25p.

N64-20593

CAT. 01 CODE-1

NASA TECHNICAL MEMORANDUM

NASA TM X-53006

FEBRUARY 3, 1964

NASA TM X-53006

1963 PUBLICATIONS

by MATERIALS DIVISION
Propulsion and Vehicle Engineering Laboratory

NASA

George C. Marshall Space Flight Center, Huntsville, Alabama

OTS PRICE

XEROX $ 2.60 ph.

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

TM X-53006

1963 PUBLICATIONS

by

Materials Division

ABSTRACT

20593 A

"1963 Publications" is a compilation of official abstracts of Marshall Technical Papers and Internal Notes, written by personnel of the Materials Division, released during 1963.

These reports may be requested, by designated report number, from the MSFC Library at the following address:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812
Attention: MS-IPL.

Author

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

TM X-53006

1963 PUBLICATIONS

by

Materials Division

MATERIALS DIVISION
PROPULSION AND VEHICLE ENGINEERING LABORATORY

TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	1
MARSHALL TECHNICAL PAPERS	
1962 Publications	2
Computer Simulation Study of Bruceton and Probit Methods of Sensitivity Testing	2
Evaluation of High Accuracy Products Corporation Model PC-101 Automatic Particle Counter	2
Corrosion Problems Associated with Metal Fasteners	3
Evaluation of the Beckman and Perkin-Elmer Total Hydrocarbon Analyzers and Their Correlation to the Carbon Tetrachloride Scrubber Method for Condensable Hydrocarbons	4
Investigation of Dielectric Materials for Space Vehicle Applications - Status Report I	4
Effects of Vacuum and Nuclear Radiation on Engineering Materials	5
Stress Corrosion of High Strength Aluminum Alloys	5
Apparatus for Determining Low Temperature Thermal Conductivity	6
Development of a Procedure for Electroplating on Ti-6Al-4V Alloy	6
Vacuum Compatibility of Engineering Materials (Solids)	6
An Ultrasonic Technique for the Evaluation of Bonded Honeycomb Structural Material	7
Corrosion Problems Associated with the Use of Titanium Fasteners to Connect Aluminum Components	7
Compatibility of Materials with Liquid Oxygen	8

TABLE OF CONTENTS (CONTINUED)

	Page
The Influence of Nuclear Radiation on Materials Technology for Space Application	8
Correlation of Particle Counts for Millipore and Whatman Methods of Analysis	9
A Survey of Vacuum Lubrication Developments	9
The Effect of Solidification Rate on the Beta Phase in 5456 Aluminum Alloy	10
Corrosive Effects of the Environment at Michoud Operations on Various Metal Alloys and Finishes	10
Computer Program for Least Squares Regression Analysis	10
A Literature Survey of the Corrosion of Metal Alloys in Liquid and Gaseous Fluorine	11
INTERNAL NOTES	
Low Temperature Mechanical Properties of Carpenter Stainless No. 20-Cb Sheet	11
Low Temperature Mechanical Properties of Aluminum Alloy Plate X7002-T6 and Its Weldments	12
Low Temperature Mechanical Properties of Parent Metal and Weldments of Waspaloy	12
Low Temperature Mechanical Properties of Aluminum Alloys X2119 and 2219	12
Low Temperature Mechanical Properties of 7075-T652 Hand Forging, 7075-T651 Plate, and 7178-T6 Extrusion	13
Evaluation of Dry Film Lubricants in Vacuum for Engine Gimbal Bearings	13
Evaluation of 2219 Aluminum Alloy Welds with the Electron Microscope	14
Elastic and Plastic Behavior of Weldments of Aluminum Alloy Plate 2219-T87	14

TABLE OF CONTENTS (CONCLUDED)

Page

Preliminary Investigation of Effects of Vacuum on Hydrogen Peroxide Systems 15

Analysis of Copper on Saturn Container Surfaces by Spectrographic and Electrographic Techniques, An Evaluation Report 15

The Low Temperature Mechanical Properties of Fe-18Ni-8Co-5Mo Maraging Steel 16

Low Temperature Properties of Composite Sandwich Constructions, Saturn S-IV Common Bulkhead Type 17

Welding of Bimetallic Pipe (ASTM-A-106 Grade C Carbon Steel Pipe Lined with Cupro-Nickel Tubing) 17

Low Temperature Mechanical Properties of "Unitemp" 212 Alloy 17

Corrosive Effects of Cape Canaveral Environment on S-I-D5 Vehicle 18

GEORGE C. MARSHALL SPACE FLIGHT CENTER

TM X-53006

1963 PUBLICATIONS

by

Materials Division

SUMMARY

This report lists and summarizes the Marshall Technical Papers and Internal Notes written by personnel of the Materials Division, Propulsion and Vehicle Engineering Laboratory, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, during 1963.

INTRODUCTION

The mission of the Materials Division is to conduct research and development in the fields of chemistry, metallurgy, chemical engineering, physics, and other technologies related to materials in research and engineering. These investigations are conducted in support of the launch vehicle programs of the George C. Marshall Space Flight Center. This report lists and summarizes the technical reports written by personnel of the Materials Division during 1963.

Requests for additional copies of these reports, designated by the report number, should be addressed to:

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812
Attention: MS-IPL.

MARSHALL TECHNICAL PAPERS

January 7, 1963 — 1962 PUBLICATIONS — MTP-P&VE-M-63-1

by Engineering Materials Branch

Unclassified, 20 pages

This report lists and summarizes the Marshall Technical Papers and Internal Notes written by personnel of the Engineering Materials Branch, Propulsion and Vehicle Engineering Division, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, during 1962.

January 31, 1963 — COMPUTER SIMULATION STUDY OF BRUCETON AND PROBIT METHODS OF SENSITIVITY TESTING — MTP-P&VE-M-63-2

by John B. Gayle

Unclassified, 24 pages, 2 illustrations, 11 tables

A computer simulation technique has been used to evaluate the suitability of the Bruceton and Probit methods of sensitivity testing for launch vehicle applications. The results indicate that either method permits satisfactory estimates for the mean value of a normal distribution. However, for launch vehicle applications, estimates of the levels of stimulus corresponding to very high or very low percentage reactions usually are required; neither method permits reliable estimates for such levels when the distribution is non-normal, a condition which occurs with sufficient frequency that assumption of a normal distribution cannot be justified as routine procedure.

February 15, 1963 — EVALUATION OF HIGH ACCURACY PRODUCTS CORPORATION MODEL PC-101 AUTOMATIC PARTICLE COUNTER — MTP-P&VE-M-63-3

by J. O. Romine and J. B. Gayle

Unclassified, 25 pages, 9 illustrations, 4 tables

The HIAC automatic particle counter has been evaluated to determine its suitability for both laboratory and in-line monitoring of particulate contamination in MIL-H-5606 hydraulic fluid. The investigations were accomplished by passing fluid, representing varying levels

of particulate contamination, through the counter. For laboratory samples, this was accomplished by use of a standpipe arrangement which was pressurized from the laboratory air supply. For in-line samples, the counter was connected to a filtration cart for which the operating flow rate and pressure were 3 gpm and 50 psi, respectively; the flow rate through the counting cell was approximately 1 ml/min.

Statistical analysis of the data indicated that the HIAC counts have an acceptable degree of precision and are closely correlated with the microscopic counts. Therefore, it was concluded that the HIAC counter is well suited for contamination analyses of particles over 10μ in size.

March 8, 1963 CORROSION PROBLEMS ASSOCIATED WITH METAL FASTENERS MTP-P&VE-M-63-4

by J. G. Williamson and E. E. Nelson

Unclassified, 15 pages, 5 illustrations, 1 table

Many mechanical properties and physical and metallurgical characteristics affect the choice of materials for fasteners used in space launch vehicles. In order to determine the extent of the corrosion problems that could arise from commercial fasteners, various fasteners presently being used in the S-I stage of the Saturn vehicle were subjected to corrosion tests. Corrosion studies were made by exposing representative fasteners with various metal alloys to a 5% salt spray environment for 2000 hours.

The tests indicated not only the need for the fasteners to be of similar material to the components being connected but that the method of fastening and the physical configuration of the fasteners should be given equal consideration. Fasteners that have unprotected areas, in the form of broken pins and collars as part of the fastening mechanism, can cause serious corrosion problems. When it becomes absolutely necessary to use this type of fastener, the unprotected part of the fastener should be given a protective treatment immediately after installation. Since only a small amount of corrosion can cause highly stressed fasteners to fail, the correct selection of material and types of fasteners becomes of paramount importance in preventing corrosion which could seriously affect the integrity of the entire vehicle.

March 14, 1963 EVALUATION OF THE BECKMAN AND PERKIN-ELMER TOTAL HYDROCARBON ANALYZERS AND THEIR CORRELATION TO THE CARBON TETRACHLORIDE SCRUBBER METHOD FOR CONDENSABLE HYDROCARBONS MTP-P&VE-M-63-5

by Cortes L. Perry

Unclassified, 14 pages, 1 table

This report presents a comparison of two commercial hydrocarbon analyzers and the correlation of results obtained by means of these analyzers with those obtained by the carbon tetrachloride scrubber method for trace hydrocarbon analysis. Both commercial instruments were of the hydrogen flame ionization type and were total hydrocarbon analyzers. They were the Perkin-Elmer Model 213-B Hydrocarbon Detector and the Beckman Model 109 Hydrocarbon Analyzer.

Data are presented which indicate a lack of correlation of the total hydrocarbon analysis with the CCl_4-Scrubber condensable hydrocarbon analysis.

A comparison of the features of each of the two total hydrocarbon analyzers and a discussion of the operation of each are presented.

April 10, 1963 INVESTIGATION OF DIELECTRIC MATERIALS FOR SPACE VEHICLE APPLICATIONS MTP-P&VE-M-63-6

STATUS REPORT I

by Raymond L. Gause

Unclassified, 45 pages, 19 illustrations

The need has been established for experimental data on dielectric materials at low pressure and low temperature to design space vehicle systems with confidence. Hence, an experimental program has been initiated, and a specialized cryogenic-vacuum dielectric test cell has been developed to obtain data on fundamental dielectric properties. A vibration test apparatus has been employed on small hook-up wires, and a high voltage, dielectric strength test apparatus is being developed for use at low temperatures and low pressures.

Dielectric constant and dissipation factor data obtained on quartz, tetrafluoroethylene (Teflon), and an aromatic polyimide (SP) indicated almost no variation with the changing environment, whereas polyvinyl chloride changed rapidly. Actual capacitors of mica and polyethylene

terephthalate (Mylar) exhibited negligible change from 20 to -268°C, where ceramic disc capacitors changed slightly and tantalum electrolytic capacitors varied drastically. These property variations could be vital to capacitor networks and coaxial cables in critical circuits if not considered in circuit design.

May 20, 1963 EFFECTS OF VACUUM AND NUCLEAR RADIATION ON ENGINEERING MATERIALS MTP-P&VE-M-63-7

by W. R. Lucas

Unclassified, 26 pages, 6 tables

The capacity of a material to maintain reasonable properties for an appropriate time in a hostile environment frequently is of greater concern in the selection of rocket and space vehicle materials than the basic properties. Of prime importance to the selection of materials, particularly organic materials, for a nuclear-powered rocket is the resistance of the materials to vacuum and radiation simultaneously. This paper deals with the state of knowledge on the resistance of engineering materials to vacuum, to radiation, and to radiation plus vacuum. The emphasis throughout the paper is on vehicle and reactor accessory hardware rather than on reactor materials.

Selected data obtained from the investigation of the combined effects of reactor radiation and vacuum on organic engineering materials (Contract NAS8-2450 with General Dynamics/Fort Worth) are discussed. The data include results of mechanical tests prior to and after irradiation. The test specimens are representative samples of thermal insulation, potting compounds, structural laminates, structural adhesives, thermal control coatings, dielectric materials, seals, and lubricants.

Plans and suggested approaches for experimental work in the immediate future are discussed.

June 24, 1963 STRESS CORROSION OF HIGH STRENGTH ALUMINUM ALLOYS MTP-P&VE-M-63-8

by T. S. Humphries

Unclassified, 19 pages, 3 illustrations, 6 tables

The stress corrosion properties of some of the most commonly used high strength aluminum alloys--2014, 2024, 2219, 7075, 7178, and 7079--are presented. The effectiveness of a few protective finishes in combating stress corrosion also is presented. Alternate immersion in 3 1/2

percent salt solution and exposure to the atmosphere at MSFC constituted the test media. It was found that all of the high strength aluminum alloys tested were highly susceptible to stress corrosion cracking in the short transverse direction except 7075-T73 and 2219-T87. Neither chemical conversion nor anodic coatings were effective in combating stress corrosion; however, either of these coatings plus zinc chromate primer afforded considerable protection.

July 16, 1963 APPARATUS FOR DETERMINING LOW TEMPERATURE THERMAL CONDUCTIVITY MTP-P&VE-M-63-9

by C. F. Smith

Unclassified, 27 pages, 12 illustrations, 5 tables

Because of the need for low temperature thermal conductivity data on a wide variety of materials used in the space launch vehicle field, an apparatus was developed for determining such information on metal over a temperature range of 80 to 225°K (-316 to -55°F). Data are presented for copper, stainless steel, and aluminum alloys and compare quite favorably with values reported by other investigators on the same alloys.

August 6, 1963 DEVELOPMENT OF A PROCEDURE FOR ELECTROPLATING ON Ti-6Al-4V ALLOY MTP-P&VE-M-63-10

by A. O. Schlosser and J. R. Lowery

Unclassified, 17 pages, 5 tables

A procedure was developed for the production of adherent electroplated coatings on Ti-6Al-4V alloy. The process consists of anodic activation in an acetic acid-hydrofluoric acid solution, followed by electroplating by conventional methods. Coatings produced were adherent and protected the metal substrate from reactions with LOX under impact. Processing treatments did not appear to have any embrittling effects on the titanium alloy due to excessive hydrogen pick-up.

September 16, 1963 VACUUM COMPATIBILITY OF ENGINEERING MATERIALS (SOLIDS) MTP-P&VE-M-63-11

by J. B. Gayle, S. V. Caruso, and C. T. Egger

Unclassified, 78 pages, 56 illustrations, 5 tables

The effects of vacuum and elevated temperature on fifty-four solid materials are reported; similar results for liquids and semi-solids will be reported separately. Although the extrapolation of laboratory results to service conditions has not been demonstrated, preliminary results discussed herein suggest that such extrapolations are possible, at least for some materials.

Other preliminary results indicate that weight regains on exposure to air subsequent to vacuum testing are small for most materials and are not influenced by the temperature used for the vacuum test. Good correlation of total weight loss generally was noted for results with continuous weighing in standard vacuum systems and those for screening tests utilizing before-and-after weighing from a vacuum oven. However, the screening tests provide little information regarding the rate of weight loss, and it was noted that some materials appear to undergo oxidation and, consequently, gain in weight during tests at elevated temperatures when the pressure in the test chamber is of the order of 10^{-1} to 10^{-2} Torr.

September 30, 1963 AN ULTRASONIC TECHNIQUE FOR THE EVALUATION OF BONDED HONEYCOMB STRUCTURAL MATERIAL MTP-P&VE-M-63-12

by W. N. Clotfelter

Unclassified, 12 pages, 6 illustrations

The widespread usage of composite honeycomb materials in launch vehicle designs has necessitated considerable effort in the development of techniques which describe, nondestructively, the condition of the honeycomb material. This report describes the progress to date in developing a continuous wave through-transmission ultrasonic technique that is applicable to the quality verification of composite honeycomb materials. Although incomplete at this time, the prospect is good for the successful solution to the problem of inspecting such composite materials.

September 30, 1963 CORROSION PROBLEMS ASSOCIATED WITH THE USE OF TITANIUM FASTENERS TO CONNECT ALUMINUM COMPONENTS MTP-P&VE-M-63-13

by E. E. Nelson and J. G. Williamson

Unclassified, 15 pages, 6 illustrations, 2 tables

Corrosion studies, conducted to determine the extent of the corrosion problems that could arise from the use of titanium fasteners to connect aluminum components, have indicated that Ti-6Al-4V alloy fasteners can be used to connect aluminum components without significant corrosion on the aluminum component in a normal atmospheric environment. However, exacting installation procedures must be followed for adequate control of galvanic corrosion.

December 4, 1963 COMPATIBILITY OF MATERIALS WITH LIQUID OXYGEN MTP-P&VE-M-63-14

by C. F. Key and W. A. Riehl

Unclassified, 94 pages, 6 illustrations, 8 tables

The test instrument and procedure developed by Lucas and Riehl (Ref. 1) was used to determine the compatibility of a wide variety of materials with liquid oxygen (LOX). This method is based upon the tendency of materials to react with LOX on impact and is commonly known as the "ABMA Tester." Within the past eight years' use, over 100,000 individual test drops have been made on approximately 1,000 different materials.

Pertinent data from these tests have been compiled, and the findings are presented in this report. Recommendations are made for guidance of designers and others in selection of safe materials for use in oxygen systems. Materials are discussed according to the following classifications: (1) Lubricants, (2) Sealants and Threading Compounds, (3) Thermal and Electrical Insulation, (4) Elastomers, Plastics, and Adhesives, (5) Gaskets and Packing, (6) Metals, Alloys, and Solders, (7) Dye Penetrants, and (8) Solvents, Cleaning Solutions, and Miscellaneous.

October 25, 1963 THE INFLUENCE OF NUCLEAR RADIATION ON MATERIALS TECHNOLOGY FOR SPACE APPLICATIONS MTP-P&VE-M-63-15

by Lowell K. Zoller

Unclassified, 17 pages, 6 tables

The extension of man's presence into the realm of "space" continually necessitates dramatic developments in materials technology to meet the unique environments and constraints imposed by the space vehicles and by "space" itself. The fundamental interest in deep space exploration has made the use of nuclear power sources attractive for space vehicles. The

presence of such a copious source of nuclear radiation, in addition to the indigenous space radiation, however, further restricts the applicability of materials, necessitates extensive multiple-environment testing, and demands the development of new, more environment-resistant materials. It is intended in this discussion to define the various material categories and the associated combinations of environments which must be investigated and to consider some imposed modifications of accepted test methods including radiation dosimetry.

November 21, 1963 CORRELATION OF PARTICLE COUNTS FOR MILLIPORE AND WHATMAN METHODS OF ANALYSIS MTP-P&VE-M-63-16

by J. O. Romine and J. B. Gayle

Unclassified, 15 pages, 3 tables, 2 illustrations

Results of particulate contamination analyses by the Millipore and Whatman methods have been correlated for samples representing a wide range of contamination levels. These data indicate that although the different types of filters afford approximately equal particle retention, the modes of retention are markedly different. The particles are retained almost exclusively on the surface of the Millipore filter; whereas, with the Whatman filter, some particles are retained on the surface, and others are embedded in the filter structure. There also appears to be a significant difference in the ease with which particles retained on the surfaces of these different types of filters can be distinguished microscopically. It, therefore, appears that any numerical equation relating the results obtained by these methods must be restricted to the particular type of contaminant present in the samples for which the equation was derived.

December 7, 1963 A SURVEY OF VACUUM LUBRICATION DEVELOPMENTS MTP-P&VE-M-63-17

by E. C. McKannan and J. E. Kingsbury

Unclassified, 14 pages, 2 tables

Current vacuum lubrication programs in eight laboratories are reviewed for several purposes, such as: (1) collecting available information in one reference and up-dating a previous effort toward this end, (2) determining the degree of coverage of probable applications and requirements by current development programs, and (3) comparing test methods and conclusions from different programs to increase the reliability in selection of specific materials and components. Some generalized conclusions have been made where there has been sufficient agreement among the programs reviewed.

December 7, 1963 THE EFFECT OF SOLIDIFICATION RATE ON THE BETA PHASE IN 5456 ALUMINUM ALLOY MTP-P&VE-M-63-18

by H. H. Kranzlein

Unclassified, 24 pages, 10 illustrations, 3 tables

The presence of beta phase (Mg_5Al_8) in the microstructure of welded 5456 aluminum alloy may be detrimental to the strength and corrosion properties of the welds. In the investigation covered by this report, the influence of solidification rate on the quantity, distribution, and particle size of the beta phase was established to determine if control of the phase is feasible through regulation of the solidification rate. Experiments with small castings indicate that limited control of the quantity and distribution of the beta phase is possible.

December 7, 1963 CORROSIVE EFFECTS OF THE ENVIRONMENT AT MICHOUD OPERATIONS ON VARIOUS METAL ALLOYS AND FINISHES MTP-P&VE-M-63-19

by R. H. Higgins

Unclassified, 19 pages, 1 illustration, 1 table

Corrosion tests of the various metal alloys and associated protective finishes being used on Saturn I and Saturn V vehicles are being conducted under atmospheric conditions at the Michoud Operations and at MSFC. These tests show the atmospheric environment at the Michoud Operations to be more corrosive than that of MSFC but not as severe as the environment at Cape Canaveral, Florida. Results and conclusions from these tests are given after a one-year exposure period.

December 13, 1963 COMPUTER PROGRAM FOR LEAST SQUARES REGRESSION ANALYSIS MTP-P&VE-M-63-20

by J. B. Gayle and C. L. Hopkins

Unclassified, 42 pages, 4 illustrations, 4 tables

Many types of numerical data are obtained in the design and development of large launch vehicles. As one method of data analysis, a computer program has been developed which utilizes the method of least squares to obtain an empirical equation relating two or more variables. Supplementary calculations included in the program provide estimates of the reliability of values obtained with the resulting regression equation and of the empirical constants contained in the regression equation.

Although the theoretical basis for the method is included in the Appendix of this report, application of the program to a wide variety of scientific and engineering data is possible without a detailed knowledge of statistical methods.

December 31, 1963 — A LITERATURE SURVEY OF THE CORROSION OF METAL ALLOYS IN LIQUID AND GASEOUS FLUORINE — MTP-P&VE-M-63-21

by J. H. Cabaniss and J. G. Williamson

Unclassified, 27 pages, 9 tables

A literature survey on the corrosive nature of both liquid and gaseous fluorine is presented. This paper contains general information regarding: (1) chemical reaction of fluorine with various metallic materials; (2) conditions under which these materials can be used with fluorine; (3) results of corrosion tests that have been conducted on various materials over the temperature range of -320°F (-196°C) to 1300°F (704°C).

INTERNAL NOTES

January 7, 1963 — LOW TEMPERATURE MECHANICAL PROPERTIES OF CARPENTER STAINLESS NO. 20-Cb SHEET — IN-P&VE-M-63-1

by C. V. Lovoy

Unclassified, 11 pages, 2 illustrations, 3 tables

The mechanical properties of Carpenter Stainless No. 20-Cb and its weldments were determined at temperatures from +80°F to -423°F. The tensile and yield strengths of weldments are equivalent to, or greater than, those obtained from the parent metal. Both parent metal and weldments had tensile and yield strengths at -423°F, approximately twice those obtained at +80°F. The notched-tensile strength increased 65%, from +80°F to -423°F. Both parent metal and weldments have favorable ductility at all test temperatures.

The relatively low yield strength (49,300 psi at +80°F) practically eliminates the use of this alloy for structural applications where a high strength/density material is required.

January 9, 1963 LOW TEMPERATURE MECHANICAL PROPERTIES OF ALUMINUM ALLOY PLATE X7002-T6 AND ITS WELDMENTS IN-P&VE-M-63-2

by W. R. Morgan

Unclassified, 14 pages, 3 illustrations, 5 tables

The mechanical properties of aluminum alloy plate X7002-T6 (0.750) inch thick) and its weldments (plate thickness 1.250 inches) were determined at temperatures from ambient to -423°F. The tensile strength of the parent alloy was considerably greater at -423°F than at ambient temperature. The notched/unnotched tensile ratios were greater than unity at temperatures from +80° to -200°F. The tensile strengths of the weldments also increased with a decrease in temperature. Weld joint efficiency remained almost constant from +80° to -200°F but decreased with additional decrease in temperature.

January 18, 1963 LOW TEMPERATURE MECHANICAL PROPERTIES OF PARENT METAL AND WELDMENTS OF WASPALOY IN-P&VE-M-63-3

by C. V. Lovoy

Unclassified, 18 pages, 5 illustrations, 6 tables

The mechanical properties of Waspaloy sheet in the annealed and age-hardened conditions were determined at temperatures from 80°F to -423°F. The mechanical properties of the material in both conditions were not altered significantly by rolling direction. Strength increased with decrease in temperature, with the age-hardened alloy (parent metal and weldments) being superior over the temperature range of 80°F to -423°F.

Composite weldments of age-hardened Waspaloy and annealed 321 stainless steel had good mechanical properties. Weld joint efficiency was 85 percent or greater, and a minimum elongation of 14.7 percent was obtained over the temperature range of 80°F to -423°F.

March 27, 1963 LOW TEMPERATURE MECHANICAL PROPERTIES OF ALUMINUM ALLOYS X2119 and 2219 IN-P&VE-M-63-4

by C. V. Lovoy

Unclassified, 11 pages, 2 illustrations, 3 tables

The mechanical properties of Kaiser aluminum alloys X2119-T6M and 2219-T6M (0.60" sheet) were determined at temperatures from 80°F (26.7°C) to -423°F (-252.7°C).

The smooth specimen ultimate tensile strength, yield strength, and elongation values for both alloys at all test temperatures are comparable to the properties of 2219-T81. However, at -423°F (-252.7°C), the toughness characteristic (as measured by the notched/unnotched tensile ratio) for both alloys was somewhat questionable. The notched/unnotched tensile ratio, at -423°F (-252.7°C), was 0.61 for X2119, and 0.63 for 2219; at -320°F (-196°C), these values were 0.86 and 0.91, respectively.

Aluminum Alloy X2119 is an experimental alloy, whose chemical composition closely resembles that of aluminum alloy 2219. The mechanical properties of both these alloys were approximately the same at corresponding test temperatures.

April 12, 1963 — LOW TEMPERATURE MECHANICAL PROPERTIES OF 7075-T652 HAND FORGING, 7075-T651 PLATE, AND 7178-T6 EXTRUSION — IN-P&VE-M-63-5

by P. C. Miller

Unclassified, 11 pages, 3 illustrations, 3 tables

The mechanical properties of two wrought aluminum alloys, 7075 and 7178, were determined at temperatures from ambient to -423°F (-252.7°C). The alloys were tested in three different forms, 7075-T652 hand forgings, 7075-T651 plate, and 7178-T6 extrusions. Although having high tensile and yield strengths at low temperatures, these alloys, in the tempers and forms tested, are not recommended for critical applications at temperatures below -200°F (-129.0°C) since both elongation and notched tensile strength decrease rapidly at temperatures below this level. The 7178-T6 extrusion material was comparatively more sensitive, in this respect, than the other two alloys.

April 29, 1963 — EVALUATION OF DRY FILM LUBRICANTS IN VACUUM FOR ENGINE GIMBAL BEARINGS — IN-P&VE-M-63-6

by K. E. Demorest and E. C. McKannan

Unclassified, 21 pages, 15 illustrations, 3 tables

A simulated gimbal test apparatus, previously employed to study materials in the RL-10 engine gimbal bearing, was used to evaluate

several dry film lubricants for application in engine gimbal bearings exposed to hard vacuum. Thirteen candidate lubricant materials were evaluated in screening tests, and two were selected for further study at various environmental pressures, temperatures, and surface velocities. The first lubricant selected for intensive study consisted of molybdenum disulfide, graphite, and gold in a binder of sodium silicate, and subsequently was designated MLF-5 in Marshall Specification #253. It has been specified as the gimbal lubricant on all RL-10 A-3 gimbal bearings. The second lubricant consisted of molybdenum disulfide, burnished into zirconium silicate. Preliminary evaluation indicates this lubricant, developed later than MLF-5, to be superior to MLF-5. Both coatings provide reproducibly low, constant friction and wear properties at all the environmental conditions tested, unlike the resin bonded coatings previously employed.

July 24, 1963 EVALUATION OF 2219 ALUMINUM ALLOY WELDS WITH THE ELECTRON MICROSCOPE IN-P&VE-M-63-7

by H. H. Kranzlein

Unclassified, 18 pages, 10 illustrations

The microstructure of 2219-T37 and -T87 aluminum alloy welds was studied with the electron microscope to evaluate the effects of welding on the micromorphology of the alloy. Particular emphasis was placed on the microstructure of the fusion zone. Electron micrographs of the fusion zone indicated a cored microstructure with grain boundary networks of the alpha plus $CuAl_2$ eutectic. The cored microstructure resulted in nonuniform response of the fusion zone and filler metal to post weld aging.

July 24, 1963 ELASTIC AND PLASTIC BEHAVIOR OF WELDMENTS OF ALUMINUM ALLOY PLATE 2219-T87 IN-P&VE-M-63-8

by W. R. Morgan

Unclassified, 11 pages, 6 illustrations

Uniaxial static tensile tests were conducted on parent metal and as-welded plate 2219-T87 (0.750 inch thick) to study the elastic and plastic behavior of the welded alloy and to determine the effect on the apparent yield strength and the percent elongation of these weldments by altering the gauge length across the weld area. All weldments tested were double V butt type with the weld beads left intact. Weld strengths were markedly lower than the respective strengths of the base material.

The yield strength and the percent elongation measured transverse to the weldments varied considerably depending upon the gauge length used. No significant differences in the mechanical properties of the weldments were noted when the included angle of the double V butt joint was changed from 60° to 86°F.

July 24, 1963 PRELIMINARY INVESTIGATION OF EFFECTS OF VACUUM ON HYDROGEN PEROXIDE SYSTEMS IN-P&VE-M-63-9

by J. B. Gayle and W. A. Riehl

Unclassified, 11 pages, 2 illustrations, 1 table

Possible problem areas in connection with the peroxide systems used for the Mercury capsule and Centaur vehicle were investigated on a limited basis. The results of thermal stability tests indicated that the samarium oxide portion of the catalyst actually consists of a mixture of samarium oxide and nitrate. These data also suggested that the integrity of the catalyst would not be affected by the short exposures and moderate temperatures experienced during operation. Results of vacuum tests indicated that hydrogen peroxide undergoes partial evaporation and freezing on sudden exposure to vacuum. However, problems resulting from formation of solid hydrogen peroxide in vent lines and/or valves can be eliminated by proper location of hardware components and, if necessary, by supplying sufficient heat to evaporate residual quantities of peroxide.

August 29, 1963 ANALYSIS OF COPPER ON SATURN CONTAINER SURFACES BY SPECTROGRAPHIC AND ELECTROGRAPHIC TECHNIQUES, AN EVALUATION REPORT IN-P&VE-M-63-10

by D. R. Hamilton and S. K. Corbitt

Unclassified, 10 pages, 5 tables

This investigation resulted from the discovery of corrosion due to copper deposits in the Saturn I LOX and fuel tanks. This copper was believed to have come from the distilled water used at Ling-Temco-Vought Company to hydrostatically test these containers. The distilled water was delivered to the tanks through approximately 2,000 feet of copper tubing. Because the rebuilding of these tanks would create a monumental slippage in the production schedule, it was decided to strip the copper from the finished tanks. A spot test using o-tolidine-potassium thiocyanate was selected to determine when these tanks were free of copper. However, during later checkout of some of the tanks, it was found that

the use of chromate as a corrosion inhibitor in the water interfered with this spot test. Therefore, it was decided that if this spot test indicated a positive test for copper, the sample in question would be checked spectrographically to confirm the presence of copper.

In addition, Ling-Temco-Vought personnel suggested using an electrographic ring oven technique employing the rubeanic acid spot test to quantitatively analyze for copper. It was found that chromates did not interfere with rubeanic acid copper spot test. However, copper occurred in the tanks in both the elemental and oxide forms, and it was found that the electrographic technique would not remove copper oxide quantitatively from the tanks. Therefore, for this application, the electrographic technique can be considered only qualitative because of the mixture of copper and copper oxide.

It was established that 6.5μ gms of copper per square inch will cause corrosion as determined by ASTM Method B-117-61. Therefore, neither the spectrographic method nor the electrographic method could be used as a quantitative procedure unless some techniques were found to quantitatively sample a tank surface for both copper states without removing copper from the 5456 aluminum alloy. Both methods may be used interchangeably for qualitative analysis.

September 10, 1963 THE LOW TEMPERATURE MECHANICAL PROPERTIES OF Fe-18Ni-8Co-5Mo MARAGING STEEL IN-P&VE-M-63-11

by C. V. Lovoy

Unclassified, 14 pages, 3 illustrations, 4 tables

The mechanical properties of Fe-18Ni-8Co-5Mo maraging steel were determined at temperatures from +80°F (267°C) to -423°F (-252.7°C). The alloy had high ultimate tensile and yield strengths, and retained ductility, as measured by percent elongation, at all test temperatures down to -423°F (-252.7°C). In addition, high notched/unnotched tensile ratios were characteristic of this material down to -320°F (-196°C). At -423°F (-252.7°C), however, low notched/unnotched tensile ratios indicated a deterioration of material toughness.

Weldments were prepared by the electron beam welding process. The joints were not optimum with respect to full penetration and smooth top and bottom beads. However, ambient and cryogenic tensile test results from these welds demonstrated the advantages derived from aging after welding. For annealed material, tested as-welded, the joints failed prior to reaching a strength level equivalent to the yield strength of the annealed parent material. Post-weld-aged joints had strength levels that were comparable to those of the aged parent material.

October 25, 1963 LOW TEMPERATURE PROPERTIES OF COMPOSITE SANDWICH CONSTRUCTIONS, SATURN S-IV COMMON BULKHEAD TYPE IN-P&VE-M-63-12

by O. Y. Reece and C. R. Denaburg

Unclassified, 35 pages, 15 illustrations, 8 tables

The mechanical properties of composite constructions similar to that used in the Saturn S-IV common bulkhead were determined from flatwise tension, flatwise compression, edgewise compression, and short beam flexure tests at temperatures ranging from ambient to -423°F (-253°C). Impact strengths, in shear, of the supported adhesive film at low temperatures were determined. Long beams, 3 inches by 16 inches, were tested in flexure at ambient and -320°F (-196°C) temperatures. The test equipment developed for cryogenic testing is described.

October 25, 1963 WELDING OF BIMETALLIC PIPE (ASTM-A-106 GRADE C CARBON STEEL PIPE LINED WITH CUPRO-NICKEL TUBING) IN-P&VE-M-63-13

by R. A. Davis and R. P. Wagner

Unclassified, 17 pages, 9 illustrations, 1 table

The Launch Operations Center proposed the use of bimetallic pipe, ASTM-A-106 Grade C carbon steel pipe, lined with cupro-nickel tubing for the gaseous nitrogen system of Vertical Launch Facility 37B (VLF-37B). This bimetallic combination was selected because of the materials cost savings over the solid stainless steel pipe, employed previously for such systems.

A program was initiated by the Materials Division to establish fabrication procedures for the bimetallic pipe, defining the parameters of joint design, joint preparation, filler alloys, welding technique, inspection procedures, and quality standards. The feasibility of joining this pipe was demonstrated by the use of special welding techniques and rigidly controlled procedures.

December 7, 1963 LOW TEMPERATURE MECHANICAL PROPERTIES OF "UNITEMP" 212 ALLOY IN-P&VE-M-63-14

by J. W. Montano

Unclassified, 24 pages, 11 illustrations, 5 tables

The mechanical properties of Unitemp 212 alloy bolts and bar stock, in the age-hardened condition, were determined for the temperature range of 80°F (25°C) to -423°F (-253°C). Both smooth and notched tensile tests were made. The smooth specimens increased in ultimate tensile and yield strengths with decreasing temperature. The percent elongation increased to a maximum at -320°F (-196°C). At -423°F (-253°C), the percent elongation decreased to approximately ninety percent of the ambient temperature elongation. The notched/unnotched tensile ratios were greater than 1.0 at all testing temperatures, indicating a relatively notch insensitive material.

Tests on actual bolts, fabricated from the Unitemp 212 alloy, revealed desirable properties at cryogenic temperatures. By comparison, the Unitemp 212 alloy has better low temperature mechanical properties than A-286, Waspaloy or 6Al-4V titanium.

December 13, 1963 CORROSIVE EFFECTS OF CAPE CANAVERAL ENVIRONMENT ON S-I-D5 VEHICLE IN-P&VE-M-63-15

by J. G. Williamson

Unclassified, 6 pages

The Saturn S-I-D5 vehicle was examined both before and after a three-month exposure to a seacoast environment. No significant effects from this exposure were noted on the over-all vehicle; however, corrosion in the form of rust and pits occurred on stainless steel bellows, fasteners, and suction lines, which indicates that protective measures should be taken where extended exposure to such an environment is necessary.

TM X-53006 APPROVAL February 3, 1964

1963 Publications

by Materials Division

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

W. R. Lucas

W. R. Lucas
Chief, Materials Division

W. A. Mrazek

W. A. Mrazek
Director, Propulsion and Vehicle Engineering Laboratory

DISTRIBUTION

DIR	Dr. von Braun	
DEP-T	Dr. Rees	
AST-S	Dr. Lange	
R-FP	Dr. Koelle	
R-SA	Mr. Dannenberg	
R-RM	Mr. McCartney	
R-AERO-DIR	Dr. Geissler	
R-ASTR-DIR	Dr. Haeussermann	
R-COMP-DIR	Dr. Hoelzer	
R-ME-DIR	Mr. Kuers	
R-RP-DIR	Dr. Stuhlinger	
R-P&VE-DIR	Dr. Mrazek	(2)
R-P&VE-T	Mr. Finzel	
R-P&VE-A	Mr. Goerner	(4)
R-P&VE-N	Col. Fellows	
R-P&VE-R	Mr. Rieger	
R-P&VE-RT	Mr. Hofues	
R-P&VE-M	Dr. Lucas	(5)
R-P&VE-MC	Mr. Riehl	(6)
R-P&VE-ME	Mr. Kingsbury	(5)
R-P&VE-MM	Mr. Cataldo	(7)
R-P&VE-MN	Mr. Shannon	(6)
R-P&VE-P	Mr. Paul	(6)
R-P&VE-S	Mr. Kroll	(6)
R-P&VE-V	Mr. Palaoro	(6)
R-QUAL-DIR	Mr. Grau	
R-TEST-DIR	Mr. Heimburg	
LVO-DIR	Dr. Gruene	
MS-H	Mr. Akens	
MS-IP	Mr. Remer	
MS-IPL		(8)
I-V	Dr. Rudolph	
CC-P	Mr. Wofford	

Scientific and Technical Information Facility (25)
Attn: NASA Representatives
(S-AK/RKT)
P. O. Box 5700
Bethesda, Maryland