of fracture toughness, its valid experimental determination can
be a complex and expensive procedure, not at present suited to routine alloy
screening or quality control purposes. To explore the feasibility of estimating
 K_{Ic} in titanium alloys using techniques that are more convenient to perform,
impact and slow-bend tests were made on either V-notched or fatigue-precracked
Charpy specimens, and the resulting energy values were compared with the
corresponding approximate K_{Ic} values. Results from five titanium-based
alloys and two steels showed that precracked specimens broken in slow bend
gave energy values that could be related to K_{Ic} in a straightforward manner.

ACCESS NO: 69,155 AD 723 636
REPORT NO: AFML-TR-70-312 February 1971
TITLE: IMPROVED PROPERTIES OF Ti-6Al-6V-2Sn
THROUGH MICROSTRUCTURE MODIFICATION

AUTHOR: J. A. Hall, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: T. M. F. Ronald (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: The fracture toughness of the Ti-6Al-6V-2Sn alloy in the annealed condition is greatly influenced by microstructural features which may vary considerably as a result of differing thermal-mechanical processing operations employed prior to the annealing heat treatment. The variety of microstructures which can result merely by heat treatment is categorized and the related tensile and toughness properties are presented. In instances where higher fracture toughness is desired, judicious heat treatment of the as-received material can often increase this property. Of the heat treatments employed in this investigation, the properties were most significantly improved by solution treating at 1710 F for 80 minutes, air cooling, and subsequently heating to 1400 F for one hour followed by an air cool.

ACCESS NO: 68,819 AD 883 606
REPORT NO: AFML-TR-70-315 January 1971
TITLE: DEVELOPMENT AND FIELD EVALUATION OF
A THIN SHEET INSPECTION SYSTEM

AUTHOR: I. R. Kraska, et al.
CONTRACT NO: F33615-69-C-1480
CONTRACTOR: General American Transportation Corporation
PROJECT MONITOR: R. R. Rowand (AFML/LLN), et al.
AFML TASK NO: 735109

ABSTRACT: This report covers the development and field evaluation of a Lamb wave ultrasonic system which is capable of on-line inspecting thin metallic sheets. Preliminary work performed on previous contracts is summarized, as are a discussion of Lamb wave principles, GARD's development of swept frequency techniques, and a description of the present inspection system. The work performed on this contract, the provision of a data recording capability, and the successful field evaluation of the system is described in detail. The field evaluation section is divided into two parts: first, a slow speed (30 ft/min), high sensitivity inspection which found laminar defects occupying approximately 3% of the sheet thickness, and second, a higher speed (450 ft/min), lower sensitivity inspection which found laminar defects occupying 20% of the sheet thickness.

ACCESS NO: 62,720 AD 884 961
REPORT NO: AFML-TR-71-18 April 1971
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 second year of Project Themis-Metal Deformation Processing are presented. The accomplishments include: 1) Plastic Flow and Fracture Studies Related to Metalworking, 2) Microstructure Studies Related to Deformation Processing, 3) Extrusion Studies, 4) Studies of Friction and Lubrication. The objectives of number one are to provide mechanical property data for use in metalworking equations and for understanding the behavior of the particular materials considered during deformation processing.

ACCESS NO: 69,096 AD 882 806
REPORT NO: AFML-TR-71-27 February 1971
TITLE: DEVELOPMENT OF AN IMPROVED ULTRA-
HIGH STRENGTH STEEL FOR FORGED AIRCRAFT
COMPONENTS

AUTHOR: R. T. Ault, et al.
CONTRACT NO: F33615-69-C-1638
CONTRACTOR: Republic Steel Corporation
PROJECT MONITOR: K. Kojola (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: The objective of this program was to develop an ultra-high strength steel in the 300 to 320 ksi ultimate tensile strength range, with improved fatigue strength, fracture toughness, and stress corrosion resistance for greater reliability in forged landing gear components. Alloy development studies were conducted on two bainitic alloy systems and two martensitic alloy systems in order to develop the best combination of mechanical properties at tensile strength levels in excess of 300,000 psi. Of the four alloy systems investigated, steels from the low alloy medium carbon Ni-Cr-Mo-Si-V martensitic system developed the best combination of fracture toughness, fatigue strength, and stress corrosion cracking resistance.

ACCESS NO: 69,295 AD 885 271
REPORT NO: AFML-TR-71-28 April 1971
TITLE:

**THE RELATIONSHIP OF MICROSTRUCTURE
AND MECHANICAL PROPERTIES OF
EXTRUDED TITANIUM ALLOY BARS TO
THE PRIOR DEFORMATION PROCESSING
HISTORY**

AUTHOR: F. J. Gurney, et al.
CONTRACT NO: F33615-69-C-1198
CONTRACTOR: Westinghouse Electric Corporation
PROJECT MONITOR: V. DePierre (AFML/LLN)
AFML TASK NO: 735108

ABSTRACT: The interrelation of extrusion process variables with mechanical properties and microstructure is analyzed for three titanium alloys; the alpha alloy Ti-5Al-2.58Sn, the alpha-beta alloy Ti-6Al-4V, and the beta alloy Ti-13V-11Cr-3Al. Process variables analyzed are reduction ratio, conical die angle, ram velocity, and billet preheat temperature. Information is obtained from duplicate billets which were extruded at each condition with one extruded bar allowed to air cool and the other bar water quenched immediately after extrusion. Room temperature mechanical properties from standard tensile and Charpy impact tests were obtained at each extrusion condition and are analyzed as a function of the pre-deformation temperature. Microstructural variations influenced by process variations are analyzed by comparing the pre-deformation microstructure and also that structure resultant from normal processing of the particular alloy.

ACCESS NO: 69,423 AD 726 998
REPORT NO: AFML-TR-71-32 May 1971
TITLE:

**THE DEVELOPMENT AND USE OF A TORSIONAL
SPLIT HOPKINSON BAR FOR EXPERIMENTS IN
DYNAMIC PLASTICITY**

AUTHOR: Dr. T. Nicholas, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The development and use of a torsional split-Hopkinson bar testing apparatus for determining the mechanical properties of materials at high rates of strain is described. The apparatus is capable of generating a smooth torsional pulse with a risetime of approximately 20 sec and can be used to generate shear stress-strain data at strain rates above 10^3 sec⁻¹. Experimental data are presented for an aluminum alloy. Results of incremental wave propagation tests on quasistatically prestressed specimens of an essentially "rate-independent" metal indicate that the velocity of propagation of the wave front is that of an elastic shear wave which is in agreement with the rate-dependent theory of plastic wave propagation.

ACCESS NO: 69, 037 AD 882 527
REPORT NO: AFML-TR-71-34 March 1971
TITLE: RESEARCH ON DIFFUSION IN MULTIPHASE
TERNARY SYSTEMS
AUTHOR: G. W. Powell, et al.
CONTRACT NO: AF33615-3948
CONTRACTOR: Ohio State University
PROJECT MONITOR: Lt. T. Moore (AFML/LLS)
AFML TASK NO: 735306
ABSTRACT: This technical report contains a detailed description and analysis of the results of the research on reaction diffusion in the Ti/SiC and Ti-6V-4Al/SiC systems; in addition, this same report also contains an analysis of reaction diffusion in binary metal-nonmetal systems. The present report describes the results of the research on displacement reactions in metal-metal oxide systems. The specific objective of this latter research was to develop a theory for the prediction (or rationalization) of the morphologies and kinetics for simple displacement reactions from a knowledge of the thermodynamic and kinetic properties of the phases involved. In this regard, significant progress in understanding and controlling the morphologies and kinetics of displacement reactions has been achieved, and a means for the formation of an interwoven two-phase structure of metal and compound has been discovered.

ACCESS NO: 69, 205 AD 884 041
REPORT NO: AFML-TR-71-37 March 1971
TITLE: EFFECT OF STRAIN RATE, TEMPERATURE
AND MULTIAXIAL STRESS ON THE STRENGTH
AND DUCTILITY OF S-200E BERYLLIUM AND
6Al-4V TITANIUM
AUTHOR: U. S. Lindholm, et al.
CONTRACT NO: F33615-69-C-1248
CONTRACTOR: Southwest Research Institute
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735106
ABSTRACT: The strength properties of S-200E beryllium and 6Al-4V titanium were determined under conditions of combined stress, elevated temperatures, and high strain rates. Beryllium specimens were obtained from both extruded rod and hot-pressed block. The range of test conditions included strain rates from 10^{-3} to 1000 sec^{-1} , temperatures from 70 to 1000°F , and both uniaxial and biaxial states of stress. The biaxial stress states were obtained with thin-walled tubular specimens loaded with axial tension or compression, torsion, or internal pressure.

ACCESS NO: 66,793 **AD 888 888L**
REPORT NO: AFML-TR-71-43 **April 1971**
TITLE: TRANSITION METAL DIBORIDE MATRIX COM-
POSITES

AUTHOR: D. A. Schulz, et al.
CONTRACT NO: F33615-69-C-1645
CONTRACTOR: Union Carbide Corporation
PROJECT MONITOR: J. R. Fenter (AFML/LLM)
AFML TASK NO: 735001

ABSTRACT: Titanium diboride and zirconium diboride composites containing "Thornel" 50 graphite fibers, silicon carbide whiskers, and "Zircar" zirconium oxide fibers were fabricated by hot-pressing. In all composites fabricated to near theoretical density, degradation of the fibrous component occurred. The degradation is a recrystallization process, rather than a chemical interaction between the fibers and the matrix components. Recrystallization took place in each of the types of fibers, including "Thornel" 50 fibers coated with TiC and TiB₂. In diboride composites containing SiC whiskers, the recrystallization of the whiskers was greatly reduced by using large diameter (>5 μ) whiskers. The strength of composites containing the undergraded SiC whiskers, however, was less than that of the unreinforced diboride matrix.

ACCESS NO: 69,518 **AD 728 225**
REPORT NO: AFML-TR-71-47 **July 1971**
TITLE: DEVELOPMENT OF TITANIUM ALLOYS FOR
CAST GAS TURBINE ENGINE COMPONENTS

AUTHOR: U. L. Hellmann, et al.
CONTRACT NO: F33615-69-C-1608
CONTRACTOR: General Motors Corporation
PROJECT MONITOR: P. L. Hendricks (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: A two-phase problem definition program was conducted to determine the need for development of titanium alloys for casting high speed rotating components, e. g., compressor impellers. Four commercially available alloys, Ti-6Al-4V, 5621S, IMI700, and Beta III were appraised with respect to castability and end-item casing performance potential. Phase I screening studies involved casting a stylized shape in refractory metal face coated ceramic shell molds by skull melting and bottom pour induction melting. Castings were subjected to non-destructive inspection, and after appropriate heat treatment, to tensile, high cycle reverse bending fatigue, ballistic impact and metallographic tests.

ACCESS NO: 69, 292 AD 884 785
REPORT NO: AFML-TR-71-48 March 1971
TITLE: STRENGTHENING MECHANISM OF HIGH STRENGTH
TITANIUM ALLOYS
AUTHOR: M. A. Greenfield, et al.
CONTRACT NO: F33615-70-C-1297
CONTRACTOR: New York University
PROJECT MONITOR: P. L. Hendricks (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: The investigation to relate fracture toughness, void formation and growth and ductility to microstructural features in an α - β alloy, Ti-5.25Al-5.5V-0.9Fe-0.5Cu has continued. New data confirm the earlier reported relationships between fracture toughness and microstructure of both equiaxed alpha and Widmanstätten plus grain boundary in aged beta matrix morphologies. In equiaxed alpha structures, fracture toughness depends linearly upon the grain boundary area per unit volume, S_V and is independent of equiaxed alpha particle size or spacing. In a grain boundary alpha structure, fracture toughness depends both on S_V and, within limits, linearly on the thickness of the grain boundary alpha.

ACCESS NO: 69, 296 AD 884 978
REPORT NO: AFML-TR-71-50 April 1971
TITLE: FATIGUE DAMAGE ACCUMULATION AND TESTING FOR PERFORMANCE EVALUATION
AUTHOR: A. M. Freudenthal
CONTRACT NO: F33615-69-C-1609
CONTRACTOR: George Washington University
PROJECT MONITOR: W. J. Trapp (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The effect of mean stress and of stress amplitude on the various stages of the fatigue process is discussed in the light of recent research on fatigue mechanisms with the purpose of assessing the relevance of fatigue testing processes under constant and under random loading as well as of the application of linear fracture mechanics in the prediction of the fatigue life of airframes. It is concluded that fatigue tests based on a mission-determined representative flight-by-flight loading spectrum will produce the closest approximation of service conditions and should be used both for life prediction of structures and for materials evaluation for fatigue performance.

ACCESS NO: 69,336 AD 725 037
REPORT NO: AFML-TR-71-52 March 1971
TITLE: OUTLINE OF A THEORY OF POWERFUL SELECTION
OF DISTRIBUTION FUNCTIONS
AUTHOR: W. Weibull
CONTRACT NO: F61052-69-C-0029
CONTRACTOR: La Rosiaz s/Lausanne (Switzerland)
PROJECT MONITOR: W. J. Trapp (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The conventional method of analysing a given set of test data consists in assuming a distribution function and estimating its parameters. The only way of deciding whether the function is acceptable or not and which of two assumed functions is the better one is by means of a test of goodness-of-fit. For small and moderate sample sizes this test makes a very unreliable basis for a decision, and the confidence that can be put in the choice is practically unknown. In order to eliminate these deficiencies a new method, called the method of powerful selection, is proposed. By use of a test statistic, called the selector, it is possible, without preceding parameter estimations, to state the acceptability of a function on the basis of a preassigned level-of-significance and the decision power, that is, the chance of making a true decision between two functions.

ACCESS NO: 69,300 AD 835 000
REPORT NO: AFML-TR-71-58 March 1971
TITLE: CORROSION CRACKING OF METALLIC MATERIALS
AUTHOR: M. G. Fontana
CONTRACT NO: F33615-69-C-1258
CONTRACTOR: The Ohio State University
PROJECT MONITOR: Dr. C. T. Lynch (AFML/LLS), et al.
AFML TASK NO: 731202

ABSTRACT: Work on the fundamental aspects of stress corrosion cracking of high-strength steels includes studies of effects of structure on crack velocity, hydrogen interactions with the steel, acoustical emission, dissolution of iron carbides, and growth kinetics of passive films. Crack velocity in a 250 maraging steel was changed substantially at the same strength level by altering the structure. Variations in crack velocity are related to microstructures determined by the electron microscope. Studies on hydrogen absorption show that the kinetics of hydrogen entry depended critically on the potential as it relates to the chemical identity of arsenic-containing species. Analysis of permeation transients for Fe-Cu alloys shows clear indications of variations in hydrogen trapping related to aging-related coherency strains. Growth kinetics of passive films at pH 4 and 6 are reported and optical constants are found to exhibit wider variations at these pH's than at pH 8.

ACCESS NO: 69,294 AD 884 796
REPORT NO: AFML-TR-71-65 May 1971
TITLE: EFFECT OF MELTING ON HIGH HARDNESS
ALPHA STABILIZED AREAS IN Ti-6Al-4V
ALLOY

AUTHOR: E. M. Grala
CONTRACT NO: F33615-69-C-1443
CONTRACTOR: TRW Inc.
PROJECT MONITOR: P. L. Hendricks (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: The chemical, metallurgical, and physical properties of a titanium oxynitride synthesized defect material introduced into a Ti-6Al-4V alloy briquette electrode and remelted were determined. The metallurgical stability of this synthesized defect material was studied by hot state microscopy and further remelt of the defect material. Experimental techniques utilized in this program were standard metallographic techniques, microhardness traverse, electron microprobe analysis, high temperature metallography, and induction melting. Twelve defect-containing specimens were characterized to a varying degree.

ACCESS NO: 69,794 AD 730 352
REPORT NO: AFML-TR-71-67 March 1971
TITLE: THEORETICAL INVESTIGATIONS OF THE
BEHAVIOR OF BRITTLE MATERIALS AT
VARIOUS RANGES OF TEMPERATURE

AUTHOR: E. H. UDO Wegner
CONTRACT NO: F61052-67-C-0064
CONTRACTOR: University of Stuttgart
PROJECT MONITOR: Dr. J. A. Herzog (AFML/LLS), et al.
AFML TASK NO: 735003

ABSTRACT: A general non-linear law of material behavior has been developed with the assumptions that the energy density of an isotropic material is invariant under the orthogonal group of transformations and that hydrostatic pressure produces only a volume change. For materials with crystal lattices, the energy density is assumed to be invariant under the crystalline group. This general law allows for the effects of thermal processes. Equations which are generalizations of the Beltrami equations and of the equation of heat conduction are stated to permit the determination of the unknown displacements and the temperature. These laws are very important in the use of brittle materials. As a part of this research, a non-linear thermodynamic theory for materials is established.

ACCESS NO: 69,395 **AD 726 582**
REPORT NO: AFML-TR-71-68 **May 1971**
TITLE: FATIGUE STUDY OF QUENCHED Al-6.5 AT
% ZN ALLOY
AUTHOR: S. Weissmann, et al.
CONTRACT NO: F33615-70-C-1240
CONTRACTOR: Rutgers University
PROJECT MONITOR: Dr. Walter H. Reimann (AFML/LLD)
AFML TASK NO: 735301

ABSTRACT: The defect structure of an Al-6.5 at % Zn alloy induced by quenching and low-temperature aging (-80° to +60°C) and the effects of fatigue cycling were investigated. The defect structure upon quenching consisted of homogeneously nucleated dislocation loops, helical dislocations developed from screw dislocations, the latter being introduced by two different processes. The defect structure also contained perfect loops converted from helical dislocations and faulted dislocation loops whose nucleation was enhanced by vacancies generated by quench deformation. Based on experimental evidence, a model is presented explaining the formation of a row of perfect dislocation loops from a single helical dislocation.

ACCESS NO: 200,105
REPORT NO: AFML-TR-71-69 **September 1971**
TITLE: STUDY OF DEFORMATION AND DEFECTS
OCCURRENCE IN ADVANCED FORGING
TECHNIQUE

AUTHOR: S. Kobayashi, et al.
CONTRACT NO: F33615-70-C-1320
CONTRACTOR: University of California
PROJECT MONITOR: S. O. Davis (AFML/LLN)
AFML TASK NO: 731508

ABSTRACT: The aim of the present investigation is to study the mechanics of plastic deformation and to find the relationship between defects formation and deformation characteristics in typical forging processes; namely plane-strain side-pressing and axisymmetric plastic indentation. This report consists of two parts. In the first part, the investigation was undertaken to examine the detailed deformation characteristics involved in axisymmetric plastic indentation. In the second part, the detailed mechanics of the side-pressing of circular cylinders under plane-strain conditions were obtained, based on the observed flow patterns of commercially pure aluminum and copper specimens.

ACCESS NO: 69,297 AD 725 761
REPORT NO: AFML-TR-71-70 April 1971
TITLE: MECHANICS OF BRITTLE MATERIALS UNDER
LINEAR TEMPERATURE INCREASES
AUTHOR: H. Neuber, et al.
CONTRACT NO: AF61052-875
CONTRACTOR: Technische Universitat, Munchen, Germany
PROJECT MONITOR: Dr. A. J. Herzog (AFML/LLS), et al.
AFML TASK NO: 735005

ABSTRACT: The results of work done to show the effects of surface roughness, residual stresses, strain rate, microstructure, alternating bending fatigue loading, and a nonuniform stress field on the strength of small (2. -8. mm diameter) alumina rods are given. The rods used in the work were characterized by determinations of grain size, porosity, hardness, surface roughness, and damping factor. Static bend tests at room temperature are used to determine the Young's modulus, the fracture stress, and the strain at fracture and to show the influence of specimen volume on the fracture stress. The effects of grain size and of porosity on these characteristics are shown. A new tensile test specimen is designed which achieves an almost uniform stress field in the test area. Some test results are given to show the validity of this procedure for brittle specimens.

ACCESS NO: 65,837 AD 728 234
REPORT NO: AFML-TR-71-73 April 1971
TITLE: DEVELOPMENT OF POROUS BERYLLIUM BY
THE HOT ISOSTATIC PRESSING OF PLASMA-
SPHEROIDIZED POWDER
AUTHOR: E. O. Speidel
CONTRACT NO: F33615-69-C-1648
CONTRACTOR: Battelle Memorial Institute
PROJECT MONITOR: K. L. Kojola (AFML/LLP)
AFML TASK NO: 735104

ABSTRACT: Spheroidal beryllium powder in the nominal 40 to 50-micron size range was prepared from irregular starting material by plasma spheroidization. An effort was made to develop hot-isostatic-pressing parameters necessary to reproducibly fabricate porous beryllium billets from this powder possessing uniform permeabilities of 0.1, 0.01, and 0.001 darcy \pm 10 percent. In the program, no billets were produced to the specified permeability of 0.1, 0.01, or 0.001 darcy \pm 10 percent. Only one full-size billet, having a permeability of 0.017 darcy, was within the range of 0.1 to 0.001 darcy. Reproducibility of the process was not established in this range as a second billet produced under identical conditions had a similar density but its permeability could not be determined.

ACCESS NO: 200, 106 AD 736 779
REPORT NO: AFML-TR-71-76 September 1971
TITLE: EFFECT OF MAGNESIUM AS AN ALLOYING
ELEMENT IN INCONEL 718
AUTHOR: W. H. Coats, Jr., et al.

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: S. Inoué (AFML/LLN)
AFML TASK NO: 735108

ABSTRACT: Six 50-lb heats of Inconel 718 were prepared with magnesium contents ranging from 1 to 350 ppm. Half were vacuum arc remelted and half were arc remelted under 1/2 atm of argon. The homogenized ingots were extruded and some bar segments were flattened. Upset tests showed decreased forgeability at the highest Mg content. Hot tensile tests at 1200°F did not show any effect of Mg. Stress rupture tests did show a considerably improved rupture ductility at 1200°F with 30 ppm of Mg and extending up to 200 ppm. The mechanism of this beneficial effect is not clear but it is suspected that Mg may influence the nucleation of Ni₃Cb platelets at grain boundaries.

ACCESS NO: 69, 394 AD 726 106
REPORT NO: AFML-TR-71-79 May 1971
TITLE: AN EXPERIMENTAL METHOD FOR DETER-
MINING MECHANICAL PROPERTIES AT HIGH
STRAIN RATES

AUTHOR: P. Madsen, et al.
CONTRACT NO: F61052-68-C-0032
CONTRACTOR: The Technical University of Denmark
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: An experimental method for determining the stress-strain relation in uniform tension at very high strain rates is presented. The equipment and the measuring technique used are described in some detail together with the numerical procedures involved in evaluating the data obtained during a test. Results obtained for commercially available copper in original and in annealed condition are presented in order to illustrate the method.

ACCESS NO: 69,541 **AD 728 239**
REPORT NO: AFML-TR-71-81 **April 1971**
TITLE: MECHANISMS OF FATIGUE IN MILL-ANNEALED
Ti-6Al-4V AT ROOM TEMPERATURE AND
600°F

AUTHOR: D. K. Benson, et al.
CONTRACT NO: F33615-70-C-1284
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: Dr. W. Reimann (AFML/LLD)
AFML TASK NO: 735301

ABSTRACT: The mechanisms of the fatigue of mill-annealed Ti-6Al-4V were studied at 600°F and room temperature. Early crack initiation (No. \sim 0.14 Nf) was found to occur in HCP α -grains by a slip-band mechanism under all but the least severe conditions of cyclic stress. Under cyclic stresses near the fatigue limit at room temperature, fatigue cracks began much later (No. \sim 0.4 N) at the interface between HCP α - and BCC β -grains without detectable slip. Under all conditions, Stage I fatigue crack growth occupied 50-80% of the total life. Although mechanical twins were produced in profusion near the growing State II fatigue cracks, they appeared to play no role in crack initiation or Stage I crack growth; nor did they facilitate Stage II growth.

ACCESS NO: 69,390 **AD 726 583**
REPORT NO: AFML-TR-71-83 **April 1971**
TITLE: THE EVALUATION OF GLASSES AS FORGING
LUBRICANTS

AUTHOR: A. T. Male, et al.
CONTRACT NO: F33615-69-C-1198
CONTRACTOR: Westinghouse Electric Corporation
PROJECT MONITOR: V. DePierre (AFML/LLN)
AFML TASK NO: 735108

ABSTRACT: The ring compression test has been successfully used to determine the relative efficiency of a number of lubrication systems for the high temperature forging of Type 300A maraging steel and titanium - 6 aluminum - 4 vanadium alloy. The results clearly indicate the advantage of using both a glass coating on the workpiece and a grease-base lubricant on the tooling. Data obtained has identified the optimum temperature range for use of each of the three glass coatings evaluated. Inaccuracies in the application of theoretical analysis to practical ring test results, due to bulging occurring at high friction levels, can be minimized by using specimens of small ratios of internal diameter and thickness to external diameter.

ACCESS NO: 69,392 AD 726 570
REPORT NO: AFML-TR-71-99 May 1971
TITLE: DYNAMICS OF PERIODICALLY STIFFENED
STRUCTURES USING A WAVE APPROACH

AUTHOR: G. S. Gupta
CONTRACT NO: F61052-68-C-0027
CONTRACTOR: University of Southampton
PROJECT MONITOR: Dr. D. G. Jones (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: Vibrations of beams, plates, periodically-stiffened in one or two directions have been analysed in terms of free flexural wave-groups. The normal modes of finite periodic beams, skin-stringer structures and "doubly-periodic structures" studied in these terms, utilising the concept of an equivalent internal restraint. Natural frequencies of finite structures are readily determined from the wave propagation constant curves. Free propagation zones of doubly-periodic structures exhibit a doubly periodic pattern. Theorems relating to the free flexural waves and their propagation constants were developed and relationships with the transfer matrix theory established.

ACCESS NO: 69,474 AD 727 773
REPORT NO: AFML-TR-71-100 June 1971
TITLE: THE REDUCTION OF RESONANT VIBRATIONS
IN INTEGRALLY STIFFENED SKIN-STRINGER
PANELS USING VISCO-ELASTIC MATERIALS

AUTHOR: F. Cicci
CONTRACT NO: F61052-68-C-0027
CONTRACTOR: University of Southampton, U. K.
PROJECT MONITOR: W. J. Trapp (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The vibration characteristics of integrally stiffened skin stringer panels have been determined using the method of transfer matrices. It was found that this type of structure can behave in a manner quite unlike a conventional structure composed of a flat skin and extruded open section stringers. The integrally stiffened skin tends to have mode shapes and natural frequencies governed by the bending stiffness of the stringers. As a result the stringers deflect with the skin and the panel mode shapes resemble those of simple flat plates. The calculated mode shapes have been verified experimentally by exciting a typical panel with harmonic sound waves at approximately grazing incidence. The response was measured by means of accelerometers and strain gauges.

ACCESS NO: 200,029 AD 732 268
REPORT NO: AFML-TR-71-102 September 1971
TITLE: THE TIME DEPENDENT MECHANICAL BEHAVIOR
OF METAL MATRIX COMPOSITES

AUTHOR: G. D. Menke, et al.
CONTRACT NO: F33615-70-C-1299
CONTRACTOR: TRW Equipment, TRW Inc.
PROJECT MONITOR: K. D. Shimmin (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The tensile, fatigue, and creep bending behavior of unidirectional and crossplied composites of 60 volume percent boron filaments in a matrix of 6061 aluminum has been investigated. The tensile strength properties of the composites fabricated as a part of this program show that the fabrication technique of diffusion bonding foil-filament arrays produces high strength, high quality material. The major part of this report deals with measurement and analyses of fatigue properties. Fatigue behavior was investigated under both axial and flexural loading conditions, with variables of filament orientation, test temperature, and A-ratio. Notch sensitivity was also investigated; fatigue of the composite was found to be insensitive to notch radius. The creep bend investigation has shown that the formability of the composite material is particularly sensitive to temperature, specimen geometry, and filament orientation.

ACCESS NO: 200,100 AD 736 047
REPORT NO: AFML-TR-71-103 September 1971
TITLE: SYNTHESIS OF SHAPE, STRUCTURE, AND
PROPERTIES BY CONTROL OF METALLURGICAL
PROCESSING VARIABLES

AUTHOR: A. T. Male, et al.
CONTRACT NO: F33615-69-C-1198
CONTRACTOR: Westinghouse Electric Corporation
PROJECT MONITOR: V. DePierre (AFML/LLN)
AFML TASK NO: 735108

ABSTRACT: This report summarizes the findings of several investigations into the synthesis of product shape, metallurgical structure, and mechanical properties by suitable control of metallurgical processing variables. Full details of each of these investigations can be found in the individual referenced reports. Two of the most significant achievements of this work are: (1) Additional work on the ring compression test has considerably enhanced its usefulness to the point where it can now be used for the quantitative determination of not only friction, but also the dynamic flow properties of metals under typical metalworking conditions (2) It has been shown that significant strength improvements can be achieved for alpha and alpha + beta titanium alloys by processing at temperatures such that the material is in the full beta range and then water quenching immediately after deformation.

ACCESS NO: 69,389 AD 726 548
REPORT NO: AFML-TR-71-105 May 1971
TITLE: NORMAL IMPACT OF AN INFINITE ELASTIC-
PLASTIC BEAM BY A SEMI-INFINITE ELASTIC
ROD

AUTHOR: S. Ranganath, et al.
CONTRACT NO: F33615-70-C-1101
CONTRACTOR: Brown University
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735303

ABSTRACT: Solutions are obtained for the problem of normal impact of an infinite elastic-plastic beam by a semi-infinite elastic rod. The effects of rotatory inertia and shear deformations are included in the equations governing the motion of the beam. A strain rate independent model based on concepts similar to those employed in quasi-static plasticity is used to describe material behavior. The interaction between moment and shear force is included. A strain hardening criterion is used based on the quasi-static moment-curvature relation for pure bending. Strain-time profiles computed using this theory agree reasonably well with those obtained in experiments on aluminum beams. The computed solutions are also computed with predictions based on a rigid perfectly plastic beam theory.

ACCESS NO: 69,376 AD 726 549
REPORT NO: AFML-TR-71-106 May 1971
TITLE: A SECOND ORDER ACCURATE DIFFERENCE
METHOD FOR SYSTEMS OF HYPERBOLIC
PARTIAL DIFFERENTIAL EQUATIONS

AUTHOR: S. Ranganath, et al.
CONTRACT NO: F33615-70-C-1101
CONTRACTOR: Brown University
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735303

ABSTRACT: A second order accurate difference method is presented for systems of first order hyperbolic differential equations. The method is analogous to the Courant, Issacson, Rees (CIR) method, except that the error introduced in one time step is $O(\Delta t^3)$ instead of $O(\Delta t^2)$ as is the case for the CIR method. Convergence of the proposed method is established. The cumulative error at a fixed time is shown to be $O(\Delta t^2)$. The proposed method is compared with several other second order accurate methods by considering in detail the special case of the system of equations governing flexural wave propagation in elastic beams. These comparisons indicate that the proposed method has substantial advantages over the other methods considered in that the method is computationally stable for larger mesh sizes. As a result, less computing time is required to obtain solutions with a given accuracy.

ACCESS NO: 69,540 AD 728 241
REPORT NO: AFML-TR-71-108 June 1971
TITLE: DETERMINATION OF THE UNLOADING BOUNDARY
IN TRANSVERSE IMPACT OF AN ELASTIC-
PLASTIC STRING
AUTHOR: P. A. Tuschak, et al.
CONTRACT NO: F33615-70-C-1020
CONTRACTOR: University of Illinois
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735106
ABSTRACT: When a thin, elastic-plastic wire is transversely impacted, both longitudinal and transverse loading waves propagate. For certain types of excitation, unloading waves also propagate, and they overtake and interact with the loading waves. These interactions occur on moving boundaries, and a knowledge of the locations of these boundaries is needed for the solution of wave propagation problems of this kind. An analytical technique and a numerical technique for the solution of such problems in long wires is presented. Examples, including response to impact by a finite mass, are given to illustrate the techniques. For finite length wires, the techniques will determine the initial portion of the solution.

ACCESS NO: 69,564 AD 728 659
REPORT NO: AFML-TR-71-109 May 1971
TITLE: MECHANISMS OF FATIGUE CRACK PROPAGATION
IN ALUMINUM ALLOYS
AUTHOR: K. Erhardt, et al.
CONTRACT NO: F33615-67-C-1441
CONTRACTOR: Massachusetts Institute of Technology
PROJECT MONITOR: Dr. F. G. Ostermann (AFML/LLD)
AFML TASK NO: 735106
ABSTRACT: The mechanisms of crack initiation and propagation in fatigue and of crack propagation under a monotonic load were studied in high strength aluminum alloys. This report is divided into five parts, in order to present the research results which are relevant to five important problems in fatigue fracture. Part I is a detailed report on the use of scanning electron microscopy in fatigue crack propagation research. The results are discussed with reference to the theories of fatigue crack propagation. Part II is a documentation of crack initiation and stage I fatigue fracture in aluminum alloys. The existence of non-propagating cracks in aluminum alloys is discussed by comparing the endurance limit and the stress intensity threshold for non-propagating fatigue cracks.

ACCESS NO: 69,430 AD 727 064
REPORT NO: AFML-TR-71-119 July 1971
TITLE: GRAPHITE MELTING BEHAVIOR
AUTHOR: N. S. Diaconis, et al.
CONTRACT NO: F33615-68-C-1713
CONTRACTOR: General Electric Company
PROJECT MONITOR: Dr. L. R. Bidwell (AFML/LLS)
AFML TASK NO: 735002

ABSTRACT: An experimental program was conducted to determine the melting behavior of graphite. Data was obtained with an electric arc heater, and a resistance heater over a pressure range from the triple point to approximately 320 atmospheres. Temperature measurements were made in the arc heater environment with a scanning spectrometer while a recording optical pyrometer was used for the resistively heated specimens. ATJS and pyrolytic graphite were the test materials and argon and nitrogen were the test gases. Within the accuracy of the data the results did not show any discernible difference with gas environments. Arc heater data showed a slight increase in melting temperature over that exhibited by the resistively heated models.

ACCESS NO: 200,031 AD 732 267
REPORT NO: AFML-TR-71-121 September 1971
TITLE: IMPROVED FATIGUE RESISTANCE OF Al-Zn-Mg-Cu (7075) ALLOYS THROUGH THERMOMECHANICAL PROCESSING
AUTHOR: F. Ostermann

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: W. J. Trapp (AFML/LLD)
AFML TASK NO: 735106
ABSTRACT: To decrease the accumulation of damage during long-life low stress cyclic loading, microstructures must accommodate inelastic deformation by homogeneous or "dispersed" slip rather than by localized slip concentrations. In age-hardening aluminum alloys this requirement can be met by introducing a dense and uniform dislocation forest through suitable thermomechanical treatments (TMT.) Such a treatment was developed for Al-Zn-Mg-Cu (7075) alloys, involving a process cycle of solution annealing, partial aging, mechanical working, and final aging.

ACCESS NO: 200,030
REPORT NO: AFML-TR-71-127 August 1971
TITLE: EVALUATION OF COATED COLUMBIUM ALLOYS
FOR BURNER APPLICATIONS

AUTHOR: J. F. Holloway, Jr.
CONTRACT NO: F33615-69-C-1634
CONTRACTOR: Pratt & Whitney Aircraft Division
PROJECT MONITOR: N. M. Geyer (AFML/LLP)
AFML TASK NO: 731201

ABSTRACT: The feasibility of using coated columbium alloys in gas turbine engine burners was investigated in a three-phase evaluation effort. The first phase consisted of identifying laboratory screening tests and test conditions which best simulate the failure modes observed in current burner materials during engine service and selection of candidate coatings and columbium alloys for laboratory screening in these tests. Failure modes were identified as buckling oxidation-erosion, thermal fatigue, and burning (melting) and were related directly to results of creep, oxidation-erosion, and thermal fatigue laboratory testing of superalloy sheet materials. A review of columbium alloy and coating performance results led to the selection of four coated columbium alloy candidates for evaluation in the screening and characterization tests.

ACCESS NO: 69,790 AD 728 277
REPORT NO: AFML-TR-71-133 August 1971
TITLE: ANALYTICAL APPROACH TO COMPOSITE
BEHAVIOR

AUTHOR: L. J. Ebert, et al.
CONTRACT NO: F33615-67-C-1487
CONTRACTOR: Case Western Reserve University
PROJECT MONITOR: Lt. B. R. Collins (AFML/LLS)
AFML TASK NO: 735301

ABSTRACT: Study in the areas of: the effects of biaxial stress states on composite deformation; the effect of a fiber-matrix diffusion layer on uniaxial composite properties; and of non-cylindrical geometry effects on model predictions is reported, as well as continuation of effects in fiber end effect and residual stress studies. Additional data were acquired on the bulging of composite sheets under balanced and unbalanced biaxial tension which supports the earlier observation of increased transverse yield and fracture strengths. A biaxial yield criterion was developed which used actual stress distributions within the composite under biaxial loads as computed by a finite element technique to predict composite yielding.

ACCESS NO: 69,658 AD 731 815
REPORT NO: AFML-TR-71-134 July 1971
TITLE:

**THERMOPHYSIOCHEMICAL COMPATIBILITY
BETWEEN METAL CARBIDES AND METAL
MATRICES**

AUTHOR: B. Botic, et al.
CONTRACT NO: F33615-69-C-1637
CONTRACTOR: Martin Marietta Corporation
PROJECT MONITOR: Capt. R. Tressler (AFML/LLS)
AFML TASK NO: 735306

ABSTRACT: A method of fabricating carbide-metal interaction specimens was developed and is described. The diffusion bonded specimens were employed in the experimental evaluation of the compatibility MC type carbides in high temperature metal matrices. This was accomplished in an effort to evaluate the stability of the MC type carbide in terms of its potential use as a diffusion barrier in a carbon filament reinforced high temperature metal matrix composite system. Six MC type carbides were chosen based on structural and thermodynamics consideration. These carbides were TiC, VC, HfC, TaC, NbC, and ZrC and were evaluated in pure Ni, pure Co, Ni-20Cr, CO-19.5Cr, IN 100, and MAR-M-509. The diffusion couples were evaluated after 25 hours at temperatures from 1000 to 1200 C.

ACCESS NO: 68,439 AD 728 667
REPORT NO: AFML-TR-71-135 June 1971
TITLE:

**CONTINUOUS OXIDE FILAMENT SYNTHESIS
(DEVITRIFICATION)**

AUTHOR: F. H. Simpson
CONTRACT NO: F33615-69-C-1614
CONTRACTOR: Boeing Company
PROJECT MONITOR: Capt. R. Tressler (AFML/LLS)
AFML TASK NO: 735001

ABSTRACT: Studies to produce continuous polycrystalline aluminum oxide filaments by vacuo-thermal conversion of precursor aluminum-boro-phosphate glass filaments are described. A field of compositions in the ternary Al₂O₃-B₂O₃-P₂O₅ system containing up to 60 percent alumina was identified from which glass melts could be produced and filaments drawn. Thoria and yttria additions to the glasses extend their working range and reduce their tendency to devitrify. Macrowarping and microkinking associated with the thermal conversion were eliminated by tensioning the filaments. Tensile strengths of the filaments produced were approximately one-third of that sought. The critical factors limiting strength in this region were not associated with grain size or internal porosity, but were likely associated with the nature of the filament surface.

ACCESS NO: 200, 130 AD 736 476
REPORT NO: AFML-TR-71-139 June 1971
TITLE: EVALUATION OF SELECTED COMMERCIAL
AND EXPERIMENTAL INTERMEDIATE
TEMPERATURE FORGING LUBRICANTS

AUTHOR: F. J. Gurney, et al.
CONTRACT NO: F33615-69-C-1198
CONTRACTOR: Westinghouse Electric Company
PROJECT MONITOR: V. DePierre (AFML/LLN)
AFML TASK NO: 735108

ABSTRACT: Several commercially available and some experimental forging lubricants were evaluated for use in the 1050 F to 1650 F temperature range to determine their potential for lowering the effective interfacial friction between the workpiece and the forging tooling during the forging process and correspondingly reducing the total process loads. Two die temperatures, 500 F and 800 F, were employed in the study. These temperature ranges were chosen to allow the evaluation of lubricants for processing materials in the intermediate temperature range, particularly the thermomechanical processing of titanium alloys. The evaluation was made by forging rings of the titanium alloy, Ti-6Al14V, between open flat dies.

ACCESS NO: 69, 786 AD 729 880
REPORT NO: AFML-TR-71-145 July 1971
TITLE: THE AFML TORSIONAL SPLIT HOPKINSON BAR
AUTHOR: Dr. T. Nicholas, et al.
CONTRACT NO: F33615-69-C-0045
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735108

ABSTRACT: The development, construction, and use of an experimental apparatus for testing materials in torsion at high rates of strain is described. Constant strain rate data can be obtained at shear strain rates from 100 to 10^4 sec^{-1} . The operation, calibration, and instrumentation of a torsional split Hopkinson bar apparatus is presented along with a discussion of the accuracy and reliability of data obtained with this device. Experimental data on commercially pure 1100-0 aluminum at high strain rates are obtained and compared with quasi-static data and those of other investigators.

ACCESS NO: 69,792 **AD 731 823**
REPORT NO: AFML-TR-71-149 **July 1971**
TITLE: DEVELOPMENT OF A HIGH SPEED BIAXIAL
TESTING MACHINE

AUTHOR: U. S. Lindholm, et al.
CONTRACT NO: F33615-70-C-1443
CONTRACTOR: Southwest Research Institute
PROJECT MONITOR: M. J. Sever, et al. (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The development of a new, high-speed biaxial materials testing facility is described. The machine combines axial and torsional loading, with each independent load axis under closed-loop servo control. A new feature of this facility is the development of a compound linear-torsional hydraulic actuator which reduces the mechanical compliance and backlash inherent in previous systems. The resultant "stiffer" machine improves the control of deformation or load at high testing speeds. The system components and operating specifications are described.

ACCESS NO: 69,536 **AD 727 781**
REPORT NO: AFML-TR-71-150 **August 1971**
TITLE: STABILITY OF OXIDES IN METAL OR METAL
ALLOY MATRICES

AUTHOR: R. L. Mehan, et al.
CONTRACT NO: F33615-69-C-1635
CONTRACTOR: General Electric Company
PROJECT MONITOR: Capt. R. E. Tressler (AFML/LLS)
AFML TASK NO: 735306

ABSTRACT: The objective of this program was to conduct a study of the chemical interaction between Tyco single-crystal sapphire filaments and nickel and nickel alloys, and to determine the effects of these reactions on filament and composite strength. During the first year's work on this contract, the reactions between sapphire and nickel, nickel-chromium, and U-700 were studied in both air and hydrogen, and the effect of these reactions on extracted filament strength was determined. During the present contract period, the emphasis was placed on the effect of filament-matrix reactions on the transverse and longitudinal strength of sapphire-nichrome composites.

ACCESS NO: 69, 926 AD 732 196
REPORT NO: AFML-TR-71-155 August 1971
TITLE: AN ANALYTICAL STUDY OF THE SPLIT
HOPKINSON BAR TECHNIQUE FOR STRAIN-
RATE DEPENDENT MATERIAL BEHAVIOR
AUTHOR: Dr. T. Nicholas

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: The validity of the split Hopkinson bar technique for determining dynamic material behavior is examined for specimen materials which exhibit strain-rate dependent mechanical behavior. The torsional mode of deformation is chosen as more closely representing a one-dimensional state of stress. The details of the propagation and reflection of stress waves within the specimen are studied using a numerical procedure based on the method of characteristics. Reconstituted stress-strain curves calculated from the conventional analysis of the split Hopkinson bar experiment are compared with actual material behavior of a number of simulated experiments involving variations in input stress, gage length, material behavior, and static stress-strain curves including statically prestressed materials.

ACCESS NO: 69, 798 AD 733 663
REPORT NO: AFML-TR-71-156 August 1971
TITLE: DIFFUSION WELDING OF WROUGHT BERYLLIUM
AUTHOR: T. J. Bosworth
CONTRACT NO: F33615-71-C-1161
CONTRACTOR: The Boeing Company
PROJECT MONITOR: L. D. Parsons (AFML/LLP)
AFML TASK NO: 735102

ABSTRACT: The objective of this study was to investigate the role of the microalloying elements on the diffusion welding of beryllium and to relate the welding behavior to variations in beryllium oxide content. Diffusion welding of beryllium was shown to involve the precipitation of inter-metallic compounds at the joint interface. The rate of precipitation was temperature related, but was also related by the BeO, iron, and aluminum contents either singularly or collectively. It was also demonstrated that the strength and ductility of beryllium sheet containing 0.97% BeO can be altered by the diffusion welding temperature, quench rate, and additional post weld thermal cycles.

ACCESS NO: 48,849 AD 731 826
REPORT NO: AFML-TR-71-158 August 1971
TITLE: PREPARATION AND CHARACTERIZATION OF
HIGH PURITY SUBMICRON REFRACTORY
OXIDES AND MIXED OXIDES FROM ALKOXIDES

AUTHOR: M. Hoch
CONTRACT NO: F33615-67-C-1296
CONTRACTOR: University of Cincinnati
PROJECT MONITOR: K. S. Mazdiasni (AFML/LLM)
AFML TASK NO: 735001

ABSTRACT: A method was developed to prepare high purity, highly uniform, very reactive, small, under 100 Å crystallite size ceramic powders. The method consists of preparing a water sensitive organo-metallic compound, preferably an alkoxide, and decomposing it by hydrolysis. The hydroxide is then washed using high purity water or alcohol, dried, ball milled, and finally calcined at 550°C. By varying the treatment of the hydroxide, two different types of powders, A and B, were obtained. Powder A is suited for hot pressing consolidation, and powder B for cold pressing and sintering. The method was specifically developed for the large scale preparation of zirconium oxide containing 6.5 mole % yttrium oxide (Zyttrite).

ACCESS NO: 200,135 AD 732 305
REPORT NO: AFML-TR-71-175 September 1971
TITLE: PLATE DEFORMATION BY PROJECTILE
TITANIUM AND FIBERGLASS

AUTHOR: R. Plunkett
CONTRACT NO: F33615-69-C-1240
CONTRACTOR: University of Minnesota
PROJECT MONITOR: J. P. Henderson (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: Titanium and fiberglass plates were struck with cylindrical projectiles. Using a technique reported elsewhere, the transverse deflection was measured as a function of radius and time. The measured values agree reasonably well with predicted deformation based on simple membrane theory for short times and small radii. Bending terms must be included if better agreement during deflection is to be calculated.

ACCESS NO: 200, 136 AD 732 269
REPORT NO: AFML-TR-71-176 August 1971
TITLE: SUDDEN EXTENSION OF A CRACK IN AN
ELASTIC SOLID

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

ABSTRACT: A particular motion of a half plane crack in an elastic solid subjected to general loading is considered. The loading is prescribed so that the mode of deformation of the crack is the plane strain opening mode. The crack is initially at rest and then at a certain instant, begins to move with a constant velocity which is less than the Rayleigh wave speed. A fundamental solution is derived for particular loading on the body which makes it possible to obtain the solution for the complete dynamic stress field due to crack extension by linear superposition. The details of the solution are worked out for the dynamic stress intensity factor for the moving crack.

ACCESS NO: 69, 797 AD 731 832
REPORT NO: AFML-TR-71-179 August 1971
TITLE: EXPERIMENTAL INVESTIGATION OF THE
FAILURE MECHANISMS OF FIBER REINFORCED
COMPOSITES SUBJECTED TO UNIAXIAL TENSION

AUTHOR: A. E. Armenakas, et al.
CONTRACT NO: F33615-70-C-1073
CONTRACTOR: Polytechnic Institute of Brooklyn
PROJECT MONITOR: M. J. Sever (AFML/LLD), et al.
AFML TASK NO: 735106

ABSTRACT: In this investigation the distribution of the axial component of displacement in the plane of thin, unilayer, fiber-reinforced composite plates subjected to quasi-statically increasing tension (from zero to failure) in the direction of the fibers, is established experimentally. The experimental results are used to (a) evaluate the strain distribution throughout the surface of the specimens during the process of loading; (b) establish the strain concentration in the neighborhood of broken fibers; (c) estimate the distribution of the normal component of strain in the fibers; (d) establish the ineffective length of broken fibers and the stress concentration in neighboring fibers as functions of the applied load.

ACCESS NO: 200, 026 **AD 889 246L**
REPORT NO: AFML-TR-71-84 **September 1971**
TITLE: FRETTING RESISTANT COATINGS FOR
TITANIUM ALLOYS
AUTHOR: D. J. Padberg
CONTRACT NO: F33615-70-C-1538
CONTRACTOR: McDonnell Aircraft Company
PROJECT MONITOR: J. Crosby (AFML/LLP)
AFML TASK NO: 731201

ABSTRACT: This report describes a program undertaken to establish the effect of airframe design parameters upon the severity of fretting in titanium structures and to determine the ability of selected coatings to prevent fretting induced fatigue failures. The program was performed in three tasks.

ACCESS NO: 69, 991 **AD 731 829**
REPORT NO: AFML-TR-71-189 **October 1971**
TITLE: EFFECT OF INTERFACES IN METAL MATRIX
COMPOSITES ON MECHANICAL PROPERTIES
AUTHOR: M. J. Klein, et al.
CONTRACT NO: F33615-70-C-1814
CONTRACTOR: International Harvester Company
PROJECT MONITOR: Capt. B. Collins (AFML/LLS)
AFML TASK NO: 735306

ABSTRACT: The effect of interface condition on the longitudinal and transverse tensile strength of 6061 aluminum/boron composites has been investigated. The interface condition was varied by heat treatments at 940 to 1100 F for time up to 192 hours, and was characterized by metallography, scanning electron microscopy, and electron microscopy of extracted interface material. Composites with 25 and 48 percent boron filaments were studied with fully annealed and with age-hardened matrices. Some studies were made of the effect of the interface on fracture toughness. The interface in aluminum/boron composites is complex and appears to break down in a nonuniform manner. The results suggest that oxides or other film break down locally, allowing a reaction product to form, believed to be AlB_2 .

ACCESS NO: 200, 028 AD 732 888
REPORT NO: AFML-TR-71-199 September 1971
TITLE: A SIMPLE NUMERICAL SCHEME FOR THE
DETERMINATION OF THE UNLOADING
BOUNDARY

AUTHOR: A. B. Schultz
CONTRACT NO: F33615-71-C-1175
CONTRACTOR: University of Illinois
PROJECT MONITOR: Dr. T. Nicholas (AFML/LLD)
AFML TASK NO: 735106

ABSTRACT: In several types of problems of one-dimensional stress wave propagation in an elastic-plastic material, unloading waves propagate and interact with loading waves at an unloading boundary. A simple, efficient numerical scheme is presented which may be used to compute the solution to problems of this kind. The scheme takes advantage of those general features of the solution which are known a priori.

ACCESS NO: 200, 238 AD 733 719
REPORT NO: AFML-TR-71-211 October 1971
TITLE: FINE SUBGRAIN STRUCTURE ADJACENT TO
FATIGUE CRACKS

AUTHOR: J. C. Grosskreutz, et al.
CONTRACT NO: F33615-71-C-1379
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: Dr. Walter Reimann (AFML/LLD)
AFML TASK NO: 735303

ABSTRACT: Deformation microstructures adjacent to fatigue cracks in 2024-T4 and 7075-T6 aluminum, and Ti-6Al-4V alloys have been examined by transmission electron microscopy. The data show that material within 1-2 μ m of a tensile-mode crack consists of very fine (0.1 μ m) subgrains in all three materials. The average misorientation between the subgrains is 2-4 degrees. The presence of this substructure, which seems to be independent of initial metallurgical condition, is used to explain the weak dependence of State II crack growth rates on the initial condition in high stacking fault energy materials. No evidence of precipitate reversion was observed adjacent to the fatigue cracks in 7075-T6 aluminum.

ACCESS NO: 65,064 **AD 736 812**
REPORT NO: AFML-TR-71-213 **October 1971**
TITLE: **DEVELOPMENT OF IMPROVED HIGH STRENGTH
STEELS FOR AIRCRAFT STRUCTURAL COM-
PONENTS**

AUTHOR: B. Mravic
CONTRACT NO: F33615-69-C-1600
CONTRACTOR: United States Steel Corporation
PROJECT MONITOR: K. L. Kojola (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: This report summarizes the results of a program to develop high-strength steels with improved reliability for use in aircraft forgings and structures. The most promising steels had very fine prior-austenite grain sizes (about ASTM No. 15) produced by multiple-cycle rapid austenitizing. At tensile strengths of 250 to 260 ksi (1.72 to 1.79 GN/m²), these steels had high toughness with K_{Ic} values greater than 100 ksi inch (101 MNm-3/2), survived a 100-day alternate-immersion test in a 3-1/2 per cent NaCl solution while stressed to 80 percent of their yield strengths, and had axial fatigue limits (10⁷ cycles with R - plus 0.1) of about 110 ksi (0.76 GN/m²) or about 43% of their tensile strengths. One of these steels was a Ni-Cr-Mo steel containing 0.25C, 0.9Mn, 3.2Ni, 1.8Cr, and 0.0Mo, and another was 10Co. The results of studies to develop a conventionally heat treated 10Ni-Cr-Mo-Co steel, studies of other types of ultra-fine grained steel, and studies of the effects of purity on toughness and ductility are also reported.

ACCESS NO: 200,178 **AD 733 712**
REPORT NO: AFML-TR-71-214 **October 1971**
TITLE: **APPLICATION OF DIGITAL TECHNIQUES TO
MICROSTRUCTURE ANALYSIS OF MATERIALS**

AUTHOR: P. J. Caulfield
CONTRACT NO: F33615-70-C-1586
CONTRACTOR: Data Corporation
PROJECT MONITOR: I. Perlmutter (AFML/LLP)
AFML TASK NO: 735105

ABSTRACT: The primary objective of this project was to develop digital computer techniques for the quantitative characterization of alloy microstructures. A secondary objective was to utilize these quantities to determine the numerical correlations between processing parameters, microstructure appearance, and mechanical properties. These objectives were restricted in scope to the 6Al-2Sn-4Zr-6Mo titanium alloy. To these ends, computer programs were written to: (1) Perform separation of individual connected regions from the background in a digitized micrograph; (2) compute 34 quantities which describe geometric properties of the photo-micrograph; and (3) correlate these 34 quantities with 8 mechanical property measurements for each of 57 alloy specimens.

ACCESS NO: 200, 134 **AD 736 053**
REPORT NO: AFML-TR-71-228 **October 1971**
TITLE: **THEORY OF TITANIUM ALLOYS FOR HIGH TEMPERATURE STRENGTH**
AUTHOR: E. W. Collings, et al.
CONTRACT NO: F33615-69-C-1594
CONTRACTOR: Battelle Columbus Laboratories
PROJECT MONITOR: Dr. H. L. Gegel (AFML/LLS)
AFML TASK NO: 735103

ABSTRACT: The aim of this project was the establishment of basic design criteria for use in the synthesis of titanium-base alloys having useful strength properties at elevated temperatures. Our philosophy was the treatment of mechanical properties from an electronic standpoint, and the approach used is outlined in the Introduction. In order to achieve our goal it was necessary to measure various electronic properties (in particular: Electrical Transport Properties; Density-of-state-related properties; and super conductive properties) on alloys in well-categorized metallurgical conditions. The results of this work are incorporated into the body of this Report, which deals essentially with the fundamental design of titanium alloys.

NONMETALLIC MATERIALS DIVISION (AFML/LN)

ACCESS NO: 69,657 AD 887 614
REPORT NO: AFML-TR-64-383 June 1971
Part VII
TITLE: SYNTHESIS INVOLVING ORGANOMETALLIC
AND ORGANOMETALLOIDAL COMPOUNDS
CONTAINING POLYFLUORO AND POLYCHLORO
SUBSTITUENTS
AUTHOR: H. Gilman, et al.
CONTRACT NO: F33615-69-C-1046
CONTRACTOR: Iowa State University
PROJECT MONITOR: Dr. C. Tamborski (AFML/LNP)
AFML TASK NO: 734201

ABSTRACT: The primary objective is concerned with new or improved syntheses of organometallic and organometalloidal compounds containing polyfluoro and polychloro substituents. These versatile reagents are to be used for the preparation of thermally stable fluids, lubricants, etc. One of the goals is to make available organometallic compounds of general types such as $CF_3(CF_2)_n-M$ and $M-(CF_2)_n-M$, in which M represents a metal or a metalloid. In addition perhaloorganometallic compounds containing heteronuclear systems such as pyridine and thiophene have been studied. These two studies admirably complement each other, for there have been developed from the perhalogenated thiophenes some novel and highly promising routes to the perhalogenated alkanes.

ACCESS NO: 47,772 AD 826 053L
REPORT NO: AFML-TR-66-161 March 1971
Part IV
TITLE: HIGH STRENGTH, HIGH MODULUS GRAPHITE
FIBERS
AUTHOR: A. J. Rosenthal, et al.
CONTRACT NO: F33615-68-C-1231
CONTRACTOR: Celanese Research Company
PROJECT MONITOR: H. M. Ezekiel (AFML/LNF)
AFML TASK NO: 732001

ABSTRACT: The objective is the exploratory development of means for producing continuous lengths of graphite fiber having tensile strength of 500,000 psi and modulus of 80×10^6 psi. Earlier work had led to the selection of dry spun polyacrylonitrile (PAN) homopolymer as the preferred starting material. The PAN yarn is dimensionally stabilized by partial oxidation in hot air; the preoxidized yarn is carbonized and graphitized by a heat treatment schedule culminating at 2900 C. The process is conducted on continuous lengths of yarn. Numerous key process variables have been identified and optimized. The target properties have been exceeded on small samples. Two 1/4 pound product demonstration samples of graphite were submitted to AFML. Attempts to prepare a 5 mil graphite monofilament by the above route have not yet achieved adequate preoxidations.

ACCESS NO: 200, 097 AD 888 745L
REPORT NO: AFML-TR-66-161 July 1970
Part V
TITLE: HIGH STRENGTH, HIGH MODULUS GRAPHITE
FIBERS
AUTHOR: A. J. Rosenthal, et al.
CONTRACT NO: F33615-68-C-1231
CONTRACTOR: Celanese Research Company
PROJECT MONITOR: H. M. Ezekiel (AFML/LNF)
AFML TASK NO: 732001

ABSTRACT: The objective is the exploratory development of means for producing continuous lengths of graphite fibers having tensile strengths of 500,000 psi and moduli of 80×10^6 psi. Earlier work had led to the selection of dry spun polyacrylonitrile (PAN) homopolymer as the preferred starting material. The PAN yarn is dimensionally stabilized by partial oxidation in hot air; the preoxidized yarn is graphitized in a continuous process by a heat treatment schedule with a peak temperature of 2900°C . Numerous key process variables have been identified and optimized. The target properties have been exceeded on small samples. Several graphite samples, including a 1/2 pound product demonstration sample, were submitted to AFML. Extremely long times are required for the preoxidation of large denier PAN.

ACCESS NO: 48, 446 AD 884 284L
REPORT NO: AFML-TR-66-246 June 1969
Part III
TITLE: CONTINUOUS SINGLE CRYSTAL SAPPHIRE
FILAMENTS AND RIBBON
AUTHOR: H. E. LaBelle, Jr., et al.
CONTRACT NO: F33615-67-C-1098
CONTRACTOR: Tyco Laboratories, Inc.
PROJECT MONITOR: H. P. Materne (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: Three techniques for the growth of $\alpha\text{-Al}_2\text{O}_3$ and other single crystals from the melt are described, together with their characterization. The floating orifice technique (FOT) makes use of a molybdenum disc, pierced at the center, floating in the melt. A second method called the self-filling tube (SFT). Here, a fixed molybdenum tube draws liquid from the crucible to the top of the tube in a region of controlled temperature gradients. This arrangement is satisfactory for the growth of several relatively simple shapes of nominal dimensional accuracy. Edge-defined, film-fed growth (EFG), combines the use of a platform having a surface outlining the inside and outside edges in the cross section to be grown with the capillary feed system. This system makes it possible for growth of virtually any cross-sectional shape, and close dimensional accuracy. Small displacements from a stable growth direction appeared to degrade the strength. The microstructure was shown to contain dislocations, microvoids, and when grown from an impure melt, segregation.

ACCESS NO: 66,571 **AD 882 535**
REPORT NO: AFML-TR-66-310 **January 1971**
TITLE: Part V Volume II
INTEGRATED RESEARCH ON CARBON COMPOSITE MATERIALS. VOLUME II: STRUCTURAL MECHANICS
AUTHOR: H. F. Volk, et al.
CONTRACT NO: F33615-68-C-1077
CONTRACTOR: Union Carbide Corporation
PROJECT MONITOR: H. S. Schwartz (AFML/LN)
PROJECT NO: ARPA 719
ABSTRACT: The work presented in Volume II is concerned with the structural mechanics and synthesis of graphite-fiber reinforced composite materials. Optimization studies (minimum weight design) of stiffened cylinders similar to the fuselage component were carried out by two different techniques. The behavior of composite structural elements was investigated in plate-buckling and post-buckling studies, buckling of stiffened plates with cutouts, and application of shell theory to anisotropic cylinders. Micro-mechanics studies of fibrous composites included development of a photo-elastic technique for analyzing frozen stresses, a discrete element microstress analysis of unidirectional fiber composites, an application of the theory of physically nonlinear elastic solids to composite materials, and an investigation of the multiple circular inclusion problem in plane elastostatics.

ACCESS NO: 67,150 **AD 884 848L**
REPORT NO: AFML-TR-66-334 **December 1970**
TITLE: Part V
HIGH STRENGTH - HIGH MODULUS CARBON FIBERS
AUTHOR: R. Bacon
CONTRACT NO: F33615-68-C-1256
CONTRACTOR: Union Carbide Corporation
PROJECT MONITOR: H. M. Ezekiel (AFML/LNF)
AFML TASK NO: 732001
ABSTRACT: A major contract goal was to demonstrate the production of graphite fibers possessing properties of 85 million psi Young's modulus and 400,000 psi tensile strength. These target properties were achieved in a limited quantity of graphite yarn, but this work was discontinued in favor of emphasizing modifications in fiber size, shape, and internal structure which might lead to improved properties in the composite, particularly compressive strength. A variety of alternate rayon raw materials, both commercial and experimental, and including round cross section fibers, were investigated in bench-scale studies. A majority of these rayons were successfully processed to yield graphite fiber properties equivalent, but not superior to those achieved by the use of standard Villwyte rayon. Properties of composites made from these fibers have not yet been determined. Bench-scale studies of annealing treatments for "Thornel" 50 graphite yarn resulted in fibers with improved tensile strength, but no improvement in composite compressive strength was achieved.

ACCESS NO: 69, 158 **AD 884 047**
REPORT NO: AFML-TR-67-121 **February 1971**

TITLE: Part V
EVALUATION OF MOLECULAR WEIGHT FROM EQUILIBRIUM SEDIMENTATION. PART V: SOLUTION BY LINEAR PROGRAMMING INCORPORATED INTO REGULARIZATION

AUTHOR: D. R. Wiff, et al.

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR: Dr. M. T. Gehatia (AFML/LNP)

AFML TASK NO: 734203

ABSTRACT: Determination of molecular weight distribution from equilibrium sedimentation has been significantly improved by incorporating linear programming into Tikhonov's regularization method. It has been found that regularization smooths the "big noise" caused by the instability of an inverse matrix appearing in improperly posed problems such as Fujita equations. On the other hand, the linear programming eliminates negative frequencies and smooths a still remaining "small noise" in the distribution curves. Good results were obtained in case of a unimodal, a bimodal, and a trimodal distribution.

ACCESS NO: 200, 201 **AD 889 865L**
REPORT NO: AFML-TR-67-172 **November 1971**

TITLE: Part IV
THERMALLY STABLE POLYMERIC FIBERS

AUTHOR: H. H. George, et al.

CONTRACT NO: F33615-70-C-1270

CONTRACTOR: Celanese Corporation

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

AFML TASK NO: 732001

ABSTRACT: A number of fused Lewis acid salts or eutectic systems can be used as polymerization medium for benzimidazo-benzophenanthroline. Best polymerization results are obtained when reacting naphthalene dianhydride with diaminobenzidine in antimony trichloride for 8 hours at 170°C. The extrusion of BBB polymer into fiber directly from the antimony trichloride reaction mixture is possible. However, it is preferred to isolate the polymer and redissolve it in sulfuric acid for extrusion by previously established procedures.

ACCESS NO: 68,887 **AD 881 630**
REPORT NO: AFML-TR-67-261 **February 1971**
TITLE: Part IV
**SYNTHESIS AND CHARACTERIZATION OF
PERFLUOROALKYL HETEROCYCLIC
ELASTOMERS**
AUTHOR: C. D. Burton, et al.
CONTRACT NO: F33615-69-C-1233
CONTRACTOR: Dow Chemical Company
PROJECT MONITOR: Dr. F. E. Arnold (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: The polymerizations of perfluorinated diimidates with dihydroxybenzidine and perfluorinated diimidates with 3,3'-diamino-4,4'-dihydroxybenzophenone have been studied. Exposure of 3,3'-diamino-4,4'-dihydroxybenzophenone to air causes it to change color from white to light yellow, but this is not detrimental to polymers formed from it. It was determined that the optimum promoter level was about two equivalents of acetic acid per imidate group. Several polymers representing both systems were prepared and structure-property relationships compared. Dihydroxybenzidine polymers have lower glass transition temperatures and are more pliable than corresponding benzophenone polymers. However, only one of the polymers synthesized, the methyl perfluoro-4,9,14,19-tetraoxadocosanediimide-dihydroxybenzidine polymer, has good potential for elastomeric applications.

ACCESS NO: 48,422 **AD 881 316**
REPORT NO: AFML-TR-68-130 **December 1970**
TITLE: Part II
**SYNTHESIS OF POLYSPIROCYCLOBUTANES AND
RELATED SPIROPOLYMERS**
AUTHOR: C. M. Sharts, et al.
CONTRACT NO: F33615-67-C-1560
CONTRACTOR: San Diego State College
PROJECT MONITOR: Dr. H. Rosenberg (AFML/LNP)
AFML TASK NO: 734201

ABSTRACT: Dispiro(3.1.1.3.1.1)decane-2,8-dicarboxylic acid was converted to the corresponding diacid chloride. Dehydrohalogenation of the diacid chloride gave a bis-ketene intermediate which polymerized to poly(trispiro(3.1.1.3.1.1)dodecane-1,3-dione) (I). Polymer I was fluorinated with sulfur tetrafluoride to a new fluorinated polyspirocyclobutane. Attempts to convert Polymer I into polyspirocyclobutane failed. Diethyl and diisooamyl 3,3-bis(hydroxymethyl)cyclobutane were synthesized by different methods. These monomers were polymerized under various conditions to a polymer believed to be a spiropolymer, poly(3,3-bis(hydroxymethyl)cyclobutane-1,1 dicarboxylate).

ACCESS NO: 200, 098 **AD 734 658**
REPORT NO: AFML-TR-68-311 **May 1971**

TITLE: Part IV
VISCOELASTIC WAVE PROPAGATION IN UNIDIRECTIONAL COMPOSITES

AUTHOR: Dr. J. Haener
CONTRACT NO: F33615-69-C-1367
CONTRACTOR: Whittaker Corporation
PROJECT MONITOR: Dr. N. J. Pagano (AFML/LNC)
AFML TASK NO: 734202

ABSTRACT: In this work the wave propagation in a unidirectional fibrous composite with viscoelastic components has been studied. A method has been developed by which the attenuation due to any viscoelastic law can be determined. The procedure is based on axial power flow and on radial energy loss, in terms of previously determined displacement fields and viscoelastic material constants. A special example using a Voigt solid has been analyzed and the equation of the viscoelastic constant established.

ACCESS NO: 724 **AD 884 887L**
REPORT NO: AFML-TR-68-338 **November 1970**

TITLE: Part 2
GREASE DEVELOPMENT AND EVALUATION FOR HELICOPTER TRANSMISSIONS AND SERVOMECHANISMS

AUTHOR: B. R. Simmons
CONTRACT NO: F33615-68-C-1389
CONTRACTOR: United Aircraft Corporation
PROJECT MONITOR: J. B. Christian (AFML/LNL)
AFML TASK NO: 734301

ABSTRACT: Experimental results are presented for several experimental grease formulations with reference to their suitability for the lubrication of helicopter transmissions and fine pitch gear trains. Simulated transmission operation in the gear fatigue tester yielded successful temperature stabilization at low load with two of the lubricants. Full-scale transmissions testing with modified S-61 intermediate and tail gearboxes demonstrated that two lubricants were able to permit stabilized operation at a continuous power level significantly higher than the normal prorated power. One grease, designated MCG-67-23, gave marginal gear lubrication, resulting in moderate scoring of the tail gearbox level gear teeth. The other grease, MCG-68-63, yielded satisfactory lubrication for both bearing and gears resulting in smooth polished gear tooth surfaces.

ACCESS NO: 49, 979 **AD 884 043**
REPORT NO: AFML-TR-68-356 **March 1971**
TITLE: Part II
IMPROVED MATERIALS FOR AIRCRAFT SELF-SEALING FUEL CELL SYSTEMS
AUTHOR: R. C. Kohn, et al.
CONTRACT NO: F33615-67-C-1720
CONTRACTOR: Uniroyal Inc.
PROJECT MONITOR: W. F. Anspach (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: A polyurethane self-sealing fuel cell construction was developed which combines excellent 20 mm. gunfire performance with good cell flexibility and light weight. This construction weighed the same as the standard US-173, 50 caliber construction. Also a self-sealing construction based on conventional fuel cell materials performed very well against 20 mm. gunfire. This excellent gunfire performance was accompanied by approximately a 17% increase in weight as compared to the standard US-173, 50 caliber resistant construction.

ACCESS NO: 68, 922 **AD 881 783**
REPORT NO: AFML-TR-68-364 **January 1971**
TITLE: Part III
SUPERSONIC RAIN EROSION RESISTANT COATING MATERIALS
AUTHOR: A. T. Sales, et al.
CONTRACT NO: F33615-69-C-1179
CONTRACTOR: Georgia Institute of Technology
PROJECT MONITOR: A. H. Krabill (AFML/LNE)
AFML TASK NO: 734007

ABSTRACT: The objective of this program is to develop ceramic coatings with improved supersonic rain erosion resistance and acceptable radar transmission properties for protection of radomes on advanced high speed aircraft and missiles. Optical plasma spray process parameters were established for the direct application of coatings of titania modified alumina to E-glass reinforced low void polyimide laminates. Matchmold slip casting of alumina for secondary bonding as coatings to polyimide laminates was also investigated. Process parameters were established and optimized for this technique. The properties of the as-deposited and slip-cast coatings were improved through the use of inorganic and/or organic impregnation.

ACCESS NO: 69,036 AD 882 634
REPORT NO: AFML-TR-69-20 November 1970

Part II

TITLE: NEW SYNTHETIC METHODS FOR SILICON-NITROGEN POLYMERS

AUTHOR: L. W. Breed, et al.
CONTRACT NO: F33615-68-C-1371
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: Dr. H. Rosenberg (AFML/LNP)
AFML TASK NO: 734201

ABSTRACT: In condensation polymerizations of N, N'-bis (dialkylamino) dimethylsilyl tetramethylcyclodisilazane and bis(p-hydroxydimethylsilylphenyl) ether, storage-stable, toluene-soluble polymers can be obtained provided the compositions are suitably stabilized with bis (trimethylsilyl)acetamide. If the dimethylamino derivative of the cyclodisilazane is used in the polymerization, polymers with inherent viscosities of about 0.3 dl/g are obtained; if the diethylamino derivative is used, polymers with inherent viscosities as high as 0.9 dl/g are produced. Other monomers examined in a preliminary way include the piperidino derivative of the cyclodisilazane and p-phenylenebis (methylvinylsilanol), bis(p-hydroxydimethylsilylphenyl) ether, N, N'-bis dimethyl(piperidino)silyl tetramethylcyclodisilazane, 1,3-dichloro-1,3-dimethyl-1,3-diphenyl-disilazane, 2,4,6-trimethyl-2,4,6-trivinylcyclotrisilazane, and various other intermediates and monomers.

ACCESS NO: 69,787 AD 887 732
REPORT NO: AFML-TR-69-20 August 1971

Part III

TITLE: NEW SYNTHETIC METHODS FOR SILICON-NITROGEN POLYMERS

AUTHOR: L. W. Breed, et al.
CONTRACT NO: F33615-68-C-1371
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: Dr. H. Rosenberg (AFML/LNP)
AFML TASK NO: 734201

ABSTRACT: The following new cyclodisilazane monomers as well as the necessary intermediates have been prepared through the equilibration of suitable $(\text{CH}_3)_2\text{RSiCl}_2$ and $[(\text{CH}_3)_2\text{RSiNH}]_3$ compounds: $(\text{CH}_3)_2\text{NSi}(\text{CH}_3)_2\text{R}$, $[\text{NSi}(\text{CH}_3)_2\text{R}]_2\text{Si}(\text{CH}_3)_2\text{RN}(\text{CH}_3)_2$, where R is CH_3 , C_2H_5 , CH_2CH_2 , and $\text{CH}_2\text{CH}_2\text{CF}_3$. The condensation polymer of bis(p-hydroxydimethylsilylphenyl) either with the cyclodisilazane ($\text{R}=\text{CH}_2\text{CH}_2\text{CF}_3$) has a greatly improved hydrolytic stability and only somewhat lower thermal stability than the cyclodisilazane ($\text{R}=\text{CH}_3$). A newly found procedure for the synthesis of N, N'-bis (chloro-dimethylsilyl)-tetramethylcyclodisilazane, which comprises the treatment of 1,3-dichlorotetramethyldisilazane with butyllithium, can probably be extended to the substituted monomers to provide materials of greater purity in improved yields.

ACCESS NO: 65,418 AD 882 809
REPORT NO: AFML-TR-69-66 January 1971
Part II
TITLE: DEVELOPMENT OF LOW PERMEABILITY
FABRICS
AUTHOR: N. J. Abbott, et al.
CONTRACT NO: F33615-69-C-1703
CONTRACTOR: Fabric Research Laboratories, Inc.
PROJECT MONITOR: S. Schulman (AFML/LNF)
AFML TASK NO: 732002

ABSTRACT: This work was concerned with various aspects of materials for use in gliding decelerators. It included an investigation of the tensile behavior of control line materials, a consideration of problems involved in making efficient seams and joints in coated canopy fabrics. The load-elongation characteristics of three candidate control line materials were compared. The currently used cored braid structure was shown to be the best of the available materials and no significant improvements in tensile properties can be expected. The seaming characteristics of four coated fabrics were studied. Reinforcing techniques were developed that raised the efficiency of seaming in an open basket weave fabric from 60 to 92 percent without making the seam excessively stiff.

ACCESS NO: 69,608 AD 887 038L
REPORT NO: AFML-TR-69-112 August 1971
Part III
TITLE: HIGH TEMPERATURE THERMALLY STABLE
GREASES
AUTHOR: K. R. Bunting, et al.
CONTRACT NO: F33615-68-C-1427
CONTRACTOR: American Oil Company
PROJECT MONITOR: J. B. Christian (AFML/LNL)
AFML TASK NO: 734301

ABSTRACT: The research described in this report is part of a continuing program to develop and test greases for high temperature and/or space applications. Emphasis was placed on new grease thickening materials and performance testing in extreme environments. Candidate thickeners included: poly-p-oxybenzoate, polyimide, amide-imides, polyamides, perchlorinated polymer, p-polyphenylenes, and a phenolic resin. Superior high temperature greases were made using the first four thickeners and silicone or perfluoro polyether fluids. The performance of ammeline, the standard for thickener performance, was exceeded in several tests.

ACCESS NO: 69,609 **AD 887 035L**
REPORT NO: AFML-TR-69-113 **July 1971**
TITLE: Part III
NEW ABLATIVE PLASTICS AND COMPOSITES,
THEIR FORMULATION AND PROCESSING
AUTHOR: B. G. Kimmel, et al.
CONTRACT NO: F33615-68-C-1336
CONTRACTOR: Hughes Aircraft Company
PROJECT MONITOR: P. F. Pirrung (AFML/LNC)
AFML TASK NO: 734001

ABSTRACT: Precise processing techniques were applied in the continued preparation of ablative composites fabricated with a variety of resins and reinforcements. Specimens were fabricated with resins which included: Branched, crosslinked polyphenylene; 91 LD phenolic resin; EC-201 phenolic resin; Polyphenylene sulfide; SC 1008 phenolic resin; Reinforcements and fibers included: High silica content fabrics; Carbon fabrics; Graphite fabrics; Carbon black. Resin impregnation techniques used in preparing pre-impregnated reinforcements included spatula coating, brush coating and continuous coating in a laboratory treater. Insoluble, nearly intractable resin such as polyphenylene sulfide was distributed from suspension in the form of a dry powder over the reinforcement layers.

ACCESS NO: 69,927
REPORT NO: AFML-TR-69-152 **June 1971**
TITLE: Part III
SHOCK HUGONIOT OF A MACROSCOPICALLY
HOMOGENEOUS COMPOSITE
AUTHOR: F. K. Tsou
CONTRACT NO: F33615-68-C-152
CONTRACTOR: Drexel University
PROJECT MONITOR: Dr. N. L. Pagano (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: The control-volume approach is applied to a composite that is macroscopically homogeneous and consists of arbitrary number of constituents. This includes true mixtures, certain alloys and any kind of composite whose constituents have dimensions much smaller than the composite. The present work represents a generalization of the control-volume approach which has been proposed recently for unidirectional fiber reinforced composites. From the present theory, the Hugoniot of the composite may be computed from the equations of state of its constituents. The calculated results of two sample composites are presented and compare satisfactorily with test data.

ACCESS NO: 70,258 AD 869 876
REPORT NO: AFML-TR-69-266 March 1970
TITLE: KG-80 SPIN AXIS INSTRUMENT BEARING
LUBRICANT
AUTHOR: G. J. Morris
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: G. J. Morris (AFML/LNL)
AFML TASK NO: 734303
ABSTRACT: This report describes the KG-80 gyroscope bearing lubricant which has been successfully developed as a replacement for the currently used Teresso V-78 in all gyro bearings of Air Force space and missile inertial guidance units. Historical background is provided leading to the development of the KG-80 replacement fluid. Detailed experimental research involving selection of base stock, additive package, and characterization of the KG-80 formulation are discussed. Performance data of the Air Force, Navy, Industry Cooperative Test Program of KG-80, and Teresso V-78 as a replacement for it in gyro bearings of inertial guidance units. Specification MIL-L-83176 Lubricant, Instrument Bearing Oil, Petroleum Based, covering KG-80 type lubricants, is included.

ACCESS NO: 70,259 AD 872 698
REPORT NO: AFML-TR-69-269 June 1970
TITLE: EFFECTS OF CONSISTENCY, OIL SEPARATION,
AND THICKENER CONCENTRATION ON GREASE
PERFORMANCE
AUTHOR: J. B. Christian
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: J. B. Christian (AFML/LNL)
AFML TASK NO: 734301
ABSTRACT: Graphs and tables have been developed which can be used to select specific non-soap, base oil grease formulations that will provide any given or desired oil separation and/or consistency for that type of grease. These graphs and tables were derived from an extensive investigation of greases formulated from several non-soap thickeners and fluids and characterized for their resultant oil separation and consistencies. Thickeners include silicas, polymeric resins, metal chelates, triazines asbestos, and carbon blacks. Fluids used were bis-m(m-phenoxyphenoxy) phenyl ether, methyl phenyl polysiloxane, and a pentaerythritol ester. Experimental data obtained have shown that by formulating a few representative greases with varying concentrations of any of the non-soap thickeners in a specific base oil and obtaining their respective consistencies and oil separation values, graphs can be made which will provide accurate predictions of the consistency and/or oil separation for any given percentage of thickener in the base oil.

ACCESS NO: 68,861 AD 881 118
REPORT NO: AFML-TR-69-292 January 1971
Part II
TITLE: DETERMINATION OF PHYSICAL AND CHEMICAL
STRUCTURE OF NEW HIGH-TEMPERATURE
POLYMERS
AUTHOR: D. A. Boni
CONTRACT NO: F33615-69-C-1095
CONTRACTOR: Pattelle Memorial Institute
PROJECT MONITOR: Dr. T. E. Helminiak (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: Two polypyrrolone samples containing an anthraqui-
none moiety were characterized. Procedures for isolation of one of these
from solution in strong acid were examined in detail. In addition, the structure
(IR and elemental analysis), thermal properties (TGA and DTA), and solubility
of both materials were obtained. A sample of a spiropolyimide was charac-
terized as to its structure (IR and elemental analysis), thermal properties (TGA and DTA),
and dilute solution viscosity. The results obtained indicated that proposed for
the sample.

ACCESS NO: 64,108 AD 871 941
REPORT NO: AFML-TR-69-302 May 1970
TITLE: SYNTHESIS OF FLUORINATED ALKOXY-AND
ALKYL-SUBSTITUTED STRIAZINES AND THEIR
FLUID PROPERTIES

AUTHOR: C. E. Snyder, Jr.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: C. E. Snyder, Jr. (AFML/LNL)
AFML TASK NO: 734303

ABSTRACT: The successful chemical synthesis of fluorinated
alkoxy- and alkyl- substituted s-triazines has resulted in the development of
a new class of fluids. These fluids, the s-triazines show a strong potential
as candidate high temperature lubricants and energy transfer fluids for future
aerospace systems. The s-triazines discussed herein are nonflammable, and
possess oxidative and thermal stability up to 650^o F. They exhibit good low
temperature properties and show little or no corrosiveness at elevated
temperature.

ACCESS NO: 64, 109 AD 703 333
REPORT NO: AFML-TR-69-322 December 1969
TITLE: TRIPLET TO TRIPLET ABSORPTION IN ORGANIC
MOLECULES FOR USE IN PHOTOCHROMIC DEVICES
AUTHOR: J. L. Kropp, et al.
CONTRACT NO: F33615-69-C-1052
CONTRACTOR: TRW Systems Inc.
PROJECT MONITOR: Dr. H. M. Rosenberg (AFML/LNP)
AFML TASK NO: 736003

ABSTRACT: This report describes a continuing program of research whose aim is to investigate and evaluate new classes of triplet state photochromic materials. This work is centered upon studies of substituted aromatics and heterocyclic compounds. The effect of solvent composition upon fluorescence, phosphorescence and T-T absorption has been investigated for several compounds with the aim of determining the conditions for which the photochromic behavior of a compound will be maximized. Studies have been made for benzquinolines, dibenzacridines, 6 amino chrysene VII and dibenzo (c, g) carbazole VIII. Results of these studies are presented and discussed in terms of the solvent influence upon the lone pair of electrons on the nitrogen in aza-aromatics and for VII and VIII in terms of a change in excited state properties compared to the ground state. The photochromic properties of several new compounds, including phenanthrolines and some oxygen containing heterocyclics have been investigated.

ACCESS NO: 69, 563 AD 886 849
REPORT NO: AFML-TR-69-326 June 1971
TITLE: Part II
RESEARCH ON SYNTHESIS PROCEDURES FOR
INTERMEDIATES REQUIRED FOR HIGH
TEMPERATURE STABLE POLYMERIC
MATERIALS

AUTHOR: C. C. Chappelow, et al.
CONTRACT NO: F33615-69-C-1351
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: G. Moore (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: Work on the synthesis of the following substances is reported: Benzidine 3, 3' -dicarboxylic acid, 6, 6'-bis-([4H] , 3, 1-benzoxazine-2, 4- [1H] -dione), diethyl 2, 5-diaminoterephthalate, pentafluorophenylphosphonous dibromide, bis(pentafluorophenyl)phosphinous bromide, perfluoro-1-bromo-4-n-octylbenzene, 1, 1'-bis(formyl)ferrocene, 1, 3-bis(phenylglyoxaloyl)benzene, pyracloquinone, and p, p'-oxydibenzil. Work on the characterization of the following compounds is reported: 1, 1'-bis(formyl)ferrocene, ruthenocene, hexabromobenzene, and hydroxymethylferrocene. The purification of 1, 4, 5, 8-naphthalenetetracarboxylic acid and 1, 4, 5, 8-naphthalenetetracarboxylic 1:8, 4:5-dianhydride, and the preparation of poly [(u-oxo-7H, 10H-benz [de] imidazo- [4', 5' :5, 6] benzimidazo [2, 1-a] isoquinoline-3, 4, :10, 11-tetrayl)-IO-carbonyl] (BB1 polymer) are also reported.

ACCESS NO: 67,668 **AD 882 034L**
REPORT NO: AFML-TR-69-343 **February 1971**

TITLE: Part II
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: F33615-69-C-1318
CONTRACTOR: General Electric Company
PROJECT MONITOR: Dr. I. J. Goldfarb (AFML/LNP)
AFML TASK NO: 734203

ABSTRACT: Research was continued using mass spectrometric thermal analysis (MAT) to study the thermal degradation of various polymers. Full 200 mass scan runs, limited mass scan runs, and data processing were carried out for a polybenzimidazole, bis benzimidazo benzophenathroline polymer, its ladder polymer, polyquinoxaline, and quinoxaline-bis benzimidazo benzophenathroline ladder copolymer. The results were compared with each other and with earlier data. The concept of an improved data processing system was developed, based on the use of analog magnetic tape. The new system is discussed, together with steps taken to implement it.

ACCESS NO: 67,422 **AD 881 989**
REPORT NO: AFML-TR-70-5 **January 1971**

TITLE: Part II
LADDER POLYMERS WITH QUINOXALINE UNITS

AUTHOR: J. K. Stille, et al.
CONTRACT NO: F33615-69-C-1076
CONTRACTOR: University of Iowa
PROJECT MONITOR: A. J. Sicree (AFML/LNP)
AFML TASK NO: 734201

ABSTRACT: The synthesis of two aliphatic cyclic tetraketones, cyclotetradecan-1,2,8,9-tetrone and cyclotetracosan-1,2,13,14-tetrone has proven to be difficult; therefore this work has been discontinued. The preparation of pyracen-1,2,5,6-tetone from pyracycloquinone or 1,2-diketopyracene has thus far not been accomplished. Napthalene-1,8,4,5-diindandione has been prepared by a known procedure. The development of an alternate synthesis of pyren-4,5,9,10-tetrone through m-cyclophane derivatives has not been successful. The tetrone and anthracen-1,2,5,6-tetrone are being synthesized on a continual basis by employing a literature preparation. Polymers with quinoxaline structures have been prepared through the condensation of aromatic tetraketones with aromatic tetraamines in m-cresol and have been evaluated.

ACCESS NO: 67,737 **AD 882 497**
REPORT NO: AFML-TR-70-6 **March 1971**
Part II
TITLE: SYNTHESIS OF THERMALLY STABLE POLYMERS
AUTHOR: C. S. Marvel
CONTRACT NO: F33615-69-C-1061
CONTRACTOR: University of Arizona
PROJECE MONITOR: Dr. G. A. Loughran (AFML/LNP)
AFML TASK NO: 734004
ABSTRACT: It has been found that tetrasiloxanes are not heat stable and work on these block copolymers has been discontinued. Work with the polymer with graphitic type structure has continued and a pre-polymer with inherent viscosities of 0.7 has been obtained. Purity of the monomers is still a problem. Some further progress has been made on the condensation of 1,5-diaminoanthraquinone and aryl diketones but difficulties of getting a balance of reagents have been met due to sublimation. Work has been started on making polyaryl ethers, polyaryl sulfides, and polyaryl ether sulfones with terminal nitrile groups as laminating resins. One polyaryl ether with nitrile and groups has been trimerized and is being tested in TGA.

ACCESS NO: 69,335 **AD 885 019L**
REPORT NO: AFML-TR-70-32 **February 1971**
Part II
TITLE: EXPLORATORY DEVELOPMENT ON ADVANCED FLUIDS AND LUBRICANTS IN EXTREME ENVIRONMENTS BY MECHANICAL CHARACTERIZATION
AUTHOR: D. R. Wilson, et al.
CONTRACT NO: F33615-69-C-1236
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: F. C. Brooks (AFML/LNL)
AFML TASK NO: 734008, 734301
ABSTRACT: Four thermal/shear stability pump loop evaluations of the synthetic hydrocarbon MLO-68-5 were completed. Two of these evaluations were made with the homogenizer pump stand operating for 100 hr. at 400° F and then for 100 hr. at 550° F. The other two evaluations were made with the high temperature hydraulic circuit operating for 50 hr. at 400° F and then for 11.8 hr. at 500° F. The MLO-68-5 fluid was not appreciably degraded during any of these evaluations; however, the copper alloy piston heads of the aircraft-type pump used in the high-temperature hydraulic circuit wore rapidly and forced termination of the 500° F run.

ACCESS NO: 69,378 **AD 871 516**
REPORT NO: AFML-TR-70-33 **June 1970**
TITLE: Part I
**INTERMEDIATES FOR HIGH-TEMPERATURE-
RESISTANT PLASTICS AND FIBERS**

AUTHOR: H. M. Grotta
CONTRACT NO: F33615-69-C-1257
CONTRACTOR: Battelle Memorial Institute
PROJECT MONITOR: A. Sicree (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: 2, 3, 7, 8-Tetranitrodibenzofuran has been prepared by the nitration of dibenzofuran to 3, 8-dinitrodibenzofuran with nitric acid-acetic acid solution, and further nitration of the latter with nitric and sulfuric acids in the cold. 2, 3, 7, 8-Tetranitrodibenzofuran was purified by several recrystallizations from acetic acid and was readily reduced in methanol containing some hydrogen chloride with hydrogen over Adams catalyst to 2, 3, 7, 8-tetraaminodibenzofuran hydrochloride. The amine salt appears to be reasonably stable as the solid though in solution it is sensitive to oxidation and the free base oxidizes very rapidly. NMR and IR spectroscopy as well as elemental analyses were used to examine the amine salt for purity. Dinitration of pyrene produced a mixture of products from which 1, 6-dinitropyrene could not be separated conveniently. Reduction of the partially purified nitration mixture permitted better purification of 1, 6-diaminopyrenes than had been possible with the nitro derivatives. Introduction of the second pair of nitro groups in the molecule has not yet been achieved.

ACCESS NO: 68,820 **AD 880 957L**
REPORT NO: AFML-TR-70-33 **February 1971**
TITLE: Part II
**INTERMEDIATES FOR HIGH-TEMPERATURE-
RESISTANT PLASTICS AND FIBERS**

AUTHOR: H. M. Grotta
CONTRACT NO: F33615-69-C-1257
CONTRACTOR: Battelle Memorial Institute
PROJECT MONITOR: A. Sicree (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: 2, 3, 7, 8-Tetraaminodibenzofuran was prepared by stepwise nitration of dibenzofuran to 2, 3, 7, 8-tetranitrodibenzofuran, reduction of the nitro compound to the amine in acidic medium, and liberation of the free amine from its hydrochloride by treatment with triethylamine in methanol. Elemental analysis of NMR and IR spectroscopy and differential thermal analysis all are indicative of high purity. The synthetic process proved to be reproducible. Attempts to prepare nitroamino acridines by known routes proved to be unsatisfactory and no successful preparation of tetraaminoacridine was achieved. Careful purification of the reaction product mixture appears to have provided pure tetraamine as indicated by elemental analysis, differential thermal analysis and NMR spectroscopy.

ACCESS NO: 68,919 AD 881 915
REPORT NO: AFML-TR-70-39 February 1971

TITLE: Part II
FUNDAMENTAL STUDIES OF REACTION
OLIGOMERS

AUTHOR: G. F. D'Alelio
CONTRACT NO: F33615-69-C-1032
CONTRACTOR: University of Notre Dame
PROJECT MONITOR: F. E. Arnold (AFML/LNP)
AFML TASK NO: 734201

ABSTRACT: These studies are a continuation of the dipolar cycloaddition reactions and have extended the use of 1,4-benzenedinitrile oxide (BDNO) as the dipole to benzenedi-(phenylnitrilimine) (BDNI). The syntheses of a number of polydipolarophiles for reaction with BDNO and BDNI, respectively, have been completed and include: triallyl cyanurate, tripropargyl cyanurate, 2,4,6-tris(allylamino)-s-triazine, 2,4,6-tris(propargylamino)-s-triazine, 2,4-bis(allylamino)-6-chloro-s-triazine, 2-anilino-4,6-bis(allylamino)-s-triazine, 2-anilino-4,6-bis(propargylamino)-s-triazine, 2-hydroxy-4,6-bis(allylamino)-s-triazine, N,N',N''-triallyl phosphonic acid triamide and tetrapropargyl silicate.

ACCESS NO: 69,659 AD 88 007
REPORT NO: AFML-TR-70-69 July 1971

TITLE: Part II
CHEMICAL AND PHYSICAL PROPERTIES OF
LUBRICANTS, HYDRAULIC FLUIDS AND
RELATED MATERIALS

AUTHOR: A. A. Krawetz, et al.
CONTRACT NO: F33615-69-C-1219
CONTRACTOR: Phoenix Chemical Laboratory
PROJECT MONITOR: C. E. Snyder, Jr. (AFML/LNL)
AFML TASK NO: 734303

ABSTRACT: The technique of thermoelectric flame detection has been utilized to determine the minimum hot-flame and pre-flame reaction thresholds of six samples at one atmosphere pressure. Micro corrosion and oxidation studies have been performed using 0.500" diameter M-10 and 52100 steel spheres and titanium spheres as test specimens instead of the standard test coupons or washers. An electrolytic cleaning procedure for the removal of deposits from corrosion and oxidation test specimens has been evaluated. The lubrication of titanium surfaces by several experimental fluids has been studied by the use of titanium balls in the 4-Ball Wear Tester. The chemical and physical properties of various lubricants and hydraulic fluids have been studied. Special emphasis has been directed toward the investigation of properties relevant to the performance of lubricants and hydraulic fluids under conditions of thermal and oxidative stress.

ACCESS NO: 71, 716 AD 871 175
REPORT NO: AFML-TR-70-84 March 1970
TITLE: DEVELOPMENT OF ROUND CROSS-SECTION
CELLULOSE FIBERS FOR EVALUATION AS
GRAPHITE YARN PRECURSORS

AUTHOR: R. H. Snyder
CONTRACT NO: F33615-69-C-1426
CONTRACTOR: IRC Fibers Company
PROJECT MONITOR: L. G. Picklesimer (AFML/LNF)
AFML TASK NO: 732001

ABSTRACT: Development work is described in which round cross-section filaments are produced by the viscose process for evaluation as graphite yarn precursors. One method employs a zinc-free spin bath which produces a yarn similar in physical and chemical properties to commercial Villwyte[®], but with considerably lower elongation at break. Two other methods resort to the use of (1), minimal amounts of modifiers incorporated in the viscose, and (2), modifiers added to the spin bath to achieve different structured, stronger, and more highly oriented yarns. Since modifier residues in the yarn are speculated to affect graphitization, amounts remaining in these yarns are estimated by chemical analyses.

ACCESS NO: 69, 476 AD 886 047L
REPORT NO: AFML-TR-70-94 July 1971
TITLE: IMPROVED RADIATION-STABLE THERMAL
CONTROL COATINGS

AUTHOR: M. Lillywhite, et al.
CONTRACT NO: F33615-69-C-1311
CONTRACTOR: Martin Marietta Corporation
PROJECT MONITOR: C. P. Boebel (AFML/LNE)
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, vapor phase, and controlled dehydration syntheses. These methods were used to prepare relatively pure crystals or crystallites whose particles were mainly less than 5.0 μ . The pigment materials synthesized were sphene (CaTiSiO₅), quartz (SiO₂), spinel (MgAl₂O₄), α -Al₂O₃, TiO₂, perovskite (CaTiO₃), and SiC. All materials except CaTiO₃ and SiC were evaluated in the simulated solar irradiance environment. Based on these data, the best three pigments (MgAl₂O₄, α -Al₂O₃, and SiO₂) were formulated into coatings using dimethyl silicone resin as a binder and were evaluated in a simulated solar irradiance environment. The coating formulation methods that were investigated to minimize damage to the pigment particles were low-speed blending and use of a polyurethane-lined ball mill.

ACCESS NO: 69, 986 **AD 888 652L**
REPORT NO: AFML-TR-70-95 **September 1971**

TITLE: Part II
**ABLATIVE MATERIALS FOR HIGH HEAT LOADS
PART II: HETEROCYCLIC RESINS, LAYERED
COMPOSITES, ELASTOMERS, AND FILAMENT
WOUND COMPOSITES**

AUTHOR: P. W. Juneau, Jr., et al.
CONTRACT NO: F33615-69-C-1503
CONTRACTOR: General Electric Company
PROJECT MONITOR: R. Farmer (AFML/LNC)
AFML TASK NO: 734001

ABSTRACT: Ablative plastic composite materials were investigated and developed for long time heating environments. The desirable materials performance goals were low surface ablation, insulative ability, and low weight without asymmetrical ablation, char instability, spallation or other thermomechanical effects. The candidate materials consisted of (a) carbon, quartz, and silica cloth reinforced polyimide resin, (b) loom woven, low density quartz (LDQ) insulative layers using polyimide resin, (c) carbon-quartz bifilament tape reinforced phenolic resin, (d) filled ablative silicone elastomers, and (e) a multiple interlock, filament wound (MIFW) carbon filament reinforced phenolic resin cylinder.

ACCESS NO: 68, 921 **AD 720 824**
REPORT NO: AFML-TR-70-100 **January 1971**
TITLE: **HIGH STRENGTH, HIGH MODULUS GRAPHITE
FIBERS**

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

ABSTRACT: The formation of high modulus and high strength graphite fibers from polymeric fibers and from fibers spun from pitches is reviewed. Methods of preparation given by patents and in the technical literature are abstracted for precursors including cellulose or rayon, polyacrylonitrile, polyvinyl alcohol, polybenzimidazole, and aromatic polyamide yarns. The properties of the graphite fibers are given and relationships between various properties and methods of preparation are cited where these exist.

ACCESS NO: 68,890 AD 718 978
REPORT NO: AFML-TR-70-113 May 1970
TITLE: VISCOELASTIC BEHAVIOR OF A NONLINEAR
FIBER-REINFORCED PLASTIC

AUTHOR: Y. C. Lou
CONTRACT NO: F33615-67-C-1412
CONTRACTOR: Purdue University
PROJECT MONITOR: Dr. J. C. Halpin (AFML/LNE)
AFML TASK NO: 734202

ABSTRACT: The nonlinear, viscoelastic behavior of a unidirectional, glass fiber-epoxy composite material is characterized by using isothermal, uniaxial creep and recovery tests together with a constitutive equation based on a thermodynamic theory. First, linear stress-strain equations for both uniaxial and multiaxial loading of orthotropic materials are reviewed, and then the nonlinear constitutive equation for uniaxial loading is given. Following a discussion of experimental aspects, creep and recovery tests together with a constitutive equation based on a thermodynamic theory. First, linear stress strain equations for both uniaxial and multiaxial loading of orthotropic materials are revised, and then the nonlinear constitutive equation for uniaxial loading is given. Following a discussion of experimental aspects, creep and recovery data obtained from several different specimens (each having a different fiber orientation relative to the loading axis) are used together with a graphical shifting procedure to evaluate all material properties.

ACCESS NO: 69,010 AD 882 064
REPORT NO: AFML-TR-70-173 July 1970
TITLE: THE EFFECTS OF BOROSILICATE CATALYSIS
ON THE THERMAL AND OXIDATIVE STABILITY
OF FLUIDS

AUTHOR: W. E. House
CONTRACT NO: F33615-69-C-1385
CONTRACTOR: University of Dayton
PROJECT MONITOR: J. M. Kelble (AFML/LN)
AFML TASK NO: 734303

ABSTRACT: The thermal stability of synthetic fluids and mineral oils, and the effects of boro-silicate catalysis on their thermal stability in air was determined by differential thermal analysis. Fluids included in this investigation were perfluorinated ether, polyphenyl ether, 1,1'diiodoferrocene, mineral oil, trimethylolpropane ester, and a fluorinated silicone. Borosilicate catalysis of the fluids was found to have a definite effect on the thermal stability in air of all the fluids investigated.

ACCESS NO: 68, 854 AD 881 476
REPORT NO: AFML-TR-70-228 December 1970
TITLE: DEVELOPMENT AND EVALUATION OF ABLATIVE COMPOSITES UTILIZING A MATRIX OF WATER-EXTENDED POLYESTER RESIN

AUTHOR: C. E. Browning, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: C. E. Browning (AFML/LNC), et al.
AFML TASK NO: 734001

ABSTRACT: A water-extended polyester resin system was evaluated in homogeneous casting and composite forms to ascertain its potential as an ablative material. Arc plasma screening tests were performed at cold-wall heat flux levels of 100 and 300 Btu/Ft 2-sec on castings of 50% water/50% polyester, and at heat flux levels of 100, 300, and 500 Btu/ft 2-sec on composites of 50% water/50% polyester/Refrasil fabric. Comparable castings and composites utilizing pure polyester resin were simultaneously treated for comparative purposes. Additional comparisons with typical ablative materials have also been made. At low heat flux levels the water-extended polyester materials had lower recession rates than pure polyester materials.

ACCESS NO: 68, 985 AD 881 812
REPORT NO: AFML-TR-70-232 February 1971
TITLE: SYNTHESIS AND PROPERTIES OF POLYMERS AND COPOLYMERS CONTAINING POLY-BENZIMIDAZOBENZOPHENANTHROLINE AND POLYIMIDE STRUCTURES

AUTHOR: J. F. Coleman, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. R. L. Van Deusen (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: A high molecular weight benzimidazobenzophenanthroline (BB) polymer containing both the "Bis-BB" (BBB) and the "BB-Ladder" (BBL) polymer structures has been prepared. This BBB/BBL polymer was synthesized from 1, 4, 5, 8-naphthalene tetracarboxylic acid (NTCA) and a stoichiometric mixture of 3, 3'-diaminobenzidine (DAB) and 1, 2, 4, 5-tetraaminobenzene tetrahydrochloride (TAB. 4HCl) by polycondensation in polyphosphoric acid. The polymer was black and amorphous with an intrinsic viscosity of 2.80 dl/gm at 30 C in sulfuric acid and 3.25 dl/gm at 30 C in methane sulfonic acid and found to be stable to 500 C in air and 600 C in nitrogen by thermogravimetric analyses. Films of this polymer were prepared using both casting and precipitation techniques. This polymer also appeared to have fiber-forming properties.

ACCESS NO: 68, 997 **AD 882 089**
REPORT NO: AFML-TR-70-233 **February 1971**
TITLE: APPROACHES TO LADDER STRUCTURES. PART VI: CONDENSATION POLYMERIZATION OF SOME DIFUNCTIONAL DERIVATIVES RELATED TO (4H), 3, 1-BENZOXAZINE-4-ONE WITH CERTAIN AROMATIC DIAMINO DICARBOXYLIC ACIDS, ESTERS OR AROMATIC TETRAAMINES
AUTHOR: G. A. Loughran

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

ABSTRACT: 2-methyl-(4H), 3, 1-benzoxazine-4-one reacted with methyl anthranilate in refluxing xylene to give 2-methyl-3-(o-carboxymethyl)-phenylquinazoline-4-one. Polyquinazolinones in the medium molecular weight range, with viscosities in the 0.25 region were obtained when 2, 7-dimethyl-(4H, 9H), 3, 1, 8, 6-benzobisoxazine-4, 9-dione was reacted with either 2, 5-diamino-terephthalic acid or its diethyl ester in sulfolane or diphenylether up to 300. 2, 7-dimethyl-(4H, 9H), 3, 1, 8, 6-benzobisoxazine-4, 9-dione and 3, 3' diaminobenzidine were reacted in dimethylformamide, diethyl cellosolve, and trimethylene glycol dimethyl ether at temperatures from 120 to 310 C to give a soluble low molecular weight linear polyamide expected to use as a pre-polymer for subsequent conversion to the corresponding quinazoline and benzimidazo-(1, 2c)-quinazoline polymers.

ACCESS NO: 69, 222 **AD 884 478**
REPORT NO: AFML-TR-70-242 **December 1970**
TITLE: WIDE-TEMPERATURE-RANGE FREE-LAYER DAMPING MATERIALS

AUTHOR: F. S. Owens
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: F. S. Owens (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: Techniques are described for extending and altering the temperature range over which viscoelastic materials are useful for free-layer damping. The approach is based upon the phenomenon that viscoelastic polymers exhibit a high level of structural damping only within a few degrees of their glass transition temperature and that certain types of polymer blends exhibit more than one glass transition temperature. The dynamic modulus and loss factor values of several vulcanized blends of mutually insoluble polymers containing selected amounts and/or kinds of polymers, fillers, plasticizers, and curing agents were measured over temperature ranges including all of the (apparent) glass transitions of the polymers used in the blends. Several very effective formulations for free-layer damping over wide temperature ranges were developed and the structural damping behavior of selected materials was investigated in simulated applications.

ACCESS NO: 69,517 AD 886 173
REPORT NO: AFML-TR-70-263 February 1971
TITLE: TRIBOELECTRICITY DURING BRITTLE FRACTURE
OF AN EPOXY RESIN

AUTHOR: W. Mahieu
CONTRACT NO: F33615-69-C-1385
CONTRACTOR: University of Dayton
PROJECT MONITOR: J. D. Ray (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: Previous observation of time dependent voltages induced on metal probes positioned near fiber/plastic composite specimens during stressing made imperative the determination of their physical significance. One possible source of such signals was cracks in the resin matrix phase of such materials, since fracture of cast epoxy resins has produced similar signals. The objective of this work was to determine the physical significance of induced voltage-time signals accompanying a simple fracture process. Fracture of a brittle epoxy resin which exhibited nearly glasslike fracture was studied. The fresh fracture surfaces were found to be electrically charged. The induced voltage-time signals were generated as the charged fracture surfaces separated, following propagation of the single crack which produced fracture.

ACCESS NO: 69,521 AD 886 154L
REPORT NO: AFML-TR-70-264 February 1971
TITLE: NEW TENSILE AND COMPRESSIVE TEST
SPECIMENS FOR UNIDIRECTIONAL REIN-
FORCED GRAPHITE EPOXY COMPOSITES

AUTHOR: J. C. Weidner
CONTRACT NO: F33615-69-C-1385
CONTRACTOR: University of Dayton
PROJECT MONITOR: J. D. Ray (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: The development of high strength and high modulus fibers for use as reinforcement in resin matrix composites has created problems in the area of mechanical testing. The difficulty appears when unidirectionally reinforced composites are tested in tension or compression

ABSTRACT (Continued)

using conventional test specimens with the test directional parallel to the fiber direction. Under these conditions failure normally occurs outside the gage section. This report describes two new test specimens developed for determining tensile and compressive properties of unidirectional, graphite reinforced epoxy composites when loading is parallel to the fiber direction. When these specimens were used to evaluate epoxy matrix composites reinforced with Morganite Type II graphite fiber, the failure always occurred in the gage section.

ACCESS NO: 68,002 **AD 888 789**
REPORT NO: AFML-TR-70-267 **May 1971**

Part II

TITLE: THE MECHANICAL, FLAMMABILITY AND
DYEABILITY PROPERTIES OF HIGH
TEMPERATURE ORGANIC FIBERS

AUTHOR: W. D. Freeston, Jr., et al.

CONTRACT NO: F33615-69-C-1167

CONTRACTOR: Fabric Research Laboratories, Inc.

PROJECT MONITOR: S. Schulman (AFML/LNE)

AFML TASK NO: 732002

ABSTRACT: Benzyl alcohol has been found to be a highly effective dyeing assistant for the application of dispersed dyes to PBI. Its use permits rapid uniform dyeings under standard atmospheric conditions with conventional dyeing equipment. Because of the excellent dye penetration into the fiber, lightfastness is appreciably enhanced. The flammability characteristics of a series of fabrics in air and oxygen-rich environments were investigated. The ignition temperature, time for ignition at various temperatures, burning rate, and limiting oxygen index (LOI) were determined. PBI, BBB, and Durette fabrics were found to be superior. The tensile properties of nylon, Dacron polyester and Nomex yarn were determined at strain rates of 1.67 and approximately 9500 %/sec at ambient and elevated temperatures. Nomex exhibited the largest strength retention at elevated temperatures.

ACCESS NO: 69,291 AD 884 808L
REPORT NO: AFML-TR-70-269 September 1970
TITLE: EFFECTS OF SELECTED METALS AND METALLIC
OXIDES UPON THE THERMAL STABILITY OF A
POLYIMIDE ADHESIVE

AUTHOR: P. W. Centers, et al.
CONTRACT NO: F33615-69-C-1465
CONTRACTOR: University of Dayton
PROJECT MONITOR: J. M. Kelble (AFML/LNC)
AFML TASK NO: 734002

ABSTRACT: The effects of selected metals and metallic oxides on the thermal degradation of a polyimide adhesive, AF-R-2009, were determined. Commercially pure (99 - 99.999%) samples of Fe, Cr, and Ni were added without further purification. Cu was reduced prior to addition in all cases. Metallic oxides were CuO and Fe₂O₃. Lap shear studies, thermogravimetric analysis, differential thermal analyses, infrared spectrophotometric analyses, and isothermal weight loss studies were made to determine the rates of degradation and to provide information on the mechanisms of degradation. Activation energies and statistical factors of degradation were determined. Activation energies calculated from lap shear data and thermogravimetric analyses were comparable.

ACCESS NO: 68,855 AD 881 146L
REPORT NO: AFML-TR-70-278 December 1970
TITLE: Part I

HYBRID FLUOROSILICONES FOR AIRCRAFT FUEL
TANK SEALANTS PARTS I: SYNTHESIS OF FLUORO-
CARBON, m-CARBORANE, FLUOROALKYLPHENYL-,
AND FLUOROPHENYL- HYBRID FLUOROSILICONE
POLYMERS

AUTHOR: O. R. Pierce, et al.
CONTRACT NO: F33615-69-C-1301
CONTRACTOR: Dow Corning Corporation
PROJECT MONITOR: W. R. Griffin (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: Two formulated sealants were prepared and evaluated from the fluorosiliconefluorocarbon hybrid (Class 2) polymer system. All other polymer samples were prepared as high consistency gums containing cross-linking sites. Samples of formulated sealants and high consistency gums were submitted to AFML for evaluation. The objective of this work is the synthesis and evaluation of hybrid fluorosilicone polymers which possess fuel and reversion resistance at elevated temperatures. These polymers are intended for use as sealants in aircraft applications where exposure to extreme environmental conditions is encountered.

ACCESS NO: 68,859 AD 881 276
REPORT NO: AFML-TR-70-279 January 1971
TITLE: EXPLORATORY DEVELOPMENT OF IMPROVED
OPTICAL FIBER BUNDLES
AUTHOR: H. B. Cole, et al.
CONTRACT NO: F33615-69-C-1391
CONTRACTOR: American Optical Corporation
PROJECT MONITOR: W. H. Gloor (AFML/LNF)
AFML TASK NO: 732001

ABSTRACT: The purpose of this contract was to conduct exploratory development on materials and techniques to improve glass optical fibers and fiber bundles with particular reference to coherent multifiber fiberscopes. Studies were carried out on improved interface formation, end tip fusing, experimental fiber drawing techniques and evaluation of various component glass, clad rods and fibers. Two basically different approaches to improving the core-cladding interface were explored: 1) the use of low melting fluxes with the rod and tube method, and 2) the use of a double crucible to completely melt the core and cladding glasses before drawing. Neither approach provided significantly better interface quality in the resulting clad rods.

ACCESS NO: 65,793 AD 879 694L
REPORT NO: AFML-TR-70-280 December 1970
TITLE: RESEARCH ON ADDITIVES FOR HIGH TEMPERA-
TURE HYDRAULIC FLUIDS
AUTHOR: R. L. Elliott, et al.
CONTRACT NO: F33615-69-C-1283
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: C. E. Snyder, Jr. (AFML/LNL)
AFML TASK NO: 734008

ABSTRACT: This program's objective was to synthesize various compounds required by the Air Force Materials Laboratory for evaluation as high-temperature fluid additives. Samples of the following compounds were synthesized: 3,5,6-Tri-chloro-as-triazine; 1-bromo-4-(perfluoroheptyl) benzene; 1-bromo-3-(perfluoroheptyl)benzene; 3-(perfluoroheptyl)phenol; tris(4-pentadecafluoroheptylphenyl)-phosphine; perfluorostyrene; 3,5,6-tris(1,1,5-tri-H-perfluoropentyloxy)-as-triazine; 3,5,6-tris(1,1,7-tri-H-perfluoroheptyloxy)-as-triazine; 3,5,6-tris-(1,1,9-tri-H-perfluorononyloxy)-as-triazine; 3,5,6-bis(1,1,7-tri-H-perfluoroheptyloxy)(1,1,9-tri-H-perfluorononyloxy)-as-triazine; 1-perfluoroheptyl-3-(3-phenoxyphenoxy) benzene; 1,3-bis(3-pentadecafluoroheptylphenoxy)benzene; 1-(3-phenoxyphenoxy)-3-(3-pentadecafluoropheptylphenoxy)benzene; and 1-(3-phenoxyphenoxy)-3-(3-pentadecafluoroheptylphenoxy) phenoxy benzene.

ACCESS NO: 69,128 AD 723 287
REPORT NO: AFML-TR-70-281 February 1971
TITLE: FOURIER ANALYSIS OF CLAMPED ANISOTROPIC PLATES

AUTHOR: J. M. Whitney
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: J. M. Whitney (AFML/LNC)
AFML TASK NO: 734202

ABSTRACT: Using a Fourier series method, a solution is obtained to the governing equations of a homogeneous, or symmetrically laminated, anisotropic, rectangular plate with clamped edges. Solutions are obtained for bending under transverse load, buckling under combinations of uniform shear and biaxial compression, and natural frequencies of flexural vibrations. Numerical results are compared to those previously obtained by the Ritz method.

ACCESS NO: 69,199 AD 724 146
REPORT NO: AFML-TR-70-282 February 1971
TITLE: FREE EDGE EFFECTS IN THE MEASUREMENT OF COMPOSITE IN-PLATE SHEAR PROPERTIES

AUTHOR: J. M. Whitney
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: J. M. Whitney (AFML/LNC)
AFML TASK NO: 734202

ABSTRACT: A Fourier series solution is obtained for the stresses in a symmetrically laminated orthotropic plate subjected to a uniform tangential displacement along one edge with the opposite edge clamped and the two adjacent edges stress-free. These are essentially the edge conditions imposed by the rail shear test. Results can also be applied to the determination of stresses in a certain class of bonded double lap joints. Numerical examples show the shear stress distribution to be a function of various in-plane stiffness ratios and the dimensions of the plate. In addition, normal stresses of large magnitude are found in the corners. Theoretical results are qualitatively verified on fiber reinforced rubber composites.

ACCESS NO: 69, 377 AD 885 668
REPORT NO: AFML-70-302 May 1971
TITLE: GRAPHITE FIBER SURFACE TREATMENTS
AUTHOR: L. A. Joo', et al.
CONTRACT NO: F33615-70-C-1374
CONTRACTOR: Great Lakes Research Corporation
PROJECT MONITOR: E. A. Arvay (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: The objective of this program was the development of new and improved surface treatments for graphite fibers in order to provide optimum bonding to structural resins. Satisfactory treatments should have little deleterious effect on fiber strength and handleability, should result in improvements in overall composite mechanical properties, and should be capable of being applied economically in a continuous, in-line apparatus. Air oxidation also was found to improve composite shear strength but at a cost to other fiber and composite properties. Continuous gas phase and other types of surface treatment experiments were performed. There was indication that silane or other types of chemical coupling agents affected the bonding of oxidized fibers to epoxy resins. Measurements of surface area and oxygen content also showed the effect of surface oxidation, both of these being increased by surface treatment.

ACCESS NO: 69, 097 AD 883 123
REPORT NO: AFML-TR-70-303 March 1971
TITLE: COATINGS FOR LIGHTNING PROTECTION OF
STRUCTURAL REINFORCED PLASTICS
AUTHOR: J. T. Quinlivan, et al.
CONTRACT NO: F33615-69-C-1612
CONTRACTOR: Boeing Company
PROJECT MONITOR: Capt. J. G. Breland (AFML/SU)
AFML TASK NO: 734007

ABSTRACT: Coatings and coating systems were developed for protection of boron and graphite fiber reinforced plastic composites from structural damage by lightning strikes. The effectiveness of the protective capability of the proposed coating systems was tested with an artificial lightning stroke consisting of both high current and high coulomb components. The primary criterion of a successful coating was the capability of a test panel to sustain a simulated lightning discharge without structural damage to the composite substrate. Numerous coatings or coating systems have been developed and evaluated. They can be classified into the following general categories: continuous metal foils; woven metal wire fabrics; knitted metal wire mesh; plasma and flame sprayed aluminum; metal pigmented paints; and nonmetallic pigmented paints with or without undercoatings.

ACCESS NO: 65, 053 **AD 882 724**
REPORT NO: AFML-TR-70-304 **April 1970**
TITLE: Part I
FLUIDS, LUBRICANTS, FUELS AND RELATED MATERIALS
AUTHOR: E. E. Klaus, et al.
CONTRACT NO: F33615-69-C-1183
CONTRACTOR: Pennsylvania State University
PROJECT MONITOR: G. Morris (AFML/LNL)
AFML TASK NO: 734303

ABSTRACT: Analytical techniques for the measurement of iron have been developed using an ashing technique. The Atomic Absorption Spectrophotometer is used. Test techniques for obtaining fluid samples and optimizing the analytical results are described. A reaction sequence involving the fluid and oxygen for the initial production of a soluble organo-iron molecule is suggested. A quantitative oxidation test procedure for use at 400^oF and above and low air rates is described. A method employing a 0.45 micron Millipore filter is discussed for the recovery of sludge from oxidized oil. Effects of fluid complexity are related to rates of primary and secondary oxidation reactions. Carbon dioxide solubility studies using mineral oils, esters, and a silicone are discussed. The sensitivity of carbon dioxide solubility to volatility is illustrated. The studies suggest a rule of carbon dioxide solubility in the oxidation behavior of fluids and lubricants.

ACCESS NO: 200, 179 **AD 889 847L**
REPORT NO: AFML-TR-70-305 **October 1971**
TITLE: **SIGNIFICANT PROPERTIES OF EPOXY RESINS AS MATRICES IN GRAPHITE COMPOSITES**
AUTHOR: W. Mahieu, et al.
CONTRACT NO: F33615-69-C-1385
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: Dr. N. J. Pagano (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: It is desirable, for purposes of developing better resins and using them wisely, to know what properties of thermosetting resins are most significant in affecting the structural properties of graphite fiber/resin matrix composites. This was the objective of the work being reported. Some evidence indicated three of the five composites evaluated may have debonded at the fiber/resin interface prior to matrix flow or cracking in the 90^o tensile test. ERLA 4617 appeared to give the best balanced composite properties from the tests conducted. The current program is being extended to consider multidirectional composites. Further research should determine if matrix resin strength and toughness and significant factors when interfacial bond strength does not limit transverse composite strain capability.

ACCESS NO: 69,391 AD 726 545
REPORT NO: AFML-TR-70-306 February 1971
TITLE: PREPARATION AND CHARACTERIZATION OF
A BENZOBISTRIAZOLOPHENANTHROLINE
POLYMER

AUTHOR: Dr. R. C. Evers
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. R. C. Evers (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: A benzobistriazolophenanthroline polymer was prepared by the polycondensation of 2,6-pyridinediylhydrazidine with 1,4,5,8-naphthalene tetracarboxylic acid or 1,4,5,8-naphthalene tetracarboxylic dianhydride in polyphosphoric acid. Inherent viscosities in the range of 0.25-0.87 dl./g. were recorded. Polymer structure was established by elemental and infrared analysis. The polymer was a reddish-brown powder soluble in sulfuric- or methane sulfonic-acid. Onset of breakdown during thermogravimetric analysis in a nitrogen atmosphere occurred at 475°C.

ACCESS NO: 200,230 AD 889 997
REPORT NO: AFML-TR-70-316 March 1971
TITLE: RAIN-EROSION BEHAVIOR OF GRAPHITE-
AND BORON-FIBER-REINFORCED EPOXY
COMPOSITE MATERIALS

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

ABSTRACT: Investigations were conducted on the rain erosion behavior at subsonic and supersonic speeds of uncoated and coated boron- and graphite-fiber-reinforced composites employing both rotating-arm and rocket-sled apparatus. In common with glass-fiber-reinforced composites and other composite materials, unprotected boron- or graphite-fiber-reinforced epoxy plastic composites as expected have been shown to be lacking in erosion resistance and require protective coatings. Electroplated nickel coatings were shown to provide substantial protection of these composites at subsonic speeds, and limited protection for short exposure periods at supersonic velocities in rain up to Mach 2.0.

ACCESS NO: 200, 102 AD 889 122L
REPORT NO: AFML-TR-70-317 August 1971
TITLE: MICROFIBER-FLUOROELASTOMER COMPOSITE
SEAL MATERIALS

AUTHOR: J. K. Sieron
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: J. K. Sieron (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: Composite fluoroelastomer-microfiber reinforced seal materials having excellent high temperature resistance and compression set resistance after long time periods at temperatures up to 500° F have been developed. A key factor in this new technology is the conception and reduction to practice of utilizing a single material, namely very pure magnesium oxide (M O) fibers as the combination reinforcing material, crosslinking accelerator, and high temperature stabilizer for fluoroelastomers. Outstanding compression set resistance was achieved by curing M O fiber elastomer composites with peroxides. Thus, after post-curing by a vacuum oven-air oven process, the new seal material consists only of M O fibers dispersed in a fluoroelastomer matrix which has very stable carbon-carbon crosslinks.

ACCESS NO: 68,477 AD 881 802
REPORT NO: AFML-TR-71-2 February 1971
TITLE: Part I
POLYMER STRUCTURES AND PROPERTIES
PART I: THERMALLY STABLE POLYMERS

AUTHOR: G. C. Berry, et al.
CONTRACT NO: F33615-70-C-1058
CONTRACTOR: Carnegie-Mellon University
PROJECT MONITOR: Dr. M. T. Gehatia (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: A new cone and plate rheometer is described and evaluated. The new instrument is intended to measure rheological properties of concentrated solutions of BBB in strong acids. It can be used to study the shear stress as a function of shear rate and time of shearing, as well as the deformation in response to an applied shear stress. Studies of several solutions with the new instrument are discussed. Dilute solution light scattering and viscometry on fractions for BBB polymer treated with fuming sulfuric acid are described. This treatment is believed to cause intrachain cyclization leading to an inflexible coil polymer. Light scattering studies on films of BBB and BBL reveal even more supramolecular structure than was anticipated. These data are considered in terms of available theories.

ACCESS NO: 69,537 AD 887 136
REPORT NO: AFML-TR-71-3 April 1971
TITLE: THE DEVELOPMENT OF HIGH TEMPERATURE
STABLE POLYIMIDE STRUCTURAL ADHESIVES
AUTHOR: E. A. Arvay, et al.

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: E. A. Arvay (AFML/LNC), et al.
AFML TASK NO: 734002

ABSTRACT: A new polyimide resin, AF-R-2009, which had exhibited an oxidative stability superior to that of commercially available polyimides under isothermal aging at 700° F was formulated into a series of adhesives. The respective adhesives were used to bond Ti-8Al-1V-1Mo titanium and 17-7 PH stainless steel alloy adherends. Tensile lap shear strength properties were determined at room temperature and at 600 and 700° F after isothermal aging at the respective temperatures. One formulation of the AF-A-2009 adhesive was essentially equivalent to commercially available polyimide adhesives at 600° F exposure with both titanium and stainless steel adherends. The effects of varying the concentration of antioxidant, arsenic thioarsenate, on bonded joint strengths were determined.

ACCESS NO: 66,898 AD 881 103L
REPORT NO: AFML-TR-71-4 February 1971
TITLE: HIGH TEMPERATURE RESINS FOR STRUCTURAL
LAMINATES AND ADHESIVES

AUTHOR: W. P. Fitzgerald, Jr., et al.
CONTRACT NO: F33615-70-C-1106
CONTRACTOR: Whittaker Corporation
PROJECT MONITOR: T. J. Aponyi (AFML/LNC)
AFML TASK NO: 734002

ABSTRACT: Initial fabrication studies have demonstrated that the silane-bearing copolymer system, AF-R-500-OBB/TCPPS, is capable of ready processing and facile cure. The proper cure schedule has not yet been determined. One such laminate was prepared with 39,300 psi flexural strength and 2.25×10^6 psi modulus at room temperature. Due to improper processing, this sample delaminated in heat aging. Bulk resin properties and torsional braid analysis studies with these homogeneously-curable systems clearly demonstrate the feasibility of this approach. For the AF-R-500-OBB/TCPPS bulk resin, a heat distortion temperature of 815 F and a glass transition temperature of ca. 935 F, have been determined.

ACCESS NO: 69,426 AD 885 338
REPORT NO: AFML-TR-71-5 April 1971
TITLE: MLO-68-5, A LESS-FLAMMABLE HYDRAULIC
FLUID FOR MIL-H-5606(B) REPLACEMENT
AUTHOR: Capt. B. A. Loving, et al.

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Capt. B. A. Loving (AFML/LNL), et al.
AFML TASK NO: 734008

ABSTRACT: This report covers the development and evaluation of MLO-68-5 less-flammable hydraulic fluid. This work has demonstrated that this fluid can be used to replace MIL-H-5606(B) hydraulic fluid in Air Force aircraft, missiles, spacecraft, and their support equipment without requiring retrofit of their hydraulic systems within the -40 to plus 275 F operational temperature and it will provide a significant reduction in vulnerability of these vehicles and equipment due to hydraulic fires resulting from enemy ground fire, accidents, and system malfunctions. MLO-68-5 hydraulic fluid has an additional advantage over MIL-H-5606(B) in that it has a high temperature capability in excess of 400 F whereas MIL-H-5606(B) is limited to 275 F.

ACCESS NO: 200,236 AD 736 786
REPORT NO: AFML-TR-71-6 January 1971
TITLE: THERMAL DEGRADATION OF COPOLYMERS
AUTHOR: N. Grassie, et al.
CONTRACT NO: AF61052-883
CONTRACTOR: University of Glasgow
PROJECT MONITOR: Dr. I. Goldfarb (AFML/LNP)
AFML TASK NO: 734203

ABSTRACT: This report is principally concerned with the thermal degradation of two copolymer systems, namely methyl methacrylate/methyl acrylate and methyl methacrylate/butyl acrylate. The photo-degradation of the methyl methacrylate/methyl acrylate system was also studied insofar as it is relevant to the thermal reaction. In view of the similarity of the monomers, reliable values of reactivity ratios were not available. An accurate method, making use of nuclear magnetic resonance spectroscopy, was devised and applied to these and other acrylate/methacrylate systems. For both systems a series of copolymers covering the whole composition range was synthesized. Degradations were carried out under vacuum either in a dynamic molecular still or using a new technique developed in these laboratories.

ACCESS NO: 69,288 AD 725 753
REPORT NO: AFML-TR-71-8 March 1971
TITLE: THE INFLUENCE OF STACKING SEQUENCE ON
LAMINATE STRENGTH
AUTHOR: Dr. N. J. Pagano, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. N. J. Pagano (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: Based upon considerations relating to the nature of the interlaminar stresses in composite laminates, an approach is presented to predict the detailed stacking sequence of specific layer orientations which leads to optimum protection against delamination under uniaxial static and fatigue loadings. In particular, it is argued that the interlaminar normal stress, as well as the interlaminar shear stress, is instrumental in precipitating delamination and subsequent strength degradation. Correlation with existing experimental evidence of the stacking sequence phenomenon is presented.

ACCESS NO: 69,290 AD 884 507
REPORT NO: AFML-TR-71-9 March 1971
TITLE: ON THE HYDROLYTIC DEGRADATION OF A
DISILOXANE/ESTER FLUID UNDER MECHANICAL
STRESS

AUTHOR: N. L. Bertram, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: F. C. Brooks (AFML/LNL), et al.
AFML TASK NO: 734008

ABSTRACT: Data are presented on the changes in the properties of a disiloxane/ester fluid resulting from reaction with water concentrations as small as 200 PPM while undergoing mechanical stress at 275° F. The response of fluid flash point, fire point, viscosity, neutralization number, and hydraulic system filter differential pressure are presented for fluid water concentrations from no water added (NWA) to 18,900 PPM. The efforts and results of previous investigators, employing bench tests and simulated systems, are reviewed. The limitations and sources of error of various methods of determining fluid degradation and level of water contamination, as determined by this study, are noted.

ACCESS NO: 65,054 **AD 886 079**
REPORT NO: AFML-TR-71-13 **February 1971**
TITLE: SAPPHIRE FILAMENTS
AUTHOR: G. F. Hurley, et al.
CONTRACT NO: F33615-69-C-1369
CONTRACTOR: Tyco Laboratories, Incorporated
PROJECT MONITOR: Capt. L. G. Tolley (AFML/LNC)
AFML TASK NO: 732001, 734003

ABSTRACT: The Tyco developed Edge Defined, Film Fed Growth technique has been further refined and successfully applied to growth of melting point materials of commercial interest such as spinel, ruby, beryllia, and in particular, α -alumina. The growth of ruby single crystals and nonsegregated Cu-Au alloy has demonstrated that EFG need not be restricted to congruently melting materials. Multiple filament and ribbon growth has been achieved with sapphire, and transparent sapphire, and transparent sapphire plates have been grown. Modifications to the growth apparatus have allowed unrestricted viewing of the growth interface and a more detailed knowledge of the effect of temperature rate of growth and mechanical vibration on the growth process. The promotion of wetting of sapphire by epoxy resins to result in high strength bonding was studied. Improvements in the quality of ribbons and plates have resulted from stress analysis of crystals grown orifices of different curvature.

ACCESS NO: 200,103
REPORT NO: AFML-TR-71-17 **August 1971**
TITLE: AGGREGATION BEHAVIOR AND FILM FORMATION OF BBL AND OTHER LADDER POLYMERS
AUTHOR: F. E. Arnold, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. R. L. Van Deusen (AFML/LNP)
AFML TASK NO: 734004

ABSTRACT: The ladder polymer, BBL, has been formed into thin films by collecting suspensions of the polymer obtained from acid reprecipitations upon a fritted glass funnel. After drying, the polymer can be removed in the form of a film with thickness dependent upon the amount of material used. The film can be freely handled and very advantageously used for obtaining infrared spectra. Such a film has a tensile strength of 9,600 lb/in² as compared to a tensile strength of 16,000 lb/in² obtained from the same polymer when cast from methanesulfonic acid solution. The films are dark with an intense golden luster which gives the appearance of a metal foil. Other aromatic heterocyclic polymers were examined to compare film formation with molecular structure.

ACCESS NO: 69,040 AD 882 334L
REPORT NO: AFML-TR-71-19 March 1971
TITLE: PROCESSABLE HIGH TEMPERATURE LAMINATING RESINS
AUTHOR: R. W. Vaughan, et al.
CONTRACT NO: F33615-70-C-1392
CONTRACTOR: TRW Inc.
PROJECT MONITOR: T. Aponyi (AFML/LNC)
AFML TASK NO: 734003
ABSTRACT: TRW P13N Polyimide Resin was modified to provide autoclave moldability for boron monofilament and graphite fiber prepregs and to improve the thermo-oxidative stability of composites. It was shown that a modified P13N resin developed during this program provided autoclave molded boron and graphite reinforced composites which possessed mechanical properties equivalent to press molded P13N composites. Concept validity was determined for improving the thermo-oxidative stability of cured P13N resin by cross-linking promoter-additives. It was established that further developmental efforts are necessary to obtain composites using crosslinking promoter-additives in the resin and also to develop vacuum-bag materials systems for use at cure temperatures 500 F.

ACCESS NO: 200,104 AD 889 219L
REPORT NO: AFML-TR-71-23
TITLE: THE LUBRICATING BEHAVIOR OF A MODIFIED FLUOROSILICONE FLUID AT 275° F
AUTHOR: F. C. Brooks
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: F. C. Brooks (AFML/LNL)
AFML TASK NO: 734008
ABSTRACT: The lubricating behavior of a modified fluorosilicone hydraulic fluid candidate, designated MLO 70-79, was characterized in the mechanical environment of a hydraulic pump circuit under Type II aircraft hydraulic system conditions and in a high temperature packing cycling apparatus to 500° F with elastomeric seals. Two hydraulic pumps of quite different design were utilized in three fluid investigations. O-ring packing of NBR and two fluorocarbon compounds were employed in the packing cycling tests. A successful fluid evaluation of 560 hours at 275° F was completed with a New York Air Brake hydraulic pump. Fluid evaluations at 275° F with Vickers hydraulic pumps were prematurely terminated at 91.1 and 42.7 hours due to pump wear.

ACCESS NO: 65,065 AD 884 990
REPORT NO: AFML-TR-71-24 March 1971
Part I
TITLE: HIGH TEMPERATURE RESISTANT ELASTOMERS
OR COMPLIANT POLYMERS
AUTHOR: R. J. Jones, et al.
CONTRACT NO: F33615-69-C-1541
CONTRACTOR: TRW Incorporated
PROJECT MONITOR: T. L. Graham (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: This final technical report describes the exploratory development of polyimide elastomeric or compliant polymers suitable for use at elevated temperature as integral fuel tank sealants. The majority of the effort was devoted to the synthesis of linear polyimides based on bis(3,4-dicarboxyphenoxyphenyl) sulfone dianhydride (BSDA). During the course of the program, linear polymers prepared from BSDA, methylene dianiline (MDA), and an intermediate molecular weight polyaliphatic ether diamine (PED) were found to possess the most promising combination of thermo-oxidative stability, elongation to break, fuel stability, and titanium alloy compatibility and adhesion.

ACCESS NO: 200,198 AD 890 107L
REPORT NO: AFML-TR-71-25 November 1971
TITLE: THERMALLY STABLE ETHYLENE-PROPYLENE
ELASTOMERS
AUTHOR: K. Murray
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: K. Murray (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: New ethylene-propylene elastomer vulcanizates have been developed which have extended heat and oxidation stability over state-of-the-art compounds. Vulcanizate formulations and physical properties are presented. The stability of ethylene-propylenediene type vulcanizates was achieved by a dual stabilization process. Initially, a high crystalline resistant chloroprene polymer and magnesium and zinc oxides were used collectively. This was supplemented by a 4,4'thiobis (2,6-di-tert-butylphenol) antioxidant aided by dilaurylthiodipropionate. The increased thermal and oxidation resistance is characterized by better than 60% retention of tensile strength and elongation after 48 hours exposure at 400°F. This represents nearly a threefold improvement over previous state-of-the-art compounds.

ACCESS NO: 69,397 AD 725 754
REPORT NO: AFML-TR-71-42 March 1971
TITLE: Part I
DEGRADATION MECHANISMS OF PIGMENTED
COATINGS

AUTHOR: W. B. Campbell, et al.
CONTRACT NO: F33615-70-C-1197
CONTRACTOR: Ohio State University
PROJECT MONITOR: C. P. Boebel (AFML/LNE)
AFML TASK NO: 734202

ABSTRACT: Polydimethylsiloxane formulated with various concentrations of rutile titanium dioxide pigment was evaluated as polymeric thermal control coatings. Oxygen permeability, diffusion, and solubility in these coatings were measured for various temperatures. It was noted that diffusion and permeability coefficients decreased as pigment concentration increased. Morphological investigations comparing surface roughness and surface area to the ultraviolet stability of a zinc orthotitanite coating indicated that pigment surface area is directly related to the increase in solar absorptance.

ACCESS NO: 69,544 AD 890 269L
REPORT NO: AFML-TR-71-45 March 1971
TITLE: ULTRAFINE CONDUCTIVE FILAMENT DEVELOP-
MENT

AUTHOR: A. J. Patrick, Jr.
CONTRACT NO: F33615-69-C-1598
CONTRACTOR: Avco Corporation
PROJECT MONITOR: W. Gloor (AFML/LNF)
AFML TASK NO: 732001

ABSTRACT: This final report describes development of ultrafine conductive fibers including metal cored glass, metallized glass and rayon, and homogeneous metallic filaments. The metal cored glass achieved fibers as small as 0.7μ but failed to achieve the 0.25μ goal. The metallized glass and rayon development achieved good metal coating of the proper dimension, but the failure to produce the necessary 0.5μ rayon limited this approach. The investigation of the metallic filaments in metal matrix led to the development of 0.5μ niobium which met the goals of the program from a diameter, conductivity standpoint. Testing of the 0.5μ niobium filaments has established the performance of the filaments.

ACCESS NO: 69, 785 AD 731 757
REPORT NO: AFML-TR-71-46 June 1971
TITLE: THE DOWNSTREAM EFFECTS OF TRANSPIRATION
COOLING ON THE HEAT SHIELD OF A SLENDER
NOSE CONE

AUTHOR: Capt. J. A. Marshall, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Capt. J. A. Marshall (AFML/LNC)
AFML TASK NO: 734001

ABSTRACT: An experimental investigation was performed to determine the effects of steady state upstream transpiration cooling on the surface temperature of a carbon phenolic downstream heat shield of an eight-degree half-angle cone. The test model was exposed to gas stream stagnation temperatures of 5950^oR to 8460^oR, enthalpies up to 4340 Btu/lb, and to velocities up to Mach 10. It was demonstrated that a helium coolant flow rate of about 3.6×10^{-4} lb/sec was sufficient to prevent model decomposition (charring) or ablation over a 100 second period. The heat losses from the temperature sensing devices (calorimeters) were estimated to be of the order of six to seven percent.

ACCESS NO: 69, 398 AD 885 419L
REPORT NO: AFML-TR-71-59 June 1971
TITLE: Part I
ELASTOMERS FOR LIQUID ROCKET PROPELLANT
CONTAINMENT

AUTHOR: J. W. Martin, et al.
CONTRACT NO: F33615-69-C-1521
CONTRACTOR: TRW Incorporated
PROJECT MONITOR: J. K. Sieron (AFML/LNE)
AFML TASK NO: 734005

ABSTRACT: New elastomeric materials intended for use as positive expulsion bladders for nitrogen tetroxide (N2O4) oxidizer and hydrazine (N2H4) propellants were developed. For nitrogen tetroxide, an improved carboxynitroso rubber (CNR) compound featuring a novel resin (HYSTL) curing system was developed. The new CNR vulcanizate has mechanical properties which compare favorably to previous CNR compounds and, most significantly, has a thousand-fold decrease in the N2O4 permeability rate. For hydrazine service, an easily processed ethylene propylene terpolymer (EPT) bladder composition having improved mechanical properties, lower permeability, and improved propellant compatibility (less hydrazine decomposition) over state-of-the-art expulsion bladder materials was developed.

ACCESS NO: 69, 221 **AD 884 765L**
REPORT NO: AFML-TR-71-60 **March 1971**
TITLE: Part I
**THERMAL DEGRADATION OF POLYMERS USING
MASS SPECTROSCOPY-THERMOGRAVIMETRIC
ANALYSIS TECHNIQUES**
AUTHOR: A. G. Jackson
CONTRACT NO: F33615-70-C-1489
CONTRACTOR: Systems Research Laboratories, Inc.
PROJECT MONITOR: Dr. I. J. Goldfarb (AFML/LNP)
AFML TASK NO: 734203

ABSTRACT: Modification of an existing microbalance TGA apparatus was made by extensively modifying the vacuum system by adding a quadrupole mass spectrometer in a configuration which allows simultaneous operation of the microbalance and the mass spectrometer. Spectra for various common gases which compare well with standard spectra were obtained after extensive optimizing tests of the mass spectrometer. Gage sensitivities, of use in analysis of complex mass spectra, were not obtained, although the experimental efforts were appropriate. The gage filament burned out, negating the results. Two samples of BBB polymer were degraded, and the data were analyzed to determine the behavior of individual mass peaks as a function of temperature.

ACCESS NO: 67, 446 **AD 883 623L**
REPORT NO: AFML-TR-71-61 **April 1971**
TITLE: Part I
**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/LNL)
AFML TASK NO: 734302

ABSTRACT: Work in six specific areas is being conducted: (1) accelerated test correlation, (2) hot-pressed solid lubricant compacts, (3) effect of additives on solid lubricant film performance, (4) application of the AFSL-28 solid lubricant film, (5) lubricant evaluation, and (6) new applications. The AFSL-28 film has been applied to several different types of test pieces for evaluation outside of MRI. Procedures used to coat these test pieces are also described. Results of tests on spherical bearings containing hot-pressed solid lubricant compact inserts show that these compacts can be successfully used in this type of application. Friction and wear property data were collected for five hot-pressed solid lubricant compacts to 1000 F to show that some have potential for use over this temperature range.

ACCESS NO: 65,315 **AD 884 244L**
REPORT NO: AFML-TR-71-62 **May 1971**
TITLE: Part I
**POLYMERIC MATERIALS FOR USE AS BINDERS
AND TRANSPARENT FILMS**
AUTHOR: R. I. Akawie
CONTRACT NO: F33615-69-C-1287
CONTRACTOR: Hughes Aircraft Company
PROJECT MONITOR: Dr. W. L. Lehn (AFML/LNE), et al.
AFML TASK NO: 734007
ABSTRACT: The purpose of this program was to develop two types of film forming materials for use as binders in pigmented coatings. One effort was directed toward the development of polymeric materials that have maximum transparency in the ultraviolet and visible portions of the spectrum and are stable to ultraviolet and particulate radiation. The other effort was directed toward the development of polymeric materials that have high transparency from the visible wavelengths out to approximately six microns and are stable up to 316°C.

ACCESS NO: 69,566 **AD 728 654**
REPORT NO: AFML-TR-71-104 **May 1971**
TITLE: **AN INVESTIGATION OF VERY-HIGH-SPEED-
DROP-IMPINGMENT EROSION OF 1100
ALUMINUM**
AUTHOR: O. G. Engel
CONTRACT NO: F33615-69-C-1385
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: G. F. Schmitt (AFML/LNE)
AFML TASK NO: 734007
ABSTRACT: An investigation of five available specimens of 1100-0 aluminum, which were tested under waterdrop impingement at velocities from Mach 1.5 to Mach 4, was undertaken to determine the mechanism of the erosion of aluminum at very high velocities. The results of inspection of the eroded specimens with use of a light microscope and scanning electron microscope revealed that plastic flow of the aluminum increased as the test velocity increased. Cross-sectional cuts of the specimens revealed a small amount of work-hardening at velocities of Mach 2.5 and above, but no evidence of crack formation was found. These findings are compatible if the heat generated by the amount of plastic flow of aluminum that occurs is large enough to anneal the worked metal. If this is the case, aluminum is a permanently plastic material.

ACCESS NO: 69,562 **AD 886 625L**
REPORT NO: AFML-TR-71-114 **April 1971**
TITLE: Part I
SYNTHESIS OF PERFLUOROALIPHATIC ETHER MONOMERS
AUTHOR: T. Psarras, et al.
CONTRACT NO: F33615-70-C-1403
CONTRACTOR: PCR Incorporated
PROJECT MONITOR: Dr. C. Tamborski (AFML/LNP)
AFML TASK NO: 734201
ABSTRACT: Trifluoromethyl trifluorovinyl ether and penta-fluorobenzoyl fluoride have been prepared and samples submitted to Air Force Materials Laboratory. Perfluoropolyether diacid fluorides have been synthesized but attempts to separate the isomers by distillation were not successful. A new synthetic route to pure unsymmetric DEDA has been demonstrated. The reaction of cesium alkoxides with fluoroolefins and iodine has been investigated. Preliminary results indicate that this reaction may be a valuable method for the preparation of difunctional monomers. Several unsuccessful attempts were made to prepare perfluorostyrene oxide by oxidation of perfluorostyrene and by difluorocarbene addition to penta-fluorobenzoyl fluoride.

ACCESS NO: 69,538 **AD 728 273**
REPORT NO: AFML-TR-71-122 **June 1971**
TITLE: **THE STRESS FIELD IN A CYLINDRICALLY ANISOTROPIC BODY UNDER TWO-DIMENSIONAL SURFACE TRACTIONS**
AUTHOR: Dr. N. J. Pagano, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. N. J. Pagano (AFML/LNC)
AFML TASK NO: 734202
ABSTRACT: In this work, a general solution for the elastic stress field in a cylindrically anisotropic body, the hollow circular cylinder, under surface tractions which do not vary along the generator and which can be expressed in the form of a Fourier series, is presented. The form of the solution is sufficiently general to permit direct extension to an important class of composite structures, namely, laminated circular cylinders. Some of the peculiar effects of anisotropy are illustrated by the solution of a specific boundary value problem - a circular hole in a large plate under tension.

ACCESS NO: 69,607 AD 728 661
REPORT NO: AFML-TR-71-123 July 1971
TITLE: WEAR RATE RELATIONSHIPS FOR THREE
LUBRICANT COMPACT MATERIALS

AUTHOR: K. R. Mecklenburg
CONTRACT NO: F33615-69-C-1236
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: F. C. Brooks (AFML/LNL)
AFML TASK NO: 734008, 734301

ABSTRACT: This report is concerned with the wear rates of three lubricant compact materials, selected as representative of a new class of engineering compounds. The compacts were subjected to various combinations of loads and sliding velocities from 200 to 1,600 psi and from 1.50 to 9.60 ft/sec. Weight loss data as a function of time are presented, showing that wear rate does not change significantly with time. Repeatability, effects of operational eccentricity, and temperature are also discussed. A statistical interpretation of the data is presented, including the concept of bands of wear rate values instead of simple arithmetic averages. Using the statistically acceptable spread of wear rate values, equations relating wear rate, load, and sliding velocity were formulated.

ACCESS NO: 69,638 AD 731 759
REPORT NO: AFML-TR-71-124 June 1971
TITLE: TESTING AND CHARACTERIZATION OF
COMPOSITE MATERIALS

AUTHOR: Dr. J. M. Whitney
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Dr. J. M. Whitney (AFML/LNC)
AFML TASK NO: 734003

ABSTRACT: Desirability of various test techniques for fiber reinforced composite materials is discussed from a stress analysis standpoint. Methods considered include tension tests, flexure tests, short beam shear, solid torsion rod, rail shear, and tubular specimens. Results show a tubular specimen provides the most unified procedure for complete characterization of a composite material. Tensile tests on orthotropic symmetric laminates are also shown to be useful. Flexure tests, while not desirable for precise characterization, seem useful for quality control purposes on 0 degree or 90 degree unidirectional specimens and bidirectional laminates.

ACCESS NO: 69,788 AD 735 278
REPORT NO: AFML-TR-71-132 June 1971
TITLE: KINETICS OF DEGRADATION OF SOME POLY-
STYRENES AND COPOLYMERS OF STYRENE
AND ACRYLONITRILE
AUTHOR: D. R. Bain
CONTRACT NO: F33615-69-C-1385
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: Dr. I. J. Goldfarb (AFML/LNP)
AFML TASK NO: 734004
ABSTRACT: The kinetics of degradation of some polystyrenes
and a series of copolymers of styrene and up to .33.4% acrylonitrile were
studied by dynamic thermogravimetry in vacuum. An average activation
energy of 42.5 k. cal was found for the entire series independent of com-
position. The primary effect of the acrylonitrile units is to increase the
rate of chain scission and this effect is masked by the overall rapid initial
rate of chain scission as the sample temperature is increased. Minor
experimental abnormalities were responsible for some variation in the Ea
values but this was never more than ± 2.5 k. cal.

ACCESS NO: 68,039 AD 889 869L
REPORT NO: AFML-TR-71-201 December 1971
TITLE: Part I
EXPLORATORY DEVELOPMENT OF NEW AND
IMPROVED SELF-SEALING SYSTEMS FOR
AIRCRAFT INTEGRAL FUEL TANKS
AUTHOR: R. M. Heitz, et al.
CONTRACT NO: F33615-70-C-1426
CONTRACTOR: Northrop Corporation
PROJECT MONITOR: T. L. Graham (AFML/LNE)
AFML TASK NO: 734005
ABSTRACT: The principal purpose of this research program
was to develop self-sealing materials systems for the protection of aircraft
integral fuel tanks against catastrophic destruction by small-arms ground
gunfire. Some effort was also devoted to investigating hydraulic ram
phenomena and factors affecting the functioning of .50- caliber API pro-
jectiles. Successful self-sealing materials systems developed for protecting
integral fuel tanks were composites of flexible laminates and compressed
elastomeric foam. Results of gunfire tests showed this type of self-sealing
materials system to be effective against 20mm AP projectiles as well as
.50-caliber (AP and API) projectiles.

ACCESS NO: 200,274 AD 890 330L
REPORT NO: AFML-TR-71-208 November 1971
TITLE: DEVELOPMENT OF HIGH TEMPERATURE
FUNCTIONAL FLUIDS
AUTHOR: R. Anderson
CONTRACT NO: F33615-70-C-1325
CONTRACTOR: PCR, Incorporated
PROJECT MONITOR: C. E. Snyder (AFML/LNL)
AFML TASK NO: 734008

ABSTRACT: A series of 1, 3, 5-mono and dumbbell triazines with perfluoroether side chains derived from oligomers of hexafluoropropylene oxide was prepared and their physical properties (viscosity, ASTM slope, pour point) were determined. Improved methods for the preparation of some intermediates and for the cyclodehydration of imidoamidines were developed. Correlations between structure and physical properties of the triazines were established. The effect of molecular weight, end groups, asymmetry, length of side chain and structure of connecting group on the physical properties of the triazines is discussed. None of the prepared triazines meets all target properties required for a hydraulic fluid. In general, an inverse relationship exists between ASTM slope and pour point. A satisfactory ASTM slope can be obtained only at the expense of low pour point and vice-versa.

MATERIALS PHYSICS DIVISION (AFML/LP)

ACCESS NO: 41,367 AD 852 010
 REPORT NO: AFML-TR-68-370 December 1968
 TITLE: RESEARCH ON MATERIALS ESSENTIAL TO
 CRYOCOOLER TECHNOLOGY: THERMOPHYSICAL
 AND TRANSPORT PROPERTIES OF ARGON, NEON,
 NITROGEN, AND HELIUM-4

AUTHOR: R. M. Gibbons
 CONTRACT NO: AF33615-2191
 CONTRACTOR: Air Products and Chemicals, Inc.
 PROJECT MONITOR: H. Marcus (AFML/LPT)
 AFML TASK NO: 147003

ABSTRACT: Internally consistent PVT, enthalpy, internal energy, and entropy values for Ar, Ne, N₂ and He4 were obtained from equations of state taken from the literature. The constants for the Ne equation were redetermined on the basis of PVT measurements for temperatures from 30°K to 70°K and pressures up to 200 atm. Correlations were obtained which were used in conjunction with the equation of state to obtain thermal conductivity and viscosity coefficients for the above substances. The thermal conductivities of Ne from 52°K to 92°K and He4 from 4.2°K to 20°K were measured at pressures up to 200 atm to substantiate the correlation. Results of thermal conductivity measurements of He3 from 3.2°K to 20°K are also presented. A method was developed to predict the solid-vapor equilibria for probable contaminants in Ar, Ne, N₂, and He4.

ACCESS NO: 68,923 AD 881 719
 REPORT NO: AFML-TR-70-66 February 1971
 TITLE: THE CONDENSATION COEFFICIENTS OF C₂
 AND C₃

AUTHOR: D. Ramakrishnan, et al.
 CONTRACT NO: F33615-69-C-1531
 CONTRACTOR: University of Cincinnati
 PROJECT MONITOR: P. W. Dimiduk (AFML/LPT)
 AFML TASK NO: 736001

ABSTRACT: The condensation coefficients of C₂ and C₃, the high temperature vapor species of carbon, were determined by using the isotopic exchange technique and a Time-of-Flight mass spectrometer. Two powder compacts of C¹²(s) and C¹³(s) were heated to 2663°K in a tungsten Knudsen cell. Initially vaporization of C¹²(s) and C¹³(s) solids will produce C¹²(g), C¹³(g), C₂¹²(g), C₂¹³(g), C₃¹²(g), and C₃¹³(g). Exchange reactions involving C₂¹³(g) and C₃¹³(g) with C¹²(s) on one hand and C₂¹³(g) and C₃¹³(g) with C¹²(s) on the other will generate isotopically mixed molecules C¹²C¹³(g), C₂¹²C¹³(g) and C¹²C₂¹³(g) in the vapor phase. The exchange reactions were studied by analyzing the vapor effusing from the Knudsen cell by a Time-of-Flight mass spectrometer.

ACCESS NO: 66,795 AD 881 236
REPORT NO: AFML-TR-70-192 February 1971
TITLE: MASS-SPECTROMETRIC STUDIES OF GRAPHITE
VAPORIZATION AT HIGH TEMPERATURES

AUTHOR: T. A. Milne, et al.
CONTRACT NO: F33615-68-C-1709
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: P. W. Dimiduk (AFML/LPT)
AFML TASK NO: 736001

ABSTRACT: The progress in a second year of study of the thermodynamics of carbon vapor is reviewed. The status and preliminary performance of a high capacity, three-stage, high pressure sampling system - Nuclide HT-12-90 mass spectrometer detector and data acquisition system (including time-of-flight velocity analysis of beam neutrals) is presented. Beam system calibrations with Ar, N₂ and Ag indicate partial pressures of about 1×10^{-10} to 1×10^{-8} atm. (depending on background) can be detected from a Knudsen cell with a 0.040 dia. orifice placed 56 cm. from the ion source. A troublesome feature of the present ion source is that some modulation of background peaks occurs in the presence of modulated beams. A series of attempts to heat graphite in vacuum to temperatures greater than 3000 K are described.

ACCESS NO: 68,858 AD 720 261
REPORT NO: AFML-TR-70-253 December 1970
TITLE: ELECTRON MICROBEAM PROBE CHARACTERIZATION OF Al-Cu ALLOYS WITH Al AND Cu SOFT X-RAY SPECTRA

AUTHOR: J. S. Solomon, et al.
CONTRACT NO: F33615-69-C-1330
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: H. Marcus (AFML/LPT)
AFML TASK NO: 736005

ABSTRACT: Al-Cu alloys were characterized with an electron microbeam probe X-ray analyzer by examining the effects of alloying on AlK β and CuL α X-ray emission spectra, and relating these effects to alloy composition. These effects include changes in spectra shapes, changes in intensity relationships, and band shifts. This method can be used to complement or substitute for the usual electron microbeam probe quantitative analysis. Speed and accuracy in measuring spectral changes are accomplished by using an automatic data acquisition and handling system that provides computer plotted spectra as well as a tabulated data printout. Two model Al-Cu systems were studied -- a diffusion couple and hypervelocity impact specimens.

ACCESS NO: 68, 951 AD 721 468
REPORT NO: AFML-TR-70-254 February 1971
TITLE: NUMERICAL CALCULATIONS OF HYPERVELOCITY
IMPACT CRATER FORMATION IN HARD AND
SOFT ALUMINUM ALLOYS

AUTHOR: M. Rosenblatt
CONTRACT NO: F33615-68-C-1138
CONTRACTOR: Shock Hydrodynamics Incorporated
PROJECT MONITOR: G. Griffith (AFML/LPH)
AFML TASK NO: 736001

ABSTRACT: The wave propagation and crater growth characteristics in hypervelocity impact events on 1100-0 and 7075-T6 aluminum alloys are analyzed using a two-dimensional Eulerian numerical code called STEEP. The material model used in the calculations includes work hardening and thermal softening effects. Impacts of .635 cm aluminum spheres into semi-infinite targets at 7 km/sec and 4 km/sec are treated. Analytical predictions which can be compared directly with experimental results include crater growth characteristics and peak stress wave propagation and decay characteristics. Also included in this report are velocity field plots and principal stress field plots at selected times. The velocity magnitude, pressure, and normal stress are also plotted versus time at selected target locations.

ACCESS NO: 68, 740 AD 880 156
REPORT NO: AFML-TR-70-284 December 1970
TITLE: INVESTIGATION OF THE MAGNETIC STRUCTURE
OF YCo5 AND NdCo5 USING NEUTRON DIFFRACTION

AUTHOR: D. J. Kaiser
CONTRACT NO: F33615-69-C-1328
CONTRACTOR: Systems Research Laboratories, Inc.
PROJECT MONITOR: H. Garrett (AFML/LPE)
AFML TASK NO: 736703

ABSTRACT: The use of neutron diffraction to determine the magnetic structure of powder samples YCo5 and NdCo5 is described. Experimental results are presented and compared to a theoretical model. The system used to control the sample temperature is described with its performance characteristics. Results show that there is no detectable magnetic moment attributed to the yttrium atoms in the YCo5 compound. Investigation of the NdCo5 sample shows that the magnetization vector rotates from the c-axis towards the a-axis as the temperature is lowered from room temperature to 108 K.

ACCESS NO: 69,127 AD 883 166
REPORT NO: AFML-TR-70-289 March 1971
TITLE: ELECTRON IMPACT IONIZATION CROSS SECTIONS
AUTHOR: K. L. Wang, et al.
CONTRACT NO: F33615-68-C-1020
CONTRACTOR: Massachusetts Institute of Technology
PROJECT MONITOR: P. W. Dimiduk (AFML/LPT)
AFML TASK NO: 736704
ABSTRACT: Absolute ionization cross sections for carbon vapor were measured using a chopped molecular beam and a quadrupole mass spectrometer. Fragmentation of polymer species in the carbon vapor was studied using a time-of-flight technique in the frequency domain. Phase differences were referred to the highest significant polymer in which fragment ions are negligible. The experiments showed that fragmentation is responsible for less than 10% of the total ion current. Cross sections were deduced by subtracting the fragment ions. Absolute values were calibrated at an electron energy of 500 eV using the total ion current, the neutral beam intensity, and ion ratios in conjunction with the additivity rule.

ACCESS NO: 69,154 AD 723 635
REPORT NO: AFML-TR-70-290 February 1971
TITLE: COMPUTER PLOTTED SOFT X-RAY SPECTRA TO FACILITATE CHEMICAL COMBINATION STUDIES WITH THE ELECTRON MICROBEAM PROBE
AUTHOR: J. S. Solomon, et al.
CONTRACT NO: F33615-69-C-1330
CONTRACTOR: University of Dayton
PROJECT MONITOR: H. Marcus (AFML/LPT)
AFML TASK NO: 736005
ABSTRACT: Changes in fine features of soft x-ray emission spectra due to chemical combination are difficult to measure and compare from the usual ratemeter - analog recording of soft x-ray emission spectra. This method is very tedious, resulting in possible measurement errors and misinterpretation of actual band shapes and changes, especially when x-ray intensities are low. To apply the chemical combination effect techniques to practical analytical use, such as electron microbeam probe analysis, a faster and highly reliable and reproducible method to obtain and analyze the soft x-ray spectra must be employed. With the development in recent years of the Nuclear Instrumentation Modular (NIM) type equipment with digital data output on computer compatible paper tape, chemical combination effect techniques can be applied to rapid, practical, and reproducible analytical use.

ACCESS NO: 68,741 AD 718 461
REPORT NO: AFML-TR-70-295 December 1970
TITLE: HYPERVELOCITY IMPACT - MATERIAL STRENGTH
EFFECTS ON CRATER FORMATION AND SHOCK
PROPAGATION IN THREE ALUMINUM ALLOYS
AUTHOR: R. F. Prater, et al.

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: H. M. Rosenberg (AFML/LPH)
AFML TASK NO: 736006

ABSTRACT: The effects of material strength upon the transient response of the thick aluminum targets to hypervelocity impact has been studied experimentally. Most experiments involved the normal impact of 2017 aluminum spheres at a velocity of about 7 km/sec. Material strength was varied by employing targets of 1100, 6061, and 7075 aluminum alloys. Flash x-ray techniques were used to measure accurately the rate at which the crater grew during the impact process. Definite material strength effects were detected, even between different heat treatments of the same alloy (7075-T0 and 7075-T6). Crater growth rates were also measured for 1100 aluminum in four separate ranges of projectile velocity from 2.3 km/sec to 7.0 km/sec.

ACCESS NO: 69,063 AD 722 487
REPORT NO: AFML-TR-71-14 March 1971
TITLE: EXPLORATORY DEVELOPMENT AND ANALYTICAL
SUPPORT OF EXPERIMENTAL MATERIALS

AUTHOR: W. C. Rateley
CONTRACT NO: F33615-70-C-1382
CONTRACTOR: Carnegie-Mellon University
PROJECT MONITOR: F. F. Bentley (AFML/LPA)
AFML TASK NO: 736005

ABSTRACT: The achievements from this research program were threefold: a) increase the analytical capabilities of the Air Force Materials Laboratory; b) develop new analytical techniques and transfer this technology to the Materials Laboratory; and c) perform nonroutine analytical research with the special capabilities and instrumentation present at Mellon Institute of Carnegie-Mellon University. Analytical capabilities of the Materials Laboratory benefitted from the spectral correlation found in the far infrared region and from Raman scattering frequencies of aromatic compounds. The use of group frequency techniques now allow the detection of aromatic compounds, determination of substitution on the benzene ring and in several cases acknowledge of the substituent group.

ACCESS NO: 69,153 AD 723 288
REPORT NO: AFML-TR-71-16 March 1971
TITLE: MOLECULAR STRUCTURE AND MATERIALS
CHARACTERIZATION
AUTHOR: W. R. Fearheller, Jr.
CONTRACT NO: F33615-70-C-1239
CONTRACTOR: Monsanto Research Corporation
PROJECT MONITOR: F. F. Bentley (AFML/LPA)
AFML TASK NO: 736005

ABSTRACT: This report summarizes the analytical services supplied on Air Force originated problems in support of their in-house programs and research programs in vibrational spectroscopy and atomic absorption spectroscopy. In the area of vibration spectroscopy, the infrared spectral study of amino acids was completed, a new program on methyl ester began, designs of far infrared liquid cells were investigated, a device to modify the chart presentation of the far infrared instrument constructed, and the second year of a three-year program on the spectra of halogen-containing materials was continued (under subcontract). Atomic absorption burner and nebulization designs were investigated to yield a system with increased sensitivity over that currently available (under subcontract).

ACCESS NO: 69,201 AD 724 147
REPORT NO: AFML-TR-71-26 March 1971
TITLE: BACK REFLECTION CAMERA ON A BUDGET
AUTHOR: M. A. Goldschmidt, et al.
CONTRACT NO: F33615-69-C-1330 and F33615-69-C-1151
CONTRACTOR: University of Dayton
PROJECT MONITOR: H. Marcus (AFML/LPT), et al.
AFML TASK NO: 736001, 736005, 735103

ABSTRACT: A simple and inexpensive true focusing back reflection camera is described. The components are described in detail and specifications are provided. Results on a tungsten standard are illustrated showing the conventional mode opposed to the modified true focusing mode. Problem areas are discussed briefly with emphasis on single-coated film and good optics.

ACCESS NO: 69,203 AD 723 295
REPORT NO: AFML-TR-71-30 December 1971
TITLE: MATERIALS PROCESSING OF RARE EARTH
COBALT (RECo5) PERMANENT MAGNETS
AUTHOR: P. J. Jorgensen
CONTRACT NO: F33615-70-C-1624
CONTRACTOR: Stanford Research Institute
PROJECT MONITOR: H. J. Garrett (AFML/LPE)
PROJECT NO: ARPA No. 1617
ABSTRACT: Rare earth-cobalt intermetallic compounds show promise for permanent magnets with a higher energy product, BH max, than are currently available. Because fine particles are required for magnetic alignment and sintering, and since the coercivities of these fine particles are sensitive to overgrinding and particle surface preparation, plasma spheroidization and electrodeposition are being investigated as alternative methods for producing strain-free particles. Apparatus for arc jet plasma spheroidization of particles in argon free of oxygen was constructed and solid spherical particles of SmCo5 and MMCo5 in a size range below 10 m were produced. Preferential vaporization of samarium causes a reduction in the samarium content of the spherical particles compared with the feed material and causes the formation of a samarium rich fume.

ACCESS NO: 69,200 AD 722 772
REPORT NO: AFML-TR-71-31 April 1971
TITLE: TECHNOLOGY DEVELOPMENT FOR TRANSITION
METAL-RARE EARTH HIGH-PERFORMANCE
MAGNETIC MATERIALS
AUTHOR: J. J. Becker
CONTRACT NO: F33615-70-C-1626
CONTRACTOR: General Electric Company
PROJECT MONITOR: J. C. Olson (AFML/LPE)
PROJECT NO: ARPA No. 1617
ABSTRACT: Magnetization reversal discontinuities were studied in samples consisting of a few particles or a single particle. Experiments with successive polishing treatments indicate that individual defects are responsible for the observed magnetization behavior. A particle of Co5Y showed a perfectly rectangular hysteresis loop and a maximum energy product of 27.6 mGOe. It has been found possible to analyze complex single-particle loops into linear combinations of elementary loops, as though the particles consisted of independent sub-particles. Metallographic studies of as-cast and annealed alloys of various compositions indicated that annealing has little effect on the observed phase distribution. Polarized light studies of finished magnets showed a greater tendency toward multidomain structures in magnets with lesser properties.

ACCESS NO: 69, 331 AD 726 104
REPORT NO: AFML-TR-71-35 April 1971
TITLE: A STATISTICAL APPROACH IN PREDICTING THE ISOTOPIC CLUSTER OF COMPLEX SPECIES BY MASS SPECTROMETRY

AUTHOR: A. K. Bhattacharya
CONTRACT NO: F33615-70-C-1021
CONTRACTOR: Miami University
PROJECT MONITOR: F. F. Bentley (AFML/LPA)
AFML TASK NO: 736005

ABSTRACT: The isotopic cluster to be expected for the molecular ion of decachlororuthenocene has been evaluated through a statistical approach. Ruthenium has seven naturally occurring isotopes of mass 96, 98, 99, 100, 101, 102 and 104 having a natural abundance of 5.51%, 1.87%, 12.72%, 12.62%, 17.07%, 31.61%, and 18.58%, respectively. Chlorine has two isotopes of mass 35 and 37 with a natural abundance of 75.4% and 34.6%, while the two isotopes of carbon of mass 12 and 13 have a natural abundance of 98.89% and 1.11%, respectively. The complete details of calculations have been incorporated. A graph has been finally drawn after normalizing the above data. The applicability of this method has been discussed.

ACCESS NO: 69, 396 AD 726 105
REPORT NO: AFML-TR-71-36 May 1971
TITLE: DETERMINATION OF CERTAIN PROPERTIES AND CHARACTERISTICS OF RARE EARTH METALS, LASER CRYSTALS, SEMICONDUCTORS, AND DIELECTRIC MATERIALS

AUTHOR: A. E. Ray, et al.
CONTRACT NO: F33615-69-C-1172
CONTRACTOR: University of Dayton Research Institute
PROJECT MONITOR: Dr. V. L. Donlan (AFML/LPE)
AFML TASK NO: 737101, 737102, 737103

ABSTRACT: Intermetallic phases of cobalt with several rare earth metals can be used to produce permanent magnets. Energy products up to 36 MGOe, more than three times the value for the best commercially available magnets, are theoretically possible. SmCo₅ and PrCo₅ magnets with more than 20 MGOe have been made, and a record value of 23 MGOe has been attained with a mixture of these in the laboratory by powder metallurgy processes. Alloying additions of copper and iron to some of the alloys has also made it possible to obtain good permanent magnet properties in cast samples. These new permanent magnets are especially well suited for microwave tubes and other electronic applications, as well as for motors and generators.

ACCESS NO: 69,039 AD 721 239
REPORT NO: AFML-TR-71-39 March 1971
TITLE: TRIPLET TO TRIPLET ABSORPTION IN ORGANIC
MOLECULES FOR USE IN PHOTOCHROMIC
DEVICES

AUTHOR: J. L. Kropp, et al.
CONTRACT NO: F33615-69-C-1052
CONTRACTOR: TRW Incorporated
PROJECT MONITOR: Dr. H. M. Rosenberg (AFML/LPH)
PROJECT NO: 7360

ABSTRACT: The photochromic behavior of hetero-aromatic molecules has been studied. Particular attention has been given to the transient absorption in the polymer host poly(methyl methacrylate). Compounds studied include 1,2,5,6 dibenzacridine, dibenzo(c,g)carbazole, 6 aminochrysene, and naphthoflavone. The latter two compounds show little triplet-triplet absorption, however the former two compounds do show good absorption. The effect of varying concentration upon T-T absorption was studied and high concentrations (10-2M) seem to show lower intensities of triplet absorption than do some less concentrated samples. The degradation of the samples under exposure to sunlight and an Hg lamp are studied.

ACCESS NO: 69,038 AD 722 060
REPORT NO: AFML-TR-71-53 March 1971
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: Capt. M. V. Turner (AFML/LPE)
PROJECT NO: 7371

ABSTRACT: Intermetallic phases with the formulas R_2Co_{17} , R_2Fe_{17} , and $R_2(Co_{1-x}Fe_x)_{17}$ are of potential interest as permanent magnets. Procedures for the preparation of these intermetallic phases are described. Descriptions are given of the design and operation of differential thermal analysis equipment and of a high temperature-high vacuum furnace for the metallurgical and magnetic evaluation of rare earth-transition metal intermetallic phases.

ACCESS NO: 69,332 **AD 884 597**
REPORT NO: AFML-TR-71-66 **April 1971**
TITLE: DIELECTRIC SPECTROSCOPY OF HIGH-TEMPERATURE MATERIALS
AUTHOR: W. B. Westphal, et al.
CONTRACT NO: F33615-70-C-1220
CONTRACTOR: Massachusetts Institute of Technology
PROJECT MONITOR: W. G. D. Frederick (AFML/LPE)
AFML TASK NO: 737101
ABSTRACT: Measuring techniques for extending dielectric-constant and loss measurements to liquid-nitrogen temperature at 10 MHz, to 2000°C at 100 MHz, and to 1600°C at 90 GHz are discussed. High-temperature measurements on spinel and sapphire are included in the dielectric data accumulated during this contract. Programs in Fortran IV are given for the general standing-wave method calculations and for covered high-loss samples one-quarter wavelength from the end of hollow waveguide.

ACCESS NO: 69,796 **AD 721 758**
REPORT NO: AFML-TR-71-72 **July 1971**
TITLE: NEMATIC LIQUID CRYSTALS FOR AIR FORCE DISPLAYS
AUTHOR: Capt. M. A. Berwick, et al.
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: H. M. Rosenberg (AFML/LPH), et al.
AFML TASK NO: 736003
ABSTRACT: Possible applications for nematic liquid crystals in Air Force displays are examined. A number of homologous liquid crystal series were synthesized in an attempt to expand the nematic temperature range. Several systems which are nematic well below room temperature in a stable phase were found. The factors influencing dynamic scattering were examined with regard to modes of activation, response times, relaxation times, and opacity. Several feasibility devices demonstrating the use of nematic liquid crystals in displays were constructed.

ACCESS NO: 200,275
REPORT NO: AFML-TR-71-75 July 1971
Volume I
TITLE: PHOTOCONDUCTIVE BEHAVIOR OF LEAD
SULFIDE FILMS
AUTHOR: D. K. Smith, et al.
CONTRACT NO: F33615-69-C-1139
CONTRACTOR: Santa Barbara Research Center
PROJECT MONITOR: R. L. Hickmott (AFML/LPE)
AFML TASK NO: 737102

ABSTRACT: The structure, chemical composition, and photo-electronic properties of chemically deposited PbS films have been investigated in relationship to variation in the concentration of oxidant used in the deposition. Structure and photoelectronic properties of the PbS film change as the concentration of oxidant is varied. Concomitant variations in the average chemical composition of the films are minor. It was found that the dependence of carrier density and mobility on temperature is divided into low and high temperature regions with distinct activation energies. The principal effect of photoexcitation is to increase the carrier density. Films produced without the use of oxidants are relatively insensitive. The primary electronic properties of PbS films may be described in terms of sensitizing centers located 0.23 eV below the conduction band, and in terms of intergrain barriers which limit the effective mobility.

ACCESS NO: 68,440 AD 889 437L
REPORT NO: AFML-TR-71-77 May 1971
TITLE: STUDIES OF GRAPHITE VAPORIZATION USING
A MODULATED BEAM MASS SPECTROMETER
AUTHOR: W. C. Steele, et al.
CONTRACT NO: F33615-68-C-1134
CONTRACTOR: Avco Corporation
PROJECT MONITOR: P. Dimiduk (AFML/LPT)
AFML TASK NO: 736001

ABSTRACT: A set of experiments employing a mass spectrometer to study the kinetics and thermodynamics of graphite vaporization are described. Results obtained by the Knudsen effusion method are compared with results of free vaporization from polycrystalline graphite surfaces. Reflection of carbon vapor beams from graphite surfaces has been studied as a function of surface temperature for the three principle carbon vapor species, C_1 , C_2 , and C_3 . These results are explained and correlated with those of the vaporization studies. Flash vaporization of thin, vapor deposited carbon films is employed to examine the nature of these deposited films. The composition of the flashed vapor is seen to vary according to the nature of the solid substrate.

ACCESS NO: 69,793 AD 731 814
REPORT NO: AFML-TR-71-84 July 1971
TITLE: A FLUORINE-19 NMR STUDY OF SOME BROMO-
FLUOROTITANATE COMPLEXES AND HYDROLYSIS
OF SOME TITANIUM TETRAFLUORIDE COM-
PLEXES

AUTHOR: R. S. Borden
CONTRACT NO: F33615-70-C-1157
CONTRACTOR: Wittenberg University
PROJECT MONITOR: Dr. D. S. Dyer (AFML/LPA)
AFML TASK NO: 736702

ABSTRACT: Low temperature fluorine-19 nuclear magnetic resonance (nmr) spectroscopy has been used to examine a number of fluorotitanate complexes of the type TiF_xBr_{4-x} . 2THF (THF -tetrahydrofuran) and TiF_xBr_{4-x} . DME (DME -1,2-dimethoxyethane) where x is 1 to 4. Hydrolysis studies have also been carried out on the TiF_4 . 2THF complex in excess THF and on TiF_4 . 2EtOH in excess EtOH (EtOH - ethanol). Attempts were also made to study similar fluorotitanate complexes containing tetrahydrothiophene in place of bromide. These latter studies gave inclusive results due to excessively fast exchange rates in the case of tetrahydrothiophene and sample decomposition in the case of complexes containing iodide. The complexes examined were found to contain octahedrally coordinated titanium and in some cases more than one geometric form was observed.

ACCESS NO: 200,200
REPORT NO: AFML-TR-71-92 July 1971
TITLE: SOFT X-RAY BAND SPECTRA AND MOLECULAR
ORBITAL STRUCTURE OF Cr_2O_3 , CrO_3 , CrO_4^{-2} ,
AND $Cr_2O_7^{-2}$
D. W. Fischer

AUTHOR:
CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: D. W. Fischer (AFML/LPA)
AFML TASK NO: 736702

ABSTRACT: A new experimental technique is described whereby the soft x-ray CrL_{III} , CrK , and OK emission and absorption spectra are combined and used to construct empirically a complete molecular orbital diagram for simple chromium-oxygen compounds. All spectral components are assigned specific transitions associated with bonding, antibonding, and nonbonding molecular orbitals. In Cr_2O_3 the spectra indicate that the three outermost electrons have t_{2g} symmetry and are involved in two distinct bonding mechanisms. One of these electrons is localized in a metal-metal covalent bond and the other two are associated with the $Cr-O \pi$ bond.

ACCESS NO: 69,393 AD 726 109
REPORT NO: AFML-TR-71-96 May 1971
TITLE: PHOTOELECTRONIC PROPERTIES OF DEFECTS
IN CADMIUM SELENIDE SINGLE CRYSTALS
AUTHOR: Capt. A. L. Robinson

CONTRACT NO:
CONTRACTOR: INTERNAL
PROJECT MONITOR: Capt. A. L. Robinson (AFML/LPE)
AFML TASK NO: 737102

ABSTRACT: The properties of electronically active imperfections in single crystals of CdSe have been investigated by photoelectronic techniques. High-conductivity, n-type crystals grown from the melt have been transformed to low-conductivity, photosensitive crystals by annealing under excess Se pressures and by diffusing Cu or Ag acceptor impurities. The photoelectronic properties of these crystals have been analyzed through measurements of dark conductivity, Hall effect, photoconductivity, and optical absorption. It was observed that as-grown and Cd-annealed crystals showed very low photosensitivity, whereas crystals annealed in Se vapor or diffused with acceptor impurities all showed photosensitivity.

ACCESS NO: 69,520 AD 727 777
REPORT NO: AFML-TR-71-98 June 1971
TITLE: STUDIES IN CHEMICAL IONIZATION MASS
SPECTROSCOPY

AUTHOR: J. H. Futrell
CONTRACT NO: F33615-70-C-1182
CONTRACTOR: University of Utah
PROJECT MONITOR: W. R. Powell (AFML/LPA)
AFML TASK NO: 736702

ABSTRACT: This report is a continuation of research on high resolution chemical ionization mass spectroscopy. Chemical ionization studies of ketones using both methane and hydrogen reagent gases have been carried out. Also survey experiments on amines and some preliminary kinetics studies concerning ion source characteristics and the question of chemical equilibrium in high pressure ion sources. These experiments have shown that chemical ionization mass spectroscopy is capable of yielding results of both a quantitative and qualitative nature; that one can obtain kinetic information on ion molecule reactions from these experiments and that the method is much more sensitive than we had suspected previously.

ACCESS NO: 90, 483 AD 887 024
REPORT NO: AFML-TR-71-101 June 1971
TITLE: RESEARCH ON MICROWAVE MEMORY
ACOUSTIC CRYSTALS
AUTHOR: D. W. Oliver, et al.
CONTRACT NO: F33615-69-C-1286
CONTRACTOR: General Electric Company
PROJECT MONITOR: R. L. Hickmott (AFML/LPE)
AFML TASK NO: 737103
ABSTRACT: The principal results of this report can be abstracted into the following four categories: first, sound attenuation measurements have been made as a function of temperature and frequency on specimens of spinel, MgAl₂O₄; sapphire, Al₂O₃; and garnet, Y₃Al₅O₁₂, which are shown at microwave frequencies and room temperature. The Czochralski spinel, which was available in large pieces, was shown to be inferior to flux grown spinel because of the presence of a high density of precipitated iridium platelets. Substantial variations in total attenuation were found in sapphire crystals grown by different techniques. The attenuation was found to be independent of variation in mosaic structure of the samples of sapphire. Attenuation in YAG was found to be relatively independent of sample source and not to be limited by crystal quality; second, the best acoustic material as projected from thermal measurements is YB66.

ACCESS NO: 69, 475 AD 727 070
REPORT NO: AFML-TR-71-126 June 1971
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 substrate crystal growth, chemical vapor deposition of magnetic garnet films, and film characterization. Detailed accounts are presented on substrate lattice parameters and techniques for characterizing magnetic bubble domain films.

ACCESS NO: 69,606 AD 729 211
REPORT NO: AFML-TR-71-138 August 1971
TITLE: RESEARCH ON PHOTOCHROMIC AND PHOTO-CHEMICAL REACTION MECHANISMS

AUTHOR: T. F. Page, Jr.
CONTRACT NO: F33615-69-C-1130
CONTRACTOR: Battelle Memorial Institute
PROJECT MONITOR: R. E. Rondeau (AFML/LPH)
AFML TASK NO: 736701

ABSTRACT: The direct observation by nuclear magnetic resonance (NMR) of a number of photochemical systems is reported. By NMR, the primary photochemical transformations in anils having a hydroxyl group ortho to the exocyclic $-CH=$ were confirmed. Experiments which required long scan times to time-average spectra were unsuccessful; probably because of the long irradiation times necessary. Fourier transform NMR would decrease the time of such experiments 100-fold. Spiroprans appear to form stable free radicals with long-term irradiation. Exact analysis of complex NMR spectra could yield new and important photochemical information. The exact analysis of the 7-spin ABB'CC'DX system of the 13 C-H satellites of benzene was carried out.

ACCESS NO: 69,795 AD 731 822
REPORT NO: AFML-TR-71-146 July 1971
TITLE: INFRARED SPECTROSCOPY OF IONIC SOLIDS

AUTHOR: W. B. White
CONTRACT NO: F33615-69-C-1105
CONTRACTOR: Pennsylvania State University
PROJECT MONITOR: N. T. McDevitt (AFML/LPA)
AFML TASK NO: 736702

ABSTRACT: The research was an investigation of the vibrational spectra of certain classes of crystal structure important to materials science and technology. Specifically the research was concerned with the characterization of chemical bonding and crystal structure and with the characterization of cation ordering. A methodology was developed for making a theoretical analysis of the vibrational spectra of arbitrarily complex crystals. The relation of the spectra to structure and bonding was studied in suites of compounds with the garnet, C-type rare earth, zircon, fergusonite, scheelite, and monazite structures. It was shown that splittings of certain vibrational bands can be correlated with structural distortion and the factor group splitting with the anisodesmicity (ionic versus covalent character) of the chemical bonds.

ACCESS NO: 69,900 AD 731 828
REPORT NO: AFML-TR-71-178 July 1971
TITLE: TECHNOLOGY DEVELOPMENT FOR TRANSITION
METAL-RARE EARTH HIGH-PERFORMANCE
MAGNETIC MATERIALS
AUTHOR: J. J. Becker
CONTRACT NO: F33615-70-C-1626
CONTRACTOR: General Electric Company
PROJECT MONITOR: J. C. Olson (AFML/LPE)
PROJECT NO: ARPA No. 1617
ABSTRACT: The angular dependence of the behavior of magnetization reversal discontinuities in single-particle samples was studied in an effort to obtain more information about the nature of the imperfections responsible for the discontinuities. In some cases a $1/\cos$ dependence is observed, as would be expected for a pinned domain wall fragment. In other cases the angular dependence is flatter and sometimes unsymmetrical. Preliminary experiments indicate that study of angular and temperature variation of nucleation fields together should be very fruitful. It has been found possible to raise the coercive force of $\text{Co}_{1-x}\text{Sm}_x$, potentially a very high-performance permanent magnet material, by chemical treatment.

ACCESS NO: 200,101 AD 723 271
REPORT NO: AFML-TR-71-182 September 1971
TITLE: MASS-SPECTROMETRIC STUDIES OF GRAPHITE
VAPORIZATION AT HIGH TEMPERATURES
AUTHOR: T. A. Milne, et al.
CONTRACT NO: F33615-68-C-1709
CONTRACTOR: Midwest Research Institute
PROJECT MONITOR: P. W. Dimiduk (AFML/LPT)
AFML TASK NO: 736001
ABSTRACT: Following a first year devoted to constructing the high-pressure sampling system, mass spectrometer and testing the effect of cold orifices on hot gases, the second year was devoted to testing and debugging the system. Equilibrium carbon species up to C_7 were observed from pyrolytic graphite Knudsen cells. The third year involved seeking a graphite cell design and heating arrangement to minimize arcing and vapor loss. The use of slotted pyrolytic graphite cells with various inserts appears to provide sufficient shielding to permit attainment of inner temperatures in the 3500°K range. Arcing could not be prevented with the RF work coil inside the vacuum system, even with the use of a step-down transformer.

ACCESS NO: 200,027 AD 736 480
REPORT NO: AFML-TR-71-188 August 1971
TITLE: MATERIALS PROCESSING OF RARE EARTH
COBALT PERMANENT MAGNETS

AUTHOR: P. J. Jorgensen
CONTRACT NO: F33615-70-C-1624
CONTRACTOR: Stanford Research Institute
PROJECT MONITOR: H. Garrett (AFML/LPE)
PROJECT NO: ARPA No. 1617

ABSTRACT: Rare earth-cobalt intermetallic compounds show promise for permanent magnets with a higher energy product, BH max, than are currently available. Because fine particles are required for magnetic alignment and sintering, and since the coercivities of these fine particles are sensitive to over-grinding and particle surface preparation, various powder preparation techniques are being investigated as alternative methods for producing strain-free particles. Methods that have been investigated include plasma spheroidization, plasma annealing, electrodeposition in fused salts, electrodeposition in organic liquids, direct reduction from amalgam droplets, precipitation from liquid zinc alloy solutions, and direct metallothermic reduction.

ACCESS NO: 200,131 AD 733 666
REPORT NO: AFML-TR-71-192 September 1971
TITLE: APPLICATIONS OF FAR INFRARED SPECTRO-
SCOPY TO THE STUDY OF THE STRUCTURE
AND DYNAMICS OF ORGANIC MOLECULES-
ALCOHOLS

AUTHOR: S. M. Craven
CONTRACT NO: F33615-70-C-1021
CONTRACTOR: Miami University
PROJECT MONITOR: F. F. Bentley (AFML/LPA)
AFML TASK NO: 736005

ABSTRACT: The far infrared spectra of a number of alcohols have been recorded as pure samples and as very dilute solutions in cyclohexane. A characteristic band (208 ± 10 cm⁻¹) is present in the spectra of aliphatic alcohols dissolved in cyclohexane. On the basis of the deuterium shifts this band is assigned to OH torsion. This characteristic band was quite strong in the spectrum of a 1% solution of cholesterol in cyclohexane. The position of this band is nearly independent of steric effects but is very sensitive to electrostatic interactions.

ACCESS NO: 200,133 AD 734 244
REPORT NO: AFML-TR-71-210 October 1971
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 Research Institute
PROJECT MONITOR: Capt. M. V. Turner (AFML/LPE)
AFML TASK NO: 737103

ABSTRACT: Intermetallic phases $R_2(\text{Co, Fe})_{17}$ with $R = \text{Ce, Pr, Nd, Sm, Y, and MM}$ (Ce-rich mischmetal) have been prepared and their metallurgical and magnetic properties studied. The melting behavior, phase transformations and Curie temperatures, lattice constants and directions of easy magnetization of the $R_2(\text{Co, Fe})_{17}$ phases were determined and the results are presented. All systems except $R = \text{Nd}$ have compositional ranges in which the easy direction of magnetization is the c-axis. The praseodymium-cobalt phase diagram has been revised and extended. Three previously unreported intermetallic phases were observed, and the structure of one, $\text{Pr}_2\text{Co}_{1.7}$, is reported.

MANUFACTURING TECHNOLOGY DIVISION (AFML/LT)

ACCESS NO: 64,110 AD 862 143
REPORT NO: AFML-TR-69-63 July 1969
TITLE: MANUFACTURING METHODS AND PROCESS
CONTROLS FOR LOW COST RESONANT
TRANSISTORS

AUTHOR: J. C. T. Sun, et al.
CONTRACT NO: F33615-67-C-1277
CONTRACTOR: Westinghouse Molecular Electronics Division
PROJECT MONITOR: Lt. R. T. Labonski (AFML/LTE)
PROJECT NO: 502-7

ABSTRACT: The main purpose of this contract is to develop and demonstrate manufacturing techniques and processes for the production of resonant gate transistors. Two particular resonant frequencies (kHz and 30 kHz) have been chosen as samples for demonstration purposes. In the photo-masking operations KMER coatings were used and special procedures developed. Electro-plating techniques for Ni and Au were modified for actual manufacturing purposes. Finally, a manufacturing dieing technique was developed to protect the delicate dangling cantilever during the dieing and mounting operations. From the unbalanced pilot production final operable device yields of about 58% and 52% were obtained for the 3kHz designs, respectively. For the 3kHz design, 92% of the operable units were within plus/minus 10% of the designed resonant frequency; for the 30 kHz, 95%.

ACCESS NO: 64,107 AD 864 988
REPORT NO: AFML-TR-69-249 November 1969
TITLE: DYNAPAK 1-1/2 MILLION FOOT POUND FORG-
ING MACHINE

AUTHOR: J. Koskoris, et al.
CONTRACT NO: F33615-68-C-1578
CONTRACTOR: General Dynamics Corp.
PROJECT MONITOR: L. C. Polley (AFML/LTP)
PROJECT NO: 173-8

ABSTRACT: A manufacturing methods requirement for this design study and engineering plans was established by Award/Contract No. F33615-68-C-1578 dated 22 April 1968. The 1-1/2 Million Foot Pound High Energy Rate Forging Press which was designed under this contract is a pneumatic-mechanical type press of true counter-blow design. The machine incorporates mechanical, hydraulic, and electrical systems.

ACCESS NO: 61,253 AD 864 987
REPORT NO: AFML -TR -69-333 February 1970
TITLE: AN IMPROVED PROCESS FOR THE WORKING
OF WELDED TITANIUM ALLOY TUBING

AUTHOR: R. F. Huber, et al.
CONTRACT NO: F33615-68-C-1364
CONTRACTOR: Whittaker Corp.
PROJECT MONITOR: G. L. Campbell (AFML/LTP)
PROJECT NO: 116-8

ABSTRACT: The objective of this work was the establishment of an economically advantageous production process for welded titanium alloy tubing for such applications as aircraft hydraulic systems. Planetary ball swaging was shown to be a very attractive method for working relatively low cost welded tubing into a final product compatible in quality to high-grade seamless tubing. Titanium alloy tubes were produced by forming Ti-6^w/o Al-4^w/o V strip into tubing and welding by standard tungsten inert gas methods. The welded tubing was processed by planetary ball swaging through reductions in area near 50 percent to final sizes near 1-inch outside diameter by 0.030-inch wall. This working removed essentially all traces of the former weld zone.

ACCESS NO: 48,640 AD 881 208
REPORT NO: AFML-TR-69-334 December 1970
Part I

TITLE: IN-PROCESS CONTROL TECHNIQUES FOR
COMPLEX SEMICONDUCTOR STRUCTURES
PART I: MANUFACTURING IN-PROCESS CON-
TROL AND MEASURING TECHNIQUES FOR MASK
EVALUATION

AUTHOR: D. K. Hartman, et al.
CONTRACT NO: F33615-68-C-1481
CONTRACTOR: General Electric Company
PROJECT MONITOR: E. H. Miller (AFML/LTE)
PROJECT NO: 531-8A

ABSTRACT: This report describes a program designed to apply a microscope-television camera-logic and automatic control system to rapidly determine the quality of photographic masks which are utilized in the production of integrated circuits and other complex semiconductor structures. The result of the program has been the design, development and construction of such an equipment and the testing and evaluation of its performance. The system can be used to inspect photographic masks of either positive image or negative image format, with image sizes of two microns and up, and with mask-pellet arrays up to 2 inches square. The inspection is performed automatically, recording on counters the final weighted numbers of pinholes found in the opaque areas and black spots and contamination found in the clear areas. The electronic logic and discriminating circuitry was designed to detect defects that are dimensionally approximately 80% of the smallest mask geometry size with a selection of defect size ranges for different mask geometries.

ACCESS NO: 49,605 AD 851 922
REPORT NO: AFML-TR-70-235 September 1970
TITLE: IN-PROCESS CONTROL TECHNIQUES FOR COM-
PLEX SEMICONDUCTOR STRUCTURES

AUTHOR: J. H. Williams
CONTRACT NO: F33615-68-C-1483
CONTRACTOR: Motorola, Incorporated
PROJECT MONITOR: E. H. Miller (AFML/LTE)
PROJECT NO: 531-8

ABSTRACT: The work described in this report is directed toward establishing high yield manufacturing methods and techniques which will lead to improved control and yield in the epitaxial phase of the fabrication of semiconductor devices. Automation of the epitaxial process control system is described, and includes the parameters of time, temperature, and gas flow. A unique feature of the system is closed loop feedback control of all process gases. A method is described for a programmed variation of dope gas flow as a function of time over a continuous range of 2000,000:1. Radiant energy is shown to be a feasible method for the deposition of silicon epitaxial films. The reactor consists of a high intensity light source that is incident on a silicon substrate located within a metal reaction chamber. Vapor phase HCl etching prior to silicon growth from silicon tetrachloride has given epitaxial a good crystal quality.

ACCESS NO: 47,225 AD 881 607
REPORT NO: AFML-TR-70-245 September 1970
TITLE: MANUFACTURING METHODS PROGRAM FOR A
KU-BAND PULSE POWER AMPLIFIER

AUTHOR: J. P. Vaszari
CONTRACT NO: F33615-68-C-1179
CONTRACTOR: Hughes Aircraft Company
PROJECT MONITOR: J. Meulemans (AFML/LTE)
PROJECT NO: 613-8

ABSTRACT: The primary objectives of this program were the development of the techniques and controls of a 200 kW Ku-band amplifier necessary for a production rate of 50 tubes per month. The initial phases of this program were devoted to the design, fabrication, test, and evaluation of the laboratory model tubes. During the second phase of the program, a total of five tubes were constructed, tested, evaluated, and modified. Results of the tests indicated that all five tubes achieved a peak power output of 200 kW; however, none of the tubes achieved full duty operation. During the course of the program, parts and subassembly drawings were prepared and completed. In order to increase the average power capability of the tube, it will be necessary to aim the beam transmission. This can be achieved by optimizing electron gun optics and refinements in the magnetic focusing structure.

ACCESS NO: 69,202 AD 883 651
REPORT NO: AFML-TR-70-277 March 1971
TITLE: THE INFLUENCE OF PROCESSING VARIABLES
ON THE STRUCTURE AND PROPERTIES OF
EXTRUDED BETA II TITANIUM

AUTHOR: A. M. Adair, et al.

CONTRACT NO:

CONTRACTOR: INTERNAL

PROJECT MONITOR: G. Trickett (AFML/LTP)

AFML TASK NO: 735108

ABSTRACT: The extrusion temperature and cooling rate after extrusion were varied for round to round axisymmetric extrusions of the Beta III titanium alloy. The microstructures after extrusion and after heat treatment were examined both by optical and transmission electron microscopy and correlated with the room temperature mechanical properties. Heat treatment following extrusion consisted of either aging only or a solution treatment followed by aging. In contrast to air cooling after extrusion, direct water quenching immediately after extrusion was effective in retaining a significant amount of dislocation structure from the hot deformation, the effect being greater at the lowest extrusion temperature. This retained dislocation structure effectively promoted the formation of alpha during aging and retarded the tendency for the omega phase to form.

ACCESS NO: 66,663 AD 880 893
REPORT NO: AFML-TR-70-300 December 1970
TITLE: MANUFACTURING TECHNIQUES TO PRODUCE
3,3'-DIAMINOBENZIDINE

AUTHOR: C. A. Rowe, Jr., et al.

CONTRACT NO: F33615-69-C-1874

CONTRACTOR: Esso Research and Engineering Company

PROJECT MONITOR: D. F. Starks (AFML/LTP)

PROJECT NO: 376-9

ABSTRACT: The hydrazine reduction reaction of DNB to DAB was demonstrated to be simple, highly selective, completely convertible, rapid, and easily adaptable to mild process conditions. A workable process to produce low cost, polymer-grade DAB was established. High current market prices of DAB were found to result from inherent processing difficulties (extreme air sensitivity and potentially carcinogenic DAB properties), poor iron reduction techniques, and high DNB market prices. Using the ESSO reduction technique and the ESSO estimated DNB purchase price, the current DAB selling price could be reduced from \$32 to \$14/lb. at the 1000 lbs./day level. Process feasibility was demonstrated by supplying a number of DAB product samples for testing. A 1000 lb./day DAB plant was designed and required \$1,150,000 total capital investment. Several process alternatives and cost sensitivities were explored to provide a flexible cost analysis.

ACCESS NO: 65,838 AD 881 272L
REPORT NO: AFML-TR-70-314 December 1970
TITLE: AF95 POWDER MANUFACTURING TECHNIQUES
AUTHOR: J. F. Barker, et al.
CONTRACT NO: F33615-69-C-1825
CONTRACTOR: General Electric Company
PROJECT MONITOR: G. W. Trickett (AFML/LTP)
PROJECT NO: 274-9

ABSTRACT: This program consisted of a study to establish powder requirements and processing procedures needed to produce AF95 powder metallurgy disk components having more consistent mechanical properties than conventional forgings at costs competitive with conventional methods. The study was based upon the concept of controlling carbon content as well as oxygen as the means for achieving these objectives. The study was conducted in two phases: Phase I-Determination of Powder Requirements and Phase II-Powder Scale-Up and Evaluation Study. Test results indicated that the creep and fracture toughness properties were equivalent to those of conventional AF95; however, yield strengths and stress-rupture ductilities were slightly lower. Heat-treatment studies indicated a trend for improved ductilities using treatments other than the standard AF95 heat treatment, which offer promise for a better balance of properties.

ACCESS NO: 60,484 AD 858 185
REPORT NO: AFML-TR-70-319 March 1971
TITLE: FORM ROLLING STRUCTURAL SHAPED TUBING
AUTHOR: G. N. Wassil
CONTRACT NO: F33615-67-C-1796
CONTRACTOR: Engelhard Minerals & Chemicals Corporation
PROJECT MONITOR: G. L. Campbell (AFML/LTP)
PROJECT NO: 100-7

ABSTRACT: This is a Manufacturing Program for the production of thin wall, hollow structural and airfoil shapes. Materials shape combinations of four alloys (Type 304 Stainless Steel, Hastelloy X, Ti-6Al-4V and Ti-3Al-2.5V) and three configurations (airfoil, balanced angle and unbalanced angle) were investigated. Starting material, tool design and processing parameters were established for form rolling close tolerance net shapes from welded tubing of .010 in. and .025 in. wall thickness. Shapes were produced in a two high variable speed rolling mill using a solid mandrel for internal support. Shapes produced exhibited less than 1/16 in. camber and less than 2 degree twist per foot of length. The surface finish of every length was identical to that of the starting material in the range of 10 to 40 RMS.

ACCESS NO: 69,095 AD 882 887
REPORT NO: AFML-TR-71-10 February 1971
TITLE: IN-PROCESS CONTROL TECHNIQUES FOR

COMPLEX SEMICONDUCTOR STRUCTURES

AUTHOR: L. A. Harris, et al.
CONTRACT NO: F33615-68-C-1481
CONTRACTOR: General Electric Company
PROJECT MONITOR: E. H. Miller (AFML/LTE)
PROJECT NO: 531-8

ABSTRACT: This program developed, established, and demonstrated the use of secondary electron spectroscopy (Auger electron analysis) as an effective in-process control technique for controlling surfaces in the manufacture of silicon semiconductor devices. The program was divided into three main phases; establishing the feasibility of using laboratory equipment and techniques for monitor and control, evaluating the utility of Auger analysis equipment in a production environment, and demonstrating the value of the equipment as an inspection and control instrument. In the initial phase, comparisons were made of Si, SiO₂, and Si₃N₄ to note the effects of variations in the chemical bonding. Effects due to the primary electron beam of the equipment were examined, the reproducibility of measurements was studied, and the equipment was used to detect alkali metals in oxide layers.

ACCESS NO: 61,246 AD 861 684
REPORT NO: AFML-TR-71-15 March 1971
TITLE: GLASS BATH HEATING OF FORGING STOCK

AUTHOR: R. E. Newcomer
CONTRACT NO: F33615-69-C-1892
CONTRACTOR: McDonnell Aircraft Company
PROJECT MONITOR: G. L. Campbell (AFML/LTP)
PROJECT NO: 226-9

ABSTRACT: This report describes a Manufacturing Methods Program to evaluate the concept of heating steel and titanium in molten glass and then directly forging. The glass used in this investigation serves a two-fold purpose: during heating, it protects the steel from decarburization and scaling and the titanium from contamination; during forging, it serves as a lubricant. Phase I consisted of forging 4340 steel and Ti-6Al-6V-2Sn in molten A-47 glass. Steel forgings were produced with no metallographic evidence of decarburization. Titanium forgings were produced with good as forged surfaces and superficial contamination; only 0.001 to 0.002 inch of stock removal was required to provide forgings free of alpha case. Phase II consisted of applying glass bath heating for forging Ti-6Al-2Sn-4Zr-6Mo, Ti-6Al-6V-2Sn, and Ti-6Al-4V below their respective beta transus temperatures on a 2500 ton mechanical press and beta forging Ti-6Al-4V on a 2000 ton hydraulic press.

ACCESS NO: 56,263 AD 882 033
REPORT NO: AFML-TR-71-22 March 1971
TITLE: MANUFACTURING METHODS FOR PRODUCING
BERYLLIUM OXIDE SINGLE CRYSTALS

AUTHOR: S. B. Austerman
CONTRACT NO: F33615-68-C-1667
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 anticipated application for BeO crystals is in the field of microelectronics. 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 developments concentrated primarily on stirred seed crystals, at temperatures of approximately 1100 C - 1150 C. Selected whole or sliced crystals were mounted on a rotating seed rack, and introduced to the flux under conditions of thermal equilibrium. Crystals up to 12 grams in weight were produced. Crystal quality ranged from virtually defect-free (zero dislocations and twin-free) to highly deformed crystals. Crystal defects in variable incidence include mosaic substructure, inclusions, inversion twins, and dislocation arrays; these are characterized.

ACCESS NO: 67,883 AD 736 869
REPORT NO: AFML-TR-71-33 April 1971
TITLE: APPLICATION OF ELECTROSLAG MELTED
STEEL TO ROCKET MOTOR CASE FABRICATION

AUTHOR: D. J. Butler, et al.
CONTRACT NO: F33615-70-C-1369
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: K. L. Love (AFML/LTF)
PROJECT NO: 783-9

ABSTRACT: This technical report discusses a program to establish manufacturing methods for fabricating rocket motor cases from hollow cylinders of D6a steel produced by the electroslag remelt (ESR) process. Seven 16-inch OD hollow billets of ESR D6a steel were cast and machined to produce 13 preforms, approximately 12 inches long. Eleven of these preforms were shear spun into thin wall rocket motor sections. Chemical, mechanical, and nondestructive tests were conducted on the ESR billets, on shear spun cylinders, and on weldments made with specimens from the cylinders. Comparisons were made between D6a ESR steel and D6ac steel which is used for current production of PHOENIX rocket motor cases. These comparisons included machinability, shear spinning behavior, weldability with an electron beam welder, and mechanical properties.

ACCESS NO: 28,453 AD 887 860
REPORT NO: AFML-TR-71-38 July 15, 1971
Volume 1
TITLE: MANUFACTURING PROCESS FOR SUPERALLOY
CAST PARTS, PHASE I-FUNDAMENTALS
AUTHOR: B. A. Heyer
CONTRACT NO: AF33615-2797
CONTRACTOR: Abex Corporation
PROJECT MONITOR: Lt. A. Lopez (AFML/LTP), et al.
PROJECT NO: 8-297

ABSTRACT: This is Volume I of the final Technical Engineering Report covering Phase I of a two-phase program designed to establish procedures for the manufacture of large, high-integrity, superalloy castings with shipping weights near 100 pounds. Specifically, a main fin-beam structural component and a hollow, air-cooled turbine rotor disc are to be produced during Phase II, with Phase I serving as the source of fundamental data required for their manufacture. A literature survey covering the field of high-integrity and superalloy castings is presented, and a survey of the current and future needs of the aerospace industry is used to document the need for the program. Based on foundry characteristics and the mechanical properties and microstructure of separately cast specimens and specimens cut from cast components with section thickness up to 5 inches, alloy 713 LC was selected from among 713 LC, 718, and R-41 alloys for sub-scale spin testing and for the final components.

ACCESS NO: 200,099 AD 726 872
REPORT NO: AFML-TR-71-40 September 1971
TITLE: GRINDING PROCESS OPTIMIZATION
AUTHOR: N. Jeffries, et al.
CONTRACT NO: F33615-69-C-1792
CONTRACTOR: University of Cincinnati
PROJECT MONITOR: Lt. R. H. Coe (AFML/LTF)
PROJECT NO: 711-9

ABSTRACT: This project was carried out to provide grinding process machinability data on three high strength steels, and to improve grinding processes through the understanding of several well-defined problem areas. The work encompasses the following primary subjects: machinability, thermal aspects of grinding, grinding wheel surface characteristics (effects of wheel dressing methods), and grinding wheel-workpiece interaction (cutting mechanism). Additional machinability data are presented for highspeed grinding ($> 10,000$ sfpm) of 300M and maraging steels and these are compared with previous low-speed grinding data. Results of the thermal tests are presented; these show heat-transfer coefficients and grinding heat for several cooling methods and cutting fluids.

ACCESS NO: 65,840 AD 727 620
REPORT NO: AFML-TR-71-44 March 1971
TITLE: ADVANCED CHEMICAL MILLING PROCESSES
AUTHOR: C. J. Staebler, Jr.
CONTRACT NO: F33615-69-C-1840
CONTRACTOR: Grumman Aerospace Corporation
PROJECT MONITOR: Lt. R. H. Coe (AFML/LTF)
PROJECT NO: 705-9

ABSTRACT: The program objective was to improve the capability, reliability, and cost-effectiveness of chemical milling when applied to selected aerospace structural materials. A completely automated, centrifugal regeneration system for titanium hydrofluoric acid etchant was designed, fabricated, and tested. This system automatically analyzes the etchant to determine the hydrofluoric acid concentration and adds fresh acid to maintain optimum concentration. The titanium section of the analyzer automatically determines the titanium concentration and activates a centrifuge which removes precipitated titanium, reclaims the hydrofluoric acid etchant, and maintains an optimum titanium concentration level.

ACCESS NO: 69,425 AD 885 959
REPORT NO: AFML-TR-71-49 June 1971
TITLE: PROJECTION MASKING SYSTEM
AUTHOR: L. Contente
CONTRACT NO: F33615-67-C-1659
CONTRACTOR: Perkin-Elmer Corporation
PROJECT MONITOR: E. H. Miller (AFML/LTE)
PROJECT NO: 510-7

ABSTRACT: Semiconductor integrated circuits and devices are presently being produced by the use of contact printing procedures to transfer the patterns on a glass plate (mask) on to a photo-sensitized silicon wafer. There are three important advantages of using a projection system in lieu of contact printing. First, because no contact is made to the master, the master life will be extended from approximately ten exposures to a theoretically infinite number of exposures (actually the handling of the master would probably limit master life). This obviously represents a major cost saving and/or affords the user an opportunity to make better masters. Secondly, the wafer yield will be increased because imperfections caused by contacting the master to the wafer can be eliminated, i. e., emulsion lift off, scratches, digs caused by epitaxial growths, etc. Thirdly, alignment errors will be reduced because both the wafer and master image are in focus and in the exposed position during alignment.

ACCESS NO: 67,518 AD 883 331
REPORT NO: AFML-TR-71-54 April 1971
TITLE: ON-LINE TRAINABLE ADAPTIVE PROCESS CONTROL
AUTHOR: J. M. Idelsohn, et al.
CONTRACT NO: F33615-70-C-1061
CONTRACTOR: Bendix Research Laboratories
PROJECT MONITOR: Lt. R. A. Dove (AFML/LTF)
PROJECT NO: 893-9
ABSTRACT: An investigation has been made of on-line trainable adaptive control for metal cutting processes. A surface grinder was selected as the test vehicle for experimental evaluation. The complete test system consists of a Do-All surface grinder modified to provide automatic control capability, a surface-finish inspection device and various process sensors, and two interfaced computers which perform adaptive control and training functions. Test results verified that the performance improvements obtainable from adaptive control could be automatically extended to cover a broad range of machining conditions by use of the on-line trainable capability. The training loop demonstrated the ability to adjust automatically the adaptive controller for optimum operation as process conditions changed.

ACCESS NO: 69,204 AD 884 630
REPORT NO: AFML-TR-71-55 March 1971
TITLE: MANUFACTURING METHODS FOR GALLIUM ARSENIDE
AUTHOR: K. L. Lawley, et al.
CONTRACT NO: F33615-69-C-1862
CONTRACTOR: Monsanto Research Corporation
PROJECT MONITOR: E. H. Tarrants (AFML/LTE)
PROJECT NO: 501-9
ABSTRACT: Manufacturing processes have been developed for preparing improved epitaxial and bulk gallium arsenide. Procedures for preparing these materials, methods of characterization, and engineering data which demonstrate the reproducibility of the processes and the uniformity of the products are presented. These materials have been used for making light emitting and microwave generating devices. Such devices have been made in order to demonstrate the utility of the products developed on this project.

ACCESS NO: 44,643 AD 850 238
REPORT NO: AFML-TR-71-63 April 1971
TITLE: DEVELOPMENT OF MANUFACTURING TECH-
NIQUES FOR PRODUCTION OF RAIN EROSION
RESISTANT COATED STRUCTURES

AUTHOR: G. E. Wintermute
CONTRACT NO: F33615-67-C-1349
CONTRACTOR: Goodyear Aerospace Corporation
PROJECT MONITOR: Capt. J. R. Williamson (AFML/LTF)
PROJECT NO: 9-452

ABSTRACT: The objectives of this program were to perform a systematic study of the variables that influence the manufacturing of reliable, ceramic-coated, plastic-reinforced radomes; to develop an optimum manufacturing process; and to demonstrate the performance and reproducibility of the established process. The work was conducted in four phases: I: Materials and process evaluation, II: Characterization and optimization of manufacturing processes, III: Demonstration of performance and reproducibility, IV: Documentation. Materials and processing methods for forming rain-erosion-resistant, ceramic-coated, plastic structures were studied and evaluated.

ACCESS NO: 45,426 AD 850 209
REPORT NO: AFML-TR-71-71 March 1971
TITLE: DEVELOPMENT OF COMPOSITE TAPE LAYING
PROCESS FOR ADVANCED FIBROUS REINFORCED
COMPOSITE STRUCTURES

AUTHOR: W. O. Sunafrank, et al.
CONTRACT NO: F33615-67-C-1271
CONTRACTOR: General Dynamics
PROJECT MONITOR: G. E. Eichelman (AFML/LTF), et al.
PROJECT NO: 872-7

ABSTRACT: The objective of this Air Force Manufacturing Technology program was to develop and fabricate a numerically controlled prototype tape laying machine for performing layup operations required by airframe structural components of filament reinforced resin matrix composites. Mechanical functions of the machine as related to airframe component design requirements were investigated and defined. These included machine head variables of roller type, heat and pressure application, laying rates, tape feed mechanisms, shearing methods, disposal of cutoffs, and tape specifications. In addition, compound contour requirements were considered.

ACCESS NO: 48,449
REPORT NO: AFML-TR-71-86 June 1971
TITLE: IN-PLACE TUBE WELDING MANUFACTURING TECHNOLOGY

AUTHOR: D. R. Brubaker
CONTRACT NO: F33615-68-C-1664
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: F. Miller (AFML/LTF)
PROJECT NO: 814-8

ABSTRACT: A welding system, comprising a weld tool and a programmer control unit, has been designed, fabricated, and tested. The system is capable of producing consistent aircraft quality butt welds in 1/2-inch diameter by 0.035-inch wall and 1-inch diameter by 0.070-inch wall 6Al-4V titanium alloy tubing. Test specimens in these tube sizes have been welded and tested in flexure fatigue, impulse cycled, and ultimate burst pressure tested at 500° F. The test results indicate this tube joining technique to be equal or superior to any other method available for service conditions of 4,000 PSI working pressure and 500° F temperature.

ACCESS NO: 28,487 AD 884 622
REPORT NO: AFML-TR-71-89 March 1971
TITLE: AUSFORGING LARGE, HIGH-STRENGTH STEEL AIRCRAFT STRUCTURAL COMPONENTS

AUTHOR: A. J. Vazquez
CONTRACT NO: AF33615-3142
CONTRACTOR: Ladish Company
PROJECT MONITOR: G. W. Trickett (AFML/LTP)
PROJECT NO: 8-354

ABSTRACT: The effects of thermo-mechanical ausforging oriented treatments were investigated using a multiple-die sequence to determine the applicability as a production process. D6ac, 4340, and HP 9-4-45 were evaluated using a simulated airframe component configuration having a weight eight times greater than parts previously ausforged. Two alloys D6ac and 4340, were significantly strengthened due to the thermo-mechanical process used, but the D6ac forgings showed maximum response. In ausforging, while tensile strengths were improved, it was noted that ductility, impact strength, fracture toughness, and fatigue life were slightly reduced. Problems were experienced in tooling failures, die underfill, and localized bainitic transformation.

ACCESS NO: 69,429 **AD 725 039**
REPORT NO: AFML-TR-71-93 **June 1971**
TITLE: **MANUFACTURING METHODS DEVELOPMENT
OF SPOT-WELD-ADHESIVE BONDED JOINING
FOR TITANIUM**

AUTHOR: D. Fields
CONTRACT NO: F33615-71-C-1099
CONTRACTOR: Lockheed-Georgia Company
PROJECT MONITOR: F. R. Miller (AFML/LTF)
PROJECT NO: 827-9

ABSTRACT: Work during this program established basic parameters for joining titanium alloy using the resistance spot-weld-adhesive bonding (weldbonding) process. Design of test parameters for evaluation of static strength of weldbond joints in titanium alloy required that first consideration be given to the probable use of the developed process. Since a high percentage of titanium used in joints of military aircraft would involve areas wither exposed to high stress and/or elevated temperatures, strength at elevated temperatures was given prime consideration. Realistic evaluation of weldbond joints in titanium required that wherever possible weldbond joint strength should be compared directly to strength of other type joints. In this program joints were made utilizing spot-welds only, mechanical fasteners only, mechanical fasteners with adhesive, and structural adhesive bonds only.

ACCESS NO: 66,794 **AD 725 895**
REPORT NO: AFML-TR-71-95 **June 1971**
TITLE: **MACHINABILITY PARAMETERS ON NEW AND
SELECTIVE AEROSPACE MATERIALS**

AUTHOR: N. Zlatin, et al.
CONTRACT NO: F33615-69-C-1925
CONTRACTOR: Metcut Research Associates Inc.
PROJECT MONITOR: Lt. R. H. Coe (AFML/LTF)
PROJECT NO: 708-9

ABSTRACT: The alloys machined under this contract can be classified under the following groups: 1) high strength steels; 2) titanium alloys; 3) nickel base alloys; and 4) hot work die steels. In addition, drilling tests were performed on boron epoxy laminates. In general, conventional tools were used in this program to determine the machining conditions required to produce components out of the aforementioned alloys. The new recently developed tool materials were also included in an attempt to improve on the machining conditions. Both single tooth and multiple tooth face milling cutters were used.

ACCESS NO: 69,477 AD 727 779
REPORT NO: AFML-TR-71-111 April 1971
TITLE: THE MANUFACTURING OF AIRCRAFT-QUALITY
HYDRAULIC TUBING WITH THE Ti-3Al-8V-6Cr-
4Mo-4Zr ALLOY

AUTHOR: J. M. Olexa, et al.
CONTRACT NO: F33615-70-C-1680
CONTRACTOR: RM Company
PROJECT MONITOR: L. C. Polley (AFML/LTP)
PROJECT NO: 154-0

ABSTRACT: Manufacturing procedures were developed for producing high-quality tubing of the metastable beta titanium alloy Ti-3Al-8V-6Cr-4Mo-4Zr. In excess of 500 feet of tubing was produced and evaluated in each of the three sizes at 0.75-, 0.54- and 0.375-inch diameter. The Ti-3Al-8V-6Cr-4Mo-4Zr alloy was found to be a highly producible tubing material with mechanical properties better than those of other titanium tubing alloys. The producibility of Ti-38-6-44 is enhanced most significantly by proper thermal treatments at initial and intermediate tube sizes, proper reduction sequences and precise tooling arrangements. Ti-38-6-44 was found to offer a wide range of strength levels, as tubing, with excellent ductility. Yield strengths were measured from 120 to more than 200 ksi.

ACCESS NO: 46,140 AD 887 384L
REPORT NO: AFML-TR-71-112 May 1971
TITLE: COMPARISON OF MAJOR FORGING SYSTEMS
AUTHOR: F. N. Lake, et al.
CONTRACT NO: F33615-67-C-1109
CONTRACTOR: TRW Inc.
PROJECT MONITOR: L. C. Polley (AFML/LTP)
PROJECT NO: 9-120

ABSTRACT: A program to compare forging equipment effectiveness in providing superior structural forgings of advanced aerospace materials has been successfully completed. Comparisons of precision, quality, properties, and costs have been made after evaluation of representative, rectangular, rib and web structural forgings produced to essentially common shapes with different forging equipment. The program was divided by equipment size into separate efforts involving intermediate size and large forgings. An "H" section, leading edge fin rib was employed as a target component enveloped by intermediate size forgings produced of a high strength steel (D6ac), a titanium alloy (Ti 6Al-4V), and a nickel-base alloy (Inconel 718).

ACCESS NO: 41,666 AD 889 3166
REPORT NO: AFML-TR-71-125 October 1971
TITLE: RESEARCH AND DEVELOPMENT OF HELICOPTER
ROTOR BLADES UTILIZING ADVANCED COM-
POSITE MATERIALS

AUTHOR: D. J. Hoffstedt
CONTRACT NO: AF33615-5275
CONTRACTOR: The Boeing Company
PROJECT MONITOR: T. Cornsweet (AFML/LTF)
PROJECT NO: 6169CW

ABSTRACT: This report describes the work performed between June 1966 and December 1970 as a result of research and development activities toward the production of helicopter rotor blades constructed of advanced composite materials. The results include the identification of advanced composite applications in an aircraft such as the CH-47 helicopter and cover such areas as cost-effectiveness analysis; development and selection of materials in tape and broadgoods forms; demonstration hardware design; fabrication and evaluation tests; design and analysis of full-scale rotor blades; tooling and fabrication considerations and problem solutions; fabrication history; structural, static, and fatigue tests of full-scale hardware; quality assurance development and application; and successful assembly and whirl-test of the rotor blades on a CH-47C rotor hub through flight angles of attack and rotating velocities.

ACCESS NO: 68,383 AD 728 274
REPORT NO: AFML-TR-71-129 July 1971
Volume I
TITLE: MANUFACTURING METHODS FOR MACHINING
PROCESSES FOR HIGH MODULUS COMPOSITE
MATERIALS VOLUME I: MATERIAL REMOVAL
TESTS AND RESULTS

AUTHOR: F. Hanley, et al.
CONTRACT NO: F33615-70-C-1427
CONTRACTOR: General Dynamics Corporation
PROJECT MONITOR: T. Cornsweet (AFML/LTF)
PROJECT NO: 707-9

ABSTRACT: Volume I presents material removal test data and subsequent recommendations for drilling, reaming, countersinking, milling, routing, and sawing boron-epoxy and boron-epoxy/titanium laminate. Material removal tests are described and cost analyses for each operation are presented.

ACCESS NO: 69,539 AD 886 587
REPORT NO: AFML-TR-71-130 July 1971
TITLE: HIGH PURITY SILICON MANUFACTURING
FACILITY

AUTHOR: B. E. Boggs, et al.
CONTRACT NO: F33615-69-C-1829
CONTRACTOR: Texas Instruments Incorporated
PROJECT MONITOR: E. H. Tarrants (AFML/LTE)
PROJECT NO: 555-9

ABSTRACT: In recent years new semiconductor devices, primarily light detectors, have generated requirements for ultrapure high resistivity silicon. The objective of providing a manufacturing capability for this material was met. A pilot line production facility was fabricated and operated. Methods of further purifying trichlorosilane, the selected feed material, were examined and purity requirements were established. Deposition, vacuum float zoning, and testing parameters and methods were determined. A significant portion of the effort was spent in an attempt to use various state-of-the-art chemical analysis techniques in solving material property problems, primarily short minority carrier lifetime, without success.

ACCESS NO: 40,448 AD 849 528
REPORT NO: AFML-TR-71-131 August 1971
TITLE: FABRICATION AND EVALUATION OF DIFFUSION-
BONDED LAMINATED SECTIONS

AUTHOR: W. D. Padian, et al.
CONTRACT NO: AF33615-3515
CONTRACTOR: North American Rockwell Corporation
PROJECT MONITOR: G. W. Trickett (AFML/LTP)
PROJECT NO: 9-122

ABSTRACT: Diffusion bonding of laminated titanium structural shapes was demonstrated. Initially, bonding parameters and procedures were identified for 6Al-6V-2Sn titanium alloy and applied to the fabrication of five full-scale F-104 fuselage ring fitting shapes weighing approximately 60 pounds each. Evaluation of these fittings by the Lockheed-California Company by mechanical testing of coupons and by structural static and fatigue testing of full-scale fittings demonstrated feasibility of the process. Test results indicated the properties of the diffusion-bonded fittings to be equivalent, or superior, to the properties of comparable forgings. Based on the satisfactory results obtained, a second-phase effort was undertaken which demonstrated scale-up of the diffusion bonding process to produce a large, complex, titanium shape - the Sikorsky Aircraft H-53 helicopter main rotor hub.

ACCESS NO: 67,602 AD 731 820
REPORT NO: AFML-TR-71-142 July 1971
TITLE: MANUFACTURING METHODS AND TECHNOLOGY
FOR PROCESSING COBALT-SAMARIUM
MAGNETS

AUTHOR: M. G. Benz, et al.
CONTRACT NO: F33615-70-C-1098
CONTRACTOR: General Electric Company
PROJECT MONITOR: H. K. Trinkle (AFML/LTE)
PROJECT NO: 612-9A

ABSTRACT: Alternative manufacturing methods, processes, and techniques for fabrication of cobalt-samarium magnets have been evaluated. A pre-production pilot line capable of producing cobalt-samarium magnets has been established. The properties of magnets produced on this pre-production pilot line exceed: (BH)max 15 MGOe, Br 8.2 kG, Hc -6.5 kOe, Hd (at B/H - -1/2) -5.0 kOe, and the irreversible loss (at B/H - -1/2) on exposure to 150 C less than 10%. The cost of magnets produced on this pre-production pilot line was approximately one fourth the cost the same size magnet would be if fabricated from cobalt-platinum. Magnets produced on this pilot line have been used to successfully fabricate five traveling wave tubes. The performance of these tubes indicates that cobalt-samarium magnets are suitable for fabrication of traveling wave tubes; and, in fact, that they will allow further advances in the state of the art in the design of such tubes.

ACCESS NO: 48,313 AD 736 477
REPORT NO: AFML-TR-71-148 September 1971
TITLE: TITANIUM POWDER METALLURGY FORGING
AUTHOR: R. E. Peebles
CONTRACT NO: F33615-68-C-1356
CONTRACTOR: General Electric
PROJECT MONITOR: G. A. Gegel, et al.
PROJECT NO: 183-8

ABSTRACT: The objective of this contract effort was to identify the processing sequences and methods needed to produce precision-forged structural and jet engine components from titanium alloy powder preforms starting from prealloyed material including scrap. The effort included identification of an economic powder production process, identification of a technique to consolidate the powder into complex-shaped forging preforms, and the establishment of a forging sequence to a fully dense forged part. A phenomenon of thermally induced porosity was encountered approximately midway in the program, and was attributed to minute quantities of argon physically entrapped in the powder preform. A mechanism for the entrapment is postulated.

ACCESS NO: 67,667 AD 721 824
REPORT NO: AFML-TR-71-151 August 1971
TITLE: MANUFACTURING METHODS FOR SAMARIUM
COBALT MAGNETS

AUTHOR: D. Das, et al.
CONTRACT NO: F33615-70-C-1097
CONTRACTOR: Raytheon Company
PROJECT MONITOR: H. K. Trinkle
PROJECT NO: 612-9B

ABSTRACT: Processes and techniques have been established for the pilot line manufacturing of samarium-cobalt permanent magnets for use in high performance periodic permanent magnet focused traveling-wave tube amplifiers. The objective of achieving a capacity for 1000 magnets per month was exceeded. Typical properties of magnets produced in quantity are: energy product (BH) max of 13 - 15 x 10⁶ GOe Br of 7800 - 200 gauss, and Hc of 6800 - 300 Oe. Extensive measurements were made to establish temperature characteristics of second quadrant properties, long-term stability, and maximum temperature use in an operating device. Irreversible temperature coefficients for magnetic properties up to 255 C were found to depend linearly on demagnetizing field, whereas reversible temperature coefficients varied only slightly.

ACCESS NO: 67,669
REPORT NO: AFML-TR-71-154
TITLE: PBI TOW MANUFACTURING METHODS
AUTHOR: A. E. Prince
CONTRACT NO: F33615-70-C-1266
CONTRACTOR: Celanese Research Company
PROJECT MONITOR: C. S. Anderson (AFML/LTP)
PROJECT NO: 389-9

ABSTRACT: The purpose of this project was to (a) scale-up the single stage polymerization process (b) increase spinning productivity (c) establish a tow process for processing large bundles of yarn in a continuous manner (d) produce 500 lbs of quality product, and (e) revise the projected economics of a 1 MM lb/yr production plant. The scale-up of the single-stage PBI polymerization process in a specially designed 50-gallon reactor was successful with the attainment of polymer I. V. 's in the 0.7 to 0.9 range at the target capacity level. Insufficient time was available, however, to fully optimized the process conditions. Continuous washing, drying, and drawing in tandem was demonstrated with PBI tows of 1000 to 5000 filaments. Target properties were achieved and a total of 500 lbs of tow was produced.

ACCESS NO: 41,253 AD 736 785
REPORT NO: AFML-TR-71-162 July 1971
TITLE:

**A MANUFACTURING PROGRAM FOR THE
ELECTROSLAG MELTING AND CASTING
OF MATERIALS**

AUTHOR: G. K. Bhat
CONTRACT NO: AF33615-5430
CONTRACTOR: Carnegie-Mellon University
PROJECT MONITOR: A. Lopez (AFML/LTP), et al.
PROJECT NO: 9-161

ABSTRACT: A program to optimize manufacturing parameters of the electroslag remelting and refining process for reliably and reproducibly producing commercial size slab ingots of maraging 300 KSI grade steel and super alloys Rene' 41 and Udimet 700 has been conducted. The feasibility of directly converting the electroslag slab ingots of these alloys into plate and ring products through reduced numbers of mill operations was demonstrated. The manufacturing and material utilization economics claimed for this process were fully realized. Manufacturing techniques for production of small and large solid round and slab ingots of titanium through single electroslag remelting were evaluated. Although scale-up titanium ESR melting studies could not be concluded within allowed costs, nevertheless, several innovations have been made in the preparation of titanium sponge electrodes for remelting by the isostatic pressing method.

ACCESS NO: 28,093 AD 888 868L
REPORT NO: AFML-TR-71-163 September 1971
TITLE:

**MANUFACTURING TECHNIQUES FOR PRECISION
FORGING TITANIUM ALLOY LANDING WHEELS
FOR THE F-111 AIRCRAFT**

AUTHOR: W. C. Travis, Jr.
CONTRACT NO: AF33615-2928
CONTRACTOR: Fairchild Industries
PROJECT MONITOR: L. C. Polley (AFMI/LTP)
PROJECT NO: 8-293

ABSTRACT: This program was undertaken to develop processes for close tolerance forging of titanium alloy Ti-6Al-6V-2Sn nose and main landing wheels designed to meet the requirements of the F-111 aircraft. The nose wheel portion of the program was subcontracted by Republic to Precision Metal Products, a Macrodyne-Chattillon Company. This effort consisted of exploring the potential for forging the nose wheel in a single die utilizing high energy rate forging equipment. The study was ended after a number of forging trials which demonstrated that the capacity of the existing equipment was insufficient to provide the required part.

ACCESS NO: 69, 722 **AD 736 790**
REPORT NO: AFML-TR-71-167 **August 1971**
TITLE: MULTI-CHIP INTEGRATED CIRCUIT PACKAGE
AUTHOR: N. P. Cerniglia, et al.
CONTRACT NO: F33615-68-C-1632
CONTRACTOR: GTE Laboratories
PROJECT MONITOR: J. Garrett (AFML/LTE)
PROJECT NO: 506-8A

ABSTRACT: The objective of the contract is to reduce to practice a compatible multichip interconnection system for unpackage integrated circuits, eliminating insofar as possible wire bonds and interconnection interfaces, and achieving high yield, low cost, and high reliability. A pilot production line was set up in this project to produce sufficient units for test and cost evaluation. This project is based on the use of beam-leaded IC's and air-insulated beam-lead crossover interconnection method. This is the final report on this multi-chip contract. The conclusions and recommendation sections support the basic advantages of the beam-lead system. Particular advantages have been seen in high reliability multi-chip bonding, and the ability to rebond or remove bad die and rework. Some incompatibility was found in using the beam-lead technology at the high temperature needed in the glass hermetic cap seal.

GUIDE TO THE SUBJECT INDEX

This subject index has been expressly constructed to allow the user to coordinate two or more terms in his search for specific information if desired. For example, to find information on boron fibers, one should look under the two separate headings **BORON, BORON COMPOUNDS** and **FIBERS, FIBROUS MATERIALS, FILAMENTS, WHISKERS**. In the Subject Index the access numbers and pages are listed as follows:

BORON, BORON COMPOUNDS: 49,781, p. 12; 65,439, p. 13; 68,383, p. 130; 68,920, p. 11; 68,923, p. 98; 69,010, p. 72; 69,097, p. 80; 69,519, p. 12; 69,991, p. 49; 200,029, p. 38; 200,230, p. 82.

FIBERS, FIBROUS MATERIALS, FILAMENTS, WHISKERS: 45,426, p. 126; 47,772, p. 53; 48,446, p. 54; 65,054, p. 87; 65,055, p. 15; 65,217, p. 14; 66,571, p. 55; 66,793, p. 29; 67,150, p. 55; 68,002, p. 76; 68,439, p. 43; 68,820, p. 68; 68,859, p. 78; 68,890, p. 72; 68,921, p. 71; 69,157, p. 22; 69,206, p. 24; 69,299, p. 18; 69,377, p. 80; 69,378, p. 68; 69,517, p. 75; 69,536, p. 45; 69,544, p. 90; 69,565, p. 8; 69,797, p. 48; 69,986, p. 71; 71,716, p. 70; 200,097, p. 54; 200,102, p. 83; 200,179, p. 81; 200,201, p. 56; 200,230, p. 82.

Access numbers appearing under both subject headings should contain the desired information. In the example given, access number 200,230, p. 82 is listed under both subjects and information on boron fibers is given in this abstract. If one were interested in all information on fibers, the one subject heading **FIBERS, FIBROUS MATERIALS, FILAMENTS, WHISKERS** would be sufficient; no coordination would be required.

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UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D		
<i>(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)</i>		
1. ORIGINATING ACTIVITY (Corporate author) AF Materials Laboratory (LAM) W-PAFB, Ohio 45433		2A. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
2B. GROUP		
3. REPORT TITLE Abstracts of AF Materials Laboratory Reports 1 January 1971 - 31 December 1971		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Bibliography 1 January 1971 - 31 December 1971		
5. AUTHOR(S) (Print name, middle initial, last name)		
6. REPORT DATE September 1972	7A. TOTAL NO. OF PAGES	7B. NO. OF REFS
8A. CONTRACT OR GRANT NO.	9A. ORIGINATOR'S REPORT NUMBER(S) AFML-TR-72-157	
A. PROJECT NO. 7381	9B. OTHER REPORT NUM(S) (Any other numbers that may be assigned this report)	
C. Task No. 738103	4.	
10. DISTRIBUTION STATEMENT OFFICIAL USE ONLY		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Materials Laboratory (LAM) AF Systems Command Wright-Patterson AFB, Ohio 45433	
13. ABSTRACT <p>Technical reports published by the Air Force Materials Laboratory during the period 1 January 1971 - 31 December 1971 are abstracted herein and indexed by divisions of the Laboratory, technical subject matter, investigator, AFML project monitor and contractor. Reports on research conducted by the Air Force, Materials Laboratory personnel as well as that conducted on contract are included.</p>		

FORM 107 68 1475

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Security Classification

NO.	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	Abstracts Air Force Materials Laboratory Reports Bibliography Materials Information Materials Research						

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Security Classification