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HIGH ENERGY PROPELLANTS

A CONTINUING BIBLIOGRAPHY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA SP-7002

HIGH ENERGY PROPELLANTS

A CONTINUING BIBLIOGRAPHY

A Selection of Annotated References to Unclassified Reports and Journal Articles introduced into the NASA Information System during the period January, 1962-March, 1964.

Scientific and Technical Information Division
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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Each entry in the bibliography consists of a citation and an abstract. The listing of entries is arranged in two major groups: all report literature references are contained in the first group and are subdivided according to their date of announcement in TPA and *STAR*; the second group includes all published literature references subdivided according to their date of announcement in *IAA*. All reports and articles cited were introduced into the *NASA* Information System during the period January 1962–March, 1964.

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1962

N62-10014 National Aeronautics and Space Administration. Lewis Research Center, Cleveland.
PRELIMINARY STUDY OF THE EFFECTS OF IONIZING RADIATIONS ON PROPELLANTS; THE X-IRRADIATION OF AMMONIA AND HYDRAZINE.
Harold W. Lucien. Feb. 1962, 9 p. 4 refs. (NASA TN D-1193) OTS, $0.50

Irradiation of ammonia vapor, liquid ammonia, and hydrazine vapor by a 250-kv, 15-ma source that provided 90 to 100 r/min resulted in decompositions varying from less than 1 to 3 percent. In addition to the formation of nitrogen and possibly hydrogen from the ammonia and hydrazine decompositions and the formation of hydrazine from ammonia and ammonia from hydrazine, other materials were formed that were not characterized.

N62-10081 National Aeronautics and Space Administration. Lewis Research Center, Cleveland.
ANALYSIS OF LIQUID-HYDROGEN STORAGE PROBLEMS FOR UNMANNED NUCLEAR-POWERED MARS VEHICLES. R. J. Brun, J. N. B. Livingood, E. G. Rosenberg, and D. W. Drier. **APPENDIX D: CALCULATIONS OF SHIELDING NECESSARY TO PREVENT RADIATION DAMAGE TO REACTOR CONTROL EQUIPMENT.** John M. Smith.
Jan. 1962, 65 p. 17 refs. (NASA TN D-587) OTS, $1.75

Tankage, nuclear shielding, and hydrogen heat-input problems are investigated for three unmanned nuclear vehicles intended for probing in the vicinity of Mars and landing freight on Mars. Tank geometry, tank and supporting-structure weight, and tank protection from meteoroids are discussed. The size and weight of the nuclear shield as required by a prescribed allowable dose and/or the heat input to the hydrogen are determined. The hydrogen heat input includes nuclear, onboard thermal, solar, and planetary sources.

N62-10095 National Aeronautics and Space Administration. Lewis Research Center, Cleveland.
A PHOTOGRAPHIC STUDY OF LIQUID HYDROGEN UNDER SIMULATED ZERO GRAVITY CONDITIONS.
Irving Brazinsky and Solomon Weiss. Feb. 1962, 16 p. 5 refs. (NASA TM X-479)

The transient behavior of liquid hydrogen in a Dewar under conditions of free fall was studied photographically. During the weightless period of approximately ¾ second, the liquid rose along the walls of the Dewar into the original gas space. Liquid rise rates were determined, and it was concluded that adhesive forces were the primary cause of the rise.

N62-10143 Pioneer-Central Div., Bendix Corp., Davenport, Iowa.
LIQUID OXYGEN CONVERTER FOR WEIGHTLESS ENVIRONMENT.
Dale L. Hankins and Paul J. Gardner. Wright-Patterson Air Force Base, Ohio, Aerospace Medical Lab., Nov. 1961. 11 p. (ASD Tech. Rept. 61-634) (Contract AF33(616)-6190) Available from OTS: ph $4.60, mi $1.52.

A liquid oxygen converter has been designed to supply breathing oxygen in a weightless environment. The converter is self pressurizing, using small quantities of liquid oxygen which are directed into a pressure buildup circuit where the liquid oxygen is vaporized and expanded to create and maintain operating pressure. The random orientation of the liquid oxygen in a weightless environment is overcome by a flexible hemispherical diaphragm attached to the inner end of the supply port. By application of buildup pressure to the exterior of the diaphragm, the collapsing diaphragm forces liquid to and through the supply port. Testing that could be accomplished in the laboratory gave every evidence that the design concept is satisfactory for weightless operation.

N62-10177 Aeronautical Research Council (Gt. Brit.)
A METHOD OF DETECTING THE FULLY COOLED STATE OF A LIQUID OXYGEN PIPELINE.
N. Shufflebotham. London, HMSO, 1961. 8[5] p. (ARC-CP-573) Previously issued as RPE-TN-193; ARC-21734.

Test sites using liquid oxygen normally rely on visual observation to determine when the pipe system is cooled to liquid oxygen temperature. Test sites for rocket engines of high thrust, however, having considerable distances between control room and test bay, necessitate the use of an automatic "precool" indicator. This note describes a method which has proved to give reliable remote indication when the fully cooled state is reached. The method is based on detecting the change in pressure at the throut of a simple venturi, which occurs when the oxygen flow changes from the gaseous to the liquid phase.

An investigation of how liquid sprays, light scattering techniques, chemical reaction rates of rocket propellants, and combustion instability influence the design of combustor systems. A significant result of the study was that combustion instability was not controlled by chemical kinetics, but that heat transfer to the injector was an important factor. Ethylene oxide decomposition and gaseous hydrazine, for propellant use, were investigated.

N62-10342 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
AN EXPERIMENTAL INVESTIGATION OF THE PERFORMANCE OF THE NITROGEN TETROXIDE-HYDRAZINE SYSTEM IN THE OXIDIZER-RICH AND FUEL-RICH REGIONS.
J. J. Chilenski and D. H. Lee. Mar. 12, 1962. 13 p. 16 refs. (JPL-TR-32-212) (NASA Contract NAS 7-100).

The results of an experimental program directed toward determining some of the operational characteristics of the nitrogen tetroxide-hydrazine propellant system under oxidizer-rich and fuel-rich conditions are reported. Data are presented for the mixture-ratio ranges of 0 to 0.55 at a nominal chamber pressure of 300 psia and characteristic chamber length of 250 in., and at mixture ratios of 5.9 to 13.0 at nominal chamber pressures of 400 and 500 psia and characteristic chamber lengths of 100 and 3900 in. The relationship of the actual performance data obtained in each region with those predicted from thermochemical performance calculations is presented. From this comparison, it is concluded that in neither region are equilibrium conditions obtained and that utilization of performance data obtained from assumptions of equilibrium will lead to serious errors. In the oxidizer-rich region investigated, temperatures considerably below those predicted occur throughout the range of mixture ratios investigated because of the lack of exothermic dissociation of the nitrogen oxides. In the fuel-rich region, below a mixture ratio of 0.3, temperatures considerably higher than those predicted occur because of the lack of endothermic dissociation of ammonia.

N62-10551 Research Inst., Temple U., Philadelphia, Pa.
ADDITION AND SUBSTITUTION PRODUCTS OF OXYGEN FLUORIDES.
Second Annual Progress Report [Jan. 1 to Dec. 31, 1961]
A. G. Streng and A. V. Grosse. Jan. 19, 1962. 49 p. 21 refs.
(Contract Nonr 3085(01))

A new type of highly colored deep-violet addition compounds of dioxygen difluoride has been obtained. These compounds are formed by addition to ClF, BrF_3 and SF_4, under mild reaction conditions. They have a remarkable oxidizing power, even at very low temperatures.

The analogous fluorides of the other elements adjoining oxygen and fluorine in the Periodic System did not form addition compounds of this type.

The O_2F_2 + ClF reaction was studied extensively. Various combinations of the factors influencing the synthesis were investigated, and the yield of the violet addition product was raised to 81 percent of the theoretical value.

The investigation of the properties of the violet compound, the elementary composition of which was found to be O_2ClF_3, showed that the solid violet compound, contaminated only by ClF_3, is stable at 195° K. At this temperature it was kept for over 9 months without any noticeable decomposition. The compound is soluble in liquid ClF_3, ClF, O_2F_2 and HF, at 125-190° K., but is insoluble in liquid O_2, O_3, ClO_3F, C_3F_8, NF_3, CCl_2F_2 and $CClF_3$ in the range of 90-160° K. The solutions are less stable than the solid compound. The measurements of the electrical conductivity of a solution of the violet compound in anhydrous HF at 78° C. showed that O_2ClF_3 is not an electrolyte.

The study of the reactivity of the violet compound at low temperatures showed its extremely high oxidizing power. The compound reacts vigorously with ammonia, ethane and ethylene, even at 120-160° K.

The violet addition product was synthesized also from ClF_3 and O_2 at 195° K. under pressure, by irradiation with ultraviolet light. The preliminary data on the visible absorption spectrum of this compound were obtained.

The decomposition of a solution of O_2ClF_3 in anhydrous HF led, under some conditions, to the formation of a blue compound or compounds. The nature of these compounds was not established.

(Author Abstract)

N62-10977 Little (Arthur D.) Inc., Cambridge, Mass.
LIQUID PROPELLANT LOSSES DURING SPACE FLIGHT.
Second Quarterly Progress Report.
May 1961. v, 84 p. 31 refs.
(Report No. 63270-00-02) (NASA Contract NASA-664)

To provide design data for liquid propellant storage systems in space vehicles, work is being undertaken to describe quantitatively environmental aspects that may be contributory to propellant losses, the interactions of the propellant and its storage system with the environment, and finally the performance of protective systems to limit such losses.

Studies are continuing to quantitatively describe aspects of the space environment that may contribute to propellant losses. The major effort in these studies has been completed, and information is being stored in a punch-card system.

Theoretical studies of thermal interactions between the space environment and the liquid propellant system have shown that performance of radiation shielding is a function of the spacing between shields. Analytic studies have resulted in formulation of a computer program for designing cryogenic propellant tanks.

A first order theory has been developed to explain the performance of meteorite bumpers as protective devices against meteorites. However, data indicates that this theory may be optimistic in estimating the protection bumpers will afford. A more detailed analysis involves the study of shocks which travel through the bumpers and the projectiles after impact and how these shocks cause particles to break up. Results have so far indicated that particle break-up is highly dependent upon the shape and attitude of particles and upon the density and state of bumper and particle materials. Also, as a consequence of considering a meteorite-protection system based on optical detection of meteoroids, the opinion is held that optical sighting may be a useful method of obtaining meteoroid data in satellite experiments.

An analysis has been made of radiation dosage resulting from high energy protons and from bremsstrahlung accompanying electron absorption in the outer Van Allen belt. Results enable the calculation of radiation dosages received by living or inanimate objects behind a barrier. In addition, an analysis has been made of the possible magnitude of radiation effects on the mechanical properties of several structural materials. Results show that molecular or atomic diffusion of hydrogen has little effect in causing hydrogen embrittlement of stainless steel. (V.D.S.)

N62-11029 Stanford Research Inst., Menlo Park, Calif.
A SURVEY AND EVALUATION OF HIGH ENERGY LIQUID CHEMICAL PROPELLANT SYSTEMS.
Quarterly Report No. 4, Dec. 16, 1961 to Mar. 15, 1962.
Adolph B. Amster. Apr. 4, 1962. iii, 41 p. refs.
(NASA Contract NASr-38; SRI Proj. PRU-3652)
OTS: ph $4.60, mi $1.52.

In a program to survey and evaluate high energy liquid propellant systems for NASA space missions, efforts have been divided among: (1) studies of O_3F_2 properties; (2) development of propellant selection criteria; and (3) construction of a liquid-test facility. Storage stability of O_3F_2 and O_3F_2-LOX (liquid nitrogen) mixtures, their compatibility with other materials, and their hypergolicity with hydrogen were considered. Samples of O_3F_2 were stored in liquid nitrogen for periods up to six months; and results revealed that storage stability of O_3F_2, stored in glassware over periods of days to several months, did not appear to be a measurable parameter. In compatibility tests, ten cylindrical samples of various materials were immersed in O_3F_2 at liquid oxygen temperatures for 22 days. Of the corrosion specimens, results showed that only with the brass sample did a significant weight loss occur; zinc appeared to have been removed, leaving the surface rich in copper. Hypergolicity test results indicated that in no case did a sample of O_3F_2-O_2 mixture ignite hydrogen at one atmosphere of pressure and that most of the samples were not hypergolic after two days. At pressures of 0.5 atmospheres or less, ignition did occur during the first few hours, but very few positive results were obtained after one day. However, positive results were observed with a sample stored for a two-week period. Rapid mixing of warm hydrogen with oxygen appears to be necessary to ensure hypergolicity since ignition occurred at 0.5/atms pressure and not at 1/atms. At reduced pressures oxygen evaporates, leaving a cooler residue. Hence, mixing of the warmer hydrogen in the gases or liquid probably occurs.

In evaluating propellants for the NASA space program, criteria will be developed primarily to evaluate new propellants and their best possible applications and to determine whether or not these propellants should be developed to operational status. The evaluation operation will ascertain whether the propellant can meet all requirements and whether a vehicle using the propellant would involve lower comparative total resource/consumption (CTRC) for the mission than another configuration using the best available propellant. (V.D.S.)

N62-11281 Little, (Arthur D.) Inc., Cambridge, Mass.
THE SPACE ENVIRONMENT AND ITS INTERACTIONS WITH LIQUID PROPELLANTS AND THEIR STORAGE SYSTEMS.
Technical Report.
Norman M. Wiederhorn. Sept. 1961. xi, 102 p. 193 refs.
(Rept. C-63270-02-1) (NASA Contract NAS5-664)
OTS: ph $9.10, mi $3.44.

Space environment and its interactions with liquid propellants and their storage systems are investigated. Results indicated: (1) Magnetic fields seem to have no direct influence upon the storage of propellants. (2) Space vacuum, with its very low pressure, increases the rate of evaporation of volatile components, such as resin laminates, from the surface of the storage tank, thus lending to the evaporation of its contents. (3) Zero gravity affects the position of the liquid in the container. This can lead to venting and piping problems as well as to blowouts. (4) Electromagnetic radiation causes the absorption of radiation as heat input to the cryogenic propellants, resulting in evaporation. In the case of noncryogenic propellants, degradation of the tank coating can lead to a change of the equilibrium temperature, which could result in a vapor pressure sufficient to rupture the tank. (5) Particulate radiation from solar winds, solar flares and the Van Allen belt does not appear to pose a serious hazard with respect to the storage of liquid propellants. (6) Meteoroids can either penetrate the storage tank or form craters. The latter could initiate propagating cracks in stressed skin. It is evident that a protective system is necessary and that, at the present time, Whipple's concept of a meteor bumper seems to be the most reasonable approach to a lightweight protective system. This study includes a bibliography of space environment, as well as abstracts. (I.v.L.)

N62-11479 Utah U., Salt Lake City
IGNITION AND COMBUSTION OF SOLID PROPELLANTS.
Final Technical Report, Mar. 1957-Sept. 30, 1961.
Rex C. Mitchell, John A. Keller, Alva D. Baer, and Norman W. Ryan. [1961?] 79 p. 13 refs.
(AFOSR-2225) (Contract AF 49(638)-170)

The original project objective, to study the ignition of composite propellants, was broadened to encompass the study of other combustion transients, these being, so far, subjected only to exploratory investigation. The study of ignition was concerned with the response of propellant to externally supplied heat flux. Both radiant flux from electrically heated tube furnaces and convective flux from shock-heated gas were employed, the former giving fluxes in the range 5 to 50, the latter, 100 to 300 Btu per sec., sq. ft. The results, ignition delay time as a function of heat flux, are correlated by a modified form of the theory originally set forth by B. L. Hicks, according to which the ignition delay time should be nearly proportional to the square of the heat flux. The extent of deviation from proportionality provides a measure of kinetic parameters. The theory is shown to predict the effect of initial propellant temperature on the ignition time-heat flux relationship, but it is noncommittal with respect to the effect of pressure. Empirically it is found that the effect of pressure on the ignition delay time or perchlorate propellants is a function of heat flux level, being very slight, for the propellants studied, at flux levels above 20 Btu per sec., sq. ft. Exploratory studies have concerned flame spread, effects of aerodynamic transients on burning propellant, and the diffusion flame between large bodies of fuel and oxidant. One firm conclusion is that flame spread across fresh surface, unassisted by external heat flux to that surface, is too slow to be an important factor in the overall ignition process. As one aspect of the aerodynamic transient studies, a theory of the rarefaction tube was developed, and is here presented. (Author Abstract)

N62-11512 Princeton U., N.J.
PROJECT SQUID: A COOPERATIVE PROGRAM OF FUNDAMENTAL RESEARCH AS RELATED TO JET PROPULSION FOR THE OFFICE OF NAVAL RESEARCH, DEPARTMENT OF THE NAVY.
Semi-Annual Progress Report Covering the Period 1 Oct. 1961 to 31 Mar. 1962.
Apr. 1, 1962. 108 p. refs.
(Contract Nonr 1858(25), NR-098-038)

CONTENTS:

PLASMA FLOW IN NOZZLES. Herbert Beckmann and Alan J. Chapman (Rice U.). p. 97-100. 1 ref.

N62-11730 Southwest Research Inst., San Antonio
A DISCREPANCY IN THE PUBLISHED RESULTS ON HEAT TRANSFER TO CRYOGENIC FLUIDS.
William Squire. Repr. from Intern. J. Heat & Mass Trans., v. 3, 1961. p. 347. 6 refs.
(NASA Contract NASw-146)

Experimental results on heat transfer to cryogenic fluids conflict. Mulford and Nigon measured heat transfer from a 12-mm copper tube to liquid hydrogen at 520 mm pressure; results indicated a critical temperature difference of 2°K for the transition from nucleate to film boiling and a heat flux of 6 W/cm^2. Weil and Lacaze measured the heat loss from copper and platinum wires and tubes to liquid nitrogen over a range of pressures; results at 1 atm indicated a critical temperature difference of 10°K and a heat flux of 10 W/cm^2. As the Mulford-Nigon and Weil-Lacaze results were reportedly unaffected by large changes in geometrical configuration, it is difficult to reconcile these discordant results. (V.D.S.)

N62-11811 Armour Research Foundation, Chicago.
FUNDAMENTALS OF LIQUID PROPELLANT SENSITIVITY. Quarterly Report No. 2, Sept. 13 to Dec. 13, 1961.
T. A. Erikson and E. L. Grove. Jan. 30, 1962. 44 p. 3 refs.
(ARF-3197-6) (Contract NOw 61-0603-c; ARF Proj. C 197)

During the second quarterly period of this basic study of liquid propellant sensitivity, positively identified, shock-tube-initiated detonations of liquid nitroglycerine were achieved after evacuation of the sample in the shock tube had been eliminated from the test procedure. Apparently, evacuation removes volatile sensitizing agents and thus desensitizes the nitroglycerine sample to the shock-tube test. In 50 tests with samples that were not desensitized, the time delay was found to decrease from 100 to 25 microseconds when the Mach number of the incident shock was raised from about 3 to 5.

Photolysis experiments indicate that a light of an absorptive wavelength causes self-heating of the nitroglycerine until either decomposition or detonation occurs, depending on the geometrics of the particular experiment.

Measurements show that water vapor rapidly contaminates the surface of nitroglycerine, as indicated by a change in surface tension, from about 50 to 55 dynes/cm, within a few hours. Over a month of storage, the surface tension of a sample of nitroglycerine was observed to increase by about 3 dynes/cm. (Author Abstract)

N62-11812 Armour Research Foundation, Chicago.
FUNDAMENTALS OF LIQUID PROPELLANT SENSITIVITY. Quarterly Report No. 3, Dec. 13, 1961 to Mar. 13, 1962.
T. A. Erikson and E. L. Grove. Apr. 20, 1962. 40 p. 6 refs.
(ARF-3167-9) (Contract NOw 61-0603-c; ARF Proj. C 197)

This program is a fundamental study of liquid propellant sensitivity. Shock reflection and flash irradiation are the two techniques being used to evaluate the manner in which energy accumulation at the liquid-vapor interface affects the detonation of a liquid propellant. The preliminary studies are being performed with nitroglycerine.

In the shock-tube studies during this quarter, incident shocks produced by oxygen gas at an intensity of Mach 4.6 were used as the standard conditions. When reflected at a nitroglycerine surface, these shocks caused detonations in approximately 75% of the tests (26 out of a total of 34). The most frequent time delay, from the moment of shock reflection to the moment of detonation, was in the vicinity of 30 microseconds. However, when nitroglycerine samples were placed in the shock tube and the shock tube was evacuated to less than 10 mm Hg prior to the tests, no detonations occurred under comparable shock conditions. Apparently, evacuation removes volatile sensitizers from the nitroglycerine.

In the flash irradiation studies, when nitroglycerine droplets were placed in contact with a black body and irradiated with a 4000-joule xenon flash, detonations occurred in approximately 90% of the tests. The average time delay, from the moment the light reached the surface of the nitroglycerine to the moment of detonation, was approximately 250 microseconds.

Evaluation of the shock-tube data indicates that the initiation process is critically dependent on the surface purity of the nitroglycerine and, when a detonation occurs, the process is virtually complete within 10^{-10} seconds. (Author Abstract)

N62-12941 Stanford Research Inst., Menlo Park, Calif.
VISCOELASTIC PROPERTIES OF SOLID PROPELLANTS AND PROPELLANT BINDERS. Quarterly Technical Summary Report No. 3, Jan. 1 to Mar. 31, 1962.
Thor L. Smith and James R. Smith. Apr. 30, 1962. 35 p. 3 refs.
(Contract NOw-61-1057-d; ARPA Order 22-61)

The small deformation shear and dilatational properties of propellants and propellant binders are being studied. Also, consideration is being given to the use of tensile stress-strain curves, determined at various strain rates, for characterizing the viscoelastic properties of propellants. The present status of a low-frequency tester for determining the dynamic shear modulus is described. Additional data on the temperature dependence of propellant specific volume are discussed, along with the possible effect on observed properties of the surface to volume ratio. Compressibilities of a polyurethane propellant and a silicon fluid are reported at 5°, 30°, and 45°C at pressures up to 1500 psi. In addition, data which show the temperature change produced in a specimen by a pressure change are presented, as well as data which show the time required to reestablish thermal equilibrium. Tensile stress-strain curves determined on a propellant at 0°F at different strain rates are analyzed. For small strains, it appears that relaxation effects can be separated from the inherent nonlinear properties of the propellant. (Author Abstract)

N62-13172 Aerojet-General Nucleonics, San Ramon, Calif.
HYDRAZINE PROCESS DEVELOPMENT. [First Quarterly] Interim Technical Engineering Report, Apr. through July 1961.
J. H. Cusack, L. G. Carpenter, R. I. Miller, R. L. Pearson, F. R. Standerfer, and H. T. Watanabe. Aug. 1961. 186 p. refs.
(Contract AF 33(600)-42996)
(ASD-TR-7-840A(II); AGN-AN-415)

The primary goal of this program is the development, design, construction and operation of a continuous in-reactor hydrazine production loop based on the fissio-chemical processing approach. This report presents the history, organization and detailed goals of the program. Theoretical background, specific requirements and initial experimental approaches in the task areas of fuel separation, product concentration, gas disengagement, materials testing, in-reactor engineering and radiolysis mechanisms are discussed. (Author Abstract)

N62-13173 Aerojet-General Nucleonics, San Ramon, Calif.
HYDRAZINE PROCESS DEVELOPMENT. [Fourth Quarterly] Interim Technical Engineering Report, Feb. through Apr. 1962.
R. I. Miller, R. L. Pearson, F. R. Standerfer, H. J. Snyder, H. T. Watanabe, and L. G. Carpenter. May 1962. 125 p. 13 refs.
(Contract AF 33(600)-42996)
(ASD-TR-7-840A(V); AGN-AN-584)

The primary goal of this program is to develop, design, construct and operate a continuous, in-reactor hydrazine production loop based on the fissio-chemical process approach. This report describes particulate fuel behavior in hydroclones, in filters, and in a flocculating environment. Alterations of the in-reactor loop, supporting components, and instrumentation, all necessitated by a change in reactor facility, are discussed. Equipment to be used for ammonia radiolysis, and for high energy compound and slurry radiation stability studies, are described. (Author Abstract)

N62-13202 Defense Metals Information Center, Battelle Memorial Inst., Columbus, Ohio.

COMPATIBILITY OF PROPELLANTS 113 AND 114B2 WITH AEROSPACE STRUCTURAL MATERIALS.

J. D. Jackson and W. K. Boyd. Apr. 27, 1962. 18 p. 14 refs. (DMIC-Memo-151)

Propellants 113 (1,1,2-trichlorotrifluoroethane) and 114B2 (1,2-dibromotetrafluoroethane) are considered for vernier rocket fuels because of their moderate boiling points and low specific heats and heats of vaporization. The physical and chemical properties, hydrolysis behavior and toxicity of these propellants were studied; and their thermal stability in the presence of aerospace structural materials and their corrosive effects on these materials were studied. Several metals commonly used as materials of construction by the aircraft and missile industry were exposed to propellants 113 and 114B2. Samples of 75A titanium, Ti-6Al-4V, 17-7 PH, aluminum alloy 6061, and AISI 4130 were exposed at 80° F in the vapor and liquid phase and at the interface of the liquids. The compounds were used both as-received and with 0.1 percent water added as a contaminant. The corrosion data indicate that stainless steels and titanium can be used with these propellants at 80° F, even when contaminated with water, with almost no attack. At elevated temperatures, the resistance of stainless steel would probably remain good; the compatibility of titanium will require more investigation. Mild or low alloy steels are satisfactory in dry propellants, but moisture causes rusting that is especially severe in propellant 114B2. Low alloy steels can be used at low temperatures, but they cause some catalytic decomposition of the propellants. Aluminum can be pitted when used with these propellants, if contamination by water is possible. The swelling characteristics for several plastics and elastomers in propellant 113 were measured. Propellant 113 caused a maximum increase in length at room temperature of 3 percent for Neoprene, type GN; 0.5 percent for Buna N; 17 percent for rubber; and 8.5 percent for GR-S. Observations suggest little or no impact sensitivity for titanium and other materials in these propellants. (M.P.G.)

N62-13775 National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

GROUND FACILITY REQUIREMENTS FOR SUBCOOLING LIQUID HYDROGEN.

W. E. Dempster and J. R. Olivier. Washington, NASA, July 1962. 22 p. 7 refs.
(NASA TN D-1276) OTS: $0.75.

This report shows that it is practical and economical to subcool liquid hydrogen (S-LH_2) by the reduced pressure boiloff method using a cold vacuum pump. The relationship between the transfer rate of S-LH_2 and the temperature rise of the liquid has been determined. The relationship between tanker heat leak and temperature rise of the liquid has been determined. The effort in keeping the liquid in a subcooled state can be varied according to the anticipated orbital storage time. The necessary GSE required to initially subcool, transfer, and maintain the liquid subcooled state during standby on the launch pad is outlined.
(Author Abstract)

N62-14047 Göttingen U. Inst. of Physical Chemistry (W. Germany).

INVESTIGATION OF GASEOUS DETONATIONS AND SHOCK WAVE EXPERIMENTS WITH HYDRAZINE. [Technical Documentary Report, 1 Oct. 1959-30 Sept. 1960.]

W. Jost. Wright-Patterson AFB, Ohio Aeronautical Research Labs., Apr. 1962. 84 p. 24 refs.
(Contract AF 61(514)-1142)
(ARL 62-330)

The implications of the "Chapman-Jouguet" condition are discussed and examined experimentally. Furthermore, investigations of the shape of a detonation front and its dependence on the reaction are reported. Experiments were made to demonstrate the influence of turbulence in the unignited gas and of obstacles to the gas flow upon the initiation time and distance for the development of a detonation. The detonability of pure hydrazine was checked. The decomposition of hydrazine, diluted with inert gas, in reflected shock waves at extremely low oxygen concentration was observed to occur with an apparent energy of activation of about 43 kcal/mole (total reaction pressure ca. 7.2 atm; hydrazine density 23.10^{-8} mole/cm^3).
(Author Abstract)

N62-14067 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

IGNITION OF A HYDROGEN-OXYGEN ROCKET ENGINE BY ADDITION OF FLUORINE TO THE OXIDANT.

R. James Rollbuhler and David M. Straight. Washington, NASA, July 1962. 22 p. 10 refs.
(NASA TN D-1309) OTS: $0.75.

Ignition delay of the propellant combination cold hydrogen gas and an oxidant mixture of liquid oxygen and liquid fluorine was determined as a function of the fluorine concentration in the oxidant, the injector type, and the percentage of hydrogen in the total propellant flow. It was found that at least 50 percent of the oxidant had to be fluorine to obtain hypergolic ignition delays of less than 1 sec with a shower-head injector, whereas a swirl-cup injector required only 35 percent fluorine concentrations to obtain the same results. The fuel-injection temperature and fuel-oxidant ratio had only slight effect on the hypergolic ignition characteristics.
(Author Abstract)

N62-14300 Aerospace Information Div., Washington, D.C.

HEAT STABILITY OF PROPELLANTS: HYDRAZINE PERCHLORATE.

June 27, 1962. 2 p. Review of: A. A. Shidlovskiy, V. I. Semishin, and L. F. Shmagin. Thermal decomposition and combustion of hydrazine perchlorate. Zhur. Priklad. Khim., v. 35, no. 4, Apr. 1962. p. 756-759.
(AID-62-90) OTS: $1.10 ph, $0.80 mf.

This paper presents data on hydrazine perchlorate, including thermal stability, impact stability, and combustion rates. The combustion rates were obtained at room temperature and in the presence of one of the following catalysts: MnO_2, CoO, or Cu_2Cl_2. Combustion without a catalyst was achieved by mixing hydrazine perchlorate (30 to 60 percent) with NH_4ClO_4. (R.C.M.)

N62-14674 Explosives Research Lab., Bureau of Mines, Pittsburgh, Pa.

STUDIES ON DEFLAGRATION TO DETONATION IN PROPELLANTS AND EXPLOSIVES. Jan. 1, 1959 to Dec. 31, 1961.

F. C. Gibson, C. R. Summers, F. H. Scott. July 16, 1962. 48 p. 14 refs.
ARPA Order Nos. 44-59 and 44-61)
(Summary Report 3863)

This report summarizes studies on propellants and explosives to evaluate mechanisms involved in the initiation and growth of detonation in systems that are capable of rapid exothermal decomposition. Both optical and electronic instrumentation are employed to investigate these mechanisms in solid propellants (composite-inert binder and double-base) and explosives (liquid and solid systems). The results are shown in oscillograms and Rapatronic camera photographs and indicate that deflagration to detonation phenomenon are related to the physical characteristics of the explosive or propellant bed. (R.C.M.)

N62-14720 National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

NUCLEAR RADIATION TRANSFER AND HEAT DEPOSITION RATES IN LIQUID HYDROGEN.

M. O. Burrell. Washington, NASA, Aug. 1962. 97 p. 8 refs.
(NASA TN D-1115) OTS: $2.25.

Stochastic methods are used to calculate the radiation transport and energy deposition of neutrons and gamma rays in liquid hydrogen slabs and cylinders. The sources are treated as monoenergetic, and either point isotropic for the cylinder, or plane parallel rays for the slabs. A description of the methods used and a rather extensive compilation of results are given. The results include heat rate deposition as a function of depth, albedo factors, slow neutron spatial distributions, and transmitted angular distributions of gamma rays. (Author Abstract)

N62-15264 Argonne National Lab., Ill.
POSSIBLE IMPLICATIONS OF THE DAMAGE BY RADIATION IN THE STORAGE OF PROPELLANTS IN OUTER SPACE AND TENTATIVE METHODS FOR ITS MEASUREMENT.
J. A. McMillan. July 1962. 19 p. 11 refs.
(Contract W-31-109-eng-38)
(ANL-6585)

The damage by radiation that can be expected during the storage of hydrogen-bonded propellants in outer space is analyzed in terms of the available data on radiation levels. On this basis, the alternatives of storing the propellants as liquids or as solids, at low temperature, are discussed, and account is taken of recent results on their thermal behavior. Vitreous states of aggregation of compounds that could crystallize spontaneously after long periods of irradiation are shown to present some hazards that can be prevented. General considerations of radiation-damage detection in outer space are also made. Paramagnetic resonance is found to be of little use in view of the relatively low-dose levels. Solid-state devices are recommended. (Author Abstract)

N62-15396 General Dynamics/Astronautics, San Diego, Calif.
HEATING OF LIQUID HYDROGEN FROM NUCLEAR RADIATION.
Wilma G. Thompson and Carl G. Johnson. [1961?] 23 p. 2 refs.

This paper presents relatively simple methods by which upper and lower bounds of temperature increase in liquid hydrogen propellant can be calculated. The results show that the maximum temperature increase at either the top or the bottom of the tank is obtained for the limiting case of complete instantaneous mixing. (Author Abstract)

N62-15693 Deutsche Forschungsanstalt für Luft- und Raumfahrt. Inst. für Strahltriebwerke, Brunswick (W. Germany).
DER ABBRANDMECHANISMUS FESTER RAKETENTREIBSTOFFE AUF AMMONIUMPERCHLORAT-BASIS. TEIL I: ÜBERSICHT ÜBER DIE LITERATUR UND ERGEBNISSE DER VORUNTERSUCHUNGEN. [THE BURNING MECHANISM OF SOLID ROCKET-PROPELLANTS ON AN AMMONIUM PERCHLORATE BASIS. PART I: SURVEY OF THE LITERATURE AND RESULTS OF PRELIMINARY INVESTIGATIONS].
H. Selzer. 1961. 58 p. 38 refs. In German.
(DFL-126)

Theories on the combustion mechanisms of solid rocket propellants based on ammonium perchlorate are briefly reviewed. These are: the granular diffusion theory of Summerfield, the heat layer mechanism according to Chaiken, and the theoretical statements of Penner, Nachbar and Spalding. The experimental results themselves do not permit a critical evaluation of the validity of individual theories. Photographic investigations of propellant combustion at atmospheric pressure are described. Results were as follows: (1) The temperature of the perchlorate crystals is higher than that of the propellant particles (agreeing with the two-temperature postulate of Schultz and Dekker). (2) The perchlorate crystals vaporize directly from the fluid phase (agreeing with Sutherland). (3) The propellant surface possesses three distinct temperature ranges close to one another; that is, there may be a minimum of two combustion mechanisms. (4) The decomposition of the propellant appears to occur in layers. The layer thickness is approximately 150 microns, the characteristic time is approximately 40 msec. (5) Upon combustion, vigorous gas jets are produced and solid propellant particles are driven out. (A.S.)

N62-15897 Space-General Corp., El Monte, Calif.
RELIABILITY ANALYSIS OF HYBRID PROPULSION SYSTEM.
W. H. Moffat. Nov. 1961. 21 p. 4 refs.
(Report 2154)

This report covers the inherent design reliability analysis and the predicted reliability growth of a hybrid rocket engine design. This design makes use of a solid aluminum polyurethane fuel and a liquid oxidizer. The estimated reliability for this type of engine is 98.2%, reached after 26 months of development testing. The predicted reliability growth is from 57% to 98.2% over a program of 1300 test runs. The ultimate estimated reliability, or the asymptotic value of the growth curve, is 99.2%. (Author Abstract)

N62-16039 National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.
HEAT-TRANSFER AND DRAG COEFFICIENTS FOR ETHANOL DROPS IN A ROCKET CHAMBER BURNING ETHANOL AND LIQUID OXYGEN.
Robert D. Ingebo. Repr. from Eighth Symposium (International) on Combustion, 1962. p. 1104-1113. 9 refs.

An ultra-high-speed camera is used to obtain both drop velocity and drop-size data for burning ethanol sprays in a rocket combustion chamber. Also, combustion-gas velocities inside the rocket chamber were determined for streak-type photographs of the flame. Heat-transfer coefficients for burning sprays as based upon the area-median drop diameter agreed with those obtained for nonburning drops vaporizing in airstreams. In a similar comparison, drag coefficients were approximately 40% greater for combustion conditions which were at static pressures of approximately 6½ times those for the nonburning case. By including the dimensionless group gl/c^{-2}, a correlation of drag coefficients with Reynolds number was obtained for burning and nonburning conditions. In a rocket combustor, vaporization rates are very high and sensible heat gained by the vapor diffusing out of the film surrounding the drop is large compared with the latent and sensible heat gained by the liquid drop. Similarly, drag-coefficient data showed that the momentum transferred to the diffusing vapor was of the same order of magnitude as that transferred to the liquid drop. Thus, high mass-transfer rates reduce the rate at which heat and momentum reach the drop surface. (J.R.C.)

N62-16121 Rocketdyne, Canoga Park, Calif.
RESEARCH IN HYBRID COMBUSTION. Quarterly Report for Period Ending 30 May 1962.
M. V. Peck and T. Houser. June 30, 1962. 33 p. 7 refs.
(Contract Nonr-3016(00))
(R-2267-7)

The equations derived from the simplified hybrid combustion theory based upon a diffusion flame model are applicable to turbulent gaseous flow upon proper definition of the parameters. The well-defined flame front is substantiated by movies taken at the end of the combustor. The complementary approach of examination of the solid phase heat conduction is being explored. (Author Abstract)

N62-16271 Aerospace Information Div., Washington, D.C.
COMBUSTION OF PROPELLANTS: AMMONIUM PERCHLORATE.
Sept. 19, 1962. 2 p. Review of: L. D. Romodanova and V. I. Roshchupkin. On the combustion of ammonium perchlorate. Zhur. Fiz. Khim. (Moscow), v. 36, no. 7, July 1962. p. 1554-1555.
(AID-62-139) OTS: \$1.10 mf, \$0.80 mf.

Data on the combustion of ammonium perchlorate (AP) propellant are given, relating pressure limit with grain size (size varied from 3 to 3000μ), and relating combustion speed with pressure. A moisture content of 0.1 to 0.7% did not affect the lower pressure limit for AP combustion, but a moisture content exceeding 2% prevented combustion in the pressure range studied (0 to 150 kg/cm^2). The lower pressure limit was found to decrease with increasing charge density.

At constant density, the lower pressure limit was found to be inversely proportional to the grain size; the lower pressure limit also decreased inversely with sample diameter. The combustion speeds of various grain size fractions of AP powders at all pressures up to 150 kg/cm^2 were dissimilar, but each fraction approached a constant combustion speed. (M.P.G.)

N62-16655 Ohio State U. Research Foundation, Columbus.
STUDY OF INFRARED EMISSION FROM FLAMES. Final Report, Part III.
Ely E. Bell, Phillips B. Burnside, Frederick P. Dickey, Stanley L. Kopczynski, and Robert F. Rowntree. Sept. 1956. 47 p. 2 refs.
(Contract AF 30(602)-1047)
(RADC-TR-57-51)

The infrared emissions from flames and hot gases were studied because these infrared sources are approximately monochromatic. In particular, the effect of noncombustible additives to flames, the radiance of hot gases independent of a combustion process, and the radiance of flames produced by a flat flame burner were examined. The effective emissivity is measured by a spectrometer which views first a source of continuous radiation and then a flame source interposed between the continuous source and the monochromator. A revolving slot chopper operates between the source and the flame so that only the radiation transmitted by the flame is detected. The two measurements are combined to give the absorptivity, and hence the emissivity, of the flame. The atmospheric transmissivity is determined by viewing the source of continuous radiation over the desired spectral range. The slit width is fixed for all measurements at a particular wavelength. Therefore, when the flame replaces the continuous source so that all path lengths are the same. Flame radiance measurements are reported for the CO - O_2 flame, the CH_4 - NO_2 - N_2 flame, and the COS - Air - O_2 flame; equivalent black body curves are plotted. Incombustible additives were added to the flames to determine the emission spectra of the additives excited by the combustion of the fuel and the oxidant. Sulfur hexafluoride, Freon 13, and boron trifluoride were examined as flame additives. The emissivity of carbon monoxide, methane and sulfur hexafluoride as hot gases was measured. (M.P.G.)

N62-16669 Bell Aerosystems Co., Buffalo, N.Y.
TITAN II STORABLE PROPELLANT HANDBOOK. Final Handbook, Revision A.
Ralph R. Liberto. Mar. 1962. 188 p. 62 refs.
(Contract AF 04(694)-72)
(Report 8182-933004; AFBSD-TR-62-2)

Summarized are the physical properties, materials compatibility, handling techniques, flammability and explosivity hazards, and procedures for storing, cleaning, and flushing of the Titan II propellants, N_2O_4 as the oxidizer and a nominal 50/50 blend of UDMH and N_2H_4 as the fuel. The data presented was derived both from a literature survey and from a test program conducted at Bell Aerosystems Company and at the U. S. Bureau of Mines. (Author Abstract)

N62-16968 Reaction Motors Div., Thiokol Chemical Corp., Denville, N.J.
INORGANIC CHEMISTRY OF THE OXYGEN SUBFLUORIDES. First Quarterly Progress Report, 15 Apr.–15 July 1962.
T. Hirata, S. Morrow, and A. Young. Aug. 15, 1962. 22 p. 9 refs.
(Contract NOnr-3824(00); ARPA Order 314-62)
(RMD-5009-Q1)

The ability of O_2F_2 to form low temperature purple solids with chlorine and a variety of other reagents, most of which contain chlorine, has been chosen as the initial area of investigation of the inorganic chemistry of the oxygen subfluorides. The reactions of several non-chlorine-containing reagents with O_2F_2 were examined qualitatively in an effort to confirm a hypothesis that the purple compounds are conventional coordination complexes in which O_2F_2 acts as a donor or base. On the basis of the data presently available, it appears doubtful that O_2F_2 acts as a Lewis base in the formation of the observed low temperature purple solids. The following reagents reacted with O_2F_2 without yielding purple solid intermediates: H_2O, HBr, CS_2, and SO_2. Reagents which failed to react with O_2F_2 were: AlF_3, TiF_4, and WF_5. Purple solids were obtained with $SiOl_4$, $TiCl_4$, and $AlCl_3{\cdot}6H_2O$. Two examples of purple solid formation need further confirmation; namely, the reactions of NaCl and of *cis*-N_2F_2 with O_2F_2. (Author Abstract)

N62-17105 Monsanto Research Corp., Dayton, Ohio
A RESEARCH PROGRAM FOR UNDERSTANDING THE MECHANISM OF FLAME INHIBITION [Final Report, Dec. 1, 1960–Nov. 30, 1961]
G. B. Skinner, D. R. Miller, J. E. Katon and W. H. Hedley Wright-Patterson AFB, Ohio, Flight Accessories Lab., Mar. 1962 99 p 11 refs
(Contract No AF 33(616)-7757)
(ASD-TR-61-717)

The effects of inhibitors on the hydrogen-air reaction were studied by measuring flame speeds of hydrogen-air-inhibitor mixtures, and via spectroscopic and shock-tube techniques. The best inhibitors were hydrocarbons as a group, several metallic chlorides, 1,2-dibromotetrafluoroethane, and iron carbonyl. Tentative explanations for the effectiveness of these inhibitors have been advanced, based on the experimental results and background information from the literature. Screening experiments so far have turned up no inhibitors for the spontaneous ignition of hydrazine in nitrogen tetroxide. The products of the nonflame reaction between hydrazine and dilute nitrogen tetroxide-air mixtures were identified as ammonium nitrate and nitrous oxide, while NH_2, NH and OH free radicals were observed spectroscopically in the hydrazine-nitrogen tetroxide diffusion flame. Author

N62-17108 Explosives Research Lab., Bureau of Mines, Pittsburgh, Pa.
EVALUATION OF RADIANT HEAT FLUX AND TOXICITY IN DYNA-SOAR-TITAN II DESTRUCT TESTS
Frank C. Gibson, John M. Murphy, and David Burgess Wright-Patterson AFB, Ohio, Dyna-Soar System Program Office, May 1962 35 p 7 refs
(ASD-TDR-62-221)

The report deals with activities of the Bureau of Mines in cooperation with two destruction tests of scale models of the Titan II fuel tankage systems. Total quantities of propellant involved were 14,000 pounds for one test, and 32,000 pounds for the other, of the Aerozine-N_2O_4 combination used in this booster. The work was restricted to providing information on three specific questions: (1) the completeness of reaction on putting together the hypergolic propellant combination; (2) the radiant heat flux from the reaction zone; and (3) the quantity and distribution of toxic vapors. It is estimated that reaction was about 20 percent completed within a period of 5 to 7 seconds. Additional reaction ensued on the test pad and all residual fuel was consumed by burning in air. About half of the oxidant was dispersed unreacted and largely carried upward in the thermal column resulting from the explosion. The peak radiation levels from the explosions were about 10^9 watts. Author

N62-17256 Little (Arthur D.) Inc., Cambridge, Mass.
ELECTROSTATIC HAZARDS ASSOCIATED WITH THE TRANSFER AND STORAGE OF LIQUID HYDROGEN Final Report to NASA. Marshall Space Flight Center, Huntsville, Ala.
May 15, 1961 83 p 13 refs
(Contract AF 18(600)-1687)
(C-61092)

An experimental investigation has been conducted to evaluate the potential hazards from static charges generated in well-grounded liquid hydrogen storage and transfer equipment. The results of the field tests carried out in this program established that, in typical transfer operations, significant electrostatic charges are generated—particularly during periods of two-phase flow. The magnitude of the charges measured, however, was not great enough to cause spontaneous ignition. The data suggest that the transfer of larger quantities as carried out at some producing and using facilities should be investigated to determine whether more critical conditions do occur. The investigation of the electrical characteristics of liquid hydrogen has shown that the maximum value of the electrical conductivity of liquid hydrogen does not exceed 10^{-17} ohm^{-1} cm^{-1} —a value much lower, than has been reported previously. The very low value of conductivity demonstrates that electrostatic charges generated during hydrogen transfer operations would persist for long periods of time. Author

N62-17364 Air Products and Chemicals, Inc., Allentown, Pa.
THERMODYNAMIC DATA ON OXYGEN AND NITROGEN [Final Report, May-Sept. 1961]
Jerome Brewer Wright-Patterson AFB, Ohio, Directorate of Materials and Processes, Sept. 1961 162 p 239 refs
(Contract AF 33(616)-8287)
(ASD-TDR-61-625)

The following data, which were compiled from published literature, are presented graphically as a function of temperature and pressure: viscosity of nitrogen, viscosity of oxygen, viscosity of air, viscosity of saturated liquid (oxygen, nitrogen, and mixtures); vapor-liquid equilibrium ratios: oxygen-nitrogen system; dew points: oxygen-nitrogen system; bubble points: oxygen-nitrogen system, thermal conductivity of nitrogen, thermal conductivity of oxygen, thermal conductivity of saturated liquefied nitrogen and oxygen, density of oxygen, density of nitrogen, Prandtl number of nitrogen, and Prandtl number of oxygen. For each of the properties a discussion of their critical evaluation was made. A complete bibliography of the sources used for each property is given as well as a master bibliography which includes all sources consulted or related to the subject. Author

N62-17768 Tokyo U. Aeronautical Research Inst. (Japan)
SOME STUDIES ON SOLID PROPELLANTS. PART I. KINETICS OF THERMAL DECOMPOSITION OF AMMONIUM PERCHLORATE
Kenji Kuratani July 1962 27 p 13 refs
(*Its* Rept. 372 (Vol. 28, No. 4))

The catalytic effects of the various catalysts on the thermal decomposition rate of ammonium perchlorate are studied. The mild decomposition kinetics of the pure AP (ammonium perchlorate) and of the AP containing 1 percent of Cu_2O and MnO_2, respectively, are represented with appropriate kinetics formulae; from these equations the critical temperatures where reaction transfers from mild decomposition to explosion are calculated, and their results are compared with the observed values. For the other catalysts, critical temperatures are observed as the measures to represent the catalytic effect of these catalysts. Author

N62-17928 Office of the Director of Defense Research and Engineering, Washington, D.C.
THE HANDLING AND STORAGE OF LIQUID PROPELLANTS
Mar. 1961 224 p refs Prepared by a Work Group of the Advisory Panel on Fuels and Lubricants
GPO: $1.25

This manual is intended to replace the earlier edition of October 1958, "Liquid Propellant Safety Manual," and supplements of January 1960. Author

N62-17995 Astropower, Inc., Newport Beach, Calif.
COMPATIBILITY OF STRUCTURAL MATERIALS WITH HIGH PERFORMANCE O-F LIQUID OXIDIZERS Quarterly Progress Report for Period 15 June to 15 Sept., 1962
N. A. Tiner and W. D. English 1962 29 p 22 refs
(Contract AF 33(657)-9162)
(Rept. 112-Q1)

An investigation is made of the compatibility of a variety of structural materials with several high performance O-F liquid oxidizers. The oxidizers to be used include fluorine oxide (OF_2), a 0.05% solution of ozone fluoride (O_3F_2) in liquid oxygen, and a mixture of 50% tetrafluorohydrazine (N_2F_4)-50% perchloryl fluoride ($FClO_3$). The program consists of four phases: (1) a literature survey, (2) preliminary compatibility tests with liquid and gaseous phases of the oxidizers, (3) development of passivation procedures to improve corrosion resistance, and (4) evaluation of long exposure times, welding, and stresses on corrosion. The literature survey has been completed, a laboratory for corrosion testing with hazardous oxidizers has been built, and all oxidizers and most of the structural materials to be tested have been received. Apparatus needed for the tests is being constructed. Author

1963

N63-10090 National Cash Register Co. Fundamental Research Dept., Dayton, Ohio
A STUDY OF THE ENCAPSULATION APPLICABLE TO LIQUID ROCKET FUEL Interim Report No. 4, 1 July 1961 to 30 June 1962
Paul Y. Hsieh July 1962 54 p refs
(Contract Nonr-2848(00))

Interfacial polymerization is studied as a promising approach to the problem of encasing a liquid within a polymer wall. Some polymers were prepared by interfacial polymerization under conditions which could be directly translated or extrapolated to actual encapsulation processes. The polymerization must occur under mild conditions and proceed with reasonable reaction rates. The resulting polymer wall must be able to protect the internal phase and to exclude moisture. The polymers formed by interfacial polymerization do not exclude moisture well. However, it is considered possible to overcome this disadvantage by post treatment of polymers by crosslinking. The prime requirement that a polymer must fulfill is that it be compatible with the internal phase. To this objective, the compatibility of hydrazine with various commercial polymers was studied. J.R.C.

N63-10149 Atlantic Research Corp., Alexandria, Va.
A PROGRAM TO ADVANCE THE TECHNOLOGY OF FIRE EXTINGUISHMENT [Interim Report, Apr. 1961–Mar. 1962]
M. Markels, Jr., R. Friedman, O. Fry, A. Macek, E. DuZubay, and R. Eichbauer Wright-Patterson AFB, Ohio, Directorate of Aeromechanics, Sept. 1962 73 p 27 refs
(Contract AF 33(616)-8110)
(ASD-TDR-62-526)

Extinguishing agents for fires of liquid hydrogen in dewars and controlled spills, and detonation suppressants for mixtures of hydrogen and oxygen gases were evaluated. Both spill and dewar fires were most effectively extinguished by first applying a mechanical foam followed by potassium bicarbonate powder. Foam by itself decreased the intensity (burning rate) but extinguished neither type of fire. Water fog, steam, sodium bicarbonate, ABC powder, bromotrifluoromethane, and nitrogen were found ineffective as extinguishing agents. Ten additives were evaluated as suppressants. Carbon tetrachloride acted as a sensitizer for the detonation. Methane or methyl chloride inhibited the detonation, but iron pentacarbonyl was the best suppressant evaluated. Author

N63-10171 Stanford Research Inst., Menlo Park, Calif.
VAPOR PRESSURE OF AMMONIUM PERCHLORATE
S. Henry Inami, Willis A. Rosser, and Henry Wise [1962] 13 p 18 refs
(Supported by the Office of Naval Research)

The equilibrium vapor pressure of ammonium perchlorate has been measured in the temperature range of 520° to 620° K by the transpiration method. The data indicate that ammonium perchlorate sublimes by the dissociation process $NH_4ClO_{4(s)} = NH_{3(g)} = HClO_{4(g)}$. The heat of dissociation has been found to be 58 ± 2 kcal/mole in the cited temperature range. Author

N63-10627 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
EFFECT OF COMPOSITION ON COMBUSTION OF SOLID PROPELLANTS DURING A RAPID PRESSURE DECREASE
Carl C. Ciepluch Washington, NASA, Dec. 1962 14 p 8 refs
(NASA TN D-1559) OTS: $0.50

The response of solid-propellant combustion to a pressure transient was studied in an apparatus that could be vented at a variable rate. The principal measurement was the time required for the pressure to decrease to one-half its initial value. The data are presented and discussed in terms of τ, the maximum value of the time required to extinguish combustion. The results indicate that the ease with which solid-propellant combustion may be extinguished is strongly dependent on physical factors such as the average size and the thermal conductivity of solid particles contained in the propellant. Analysis of the results suggested that hot-particle retention at the surface of the propellant was a major cause of the continuance of combustion in a rapidly decreasing pressure field. An examination of the data also indicated no correlation between τ and the propellant-strand burning rate. Author

N63-10766 Tokyo U. Aeronautical Research Inst. (Japan)
SOME STUDIES ON SOLID PROPELLANTS. PART II. BURNING RATE OF THE PERCHLORATE-POLYESTER (CASTABLE) PROPELLANTS
Kenji Kuratani Sept. 1962 15 p 4 refs
(*Its* Rept. 373 (Vol. 28, No. 5))

To find out the correlation between the burning rate of propellant and the thermal decomposition rate of ammonium perchlorate, the burning rates of propellants composed of ammonium perchlorate (AP) and polyester are measured at one atmosphere. The experimental procedures are defined precisely to obtain the reproducible result. Between the effects of various catalysts on the burning rate of propellant and on the pyrolysis rate of AP, there is no appreciable correlation. Moreover, the poor correlation between the burning rate and combustion temperature of propellant is also found. The burning rate up to the higher pressure region is also measured by Crawford method. Author

N63-10993 Monsanto Research Corp. Boston Labs., Everett, Mass.
RESEARCH ON SYNTHESIS OF NEW OXIDIZERS FOR SOLID PROPELLANTS Quarterly Technical Summary Report No. 1, July 1, 1962—Sept. 30, 1962
James W. Dale, Henry P. Beltramini, Carl A. Olson, Stephen P. Terpko, and George A. Tsigdinos Dec. 10, 1962 11 p 6 refs
(Contract AF 04(611)-8520; ARPA Order 352-62)
(MRB2022Q1)

The objectives of this research are (a) the study, by conductimetric means, of metathetic reactions of compounds involving the ions ClF_2^+ and ClF_4^- in various inert solvents such as ClF_3, HF, OF_2, etc.; and (b) the study of various energetic oxidizing compounds such as NF_3, $ClNO_3$, $FClO_3$, etc., with liquid OF_2 and further examination of the behavior of selected combinations of these agents in liquid OF_2 as a solvent, where feasible. Author

N63-11133 Army Chemical Center, Edgewood, Md.
MODIFIED TYPE A-1B UDMH & HYDRAZINE SERVICING TRAILER. VOLUME I: OPERATION AND SERVICE INSTRUCTIONS; VOLUME II: PARTS BREAKDOWN; VOLUME III: OVERHAUL INSTRUCTIONS [Final Report]
Edwards AFB, Calif., 6593 Test Group (Development), Nov. 1962 206 p In 3 vols.
(Contract AF MIPR (33-616)60-20)
(SSD-TDR-62-176)

Detailed information is given containing parts nomenclature, material and operating specifications, plus the proper sequence for replacing parts. Author

N63-11329 Martin Co., Denver, Colo.
CRYOGENIC PROPELLANT STRATIFICATION ANALYSIS AND TEST DATA CORRELATION
Thomas B. Jefferson (Arkansas U.), Thomas Bailey, Richard Vande-Koppel, and Gary Skartvedt [1962] 29 p 2 refs

An analytical model for prediction of temperature stratification in liquids is developed. This analysis permits the rocket designer to calculate liquid-propellant temperature and vapor-pressure histories during flight. The method is based on integration of the internal free-convection boundary layer along the portion of the tank wall exposed to aeroheating. Data are presented which show that the analysis successfully predicts the degree of temperature stratification measured in ground and flight tests with liquid oxygen and liquid nitrogen. Author

N63-11416 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
PREPARATION AND STORAGE STABILITY OF HIGH-PURITY HYDRAZINE
Harold W. Lucien Repr. from J. Chem. Eng. Data, v. 7, no. 4, Oct. 1962 p 541-542 9 refs

Several procedures for concentrating aqueous solutions of hydrazine and for obtaining the anhydrous product have been described. To avoid certain hazards, low yields, and time-consuming aspects of most of these methods, a new procedure was adopted in which a commercial grade of anhydrous hydrazine was treated with calcium hydride in an inert atmosphere. Calcium hydride has been previously used to dry alkyl hydrazines. The method used in this work was relatively simple and did not require heating or refluxing of the hydrazine. The purity and stability of hydrazine obtained by the calcium hydride method were similar to the respective values found for hydrazine derived from the ammonolysis of hydrazine sulfate. Author

N63-11616 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
RELATIVE IGNITABILITY OF TYPICAL SOLID PROPELLANTS WITH CHLORINE TRIFLUORIDE
Harrison Allen, Jr., and Murray L. Pinns Washington, NASA, Jan. 1963 24 p 2 refs
(NASA TN D-1533) OTS: $0.75

Ignition delays were measured after exposing samples of solid propellants and their components to the hypergolic fluid, chlorine trifluoride (ClF_3), in both the liquid and the gas phases. A comparison of these ignition-delay data serves as a measure of the relative reactivity of these propellant compositions with ClF_3. The gas-phase studies showed that the ignition delay varied exponentially with ClF_3 pressure and approached a limit of less than 50 milliseconds at 14 pounds per square inch absolute, the maximum pressure permitted by the experimental apparatus. The gas-phase studies also revealed that the reactivity of the propellant formulation was greatly affected by changes in concentrations of the dispersed solid components (ammonium perchlorate and aluminum) of the propellant. After reaching a minimum point, the ignition delay of the propellant increased with an increase in the concentration of the ammonium perchlorate component; with an increase in the concentration of the aluminum component, the ignition delay was decreased. All the propellant formulations were extremely reactive with liquid ClF_3 and had ignition delays of less than 3 milliseconds. Author

N63-11736 Hynes Chemical Research Corp., Durham, N.C.
FUNDAMENTAL RESEARCH ON THE DIRECT FLUORINATION OF ORGANIC COMPOUNDS. SECTION A Quarterly Technical Report No. 1, September 1, 1962-November 30, 1962
Lucius A. Bigelow, John B. Hynes, Abe F. Maxwell, and Brian C. Bishop [1962] 15 p 7 refs
(ARPA Order 40-62, Amend. 21)

The mild, direct fluorination of chlorodifluoroacetonitrile has been studied and shown to yield two interesting new compounds, $CClF_2CF_2NF_2$ and $CClF_2CF{=}NF$. The formation of the latter suggested that other halogenated nitriles could also be partially fluorinated under carefully controlled conditions. Accordingly, the fluorination of trifluoroacetonitrile has been reexamined and found to yield $CF_3CF{=}NF$ in fairly substantial quantity for this type of reaction. An alternate route to unsaturated, highly fluorinated carbon-nitrogen systems, namely the pyrolytic defluorination of perfluorinated compounds, has also been studied. Perfluoropiperidine yielded nonafluoro-1-piperidine in 50% to 60% yield. The pyrolyses of CF_3NF_2, $C_2F_5NF_2$, $C_4F_9NF_2$, $CF_3NFC_3F_7$ and $(CF_3NF)_3$ have also been examined, the first of which provided a new method for preparing perfluoromethyleneimine, $CF_2{=}NF$. Author

N63-11878 Atlantic Research Corp., Alexandria, Va.
HAZARDS OF LIQUID HYDROGEN IN RESEARCH AND DEVELOPMENT FACILITIES [Final] Technical Documentary Report [May 1-Nov. 1, 1962]
Guenther von Elbe and Howard T. Scott, Jr. Wright-Patterson AFB, Ohio, Directorate of Aeromechanics, Dec. 1962 81 p 27 refs
(Contract AF 33(657)-8952)
(ASD-TDR-62-1027)

The physical and chemical properties of hydrogen have been summarized with emphasis on the relation of these properties to combustion and detonation processes, and information has been collected on experiences and practices in numerous facilities. Hazards comprise the possibility of pressure rupture of containers, initiation of flammable mixtures formed by release of hydrogen due to vessel failure or other causes, and explosion of hydrogen and contaminating oxygen under cryogenic conditions. It is shown that the theory of chemical reaction provides a complete understanding of the combustion and detonation characteristics of hydrogen-oxygen systems and defines the chemical and physical requirements for inhibition and control of combustion and detonations. Experiences and practices in research and development facilities have been reviewed, and subjects warranting further investigation have been determined. Author

N63-12123 Rocketdyne, Canoga Park, Calif.
RESEARCH IN HYBRID COMBUSTION Quarterly Report for Period Ending 31 August 1962
M. V. Peck, T. Houser, and H. N. Chu Jan. 16, 1963 32 p 8 refs
(Contract Nonr-3016(00))
(R-2267-8)

The radius vs. time data taken at two oxygen flow rates were fitted by the empirical equation $r = A + Bt^c$. The instantaneous burning rate, r, is obtained by differentiation of this equation. The thermocouple measurements were described by the pseudo-steady-state heat conduction equation $T = T_S \exp(-bx/k)$. Author

N63-12170 Monsanto Research Corp., Dayton, Ohio
MECHANISM AND CHEMICAL INHIBITION OF THE HYDRAZINE-NITROGEN TETROXIDE REACTION [Final Report, Aug. 1961-Oct. 1962]
G. B. Skinner, W. H. Hedley, and A. D. Snyder Wright-Patterson AFB, Ohio, Flight Accessories Lab., Dec. 1962 35 p 21 refs
(Contracts AF 33(616)-7757 and AF 33(657)-7617)
(ASD-TDR-62-1041)

The mechanism of the hydrazine-nitrogen tetroxide reaction was investigated by examination of the variation in reaction products and equilibrium reaction temperature with increasing reactant concentration when argon-diluted reactant streams were rapidly mixed in a flow reactor. It is concluded that the reaction proceeds through a thermal reaction mechanism rather than a chain-branched explosion mechanism. An ignition test was devised to determine the effect of candidate reaction inhibitors. No effective inhibitors were found among 27 gaseous and 28 liquid additives tested. Thiophene, toluene, trimethyl borate, ethyl bromide, and benzene produced some inhibition, but only at high concentrations. These results support the conclusions that a thermal mechanism is operative. Author

N63-12280 Warner & Swasey Co. Control Instrument Div., N.Y.
INFRARED RADIATION AND TEMPERATURE MEASUREMENTS IN SOLID PROPELLANT FLAMES. I. PRELIMINARY STUDY OF ARCITE 368
Gunter J. Penzias, Eliot T. Liang, and Richard H. Tourin Oct. 1962 36 p 8 refs
(Contracts Nonr-3657(00) and ARPA Order 237-62; Proj. DEFENDER)
(TR-800-5)

Infrared radiation and temperature measurements have been made of combustion gases evolved in the burning of Arcite 368, a composite-type solid propellant. A combustion system and instrumentation were constructed which permitted measurements to be made under controlled conditions. The spectral radiance, emissivity, and temperature of the solid propellant flame were measured in the 1.0μ to 5.0μ region, at several distances from the burning surface. The chemical species observed were HCl, CO_2 and H_2O. These results can be used to predict radiation of larger flames. Flame temperature increased with the distance from the burning surface, reaching a maximum equal to the adiabatic temperature at 0.8 mm. The indicated reaction-zone thickness is in agreement with measurements made by photographic techniques. Author

N63-12402 Tokyo U. Aeronautical Research Inst. (Japan)
SOME STUDIES ON SOLID PROPELLANTS. PART III. ANALYTICAL RESULTS OF THE COMBUSTION GASES
Kenji Kuratani Sept. 1962 17 p 18 refs
(*Its* Rept. 374 (Vol. 28, No. 6))

The variations of the composition of combustion gases of ammonium perchlorate (AP) with the addition of various catalysts are studied in hopes of finding good correlation to the burning rate of AP propellant. The effects of the catalysts on the composition of gaseous products of AP combustion are remarkable, and it is concluded that catalysts which produce higher concentration of oxygen and lower concentration of nitric oxide during the combustion of AP may increase the burning rate of propellant. At the same time, some catalysts are very effective in decreasing the mean molecular weight of combustion products of AP. Similar analyses of the combustion products of AP composite propellants are also carried out, but the effect of these catalysts is negligible, and little variation of gaseous composition by the addition of these catalysts is observed. Accordingly, the catalytic effect on the decrease of mean molecular weight of the combustion products of propellants is not remarkable. Theoretical calculations of specific impulse are presented as a reference to the experimental studies. Author

N63-12425 Picatinny Arsenal. Liquid Rocket Propulsion Lab., Dover, N.J.
A CLOSED-LOOP HEAT TRANSFER TEST APPARATUS
Jay R. Grossman Oct. 1962 19 p 8 refs
(Picatinny Arsenal Tech. Memo 1119)

The ability of a propellant to regeneratively cool is limited by the values of heat flux at the upper limit of nucleate boiling qul. A closed-loop test apparatus to determine the heat transfer characteristics of high-energy monopropellants has been designed and operated. Included are details of the flow circuit and calculations used to determine heat flux values. Verification of the system was accomplished in two ways: (1) comparing test data to a theoretical standard and (2) comparing consistency of similar data. Test results using white fuming nitric acid (WFNA) compare within 15 percent of theoretical predicted by the Sieder and Tate equation for turbulent flow through tubes, which is typical of forced convection nonboiling heat transfer measurements. Slopes and inception of nucleate boiling for two different tests under similar conditions were identical. These initial tests, using a high-energy monopropellant as the test fluid, successfully demonstrated that the upper limit of nucleate boiling can be attained. At burnout there were no detonations or explosions, which demonstrates the adequacy of the system relative to safety precautions. Author

N63-12535 National Advisory Committee for Aeronautics. Lewis Flight Propulsion Lab., Cleveland, Ohio

AIRCRAFT-FUEL-TANK DESIGN FOR LIQUID HYDROGEN

T. W. Reynolds Washington, NACA, Aug. 9, 1955 28 p 26 refs
(NACA RM E55F22) OTS: $2.60 ph, $1.04 mf (Declassified)

Some of the considerations involved in the design of aircraft fuel tanks for liquid hydrogen are discussed. Several of the physical properties of metals and thermal insulators in the temperature range from ambient to liquid-hydrogen temperatures are assembled. Calculations based on these properties indicate that it is possible to build a large-size liquid-hydrogen fuel tank which (1) will weigh less than 15 percent of the fuel weight, (2) will have a hydrogen vaporization rate less than 30 percent of the cruise fuel-flow rate, and (3) can be held in a standby condition and readied for flight in a short time. Author

N63-12536 National Advisory Committee for Aeronautics. Lewis Flight Propulsion Lab., Cleveland, Ohio

ROCKET ENGINE STARTING WITH MIXED OXIDES OF NITROGEN AND LIQUID AMMONIA BY FLOW-LINE ADDITIVES

George R. Kinney, Jack C. Humphrey, and Glen Hennings Washington, NACA, Aug. 19, 1953 32 p 11 refs
(NACA RM E53F05) OTS: $3.60 ph, $1.16 mf (Declassified)

Starting characteristics of mixed oxides of nitrogen-ammonia rocket engines were investigated with additives in the ammonia flow line for ignition. The oxidant was 70 percent by weight N_2O_4 and 30 percent NO. Starting with lithium as an additive was satisfactory over a wide range of conditions. A 1000-pound-thrust engine at ambient temperature started under all conditions during a 25-run series, including oxidant-fuel weight ratios from 0.6 to 14, oxidant and fuel leads, and times to reach starting flows from 0.1 to 3 seconds. With propellants and engine at -85° F, 200-pound-thrust engines started at oxidant-fuel weight ratios from 1.1 to 4.4; operating flow and combustion pressure were reached in 0.25 second. Weights of lithium in ammonia were of the order of 0.05 to 0.15 percent. In additional experiments at -85° F, all of five attempts with calcium resulted in satisfactory starts; starting was unreliable in three attempts with magnesium. Author

N63-12540 National Advisory Committee for Aeronautics. Lewis Flight Propulsion Lab., Cleveland, Ohio

LOW-TEMPERATURE CHEMICAL STARTING OF A 200-POUND-THRUST JP-4-NITRIC ACID ROCKET ENGINE USING A THREE-FLUID PROPELLANT VALVE

Glen Hennings and Gerald Morrell Washington, NACA, June 30, 1955 25 p 16 refs
(NACA RM E55E04) OTS: $2.60 ph, $0.95 mf (Declassified)

Studies in a 200-pound-thrust rocket engine showed that the JP-4 nitric acid system could be started at temperatures as low as -65° to -60° F with a hydrazine-water igniter fuel. A three-fluid control valve scheduled the transition from igniter fuel to JP-4. Limiting igniter-fuel compositions for starting at -60° F were 55 and 69 percent hydrazine. When the same technique was used with an organophosphorous igniter fuel (RF 208) and with a blend of 70 percent triethylamine and 30 percent o-toluidine starts were obtained at -80° F. Author

N63-12541 National Advisory Committee for Aeronautics. Lewis Flight Propulsion Lab., Cleveland, Ohio

LIQUID HYDROGEN AS A JET FUEL FOR HIGH-ALTITUDE AIRCRAFT

Abe Silverstein and Eldon W. Hall Washington, NACA, Apr. 15, 1955 57 p 6 refs
(NACA RM E55C28a) OTS: $5.60 ph, $1.91 mf (Declassified)

The performance of hydrogen as a jet fuel was investigated for the following missions: subsonic bomber, subsonic reconnaissance, supersonic bomber, supersonic reconnaissance, and supersonic fighter. Comparisons are made in some cases with configurations suitably designed for the use of JP-4 fuel. The analysis showed that aircraft designed for liquid-hydrogen fuel with ramjet and/or turbojet engines may perform several imporant military missions that comparable aircraft using conventional hydrocarbon fuel cannot accomplish. M.P.G.

N63-12640 National Aeronautics and Space Administration, Washington, D.C.

LUNAR LANDING PROPULSION CONSIDERATIONS

K. R. Stehling Feb. 1963 23 p 3 refs
(NASA TN D-1723) OTS: $0.75

The propellant must have high density impulse, low ignition lag, and storability in space. The overall propulsion system must have operational reliability, simplicity, low weight, and throttling capacity. The four propellant combinations are rated in order of burnout velocities: F_2/N_2H_4, F_2/H_2, N_2O_2/N_2H_4, and H_2/O_2. The OF_2-diborane combination has interesting possibilities for further research. Author

N63-12832 Aeronutronic, Newport Beach, Calif.

CHEMICAL CORROSION OF ROCKET LINER MATERIALS AND PROPELLANT PERFORMANCE STUDIES. VOL. II. DETAILED THEORETICAL PERFORMANCE OF SOME LIQUID PROPELLANT SYSTEMS Second Quarterly Technical Summary Report

R. C. Oliver, S. E. Stephanou, R. J. Getz, D. Piper and R. W. Sprague Jan. 20, 1963 268 p 10 refs
(Contract NOw-61-0905-c; ARPA Order 22-62)
(C-1960)

The theoretical performance of certain binary liquid-propellant systems under a wide variety of expansion conditions and mixture ratios has been computed and results are presented in graphical and tabular form. The graphs show vacuum specific impulse for area ratios of 8, 20, and 50, sea level optimum specific impulse, characteristic velocity, molecular weight and chamber temperature as a function of mixture ratio, for both frozen and equilibrium (shifting) expansion conditions, at chamber pressures of 300 and 1000 psi. The tabular data are in the form of computer output sheets, and give detailed performance and other data for all integral area ratios from 1 to 50; values are also given at two larger area ratios, the values depending on the system. Altitude effects are discussed, and techniques described for computing ideal performance for any of these mixtures at any altitude; results are given for sea level, 10,000 feet and 50,000 feet and vacuum as a function of area ratio for each mixture for zero divergence angle. The methods used in carrying out the computations are described briefly, with reference to more detailed descriptions. The latest thermodynamic data are used, and a large number of minor species are considered for maximum precision. Author

N63-13071 Defense Metals Information Center, Battelle Memorial Inst., Columbus, Ohio

REACTIVITY OF METALS WITH LIQUID AND GASEOUS OXYGEN

J. D. Jackson, W. K. Boyd, and P. D. Miller Jan. 15, 1963
(Contract AF 33(616)-7747)
(DMIC-MEMO-163)

Of all the metals studied to date, titanium exhibits the greatest sensitivity to impact when immersed in LOX. Its sensitivity approaches that of many organic materials, such as greases and oils. Reactivity is observed in liquid oxygen and mixtures of liquid oxygen and liquid nitrogen at 20 ft-pounds until the LOX concentration is reduced to 30 percent. Titanium can be partially protected from reactivity in LOX under impact by certain protective coatings, provided the coatings are not broken. Protection is given by electroless copper and nickel, possibly aluminum, and to a lesser extent by Teflon and a fluoride-phosphate coating. Protection is also obtained by nitriding, which adds a protective film to the surface, and by annealing, which increases the thickness of the oxide film. Titanium exhibits no great reactivity in LOX when deformed by compression, by exposure of a fresh surface by machining or rupture, or by exposure of bulk titanium to high-pressure or high-velocity LOX. In gaseous oxygen, titanium is highly reactive when a freshly formed surface is exposed at even moderate pressures. When a titanium vessel containing LOX or gaseous oxygen is ruptured by a bullet, by a simulated micrometeoroid, or by other mechanical puncture, violent burning begins at almost 0 psig. If the vessel is not fractured by external impact, vibration, acoustic energy, thermal effects, or with slowly propagated cracks, such as fatigue cracks, no reactivity is noted. Of other metals discussed, only zirconium shows similar reactions in oxygen. Stainless steels are found to exhibit almost no reactivity in oxygen under impact, rupture, explosive shock, or heating. Aluminum is similarly unreactive, but will ignite under conditions of high-explosive shock. Magnesium shows reactivity to explosive shock lying about midway between that of aluminum and titanium. For high-pressure oxygen systems, stainless steel and Monel were found to be satisfactory.

Author

N63-13081 Stanford Research Inst., Menlo Park, Calif.

A SURVEY AND EVALUATION OF HIGH ENERGY LIQUID CHEMICAL PROPULSION SYSTEMS. PART I: PROPELLANT SELECTION CRITERIA FOR SPACE MISSIONS Final Report, March 15, 1961 to October 15, 1962

James A. Mac Leod and P. Roger Gillette Nov. 1, 1962 85 p 23 refs

(NASA Contract NASr-38; SRI Proj. PRU-3652)

OTS: $8.10 ph, $2.75 mf

Results of a study are presented to develop a procedure for evaluating liquid propellants in order (a) to select the most appropriate propellant (from among those under development) for each of several applications on each of the various missions in the NASA program, or (b) to select new propellants (from among those being proposed) for initiation or continuation of research and development.

Author

N63-13082 Stanford Research Inst., Menlo Park, Calif.

A SURVEY AND EVALUATION OF HIGH ENERGY LIQUID CHEMICAL PROPULSION SYSTEMS. PART II: PREPARATION AND PROPERTIES OF OZONE FLUORIDE Final Report, Mar. 15, 1961 to Oct. 15, 1962

Adolph B. Amster, Joseph A. Neff, and A. J. Aitken Nov. 1, 1962 64 p 39 refs

(NASA Contract NASr-38)

OTS: $6.60 ph, $2.12 mf

Rocket engines which use liquid hydrogen and liquid oxygen are being developed for use in missiles for space exploration. The reliability of these engines would be improved by making the propellant combination hypergolic: Ozone fluoride, O_3F_2, when dissolved at very low concentrations in liquid oxygen reportedly accomplishes this end. This report contains a review of the properties of O_3F_2 and other fluorine-oxygen compounds. Also included are results of studies of O_3F_2 conducted at Stanford Research Institute. These studies have confirmed the synthesis and photochemical decomposition of O_3F_2. Results from both laboratory and engine ignition tests suggest conditions under which O_3F_2 renders the liquid system O_2-H_2 hypergolic. The report begins with a review of the chemical and physical properties of other compounds of oxygen with fluorine and concludes with suggestions for the additional research required to establish the utility and reliability of O_3F_2 as a hypergolic additive. In addition, information concerning safety and compatibility problems is included.

Author

N63-13093 Pennsalt Chemicals Corp. Research and Development Dept., Wyndmoor, Pa.

RESEARCH ON THE COMPATIBILITY OF WELDED STRUCTURAL MATERIALS WITH CHLORINE TRIFLUORIDE, PERCHLORYL FLUORIDE AND MIXTURE OF THESE Third Quarterly Progress Report [Oct. 1-Dec. 31, 1962]

John C. Grigger and Henry C. Miller Jan. 15, 1963 45 p 1 ref

(Contract AF 33(657)-8461)

Fabrication, including heat treatment and cleaning, of all welded metal specimens, both tensile and stress form, required for the static immersion tests has been completed. Mechanical properties (T.S., Y.S., and % elong.) have been determined for four replicate welded tensile specimens of each of the nine alloys after heat treatment, to serve as control values. Thermostated safety-cell facilities in a high pressure laboratory were assembled and tested for the one-year, 30° C immersion tests. Three oxidizers and 540 tensile and stress specimens were loaded into 36 steel pressure tanks to begin these one-year exposures. This test phase provides for liquid, vapor, and interface exposures to chlorine trifluoride, perchloryl fluoride and a 25% ClO_3F - 75% ClF_3 mixtures. The 21-day, 30° C immersion tests have been started in a second safety-cell facility containing 12 pressure tanks. Planning and assembling of equipment and specimens for the dynamic exposure tests have begun.

Author

N63-13145 AiResearch Mfg. Co., Los Angeles

SUBCRITICAL LIQUID OXYGEN STORAGE AND CONVERSION SYSTEM FOR OMNIGRAVIC OPERATION [Final] Report

R. L. Polk Wright-Patterson AFB, Ohio, Life Support Systems Lab., Dec. 1962 24 p

(Contract AF 33(616)-7153)

(Engineering Rept. AE-2072-R; AMRL-TDR-62-143) OTS: $0.75

This program was directed toward the design and development of a low-pressure storage system for the storage of liquid oxygen, the conversion of the liquid to usable, gaseous state, and the controlled delivery of the gaseous oxygen under omnigravic conditions. The program was an extension of the feasibility study of a system employing an internal relief valve, and provided for, in particular, the minimization of evaporation loss of stored liquid oxygen through standby venting caused by heat leakage to the stored liquid, and the development of suitable fluid capacity gaging equipment. This report presents an account of the design and development of a subcritical liquid oxygen storage and conversion system and outlines the final engineering conclusions and recommendations.

Author

N63-13249 Reaction Motors Div., Thiokol Chemical Corp., Denville, N.J.

INVESTIGATION OF ADVANCED HIGH ENERGY SPACE STORABLE PROPELLANT SYSTEM [Final Report] June-November 1962

B. E. Dawson, A. F. Lum, and R. R. Schreib [1962] 118 p 25 refs

(NASA Contract NASw-449)

(RMD-5507-F) OTS: $9.60 ph, $3.74 mf

The feasibility of using an oxygen difluoride-diborane propellant combination for use in space applications was investigated. Results indicate that the OF_2-B_2H_6 propellant combination is feasible for space applications. High performance and hypergolic ignition under simulated altitude starting conditions were demonstrated. No unexpected problem areas were encountered in the experimental program attributable to the physical properties, material compatibility, or the handling and safety characteristics of either propellant. Further tests should be made to substantiate the vacuum operational cooling requirements of the propellant combination, as well as to demonstrate its scalability to thrust ranges suitable for space applications.

I.v.L.

N63-13326 Frankford Arsenal. Pitman-Dunn Labs., Philadelphia, Pa.

COMPATIBILITY OF LUBRICANTS WITH MISSILE FUELS AND OXIDIZERS

Kurt R. Fisch (ASD. Materials Central, Wright-Patterson AFB), Louise Peale, Joseph Messina, and Henry Gisser Repr. from ASLE Trans.,

v. 5, 1962 p 287-296 11 refs Presented at the Annual Meeting of the Amer. Soc. of Lubrication Engineers (ASLE), St. Louis, May 1962 (Rept. A62-13)

Various compounds were studied to determine their suitability as lubricants in the presence of fuels and oxidizers used in missile systems. The classes of compounds studied were the halogenated aliphatic and aromatic hydrocarbons, the silicon and perfluorocompounds, esters, ethers, and compounds containing nitrogen. The fuels and oxidizers included ethyl alcohol, hydrocarbon fuel, unsymmetrical dimethylhydrazine, diethylenetriamine, a mixture of the latter two, hydrogen peroxide, inhibited red fuming nitric acid, and liquid oxygen. The most promising compounds were studied for their extreme pressure, antiwear, volatility, and viscometric properties. Three compounds were found to be completely inert (unreactive and insoluble) with all the fuels and oxidizers. One was a liquid (perfluorotributylamine) and the other two were solids (polytetrafluoroethylene and tetrafluoroethylene-hexafluoropropylene copolymer). The perfluorotributylamine exhibited adequate lubrication properties except for excessive volatility. The preparation of higher homologs of this compound is expected to remedy this shortcoming. The polytetrafluoroethylene and the copolymer may find application as components of a grease-type lubricant. Author

N63-13417 Office of Research Analyses. Science and Engineering Div., Holloman AFB, N. Mex.

ANALYSIS OF ADVANCED TRACK PERFORMANCE CHARACTERISTICS

Herman F. Borges Jan. 1963 36 p 5 refs
(ORA-63-1)

Velocity and acceleration profiles of rocket sleds on an advanced track were determined, based on existing and advanced rocket-engine and sled designs. Sled families with a unit thrust of 100,000 pounds, using propellants of different specific impulse, were postulated. Rocket assembly weight and payload weight were expressed in terms of thrust, and tank and structural weight in terms of propellant weight. The upper limit for rocket sleds using liquid oxygen and liquid hydrogen as propellants is about 5400 feet per second in ambient air density at one percent payload-to-thrust ratio. This speed will increase to about 8000 feet per second if the track is enclosed in an evacuated tube at about one-third of the ambient air density. To attain this performance, a track about 40 statute miles long is required. Author

N63-13444 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

DETERMINATION OF WATER IN HYDRAZINE BY GAS CHROMATOGRAPHY

Daniel M. Kuwada Nov. 15, 1962 8 p 4 refs
(NASA Contract NAS7-100)
(JPL-TR-32-362) OTS: $1.10 ph, $0.50 mf

The gas chromatographic separation of water and hydrazine has been accomplished on a column of Fluoropak-80 coated with 20% Ucon Oil 550X. This separation was applied to the determination of small quantities of water in hydrazine. An automatic integrator was used to make the analysis rapid and reproducible. This analytical scheme is simple and accurate for concentrations of water in hydrazine, ranging from 0.5 to 2.0 wt. percent. Author

N63-13605 Air Reduction Co., Inc. Central Research Labs., Murray Hill, N. J.

ADVANCED TEST METHODS FOR DETERMINING OPERATIONAL CHARACTERISTICS OF PROPELLANTS Sixth Quarterly Progress Report, Sept. 1, 1962 to Nov. 30, 1962

G. A. Mead [1962] 23 p
(Contract AF 04(611)-7413)

Simultaneous streak photograph and electronic conductance probe measurements have been made on nitromethane and nitromethane sensitized with 3% ethylene diamine. Definition of data in the preignition region is not yet satisfactory. Attempts to detect passage of the detonation front by spaced Teflon sleeves on the conductance probes were unsuccessful, probably because the Teflon became conductive under the conditions of the test. A remote loading system and cold-gas sample refrigeration system have been installed and tested for use with liquids having high vapor pressure. Modification of the U-tube compression test has resulted in some positive results on nitromethane, but these were not reproducible. Pressure calibration tests with inert liquids gave traces with the expected characteristics, but valve operation may have been erratic. In the batch-type thermal stability test, two new bomb designs have been tried with the intent of reducing the resistance to heat transfer between the sample and the heating bath. Results were obtained on nitromethane, nitromethane sensitized with 3% ethylene diamine, n-propyl nitrate, and monomethyl hydrazine. A remote loading system was assembled. In the first test with acetylene, explosion occurred at about 540° F, demolishing the bath. Author

N63-13706 Aerojet-General Nucleonics, San Ramon, Calif.

HYDRAZINE PROCESS DEVELOPMENT Interim Technical Engineering Report, August through October 1962

F. R. Standerfer, H. J. Snyder, H. T. Watanabe, L. G. Carpenter, R. I. Miller, and R. L. Pearson Wright-Patterson AFB, Ohio, ASD [1962] 218 p 19 refs
(Contract AF 33(600)-42996)
(ASD-TR-7-840A(VII); AGN-AN-756)

The primary goal of this program is to develop, design, construct, and operate a continuous, in-reactor, hydrazine-production loop based on the fission chemical-process approach. This report discusses fission-fragment distribution studies, colloidal UO_2 preparation, improvements in uranium and hydrazine analytical techniques, in-reactor loop-design modifications, fission-fragment deposition measurements for a variety of sources, correlation of experimental heat-transfer data, and a parametric reactor-systems analysis. B.J.C.

N63-13739 Gt. Brit. Ministry of Aviation. Technical Information and Library Services, Mottingham

INVESTIGATIONS OF NITROGEN-CHLORIDE COMPOUNDS. NITROGEN-MONOHYDRIDE AS AN INTERMEDIATE PRODUCT OF THE DECOMPOSITION OF CHLORAMINE (STICKSTOFF-MONOHYDRID ALS ZWISCHENPRODUKT DER CHLORAMIN-ZERSETZUNG)

J. Jander and J. Fischer Feb. 1962 11 p 16 refs Transl. from Z. Anorg. Allgem. Chem., (Leipzig), v. 313, 1961 p 37-47
(TIL/T-5368)

Solid chloroamine has been decomposed at -190° C by ultraviolet irradiation. The blue product formed is stable below -150° C. This result is supported by the identification of hydrogen cyanate during the thermal decomposition of gaseous chloroamine in the presence of carbon monoxide (5 to 10 mm Hg, 500° C). Under the same conditions, hydrazine also produces hydrogen cyanate. Studies have shown that nitrogen monohydride and ammonia react to form hydrazine, therefore it is experimentally possible to synthesize hydrazine from chloroamine and ammonia by way of the intermediate product nitrogen monohydride. Author

N63-13768 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

THE EFFECTS OF MOISTURE ON THE DYNAMIC MECHANICAL PROPERTIES ON AMMONIUM PERCHLORATE—POLYURETHANE PROPELLANTS

Robert F. Landel and B. G. Moser Feb. 26, 1963 22 p 8 refs
(NASA Contract NAS7-100)
(JPL-TR-32-389) OTS: $2.60 ph, $0.86 mf

The detrimental effect of moisture on ammonium perchlorate—polyurethane propellant appears to be due to one or more of the following mechanisms: solution, migration, and precipitation of the oxidizer. Direct microscopic observation indicates that the ammonium perchlorate grains are physically separated from the binder, when exposed to relative humidities greater than 15% at ambient temperatures. This physical dewetting leads to small-strain dynamic shear compliance instability which is a function of time and environment. The environmental effect, producing either a softening or an embrittlement, is established to be a function of the previous humidity history and the environment at the time of measurement. There appears to be an optimum amount of water necessary for maximum embrittlement at any given temperature, and additional water tends to decrease embrittlement. The detrimental effects can be reversed, apparently by a healing of the salt-binder adhesion on the surface of the initial grains, and additional reinforcement provided by the precipitation of new, euhedral crystals of ammonium perchlorate. Author

N63-13887 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

EVALUATION OF INJECTOR PRINCIPLES IN A 2400-POUND-THRUST ROCKET ENGINE USING LIQUID OXYGEN AND LIQUID AMMONIA

Robert C. Hendricks, Robert C. Ehlers, and Robert W. Graham Washington, NASA, Jan. 1959 34 p 11 refs

(NASA MEMO 12-11-58E) OTS: $3.60 ph, $1.22 mf (Declassified)

The performances of three injector types were evaluated in a 2400-pound-thrust rocket test chamber to compare the relative effects of fuel and oxidant atomization. Injector 1 atomized the fuel and oxidant to a fine degree. Injector 2 atomized the fuel to a coarse degree with straight streams of oxidant. Injector 3 gave coarse oxidant atomization with straight streams of fuel. Each injector represents one of the eighteen such units forming the injector for a 50,000-pound-thrust rocket engine. Author

N63-14122 General Dynamics/Astronautics, San Diego, Calif.

EVALUATION TEST OF LIQUID OXYGEN PROPELLANT DUCT

D. E. Lawrance Jan. 16, 1963 23 p 5 refs

(Rept. 55A-1354-4)

The main propellant line between a liquid-oxygen sump and a rocket engine was tested for leakage at cryogenic temperatures during vibration. The system consisted of a liquid-oxygen propellant duct, a liquid-oxygen recirculating line, a liquid-oxygen boost-pump sump, and associated hardware. Structural failure of the 55-02139-3 liquid-oxygen recirculation flex hose resulted in termination of the testing. M.P.G.

N63-14221 Monsanto Research Corp. Boston Labs., Everett, Mass.

RESEARCH ON SYNTHESIS OF NEW OXIDIZERS FOR SOLID PROPELLANTS Quarterly Technical Summary Report No. 2, October 1 to December 31, 1962

James W. Dale, Henry P. Beltramini, Carl A. Olson, Stephen P. Terpko, and George A. Tsigdinos Feb. 26, 1963 20 p 19 refs

(Contract AF 04(611)-8520; ARPA Order 352-62)

(MRB-2022Q2)

The preparation and purification of various energetic oxidizing compounds required for miscibility and reactivity studies in liquid oxygen fluoride, and for conductimetric study of metathetic reactions involving the ions ClF_2^+ and ClF_4^- in various inert solvents was investigated. Of the oxidizing compounds studied, OF_2, ClF_3, N_2F_4, and ClO_3F were proved to be nonconducting; ClF_3, N_2F_4, and ClO_3F were found to be unreactive towards OF_2. The binary system ClF_3-ClO_3F was examined but no reaction was observed either in the gas or liquid phases; the ternary system ClF_3-ClO_3F-OF_2 behaved similarly. A.R.B.

N63-14488 Aerojet-General Corp. Solid Rocket Plant, Azusa, Calif.

INVESTIGATION OF THE MECHANISMS OF DECOMPOSITION, COMBUSTION, AND DETONATION OF SOLIDS [Technical Operating Report, Jan. 1-Mar. 31, 1963]

D. J. Sibbett Mar. 3, 1963 17 p 5 refs

(Contract AF 49(638)-851; ARPA Order 24-60)

(Rept. 0372-01-13)

The "apparent flame strength" of the ammonia-oxygen system has been determined as a function of reactor pressure between 250 and 763 torr. A value of 0.81 g/cm^2-sec was obtained at 1 atmosphere, using the opposed-jet reactor with 2.0-cm nozzle separation. The second-order dependence of flame strength on reactor pressure indicated the overall order of the reaction. Based on the theoretical analysis of Spalding, a maximum volumetric consumption rate of ammonia at 1 atmosphere has been estimated as 4.5 g/cm^3-sec. The corresponding volumetric heat release rate was 2.4×10^4 cal/cm^3-sec for the ammonia-oxygen flame. The ethylene-air system was also studied as a function of pressure. The "apparent flame strength" was also shown to be approximately second-order. At 1 atmosphere, a value of 0.19 g/cm^2-sec was obtained as the limiting rate of combustion. The volumetric rate of ethylene consumption was 1.8×10^{-1} g/cm^3-sec; the volumetric heat release rate was 2.2×10^3 cal/cm^3-sec. Initial experiments have been carried out with oxygen-chlorine compositions in the oxidizer gas stream for opposed-jet studies of the reaction with ammonia. Measurement of "flame strength" for these systems was more difficult than with pure oxygen because of considerably increased flame instability. Author

N63-14582 National Aeronautics and Space Administration, Washington, D.C.

RESEARCHES IN SPACE FLIGHT TECHNOLOGY

Abe Silverstein Repr. from J. Roy. Aeron. Soc. (London), v. 65, no. 612, Dec. 1961 p 779-795 10 refs 49th Wilbur Wright Memorial Lecture, London, Sept. 12, 1961

(*Its* Aeronaut. Repr. 143)

Problem areas in propulsion, aerodynamics, and structures are presented. Topics discussed are: liquid hydrogen technology, storage problems, meteoroids, weightless flight, pumping of liquid hydrogen, nuclear rocket propulsion, reentry configurations, and reentry heating. A.R.B.

N63-14617 Stanford Research Inst., Menlo Park, Calif.

SOLID PROPELLANT MECHANICAL PROPERTIES INVESTIGATIONS Quarterly Progress Report No. III, Dec. 1, 1962-Feb. 28, 1963

Norman Fishman and James A. Rinde Mar. 25, 1963 31 p 1 ref

(Contract AF 04(611)-8388)

(Rept. 9)

Mechanical properties (consisting of results from constant strain rate, constant load, and constant loading-rate tests) of the two compositions AFBA-1 and AEBA-15 have been determined. Volume change data are being obtained by performing selected tests in the dilatometer. All work thus far has been with desiccated specimens tested under dry conditions. Dilatometric tests under conditions of constant load have verified the thesis that the linear strain-time portion of the creep curve represents a region where dewetting is the process which controls the creep rate. In this region, the volume was found to increase linearly with time. Constant strain tests in the dilatometer at 100° F showed that little or no volume change occurred after the selected value of constant strain was reached. Further, it was found that the physical state of a propellant was not dependent solely on strain but was also a function of path. When comparable extension rates under constant load and constant strain-rate conditions were used to extend the specimens to selected values of constant strain, it was found that different volume changes resulted, the higher volume change being associated with extension under constant load. Volume change measurements during constant strain-rate tests at 100° F showed that the volume change at large deformations increased with the strain rate and, further, that the minimum value of Poisson's ratio at large deformations decreased as the strain rate increased. Author

N63-14676 Beech Aircraft Corp., Boulder, Colo.

ESTABLISHING DESIGN CRITERIA FOR LIQUID HYDROGEN ROCKETS. VOLUME III—MATERIALS FOR LIQUID HYDROGEN BOOST TANKS Final Report [Dec. 1958-Sept. 1961]

J. E. Bell and H. E. Sutton May 1962 147 p 28 refs

(Contract AF 33(616)-5154)

(AFFTC-TR-60-43, Vol. III)

Materials have been evaluated for use in fabrication of liquid hydrogen tanks for boosters and spacecraft. The criteria for material selection were for a 7000-gallon tank with optimum strength-to-weight ratio in the temperature range from 423° F to 1000° F. The areas covered include the selection and testing of materials for tank structure, insulation, and encapsulation. R.C.M.

N63-14740 Aeronutronic, Newport Beach, Calif.
STUDY OF DETONATION BEHAVIOR OF SOLID PROPELLANTS Final Technical Report
M. H. Boyer, D. A. Schermerhorn, and H. Uyehara Mar. 30, 1963 115 p 34 refs
(Contract NOw-62-0503-c)
(U-2059)

The proper form of basic equations has been determined, and the development of suitable mathematical techniques for solution of the basic equations has been completed. Mathematical techniques and computer programs have been written and checked out for solving the basic equations in one or two space dimensions and for pressure initiation. It has been concluded that thermally initiated detonation is beyond the capability of the present generation of computers. Experimental data have been obtained on the equation of state parameters for the unreacted solid phase, and similar data for the reacted gaseous products have been obtained from detonation literature. Success has been achieved in demonstrating that theoretically computed detonations generally agree with experimentally observed behavior; the theoretical method has also been used to compute the quantitative initiation behavior of real materials. A.R.B.

N63-14761 National Advisory Committee for Aeronautics. Lewis Flight Propulsion Lab., Cleveland, Ohio
ATTENUATION OF TANGENTIAL-PRESSURE OSCILLATIONS IN A LIQUID-OXYGEN-*n*-HEPTANE ROCKET ENGINE WITH LONGITUDINAL FINS
Richard J. Priem Washington, NACA, June 28, 1956 38 p 6 refs
(NACA RM E56C09) OTS: $3.60 ph, $1.34 mf (Declassified)

In an effort to prevent high-frequency combustion-pressure oscillations (screaming), fins were installed in the combustion chamber of a 1000-pound-thrust rocket engine with a chamber pressure of 300 pounds per square inch and using liquid oxygen and *n*-heptane as propellants. Tangential combustion-pressure oscillations were eliminated with longitudinal fins located in the combustion zone. The fin position for the liquid-oxygen - *n*-heptane engine was different from that of the nitric acid - JP-4 fuel system investigated by Theodore Male and William R. Kerslake. With four fins, 4 inches or more in length, complete elimination of the traveling form of the tangential-pressure oscillation was obtained when the fronts of the fins were 3 inches or less from the injector face. With the fronts of the fins located 4 or more inches from the injector face, tangential oscillations were not eliminated; however, the frequency of their occurrence was reduced about 40 percent. The amplitudes of the pressure oscillations were estimated from streak photographs. Fins were relatively ineffective in reducing the amplitude of the pressure oscillations (measured between the injector and fins) in runs where oscillations occurred with fins. Amplitude decreased with increasing chamber length. Unsymmetrical injection patterns were briefly investigated. These injectors had about the same probability of screaming as those with symmetrical injection patterns and the same amplitude of the pressure wave. Author

N63-14981 Bureau of Mines. Explosives Research Lab., Pittsburgh, Pa.
RESEARCH ON THE HAZARDS ASSOCIATED WITH THE PRODUCTION AND HANDLING OF LIQUID HYDROGEN
M. G. Zabetakis and D. S. Burgess 1961 58 p refs
(BM-RI-5707)

Unconfined liquid hydrogen was studied to determine the danger of explosion and related hazards so as to devise emergency procedures for: protecting personnel and equipment when an accidental spillage of liquid hydrogen occurs and establishing a quantity-distance table for the storage of this fuel. It was found that the chief hazards associated with the use of liquid hydrogen in unconfined spaces are those attributed to the formation of shock sensitive condensed (liquid hydrogen-solid oxygen) mixtures and to fire. The quantity-distance table for liquid hydrogen is based on the radiation and flame size, derived in this study. A.R.B.

N63-15160 Temple U. Research Inst., Philadelphia, Pa.
ADDITION AND SUBSTITUTION PRODUCTS OF OXYGEN FLUORIDES Third Annual Progress Report [Jan. 1-Dec. 31, 1962]
A. G. Streng, A. D. Kirshenbaum and A. V. Grosse Jan. 15, 1963 68 p 34 refs
(Contract Nonr-3085(01))

Chemical reactions of oxygen fluorides were studied to obtain addition products of high oxidizing power. The chemical characterization of dioxygen difluoride is given, and the reactions of formation of the intermediate compounds O_2ClF_3, O_2BrF_5, and O_2SF_6, as well as some others, are described. A new method, which uses electric discharge, of preparing xenon tetrafluoride, XeF_4, is given. The preparation of xenon oxyfluorides is described. Using the same method, at liquid air temperatures, it was possible to synthesize the first compound of krypton, i.e., krypton tetrafluoride or KrF_4. It forms colorless transparent crystals, more volatile and less thermally stable than XeF_4. Author

N63-15576 Applied Physics Lab. Johns Hopkins U., Silver Spring, Md.
TECHNICAL PANEL ON SOLID PROPELLANT COMBUSTION INSTABILITY Unclassified Proceedings of the Second Meeting, Stanford Research Inst., Menlo Park, Calif., Mar. 8-9, 1962 May 1962 146 p 16 refs

(Contract NOw 62-0604-C)
(TG 371-4B)

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N63-15589 Canadian Armament Research and Development Establishment, Valcartier

CARDE INVESTIGATIONS OF FINITE WAVE AXIAL COMBUSTION INSTABILITY

L. A. Dickinson *In* Applied Physics Lab., Johns Hopkins U. Silver Spring, Md. Technical Panel on Solid Propellant Combustion Instability Proc. of Second Meeting, Stanford Res. Inst., Menlo Park, Calif., Mar. 8-9, 1963 May 1962 p 59-66 3 refs (See N63-15576 12-26)

A pulse technique has been used to assess the finite-wave axial-combustion instability of aluminized, ammonium perchlorate/polyurethane propellant formulations. This technique is based on the assumption that if a pressure disturbance is introduced during burning at a time when the engine is in an incipiently unstable condition, amplification of the disturbing pulse will occur; conversely, if the engine is operating in the stable regime, pulsing should have no effect. Experimental data obtained using three propellant formulations and engines of two diameters are being used to delineate the effects of engine operating parameters, engine size, and diverse propellant factors. Concurrent studies of erosive burning indicate that propellants with high erosion factors may be more prone to finite-wave axial-combustion instability. M.P.G.

N63-15620 Bendix Corp. Pioneer-Central Div., Davenport, Iowa

CAPILLARY ACTION LIQUID OXYGEN CONVERTER FOR WEIGHTLESS ENVIRONMENT [Final Report, May 1, 1961-Aug. 25, 1962]

Duane E. Hinds and John Cleveland Wright-Patterson AFB, Ohio, Life Support Systems Lab., Jan 1963 22 p 2 refs
(Contract AF 33(616)-8185)
(AMRL-TDR-63-10)

A 25-liter, capillary-action liquid-oxygen converter has been fabricated to incorporate all the components required to provide a completely operational, self-contained system to supply breathing oxygen in a weightless environment. The converter design of functional components and the principle of operation has combined the forces of surface tension, wetting, and capillary action of liquid oxygen to provide adequate forces to ensure satisfactory operation of the system during space environments. These forces will provide for the expulsion of liquid oxygen under standard conditions, during acceleration forces up to and including 14 G, and in the zero-gravity condition. The report includes all the test data and results of the complete development program and the physical arrangement required for the capillary action converter system. The testing which could be accomplished in the laboratory gave every evidence that the design concept is satisfactory for zero-gravity operation. Author

N63-15735 Army Chemical Center, Edgewood, Md.

HANDLING AND STORAGE OF NITROGEN TETROXIDE [Final Report]

Edwards, Calif., Air Force Systems Command, Rocket Propulsion Lab., May 1963 106 p
(Contract AF 33(616)60-20)
(RTD-TDR-63-1033)

A comprehensive source of basic information for use in the design, fabrication, and operation of nitrogen tetroxide handling equipment is presented. The chemical and physical properties of this propellant are included so that the hazards will be recognized and understood. Principles underlying the prevention of fire, explosion, and toxic effects are presented, along with the information on the disposal and neutralization of vapors and liquids. Author

N63-15917 Rocketdyne, Canoga Park, Calif.

RESEARCH IN FLUORINE CHEMISTRY Summary Report, Mar. 16, 1962 to Mar. 15, 1963

H. H. Rogers, S. Evans and J. H. Johnson Apr. 30, 1963 100 p 3 refs
(Contract Nonr-1818(00))
(R-5077)

This review of electrolysis of anhydrous hydrogen fluoride includes: (1) the drying of hydrogen fluoride by electrolysis, (2) the hydrogen fluoride-nitrous oxide system, (3) the hydrogen fluoride-dinitrogen tetraoxide system, and (4) the hydrogen fluoride-nitric oxide system. I.v.L.

N63-15989 National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

DEVELOPMENT TRENDS OF LIQUID PROPELLANT ENGINES

A. A. Mc Cool and Keith B. Chandler *In its* From Peenemünde to Outer Space. [A Volume of Papers] Commemorating the Fiftieth Birthday of Wernher Von Braun Mar. 23, 1962 p 289-307 1 ref (See N63-15976 13-01)

The historical development of the liquid propellant rocket engine is summarized. The design and operation of the V-2(1942), the Redstone A-7(1952), the Jupiter S-3D(1956), the Saturn H-1(1958) and the Saturn F-1(1961) are described. Each of these engines represents a performance advantage and a reduction in complexity over the preceding engine. The progress made over the past twenty years in specific impulse, thrust-to-weight ratio, chamber pressure, and thrust is charted. Future gains are expected from the use of tap-off and secondary injection techniques, and from improved nozzle concepts. M.P.G.

N63-15990 Forschunginstitut für Physik der Strahlantriebe, Stuttgart (W. Germany)

ÜBER BALLISTISCHE UND AERONAUTISCHE RAUMFAHRT [CONCERNING BALLISTIC AND AERONAUTICAL SPACE TRAVEL]

Eugen Sänger *In* NASA. Marshall Space Flight Center, Huntsville, Ala. From Peenemünde to Outer Space. [A Volume of Papers] Commemorating the Fiftieth Birthday of Wernher Von Braun Mar. 23, 1962 p 309–317 4 refs In German (See N63-15976 13-01)

This review of the state-of-the-art of propulsion systems and their applications includes: (1) propulsions systems, with a specific impulse in vacuum of ~280 sec, that use kerosene-liquid oxygen or hydrazine-nitrogen tetraoxide for four-stage rockets; (2) propulsion systems, with a specific impulse in vacuum of ~450 sec, that use liquid hydrogen-liquid oxygen or liquid hydrogen-liquid fluorine for two-stage rockets; (3) propulsion systems with a specific impulse in vacuum of 800 sec to 3000 sec that use nuclear fission with hydrogen, water vapor, or ammonia for space vehicles; and (4) propulsion systems, with a specific impulse of 3000 sec to 30,000,000 sec, that use nuclear fission, nuclear fusion or radiation materials for interplanetary and interstellar space vehicles. I.v.L.

N63-16261 Aerojet-General Corp. Ordnance Div., Downey, Calif.

STUDY OF SUSCEPTIBILITY OF SOLID COMPOSITE PROPELLANTS TO EXPLOSION OR DETONATION Final Report

T. G. Owe Berg Apr. 12, 1963 89 p 211 refs
(Contract NOrd 18487)
(Rept. 0253-05(01)FP)

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N63-16374 Monsanto Research Corp. Boston Labs., Everett, Mass.

RESEARCH ON SYNTHESIS OF NEW OXIDIZERS FOR SOLID PROPELLANTS Quarterly Technical Summary Report No. 3, Jan. 1, 1963–Mar. 31, 1963

James W. Dale, Stephen P. Terpko, and George A. Tsigdinos Apr. 22, 1963 32 p 16 refs
(Contract AF 04(611)-8520; ARPA Order 352-62)
(MRB-2022Q3)

Investigation of interactions and compatibility of various binary and ternary combinations of active oxidizers (NO_2F, NOF, N_2F_4, ClO_3F, etc.) in liquid OF_2 has continued. The binary systems NF_3/OF_2, ClO_3F/OF_2, and N_2F_4/OF_2, and the ternary system $ClF_3/ClO_3F/OF_2$, showed complete miscibility, the latter under pressure at −78° C. Pure NOF has been found not to react with OF_2; the explosive reaction reported in the literature ($NOF + OF_2 \rightarrow NF_3 + O_2$) was probably due to a large NO content in the supposedly pure NOF. Conductimetric investigation involving compounds formulated as containing ClF_2^+ and ClF_4^- ions is continuing using ClF_3 as ionizing solvent. The "neutralization," $ClF_2^+AsF_6^- + NO^+ClF_4^- \rightarrow NOAsF_6 + 2ClF_3$, can be followed by conductimetric titration to a sharp end-point at 1:1 stoichiometry. A new and facile route to the derivatives $MClF_4$ (M = K, Rb, Cs) has been found to give these compounds in high yield and good purity. The new compounds $(ClF_2)_2SnF_6$ and $(ClF_2)_2TiF_6$ have been synthesized and tentatively identified. Author

N63-16443 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

PERFORMANCE CALCULATIONS FOR MONOPROPELLANT HYDRAZINE AND MONOPROPELLANT HYDRAZINE-HYDRAZINE-NITRATE MIXTURES

Donald H. Lee Dec. 3, 1962 92 p 9 refs
(NASA Contract NAS7-100)
(JPL-TR-32-348) OTS: $8.60 ph, $2.96 mf

Results of thermochemical performance calculations are presented for the monopropellant hydrazine system and several monoproplelant hydrazine-hydrazine nitrate mixtures. In view of the ability to obtain dissociation of the ammonia present in the gaseous exhaust products by utilizing catalysts in the decomposition of these propellants, data are presented for the cases of 0%, 20%, 40%, 60%, 80%, and equilibrium ammonia dissociation. Performance values for expansion ratios up to 200:1 are presented at chamber pressures of 50 psia, 150 psia, 300 psia, and 1000 psia. All results were calculated by the free-energy minimization method. Author

N63-17166 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

ALL SOLID-PROPELLANT INJECTION VEHICLES FOR LARGE-PAYLOAD SPACE MISSIONS. APPLICABILITY OF SOLID PROPELLANTS TO HIGH-PERFORMANCE ROCKET VEHICLES

M. Summerfield, J. I. Shafer, H. L. Thackwell, Jr., and C. E. Bartley Repr. from Astronautics, Oct. 1962 p 37–56 6 refs
(NASA Contract NAS7-100; Contract W-04-200-ORD-455)
(JPL-TR-32-352)

Studies of large-scale vehicles (capable of placing at least 500,000 lb into earth orbit) based on all-liquid and all-solid propulsion systems have revealed the following conclusions: (1) Vehicle system reliability will probably prove to be unacceptably low for complex manned space missions if development programs are based on the philosophy and program approaches used in the past; (2) a design and development philosophy which advocates unusual conservatism and design within the state of the art leads to the desired high reliability; (3) with this philosophy, and unique characteristics of an all-solid rocket, a basically new approach to early high reliability of flight vehicles becomes possible; program implementation would consist of early evaluation of the motor designs, vehicle structure, and flight dynamics in scale-model tests, followed by assembly of the scaled-up, full-sized components as a complete vehicle for immediate use; (4) all-solid-propellant injection vehicles of 25- to 35-million-lb launch weight are feasible; when compared with liquid or hybrid-stage vehicles of comparable capability, the development risk would be very low, and the resultant vehicle reliability at an early date unusually high—provided suggested philosophy and program approach were utilized; (5) schedules and costs for all-solid injection vehicles studied are significantly lower than for hybrid-stage and liquid propellant vehicles of comparable payload capability; and (6) by replacing solid upper stages with liquid-hydrogen–liquid-oxygen stages as these become available, the growth potential of all-solid vehicles is favorable for space missions which require large payloads and high sophistication. N.E.A.

N63-17542 Aerojet-General Corp. Solid Rocket Plant, Azusa, Calif.

INVESTIGATION OF THE MECHANISMS OF DECOMPOSITION, COMBUSTION, AND DETONATION OF SOLIDS [Technical Operating Report No. 14, Apr. 1–June 30, 1963]

J. P. Kispersky June 1963 24 p 8 refs
(Contract AF 49(638)-851; ARPA Order 24-60)
(Rept. 0372-01-14)

"Apparent flame strengths" for the ammonia-oxygen and ammonia-oxygen-chlorine reactions have been determined as a function of reactor pressure, using the opposed-jet technique and 0.77-cm-ID nozzles. It has been shown that the ammonia-oxygen flame strength is dependent on the square of the reactor pressure when both 0.46- and 0.77-cm jets are used. The proportionality of the flame strength with the diameter of the jet, which is required by theory, has also been demonstrated. "Apparent flame strength" measurements for ammonia as fuel, with oxygen-chlorine mixture as oxidizer, have been made at 300, 450, 600, and 745 torr. The flame strength was inversely proportional to the mass fraction of Cl_2 in the mixture. Extrapolations to zero flame strength indicated that no flame is possible at mass fractions of chlorine of approximately 0.5. Analyses of the data for ammonia-oxygen-chlorine systems indicate that chlorine does not act as a diluent but competes with oxygen in reaction with NH_3. The three-component system also shows flame strength dependence on the square of the reactor pressure. Author

N63-17832 Frankford Arsenal. Pitman-Dunn Labs., Philadelphia, Pa.
GREASE-TYPE LUBRICANTS COMPATIBLE WITH MISSILE FUELS AND OXIDIZERS
J. Messina and H. Gisser 13 p 13 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-A, San Antonio, Tex., Apr. 16–19

A thickening of mixed perfluorotrialkylamines (alkyl = C_4-C_6) with tetrafluoroethylene polymers, mol wt 2000 to 30,000, was studied in connection with the development of grease-type lubricants for liquid-fuel-powered missiles. Grease-type mixtures were obtained which were stable to shear stresses, showed no separation on standing (up to periods of one year), and showed little separation in the cone tests at 100° C. The greases were not reactive with and insoluble in ethyl alcohol, JP-4 fuel, unsymmetrical dimethylhydrazine, diethylenetriamine, a 60:40 mixture of the last two, a 50:50 mixture of unsymmetrical dimethylhydrazine and hydrazine, 90% hydrogen peroxide, and inhibited red fuming nitric acid. There was no explosive reactivity in impact tests with liquid oxygen or nitrogen tetroxide. Although N_2O_4 is somewhat soluble in the perfluorotrialkylamine, the greases showed no reactivity or observable solubility with N_2O_4, and when the N_2O_4 was permitted to evaporate from its mixture with the greases, the latter appeared unchanged. A typical grease exhibited antiwear and extreme pressure properties (4-ball tests) comparable to conventional petroleum greases, and did not attack most of the conventional elastomers. The tetrafluoroethylene polymers used had 0.20% chlorine or less. Greases made of tetrafluoroethylene polymers having 0.5 to 1.0 percent chlorine showed some reactivity with the amines. Average particle size of the polymers was 5 microns. Author

N63-17834 Southwest Research Inst., San Antonio, Tex.
EVALUATION OF IMPACT SENSITIVITY OF MATERIALS IN CONTACT WITH LIQUID OXYGEN AND NITROGEN TETROXIDE
F. Chang, B. B. Baber, and P. M. Ku 11 p 7 refs Presented at the 1963 USAF Aerospace Fluids and Lubricants Conf., Session VII-A, San Antonio, Tex., Apr. 16–19
(Contracts AF 33(616)-6232 and AF 33(616)-7223)

Tests for evaluating the impact sensitivity of liquid, grease, and solid materials in contact with liquid oxygen and nitrogen tetroxide are described. A drop-weight impact tester, basically of ABMA design, was employed; however, modifications and refinements have been made in the course of the work. Typical test results are presented and discussed. Author

N63-17907 Linde Co. Div. of Union Carbide Corp., Tonawanda, N.Y.
ADVANCES IN CRYOGENIC TECHNOLOGY
C. R. Lindquist Mar. 1, 1963 9 p
(Contract AF 33(657)-10248)

Progress in developing Super Insulation concepts for space vehicle applications is reported, as well as advances in the production and utilization of solid hydrogen. Super Insulation, consisting of alternate layers of metallic foil radiation shields and fiber spacers maintained in a vacuum by a rigid casing, has been used in ground-based applications by providing a rigid casing to prevent compression of the evacuated insulation. Because of possibility of using a flexible vacuum casing over the insulation for space applications on the assumption that the insulation will recover its optimum performance in the vacuum of space, a small stainless steel tank has been Super Insulated and encased in plastic. Tests indicate a satisfactory overall vacuum leak rate after flexing of the plastic jacket. Further studies of Super Insulation application techniques to obtain near optimum performance while reducing cost and weight factors are being conducted from both ground-based tankage and space vehicle applications. Results of an engineering study of the commercial production, transfer, and utilization of hydrogen slush indicate that (1) standard liquid hydrogen transfer techniques can be used; (2) vacuum pumping is the most attractive method of slush production at a plant or at a launch facility; (3) either a closed cycle or liquid-addition open cycle refrigeration system would maintain the slush hydrogen fuel in space vehicle storage tanks. M.P.G.

N63-17985 Atlantic Research Corp., Alexandria, Va.
A STUDY OF EXPLOSIONS INDUCED BY CONTACT OF HYDRAZINE-TYPE FUELS WITH NITROGEN TETROXIDE [Final Report, June 1, 1961–May 31, 1962]
R. Friedman, W. P. Barnes, Jr., and M. Markels, Jr. Wright-Patterson AFB, Ohio, Flight Accessories Lab., Sept. 1962 36 p 8 refs
(Contract AF 33(616)-6918)
(ASD-TDR-62-685)

The mechanism of explosions which may result when a hydrazine-type liquid is brought into contact with liquid nitrogen tetroxide was studied. Falling-droplet experiments showed correlation between distance of fall and probability of explosion. Sudden injection of one liquid into the other, with high-speed photography, gave nonreproducible results. Occasional explosions occurred, preceded by bubble formation. Alternate theories of the explosion phenomenon are discussed. Author

N63-18208 Aerojet-General Corp. Solid Rocket Plant, Sacramento, Calif.
ALGOL SOLID ROCKET MOTOR PROGRAM Twenty-third Monthly Progress Report, Apr. 1963
May 15, 1963 40 p
(NASA Contract NAS1-1330)
(NASA CR-50635; Rept. 0498-01M-23) OTS: **$3.60 ph, $1.40 mf**

The sixth full-scale static firing using the Algol IIA-18 rocket motor was conducted and all test objectives were achieved. This is the first test in which jet vanes were not used; therefore, it was not necessary to correct ballistic data obtained for the axial impulse loss due to the jet vanes. The total delivered impulse of this rocket motor was 4,726,314 lbf/sec; action time was 67.9 sec; specific impulse was 223.2 lbf-sec/lbm. The web burning time was 48.1 sec, and the web impulse was 4,173,352 lbf/sec. As a result of the hangfire that occurred in the test of Algol IIA-3 (Rehab), an igniter-recovery program was conducted. This program consisted of the testing of both existing igniters (1400-gm main charge) and four modified igniters in a simulated free-volume chamber. A modified igniter was also used in the Algol IIA-18 during the sixth static firing. A study was made to determine if the wax coating left on the surface of the grain after removal of the core had any effect on ignition. In conjunction with this study, propellant samples were taken from the grain surfaces of motors Algol IIA-13 and

Algol IIA-19 and were photographed and chemically analyzed to determine wax-residue and ammonium perchlorate (oxidizer) content. The delivery of all motors and the processing of motors subsequent to Motor Algol IIA-20 were suspended pending results of the igniter-recovery program. I.v.L.

N63-18342 Reaction Motors Div., Thiokol Chemical Co., Denville, N.J.
INVESTIGATION OF ADVANCED HIGH ENERGY SPACE STORABLE PROPELLANT SYSTEM – OF_2/B_2H_6
Rolland R. Schreib, Jr. (Bellcomm, Inc.) and Bruce E. Dawson
N. Y., Am. Inst. of Aeron. and Astronautics [1963] 14 p
Presented at the AIAA Summer Meeting, Los Angeles, June 17-20 1963
(NASA Contract NASw-449)
(AIAA Paper 63-238) AIAA: $0.50 members, $1.00 nonmembers

The feasibility of oxygen difluoride-diborane propellants for use in space propulsion systems was investigated. Tests show that the OF_2-B_2H_6 propellant combination is hypergolic at both sea level and high altitude. High theoretical performance is readily attainable with standard injection techniques. The propellants can be easily handled in equipment suitable for the cryogenic temperature range when the components have been properly cleaned and passivated. Heat rejection rates are high due to the combination of high combustion temperatures and radiating combustion products, but the heat fluxes are within the present state-of-the-art for ablative chambers and nozzles. Author

N63-18501 Combustion Inst., Pittsburgh, Pa.
NINTH SYMPOSIUM (INTERNATIONAL) ON COMBUSTION [HELD AT] CORNELL UNIVERSITY, ITHACA, NEW YORK, AUGUST 27 TO SEPTEMBER 1, 1962
W. G. Berl, ed. (Appl. Phys. Lab.) N.Y., Academic Press, 1963 1106 p refs
(NASA Grant NsG-245-62; Grants NSF 20174 and NSF 21506; and Contract DA-36-034-ORD-3534RD)
(NASA CR-50312)

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88. A MODEL STUDY OF THE INTERACTION OF MULTIPLE TURBULENT DIFFUSION FLAMES A. A. Putnam and C. F. Speich (Battelle Mem. Inst.) p 867–877 5 refs (See N63-18580 17-26)

89. SOME EXPERIENCES IN GAS TURBINE COMBUSTION PRACTICE USING WATER FLOW VISUALIZATION TECHNIQUES A. E. Clarke, A. J. Gerrard, and L. A. Holliday (Lucas Gas Turbine Eqpt. Ltd., Gt. Brit.) p 878–891 36 refs (See N63-18581 17-06)

90. MODELING OF DOUBLE CONCENTRIC BURNING JETS J. M. Beer, N. A. Chigier, and K. B. Lee (Intern. Flame Res. Found., Ijmuiden, Netherlands) p 892–900 10 refs (See N63-13582 17-11)

91. APPLICATION OF THE WATER TRAVERSE TECHNIQUE TO THE DEVELOPMENT OF AN AFTERBURNER J. O. Ellor (Rolls-Royce, Ltd., Gt. Brit.) p 901–906 5 refs (See N63-13583 17-26)

92. SIMILARITY AND SCALE EFFECTS IN RAMJET COMBUSTORS D. G. Stewart and G. C. Quigg (Aeron. Res. Labs., Australia) p 907–922 16 refs (See N63-18584 17-26)

93. MODELING STUDIES OF BAFFLE-TYPE COMBUSTORS H. C. Hottel, G. C. Williams (MIT), W. P. Jensen (Atlantic Res. Corp.), A. C. Tobey, and P. M. R. Burrage (Little (Arthur D.) Inc) p 923–935 25 refs (See N63-18585 17-27)

94. EXAMINATION OF THE POSSIBILITY OF PREDICTING REACTION-RATE CONTROLLED FLAME PHENOMENA BY THE USE OF COLD MODELS D. Vortmeyer (Imp. Coll. of Sci. and Tech. (Gt. Brit.) p 936–948 33 refs (See N63-18586 17-26)

95. SEMITHEORETICAL CONSIDERATIONS ON SCALING LAWS IN FLAME STABILIZATION K. R. Löblich (Tech. Hochschule Hannover) p 949–957 16 refs (See N63-18587 17-26)

96. MODELING TECHNIQUES IN REACTOR DESIGN C. H. Barkelew (Shell Develop. Co.) p 958–964 7 refs (See N63-18588 17-10)

N63-18536 Aerojet General Corp., Downey, Calif.
DEFLAGRATION CHARACTERISTICS OF AMMONIUM PERCHLORATE AT HIGH PRESSURES
O. R. Irwin, P. K. Salzman, and W. H. Andersen *In* Ninth Symp. (Intern.) on Combust., Cornell U., Ithaca, N.Y., Aug. 27–Sept. 1, 1962 1963 p 354–365 20 refs (See N63-18501 17-26)
(Contract NOrd 18487)

The deflagration characteristics of pure ammonium perchlorate (AP) strands have been investigated by means of a closed-bomb strand burning technique at pressures from 1000 to 23,000 psi. The data are in general agreement with vented-chamber AP burning-rate data of other investigators at pressures from 1000 to 5000 psi. At pressures above 5000 psi (the pressure limit of previously reported studied), a marked increase in pressure dependence of the linear burning rate occurs. It is postulated that the observed increase in burning rate results from an increased burning surface area, i.e., surface breakup, under the action of the very high pressures existing in the closed bomb. The action of pressure, or stress, upon the burning surface can produce shearing giving rise to increased burning area by forming new cracks and pores or by enlarging existing cracks and pores. It appears reasonable that the rate at which such cracks can propagate in a material under an applied stress will be determined by the mechanical properties of the material. The crack growth process has therefore been analyzed in terms of a theory, due to Eyring, which relates creep and fracture to fundamental atomic and molecular properties of a material. A geometrical model is presented which considers the accelerated burning process as a development of micro-cracks that form into conically-shaped burning surfaces, the area of which depends upon the pressure. The model is in good agreement with the experimental burning-rate data and with the pressure versus time data for individual burning-rate experiments at pressures above 5000 psi. Author

N63-18537 Imperial Coll. of Science and Tech., London (Gt. Brit.)
A SIMPLE THEORY OF SELF-HEATING AND ITS APPLICATION TO THE SYSTEM AMMONIUM PERCHLORATE AND CUPROUS OXIDE
P. W. M. Jacobs and A. R. Tariq Kureishy *In* Ninth Symp. (Intern.) on Combust., Cornell U., Ithaca, N.Y., Aug. 27–Sept. 1, 1962 1963 p 366–370 18 refs (See N63-18501 17-26)

The approximations usually made in theories of self-heating are discussed briefly. It is pointed out that kinetic experiments close to the critical ignition state yield results for the fractional decomposition α as a function of time t which depart from the kinetic law applicable at lower temperatures. Nevertheless, these $\alpha(t)$ curves can be analyzed to yield effective rate constants which depend on the temperature of the surrounding (T_0) rather than on the temperature of the reactant (which is, of course, a function of time). A theory of self-heating is developed using these effective rate constants, and this is applied to the calculation of ignition times and self-heating curves. Results are in good agreement with experiment. Author

N63-18566 Atlantic Research Corp., Alexandria, Va.
COMBUSTION STUDIES OF SINGLE ALUMINUM PARTICLES
R. Friedman and A. Macek *In* Ninth Symp. (Intern.) on Combust., Cornell U., Ithaca, N.Y., Aug. 27–Sept. 1, 1962 1963 p 703–712 12 refs (See N63-18501 17-26)
(Contract Nonr 1858(25); Proj. Squid)

Earlier work of the authors, both experimental and theoretical, on ignition and combustion of single aluminum particles at atmospheric pressure is briefly reviewed, and new experimental data, obtained by two methods, are presented. In the first method, the aluminum particles are injected into the stream of hot gases generated by means of a flat-flame burner. In the second method, the particles are burned in the combustion products of ammonium perchlorate flames with organic fuels added. In both cases, aluminum is burned in an atmosphere of controlled temperature and composition. It is concluded that ignition occurs only upon melting of the oxide layer (m.p., 2300° K) which coats the particle. The process of ignition is not affected by the moisture content of the hot ambient gas and only slightly by its oxygen content. On the other hand, there are distinct effects of oxygen and of water vapor on combustion of the metal. Oxygen promotes vigorous combustion, and, if its concentration is sufficiently high, there is fragmentation of particles. In the virtual absence of water, diffusion and combustion take place freely in the gas phase, whereas in the presence of significant amounts of water, the process is impeded and confined to a small region, because the reactants must diffuse through a condensed oxide layer. Author

N63-18834 Aerojet-General Corp. Liquid Rocket Plant, Sacramento, Calif.
STORABLE LIQUID PROPELLANTS, NITROGEN TETROXIDE/AEROZINE 50

W. R. Fish et al, June 1962 384 p
(LRP-198 (2d Ed.))

The advantages of nitrogen tetroxide (N_2O_4), and Aerozine 50, storable liquid propellants, over current nonstorable systems are given as: stability in closed tankage over long periods and hypergolic ignition. These propellants permit the design of high performance, instantly ready, simple, reliable propulsion systems. In this report, the characteristics of nitrogen tetroxide and Aerozine 50 that are discussed include: chemical and physical properties; material compatibility; storability; the detection and natural decay of propellant vapors; safety; propellant pressure effects; fume, fire, and explosion hazards; test operation; and cleaning and decontamination procedures. D.E.R.

N63-18899 Atlantic Research Corp., Alexandria, Va.
A PROGRAM TO ADVANCE THE TECHNOLOGY OF FIRE EXTINGUISHMENT (HYDROGEN-OXYGEN) [Annual Report] Apr. 1962-Mar. 1963
M. Markels, Jr., R. Friedman, A. Macek, W. Haggerty, and R. Eichbauer Wright-Patterson AFB, Ohio, AF Aero Propulsion Lab., Mar. 1963 76 p 15 refs
(Contract AF 33(616)-8110)
(ASD-TDR-62-526, Pt. II)

The second year's effort included the study of (1) suppression of gaseous hydrogen-oxygen detonations, (2) methods for controlling liquid-hydrogen combustion, and (3) extinguishment of liquid hydrogen-metal slurry fires. Of several gaseous inhibitors for 62:38 (percent by volume) mixtures of hydrogen and oxygen, isobutene was found to be the best from evaluations of several low-molecular-weight alkanes and alkenes, acetylene, methyl halogenides, chlorine, and pentacarbonyl iron. Isobutene was effective at a concentration of 1 percent. Confined liquid-hydrogen combustion was effectively suppressed by air-halogenated hydrocarbon mixtures with 13 to 65 percent of inhibitor. It was also shown that effective concentrations can be predicted from standard flammability data. Confined liquid-hydrogen combustion was extinguished by either powdered solids or liquid agents. Potassium bicarbonate and halogenated hydrocarbons were most effective of the substances studied. Minimum amounts for extinguishing fires of liquid hydrogen, burning at a rate of 1 liter/hour, ranged from 0.5 to 0.8 gram. Author

N63-19099 Cryogenic Engineering Lab., National Bureau of Standards, Boulder, Colo.
EXPERIMENTAL DETERMINATION OF THE BULK DENSITY OF BOILING LIQUID OXYGEN
R. W. Arnett, D. R. Millhiser, and W. H. Probert [1962] 17 p 5 refs For presentation at the Cryogenic Eng. Conf., Calif. U., Los Angeles, Aug. 14–16, 1962
(NASA Order R-249)
(Preprint Paper E-4) Available from Cryogenic Data Center, NBS, Boulder, Colo.: $1.00

Results of an experimental program aimed at determining the bulk density of boiling liquid oxygen are presented. A comparison is made between the results of this study and that of previously reported experimental work. Comparison is also made with the results of a theoretical analysis. Curves are presented showing the variation of liquid density with ullage pressure, liquid-depth-to-tank-diameter ratio, and liquid depth. Temperature distribution within the boiling liquid oxygen is also shown. Results of the study tend to support the hypothesis that the bulk density of boiling liquid oxygen differs only slightly from the saturation density. Author

N63-19102 Monsanto Research Corp. Boston Labs., Everett, Mass.
RESEARCH ON SYNTHESIS OF NEW OXIDIZERS FOR SOLID PROPELLANTS Quarterly Technical Summary Report No. 4, Apr. 1, 1962-June 30, 1963
James W. Dale, Stephen P. Terpko, and George A. Tsigdinos July 23, 1963 18 p 8 refs
(Contract AF 04(611)-8520; ARPA Order 352)
(MRB-2022Q4)

The two major areas of work consisted of (1) study of the behavior of binary combinations of energetic fluorine-containing oxidizers in liquid OF_2 as a solvent, and (2) study, using conductimetric titrations, of metathetic reactions involving compounds containing ClF_2^+, ClF_4^- and F^- ions in liquid ClF_3. Author

N63-19272 Institute for Defense Analyses. Research and Engineering Support Div., Washington, D.C.
AN ANALYSIS OF THE MATERIALS PROBLEM FOR THROAT INSERTS OF HIGH ENERGY SOLID PROPELLANT ROCKETS
Walter H. Jones and Lawrence J. Delaney Nov. 1962 145 p 52 refs
(ARPA-SD-50; Proj. PRINCIPIA)
(IDA-TR-62-19; UBG-62-559)

The materials problem for throat inserts of high-energy solid propellant rockets is analyzed. The major conclusion is that graphite inserts can probably be designed which will withstand the thermal, mechanical, and chemical environments to be expected. The principal problem to be solved is the control of graphite erosivity. A computer program was developed which enables calculation of graphite erosion, account being taken of the chemistry of the exhaust stream, the temperature history of the wall material, the ballistic effects of erosion, the rates of diffusion of the corrosive species and corrosion products through the boundary layer, and the chemical kinetics of the surface reactions. Semiquantitative agreement with experiment is found. Author

N63-19645 Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div.
THE CHEMISTRY OF REACTION FUELS (FUELS FOR AIR-REACTION AND ROCKET ENGINES) [KHIMIYA REAKTIVNYKH TOPLIV (TOPLIVA DLYA VOZDUSHNOREAKTIVNYKH I RAKETNYKH DVIGATELEY)]
Ya. M. Paushkin Nov. 8, 1963 729 p 419 refs Transl. into ENGLISH from Moscow, Acad. Sci. (USSR), Inst. Petrol.-Chem. Syn., 1962 437 p
(FTD-TT-62-1417/1+2+3+4)

This review presents an extensive coverage of the following: (1) hydrocarbon fuels (propellants) for use in air-breathing engines and in liquid- and solid-propellant rocket engines; (2) fuels for liquid- and solid-propellant rocket engines; and (3) oxidizers for use in liquid-propellant rocket engines. I.v.L.

N63-19845 Aerojet-General Corp., Azusa, Calif.
TOXIC HAZARDS EVALUATION OF TITAN II TEST FIRINGS: METHODS AND RESULTS OF LABORATORY AND FIELD INVESTIGATIONS [Final Report, Apr. 1962-Jan. 1963]
M. Kennebeck, Jr., R. Wetherington (McClellan AFB), D. A. Nole, H. Roby, and M. Y. Longley Wright-Patterson AFB, Ohio, Biomedical Lab., June 1963 77 p 20 refs
(Contract AF 33(616)-7836)
(Rept. 2552; AMRL-TDR-63-52) OTS: $2.00

Toxicologically significant environmental contaminants near Titan II test-stand facilities were studied, with specially developed field and laboratory techniques, primarily to determine the degree of hazard associated with exhaust constituents. For exhaust products that were identified and quantitatively evaluated, it was found that normal test firings create no significant personnel hazard in test areas and that, with proper treatment procedures, no significant water-pollution problems are created. A method for determining Titan II test-firing contributions to a community-air-pollution situation was also developed. This study emphasizes the need for investigation of more-refined atmospheric-analysis techniques and instruments to determine trace contaminants resulting from static and dynamic missile firings. Detailed analytical methods for field samples containing unsymmetrical dimethylhydrazine, hydrazine, and nitrogen dioxide are presented. Author

N63-19901 Astropower, Inc., Newport Beach, Calif.
COMPATIBILITY OF STRUCTURAL MATERIALS WITH HIGH PERFORMANCE O-F LIQUID OXIDIZERS Quarterly Progress Report, 15 March-15 June 1963
S. W. Pohl, N. A. Tiner, and W. D. English [1963] 89 p
(Contract AF 33(657)-9162)
(Rept. 112-Q4)

This report is on the compatibility of structural materials with fluorine oxide, perchloryl fluoride-tetrafluorohydrazine (1:1) blend, and ozone fluoride-LO_2 solutions. Preliminary (1- and 21-day) exposures of structural materials to liquid F_2O and $FClO_3$-N_2F_4 were completed. Long-term (four-month and one-year) exposure tests are underway. Author

N63-20061 Stanford Research Inst., Menlo Park, Calif.
INITIATION OF DEFLAGRATION WAVES AT SURFACES OF AMMONIUM PERCHLORATE-COPPER CHROMITE-CARBON PELLETS
Marjorie W. Evans, Rodney B. Beyer, and Leonard Mc Culley Aug. 19, 1963 32 p 28 refs
(Contract Nonr-3415(00))

A study was made of the initiation of a deflagration wave at the surface of ammonium perchlorate-copper chromite-carbon pellets in nitrogen at 25 atmospheres. The relationship between energy flux density I and exposure time τ_I, which defines the family of boundary conditions necessary and sufficient to cause initiation, was measured. Theoretical analysis was made by means of the partial differential equation which describes the space-time temperature distribution in the pellet in terms of chemical reaction rate, heat of reaction, thermal conductivity, heat capacity, optical absorptivity, and surface reflectivity. Integration of the equation using the experimentally determined chemical and physical parameters and boundary conditions gave the temperature of the pellet—and in particular the temperature of the pellet surface—as a function of time, with flux as a parameter. From this solution one obtained for given flux density (1) the temperature $T(O,\tau_I)$ of the initiating surface at the moment τ_I of cutoff of the energy pulse and (2) a lower bound for the minimum thermal ignition time τ_{Im}. The $T(O,\tau_I)$ for ammonium perchlorate with 5% copper chromite was $380 \pm 31°$ C. It was drastically lowered when carbon was added, the amount of lowering being proportional to carbon concentration. It ranged from 300° to 215° C for carbon percentages ranging from 0.5 to 4. For given composition $T(O,\tau_I)$ was independent of flux density over the range 9 to 63 cal/cm^2-sec. Initiation occurred substantially before the calculated minimum thermal ignition time τ_{Im}. The results provide support for the view that thermal ignition of the solid material is not a prerequisite for initiation of a deflagration wave. Author

N63-20643 Aerojet-General Nucleonics, San Ramon, Calif.
HYDRAZINE PROCESS DEVELOPMENT Interim Report, May-July, 1963
J. C. Whipple et al 1963 146 p
(Contract AF 33(600)-42996)
(AGN-AN-1013; ASD-TR-7-840A(X))

Progress was reported on a program which was undertaken to develop, design, construct, and operate a continuous in-reactor loop as well as the associated fuel handling and product purification sections. Work necessary for the development of the loop and its components included studies in decontamination, purification, fuel cycle materials, chemical analysis, energy deposition, and reactor physics. Secondary support to the program included capsule yield studies, basic studies of ion and free radical yield, and new product investigation. The results of these tasks will be coordinated to provide preliminary design and cost estimates for a self-critical pilot plant and prototype production plant. Areas in which work was concentrated were: chemical processing, materials science, in-reactor engineering, equilibrium hydrazine concentration, mechanisms involved in fission fragment radiolysis of ammonia, nuclear engineering, and program scheduling. C.L.W.

N63-20943 Stauffer Chemical Co., Richmond, Calif. Richmond Research Center
HIGH ENERGY OXIDIZERS Quarterly Technical Summary Report, May 1, 1963-Aug. 1, 1963
K. O. Christe and A. E. Pavlath [Aug. 23, 1963] 11 p 1 ref
(Contract Nonr-4019(00))

In the investigation of chlorinetrifluoride complexes, modification was made on the vacuum line, mostly to make its operation safer. Oleum, fluorosulfonic acid, sulfurtrioxide, and BrF_5 were investigated as possible solvents for the complexes in the NMR studies. The first three gave chemical interactions, while BrF_5 exchanged fluorine with the complexes. Infrared studies were made on ClF_3, AsF_5 (both in solid and gas phase), $KAsF_6$ and $ClF_2{}^+AsF_6{}^-$. Different windows were used and the application of KBr coated with a thin Kel-F layer was found to be the most suitable among the possible solutions. Definite proof was obtained for the presence of the $AsF_6{}^-$. Author

N63-21007 Wissenschftliche Gesellschaft für Luft- und Raumfahrt, Cologne (W. Germany)
PROPELLANTS AND ROCKET TECHNOLOGY [TREIBSTOFFE UND RAKETENTECHNIK]
A. Dadieu and K. Dreyer 17 p In GERMAN Proc. of the Joint Meetings of the Comms. on Propellants and Rocket Technology, Ottobrunn, Mar. 3, 1962
(WGL-2/1962)

Abstracts are presented of the following speeches: (1) High-Performance Liquid-Propellants for Rockets; (2) Liquid-Fluorine Rocket Propellants; and (3) Production and Handling of Liquid Fluorine. I.v.L.

N63-21071 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
HYDRAZINE MONONITRATE IN HYDRAZINE, SUPPLEMENTAL PHYSICAL DATA
Stephen P. Vango and John B. Krasinsky Mar. 24, 1963 15 p 1 ref
(NASA Contract NAS7-100)
(NASA CR-50970; JPL-TM-33-122) OTS: $1.60 ph, $0.80 mf

The density, vapor pressure, viscosity, and freezing point are reported for a solution of hydrazine mononitrate dissolved in hydrazine with approximately 1% water added. Author

N63-21363 Schjeldahl (G.T.) Co., Northfield, Minn.
EVALUATION OF THE COMPATIBILITY OF POLYVINYLIDENE FLUORIDE (KYNAR) WITH STORABLE LIQUID PROPELLANTS (NITROGEN TETROXIDE AND HYDRAZINE) Final Report
Herbert J. Fick Jan. 30, 1963 23 p 11 refs Prepared for Jet Propulsion Lab. Pasadena, Calif.

(NASA Contract NAS7-100. JPL Contract NI-120421)
(NASA CR-50999) OTS: $2.60 ph, $0.89 mf

An evaluation is made of polymeric materials potentially usable to construct expulsion membranes for storable liquid propellants, such as nitrogen, tetroxide, and hydrazine. The material studied was polyvinylidene fluoride available as Kynar. The polyvinylidene fluoride polymer is unattached chemically by N_2O_4 or hydrazine. Swelling occurs with N_2O_4, and some brittleness develops on long contact with hydrazine. The testing conducted with polyvinylidene fluoride and Teflon FEP indicated promise for the former for use in applications of intermittant exposure or where permeability is not an important factor. Evidence was obtained to indicate that polyvinylidene fluoride films can be oriented by application of strain at a proper temperature. Sensitivity of the material to melt fracture and to temperature is sufficiently great to indicate that operation within very narrow limits will be necessary. J.R.C.

N63-21722 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena
CHLORINE TRIFLUORIDE-HYDRAZINE LIQUID PROPELLANT EVALUATION AND ROCKET MOTOR DEVELOPMENT
Walter B. Powell, James P. Irving, and Merle E. Guenther May 15, 1963 57 p 7 refs
(NASA Contract NAS7-100)
(NASA CR-51004; JPL TR-32-305) OTS: $5.60 ph, $1.91 mf

The chlorine trifluoride-hydrazine liquid bipropellant combination is storable and hypergolic; it has a high average density and gives a moderately high specific impulse. During an experimental program, this propellant was handled and used for rocket motor firings. A multielement "cup and plug" injector was developed which gave good performance and had a reasonable lifetime when used with this propellant. Heat-transfer-rate profile in the chamber and nozzle were determined calorimetrically from tests of a water-cooled sectional rocket motor. Chamber heat transfer determined by the thermocouple-plug transient-temperature measurement method was in good agreement with the calorimetric data. The chlorine trifluoride-hydrazine propellant can be recommended where high density and good performance are required, and for application where short-duration uncooled motors are appropriate. Author

N63-21805 Purdue U., Lafayette, Ind. Jet Propulsion Center
THE COMBUSTION OF HYDRAZINE GEL
Richard J. Zabelka Mar. 1963 33 p 5 refs For presentation at the 1963 Spring Meeting, Western States Sect., the Combustion Inst.
(WSS/CI Paper 63-1)

A study is made to determine the effects of chemical reactions, fluid flow, oxidizer concentration, heat transfer, fuel composition, and chamber geometry upon the combustion processes of selected hybrid propellants. Results are presented on the study of the combustion of a hydrazine gel (HG) fuel utilizing gaseous oxygen as the oxidizer. The experimental results indicate that the decomposition rate of the HG is a function of the heat transfer from the flame to the burning surface and the surroundings. The limiting burning rate of the HG was roughly proportional to the pressure, although there is considerable scatter to the experimental points. The burning rate of the HG was found to be a linear function of the velocity of the injected oxidizer over a large range of velocities. J.R.C.

N63-21913 General Dynamics/Astronautics, San Diego, Calif.
ZERO-G PROGRAM Final Report, May 1960-Mar. 1962
J. E. Sherley Aug. 15, 1962 105 p 40 refs
(NASA Contract NAS8-2664 and Contract AF 18(600)-1775)
(NASA CR-51278; AY62-0031) OTS: $9.10 ph, $3.35 mf

Results of the theoretical and experimental zero-gravity program carried out in support of the Centaur design and development program included the following: (1) parameters governing the liquid-gas configuration in the Centaur tanks were determined; (2) the behavior of the hot-wire liquid-vapor sensor was established; (3) with a maximum expected heating rate on the Centaur cylindrical tank walls of 25 Btu/hr-ft^2, boiling will most likely occur while the vehicle is in the parking orbit and transfer ellipse; (4) no additional complications to the settling problem need be feared from the eventuality of liquid hydrogen impinging against warm unwetted surfaces; and (5) Centaur orientation maneuvers will cause considerable liquid rotation, but will not cause the liquid to be dispersed throughout the tank. P.V.E.

N63-22161 Air Products and Chemicals, Inc., Allentown, Pa.
DEVELOPMENTAL TESTS FOR THE LIQUID HYDROGEN SERVICING SYSTEMS, COMPLEX 37B, SATURN C-1, CAPE CANAVERAL, FLORIDA
R. E. Sotak Feb. 28, 1962 105 p
(NASA Contract NAS8-1546; APCI Proj. 00-1-3140)
(NASA CR-51733) OTS: $9.10 ph, $3.35 mf

A liquid hydrogen service system to include a storage pressure maintaining vaporization coil, a vehicle vent to eliminate hydrogen vapors by burning them in a water pit, a liquid hydrogen subcooler to cool the hydrogen on its way to the vehicle, and a cold gas vacuum pump to operate the liquid hydrogen subcooler are investigated. U.W.L.

N63-22347 Göttingen U. (W. Germany)
DETONATION AND SHOCK TUBE STUDIES OF HYDRAZINE AND NITROUS OXIDE
A. Jost, K. W. Michel, I. Troe, and H. Gg. Wagner Wright-Patterson AFB, Ohio, ARL, Sept. 1963 75 p 49 refs
(Contract AF 61(514)-1142)
(ARL 63-157)

No detonations could be produced in mixtures containing less than 7 vol.% of N_2O. Pure hydrazine shows a detonation velocity of about 2450 m/sec, which is close to the theoretical value calculated on the assumption of chemical equilibrium in the Chapman-Jouguet region. The measured velocities meet some of the criteria for stable detonations. Spectroscopic investigations of the wake behind N_2H_4 detonations, however, revealed great amounts of ammonia which had not yet disappeared 300 μsec behind the detonation front. In compiling data for the understanding of the kinetic aspects of the above detonations, shock-tube studies of the pyrolysis of nitrous oxide and hydrazine have been continued. Absorption coefficients of N_2O up to 1800° K have been measured. In the temperature interval from 1530° K to 1820° K and at total gas densities of $1.5 \cdot 10^{-4}$ mole/cm^3 (6 atm.) The initial decomposition rate of N_2O mixed with an excess of Ar is given by the rate law $k_1 = 10^{10.8} \cdot \exp(-60\,000/RT)$ sec^{-1}. This is in agreement with results from measurements of the unimolecular decomposition rate at low temperatures. Measurements of the decomposition rate of hydrazine behind reflected shock waves with an excess of He have been extended up to temperatures of 1550° K. Using He as a carrier gas reduces schlieren effects and facilitates the kinetic evaluation of short reaction periods, even though the shock-front curvature has to be accounted for. Limitations of the present shock tube are indicated, and a new tube, which has been constructed to meet more stringent requirements, is described. Author

N63-22477 Bureau of Mines, Pittsburgh, Pa.
REVIEW OF FIRE AND EXPLOSION HAZARDS OF FLIGHT VEHICLE COMBUSTIBLES
Robert W. Van Dolah, Michael G. Zabetakis, David S. Burgess, and George S. Scott 1963 85 p 228 refs
(Contract DO (33-616)60-8)
(BM-IC-8137)

This circular is a compilation of the available characteristics data for a series of combustibles and oxidants of current interest. Vapor-pressure data are presented for fluorine, oxygen, chlorine trifluoride, nitrogen tetroxide, nitric acid, hydrogen peroxide, ethylene oxide, hydrogen, ammonia, pentaborane, unsymmetrical dimethylhydrazine, monomethylhydrazine, hydrazine, and a series of hydrocarbons including decalin, tetralin, bicyclohexyl, and other high-density fuels. In addition, flammability characteristics diagrams are included for each of the fuels in contact with air and, where available, other oxidants (for example, oxygen and nitrogen tetroxide). To assist in understanding these data, sections on definitions, theory, and applications have been included. Author

N63-22795 Astropower, Inc., Newport Beach, Calif.
SOLUTION AND CONDUCTIVITY STUDIES IN FLUORINE CONTAINING LIQUID OXIDIZERS Quarterly Progress Report, 10 June-10 Sept. 1963
W. D. English and A. V. Brown [1963] 22 p 4 refs
(Contract DA-31-124-ARO(D)-115; ARPA Order 470)
(Report 144-Q1)

Construction of a new fluorine laboratory was completed. Initial miscibility and conductivity studies have been carried out. Author

N63-22817 Battelle Memorial Inst., Columbus, Ohio Defense Metals Information Center
REACTIVITY OF TITANIUM WITH GASEOUS N_2O_4 UNDER CONDITIONS OF TENSILE RUPTURE
J. D. Jackson, P. D. Miller and W. K. Boyd Aug. 1, 1963 10 p 4 refs
(Contract AF 33(616)-7747)
(DMIC Memo. 173)

Titanium is known to be impact sensitive in liquid N_2O_4, although it is much less sensitive to impact in this medium than in liquid oxygen. A limited study was made to determine whether reactions can occur between a freshly ruptured titanium surface and gaseous N_2O_4, similar to reactions between titanium and gaseous oxygen. Experimental conditions were chosen which were more severe than those existing in actual service. No reactions were observed when commercially pure titanium or Ti-6Al-4V was ruptured in gaseous N_2O_4 at pressures as high as 535 psi and at a temperature of about 260° F. Author

N63-23574 Texas A. and M. Research Foundation, College Station
ENVIRONMENTAL POLLUTION BY MISSILE PROPELLANTS [Final Report, Jan. 1962-Nov. 1962]
Walter W. Heck, Morris E. Bloodworth, William J. Clark, Dale R. Darling, and William Hoover Wright-Patterson AFB, Ohio, Biomed. Lab., Aug. 1963 89 p refs
(Contract AF 33(616)-7801)
(AMRL-TDR-63-75) OTS: $2.25

Experimental procedures were developed to study the effects of hydrazine, unsymmetrical dimethylhydrazine (UDMH), pyridine borane, and nitronium perchlorate on plant growth and development, soil and soil structure, and aquatic organisms. Under the conditions used in this study, the four chemicals do not appear to be important environmental contaminants in relation to plant growth and development. Both UDMH and hydrazine are strongly adsorbed or decomposed on clay particles. Montmorillonite and kaolinite clays, as well as the test soils, seem to accelerate the decomposition of the UDMH and hydrazine. Pyridine borane was adsorbed on the test soils but apparently was not adsorbed on the pure clays. The aquatic life was very sensitive to the three organic compounds, and to some extent to the perchlorate ion. Author

N63-23609 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio
REACTION OF HYDRAZINE AND NITROGEN TETROXIDE IN A LOW-PRESSURE ENVIRONMENT
Robert A. Wasko Repr. from AIAA Journal, 1963 1 p

A preliminary study was made of the reaction N_2H_4 and N_2O_4 at pressures as low as 10^{-4} torr (mm Hg). A steel vacuum tank served as a vessel wherein stoichiometric quantities of these propellants, separately encapsuled in glass tubing under atmospheric pressure and at room temperature, were broken simultaneously. Results indicate that: (1) an explosive reaction occurs only when a sufficient quantity of propellant was used to produce a vaporized mixture pressure greater than 4 torr; (2) the reaction changed from an explosion to a slower reaction, for the decade of initial ambient pressure from 10^{-1} to 1 torr, as evidenced by a decrease in the magnitude of the explosion pressure and an increase in the reaction delay time; and (3) the N_2O_4 vaporized more quickly than N_2H_4, and the temperature decrease due to vaporization was sufficient to cause freezing of a portion of the N_2H_4. I.v.L.

N63-23789 Army Missile Command, Huntsville, Ala.
CHEMISTRY OF CERTAIN INORGANIC FLUORIDES OF NITROGEN
A. V. Pankratov Oct. 8, 1963 Transl. into ENGLISH from Uspek. Khimi., v. 32, no. 3, p 336-353 (1963) refs
(RSIC-77)

A survey is given that is devoted to the chemistry of the enumerated nitrogen fluorides. The survey includes: studies of the structure of the nitrogen trifluoride molecule; physicochemical and chemical properties of tetrafluorohydrazine; studies of difluoramine and chlorodifluoramine; and fluorine azide and isomers of difluorodiazine. C.L.W.

1964

N64-10128 General Dynamics/Astronautics, San Diego, Calif.
LIQUID HYDROGEN TECHNOLOGY
Sept. 1962 313 p refs
(AE62-0774)

This report contains information on liquid hydrogen as related to its use as a propellant of space vehicles, e.g., the hydrogen fueled Centaur for NASA. The following areas are included: (1) manufacture; (2) current methods for transporting liquid hydrogen; (3) the four main hazards associated with the use of liquid hydrogen with respect to the design and operation of a liquid-hydrogen system; (4) material problems encountered with liquid and gaseous hydrogen contact; (5) cryogenic insulation; (6) transfer; (7) liquid-hydrogen measurements; (8) propulsion systems that presently use or contemplate using liquid hydrogen; (9) sloshing; (10) vortexing; (11) propellant heating; (12) zero-gravity behavior; (13) space storage; and (14) properties. I.v.L.

N64-10148 Hellmuth Walter GmbH, Kiel (W. Germany)
H_2O_2 AS AN ENERGY SOURCE FOR SPACE FLIGHT [H_2O_2 ALS ENERGIETRAGER FUR DIE RAUMFAHRT]
Emil Kruska [1963] 13 p In GERMAN Presented at the Ann. Meeting of the Wiss. Ges. Luft- und Raumfahrt, Munich, Oct. 8-12, 1963

Five methods for using H_2O_2 power in space travel are discussed. These methods are: (1) simple decomposition, (2) decomposition and combustion with an average- or high-energy propellant, (3) combustion in a solid-liquid bipropellant system, and (4) as an oxygen supply in a fuel element. The various uses of H_2O_2 include: (1) warming and air purification of space cabins, (2) driving turbogenerators, and (3) utilization in propellants. I.v.L.

N64-10991 Canadian Armament Research and Development Establishment, Valcartier
METHODS OF CHEMICAL ANALYSIS OF CARDEPLEX PROPELLANT No. 4760/A5 AND ITS INGREDIENTS
R. Mac Donald and A. M. Bedard Mar. 1963 36 p
(CARDE TR-426/63)

This report describes the methods currently used to control the manufacture of ammonium perchlorate-polyurethane propellant. Most of these methods are concerned with propellant formulation No. 4760/A5. The analysis of starting materials is given. Control analyses of premixed ingredients are described, and the analysis of partially cured and fully cured propellant is given. Author

N64-12705 Frankford Arsenal, Philadelphia, Pa.
GREASES NONREACTIVE WITH MISSILE FUELS AND OXIDIZERS
Joseph Messina Sep. 1963 10 p refs Presented in part at the Natl. Symp. of the Soc. of Aerospace Material and Process Engr., Hollywood, Nov. 1962
(FA-A63-10; AD-422788)

Polytetrafluoroethylene, graphite, and silica greases have been found to be essentially inert and unreactive with fuels and oxidizers, including ethyl alcohol, hydrocarbon fuel, unsymmetrical dimethylhydrazine, diethylenetriamine, a 60-40 mixture of the latter two, a 50-50 mixture of hydrazine and unsymmetrical dimethylhydrazine, hydrogen peroxide, inhibited red fuming nitric acid, nitrogen tetroxide, and liquid oxygen. Impact tests in the presence of lox and N_2O_4 indicate nonsensitivity of the greases at high impact energy levels. The greases exhibit adequate lubricating properties, such as oxidation and mechanical stability, antiwear, extreme pressure, and they are not deleterious to many of the conventional elastomers used in missile systems. The polytetrafluorethylene grease was found to be nonexplosive with aluminum when subjected to mutual shear at high loads. Author

N64-12819 Shell Development Co., Emeryville, Calif.
FUNDAMENTAL RESEARCH ON ADVANCED OXIDIZERS Quarterly Technical Report No. 3, June-Aug. 1963
D. W. Barnum, R. M. Curtis, F. S. Mortimer, and J. N. Wilson [1963] 42 p refs
(Contract DA-31-124-ARO(D)-54; ARPA Order 402)
(S-13892; AD-424753)

The study of "nonbonded" interactions in polyatomic molecules has been continued with the objective of developing an improved bond-energy correlation scheme. It has been found possible to fit many of the Urey-Bradley force constants for the nonbonded interactions between pairs of hydrogen, oxygen, fluorine, chlorine, or bromine atoms to smooth curves which can be described in terms of a reasonable potential function which combines an attractive force of the London type with a repulsion. Parameters of this potential function have been determined from the data. A computer program for extended Huckel-type semi-empirical molecular orbital calculations has been written and tested. The major uncertainty in the estimation of the lattice energy of crystals made up of monatomic ions is the form of the repulsive potential. The form of the repulsive potential and the importance of second-neighbor repulsions have been reexamined for sodium chloride and potassium chloride. The lattice energies and heats of formation of the hypothetical salts NF_4F, NF_4ClO_4, and $(NF_4)_2SO_4$ are estimated by means of an approximate procedure due to Kaputinskii. Author

N64-12936 Phillips Petroleum Co., Bartlesville, Okla.
GAS TURBINE AND JET ENGINE FUELS Progress Report 2
William L. Streets [Oct. 1963] 19 p refs
(Contract NOw-63-0406-d)
(Rept. 851-63R; AD-422582)

Efforts included: (1) endurance testing of two promising new splash-cooled 2-inch test-combustor designs capable of operating under conditions simulating low-level tactical fighter attack missions and/or submarine search missions by a regenerative turboprop-equipped aircraft; (2) planning and statistical design of a test program to determine whether or not the 0.4 weight percent maximum total sulfur now allowed in JP-5 fuel is a safe level for protection of modern turbine blading alloys from hot gas corrosion. These studies will be carried on with and without ingested sea water to show whether or not fuel sulfur accelerates sea-salt corrosion. Author

N64-12973 Stanford Research Inst., Menlo Park, Calif.
HIGH ENERGY OXIDIZERS IN SOLUTION Technical Progress Report No. 1-Quarterly, 1 Jul.-30 Sep. 1963
W. E. Tolberg and M. E. Hill 31 Oct. 1963 14 p refs
(Contract AF 04(611)-9370; ARPA Order 24, Amend. 64)
(AD-423094)

A literature survey was completed, and an all-monel vacuum system for the production of conductimetrically pure HF was designed and built. Construction of an all-copper vacuum line and a Kel-F conductometric cell and vacuum system was begun. Author

N64-12999 Aerojet-General Corp., Azusa, Calif.
CRYOGENIC-SOLID COOLING TECHNIQUES Interim Engineering Report, 1 Jan. 1963-31 Mar. 1963
U. E. Gross Apr. 1963
(Contract AF 33(657)-8863)
(Engineering Rept.-0694-01-3; AD-403445)

The technique evolved for solidifying liquid hydrogen and neon to the desired density is described, as are the evaluation of a prototype model pressure-control valve, and completion of the deliverable model of the cryogenic-solid cooler. Author

N64-13099 Stauffer Chemical Co., Richmond, Calif. Richmond Research Center
HIGH ENERGY OXIDIZERS Quarterly Technical Summary Report, 1 Aug.-1 Nov. 1963
K. O. Christe and A. E. Pavlath [1963] 13 p refs
(Contract Nonr-4019(00); ARPA Order 399-62)
(AD-424714)

This report discusses an investigation on chlorinetrifluoride-based complexes. Some modification was made on the vacuum line to allow its use in conductometric titration and molecular-weight determination. At the same time, a dry-box was assembled for use with chlorinetrifluoride and similar corrosive materials. Low-temperature NMR work was repeated, but only qualitative proof was obtained for the ionic structure. The dissociation of the complex was measured in IF_5 and found to be complete within the error of the measurement. The ionic structure was proved by conductometric titration too. The Debye-Scherrer powder diagram was obtained for both $KAsF_6$ and $ClF_2^+AsF_6^-$ Author

N64-13283 Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

SOME EXPERIMENTAL AND THEORETICAL SIGNIFICANCES ASSOCIATED WITH IRRADIATED PROPELLANT

Anthony San Miguel and Edward N. Duran 1 Nov. 1963 17 p refs

(NASA Contract NAS7-100)

(NASA CR-53012; JPL-TR-32-518) OTS: $1.60ph, $0.80mf

The mechanical properties of polyurethane solid propellant are degraded significantly by irradiation dosages greater than 10^6 rads. Four mechanical tests that provide sufficient data to characterize the degradation are described. These tests consist of (1) swelling, (2) torsion, (3) uniaxial tension, and (4) multiaxial tension and compression. The experimental data are characterized in terms of average molecular weight between cross-links(M_c), percent sol, small-strain shear modulus, tension modulus, and strain energy for increasing irradiation dosage. Conclusions obtained in this study indicate that (1) the usefulness of M_c is questionable with regard to defining ionizing radiation degradation in a composite propellant such as polyurethane, (2) the torsion test is a simple and expedient method that may be used to study irradiated propellant quantitatively, (3) certain aspects of the kinetic theory of rubber elasticity are not quantitatively applicable to polyurethane propellant, and (4) the degradation response of irradiated propellant obtained from a uniaxial tension test typifies the degradation response of irradiated propellant obtained from multiaxial tests. Author

1963

A63-10109

MEASUREMENT OF THE BURNING SURFACE TEMPERATURES OF PROPELLANT COMPOSITIONS BY INFRA-RED EMISSION

J. Powling and W. A. W. Smith (Ministry of Aviation, Explosives Research and Development Establishment, Essex, England).

Combustion and Flame, vol. 6, Sept. 1962, p. 173-181.

Determination of the temperatures of extremely thin surface layers of burning solid-propellant compositions by measurement of their IR radiation. The surface temperatures of ammonium-perchlorate compositions are examined in some detail, and the effect of the magnitude of the absorption coefficient of the material on the observed temperature is demonstrated with this system. Practical propellant compositions, based on ammonium perchlorate and containing rather more than stoichiometric proportions of fuel, give the same temperature provided that the hot gas emission can be successfully eliminated, but observed temperatures are in some instances raised (up to 560°C) by gas interference. It is concluded that the process taking place at the burning ammonium perchlorate surface is an equilibrium sublimation process, and that the rate of consumption of the solid is controlled by subsequent gas-phase reactions among the dissociation products.

A63-10182

EXPERIMENTAL PERFORMANCE OF MODEL LIQUID HYDROGEN SPACE TANKAGE WITH A COMPRESSIBLE SUPER INSULATION.

P. J. Murto, C. R. Lindquist, and L. R. Niendorf (Linde Co.)

Society of Automotive Engineers, National Aerospace Engineering & Manufacturing Meeting, Los Angeles, Calif., Oct. 8-12, 1962, Paper 578D. 5 p. 14 refs.

Description of scaled tank tests of compressible insulators in liquid hydrogen service, which represents a significant indication of the applicability of the compressed super insulation concept as a solution to the problem of atmospheric storage of cryogenic fluids. A detailed description of the apparatus is given, and an analysis of the results is made, indicating that further research is necessary for the establishment of design criteria for a particular application.

A63-10205

PROPELLANTS AND COMBUSTION.

Stanford S. Penner (Institute for Defense Analysis, Washington, D.C.)

Astronautics, vol. 7, Nov. 1962, p. 97, 98.

Brief review of the state-of-the-art of propellants and combustion, including the following areas: (1) steady combustion processes in a liquid-fuel-rocket engine; (2) burning mechanism and decomposition rate of ammonium perchlorate; (3) two-phase flow in nozzles; (4) shock and detonation phenomena; (5) the composite-propellant burning and resonance burning in solid rockets; (6) supersonic burning; (7) hybrid rockets; (8) combustion processes of metals; and (9) nature of the elementary processes responsible for the production of ions and electrons in flames.

A63-10397

DEFLAGRATION OF PRESSED AMMONIUM PERCHLORATE.

M. D. Horton and E. W. Price (U.S. Naval Ordnance Test Station, Research Dept., China Lake, Calif.)

ARS Journal, vol. 32, Nov. 1962, p. 1745.

Investigation of the deflagration characteristics of ammonium perchlorate, with particular reference to the pressure dependence of the burning rate, the low-pressure deflagration limit, and the contribution of ammonium-perchlorate deflagration to the amplification of pressure waves during combustion instability. Tests at pressures ranging from 1 to 60 atm to determine the ability of the deflagration to induce oscillatory combustion in an acoustically conservative system are described, and preliminary results are given.

A63-10691

BIG ROCKETS.

Milton W. Rosen (NASA, Office of Manned Space Flight Programs, Washington, D.C.)

International Science and Technology, Dec. 1962, p. 66-71, 88, 90.

Discussion of the advances in rocket technology in the US. The US lag in outer space exploration is attributed to the inability to launch rockets of great power. The greatest single factor in rocketry-power progress is said to be the advent of the ballistic missile as a primary weapon of long-range bombardment. Now that the technology of rocketry is beginning to advance, the nation's program of space exploration is accelerating to the point of optimism regarding impending trips to other planets. The initial manned-lunar landing and the return program depend mainly upon the three Apollo project rockets, the Saturn C-1 and Saturn C-1B, which will be used for developmental flights in Earth orbit, and the C-5 Advanced Saturn rocket, which is capable of sending a 90,000-lb spacecraft into lunar orbit. The latter will be powered, in its first 7.5-million-lb-thrust stage, by five kerosene engines. The second stage, consisting of a million-lb thrust, will rely upon five hydrogen-fueled J-2 engines. The last stage will consist of a single C-5 Advanced Saturn that will launch the three-part Apollo spacecraft on an escape trajectory to the Moon.

A63-10920

SVILUPPO DEI PROPELLENTI CHIMICI [DEVELOPMENT OF CHEMICAL PROPELLANTS].

Riccardo Masaniello Corelli (Università di Roma, Scuola d'Ingegneria Aerospaziale, Rome, Italy).

Missili, vol. 4, Aug. 1962, p. 13-24. In Italian.

Classification of high-energy propellants into two broad categories. The first group, consisting of liquid, solid, and hybrid (liquid-solid or lithergolic) propellants, is based on the combustive oxidation-reduction reactions (redux systems). The second category, based on the metastability of the substance, is the so-called free-radical group of high-energy fuels, primarily atomic hydrogen, oxygen, nitrogen, and such radicals as NH_3, CH_3, and C_2H_5. The liquid propellants briefly discussed include oxygen, ozone, fluorine, boranes, hydrogen, dimethylhydrazine, and various derivatives of fluorine and boron. The solid propellants mentioned include: (1) the thermoplastics, such as polyvinylchloride and polyethylene; (2) the thermosetting compounds, such as polyurethane, epoxy, and polyester resins; and (3) elastomers, such as polyisobutylene and thiokol. The free-radical group of fuels offers specific impulses which are incomparably higher than those offered by the conventional liquid or solid propellants, but it presents some handling problems that appear to be insurmountable.

A63-11065

MECHANISM OF COMPOSITE SOLID PROPELLANT COMBUSTION.

Raymond Friedman (Atlantic Research Corp., Kinetics and Combustion Div., Alexandria, Va.)

Applied Mechanics Reviews, vol. 15, Dec. 1962, p. 935-937. 61 refs.

USAF-supported research.

Brief qualitative review of research on the combustion behavior of composite solid propellants. The findings most relevant to the burning mechanism are listed. It is noted that no general solid-propellant combustion theory encompassing all the phenomena discussed has yet been advanced. This is not only because of the formidable mathematical difficulties but also because of uncertainty concerning the underlying physicochemical parameters.

A63-11418

OF_2 LOOKS PROMISING AS SPACE-STORABLE PROPELLANT.

D. S. Smith and D. J. Mann (Thiokol Chemical Corp., Reaction Motors Div., Denville, N.J.)

Space/Aeronautics, vol. 39, Jan. 1963, p. 103-106, 108.

Summary of performance calculations for storable hypergols, oxygen and borane systems, and fluorinated oxidizers, to determine payload potential in terms of velocity increment. The increment is expressed as a function of the specific impulse, the propellant bulk density, the propellant-volume-insensitive weight fraction, and the tankage factor. It is shown that oxygen difluoride, combined with dimethyl hydrazine (MMH) or B_2H_2 fuel, may be considered competitive with O_2-H_2. The relatively low specific impulse of the OF_2-MMH is offset by its relatively higher bulk density and better adaptability to the thermal environment of space.

It is shown that upper stages of the Saturn space vehicle burning OF_2-MMH would be shorter by 13 ft than stages burning O_2-H_2. It is possible, for example, to shorten an Apollo-type vehicle by nearly seven ft if OF_2-MMH is used instead of O_2-H_2. This means a shortening of the 10-ft-diam. shroud around the propulsion module that would save about 350 lb.

A63-11568

SOME ASPECTS OF THE CRYSTALLOGRAPHIC TRANSITION OF AMMONIUM PERCHLORATE.

M. M. Markowitz and D. A. Boryta (Foote Mineral Co., Research Center, Exton, Pa.)

ARS Journal, vol. 32, Dec. 1962, p. 1941, 1942. 23 refs.

Determination of the enthalpy of transition at 240°C of ammonium perchlorate from the low-temperature rhombic to the high-temperature cubic form. Measurements, made by a differential thermal analysis method as facilitated by the pronounced stabilizing effect of ammonia gas on ammonium perchlorate at elevated temperatures, indicate the value of the enthalpy to be 2.3 ± 0.2 kcal/mole. It is shown that the occurrence of the crystallographic transition is neglected unjustifiably in tabulations of the thermochemical properties of solid ammonium perchlorate. From published data on the structural parameters of the high-temperature form of the compound, its density is computed to be 1.76, as compared with 1.95 for the low-temperature polymorph. Thus, at 240°C and above, propellants containing ammonium perchlorate may be subject to considerable distortion due to expansion of the perchlorate.

A63-11744

POSSIBLE IMPLICATIONS OF THE DAMAGE BY RADIATION IN THE STORAGE OF PROPELLANTS IN OUTER SPACE AND TENTATIVE METHODS FOR ITS MEASUREMENT.

J. A. McMillan (Argonne National Laboratory, Argonne, Ill.)

(IRE-NASA-AEC, International Symposium on Space Phenomena and Measurement, Detroit, Mich., Oct. 15-18, 1962.)

IEEE Transactions on Nuclear Science, vol. NS-10, Jan. 1963, p. 24-30. 12 refs.

Analysis, in terms of the available data on radiation levels, of the damage by radiation that can be expected during the storage of hydrogen-bonded propellants in outer space. Alternatives of storing the propellants as liquids or as solids, at low temperature, are discussed. Recent results obtained on the thermal behavior of the propellants are taken into account. Vitreous states of aggregations, which could crystallize spontaneously after long periods of irradiation, are shown to present some additional hazards, such as warming and explosion, that can be prevented. General considerations of radiation-damage detection in outer space are also made. Paramagnetic resonance is found to be of limited use, although it could be used for studying the damage produced by intense solar flares. Solid-state devices are finally recommended.

A63-11769

STUDIES OF THE LIQUID-VAPOR INTERFACE CONFIGURATION IN WEIGHTLESSNESS.

Donald A. Petrash and Edward W. Otto (NASA, Lewis Research Center, Cleveland, Ohio).

American Rocket Society, Space Power Systems Conference, Santa Monica, Calif., Sept. 25-28, 1962, Paper 2514-62. 20 p.

Analytical and experimental investigation of the behavior of rocket-engine propellants stored in space-vehicle tanks at zero g. The results indicate that the principal factors determining the interface configuration in a tank are the minimization of the free-surface energies of the system and the preservation of the contact angle of the liquid at the tank wall. Knowledge of the tank geometry and the contact angle, therefore, permits prediction of the configuration of the liquid in the tank. A study of the application of these principles to the design of actual tank geometries shows internal tank baffling to be an effective means of positioning the liquid in a suitable location for venting and engine restart.

A63-11846

SUPERCRITICAL CRYOGENIC HYDROGEN AND OXYGEN STORAGE SYSTEMS FOR DIRECT ENERGY CONVERTER REACTANT SUPPLY IN MANNED SPACECRAFT.

J. A. Potter and J. S. Tyler (Garret Corp., AiResearch Manufacturing Co., Los Angeles, Calif.)

American Rocket Society, Space Power Systems Conference, Santa Monica, Calif., Sept. 25-28, 1962, Paper 2515-62. 24 p.

Discussion of some methods used for storing low-boiling-point reactant fluids in space vehicles. Particular reference is made to the following: (1) ambient-temperature gas storage at high pressure; (2) single-phase, cryogenic fluid storage at supercritical pressure; and (3) two-phase, cryogenic fluid storage at subcritical pressure. A comparison of the three methods shows that supercritical storage is a lighter, more compact method of fluid storage than the high-pressure gas technique. For applications in which use rates are high enough that minimum thicknesses of insulation are adequate to prevent unwanted venting, supercritical storage is an exceptionally straightforward, light, and reliable storage method.

A63-12222

LIQUID HYDROGEN FLOW MEASUREMENT AND CALIBRATION.

Richard L. Bucknell (United Aircraft Corp., Pratt and Whitney Aircraft Div., Florida Research and Development Center, West Palm Beach, Fla.)

(Instrument Society of America, 1962 National Aero-Space Instrumentation Symposium, 8th, Washington, D.C., May 21-23, 1962.)

ISA Proceedings, vol. 8, 1962, p. 145-152. Price of entire volume (175 p.): Members, \$6.00; nonmembers, \$9.00.

Discussion of a system for measuring liquid-hydrogen mass flow in rocket engine testing. The design principles and performance of a liquid-hydrogen-flow calibration stand are reviewed, as is experience acquired with the use and calibration of turbine-type flowmeters. Redundant measurements are found to be essential in verifying accuracies and in detecting unsuspected errors in both calibration and test-stand measurements.

A63-12336

COMBUSTION OF UNSYMMETRICAL DIMETHYL HYDRAZINE: SPONTANEOUS IGNITION IN DECOMPOSITION AND OXIDATION.

P. Gray and M. Spencer (University of Leeds, School of Chemistry, Leeds, England).

Combustion and Flame, vol. 6, Dec. 1962, p. 337-345. 14 refs.

Investigation of the combustion in the gaseous phase of 1,1-dimethyl hydrazine, an endothermic compound that will support a flame in both decomposition and oxidation. The critical conditions of pressure and temperature and the composition (critical limits) necessary for explosion are measured. The effects of vessel surface, vessel diameter, and inert diluents on the critical conditions are examined. The spontaneous ignition limit for the decomposition of pure dimethyl hydrazine is shown to satisfy the criteria for thermal explosion. The overall activation energy, $E = 28 \pm 1$ kcal/mole, derived from the measured (pressure vs temperature) limit by application of the thermal-explosion theory, is found to agree with that derived from kinetic investigations of the slow decomposition. By contrast, spontaneous ignition in oxidative combustion is shown to be extremely complex, and to differ qualitatively and quantitatively from the superficially analogous, combustion mono-, di-, and trimethylamines. The following distinct oxidation regimes are established: (1) slow reaction, (2) chemiluminescent oxidation, (3) weak ignition, and (4) strong explosion. In addition, multiple ignitions are observed. The chemical characteristics of the different modes, the conditions for their occurrence, and the role of self-heating are investigated.

A63-12337

THE EFFECT OF SOME ADDITIVES ON THE BURNING RATE OF LIQUID HYDRAZINE.

A. C. Antoine (NASA, Lewis Research Center, Cleveland, Ohio).

Combustion and Flame, vol. 6, Dec. 1962, p. 364, 365.

Presentation of burning-rate values, measured in a nitrogen atmosphere, for 1% by volume solutions of the following compounds in hydrazine: methyl hydrazine, ethyl alcohol, n-butyl alcohol, t-butyl alcohol, ethylene diamine, n-amyl amine, and pyridine. The results, presented in the form of a graph, show that the additives affect the burning rate just as small additions of water affect it. The burning rate at any pressure is lowered, and the pressure at which an abrupt increase in burning rate takes place is increased. The only exception is found to be methyl hydrazine, the behavior of which is about the same as that of hydrazine itself.

A63-12693

AN EVALUATION OF THE SPACE STORABILITY OF PROPELLANTS. Appendix A - PROPELLANT TANK SURFACE TEMPERATURE ANALYSIS. Appendix B - NONVENTED TANK ANALYSIS.
W. Richard Davison and Jeffrey P. Carstens (United Aircraft Corp., Research Laboratories, East Hartford, Conn.)
American Rocket Society, Annual Meeting, 17th, and Space Flight Exposition, Los Angeles, Calif., Nov. 13-18, 1962, Paper 2723-62. 32 p. 13 refs.

Investigation of factors considered in assessing storability and performance characteristics of a given propellant combination. Storability effects are represented by the additional vehicle weight incurred in maintaining the propellant during some mission waiting time. Design effects of structural heat leaks and of a type of insulation are described. Vented (constant pressure), nonvented (constant volume), and refrigerated storage systems, are considered. Stage weights, including storability penalty weights, are calculated for a lunar-surface mission and an Earth-orbital mission. The stage weights are compared on the basis of theoretical performance characteristics of the following propellant combinations: hydrogen-oxygen, hydrogen-fluorine, hydrazine/nitrogen tetroxide, and diborane/oxygen difluoride. Results of the mission analysis show that, with short fuel-storage times (less than two weeks) and the use of metal-foil superinsulation, propellant-storability characteristics have less effect on the stage weight than do performance characteristics. For longer storage times, or less efficient insulations, the storage-system weights become appreciable, to the disadvantage of the cryogenic combinations.

A63-13115

HORIZONS IN LIQUID-PROPELLANT ROCKET PROPULSION.
S. S. Penner (California Institute of Technology, Florence Guggenheim Jet Propulsion Center, Pasadena, Calif.) and L. L. Bixson (Sundstrand Corp., Sundstrand Aviation Div., Pacoima, Calif.)
(Istituto Lombardo Academia di Scienze e Lettere and NATO-Advisory Group for Aeronautical Research and Development, Seminar, Milan, Italy, Sept. 8-12, 1960.)
IN: Advances in Astronautical Propulsion. New York, Pergamon Press, Inc.; Milan, Italy, Editrice Politecnica Tamburini, 1962, p. 107-146. 42 refs.
Contract Nos. AF 18(603)-107 and DA 04-495-Ord-1643.

Review of recent developments in liquid-propellant rocket propulsion, with particular reference to high-energy propellants, storable liquid fuels, variable-thrust rockets, and hybrid propulsion systems. Scaling procedures for liquid-fuel engines are discussed. The diverging liquid-fuel rocket engine is considered. Other topics studied include the burning rates of propellant droplets, flame propagation in droplet arrays, chemical reactions during nozzle flow, and combustion processes.

A63-13154

EFFECTS OF SOME OF THE SPACE ENVIRONMENTS ON PROPELLANT ACTUATED DEVICES.
Maurice H. Simpson (Frankford Arsenal, Pitman-Dunn Laboratories, Environmental Engineering Section, Philadelphia, Pa.)
IN: Institute of Environmental Sciences, 1962 Annual Technical Meeting, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1962, p. 401-418.

Discussion of some of the results of a current investigation on the operation of standard propellant-actuated devices in space. The investigation covers the effects of ozone, solar radiation, nuclear radiation, acceleration, temperature, and altitude. Apparent physical damage and the effects on ballistic (firing) performance are analyzed. Changes in chemical composition, internal pressures, and other operational criteria are also evaluated, and the important findings are presented. The resulting failures caused by these environmental factors of space are discussed. Results show that the effects of ozone and solar radiation are the most critical.

A63-13434

FOR ALL-ROUND PROPELLANT PERFORMANCE: 98% H_2O_2.
James C. McCormick (FMC Corp., Inorganic Chemicals Div., Buffalo, N.Y.)
Space/Aeronautics, vol. 39, Mar. 1963, p. 101, 103, 105, 107, 109. 19 refs.

Discussion indicating the advantages of using 98% hydrogen peroxide as a liquid propellant of exceptionally high performance. The performance of this propellant is nearly as good as that of the cryogenic propellants. However, its handling and storage characteristics are much more favorable. The performance of 98% H_2O_2 in bipropellant systems, in hybrid rockets, as a monopropellant, and as a secondary injection fluid are reviewed. Extensive data are given on the heat-transfer characteristics, storability, radiation resistance, and materials compatibility of the propellant.

A63-13738

PHYSICAL AND CHEMICAL PROPERTIES OF HEXANITROETHANE.
P. Noble, Jr., W. L. Reed, C. J. Hoffman, J. A. Gallaghan, and F. G. Borgardt (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Materials Sciences Laboratory, Palo Alto, Calif.)
AIAA Journal, vol. 1, Feb. 1963, p. 395-397.

Discussion of recent developments in the synthesis of hexanitroethane, and consideration of its possible use as a high-energy oxidizer. Results are presented of an extensive study of the chemical reactivity and the physical properties of hexanitroethane. It is a solid, high-energy oxidant, melting at about 150°C, and containing 92% NO_2 by weight. It has a crystalline density of 2.25 gm/cm^3, and a vapor pressure of 0.5 mm Hg at 25°C. The heat of formation of hexanitroethane is determined to be + 28 kcal/mole.

A63-13904

LE KEROSENE CONTRIBUE-T-IL A LA SECURITE DES AVIONS? [DOES KEROSENE CONTRIBUTE TO AIRPLANE SAFETY?]
R. Le Claire.
Aero-Revue, July 1962, p. 373, 374. In French.

Brief comparison of the properties of kerosene and JP 4 fuels, with respect to their relative safety in turbine engines. The physical properties of both fuels are discussed. The feasibility of their employment is seen to depend on the maximum and minimum combustion limits, which are functions of pressure and temperature. Based on combustion characteristics, kerosene is found to be the better fuel. It is pointed out than an electric charge is acquired by the flowing fuel - the faster the flow, the higher the charge. If a spark is caused by the difference of potential between the aircraft and the fuel, the air-vapor mixture in the reservoir could explode. It is seen that the JP 4 fuel is less susceptible to such explosions. Practical flight and accident experience are briefly considered, and several methods for increasing safety are suggested.

A63-14068

RAMAN AND INFRARED SPECTRA OF LIQUID DEUTERATED HYDRAZINE N_2D_4.
Iu. I. Kotov and V. M. Tatevskii.
(Optika i Spektroskopiia, vol. 13, Dec. 1962, p. 855-857.)
Optics and Spectroscopy, vol. 13, Dec. 1962, p. 487, 488. Translation.

Investigation of the Raman and IR spectra of liquid N_2D_4 and N_2H_4. The Raman spectra are studied with a DFS-4 spectrometer, and the IR absorption spectra are studied with IKS-14 double-beam spectrometer. The results obtained are tabulated. It is seen that the frequencies of the fundamental bands of N_2H_4 agree in general with those given in the literature.

A63-14288

EXPLOSION HAZARDS IN LIQUID BIPROPELLANTS.
M. A. Cook (University of Utah, Institute of Metals and Explosives Research, Salt Lake City, Utah).
IN: Applied Cryogenic Engineering. New York, John Wiley and Sons, Inc., 1962, p. 293-320. 17 refs.

Study of the explosion hazards in the bipropellants currently in use. First, the explosion initiation characteristics of liquids and vapors, the laws of blast-wave formation and propagation, and the nature of various types of blast damage in relation to blast-wave propagation are briefly outlined. Estimated ideal or theoretical TNT equivalents of some bipropellants of greatest current interest are given, followed by an outline of the nature of the hazards and a hazards classification for bipropellants. An outline of the behavior of the currently most important bipropellant systems - liquid oxygen (lox) and kerosene (RP-1) - is then given. Finally, based largely on the observed behavior of the lox/RP-1 system, together with thermochemical considerations and the known explosive behavior of liquid and gaseous explosives, predictions of the relative hazards and magnitudes of accidental explosions in other bipropellant systems are presented with the recognition that these predictions are subject to considerable uncertainty.

A63-14292

THE FUTURE OF CRYOGENIC FUELS FOR SPACE SYSTEMS.

R. D. Long (Aerospace Corp., El Segundo, Calif.)

IN: Applied Cryogenic Engineering. New York, John Wiley and Sons, Inc., 1962, p. 395-426. 10 refs.

Comparison of the performances of cryogenic propellants with those of storable and solid propellants. First, the rocket engine is discussed as an energy-conversion device; the process of combustion and thrust production is then considered in terms of the propellant combination. The more advanced propulsion systems are also discussed, including the use of free radicals and nuclear power. In addition, the necessity for using high-energy cryogenic propellants for space missions is demonstrated.

A63-14723

THEORETICAL PERFORMANCE OF HYDRAZINE-CHLORINE TRIFLUORIDE HYPERGOLIC PROPELLANT SYSTEM.

Akira Iwama, Kiroku Yamazaki, and Ken Kikuchi.

University of Tokyo, Aeronautical Research Institute, Bulletin, vol. 3, Sept. 1962, p. 179-187. In Japanese, with summary in English.

Calculation of the theoretical performance and various thermodynamic data of the hydrazine-chlorine trifluoride hypergolic propellant system, performed with a PC-1 parametron computer. It is shown that the maximum theoretical specific impulse of the system is 247.6 sec at mixture ratio of 1.9. A diagram is obtained of the combustion temperature, applicable even when heat loss is taken into account. A chart is presented concerning specific volume, heat capacity, ratio of specific heat, and mean molecular weight of combustion products at various temperatures.

A63-14925

LES HYPERGOLS PHOSPHORES. I - CARACTERISTIQUES ET EMPLOI [PHOSPHOROUS HYPERGOLS. I - CHARACTERISTICS AND EMPLOYMENT].

M. Lemaitre.

Technique et Sciences Aéronautiques et Spatiales, July-Aug. 1962, p. 288-291. In French.

General considerations of hypergols, including: (1) basic definitions, (2) the difference between hypergolic and nonhypergolic propellants, (3) determination of ignition delay, and (4) hypergolic propellant reactivity and structure. Considered are organic-phosphorous hypergols which are substitution products of a cyclic glycol (2-chloro, 1-3-2-dioxyphospholane). Their properties are briefly outlined, and their molecular structures are diagramed.

A63-14926

LES HYPERGOLS PHOSPHORES. II - PREPARATION [PHOSPHOROUS HYPERGOLS. II - PREPARATION].

R. Marquié.

Technique et Sciences Aéronautiques et Spatiales, July-Aug. 1962, p. 292-295. In French.

Outline of the preparation of various organic derivatives of phosphorus, produced in order to determine the hypergolic properties of each. Investigated are the possibilities of forming various P-N bond arrangements. For this purpose, derivatives of dioxyphospholane, and triamidophosphite are prepared. Tables list the experimental conditions, the nature of the reactants, and the physical and chemical properties of the products.

A63-14927

LES HYPERGOLS PHOSPHORES. III - SPECTRES D'ABSORPTION INFRA-ROUGE [PHOSPHOROUS HYPERGOLS. III - INFRARED ABSORPTION SPECTRA].

R. Mathis and J. Roussel (Université de Toulouse, Faculté des Sciences, Laboratorie de Chimie Agrégation, Toulouse, France).

Technique et Sciences Aéronautiques et Spatiales, July-Aug. 1962, p. 296-300. In French.

Spectrographic investigation of the IR absorption bands of six organic-phosphorous compounds, in the wave number region 600 to 3,000 cm^{-1}. Especially important is the study of the bands representing valence vibrations of the CH_2 and CH_3 groups in the neighborhood of a phosphorus atom. The results are listed in tables, and their significance in relation to the nature of the bonds involved is briefly considered.

A63-15099

THERMAL MECHANISMS RELATED TO THE PHOTOLYSIS OF NITROGEN DIOXIDE.

Hadley Ford (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.)

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 119-127. 26 refs.

NASA-supported research.

Detailed survey of the literature and compilation of experimental results obtained in the study of the thermal mechanisms related to the photolysis and the thermal decomposition of nitrogen dioxide. A tabulation of the mechanisms is given for irradiation at wavelengths between 3,100 and 3,700 Å and the rate constants for the mechanisms under the same irradiation at room temperature. The mechanisms are discussed for the thermal decomposition of O_3, NO_2, N_2O, HNO_3, and the N_2O_5-sensitized thermal decomposition of O_3. The closely related field, the reactions of atoms formed in microwave glow discharges, is analyzed for the oxygen-nitrogen system. All the kinetic systems discussed are compiled in a single table, and their relationships in terms of common elementary reactions are indicated.

A63-15118

RADIANT ENERGY EMISSION FROM THE EQUILIBRATED REACTION PRODUCTS OF A PURE AMMONIUM PERCHLORATE PELLET.

D. Olfe (New York University, College of Engineering, New York, N.Y.) and S.S. Penner (California Institute of Technology, Div. of Engineering, Pasadena, Calif.)

(Lockheed Missiles and Space Div. Report Nos. LMSD-288169, Sept. 1959, and LMSD-288169A, Mar. 1960.)

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 293-303.

Contract No. AF 49(638)-412.

Estimation of radiation losses from the combustion products and radiant heat transfer to the burning propellant surface. The propellant considered is a rectangular block of NH_4ClO_4 burning in a rectangular enclosure with a square base. The mean beam length is determined for a uniform gas enclosed by a rectangular parallelepiped. Analysis suggests that emission and absorption of radiant energy in the reaction zone may be neglected. The emissivities of HCl and H_2O are computed under the prevalent pressure and temperature conditions, and the total emissivity overlapping between the emission spectra of HCl and H_2O is considered for appropriate mixture compositions. Estimates are made of radiant energy loss from the combustion products and of radiant heat transfer to the burning propellant surface.

A63-15209
HANDLING LIQUID HYDROGEN FOR CENTAUR.
John S. Harrison (General Dynamics Corp., Astronautics Div., San Diego, Calif.)
American Institute of Aeronautics and Astronautics, Space Flight Testing Conference, Cocoa Beach, Fla., Mar. 18-20, 1963, Paper 63090-63. 9 p.

Discussion of experience gained from the Centaur program in designing for, and handling, liquid hydrogen. Among the test-site facilities described are (1) a 28,000-gal storage tank, insulated and vacuum-jacketed, with vacuum pump, relief valves, vacuum-jacketed filters, and remote-control outlet valves; (2) a vaporizer system for pressurization of the storage tank to transfer liquid hydrogen to test stands and vehicles; (3) a transfer line from storage tank to test stand; and (4) safety devices for hydrogen leak detection, fire detectors, remote-control valves, and instrumentation. Outlined are the design considerations on which Centaur hydrogen facilities are based and the criteria for the test and launch facilities.

A63-15388
SULLA TOSSICITÀ DI ALCUNI PROPELLENTI PER MISSILI [ON THE TOXICITY OF SOME MISSILE PROPELLANTS].
Giuseppe Lalli (Centro di Studi e Ricerche di Medicina Aeronautica e Spaziale, Rome, Italy).
Rivista di Medicina Aeronautica e Spaziale, vol. 25, Oct.-Dec. 1962, p. 678-707. 34 refs. In Italian, with summaries in English, French, Spanish, and German.

Study of the toxic effects of boranes and methyl hydrazine derivatives. Indicated are their major physical and chemical properties, the channels through which they penetrate the human body, and data pertaining to acute, sub-acute, and chronic poisoning. Particular attention is given to concentrations which approach toxicity limits, intoxication symptoms, and methods of protection from the harmful effects of these compounds.

A63-15389
IMPIANTI MOBILI DI OSSIGENO LIQUIDO PER MOTORI A RAZZO [MOVABLE LIQUID OXYGEN PLANTS FOR ROCKET MOTORS].
Glauco Partel.
Tecnica Italiana, vol. 28, Jan.-Feb. 1963, p. 17-24. In Italian.

Demonstration that a low-pressure cycle can be used to manufacture liquid oxygen for the fueling of rocket engines. Initial design data are presented for two lox plants. The smaller plant is required to replace the oxidizer lost by evaporation from the tanks of the aircraft or missile awaiting takeoff. It has an estimated weight of 300 kg and a lox yield of 16 kg/hr. The larger plant, designed to produce 1 kg/sec of lox, weighs approximately 9,700 kg, and may be mounted on a 10-ton truck. The weights include the prime movers of 33 hp and 8,500 hp, respectively.

A63-15434
LES PROPERGOLS SOLIDES MODERNES [MODERN SOLID PROPELLANTS].
J. Boisson.
Doc-Air-Espace, Mar. 1963, p. 25-32. In French.

General discussion of the production and properties of solid propellants. The development of such fuels is outlined, and their attractive features, among the most important of which is simplicity, are briefly discussed. The constituents of the various types of solid propellants - homogeneous, double base, and composite - are described, and the steps in their fabrication are outlined. A discussion of the general characteristics of the fuels includes: (1) the criteria which a solid propellant must meet; (2) the energy derived from the fuel, for which several equations are presented; (3) the speed of combustion of the fuel (kinetic properties); and (4) the geometry of the propellant.

A63-15707
A STUDY OF COMBUSTION AND RECOMBINATION REACTIONS DURING THE NOZZLE EXPANSION PROCESS OF A LIQUID PROPELLENT ROCKET ENGINE.
J. D. Lewis (Ministry of Aviation, Rocket Propulsion Establishment, Westcott, Buckinghamshire, England) and D. Harrison (Cambridge University, Dept. of Chemical Engineering, Cambridge, England).
IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 366-374.

Description of a gas-sampling technique developed to study the variations in chemical compositions across the entry and exit of the exhaust nozzle of a small-scale liquid-propellant rocket engine. The technique enables measurements to be made of the efficiency of both the combustion and mixing processes which occur within the combustion chamber. The experiments described are carried out in the rocket engine in which a single spray of n-heptane fuel burns in the decomposition products of concentrated hydrogen peroxide. On the basis of the results obtained experimentally it is shown that it is possible to apply gas-sampling techniques to the study of chemical reactions occurring during the nozzle expansion process. In particular, a practical solution is found to the problems associated with sampling from high-temperature gas streams at supersonic velocities.

A63-15739
THE CATALYTIC DECOMPOSITION OF AMMONIUM PERCHLORATE.
A. Hermoni (Ministry of Defense, Tel Aviv, Israel) and A. Salmon.
IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams, and Wilkins Co., 1962, p. 656-662.

Investigation of the kinetics of the thermal decomposition for mixtures of ammonium perchlorate with manganese dioxide, nickel trioxide, chromium trioxide, magnesium oxide, and a mixture of cobalt oxides (Co_2O_3 + Co_3O_4). In the temperature range of 170 to 200°C the rate of decomposition is measured gravimetrically by determining the loss of weight of the mixture ammonium perchlorate-catalyst as a function of the time. At temperatures above 200°C the rate of the decomposition is followed gasometrically, condensing out all of the gaseous products other than oxygen and nitrogen, and measuring the rate of increase of pressure in an apparatus of constant volume. The experimental results indicate that the catalysts influence reactions in both the solid and the gaseous phases. That catalysts participate in reactions in the solid phase is indicated by the increase of the rate of the decomposition of ammonium perchlorate in the presence of the catalysts, and by the fact that the quantity of catalyst required to achieve maximum reduction of the ignition delay time decreases as the particle size of the perchlorate increases. The following results are found to be in accordance with the assumption that the oxides also catalyze reactions among the gaseous products of the decomposition reaction: (1) the change in the distribution of the gaseous products with the catalyst used; and (2) increasing the amount of the catalyst does not change the value of P/P_f but changes both P and P_f (initial and final pressure).

A63-15740
FURTHER STUDIES OF PURE AMMONIUM PERCHLORATE DEFLAGRATION.
Joseph B. Levy and Raymond Friedman (Atlantic Research Corp., Alexandria, Va.)
IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams, and Wilkins Co., 1962, p. 663-672. 14 refs.
USAF-supported research.

Investigation of the deflagration of pure pressed strands of ammonium perchlorate in an effort to gain a basic understanding of this process and, through it, of the burning of rocket propellants containing ammonium perchlorate as the oxidizer. Covered are two general directions: (1) the study of the effects of pressure, catalysts, and added radiant energy on the burning rate; and (2) the study of the chemistry of the deflagration process and the effect of various parameters on it.

A63-15741
DEFLAGRATION LIMITS IN THE STEADY LINEAR BURNING OF A MONOPROPELLANT WITH APPLICATION TO AMMONIUM PERCHLORATE.
W. E. Johnson and W. Nachbar (Lockheed Aircraft Corp., Missiles and Space Div., Sunnyvale, Calif.)
IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams, and Wilkins Co., 1962, p. 678-689. 17 refs.
Contract No. AF 49(638)-412.

Application of a laminar-flame theory to the steady one-dimensional, linear burning of a monopropellant to ammonium perchlorate. The analysis is made in order to: (1) obtain a sensitive check on the validity of representing the deflagration of a solid propellant by a combination of the gas-phase laminar-flame equations with a rate law, or laws if the solid is complex, for the decomposition of the solid; and (2) give a formal derivation of new methods for calculating rigorous upper and lower bounds for the eigenvalues of the laminar-flame monopropellant problem with adiabatic phase. These methods give not only a close estimate of the eigenvalue but also a precise bound on the error for every calculation. The behavior of the low-pressure deflagration limit in this model is analyzed, and some numerical calculations in comparison with the experimental data on ammonium perchlorate are presented.

A63-15742
REMARKS ON THE BURNING MECHANISM AND EROSIVE BURNING OF AMMONIUM PERCHLORATE PROPELLANTS.
J. Vandenkerckhove and A. Jaumotte (University of Brussels, Institute of Aeronautics, Brussels, Belgium).
IN: Combustion Institute, International Symposium on Combustions, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams, and Wilkins Co., 1962, p. 689-693.

Comparison of the burning rate of propellants and that of pure ammonium perchlorate as reported by Friedman in an attempt to obtain a more precise information than the general statement that the burning rates are similar. It is shown that the burning rate of the propellant can be higher or lower than that of the pure oxidizer, depending upon the pressure, mixture ratio, and granulation. For coarse granulation and low oxidizer contents, the burning rate is higher at low pressure, and smaller at high pressure than that of pure perchlorate. For fine granulations and high oxidizer contents, the burning rate is higher at all pressures in the considered range. After reviewing some of the characteristic experimental data, a model of the burning mechanism and erosive burning of ammonium perchlorate are discussed.

A63-15743
THE COMBUSTION OF PROPELLANTS BASED UPON AMMONIUM PERCHLORATE.
G. K. Adams, B. H. Newman, and A. B. Robins.
IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore. Williams, and Wilkins Co., 1962, p. 693-705.

Determination of the effect of the following variables on the burning rates of solid composite systems containing ammonium perchlorate as oxidizer: (1) particle size of oxidant and fuel, (2) the pressure under which the mixtures are burned, (3) the oxidant/fuel ratio, and (4) the chemical composition of the fuel. It is shown that the burning of ammonium perchlorate fuel mixtures is a more complex process than has been assumed. The dependence of linear burning rate on either pressure, oxidant particle size, or fuel stoichiometry is sensitive to the values of the other parameters. There are large differences in behavior between mixtures with fuel of different chemical composition. In view of these observations and also of the possible theoretical complexity of composite propellant combustion, it is unlikely that any simple quantitative theory can be developed on the basis of the present knowledge of such systems and related problems. Attention is, therefore, called only to what is considered to be the salient features of these results which any theoretical model must comprehend and which may help in formulating such a model.

A63-15744
REACTION RATE AND CHARACTERISTICS OF AMMONIUM PERCHLORATE IN DETONATION.
W. Hoyt Andersen and R. E. Pesante (Aerojet-General Corp., Ordnance Div., Azusa, Calif.)
IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams, and Wilkins Co., 1962, p. 705-710. 13 refs.
Navy-supported research.

Presentation of experimental data and analyses necessary to evaluate the characteristics and the reaction (energy-release) rate of pure ammonium perchlorate (AP) in detonation. These data and analyses are necessary for any quantitative understanding of the detonation of mixtures containing ammonium perchlorate. The steady-state detonation velocities of the cylindrical charges of essentially pure ammonium perchlorate are determined as a function of charge diameter, charge density, and ammonium perchlorate particle size. The dependence of the nonideal detonation velocity on particle size suggests that a grain-burning detonative mechanism occurs. It also partially isolates the critical (minimum) diameters for propagating detonation in the ammonium perchlorate charges studied. The Chapman-Jouguet detonation characteristics of the ideally detonating ammonium perchlorate charges are estimated and tabulated. These characteristics are computed with the conventional thermodynamic-hydrodynamic theory of detonation, the experimentally observed detonation velocities, and Cook's detonation equation of state.

A63-16908
TITAN II PROPELLANT HANDLING AND COMPATIBILITY PROBLEMS.
O. C. Bender (Martin-Marietta Corp., Canaveral Div., Cocoa Beach, Fla.)
American Institute of Aeronautics and Astronautics, Space Flight Testing Conference, Cocoa Beach, Fla., Mar. 18-20, 1963, Paper 63086. 34 p.

Study of the problems associated with propellant compatibility, protective clothing, and range-safety restrictions. Experience gained in the handling of millions of pounds of nitrogen tetroxide (the oxidizer) and hydrazine-UDMH (the fuel) in the Titan II program is reviewed. Described is a self-contained atmospheric protective ensemble (SCAPE) to protect the operator from exposure to the oxidizer and fuel.

A63-17021
MECHANISM OF THE ACCELERATED BURNING OF AMMONIUM PERCHLORATE AT HIGH PRESSURES.
O. R. Irwin, P. K. Salzman, and W. H. Andersen (Aerojet-General Corp., Ordnance Div., Downey, Calif.)
AIAA Journal, vol. 1, May 1963, p. 1178-1180.
Navy-supported research.

Investigation of the possibility that the steep thermal gradient existing at the burning surface of ammonium perchlorate at high pressures can, among other factors, lead to the shear stress responsible for cracking. The analysis indicates that thermal stress is almost solely responsible for the cracking over the entire pressure range of the burning rate experiments.

A63-17024
PARTICLE SIZE ANALYSIS OF AMMONIUM PERCHLORATE BY LIQUID SEDIMENTATION.
E. K. Bastress, K. P. Hall, and M. Summerfield (Princeton University, Dept. of Aeronautical Engineering, Guggenheim Jet Propulsion Center, Princeton, N. J.)
AIAA Journal, vol. 1, May 1963, p. 1182-1185.
Contract No. Nonr 1858(32).

Description of a method for obtaining particle-size distributions in ammonium perchlorate and other finely divided materials from 400-μ diam. to 1 μ and below. The method offers advantages including rapid operation and moderate equipment costs. Validity and accuracy of the method are found to be satisfactory for use in studies of particle-size effects in solid-propellant combustion.

A63-17333

COMBUSTION IN LOOSE GRANULAR MIXTURES OF POTASSIUM PERCHLORATE AND ALUMINUM.

J. Hershkowitz, F. Schwartz, and J. V. R. Kaufman (Feltman Research and Engineering Labs., Picatinny Arsenal, Dover, N. J.)

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 720-727. 14 refs.

Application of high-speed photography to the investigation of factors responsible for the combustion characteristics of a loose granular mixture of an oxidant and a fuel. Determined are the reaction-zone profiles and their rates of propagation for several particle-size combinations of potassium perchlorate and aluminum. Also studied is the effect of including a small quantity of fine explosive in the mixture. The results are used to propose a model of the reacting medium, suitable for further experimental and theoretical study.

A63-17366

THE MECHANISM OF BURNING OF LIQUID HYDRAZINE.

Albert C. Antoine (NASA, Lewis Research Center, Cleveland, Ohio).

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 1057-1059; Discussion, p. 1059.

Experimental investigation of the burning rates of liquid hydrazine at pressures above 1 atm, in order to clarify the combustion mechanism. It is found that the burning rate of liquid hydrazine is controlled primarily by a second-order, gas-phase reaction rate. However, in certain pressure ranges, determined by the tube diameter and the concentration of the liquid, the burning rate is limited by an evaporation rate. A calculated value for the burning rate at 1 atm, based on heat generation in the gas phase and thermal conduction to the surface, gives good agreement with the observed results.

A63-17369

ON THE EXISTENCE OF DETONATION CONDITIONS IN THE COMBUSTION OF SOME NITRIC ACID PROPELLANTS.

Michel L. J. Bernard and J. Dufour (Université de Poitiers, Lab. de Chimie Minérale, Poitiers, France).

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 1074-1084. 12 refs.

Experimental investigation of the causes of the abnormal pressures obtained when certain aminated fuels ignite with nitric acid. The equipment used consists of a microrocket with a transparent chamber similar to those employed by Ladanyi and by Barrère. Investigated are the ignition with no overpressure with furfuryl alcohol, and ignition with strong overpressures using variably a mixture of Tonka amines, nitrogenous substances, and ethylenediamine. It is established that the abnormal pressures are in close relationship with the formation of unstable intermediate compounds. According to the experimental conditions, these compounds are identified as amine or hydrazine nitrates, which tend to decompose explosively under the influence of sudden temperature or pressure rises.

A63-17370

THE CATALYTIC DECOMPOSITION OF NITROMETHANE UNDER HIGH PRESSURE.

A. Hermoni (Ministry of Defense, Tel Aviv, Israel) and T. B. Grunwald (Technion-Israel Institute of Technology, Haifa, Israel).

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 1084-1088.

Experimental investigation of the nature of the chemical reactions which occur when nitromethane decomposes under high pressure in the presence of chromium and iron oxides, and in the temperature range 220°-245°C. Iron oxide loses its catalytic activity after about 33% decomposition of nitromethane, whereas no such loss of activity is observed for chromium oxide. Tabulated is the distribution of products obtained at 30% decomposition in the presence of chromium oxide at approximately 36 atm initial pressure and 230°C. Two different mechanisms are proposed in order to account for the distribution of the reaction products, the first of which assumes the same initial step as in the noncatalytic decomposition, and the second postulates N-O bond rupture as the rate-determining step.

A63-17371

THE EXPLOSIVE REACTION OF CHLORINE TRIFLUORIDE WITH PARAFFIN HYDROCARBONS.

C. B. Baddiel (University of London, Imperial College of Science and Technology, Dept. of Chemistry, London, England) and C. F. Cullis (University of London, Imperial College of Science and Technology, Dept. of Chemical Engineering, London, England).

IN: Combustion Institute, International Symposium on Combustion, 8th, Pasadena, Calif., Aug. 28-Sept. 3, 1960. Baltimore, Williams and Wilkins Co., 1962, p. 1089-1095. 14 refs.

Experimental investigation of the interaction of chlorine trifluoride with methane and propane, in order to determine the potentiality of the interhalogen reagent as a rocket fuel. A known pressure of chlorine trifluoride is first admitted to the reaction vessel. It is then possible, by connecting this to a vessel of known volume (filled to a predetermined pressure with hydrocarbon), to admit rapidly the required amounts of the other reactants to the interhalogen. The products of the reaction are analyzed by chemical analysis, IR spectroscopy, nuclear magnetic-resonance spectroscopy, and gas-liquid chromatography. The acid products formed after explosion at 70°C are tabulated and plotted. The chain character of the reaction is discussed, and the analytical evidence for chemical change is evaluated.

A63-17940

THE EXPERIMENTAL DEVELOPMENT OF AN ISOCYANATE SOLID PROPELLANT. II.

F. J. Kosdon (Massachusetts Institute of Technology, Cambridge, Mass.) and R. H. Winston (Harvard University, Cambridge, Mass.)

AIAA Student Journal, vol. 1, Apr. 1963, p. 32-38.

Further description of a test program aimed at the development of an isocyanate propellant, using a new static test motor. The results of several firings with a propellant, designated X-14, are discussed and graphically illustrated. The propellant is a mixture of coarse (48%) and fine (26%) NH_4ClO_4, 16% Adiprene L-100, a plasticizer, some light oil, aluminum dust, and a curing agent (MOCA). Various alternate compositions of Adiprene L-100 are presented in a table. Development and combustion characteristics of an internal burning star are considered, as is the determination of more exotic methods of increasing the total energy available for oxidation. Modifications of the motor are discussed in an appendix. It is noted that the nozzle insert, rather than the fuel capsule, is ejected from the improved motor, thus protecting the capsules, which are more delicate than the nozzles, from damage. Another innovation is the head-end ignition-system attachment which allows more efficient ignition of internal-burning grains.

A63-18122

ELASTOMERS FOR LIQUID ROCKET FUEL AND OXIDIZER APPLICATION.

Joseph Green, Nathan B. Levine, and Robert C. Keller (Thiokol Chemical Corp., Reaction Motors Div., Chemistry Dept., Denville, N. J.).

(American Chemical Society, Div. of Rubber Chemistry, Meeting, 82nd, Cleveland, Ohio, Oct. 1962.)

I & EC - Product Research and Development, vol. 2, June 1963, p. 126-133.

Contract No. AF 33(616)-7227.

Investigation of the resistance of commercially available and experimental polymers to hydrazine-type fuels, nitrogen tetroxide, and fluorine-containing oxidizers. On the basis of static and dynamic tests, several materials are recommended for application in each of these propellants. Techniques for encapsulating elastomer O-rings with inert resins and metals are discussed.

A63-18444

GRAPHICAL EVALUATION OF THE TRADE-OFF BETWEEN SPECIFIC IMPULSE AND DENSITY.

Morton A. Klotz (Aerojet General Corp., Azusa, Calif.).

American Institute of Aeronautics and Astronautics, Summer Meeting, Los Angeles, Calif., June 17-20, 1963, Paper 63-198. 5 p.

Members, \$0.50; nonmembers, \$1.00.

Application of Gordon's demonstration (of the use of an equation for the effective specific impulse to evaluate the relative effects of propellant specific impulse and density in a volume-limited vehicle) to the plotting of graphs from which the fuels to be used for the various stages of a rocket can be determined. Hypothetical graphs, which plot the effective specific impulse semilogarithmically against a parameter which depends on the density of the propellant in the higher stages, are presented and evaluated, as are graphs which compare metals and metallic hydrides as fuels in solid propellants, and several liquids as oxidizers for liquid hydrogen, including, O_2, ClF_3, F_2, and CH_2.

A63-18455

COMPARISON OF STORABLE AND CRYOGENIC PROPELLANTS.

Walter D. Smith and O. C. Bender (Martin Marietta Corp., Martin Co., Canaveral Division, Cocoa Beach, Fla.).

American Institute of Aeronautics and Astronautics, Summer Meetting, Los Angeles, Calif., June 17-20, 1963, Paper 63-177. 29 p. Members, \$0.50; nonmembers, \$1.00.

Demonstration (by comparing range safety restrictions, protective clothing, propellant handling, and compatibility problems of both cryogenic and storable propellants) that either propellant can be used safely. The comparison is based on actual experience in working with cryogenic propellants on the Titan I research and development flight-test program (1958-1962), and the storable propellants on the Titan II program (1961-1963). The comparison is largely restricted to the problems experienced in the handling of lox vs nitrogen tetroxide, and the mixture of unsymmetrical dimethyl hydrazine and hydrazine.

A63-18514

ON THE DETONATION OF NITROMETHANE.

A. N. Dremin, O. K. Rozanov, and V. S. Trofimov (Moscow Institute of Chemical Physics, Moscow, USSR).

Combustion and Flame, vol. 7, June 1963, p. 153-162. 13 refs.

Discussion of data thought to support Shchelkin's suggestion that detonation of condensed explosives may be of similar nature to that of gaseous detonation, with particular reference to nitromethane either alone or in admixture with acetone. The passage of inhomogeneities from narrow tubes into broader ones is described and some attention given to the material containing the test mixture, and to the nature of its inner surface. A mathematical appendix is included dealing with Shchelkin's criterion.

A63-18796

STORABILITY DESIGN CRITERIA FOR SPACE PROPULSION.

Philip D. Gray (Aerojet-General Corp., Azusa, Calif.).

American Institute of Aeronautics and Astronautics, Summer Meeting, Los Angeles, Calif., June 17-20, 1963, Paper 63-259. 10 p. Members, \$0.50; nonmembers, \$1.00.

Contract No. AF 04(611)-7441.

Review of analytical and experimental investigations to determine the conditions under which cryogenic propellants might be used, and to develop techniques for their storage. Briefly described is an analytical technique to permit prompt, accurate evaluation of a wide variety of propellant combinations stored in space for time periods of up to 2 yr. The experimental evaluation of storability is described, including the tank design and insulation, the propellant line, and the effects of radiation on propellants. It is noted that propellants which are not significantly affected in the liquid phase by irradiation include hydrazine, chlorine trifluoride, nitrogen tetroxide, and pentaborane. It is demonstrated that, while the optimization of upper-stage vehicle parameters is extremely complex, it can be accomplished by means of an appropriate computer program.

A63-18882

INVESTIGATION OF ADVANCED HIGH ENERGY SPACE STORABLE PROPELLANT SYSTEM - OF_2/B_2H_6.

Bruce E. Dawson and Rolland R. Schreib, Jr. (Thiokol Chemical Corp., Reaction Motors Division, Denville, N.J.).

American Institute of Aeronautics and Astronautics, Summer Meeting, Los Angeles, Calif., June 17-20, 1963, Paper 63-238. 14 p. Members, \$0.50; nonmembers, \$1.00.

Investigation of the feasibility of oxygen difluoride-diborane propellants for use in space propulsion systems. It was shown in previous analytical studies that this combination possesses performance and space storability advantages in a variety of missions. Tests show that the OF_2-B_2H_6 propellant combination is hypergolic at both sea level and high altitude. High theoretical performance is readily attainable with standard injection techniques. The propellants can be easily handled in equipment suitable for the cryogenic temperature range when the components have been properly cleaned and passivated. Heat rejection rates are high due to the combination of high combustion temperatures and radiating combustion products, but the heat fluxes are within the present state-of-the-art for ablative chambers and nozzles.

A63-19065

HEALTH HAZARDS OF SELECTED ROCKET PROPELLANTS.

John E. Boysen (USAF, Logistics Command, Professional Services Division, Wright-Patterson AFB, Ohio).

(American College of Preventive Medicine, Annual Meeting, 9th, Miami Beach, Fla., Oct. 18, 1962.)

Archives of Environmental Health, vol. 7, July 1963, p. 71-75.

Discussion of the problems involved in research and prevention of the poisonous effects of rocket propellants. The development of toxicological experiments involving first animals and then man to investigate dosage effects is outlined. A table lists representative propellants and oxidizers and their threshold limit values. Considered are the problems created by the "concept of concurrency," which involves the fact that design and procedural decisions must be made before the development of adequate toxicological and clinical data. Possible methods of evaluating the operational risk involved in the transport, storage, and firing of a propellant are delineated, and the design of a medical program involving the use of propellants is discussed.

A63-19437

CRYOGENIC PROPELLANT STRATIFICATION ANALYSIS AND TEST DATA CORRELATION.

T. Bailey, R. VandeKoppel, G. Skartvedt (Martin Marietta Corp., Martin Co., Denver, Colo.), and T. Jefferson (University of Arkansas, Fayetteville, Ark.).

AIAA Journal, vol. 1, July 1963, p. 1657-1659.

Development of an analytical procedure to accomplish quantitative analysis of the cryogenic propellant stratification phenomenon. Development of the analysis proceeds from basic considerations, and no scale-effect factors or other gross empirical coefficients are required. Results of the analysis consist of volume and temperature of the warm upper-propellant layer as functions of time. Correlations of predicted results with liquid-nitrogen ground-test data and liquid-oxygen Titan and Vanguard flight-test data confirm the validity and usefulness of the analytical model.

A63-19458

THERMAL CONDUCTIVITY OF GASEOUS UNSYMMETRICAL DIMETHYLHYDRAZINE.

Robert D. Allen (Dynamic Science Corp., South Pasadena, Calif.).

AIAA Journal, vol. 1, July 1963, p. 1689-1691.

Lockheed Aircraft Corp., Lockheed Missiles and Space Co.-supported research.

Determination of the thermal conductivity of gaseous unsymmetrical dimethylhydrazine by a modified hot-wire technique employing five standard gases. Data are obtained at average temperatures of about 5°, 10°, 30°, and $35^{\circ}C$. All gases are run at a pressure of 1/6 atm in order to overcome convection effects. Assuming linearity with temperature, the thermal conductivities are 266×10^{-7} and 316×10^{-7} cal/cm-sec-$^{\circ}C$ at 0° and $50^{\circ}C$, respectively.

A63-20498
EFFECT OF ADDITIVES ON FORMATION OF SPHERICAL DETONATION WAVES IN HYDROGEN-OXYGEN MIXTURES.
Andrej Maček (Atlantic Research Corp., Alexandria, Va.).
AIAA Journal, vol. 1, Aug. 1963, p. 1915-1918. 15 refs.
Contract No. AF 33(616)-8110.

Study of the initiation, by means of exploding wires, of spherical detonation in a gaseous mixture consisting of 62 mole % of hydrogen and 38 mole % of oxygen. The minimum electrical energy, stored in the condenser of the initiator circuit, needed for initiation of detonation is $E_i = 10.5 \pm 0.3$ joules, in agreement with results reported in the literature. The effect of up to 5% of various gases, added to this hydrogen-oxygen mixture, on E_i is studied. It is found that, while some gases inhibit the formation of detonation, others promote it. Of the additives studied, the best inhibitor is isobutene; trans-butene-2, propylene, and pentacarbonyl iron are also quite effective.

A63-20500
REACTION OF HYDRAZINE AND NITROGEN TETROXIDE IN A LOW-PRESSURE ENVIRONMENT.
Robert A. Wasko (NASA, Lewis Research Center, Cleveland, Ohio).
AIAA Journal, vol. 1, Aug. 1963, p. 1919, 1920.

Preliminary study of the reaction of hydrazine and nitrogen tetroxide at pressures as low as 10^{-4} torr in a steel vacuum tank. Curves showing the effects of varying propellant quantity on tank-pressure rise are presented. It is found that: (1) an explosive reaction occurs only when a sufficient quantity of propellant is used to produce vaporized mixture pressure greater than 4 torr; (2) for the decade of initial ambient pressure from 0.1 to 1 torr, the reaction changes from an explosion to a slower reaction, as evidenced by a decrease in the magnitude of the explosion pressure and an increase in the reaction delay time; and (3) N_2O_4 vaporizes more quickly than N_2H_4 and the temperature decrease due to vaporization is sufficient to cause freezing of a portion of the N_2H_4.

A63-20525
SPONTANEOUS IGNITABILITY OF NONHYPERGOLIC PROPELLANTS UNDER SUITABLE CONDITIONS.
N. L. Munjal (Gorakhpur University, Gorakhpur, India).
AIAA Journal, vol. 1, Aug. 1963, p. 1963.

Brief discussion of the role of some additives used to accelerate the chemical reaction preceding the ignition of bipropellants. Results showing the average ignition delay of several nonhypergolic fuels using red-fuming nitric acid as oxidizer are presented.

A63-21240
PROPULSION OF THE FINAL STAGE OF A SATELLITE LAUNCHER USING LIQUID HYDROGEN AS FUEL.
A. W. T. Mottram (Bristol Siddeley Engines, Ltd., Rocket Dept., Coventry, Warwickshire, England).
IN: 12th INTERNATIONAL ASTRONAUTICAL CONGRESS, PROCEEDINGS, vol. 1. Washington, D.C., Oct. 1-7, 1961. New York and London, Academic Press, Inc., 1963, p. 1-9.

Study of a possible design of a third stage for a communication satellite launching system based on the Blue Streak launcher. A liquid hydrogen/liquid oxygen propellant combination is considered for a third stage. It is felt that the benefits resulting from the high specific impulse obtainable, using hydrogen as a fuel, outweigh the disadvantages due to its low density. Moreover, since it gives the best returns when used in the top and physically smallest stage of a launching vehicle it enables the capabilities of vehicles based on existing booster stages to be stretched.

A63-22423
GREASE-TYPE LUBRICANTS COMPATIBLE WITH MISSILE FUELS AND OXIDIZERS.
Joseph Messina and Henry Gisser (U.S. Army Munitions Command, Pitman-Dunn Institute for Research, Frankford Arsenal, Philadelphia, Pa.).
(American Chemical Society, Division of Petroleum Chemistry, Meeting, 144th, Los Angeles, Calif., Mar. 1963.)
I & EC - Product Research and Development, vol. 2, Sept. 1963, p. 209-212. 14 refs.

Study of the thickening of mixed perfluorotrialkylamines (alkyl = C_4 to C_6) with tetrafluoroethylene polymers (molecular weights 2,000-30,000) in connection with the development of grease-type lubricants for liquid-fuel-powered missiles. Grease-type mixtures were stable to shear stresses, and showed no separation on standing (up to one year) and little separation in the cone tests at 100°C. The greases were unreactive with, and insoluble in, ethyl alcohol, JP-4, unsym-dimethylhydrazine, diethylenetriamine, a 60:40 mixture of the last two, a 50:50 mixture of unsym-dimethylhydrazine and hydrazine, 90% hydrogen peroxide, and inhibited red fuming nitric acid. There was no explosive reactivity in impact tests with liquid oxygen or nitrogen tetroxide. A typical grease exhibited antiwear and extreme pressure properties comparable to conventional petroleum greases, and did not attack most conventional elastomers. Average particle size of the polymers was 5 μ.

A63-22455
CONTRIBUTION TO THE STUDY OF COMBUSTION IN ROCKETS USING LITHERGOLIC OR HYBRID PROPELLANTS [CONTRIBUTION A L'ETUDE DE LA COMBUSTION DANS LES FUSEES A LITHERGOL OU HYBRIDES].
André Moutet (Office National d'Etudes et de Recherches Aéronautiques, Groupe de Recherches, Châtillon-sous-Bagneux, Seine, France) and Marcel Barrère (Office National d'Etudes et de Recherches Aéronautiques, Châtillon-sous-Bagneux, Seine, France).
IN: ADVANCES IN AERONAUTICAL SCIENCES. VOL. 3. 2nd International Congress in the Aeronautical Sciences, Proceedings, Zurich, Switzerland, Sept. 12-16, 1960.
New York, Pergamon Press, Inc., 1962, p. 465-496. 16 refs.
In French.

Experimental investigation of the combustion of solid hypergolic fuels in the presence of a liquid oxidizer injected into the combustion chamber. The phenomena analyzed correspond to the ignition of the chamber in the steady-state regime and at combustion stability. The ignition process is investigated with an apparatus which measures the ignition delay as a function of the nature of the fuel and of the oxidizer. The steady-state is characterized by the value of the ablation velocity of the solid fuel when placed in the hot oxidant flow. This velocity is evaluated as a function of the propellant parameters and of the physical laws explicitly obtained for the operation of the lithergolic rocket. The stability of such a system is investigated.

A63-22576
FLAME CHARACTERISTICS OF THE DIBORANE-HYDRAZINE SYSTEM.
M. W. Vanpée, A. H. Clark, and H. G. Wolfhard (Thiokol Chemical Corp., Reaction Motors Division, Denville, N.J.).
IN: 9th INTERNATIONAL SYMPOSIUM ON COMBUSTION. Ithaca, N.Y., Aug. 27-Sept. 1, 1962. Edited by W. G. Berl. New York and London, Academic Press, Inc., 1963, p. 127-136; Discussion, p. 136.
Contract No. Nonr 1858(25).

Experimental investigation of diborane-hydrazine flames. The conditions under which the stabilization of a premixed flame was obtained is described. Various flame characteristics, among them burning velocity, spectrum, and solid and gaseous combustion products, were measured, and the results are analyzed. The kinetics of the diborane-hydrazine flame are considered in terms of the experimental observations.

A63-22578
STUDIES OF THE COMBUSTION OF DIMETHYL HYDRAZINE AND RELATED COMPOUNDS.
Peter Gray and Malcolm Spencer (University of Leeds, Leeds, England).

IN: 9th INTERNATIONAL SYMPOSIUM ON COMBUSTION. Ithaca, N. Y., Aug. 27-Sept. 1, 1962. Edited by W. G. Berl. New York and London, Academic Press, Inc., 1963, p. 148-156; Discussion, p. 156, 157. 21 refs.

Experimental investigation of the spontaneous ignition of N_2H_4 + NO and of N_2H_4 + N_2O, in order to determine the modes of reaction, to investigate the mechanisms of ignition, and to investigate the role of self-heating in these reactions. In addition, the necessary conditions for the spontaneous ignition of dimethyl hydrazine (DMH) are determined, as are the conditions for the spontaneous combustion (strong explosion) of DMH plus oxygen; the weak ignition and chemiluminescent ignitions in mixtures of DMH with oxygen are also investigated.

A63-22583

THE NATURE AND CAUSE OF IGNITION OF HYDROGEN AND OXYGEN SENSITIZED BY NITROGEN DIOXIDE.

P. G. Ashmore and B. J. Tyler (University of Cambridge, Cambridge, England).

IN: 9th INTERNATIONAL SYMPOSIUM ON COMBUSTION. Ithaca, N. Y., Aug. 27-Sept. 1, 1962. Edited by W. G. Berl. New York and London, Academic Press, Inc., 1963, p. 201-209. 14 refs.

Explanation of the observation that ignitions in mixtures of hydrogen, oxygen, and nitrogen dioxide are isothermal near some ignition boundaries and thermal near others. Experimental investigations of these mixtures are performed, and a mechanism is proposed which can account for the two types of observed ignition, as well as for the occurrence of ignition limits, and for induction periods.

A63-22600

DEFLAGRATION CHARACTERISTICS OF AMMONIUM PERCHLORATE AT HIGH PRESSURES.

O. R. Irwin, W. H. Andersen (Aerojet-General Corp., Ordnance Division, Downey, Calif.), and P. K. Salzman (Aerojet-General Corp., Downey, Calif.).

IN: 9th INTERNATIONAL SYMPOSIUM ON COMBUSTION. Ithaca, N. Y., Aug. 27-Sept. 1, 1962. Edited by W. G. Berl. New York and London, Academic Press, Inc., 1963, p. 358-364; Discussion, p. 365. 20 refs.

Contract No. NOrd 18487.

Investigation of the deflagration characteristics of pure ammonium perchlorate (AP) strands, by means of a closed-bomb strand burning technique, at pressures from 1,000 to 23,000 psi. The data are in general agreement with vented-chamber AP burning-rate data of other investigators at pressures from 1,000 to 5,000 psi. At pressures above 5,000 psi (the pressure limit of previously reported studies) a marked increase in pressure dependence of the linear burning rate occurs. It is postulated that the observed increase in burning rate results from an increased burning surface area - i.e., surface break-up, under the action of the very high pressures existing in the closed bomb. The action of pressure, or stress, upon the burning surface can produce shearing giving rise to increased burning area by forming new cracks and pores or by enlarging existing cracks and pores. A geometrical model is presented which considers the accelerated burning process as a development of micro-cracks that form into conically-shaped burning surfaces, the area of which depends upon the pressure. The model is in good agreement with the experimental burning-rate data and with the pressure vs time data for individual burning-rate experiments at pressures above 5,000 psi.

A63-22601

A SIMPLE THEORY OF SELF-HEATING AND ITS APPLICATION TO THE SYSTEM AMMONIUM PERCHLORATE AND CUPROUS OXIDE.

P. W. M. Jacobs and A. R. Tariq Kureishy (University of London, Imperial College, London, England).

IN: 9th INTERNATIONAL SYMPOSIUM ON COMBUSTION. Ithaca, N. Y., Aug. 27-Sept. 1, 1962. Edited by W. G. Berl. New York and London, Academic Press, Inc., 1963, p. 366-370; Discussion, p. 370. 18 refs.

Analysis of the differential equation governing the temperature, as a function of time and position, in a solid undergoing an exothermic chemical reaction. The approximations usually made in theories of self-heating are discussed briefly. It is pointed out that kinetic experiments close to the critical ignition state yield results for the fractional decomposition α as a function of time t which depart from the kinetic law applicable at lower temperatures. Nevertheless, these $\alpha(t)$ curves can be analyzed to yield effective rate constants which depend on the temperature of the surroundings (T_0) rather than on the temperature of the reactant (which is, of course, a function of time). A theory of self-heating is developed using these effective rate constants and this is applied to the calculation of ignition times and self-heating curves of systems of NH_4ClO_4 and Cu_2O.

A63-22631

COMBUSTION STUDIES OF SINGLE ALUMINUM PARTICLES.

R. Friedman and A. Maček (Atlantic Research Corp., Alexandria, Va.).

IN: 9th INTERNATIONAL SYMPOSIUM ON COMBUSTION. Ithaca, N. Y., Aug. 27-Sept. 1, 1962. Edited by W. G. Berl. New York and London, Academic Press, Inc., 1963, p. 703-709; Discussion, p. 709-712.

Contract No. Nonr 1858(25).

Review of work, both experimental and theoretical, on the ignition and combustion of single aluminum particles at atmospheric pressure; new experimental data, obtained by two methods, are presented. In the first method, the aluminum particles are injected into the stream of hot gases generated by means of a flat-flame burner. In the second method, the particles are burned in the combustion products of ammonium perchlorate flames with organic fuels added. In both cases, aluminum is burned in an atmosphere of controlled temperature and composition. It is concluded that ignition occurs only upon melting of the oxide layer (mp, 2,300°K) which coats the particle. The process of ignition is not affected by the moisture content of the hot ambient gas, and only slightly by its oxygen content. On the other hand, there are distinct effects of oxygen and of water vapor on combustion of the metal. Oxygen promotes vigorous combustion, and, if its concentration is sufficiently high, there is fragmentation of particles. In the virtual absence of water, diffusion and combustion take place freely in the gas phase, whereas in the presence of significant amounts of water, the process is impeded and confined to a small region, because the reactants must diffuse through a condensed oxide layer.

A63-23094

THE CHEMICAL COMPOSITION AND PROPERTIES OF FUELS FOR JET PROPULSION.

Ia. M. Paushkin.

New York, Pergamon Press, Inc., 1962. 480 p.

$15.

Translation of KHIMICHESKII SOSTAV I SVOISTVA REAKTIVNYKH TOPLIV. Translated from the Russian by William E. Jones (United Kingdom Atomic Energy Authority, London, England). Edited by B. P. Mullins (Ministry of Aviation, Farnborough, Hampshire, England).

Comprehensive examination of the physics and chemistry of jet propulsion fuels. Described in detail are the relationship between the chemical composition and the properties of fuels used in gas turbines, ramjets, and rockets; the development of fuel production methods; the component processes of combustion; and lubricants for gas-turbine engines. The characteristics of various mono- and bipropellants are presented, including the wide range of oxidants used in liquid-propellant rocket systems. Coverage extends to recent advances in high-energy fuels and the general descriptions of various Earth satellites and space probes.

A63-23915

HEAT TRANSFER TO UNINSULATED MISSILE TANKS CONTAINING LIQUID HYDROGEN.

Wolfgang Schaechter (Thiokol Chemical Corp., Rocket Operations

Society of Automotive Engineers, National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., Sept. 23-27, 1963, Paper 753A. 18 p. 14 refs.
Members, $0.75; nonmembers, $1.00.

Development of an approximate analytical method for the prediction of boil-off losses due to external heating of uninsulated missile tanks containing liquid hydrogen. The analysis is applied to the upper-stage tankage of two typical missile configurations which differ only in the type of propulsion utilized; a solid propellant first stage with 90 sec of action time, and a liquid propellant first stage, burning for 140 sec. It is predicted that during first-stage flight, 15-16% of the liquid hydrogen fuel would be lost due to boil-off. These prohibitive losses could be avoided with a thin layer of light insulation, such as corkboard.

A63-23928
TEMPERATURE DISTRIBUTION DURING BURNING OF AMMONIUM-PERCHLORATE [O PROFILIAKH TEMPERATUR PRI GORENII PERKHLORATA AMMONIIA].
V. K. Bobolev, A. P. Glazkova, A. A. Zenin, and O. I. Leipunskii.
Akademiia Nauk SSSR, Doklady, vol. 151, July 21, 1963, p. 604-607.
In Russian.

Presentation of combustion oscillograms obtained in the stable and unstable regions of ammonium-perchlorate burning. Discussed and presented graphically are: (1) the temperature distributions derived from the stable-combustion oscillograms, including the total heat release, and the heat release in the gaseous and condensed phases, as well as their dependence on pressure; and (2) the dependence of the surface temperature of ammonium-perchlorate combustion on pressure, as determined under various conditions.

A63-24079
THE SPACE HYPERGOLIC BIPROPELLANT INTERNAL COMBUSTION ENGINE.
W. P. Boardman, Jr. (Marquardt Corp., Power Systems Division, Advanced Product Development, Van Nuys, Calif.).
Society of Automotive Engineers, National Powerplant Meeting, Chicago, Ill., Oct. 14-17, 1963, Paper 768A, 10 p.
Members, $0.75; nonmembers, $1.00.

Description of two unconventional types of internal combustion reciprocating engines designed to drive rectified alternators which provide electric power for space missions. The engines use Aerozine 50 as the fuel and nitrogen tetroxide as the oxidizer. These two propellants are commonly used in liquid rockets, and are characterized by the combination of high-energy release and immediate recognition upon contact. The first engine is designed to provide 6 hp using a plunger-type-propellant injection system and an in-head exhaust valve. The second engine provides 4.5 hp using a unique pressure-fed, cam-operated, poppet injector, and cylinder exhaust ports. One of the critical problems in the design of these engines concerns the very short time interval during which the propellants must be injected and burned.

A63-24279
CONCERNING ROCKET FUELS WITH HYPERGOLIC PROPERTIES. I - A METHOD FOR MEASURING IGNITION DELAYS [ÜBER RAKETENTREIBSTOFFE MIT HYPERGOLEN EIGENSCHAFTEN. I - METHODE ZUR MESSUNG VON ZÜNDVERZÜGEN].
Günter Spengler and Albert Lepie.
Zeitschrift für Flugwissenschaften, vol. 11, May 1963, p. 197-203. 12 refs. In German, with summaries in English and French.

Description of an instrument whereby ignition delay in hypergolic fuels can be established rapidly under various conditions. The method is based on the principle of two fluid jets converging freely in a combustion chamber. The principles of this two-jet method are discussed, with emphasis on its basic differences from the droplet-test method. The instrument parameters affecting ignition delay are examined, and these results are used to derive instrument specifications.

A63-24283
CONCERNING ROCKET FUELS WITH HYPERGOLIC PROPERTIES. II - IGNITION DELAY OF LIQUID FUEL COMBINATIONS WITH NITRIC ACID AS OXIDIZER [ÜBER RAKETENTREIBSTOFFE MIT HYPERGOLEN EIGENSCHAFTEN. II - ZÜNDVERZÜGE VON FLÜSSIGEN TREIBSTOFFKOMBINATIONEN MIT SALPETERSÄURE ALS OXYDATOR].
Günter Spengler and Albert Lepie.
Zeitschrift für Flugwissenschaften, vol. 11, June 1963, p. 241-247. 10 refs. In German, with summaries in English and French.

Determination, using the two-jet method, of the ignition delay of several two-component fuels as a function of mixture ratio. The results are used to clarify the catalytic effect of Fe^{+++} ions. Included is a theoretical discussion of the hypergolic ignition process.

A63-24444
STORAGE LIFE OF JP-6 GRADE JET FUELS.
G. D. Kittredge and W. L. Streets (Phillips Petroleum Co., Bartlesville, Okla.).
Society of Automotive Engineers, National Fuels and Lubricants Meeting, Tulsa, Okla., Oct. 30-31, 1963, Paper 773B. 8 p. 12 refs.
Members, $0.75; nonmembers, $1.00.
Contract No. AF 33(616)-7241.

Discussion of the results of an investigation of the problem of JP-6 jet fuel deterioration during ambient storage. Changes in thermal stability are produced under controlled conditions, and their relation to specific types of fuel components and contaminants is studied by chemical analysis, and by tests with synthetic fuel blends. The effects of various additives and gases upon the stability of jet fuels are given, and the analytical work is described.

A63-24569
THE SURFACE TEMPERATURE OF BURNING AMMONIUM PERCHLORATE.
J. Powling and W. A. W. Smith (Explosives Research and Development Establishment, Waltham Abbey, Essex, England).
Combustion and Flame, vol. 7, Sept. 1963, p. 269-275.

Measurement of the surface temperatures of burning ammonium perchlorate-weak fuel mixtures by an IR emission method, over a range of pressures below ambient. It is shown that the condition at the solid/gas interface is one of equilibrium between crystalline ammonium perchlorate and the gaseous products, most probably ammonia and perchloric acid. The heat of dissociation for this process has been derived from the observed variation of surface temperature with pressure. It is suggested that the surface temperature of the ammonium perchlorate in burning composite propellants is only of incidental importance at moderate pressures, and that the gas-phase reactions between the primary products control the rate of consumption of the oxidizer. Temperature profiles for the combustion wave of a weak fuel-ammonium perchlorate mixture have been recorded at several pressures using fine thermocouples. These measurements and the changes brought about by a burning-rate catalyst support the hypothesis that the gas-phase reactions control the burning rate.

A63-25049
PUMPING BOILING LIQUID HYDROGEN WITHOUT CAVITATION.
John F. DiStefano (Borg-Warner Corp., Pesco Products Div., Cleveland, Ohio).
Hydraulics and Pneumatics, vol. 16, Sept. 1963, p. 118-120, 122, 123.

Description of a booster pump which, submerged in liquid hydrogen at -420°F, can deliver boiling hydrogen with enough pressure to avoid cavitation in a downstream pump. Experimental results indicated that a tank-mounted booster pump can provide the necessary net positive suction head to deliver the liquid hydrogen to the inlet of a turbopump in a reactor-powered vehicle. A schematic shows the proposed arrangement of such a system.

A63-25085
THE SOLID PROPELLANT ROCKET INDUSTRY - WHERE DOES THE CHEMICAL ENGINEER FIT IN?
W. P. Killian (Thiokol Chemical Corp., Wasatch Div., Process Engineering Dept., Brigham City, Utah).
Chemical Engineering Progress, vol. 59, Sept. 1963, p. 43-48.

Discussion of composite rocket propellants, and the ways in which they differ from double-base propellants, emphasizing methods of preparation. Considered are rocket-case preparation; oxidizer and fuel-binder preparation; and propellant composition, mixing, casting, curing, and shaping. Material and process research and process development are briefly considered, and the necessity for developing new propellants, liners, insulators, and adhesives, as well as new plastics and metals for rocket-motor cases, is indicated.

A63-25883
GROUND HANDLING SYSTEMS FOR LIQUID HYDROGEN.
J. J. Gilbeau and D. G. Huber (General Dynamics Corp., Astronautics Div., San Diego, Calif.).
Society of Automotive Engineers, National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., Sept. 23-27, 1963, Paper 753C. 5 p.
Members, $0.75; nonmembers, $1.00.

Discussion of the basic design philosophy of the development of ground handling systems for liquid hydrogen. Reviewed are various problems and solutions associated with this development. The design system for handling liquid hydrogen is described in brief. It is shown that handling of LH_2 can be safely accomplished if based on the safety precautions developed in the Centaur program.

1964

A64-10077
CRYOGENIC PROPELLENT SUPPLY FACILITIES.
J. B. Gardner (British Oxygen Co., Ltd., Scientific Div., London, England).
(British Interplanetary Society, Symposium on Ground Support Facilities in Astronautics, Mar. 6, 1963, London, England, Paper.)
British Interplanetary Society, Journal, vol. 19, Sept.-Oct. 1963, p. 230-240; Discussion, p. 240.

Techniques and problems which arise in the large-scale production and handling of cryogenic fluids are discussed. The paper is mainly concerned with propellents (liquid oxygen and hydrogen), but some mention is made of liquid nitrogen and helium and their applications in astronautics.

A64-10078
CHEMISTRY OF SOME INORGANIC NITROGEN FLUORIDES.
A. V. Pankratov.
(Uspekhi Khimii, vol. 32, Mar. 1963, p. 336-353.)
Russian Chemical Reviews, vol. 32, Mar. 1963, p. 157-165.
75 refs. Translation.

The chemical and physical properties of tetrafluorohydrazine, difluoramine, chlorodifluoramine, fluorine azide, trans-difluorodiazine, and cis-difluorodiazine, in the light of the interest in compounds containing the NF_2 group as rocket fuels. An analysis of the structure of the nitrogen trifluoride molecule is given to provide a better understanding of the properties of the nitrogen fluorides.

A64-10250
THERAPY OF ACUTE UDMH INTOXICATION.
Kenneth C. Back, Mildred K. Pinkerton, and Anthony A. Thomas (USAF, Systems Command, Aerospace Medical Div., Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio).
Aerospace Medicine, vol. 34, Nov. 1963, p. 1001-1004. 10 refs.

Investigation of both symptomatic and antidotal treatment of acute intoxication by UDMH (missile fuel, 1,1-dimethylhydrazine), emphasizing the effect of two Vitamin B_6 congeners, pyridoxine and pyridoxamine. Symptomatic treatment consisting of a combination of sedatives, anticonvulsants, cardiac glycosides, potent vasoconstrictors, artificial respiration, and plasma expanders failed to protect animals from lethal doses of UDMH. Vitamin B_6 analog therapy is seen to constitute the first successful approach to specific treatment which prevents convulsions and death in all species tested. The ED_{50}'s (effective doses) of pyridoxine hydrochloride and pyridoxamine dihydrochloride were determined in mice, rats, dogs, and monkeys. The only manifestation which was not abolished by this therapy in dogs and monkeys was vomiting. The data presented are the basis for a suggested emergency treatment of severely exposed personnel, consisting of the injection of 25 mg/kg pyridoxine hydrochloride.

A64-11112
REACTION OF PENTABORANE AND HYDRAZINE AND THE STRUCTURE OF THE ADDUCT.
H. V. Seklemian and R. W. Lawrence (Aerojet-General Corp., Azusa, Calif.).
AIAA Heterogeneous Combustion Conference, Palm Beach, Fla., Dec. 11-13, 1963, Preprint 63-503. 5 p.
Members, $0.50; nonmembers, $1.00.
USAF-supported research.

Brief description of tests on the reaction of pentaborane with hydrazine carried out in very dilute cyclohexane solutions, where the products are an insoluble adduct and hydrogen. It is found by observing the amount of reactants consumed that the adduct formed was of a molar ratio of one mole of pentaborane to two moles of hydrazine. Any hydrazine in greater concentration than this two-to-one-ratio could be separated from the adduct along with the solvent by vacuum evaporation. It was concluded that the adduct composition was that of the two-to-one molar ratio, $B_5H_9 \cdot 2\, N_2H_4$. The kinetics of the reaction and the decomposition of the insoluble adduct are described.

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