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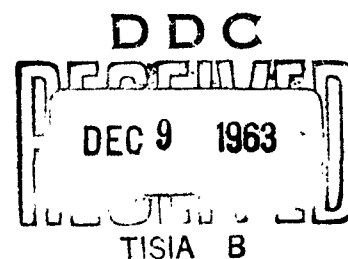
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NOVEMBER, 1963

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SELECTED ACCESSIONS



BATTELLE MEMORIAL INSTITUTE
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The DMIC maintains a search system for visitor usage, which consists of both technical extracts and original documents. In addition, requests for specific data to supplement the abstracts in this listing may be directed to the DMIC.

Author, subject, and DMIC numerical indexes for the individual abstracts are provided for the reader's convenience.

Compiled by:

Mary F. Banks

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Selected Accessions

November 1963

HIGH-STRENGTH ALLOYS

- 53199 ZONE MELTING OF EUTECTIC-FORMING MIXTURES. W. R. Wilcox, Aerospace Corporation, El Segundo, California. Report No. ATN-64(9236)-2, August 21, 1963
(8 references, 24 pages, 7 figures)

The problem of solute redistribution resulting from the zone melting of eutectic-forming mixtures has been solved analytically for pure diffusional mass transfer. The solute distribution during the initial period (in which no solute is contained in the solid) was solved by the method of Laplace transforms. The final period (in which the solute concentration at the freezing interface remains fixed at the eutectic concentration) was solved by separation of variables. For a ratio of eutectic concentration to original solute concentration greater than 4, the solute concentration profile in the solid during the final period was found to be independent of this ratio.

- 53242 FINAL REPORT ON SHEET METAL FORMING TECHNOLOGY, VOL. I. W. W. Wood, Chance Vought Corporation, Dallas, Texas. ASD, Report No. ASD-TDR-63-7-871, Final Technical Documentary Report, Vol. I, July, 1963, Contract No. AF 33(657)-7314
(360 pages, 196 figures, 4 tables)

The purpose of this project is to determine the inherent limitations of sheet metal forming processes, to develop the knowledge to significantly advance these, and to recommend the manner in which this can be accomplished.

This report (Volume I) presents the experimental work on the program for tensile testing, free bulging of tubing and domes, and forming of parts with dies using a projectile impact tensile test fixture, low explosive - closed system, high explosive - open system, electro-hydraulic-open system, electromagnetic system, and conventional presses. In addition, high pressure rubber forming was investigated utilizing both static and impact presses in conjunction with heat. Recommendations are made on the most promising sheet metal forming processes for the future based on material formability, process competitive factor, part shape applicability, tooling potential, and manufacturing potential.

- 53243 FINAL REPORT ON SHEET METAL FORMING TECHNOLOGY, VOLUME II (HANDBOOK).
W. W. Wood, Chance Vought Corporation, Dallas, Texas. Report No. ASD-TDR-63-7-871, Handbook, July, 1963, Contract No. AF 33(657)-7314
(numerous pages, numerous figures, numerous tables)

The Handbook (Volume II) is presented in three major sections: Material Purchasing Information, Conventional Forming, and Advanced Methods of Forming. The first gives availability, costs, chemical composition, heat treatment, and properties for a broad range of sheet metal alloys. Quantitative design limits are given in the Conventional Forming Section. The section on Advanced Methods of Forming presents the fundamentals for such forming processes as explosive, capacitor discharge, combustible gas, high pressure rubber, and vibration.

- 53282 AN INVESTIGATION OF THE NATURE OF STRUCTURAL DAMAGE IN METAL FORMING PROCESSES. R. C. Leech, L. F. Coffin, and H. C. Rogers, General Electric Company, Schenectady, New York. Bureau of Naval Weapons, Report No. 63-GC-0252M, Progress Report No. 2, October, 1963, Contract No. NOW 63-0671-C
(5 pages, 2 figures)

Phase I of the contract includes sheet drawing under normal ambient pressures, and the attempt to relate evidence of structural damage with the various states of stress from which this damage arose.

Cobalt Base

- 53078 THE ROLE OF OXYGEN IN THE BRITTLE BEHAVIOR OF METALS. E. S. Tankins, United States Naval Air Material Center, Philadelphia, Pennsylvania. USN, Report No. NAEC-AML(9)-R36OFR101, Ninth Progress Report, April 3, 1963, AD 404219 (3 references, 5 pages, 8 tables)

The equilibrium constants for the reaction, $H_2(g) + O$ (in alloy) = $H_2O(g)$ for the Fe-Co and Co-Ni alloy systems have been determined for the temperature range 1470 C to 1700 C. Additionally, the standard free energies for transformation of gaseous oxygen into dissolved oxygen, for these alloy systems and temperature range, were determined.

- 53079 See Iron Base.

Nickel Base

- 53015 MACHINABILITY OF NICKEL-TITANIUM ALLOYS. J. V. Gould, Metcut Research Associates, Inc., Cincinnati, Ohio. USN Ordnance Laboratory, Report No. 573-4062-1, Report, June 24, 1963, Contract No. N60921-6814 (14 pages, 18 figures, 4 tables)

The purpose of this project was to determine the machining characteristics of the ductile intermetallic compound NiTi alloys. This was accomplished by conducting tool life tests in turning, face milling, drilling and tapping these alloys. In addition, grinding tests were also made.

The results of these tests were then used in establishing the recommended cutting speeds, feeds, tool geometries, cutting fluids and grinding conditions for machining the alloys.

- 53078 See Cobalt Base.
- 53079 See Iron Base.
- 53244 See Stainless Steels.

Engineering Steels

- 53042 EFFECT AND CONTROL OF CHATTER VIBRATIONS IN MACHINE TOOL PROCESS. J. R. Lemon and G. W. Long, Cincinnati Milling and Grinding Machines, Inc., Cincinnati, Ohio. Interim Technical Documentary Progress Report, ASD, Contract No. AF 33(657)-9143 (86 pages, numerous figures, numerous tables)

This project is engaged in a program of research, which is directed at the problem of developing significant information and data relating to the mechanism of chatter originating from self-excited vibration within a dynamic machine tool system. From this study, criteria for the design, installation and operation of essentially chatter free machine tools will be created.

The transfer function theory of structures is presented in this report. Such a theory will allow the equations, governing the motion of structures to be defined and apparently eliminate any need for curve fitting the data taken from the structures in experimentation.

Frequency response plots measured on the test drilling machine are presented and compared to preliminary predicted response plots. Comparisons are also made between response plots measured in the same directions but where the position of some components has been varied.

Expressions have been derived for the cutting stiffness for round nose tools and the initial analytic work on the dynamics of the cutting process is presented.

Two popular theories of chatter are discussed, evaluated and compared with the theory being developed under the auspices of this program.

- 53054 INVESTIGATION OF HYDROSTATIC EXTRUSION. R. J. Fiorentino, A. M. Sabroff, and F. W. Boulger, Battelle Memorial Institute, Columbus, Ohio. ASD, Report No. RTD TR 63-7-916(V), Interim Technical Progress Report No. 5, September, 1963, Contract No. AF 33(600)-43328 (3 references, 44 pages, 12 figures, 9 tables)

Hydrostatic extrusion of AISI 4340 into 1-inch diameter rounds was accomplished at extrusion ratios up to 4:1 (75 per cent reduction). Ti-6Al-4V was extruded hydrostatically at ratios up to 2:1 (50 per cent reduction). Commercial-purity aluminum was extruded by this method at ratios up to 200:1 (99.5 per cent reduction).

- 53126 MATERIAL EVALUATION CHARPY IMPACT STRENGTH F-111 STEEL ALLOYS. F. L. Nordquist, General Dynamics, Fort Worth, Texas. ASD, Report No. FTDM-3130, Report, August 5, 1963, Contract No. AF 33(657)-11214 (10 pages, 4 figures, 4 tables)

The object of this work was to determine the charpy impact strength of D6ac, H-11 and 4330-V alloy steels.

The specimens used in this test came from 4 inch x 12 inch x 30 inch preforged billets of the three alloys.

Only D6ac had an average impact strength of greater than 15 foot-pounds at room temperature when heat treated to the 220-240 ksi range.

53159 See Miscellaneous.

53252 See Iron Base.

Stainless Steels

- 52992 DETERMINATION OF THE EMISSIVITY OF MATERIALS. R. J. Hayes, Pratt and Whitney Aircraft, Division United Aircraft Corporation, East Hartford, Connecticut. NASA, Report No. PWA-2255, Progress Report, Contract No. NASw-104
(54 pages, 25 figures, 11 tables)

This report covers emittance measurements and long term endurance tests were concluded. The total hemispherical emittance rig has been returned to service and the quality of temperature measurement has been investigated. An analysis of slurry coating procedures is being conducted.

Total hemispherical emittance measurements were made and are reported for AISI-310 stainless steel, tantalum, and coatings of crystalline boron, nickel-chrome spinel, calcium titanate, and iron titanate. All coating materials were plasma-arc sprayed onto columbium - 1 per cent zirconium tubes. Emittance values of 0.87 or above were obtained with coatings of nickel-chrome spinel, calcium titanate, and iron titanate. An endurance test conducted on a calcium-titanate coated specimen resulted in lower emittance values than anticipated but these values are not believed to be characteristic of this coating.

- 53244 IMPROVED PRODUCTION OF POWDER METALLURGY ITEMS. K. Farrell, S. A. Spachner, and N. M. Parikh, IIT Research Institute, Chicago, Illinois. ASD, Report No. ASD-TDR-7-911(V), Interim Technical Documentary Progress Report, September, 1963, Contract No. AF 33(657)-9140
(16 pages, 3 figures, 3 tables)

The synthesizing results on TZM alloy are summarized, and it is shown that it is difficult to obtain the precise carbon content.

The atomizing technique has been modified so that superalloy powders of low gas content can now be made on a commercial scale.

The results of extrusion experiments in which T-sections are made from PH 15-7Mo alloy, TZM alloy, and a sintered powder billet of Udimet 700 alloy are described and discussed.

- 53252 See Iron Base.

- 53276 DEVELOPMENT OF HIGH STRENGTH AND FRACTURE TOUGHNESS IN STEELS THROUGH STRAIN-INDUCED TRANSFORMATIONS. J. D. Morrison, M. A. Campbell, and J. R. Kattus, Southern Research Institute, Birmingham, Alabama. Report No. WAL TR 323.4/2-3, Summary Technical Report, September 5, 1963, Contract No. DA-01-009-ORD-1070
(12 references, 84 pages, 23 figures, 9 tables)

An investigation was made to determine the effects of variations in alloy content, cold-working temperature, and amount of cold work, on the tensile and toughness properties of metastable austenitic stainless steels. The purpose of this program was to arrive at an alloy composition and processing procedure that results in an optimum combination of strength and toughness in a structural sheet material that can be used in the fabrication of highly stressed structures, such as rocket motor casings.

Iron Base

- 52997 STRESS-CORROSION CRACKING OF HIGH-STRENGTH ALLOYS. R. B. Setterlund, Aerojet-General Corporation, Azusa, California. Frankford Arsenal, Report No. 2684, Final Report, September, 1963, Contract No. DA-04-495-ORD-3069
(11 references, 20 pages, 27 figures, 23 tables)

A stress-corrosion-cracking investigation was performed on one heat of 20 per cent nickel maraging steel and five heats of 18 per cent nickel maraging steel. These alloys were tested under three metallurgical conditions: (1) annealed and maraged, (2) cold-reduced and maraged, and (3) welded and maraged. Test environments included aerated distilled water, tap water, and 3 per cent NaCl and 0.25 per cent sodium dichromate solutions, as well as ambient air, 140 F water-saturated air, seacoast atmospheric exposure, hydrocarbon oil, soluble oil-water mixtures and trichloroethylene. Test methods included both two-point loaded beams and tensile-loaded samples having fatigue-crack stress-raisers.

Test results show that both the 20 per cent and 18 per cent nickel grades of maraging steel are susceptible to stress-corrosion cracking in specific environments. With the 18 per cent nickel steel the susceptibility is found to increase with increasing titanium content. With both alloys, prior cold-reduction is found to lessen susceptibility.

Tests on 6Al-4V titanium show it to be immune to failure under these same test conditions, while limited testing on a new vacuum melted steel having 9 per cent N, and 4 per cent Co shows marginal susceptibility.

- 53078 See Cobalt Base.

- 53079 CORRELATION AND INTERPRETATION OF HIGH-TEMPERATURE MECHANICAL PROPERTIES OF CERTAIN SUPERALLOYS. H. Conrad, J. White, and E. Bernett, Aerospace Corporation, El Segundo, California. USAF, Report No. TDR-169(3240-11) TN-1, Technical Documentary Report, March 11, 1963, Contract No. AF 04(695)-169, AD 404460
(27 references, 26 pages, 10 figures, 3 tables)

High-temperature mechanical property data (tensile and compressive proportional limit, 0.2 per cent yield strength, flow stress, tensile strength, creep rate and time to rupture) for an iron-base (N-155), a nickel-base (Rene'41) and a cobalt-base (L-605) superalloy were analyzed to evaluate the equation which correlates the data and to identify the dislocation mechanism which is rate controlling.

- 53129 STRAIN HARDENING AND AUSFORMING IN AN IRON-NICKEL ALLOY. M. Cohen and J. Taranto, Massachusetts Institute of Technology, Cambridge, Massachusetts. USAF, Report No. ARL 63-124, Final Technical Report, July, 1963, Contract No. AF 33(616)-6873
(31 references, 40 pages, 21 figures, 1 table)

By using a low-carbon iron - 31.9 weight per cent nickel alloy with $M_s = -28^\circ\text{C}$, it was possible to study the fine structure, diffraction line-broadening, and mechanical properties of plastically deformed austenite, ausformed martensite, and plastically deformed martensite. Both the

53129 (Continued)

refinement of martensitic plates (which increases the number of martensitic boundaries per unit slip path) and the high density of dislocations inherited from the strain-hardened austenite contribute to the strengthening of martensite by ausforming, with the former being more important in the yield strength and the latter being more important in the tensile strength. The micro-strains in the plastically deformed austenite are transmitted effectively to the ausformed martensite, but they do not play an essential role in the strengthening process.

The ductility of austenite and martensite decreases during strain hardening, but the ductility of the ausformed martensite remains constant. This favorable characteristic of ausformed martensite is attributed to the increased number of martensitic boundaries per unit fracture path.

In medium-carbon low-alloy steels, the observed strengthening due to ausforming is much larger than is found in the iron-nickel alloy investigated here, because the precipitated carbides in (tempered) martensite dominate the strengthening process.

53252 EFFECT OF HEAT TRANSFER ON CORROSION OF FERROUS ALLOYS IN BOILER WATERS.
W. E. Berry and F. W. Fink, Battelle Memorial Institute, Columbus, Ohio.
Report No. BMI-1626, Report, April 16, 1963, Contract No. W-7405-eng-92
(98 references, 30 pages, 2 figures, 1 table)

A survey has been made of the effect of heat transfer on the corrosion behavior of ferrous alloys in boiler waters, particularly as applied to liquid-metal-heated steam generators. The results have shown that ferrous alloy boiler tubes may fail during operation from general corrosion, oxygen pitting, on-load pitting, caustic embrittlement, chloride stress-corrosion cracking, or corrosion fatigue. All of these forms of corrosion, except on-load pitting, can be avoided by appropriate changes in design, operation, or boiler-water treatment. On-load pitting appears to be related to heat-transfer conditions, but its cause is not yet known. Heat transfer appears to affect corrosion behavior by raising the metal surface temperature, concentrating corrosive solids in the boiler water, releasing corrosion-promoting gases from solution, or providing thermal gradients in the metal and protective oxide film. Additional fundamental and applied research to define the variables and limiting conditions associated with thermal gradients as related to nucleate boiling, steam slug-flow, and thermogalvanic corrosion appears desirable.

LIGHT METALS

53159 See Miscellaneous.

53242 See High Strength Alloys.

53243 See High Strength Alloys.

Beryllium

- 53039 DEVELOPMENT OF IMPROVED FABRICATION METHODS, PROCESS AND TECHNIQUES FOR PRODUCING TYPICAL AIRCRAFT SHAPES FROM BERYLLIUM. R. G. Jenkins and J. M. Siergiej, Nuclear Metals, Inc., Concord, Massachusetts. ASD, ASD-TDR 7-644(III), Interim Technical Documentary Progress Report, June, 1963, Contract No. AF 33(657)-8783 (4 references, 23 pages, 7 figures, 5 tables)

A program for producing beryllium U-channel with excellent surfaces, unique mechanical properties and superior dimensional tolerances by extrusion and warm drawing is continuing. Extruded beryllium channel has been drawn at about 800 F to a thickness reduction of about 40 per cent. A thickness reduction of approximately 10 per cent causes some loss in ductility and increases the yield strength. Material that was drawn, annealed, redrawn, and reannealed contained enlarged grains and had mechanical properties no better than those of as-extruded material. Initial work to extrude and draw beryllium channel to prefixed target dimensions is under way.

New extrusions have been made to test the extrusion die design intended to provide feed material for the new draw dies. These latest dies are aimed at producing beryllium channel with prefixed target dimensions: (1) Flange height: 1 inch, (2) Channel widths: 1.5 inches, (3) Thickness: 0.040 inch.

Dimensions of extruded channels appear to be satisfactory for drawing; however, cladding breakthrough occurred.

- 53086 ROLLING IMPROVED BERYLLIUM SHEET-PHASE IV - PRODUCTION. M. B. Hornak, E. M. Grala, R. G. O'Rourke, G. L. Marsh, and L. S. Busch, The Brush Beryllium Company, Cleveland, Ohio. ASD, Report No. IR-7-753(IV), Interim Engineering Progress Report, Contract No. AF 33(600)-43037 (4 pages, 1 figure)

The object of this program is to develop improved flat beryllium sheet with high mechanical properties and good reproducibility.

The required amounts of virgin and recycle powders were collected and fabricated into two hot pressed blocks, each 29 1/2 x 28 1/2 x 12 inches thick.

- 53135 FIBER-REINFORCED METALS AND ALLOYS. IIT Research Institute, Chicago, Illinois. Bureau of Naval Weapons, Report No. IITRI-B241-8, Final Report, August 31, 1963, Contract No. N0w 62-0650-c (31 pages, 19 figures, 8 tables)

This report describes attempts to produce high-strength, low-weight fiber composites from beryllium fibers and aluminum matrix materials. The principles of fiber metallurgy strengthening are outlined, and the difficulties encountered in the Al-Be fiber system are described and discussed. It is concluded that the presently available beryllium fibers are unsuitable for fiber reinforcement purposes.

Titanium

52997 See Iron Base.

53015 See Nickel Base.

53054 See Engineering Steels.

53153 ELEVATED TEMPERATURE TENSILE AND CREEP PROPERTIES OF Ti-6Al-6V-2Sn BAR.
S. R. Seagle, Bridgeport Brass Company, Bridgeport, Connecticut. Report
No. 1000R445 M.O. 83016, Research Report, July 8, 1963
(3 references, 21 pages, 11 figures, 4 tables)

Both annealed and age hardened 5/8 inch diameter bar from a production heat of Ti-6Al-6V-2Sn were evaluated for elevated temperature properties. Tensile tests were conducted at 72, 200, 400, 600, 700, 800, and 1000 F. Long time creep exposures were conducted at 600, 700, and 800 F. The results are discussed and compared with data available on Ti-6Al-4V bar.

53255 EFFECT OF PROCESSING ON THE PROPERTIES OF Ti-8Al-1Mo-1V BAR. S. R. Seagle,
Bridgeport Brass Company, Bridgeport, Connecticut. Report No. 1000R444,
P.N. 93007, Research Report, June 26, 1963
(2 references, 34 pages, 13 figures, 10 tables)

Problems have been encountered in obtaining consistent static notch properties and satisfactory stress rupture strength in bar product of Ti-8Al-1Mo-1V. This study was designed to evaluate the effect of fabrication temperature and heat treatments on the static notch strength, stress-rupture strength, creep strength, and tensile properties of Ti-8Al-1Mo-1V. As a result of this work, a fabrication process is recommended.

Magnesium

53200 See Aluminum.

53283 MATERIAL DAMPING UNDER BIAXIAL STATE OF STRESS GENERATED BY COMBINED AXIAL AND INTERNAL PRESSURE LOADINGS. T. J. Mentel and S. H. Chi, University of Minnesota, Minneapolis, Minnesota. ASD, Report No. ASD-TDR-63-647, Final Report, July, 1963, Contract No. AF 33(657)-7453 (30 pages, 18 figures)

A test machine has been constructed which measures material damping in thin-walled, cylindrical specimens subject to combined internal pressure and axial cyclic loading. The purpose of this machine is to allow the complete range of biaxial stress states to be developed, so that the individual damping effects of distortional and dilatational straining action might be clearly discerned. Experimental results on a series of manganese alloy specimens are found to display significant damping effect associated with dilatational straining.

Aluminum

53054 See Engineering Steels.

53135 See Beryllium.

53200 STABLE WHITE COATINGS. G. A. Zerlaut and Y. Harada, IIT Research Institute, Chicago, Illinois. Jet Propulsion Laboratory, Report No. IITRI-C207-25, Summary Report, August 27, 1963, Contract No. NAS7-100 (180 pages, 65 figures, 38 tables)

The principal objective of this program was the development of a white spacecraft-thermal-control coating with exceptional stability to extraterrestrial solar radiation.

Other requirements were that: (1) the coating cure at 300 F or less, (2) the coating remain adherent to aluminum alloys and other spacecraft structural materials through temperature changes of 50 F per minute between 200 and -100 F.

Pigmented coatings, i.e., paints, were studied rather than evaporated metal films or chemical conversion coatings because of practical considerations.

In order to reduce the complexity of the problems involved, pigments and paint vehicles were exposed individually to ultra-violet radiation in vacuum.

The bulk of the research effort was devoted to the development of still more stable pigmented potassium silicate and methyl silicone paints. Various methyl silicone resins were synthesized in attempts to improve both their ultraviolet stability and their film-forming characteristics. The physical and optical properties of the silicate and silicone paints were measured as functions of paint thickness and composition. The effects of soiling and cleaning candidate coatings were studied in an attempt to define the problems anticipated during spacecraft fabrication and during checkout just prior to launch.

53241 DEVELOPMENT OF HIGH STRESS-CORROSION RESISTANCE IN 7XXX SERIES ALUMINUM ALLOYS. P. L. Mehr and E. H. Spuhler, Aluminum Company of America, Pittsburgh, Pennsylvania. Alcoa Green Letter, July 15, 1963 (4 references, 14 pages, 5 figures, 4 tables)

Extensive efforts at Alcoa Research Laboratories over the past few years have resulted in the development of new thermal treatments which provide excellent corrosion resistance in aluminum-zinc-magnesium-copper type alloys. The new temper, designated -T73 for 7075, is highly resistant to stress-corrosion cracking (SCC), does not exfoliate, and is practically immune to intergranular (I.G.) corrosion. The general surface corrosion which occurs in severe environments is predominantly a pitting type.

The new thermal treatments greatly increase the corrosion performance of the 7XXX series alloys, and practically eliminate the possibility of costly repairs or maintenance sometimes required because of SCC or exfoliation.

NONMETALLICS

Special Refractories

- 53021 THERMODYNAMIC AND KINETIC STUDIES FOR A REFRACTORY MATERIALS PROGRAM.
L. A. McClaine, Arthur D. Little, Inc., Cambridge, Massachusetts.
ASD, Fourth Semiannual Progress Report, August, 1963, Contract No.
AF 33(616)-7472
(36 references, 81 pages, 25 figures, 28 tables)

The objective of this program is to provide thermodynamic and kinetic data required to describe the chemical behavior of the zirconium and hafnium carbides and borides in oxygen, halogen, and nitrogen containing atmospheres. The preparation of HfC , $\text{ZrC}_{0.66}$ and HfB_2 are discussed. Low temperature heat capacity data and derived thermodynamic properties are presented for HfB_2 . The status of low temperature heat capacity, heat content, heat of formation, and vapor pressure studies on the carbides and borides are discussed. Studies to provide thermodynamic data on zirconium and hafnium halides and oxides by means of electron diffraction, equilibria, heat of solution, and spectroscopic techniques are reviewed. A detailed report is given on the kinetics of fluorination of ZrC and ZrB_2 . The status of studies on the defect structure of ZrO_2 by means of electrical conductivity techniques is presented. Additional studies on the oxidation of ZrB_2 in the 1200-1400 K region are presented and probable differences in oxidation mechanism above and below 1400 K are discussed. Oxidation studies presented for HfB_2 show it to be more resistant to oxidation than ZrB_2 .

- 53251 STRUCTURE AND PROPERTIES OF METALS BORIDES. Polytechnic Institute of Brooklyn, Brooklyn, New York. Report No. 032-414, Final Report, August, 1963, Contract No. Nonr 839(12)
(numerous references, 112 pages, numerous figures, numerous tables)

Research studies reported have had as their general objective the investigation of the structures and properties of selected refractory borides. A major effort has been devoted to the investigation of electron distribution and atomic thermal motions in titanium diboride in order to check on various types of electron transfer between boron and metal atoms which have been postulated to account for the electrical and related properties of this compound. Other efforts have been directed at the synthesis of related groups of boride phases, the determination of their crystal structures, and the investigation of their properties.

In this report the more significant findings of these investigations are summarized in the form of brief discussions of results which have been published.

Ceramic Oxide

- 53035 FABRICATION AND PLASTIC BEHAVIOR OF SINGLE CRYSTAL MgO-NiO AND MgO-MnO SOLID SOLUTION ALLOYS. T. S. Liu, R. J. Stokes, and C. H. Li, Honeywell Research Center, Hopkins, Minnesota. ONR, Twenty First Technical Report, August, 1963, Contract Nos. Nonr-4076(00) and NR-032-451 (17 pages, 10 figures)

A method of producing solid solution MgO-NiO and MgO-MnO single crystals is presented. The compressive yield strength of MgO is shown to increase nearly four-fold when small amounts of either NiO or MnO are in solid solution in MgO. The cleavage and slip behavior of these alloy crystals are found to be identical to that of MgO.

- 53173 DIRECT HIGH-TEMPERATURE SINGLE-CRYSTAL OBSERVATION OF ORIENTATION RELATIONSHIP IN ZIRCONIA PHASE TRANSFORMATION. G. M. Wolten, Aerospace Corporation, El Segundo, California. Report No. ATN-64(9236)-3, General Research, September 4, 1963 (10 references, 8 pages, 2 figures)

Work was undertaken to examine the validity of predictions concerning behavior of forward and reverse transformations of ZrO_2 single crystals from monoclinic structure to tetragonal structure. Single crystals of zirconia were attached to an insulator, oriented in a diffractometer and heated through the transformation. Axial relations were observed for both the forward and reverse transformations.

REFRACTORY METALS

53159 See Miscellaneous.

53242 See High Strength Alloys.

53243 See High Strength Alloys.

53248 INVESTIGATION OF MECHANISMS FOR OXIDATION PROTECTION AND FAILURE OF INTERMETALLIC COATINGS FOR REFRACTORY METALS. R. W. Bartlett, Philco Corporation, Newport Beach, California. ASD, Report No. ADF-TDR-63-753, Part I, Technical Documentary Report, June, 1963, Contract No. AF 33(657)-9170
(13 references, 68 pages, 36 figures, 4 tables)

A thermogravimetric and electron microscopic study of the oxidation of molybdenum silicides, particularly MoSi_2 , was made using powders and hot pressed samples. Temperatures below 1450 C and oxygen pressures from 0.01 to 1 atm were employed.

53257 EVALUATION TEST METHODS FOR REFRACTORY METAL SHEET MATERIAL. National Academy of Sciences, National Research Council, Washington, D. C. Report No. MAB-192-M, SD-118, Materials Advisory Board Report, April 22, 1963
(4 references, 39 pages, numerous figures, numerous tables)

The first edition of this report was issued by the Materials Advisory Board in September, 1961, as MAB-176-M.

A number of revisions have been made in an effort to improve the original edition, particularly in connection with the bend test. In addition, a number of new tests have been added. These are intended to take care of anticipated data requirements for fabrication evaluation and preliminary design study of refractory metal sheet materials. The new procedures include physical properties determinations as well as mechanical properties tests.

Columbium

52992 See Stainless Steels.

52996 COLUMBIUM ALLOY SHEET ROLLING PROGRAM. W. O. Gentry and H. A. Moreen, Fansteel Metallurgical Corporation, North Chicago, Illinois. Bureau of Naval Weapons, Interim Report No. 3, September 7, 1963, Contract No. NOW 63-0231-c
(4 pages, 2 tables)

The cast ingots of FS-85 (Cb-27Ta-10W-1Zr) and B-66 (Cb-5V-5Mo-1Zr), the two alloys selected for preparation and evaluation of pre-production quantities of sheet, have been converted to sheet-bar.

Conversion of the FS-85 was by forging. An attempt at upset forging a 9-inch length of the B-66 ingot was unsuccessful and the conversion of the remainder was by extrusion.

53022 See Vanadium.

53032 THE DEVELOPMENT OF OPTIMUM MANUFACTURING METHODS FOR COLUMBIUM ALLOY SHEET. A. L. Mincher, E. I. du Pont de Nemours and Company, Inc., Baltimore, Maryland. ASD, Interim Technical Progress Report No. IX, Contract No. AF 33(600)-39942
(62 pages, 27 figures, 15 tables)

Sheet panels of the D-43 alloy (Cb-10W-1Zr-0.1C) have been produced to 24 inch widths in three gages: 0.012 inch, 0.018 inch, and 0.030 inch.

This report describes the conversion of 8 inch diameter arc-cast ingots of the D-43 alloy to thin gage sheet by extrusion and rolling. The process schedule included a high temperature (3000 F) solution treatment.

A comprehensive evaluation of D-43 sheet properties is reported including: (1) Short time tensile properties to 3000 F, (2) Modulus to 3000 F, (3) Stress rupture behavior at 2000, 2200, 2400 F, (4) Thermal stability after high temperature exposures, (5) Creep data.

53081 STUDY OF DUCTILE COATINGS FOR THE OXIDATION PROTECTION OF COLUMBIUM AND MOLYBDENUM ALLOYS. Metals and Controls, Inc., Division of Texas Instruments Inc., Attelboro, Massachusetts. Navy Bureau of Weapons, First Bimonthly Progress Report, September 30, 1963, Contract No. NOW 63-0706-C
(14 pages, 2 figures, 3 tables)

Present day oxidation resistant coatings for columbium and molybdenum base alloys are deficient in ductility. Feasibility of developing ductile coatings for service to 3000 F is being explored, initially based on the use of platinum metals. Development of suitable diffusion barriers is required if platinum metals are to be successful.

Literature review of the performance of present day coatings and platinum metals has been conducted. Review of diffusion barrier literature has begun.

Equipment for screening oxidation tests has been set up and calibrated. Weight loss tests for platinum metals are under way.

53081 (Continued)

Columbium FS85 alloy and molybdenum TZM base metals have been ordered along with platinum coating metals.

A testing and evaluation program to produce and screen potentially useful composites is presented.

53236 See Molybdenum.

53245 DESIGN DATA STUDY FOR COATED COLUMBIUM ALLOYS. D. B. Warmuth, Thompson Ramo Wooldridge Inc., Cleveland, Ohio. Bureau of Naval Weapons, Report No. TM-3797-67, Third Bimonthly Technical Progress Report, October 1, 1963, Contract No. NOW 63-0471c
(5 references, 37 pages, 17 figures, 4 tables)

A brief resume' is presented of the preliminary evaluation tests conducted on Pfadler and TRW coated B-66 and X-110 alloy sheet. Additional analyses of these tests by metallographic investigations are complete and are presented with reference to the test results.

Microhardness tests were conducted in an effort to determine whether substrate contamination occurred during cyclic oxidation testing, in the absence of visible coating failure. Results of this study are discussed.

Extensive metallographic examination of coated specimens subjected to reduced pressure environments has been completed and is discussed.

The initial phase of the current Design Data Study; i.e., tensile tests on uncoated B-66 and X-110 alloy in the temperature range from temperature to 2600 F, has been completed and the results are reported. These data provide base-line properties for evaluation of coated-base metal systems.

Molybdenum

- 53037 MANUFACTURING METHODS FOR HIGH TEMPERATURE COATING OF LARGE MOLYBDENUM PARTS. G. J. Dormer and E. G. Pike, The Pfaudler Company, Rochester, New York. ASD, Report No. IR-7-977(IV), Interim Engineering Progress Report, Contract No. AF 33(657)-9343 (26 pages, 16 tables)

Installation and checkout of all equipment which has been approved for the PFR-6 coating of large molybdenum parts has been completed. Analysis of variance studies show the performance of the oxyacetylene torch test facility to be improved as a result of the modifications. Cleaning of large parts to be coated will consist of a wash in 6 per cent NaOH at 120 F, a rinse in warm tap-water, and a final rinse in deionized water at 190 F. Pack reuse studies show that a pack mixture may be reused at least three times provided ammonium chloride is added in each rerun. A study of process variables influencing scale-up of the pack cementation process shows ammonium chloride content of the mixture and process temperature to be the statistically important factors.

- 53081 See Columbium.

- 53235 See Coatings.

- 53236 BUREAU OF NAVAL WEAPONS REFRACTORY METAL STANDARDS PROGRAM. A. H. Roberson, United States Department of the Interior, Bureau of Mines, Washington, D. C. Bureau of Weapons, Quarterly Progress Report, September, 1963 (3 pages)

The object of this program is to prepare and chemically characterize samples of refractory metal alloys. Alloys chosen for this study are: (1) TZM (Mo - 0.5 Ti - 0.8 Zr), (2) FS-85 (Cb - 27 Ta - 0.7 Zr - 10 W), (3) T-111 (Ta - 8 W - 2 Hf).

- 53244 See Stainless Steels.

Tantalum

52992 See Stainless Steels.

53236 See Molybdenum.

53275 DEVELOPMENT OF TANTALUM - TUNGSTEN ALLOYS FOR HIGH PERFORMANCE PROPULSION SYSTEM COMPONENTS. R. W. Douglass, National Research Corporation, Cambridge, Massachusetts. Bureau of Naval Weapons, Final Summary Report, Contract No. NOrd-18787
(8 references, 117 pages, numerous figures, numerous tables)

Tantalum alloys containing up to 30 per cent tungsten were successfully arc-melted as 3-1/2 inch diameter ingots and fabricated to rod and sheet bar using conventional techniques.

Carbide thicknesses in the range 1 to 60 mils were obtained by carburizing tantalum and tantalum-tungsten alloys in the range 2000 to 2500 C.

Experimental rocket nozzle firings showed tungsten additions significantly improved the performance of tantalum and carburizing resulted in further improvement. Limitations of various carburized and uncarburized alloys as rocket nozzle materials were established.

Two full scale nozzles and two throat approach sections were prepared from the Ta-10W alloy, carburized and shipped to Aerojet-General Corporation for test firing.

Vanadium

- 53022 PILOT EVALUATION OF VANADIUM ALLOYS. F. C. Holtz, IIT Research Institute, Chicago, Illinois. Bureau of Naval Weapons, Report No. IITRI-B231-9, Interim Report, September 20, 1963, Contract No. NOW 62-0101-c (30 pages, 4 figures, 10 tables)

Two experimental alloys, V-35 Cr-1 Zr and V-25 Mo-2.5 Hf-0.1 C, exhibited severe cracking when fabricated to 0.050 inch sheet; grain boundary precipitates were noted.

Property evaluations for wrought material from 100-pound melts of V-60 Cb-1 Ti and V-20 Cb-4 Ti-1 Zr-0.075 C are reported from data obtained at IITRI and at other organizations participating under this data exchange program. Results of bend, tensile, compression, and oxidation tests are tabulated for alloy specimens at room and elevated temperatures; welded sheet samples were included in these evaluations. (The alloy compositions given above are percentage by weight.)

- 53038 HIGH-TEMPERATURE OXIDATION PROTECTIVE COATINGS FOR VANADIUM-BASE ALLOYS. IIT Research Institute, Chicago, Illinois. Bureau of Naval Weapons, Report No. IITRI-B6001-5, Final Report, September 12, 1963, Contract No. N600(19)59182 (44 pages, 18 figures, 10 tables)

Basic pack-siliconizing parameters--time, temperature, activator concentration and location--and edge and surface preparation techniques have been optimized for thin 0.020 to 0.030 inch sheet with respect to static and dynamic oxidation life, coating thickness, and coating adherence during elastic and plastic deformation.

Sixteen other vanadium-columbium base alloys containing various refractory metal additions were pack-siliconized and oxidation tested.

Oxidation behavior of compounds based on (V,Cb)Ni₂, (V,Cb)Ni₃, (V,Cb)Co₂, and (V,Cb)Co₃ were studied at 2000 and 2200 F.

- 53057 EVALUATION OF MECHANICAL PROPERTIES OF V-60CB-1Ti ALLOY. J. P. O'Connor, McDonnell Aircraft Corporation, St. Louis, Missouri. ASD, Report No. A073, Final Report, September 10, 1963, Contract No. AF 33(657)-11215 (24 pages, numerous figures, numerous tables)

Test results are presented concerning the weldability and formability of .050-inch thick annealed V-60 Cb-1Ti vanadium base alloy.

The bend radius, springback and other pertinent data for each specimen are presented.

While more specimens should be tested to define the limits of banding, test results indicate that base metal specimens may be bent around a 1t or smaller radius mandrel. However, welded specimens do not readily bend around a 1t radius.

- 53259 DISPERSION-STRENGTHENED VANADIUM ALLOYS. F. C. Holtz, IIT Research Institute, Chicago, Illinois. Bureau of Naval Weapons, Report No. IITRI-B6007-4, Bimonthly Report No. 4, September 9, 1963, Contract No. N600(19)59567 (12 pages, 3 figures, 1 table)

53259 (Continued)

Dispersion-strengthening mechanisms are being investigated as a means of improving creep and stress-rupture properties of vanadium-columbium-base alloys. Heat-treating studies of arc-melted and wrought materials containing hafnium or zirconium with carbon were studied.

Carbide and oxide dispersants were produced in a V-60 Cb-1 Ti matrix by powder metallurgy techniques. After sintering the compacted powders for 10 minutes at 2800 F and annealing for 16 hours at 2400 F, compositions containing HfC and ZrC were examined for hardening of the V-Cb-Ti alloy matrix.

Tungsten

- 52990 THERMIONIC EMISSION FROM CESIUM-COATED ELECTROSTATIC ION-THRUSTER ELECTRODES. T. W. Reynolds and E. A. Richley, Lewis Research Center, Cleveland, Ohio. NASA TN D-1879, September, 1963 (12 references, 33 pages, 12 figures, 1 table)

An analysis was made of the possible thermionic electron-emission currents attainable from cesium-coated tungsten accelerator electrodes in ion thrusters. Both an axisymmetric and a rectangular electrode configuration were examined for accelerator temperatures near the values yielding maximum emission.

Calculations of thermionic electron emission from cesium-coated tungsten accelerator electrodes are presented for a range of expected neutral-cesium emission fluxes. The qualitative effect of varying the accelerator material is discussed.

- 52995 TUNGSTEN FORGING DEVELOPMENT PROGRAM. E. J. Breznyak, Thompson Ramo Wooldridge Inc., Cleveland, Ohio. ASD, ASD TR 7-797 (IX), 9th Interim Technical Progress Report, August 19, 1963, Contract No. AF 33(600)-41629 (8 references, 45 pages, 19 figures, 5 tables)

The principal objective of the program was the development of methods for producing tungsten forgings for structural use in aerospace vehicles. To accomplish this aim the program was originally divided into five phases consistent with the state-of-the-art and with the non-integrated nature of the refractory metal and forging industries. The original five phases were: Phase I State-of-the-Art-Analysis, Phase II Billet Process Development, Phase III Development of the Forging Operation, Phase IV Forging Process Verification and Post-Forging Development, Phase V Final Pilot Production.

The program objectives were met. The specific objectives of the revised fifth phase and the additional sixth phase are: Phase V Development of Thin Section Forging Process - Extension of the developed forging process to controlled precision forging of thin section, non-structural tungsten shapes having optimum properties. Phase VI Verification of Thin Section Forging Process - Production of scaled-up thin section forgings to verify and demonstrate applicability of the process.

This report details the initial scaled-up forging trials of the Phase VI program effort.

- 53127 THEORETICAL AND EXPERIMENTAL INVESTIGATION OF ARC PLASMA-GENERATION TECHNOLOGY, PART II - VOLUME 2. R. R. John, W. L. Bade, M. M. Chen, H. DeBolt, T. W. Gibbs, H. Hoercher, R. W. Liebermann, P. Neurath, and J. Yos, Avco Corporation, Wilmington, Massachusetts. ASD, Report No. ASD-TDR-62-729, Final Technical Documentary Report, September, 1963, Contract No. AF 33(616)-7578 (84 references, 209 pages, 44 figures, 52 tables)

A series of electric arc phenomena including behavior of a fully developed laminar column, electrode materials behavior, and magnetic field arc discharge interaction have been studied analytically and experimentally. Numerical solutions are presented for the arc column

53127 (Continued)

energy balance equation, including consideration of column radiation, for hydrogen, nitrogen, oxygen, and air. General similarity relations are presented for describing arc column behavior. Experiments on a low power (50 kilowatt) gas stabilized plasma generator indicate that arc voltage and exit stream gas enthalpy decrease with increase in molecular weight of the working fluid. The performance of tungsten cathodes with stationary spots is shown to be improved by impregnating the tungsten with low work function materials such as thoria, and a mixture of oxides of barium, aluminum, and calcium. The presence of the low work function additives reduces electrode spot temperature. In contrast, arc rail experiments have shown that low work function electrodes are not desirable for arc discharges with magnetically driven roots. Magnetically driven arc roots tend to "stick" on low work function electrodes. Electrodes for magnetically driven arc configurations should have high work functions and clean, smooth surfaces.

- 53 128 THEORETICAL AND EXPERIMENTAL INVESTIGATION OF ARC PLASMA-GENERATION TECHNOLOGY, PART II - VOLUME I. W. L. Bade and J. M. Yos, Avco Corporation, Wilmington, Massachusetts. ASD, Report No. ASD-TDR-62-729, Final Technical Documentary Report, September, 1963, Contract No. AF 33(616)-7578
(190 pages, 70 figures, 11 tables)

The operating mechanism of thermionic arc cathodes is studied theoretically and experimentally. A theoretical model is formulated including important processes in the plasma of the cathode fall zone, at the plasma cathode interface, and in the cathode interior. In principle, this model permits detailed calculations of cathode performance solely from geometrical considerations and the physical properties of the cathode material and the gas. An approximate analysis indicates that the system has two different types of solution, the occurrence of which depends primarily upon how well the cathode is cooled. Well cooled cathodes tend to operate with a concentrated arc spot, while very poorly cooled cathodes operate without such a spot. Approximate solutions are worked out in numerical detail for spot-mode operation of a semi-infinite cathode and spotless mode operation of a thin rod shaped cathode cooled at one end. The results of a series of experiments on rod shaped thoriated tungsten cathodes are reported. The theory correctly predicts general trends of these data.

- 53196 OXIDATION RESISTANT HIGH TEMPERATURE PROTECTIVE COATINGS FOR TUNGSTEN. N. J. Nolting and R. A. Jefferys, Thompson Ramo Wooldridge Inc., Cleveland, Ohio. ASD, Report No. ASD TDR 63-459, Final Report, May, 1963, Contract No. AF 33(616)-8188
(127 pages, 82 figures)

The objective of this program was to develop and apply oxidation resistant high temperature protective coatings on 60 mil tungsten sheet.

A series of screening tests, conducted on various tungsten-coating combinations in air at 3300 F, determined that three of the coating composites developed exhibited sufficient potential for more extensive study and evaluation. These coatings were: a co-deposited diffusion alloy of silicon and tungsten, a diffusion alloy composite consisting of

53196 (Continued)

titanium, zirconium and silicon-tungsten deposited in successive cycles, and a diffusion alloy composite of titanium, zirconium-boron, silicon-tungsten deposited in successive cycles. The coated tungsten systems, in the oxidized state, were identified as W+(Si-W)-O, W+Ti-Zr-(Si-W)-O and W+Ti-(Zr-B)-(Si-W)-O. A laboratory scale process for application of each coating system to tungsten by the vacuum pack deposition process was developed and optimized. Oxidation characteristics of the coated systems in air under various static and cyclic conditions were determined from 1600 to 3650 F. Several hours protection was achieved under cyclic conditions as high as 3550 F.

Tensile tests on the W+(Si-W)-O and W+Ti-Zr-(Si-W)-O systems were conducted at regular temperature increments from room temperature to 3300 F under various environmental conditions. Tensile properties of uncoated tungsten sheet were determined at the same temperatures under inert atmosphere and vacuum as a basis for comparison. Stress oxidation tests on the W+(Si-W)-O and W+Ti-Zr-(Si-W)-O systems were conducted in air at 3000, 3200 and 3300 F under loads approximating 10 per cent and 20 per cent of the respective system yield strengths.

Thermal shock and hot gas erosion tests were also conducted on these coated systems in air at elevated temperatures.

Hardness values were determined and reported for the (Si-W)-O and Ti-Zr-(Si-W)-O coatings in the as coated and exposed conditions. X-ray diffraction patterns of the Ti-Zr-(Si-W)-O coating in the as coated, converted (preoxidized), and exposed conditions were made. Calculated "d" spacing values are reported for the phases present in each condition. X-ray diffraction patterns were also made on the (Si-W)-O coating in the as coated condition and after exposure in air.

Construction and design of a high temperature oxidation furnace for coating evaluation tests are described. Operation of the furnace at temperatures of 3000 to 3600 F for six week periods without interruption is discussed.

- 53247 PRELIMINARY INVESTIGATION OF MELTING, EXTRUDING, AND MECHANICAL PROPERTIES OF ELECTRON-BEAM-MELTED TUNGSTEN. W. R. Witzke, E. C. Sutherland, and G. K. Watson, NASA, Lewis Research Center, Cleveland, Ohio. Report No. NASA TN D-1707, Technical Note, May, 1963
(20 references, 41 pages, 21 figures, 6 tables)

Three tungsten ingots were prepared by the electron-beam-melting process. Billets machined from the ingots were successfully hot extruded in high- and low- velocity extrusion presses. The mechanical properties of the extruded electron-beam-melted tungsten were determined by tensile tests at temperatures from 70 to 3900 F. These data were compared to those of tungsten prepared by the powder metallurgy process.

Platinum Group

53081 See Columbium.

MISCELLANEOUS

53055 See Applications.

53080 ANALYTICAL STUDY FOR A HYDRODYNAMIC TEST SYSTEM. C. W. Semple, United States Army Materials Research Agency, Watertown, Massachusetts. USA, Report No. AMRA TR 63-12, Technical Report, September, 1963 (7 references, 25 pages, 11 figures, 7 tables)

Analytical equations relating specimen pressure to rise time were developed for specimens subjected to internal pressure by a hydrodynamic loading system. Rise time measurements were made during dynamic pressurization of a pressure vessel, and the experimental and analytical results compared. The effects of various system parameters on rise time were established from the analytical equations. Design guide lines are outlined for the construction of similar hydrodynamic systems.

53159 STUDY OF THE PHENOMENA OF HYPERVELOCITY IMPACT. D. R. Christman, J. W. Gehring, C. J. Maiden, and A. B. Wenzel, General Motors Defense Research Laboratory, Santa Barbara, California. NASA, TR63-216, George C. Marshall Space Flight Center, Huntsville, Alabama, Summary Report, June, 1963, Contract No. NAS8-5067 (numerous references, numerous pages, numerous figures, numerous tables)

This report is a critical investigation of the meteoroid hazard and of theoretical, empirical, and experimental investigations of hypervelocity impact. Simple and complex models of cratering and perforation are considered, as are the limitations and requirements imposed by practical engineering considerations. Results presented in this report are based on a detailed review of the published works of the many investigators in the field of hypervelocity impact and on a number of independent experimental and theoretical research programs being conducted at GM Defense Research Laboratories. The conclusions are summarized, and specific recommendations are made concerning future experimental and theoretical studies of hypervelocity impact.

53238 COMMERCIAL SUPERSONIC TRANSPORT AIRCRAFT RESEARCH PROGRAM. Defense Documentation Center, Alexandria, Virginia. ASTIA, Selected References-Bibliographic List No. 8, April, 1963, AD 404562 (38 pages)

This bibliography lists citations on the subject of the commercial supersonic transport aircraft research program, the ultimate goal being the development of a Mach 3 and 3,500 mile range transport that can cruise the world airlines.

Coatings

52992 See Stainless Steels.

53037 See Molybdenum.

53196 See Tungsten.

53235 DEVELOPMENT OF PROTECTIVE COATINGS FOR REFRACTORY ALLOYS. M. H. Ortner, Vitro Corporation, West Orange, New Jersey. Paper, (Received November, 1963)
(6 pages, 2 figures, 2 tables)

This program dealt with the application of oxidation-resistant coatings to refractory alloys by means of electrophoretic deposition. Particular emphasis has been placed upon the coating of molybdenum alloy threaded fasteners and foil, and a variety of coated samples have been evaluated.

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Applications

52990 See Tungsten.

52992 See Stainless Steels.

52993 See Composites.

52999 PROCESS DEVELOPMENT FOR INTERNAL ROLL EXTRUSION OF LARGE ROCKET MOTOR CASES. A. W. Ernestus, F. J. Kogel, and R. Gasik, N.T.W. Missile Engineering, Inc., Los Angeles, California. ASD, Report No. IR-7-992(III), Interim Engineering Progress Report, Contract No. AF 33(657)-9754 (11 pages)

This program has been initiated for the purpose of developing a machine capable of producing large one-piece rocket motor cases. The maximum size of such cases shall be 160 inches in diameter by 240 inches long. The machine necessary to generate these cases shall be designed and constructed, facilities shall be provided and two sample parts of 120 inches in diameter by 192 inches long shall be produced.

53055 AN EXPERIMENTAL INVESTIGATION OF GASEOUS-FILM COOLING OF A ROCKET MOTOR. J. G. Lucas and R. L. Golladay, NASA, Lewis Research Center, Cleveland, Ohio. Report No. TN D-1988, Technical Note, October, 1963 (12 references, 30 pages, 16 figures)

Data indicate that the Hatch-Papell gaseous-film-cooling correlation may be used in rocket combustion chambers with purely convective heating and nonreactive, nondecomposable coolants and in convergent and throat regions of the nozzle, if an increase heat-transfer coefficient is used. Reactive coolants may be used at the possible expense of a required flow somewhat higher than would be predicted for a nonreacting coolant with equivalent transport properties. The data indicate a possible large wall-temperature effect due to flame radiation, and an approximate method is presented for inclusion of this effect in the correlation.

53080 See Miscellaneous.

53093 INVESTIGATION OF STRUCTURAL PROBLEMS WITH FILAMENT WOUND DEEP SUBMERSIBLES. N. C. Myers, G. D. Lee, and F. C. Wright, H. I. Thompson Fiber Glass Company, Gardena, California. Bureau of Ships, Report No. MRD 2134, Second Quarterly Report, July, 1963, Contract No. NObs-88351 (numerous pages)

This program investigates some of the structural problems originating in the application of the filament wound composite to deep submersible vehicles. Small scale models are designed, fabricated, and tested under static and cyclic external pressure. Problems of major concern are penetrations, closure attachment, frame attachment, cylinder joints, and machinery-equipment installation and attachment.

The report contains design, fabrication, and test result data on closures, closure penetrations, cylinder-closure joints, and frame attachment.

53099 See Composites.

53109 See Composites.

53110 See Composites.

53137 See Composites.

53275 See Tantalum.

Composites

- 52993 DEVELOPMENT OF IMPROVED CUTTING TOOL MATERIALS. F. C. Perkins and R. Venuti, University of Denver, Denver Research Institute, Denver, Colorado. ASD, IR-7-714(III), Interim Engineering Progress Report, Contract No. AF 33(657)-9836 (55 pages, 26 figures, 5 tables)

Wettability studies have been conducted to determine carbide-refractory binder combinations which are promising for future cemented carbide tool development. Columbium and columbium alloys were found to wet HfC and ZrC, while stainless steel and chromium binder materials wetted TiC, TaC, HfC and ZrC. Hot pressing and liquid-phase sintering experiments have been performed in order to consolidate large compacts of some of the more likely combinations. Best densification of compacts was achieved by simultaneously liquid-phase sintering during hot pressing. Preliminary machinability tests and transverse rupture tests were conducted upon material from two of the most dense compacts.

Difficulty was experienced in liquid-phase sintering compacts with binder materials melting above 2000 C because of the tendency of the binder to react with the carbide. Certain highly refractory compositions have been successfully liquid-phase sintered during wettability studies. Experiments have suggested alternate approaches in order to alleviate the reactivity difficulty.

- 52994 FINAL REPORT ON FIBER REINFORCEMENT OF METALLIC AND NONMETALLIC COMPOSITES. R. H. Baskey, Clevite Corporation, Cleveland, Ohio. ASD, ASD-TDR-63-619, Final Report, July, 1963, Contract No. AF 33(657)-7139 (31 references, 109 pages, 24 figures, 20 tables)

The objective of this program was to establish parameters for the selection and application of fibers to the reinforcement of metal matrices and demonstrate that this could be achieved through the fabrication of sheet and forged products.

The program scope was divided into the following three phases: Phase I State-of-the-art survey on fiber metallurgy and compilation of bibliography, Phase II Parameter Study, Phase III Process Development.

The basic concept under development on this program involved the reinforcing of a high-temperature oxidation-resistant metal (i.e. nickel, nickel alloys, cobalt, and cobalt alloys) with a high-strength, high-temperature wire (i.e. tungsten or molybdenum). These fine wires possess exceptional strength and high modulus of elasticity at elevated temperature.

The experiments were designed to obtain preliminary tensile strength data by studying the effect of various length wires in reinforcing the above matrix materials. These materials were combined by conventional powder metallurgy techniques (i.e. cold pressing followed by sintering or hot pressing). Then the compacts were hot rolled or forged.

The fundamental properties and rolling characteristics gained from evaluating the above systems will also apply in other fiber-metal systems, provided that the components are compatible.

- 53058 STUDY OF STRESSES NEAR A DISCONTINUITY IN A FILAMENT-REINFORCED COMPOSITE METAL. N. F. Dow, General Electric, Philadelphia, Pennsylvania. U. S. Navy, Bureau of Weapons, Report No. R63SD61, Technical Information Series, August, 1963, Contract No. NOW-60-0465-D (49 pages, 12 figures)

An analysis is made of the stresses in the vicinity of a discontinuity in reinforcing filaments. The elastic analysis of Vinson is extended to apply to filament reinforcements, and this analysis in turn is extended to approximate the effects of yielding of the binder surrounding the filament. The results of the analysis are used to calculate typical stresses in filaments and binders, using as a model aluminum oxide whiskers in a binder of pure aluminum.

- 53074 PREPARATION AND PROPERTIES OF FIBER-REINFORCED STRUCTURAL MATERIALS. D. E. Price and H. J. Wagner, Battelle Memorial Institute, Columbus, Ohio. DMIC Memo 176, August 22, 1963 (1 page)

Metallic fibers in the form of whiskers, chopped fine wire, or wool have been incorporated into metallic matrices by two principal methods: classical powder-metallurgical methods, and infiltration of the fibers with molten matrix metal. Ceramic fibers, notably α - Al_2O_3 , have been used as whiskers or wool for reinforcing metallic matrices, the methods of preparation of the composite being the same as with metallic fibers. When metallic fibers are used to reinforce ceramics, the ceramic is either slip cast into the fiber mat and dried, or a mixture of the fiber and ceramic is hot pressed. Plastics and elastomers are combined with fibers by several methods.

- 53093 See Applications.

- 53095 OPTIMUM CONSTRUCTION OF REINFORCED PLASTIC CYLINDERS SUBJECTED TO HIGH EXTERNAL PRESSURE. H. R. Jacobson, Douglas Aircraft Company, Inc., Santa Monica, California. Bureau of Ships, Report No. SM-44057, Quarterly Progress Report No. 1, June 6, 1963, Contract No. NObs-88425 (34 pages, 7 figures, 3 tables)

The purpose of this program is to develop and prove out a theoretical method for accurately predicting the critical buckling strength of externally pressurized cylinders made from orthotropic materials and to find the optimum construction of filament reinforced plastic (FRP) cylinders under such loading.

A description of the program and its significance to the over-all BuShips Deep Submergence program and a summary of the work accomplished to date and that to be performed in the next period are given. Theoretical analytical expressions for predicting elastic buckling collapse and elastic constants of FRP cylinders are presented and discussed. Results of initial buckling and discontinuity stress analysis of proposed test cylinders are presented.

- 53099 MATERIALS STUDY - HIGH STRENGTH HIGH MODULUS FILAMENT WOUND DEEP SUBMERGENCE STRUCTURES. W. J. Eakins, De Bell and Richardson, Inc., Hazardville, Connecticut. Bureau of Ships, Final Report, February 15, 1963, Contract No. NObs-84672 (180 pages, 16 figures)

53099 (Continued)

The interaction among the resin, finish and glass was studied in detail. The surface chemistry of various fibrous glasses, before and after heat treatment, was studied by a refined titration technique. The etching effect of hot water on these glasses with several different surface treatments was found to be severe. A way was found to apply a stress either normal or parallel to the glass surface. An extended study was made applying the parallel or shear stresses to cut hoop specimens.

- 53102 OPTIMUM FILAMENT DIAMETER. D. Stevens, Narmco Research and Development Corporation, San Diego, California. Bureau of Ships, Twelfth Monthly Letter Report, June 10, 1963, Contract No. NObs 86347 (8 pages, 3 tables)

Data are presented on compressive strength and modulus of elasticity of glass filament wound rings made with fibers of various diameters. The effect of wall thickness on burst pressure of a filament wound pressure vessel is being investigated. The effect of wall thickness on ring bending modulus is also being studied. Unidirectional composite properties perpendicular to the fibers are being determined.

- 53109 STUDY OF THE EFFECTS OF THICKNESS ON THE PROPERTIES OF LAMINATES FOR UNDERWATER PRESSURE VESSELS. R. D. Saunders and R. L. Smith, Aerojet General Corporation, Azusa, California. Bureau of Ships, Report No. 2503, Final Report, April, 1963, Contract No. NObs 86406 (numerous pages, 36 figures, 1 table)

The basic program was to study the effects of thickness on the mechanical and physical properties of fiber-reinforced plastic laminates for deep-submersible external pressure vessels. An analysis of fabrication methods investigated, and problems related to thick-walled cylinders, are given. Methods of testing and test results of cylinders and rings are presented.

- 53110 RESIN SYSTEMS FOR FILAMENT-WOUND PRESSURE HULL STRUCTURES. I. Petkev and D. H. Eilfort, Aerojet General Corporation, Azusa, California. Bureau of Ships, Report No. 2534, Summary Report, April, 1963, Contract No. NObs 86307 (numerous pages, 15 figures, 20 tables)

Test methods and results are presented for the mechanical properties of a variety of cast thermosetting resins. Data are given for compressive yield strength and modulus, block and Johnson shear strength, interlaminar shear strength, and tensile strength.

Results are also presented from a water permeability study of both resin castings and NOL rings.

Fabrication techniques, test methods, and a statistical analysis of the test results are presented for composite cylinders having 0.31-inch and 0.50-inch wall thicknesses which were hydrostatically burst under biaxial external pressure. The mechanical properties of resin systems that are important to optimum cylinder performance under high external biaxial pressure were established by a statistical analysis of results and are also presented.

- 53134 DEVELOPMENT OF COMPOSITE STRUCTURAL MATERIALS FOR HIGH TEMPERATURE APPLICATIONS. W. H. Sutton, J. Chorne', A. Gatti, and E. Feingold, General Electric Company, Philadelphia, Pennsylvania. Bureau of Naval Weapons, Thirteenth Progress Report, August, 1963, Contract No. NOW 60-0465d
(14 references, 40 pages, 16 figures, 4 tables)

The purpose of this program is the development of new structural composite materials with high strength-to-weight ratios at elevated temperatures. The specific approach being used in the accomplishment of this goal is the reinforcement of metals with ultra-high strength, refractory single crystals (whiskers). The current emphasis in this program has been to demonstrate the potential of the concept through the reinforcement of silver with α -Al₂O₃ whiskers. The results obtained to date have been very encouraging, and a point has now been reached where the emphasis will be shifted from silver to nickel as the matrix material.

- 53135 See Beryllium.

- 53137 STUDY OF THE EFFECTS OF MECHANICAL DAMAGE ON THE PERFORMANCE OF FILAMENT-WOUND MOTOR CASES. R. A. Burkley, T. J. Boller, and I. R. Butcher, Goodyear Aerospace Corporation, Akron, Ohio. Bureau of Naval Weapons, Report No. GER 11154B, Progress Report No. 3, October 20, 1963, Contract No. NOW 63-0449-c(FBM)
(3 references, 19 pages, 8 figures, 2 tables)

This report discusses the conclusion of the fabrication, machine flanging, and testing of six-inch diameter filament-wound bottles.

The objectives of the study program under this contract are to study the effects of surface flaws on the performance of Polaris motor cases, to compare the effect of winding sequence on the ability to resist failure from surface flaws, and to determine the reliability of various repair techniques.

- 53258 FIBER-REINFORCED METALS AND ALLOYS. K. Farrell and N. M. Parikh, IIT Research Institute, Chicago, Illinois. Bureau of Naval Weapons, Report No. IITRI-B241-7, Bimonthly Report No. 7, July 4, 1963, Contract No. NOW 62-0650-c
(8 pages, 6 figures, 1 table)

A study of the strengthening effects of beryllium fibers in metal matrices is being made. The composites are prepared either by mixing powder matrix material with the beryllium fibers and then hot extruding the green compact or by casting and extruding. Present research effort is concerned with composites of beryllium fibers with aluminum powder and with aluminum alloy powder.

- 53272 EXPLORATION AND EVALUATION OF NEW GLASSES IN FIBER FORM. G. K. Schmitz, Solar, A Division of International Harvester Company, San Diego, California. Naval Research Laboratory, Report No. RDR 1343-4, Bi-monthly Progress Report No. 4, October 24, 1963, Contract No. NONR 3654(00)(X)
(19 pages, 4 figures, 1 table)

53272 (Continued)

The prime objectives of the program are: the examination of strength properties of virgin and damaged glass fibers by means of the length effect, and the determination of the strongest fiber for particular applications. Further objectives are: the systematic study of failure distributions at different strength levels; the effect of distribution variations on the strength-length relationship and, correlation of single fiber strength with the strength of strands of the same glass formulations.

These objectives will be attained by tensile tests on monofilaments, drawn at Solar and/or supplied by commercial vendors, and on current production strands supplied by the same vendors.

- 53281 THE SYNTHESIS OF BORON CARBIDE FILAMENTS. A. Gatti, R. Cree, and E. Feingold, General Electric, Missile and Space Division, Philadelphia, Pennsylvania. NASA, 1st Quarterly Report, October 10, 1963, Contract No. NASw-670
(35 pages, 9 figures, 1 table)

A study has been started which has as its goal the synthesis of boron carbide whiskers, their characterization in terms of chemistry and physical properties, and the utilization of such whiskers in composites.

Boron carbide whiskers have been grown successfully both by evaporation from pure B_4C vapor and by a chemical method based on the flow of appropriate gases over a heated substrate. Thus far, the best whiskers are grown by the pure vapor method. The experimental conditions required to grow B_4C whiskers, along with a description of the experimental equipment used, are presented. Included in this progress report is a short history of whisker growth and properties in general, along with a discussion of the expected advantages which could be realized if B_4C whiskers can be grown and utilized in composites.