NASA SP-7002(04)

HIGH ENERGY PROPELLANTS

A CONTINUING BIBLIOGRAPHY

WITH INDEXES

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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NASA SP-7002(04)

HIGH ENERGY PROPELLANTS

A CONTINUING BIBLIOGRAPHY

WITH INDEXES

A Selection of Annotated References to Unclassified Reports and Journal Articles introduced into the NASA Information System during the period January through December 1967.

Scientific and Technical Information Division
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WASHINGTON, D.C. JUNE 1968

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INTRODUCTION

What *High Energy Propellants* is

This publication is the fourth supplement to the continuing bibliography *High Energy Propellants* (NASA SP-7002). It contains references to reports and journal articles announced in the NASA abstract journals during the period January 1967 through December 1967. 103 references are included.

Previous bibliographies in this series are NASA SP-7002 (January 1962–March 1964), NASA SP-7002(01) (April 1964–December 1964), NASA SP-7002(02) (January 1965–December 1965), and NASA SP-7002(03) (January 1966–December 1966).

Scope of Bibliography

References are included for research and development studies on solid, liquid, and hybrid propellants and oxidizers. References to such related topics as propellant handling and storage, combustion characteristics, toxicity, hazards, and safety measures are also included.

Organization of Bibliography

The bibliography is arranged in Abstracts and Index sections. The Abstracts section contains bibliographic citations and informative abstracts for the references selected from *STAR (Scientific and Technical Aerospace Reports)* and *IAA (International Aerospace Abstracts)*. Each set of abstracts is arranged in ascending accession number order.

The Index Section contains two indexes, subject and personal author, in that order.

How to Use this Bibliography

Reports are referenced in the *STAR* Abstracts section. Published literature items are referenced in the *IAA* Abstracts section. The subject index may be used to locate references to specific topics or technical areas; the personal author index may be used to locate references to reports or articles written by a particular individual.

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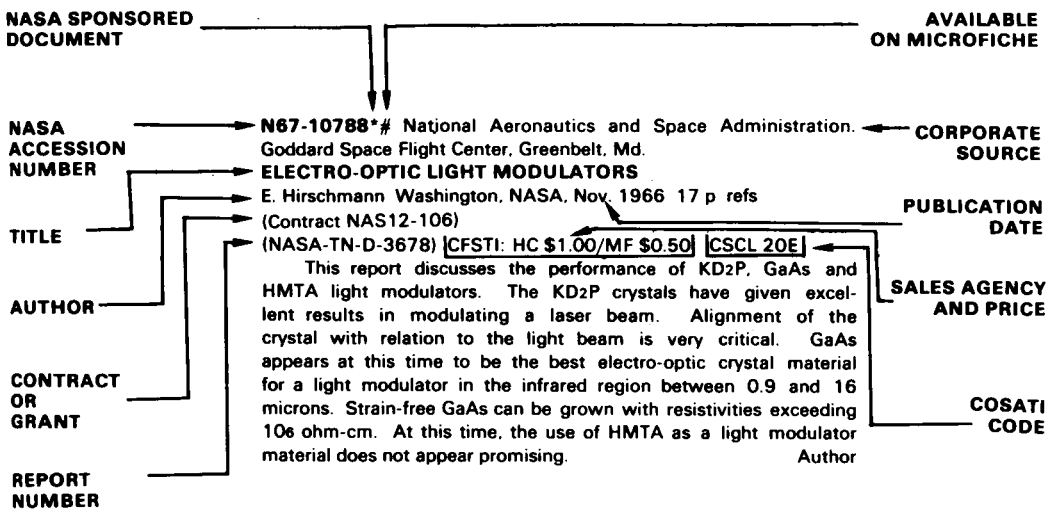

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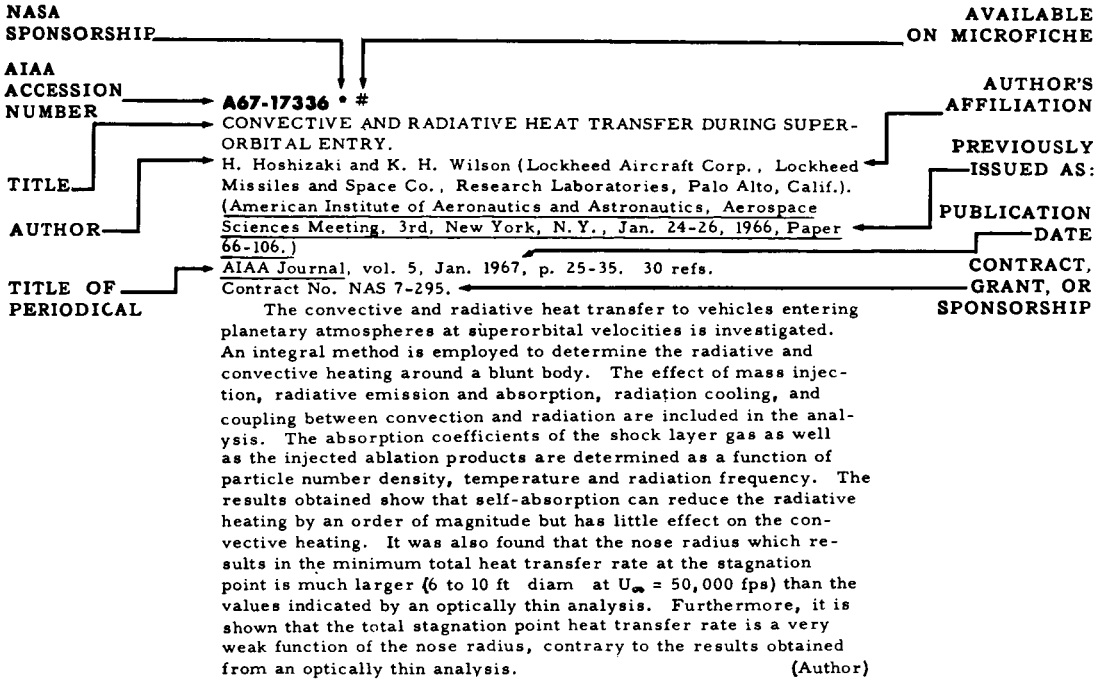

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HIGH ENERGY PROPELLANTS

a continuing bibliography with indexes JUNE 1968

STAR ABSTRACTS

N67-15055# Aeronutronic, Newport Beach, Calif. Applied Research Labs.
THERMODYNAMIC PROPERTIES OF PROPELLANT COMBUSTION PRODUCTS Third Quarterly Letter Report, 1 Jan.–31 Mar. 1966
31 Mar. 1966 9 p refs
(Contract AF 49(638)-1577; ARPA Order 317)
(QLR-66-4; AFOSR-66-1367; AD-640471) CFSTI: HC $1.00/MF $0.50

The objective of the program is to provide thermodynamic data for species which are potentially important combustion products of advanced chemical rockets and for related species. Enthalpy and entropy data are obtained from equilibrium measurements made by torsion-free evaporation and torsion-effusion techniques and by high temperature mass spectrometry. Vapor pressure data for lithium were obtained and, from these measurements the heat of vaporization of lithium was found to be 38.3 plus or minus .4 Kcal/mole. The beam modulation modification for the mass spectrometer was found to operate very well. TAB

N67-15116# Texaco Experiment, Inc., Richmond, Va.
DECOMPOSITION CHEMISTRY OF NF_2 COMPOUNDS Final Report
P. L. Goodfriend and H. P. Woods Aug. 1966 25 p refs
(Contract Nonr-1883(00))
(TP-283; EXP-223; AD-642190) CFSTI: HC $3.00/MF $0.65

Work included: Investigations of the flash photolysis-kinetic spectroscopy of NF3, N2F4=2NF2, HNF2, CINF2, and FNC12; studies of the emission spectra of electrical discharges through NF3 and N3F4=2NF2 and of flames of NF-containing oxidizers; attempts to follow the kinetics of the NF radical by means of flash photolysis-kinetic infrared spectrophotometry. The more significant results of these investigations were: elucidation of the 2600A absorption NF2; a useful apparatus for flash pholysis-kinetic spectroscopy in the vacuum ultra-violet; discovery of a transient absorption spectrum in the flash photolysis of HNF2 and assignment of the carrier as the HNF radical; discovery of an unidentified transient spectrum in the flash photolysis of FNC12; discovery of two bands in the emission spectra of flames of NF containing oxidizers which proved to be bands of the NF radical emission spectrum. Author (TAB)

N67-15731*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
STERILIZABLE LIQUID PROPULSION SYSTEM DEVELOPMENT
T. A. Groudle *In its* Space Programs Sum. No. 37–41, Vol. IV 31 Oct. 1966 p 151–156 CFSTI: HC $3.00/MF $0.65

To evaluate the heat sterilizability of monopropellant-hydrazine for spacecraft application, a propulsion was constructed which included the following components: a heavy spherical stainless steel propellant tank, a squib-actuated, aluminum propellant valve, and a 50-lb_f monopropellant rocket engine with a spontaneous catalyst in the chamber Heat sterilization cycles and instrumentation parameters monitored on the system are listed. The ability of a monopropellant-hydrazine system to undergo heat cycling was demonstrated, and the thrust chamber assembly was found to perform satisfactorily. R.LI.

N67-15989*# TRW Systems, Cocoa Beach, Fla.
SPECIAL PROBLEMS OF LIQUID PROPELLANTS, PART II
G. N. Woodruff *In its* Explosive Safety Executive Lecture Ser. Jun. 1965 5 p CFSTI: HC $3.00/MF $0.65

Toxic hazard limits are defined, the maximum allowable concentration (MAC) that presents no danger to humans is discussed, and emergency tolerance limits (ETL) are included for typical liquid propellants. Presented as time-weighted numbers that establish exposure limits for varying concentrations of vapor based on exposure times, the ETL's are given for nitrogen dioxide, unsymmetrical dimethylhydrazine, and monomethylhydrazine. The MAC figures include additional liquid propellants; and both sets of limits are those which the body can withstand without either temporary or permanent injury. Hazard sources are considered, along with the minimization and control of toxic hazards. Suppression and neutralization methods of controlling hazards are mentioned. The only neutralization method is a chemical reaction, and this differs for each propellant. Vaporization rates from toxic propellant spills can be suppressed by fine water spray, freezing, or application of foam. M.W.R.

N67-16435# Atlantic Research Corp., Alexandria, Va. Kinetics and Combustion Group.
RESEARCH ON THE DEFLAGRATION OF HIGH-ENERGY SOLID OXIDIZERS Quarterly Technical Summary Report, 1 Jun.–31 Aug. 1966
G. von Elbe, J. B. Levy, R. Friedman, and E. T. McHale 30 Sep. 1966 27 p refs
(Contract AF 49(638)-1645)
(Rept.-3; AFOSR-66-2649; AD-642420) CFSTI: HC $3.00/MF $0.65

The chemistry and kinetics of reactions involving various oxides of chlorine were studied using the data obtained in the present investigation in conjunction with data reported in the

literature. Additional experiments on the interaction of Cl2O3 with ClO2 were performed in order to obtain more complete information on the effect of kinetic variables. The decomposition of ClO2 is represented by the following reaction mechanism: 2ClO2 (on wall) to ClO + ClO3; ClO2 + Clo to Cl2O3; Cl2O3 + ClO to ClO2 + 2Cl + O2; Cl + ClO2 to 2ClO; Cl + ClO2 to Cl2 + O2; Cl (on wall) to 1/2 Cl2. It is shown that the observed characteristics of the explosive decomposition of ClO2 are fully consistent with the reaction-kinetic equations developed on the basis of this scheme. Author (TAB)

N67-16559*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
STORAGE TESTS OF NITROGEN TETROXIDE AND HYDRAZINE IN ALUMINUM CONTAINERS
L. P. Hollywood, T. R. Metz, and R. N. Porter 15 Jan. 1967 27 p refs
(Contract NAS7-100)
(NASA-CR-81294; JPL-TR-32-1039) CFSTI: HC $3.00/MF $0.65 CSCL 21I

Small canisters of Types 2014 and 6061 aluminum alloy were subjected to short-term compatibility tests with nitrogen tetroxide and hydrazine to determine the effect of different cleaning procedures. Only minor differences were noted. A flight-weight propellant tank of Type 2014 aluminum alloy was used to store hydrazine for 46 months. At the end of that test, the tank was found to be only slightly corroded. Firing tests showed the stored fuel delivered slightly less performance; but it ignited and burned as smoothly with nitrogen tetroxide as stock hydrazine burned with nitrogen tetroxide. Author

N67-18000* IIT Research Inst., Chicago, Ill. Technology Center.
DEVELOPMENT OF A FLEXIBLE MATERIAL RESISTANT TO NITROGEN TETROXIDE AND HYDRAZINE Interim Technical Report, May 16–Nov. 30, 1966
T. H. Metzer and T. Yamauchi 22 Dec. 1966 105 p refs
(Contracts NAS7-100; JPL-951483)
(NASA-CR-81645; IITRI-U6046-6) CFSTI: HC $3.00/MF $0.65 CSLC 11I

Progress is reported on a research project to synthesize novel fluorinated polymer systems to be used in preparing elastomeric bladders suitable for the containment of nitrogen tetroxide and hydrazine fuels. Efforts during this period were directed toward the preparation of polyperfluoroglutaric anhydride, octafluorofuran, perfluoro aromatic systems, and tetrafluorodithietane. R.N.A.

N67-18326*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
LIQUID PROPULSION SYSTEMS
L. R. Toth, R. S. Weiner, O. F. Keller, and H. B. Stanford *In its* Space Programs Sum. No. 37–42, Vol. IV 31 Dec. 1966 p 80–88 refs CFSTI: HC $3.00/MF $0.65

Recent accomplishments in the development of bladder and expulsion devices for spacecraft liquid propulsion systems are described. These include a new test fixture for studying fluid leaks from metal foil pinholes, permeation leakages through plastics and elastomers, and ethylene–propylene elastomeric diaphragm-type bladder with hydrazine; and the recycling and fabrication of convoluted diaphragms from stainless steel and titanium. R.N.A.

N67-18688*# General Dynamics/Convair, San Diego, Calif.
FABRICATION PROCESS DEVELOPMENTS OF A STRUCTURAL MODEL FOR RESEARCH ON HYDROGEN-FUELED HYPERSONIC VEHICLES
John C. Hopkins Feb. 1967 87 p refs
(Contract NAS1-4017)
(NASA-CR-66198) CFSTI: HC $3.00/MF $0.65 CSCL 22B

A structural model was fabricated which was designed to test a new structure and insulation concept and establish that it was practical to manufacture as part of a research study on hydrogen-fueled hypersonic vehicles. The model represents a fuselage section of a hydrogen-fueled vehicle. It has a welded outer structure of annealed René 41. This primary structure is made of sheet metal skins, Zee stringers, and frames fastened together with resistance and fusion spotwelds. Machined ring forgings are fusion seam welded to the forward and aft ends of the structure. A liquid hydrogen tank is suspended within the primary structure by means of draw formed Inconel 718 bellows which permit expansion and contraction. The tank was made of 2219 aluminum machined and formed panels, explosive formed dome ends and access door. The tank components are joined by fusion welding. An access door bolts to the tank, and a plastic seal prevents leakage. Author

N67-19122* Rocket Research Corp., Seattle, Wash.
DEVELOPMENT OF DESIGN AND SCALING CRITERIA FOR MONOPROPELLANT HYDRAZINE REACTORS EMPLOYING SHELL 405 SPONTANEOUS CATALYST, VOLUME I Final Report
19 Jan. 1967 166 p
(Contract NAS7-372)
(NASA-CR-82457; RRC-66-R-76, Vol. I) CFSTI: HC $3.00 CSCL 21H

The test plan, engine design employed, and test data obtained are presented from a study to develop the empirical scaling formulae necessary for the design of monopropellant hydrazine reactors over a thrust range of 0.5 to 100 lbf. Design and scaling criteria developed are applicable to the design of either rocket engines or gas generators. The development of flightweight 5 lbf engine operating under pulsed and throttled modes of operation and with hydrazine mixtures which have low freezing points is also reported. Included are results from injector optimization tests, catalyst bed design parameter studies, and catalyst degradation measurements. It is noted that the showerhead injector is superior to the rigimesh injector on the basis of smoother operation, and that chamber pressure oscillations encountered during engine testing could be reduced through the use of a layer of fine mesh catalyst on the top of the catalyst bed. A.G.O.

N67-19123*# Rocket Research Corp., Seattle, Wash.
DEVELOPMENT OF DESIGN AND SCALING CRITERIA FOR MONOPROPELLANT HYDRAZINE REACTORS EMPLOYING SHELL 405 SPANTANEOUS CATALYST, VOLUME II Final Report
18 Jan. 1967 99 p refs
(Contract NAS7-372)
(NASA-CR-82456; RRC-66-R-76, Vol. II) CFSTI: HC $3.00/MF $0.65 CSCL 21H

A design manual for monopropellant hydrazine rocket engines and gas generators employing a spontaneous catalyst is represented. The development of theoretical models of reaction chamber operation is covered, and the correlation analysis conducted to develop design and scaling criteria is summarized. Design formulae are presented to define catalyst bed configuration, ammonia dissociation, catalyst bed pressure drop, and chamber pressure response time as a function of reaction chamber design parameters. Design parameters studied include chamber pressure from 50 to 1000 psia, bed loading from 0.01 to 0.045 lbm/in^2-sec, catalyst bed length from that required for satisfactory (smooth) operation to a value which resulted in approximately 85% ammonia

dissociation, and catalyst particle sizes from 1/8"×1/8" cylindrical pellets to 25–30 mesh size granules. An empirical formula which defines the required catalyst bed configuration for smooth, stable, steady state operation as a function of chamber pressure, bed loading, and catalyst particle size is also considered. A.G.O.

N67-19162# Deutsche Versuchsanstalt fur Luft- und Raumfahrt, Stuttgart (West Germany). Institut fuer Raketentreibstoffe.
HYDRAZINENITRATE-HYDRAZINE AS A MONERGOLIC PROPELLANT, PART I [DAS SYSTEM HYDRAZINNITRAT-HYDRAZIN ALS MONERGOLER TREISBTOFF, TEIL I]
Fritz Bachmaier and Jose Jimenez-Barbera Nov. 1966 28 p refs In GERMAN; ENGLISH summary
(DVL-568; DLR-FB-66-76) CFSTI: HC $3.00/MF $0.65

Theoretical performance calculations show that the specific impulse of the hydrazine monergol may be considerably increased by adding hydrazine-nitrate. Therefore, the data pertinent to rocketery were investigated for solutions of hydrazine-nitrate in hydrazine. The results from these investigations as well as the sensitivity concerning shock and friction of such solutions, are reported. The results obtained indicate the densities and viscosities to behave like ordinary binary systems. With a content of 55 weight % of hydrazine-nitrate, surface tensions show a peak, whereas an eutectic results from thermal analysis at a hydrazine-nitrate-hydrazine ratio of 48 to 52 weight %. Sensitivities concerning shock and friction lie beneath those of tetryl, picric acid and TNT, i. e. explosives known to be largely insensitive. Further investigations will soon be published in a sequel report. Author

N67-19913*# Pratt and Whitney Aircraft, West Palm Beach, Fla.
IGNITION OF HYDROGEN-FLUORINATED OXIDIZERS Final Report, 30 Jun.–30 Nov. 1966
William J. McAnally, III 15 Mar. 1967 32 p refs
(Contract NAS3-7964)
(NASA-CR-72153; PWA-FR-2222) CFSTI: HC $3.00/MF $0.65 CSCL 21B

Experimental definition of the limits of hypergolicity of fluorine-oxygen mixtures with hydrogen under liquid rocket operating conditions, was accomplished by conducting five series of ignition tests. For each series, a different percentage of fluorine in the flox mixture was used, and tests were conducted at mixture ratios of approximately 1, 5 and 8. High-frequency response instrumentation was used to sense ignition of cold gaseous hydrogen with pure fluorine and flox mixtures containing 53.4, 50.2, 46.5 and 39.5% fluorine under altitude conditions in a small-scale rocket engine which was liquid nitrogen cooled. Rapid ignition with minimum variation in delay times was demonstrated with pure fluorine. No ignition was recorded for the tests conducted with 39.5% fluorine in flox, whereas in the tests conducted with concentrations of 46.5, 50.2 and 53.4% fluorine in flox, ignition and/or sustained combustion was not obtained under all conditions. These results indicate that for practical design purposes the flox concentration necessary for consistent ignition is sufficiently high to require that vehicle and engine systems using the mixture must be compatible with pure fluorine. Author

N67-20006# City of Hope Medical Center, Duarte, Calif.
FURTHER TOXICOLOGIC STUDIES OF ACUTE HYDRAZINE TOXICITY IN MICE, 1 JULY 1965–31 MARCH 1966
Eugene Roberts and Daisy G. Simonsen Brooks AFB, Tex., USAF School of Aerospace Medicine, Oct. 1966 18 p refs
(Contract AF 41(609)-2949)
(SAM-TR-66-89; AD-644027) CFSTI: HC $3.00/MF $0.65

Toxicologic studies of acute hydrazine toxicity in mice were continued. The results indicate that acute toxicity of hydrazine probably is not mediated through a histamine-release mechanism. Various experiments showed that the type of lethal seizure produced by hydrazine probably has no relationship to the sound-induced seizures in susceptible strains of mice. It was found that sodium phenobarbital had a marked protective effect against hydrazine toxicity when given in subhypnotic amounts. Sodium phenobarbital had an additive protective effect when it was administered together with the previously studied protective mixture (AGKO) containing arginine, glutamate, alpha-ketoglutarate, and oxalacetate. NaBr also was found to be protective and was found to act additively with either sodium phenobarbital or with the AGKO mixture. It was found in the course of the above experiments that imidazoleacetic acid, a substance not protecting mice against acute hydrazine toxicity, had interesting analgesic and hypnotic effects in mice. The quantitative aspects of these effects were worked out, and it is suggested that this agent should be explored further as a possibility for human use. Author (TAB)

N67-21219*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
AN ANALYSIS OF THE PERFORMANCE AND SPACE STORAGE CHARACTERISTICS OF SMALL PROPANE-FLOX UPPER STAGES
Harold H. Valentine, David A. Turner, and Jon C. Oglebay 1967 33 p refs
(NASA-TM-X-52280) CFSTI: HC $3.00/MF $0.65 CSCL 22D

The use of hydrogen in rocket stages poses a significant insulation problem for missions involving space storage times greater than a few hours. There is a great lack of information regarding both the distribution of incoming heat in a hydrogen tank in zero g and the weight penalties associated with zero g propellant venting devices for low coast missions. The purpose of this study was to examine one such combination propane-flox, for use in a multipurpose upper stage in order to determine its space storage characteristics and payload capability, and compare its performance capability with that of other propellant combinations. The results indicate that it is possible to design a propane-flox stage having a long space storage (no vent) capability. The performance of such a stage, however, is inferior to hydrogen fueled stages for high energy, short coast missions. For long coast low energy missions, specifically the Mars orbiter mission, the propane-flox stage displayed only a small performance advantage over an earth storable stage. Author

N67-21718# California Univ., Berkeley. Thermal Systems Div.
OXIDES OF NITROGEN IN ENGINE EXHAUST WITH AMMONIA FUEL
R. Sutton and E. S. Starkman Jun. 1966 27 p refs
(Contract DA-04-200-AMC-791(X))
(TS-66-4; TR-7; AD-640444) CFSTI: HC $3.00/MF $0.65

At maximum output, more oxides of nitrogen are produced by combustion of ammonia than with hydrocarbon fuels. This is partly a result of peak power occurring at low mixtures with ammonia. Disproportionate quantities of nitrogen oxides which are encountered with ammonia at lean mixture ratios indicate a probable result of the direct production of NO in the ammonia pyrolysis scheme. Author (TAB)

N67-22492# Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon (France)
CHEMICAL PROBLEMS INHERENT TO USE OF PROPELLANTS ON THE SECOND STAGE OF LAUNCH VEHICLE EUROPA [PROBLEMES CHIMIQUES POSES PAR L'EMPLOI DES ERGOLS DU DEUXIEME ETAGE DE L'ENGIN EUROPA I]
M. Lemaitre *In* ELDO Tech. Rev., Vol. I, No. 3 1966 p 155–172 refs In FRENCH; ENGLISH summary
CFSTI: HC $3.00/MF $0.65

After a short account of the synthesis and of the principal properties of the propellants, nitrogen peroxide and unsymmetrical dimethyl hydrazine, a number of chemical problems concerning specification and use (safety precautions and emergency measures) are described. Author (ESRO)

N67-22859*# Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.

SUPERSONIC MIXING OF HYDROGEN AND AIR

John H. Morgenthaler Washington, NASA, Apr. 1967 84 p refs

(Contract NOw-62-0604-c)

(NASA-CR-747) CFSTI: HC$3.00/MF$0.65 CSCL 21B

The effects of fuel injection parameters on the mixing of gaseous hydrogen with a supersonic air stream confined within a cylindrical duct was quantitatively studied to provide background information necessary for the design of combustors for supersonic combustion ramjets. Hydrogen was injected at sonic velocity into Mach 2 and Mach 3 air streams in a 1-inch diameter duct at overall fuel-air equivalence ratios (ER) of 0.17 to 0.50, in both radial (transverse) and axial (downstream) directions from circumferential wall slots. The hydrogen and air supplies were at ambient temperature; air pressure was adjusted to give test section pressures slightly greater than 1 atm. Radial injection gave considerably better penetration and mixing than axial injection at the expense of a greater loss in stagnation pressure. Author

N67-23126# Rocket Propulsion Establishment, Westcott (England).

PERCHLORIC ACID FLAMES. PART V: ETHYLENE-RICH FLAMES

G. S. Pearson Mar. 1966 33 p refs

(RPE-TR-66/1, Pt. V; AD-645817) CFSTI: HC $3.00/MF $0.65

Burning velocities, temperatures and burnt gas compositions were measured for ethylene-perchloric acid premixed flames containing from 2 to 24 times as much ethylene as is required for a stoichiometric mixture. Soot formation is observed for a limited range of mixture ratios. When the amount of ethylene exceeds three moles per mole of acid, the excess ethylene does not react but functions as a diluent. The results are compared with those for methane-rich flames and a mechanism is proposed. Author (TAB)

N67-23315*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

LIQUEFIED NATURAL GAS AS A FUEL FOR SUPERSONIC AIRCRAFT

Richard J. Weber Washington, NASA, 1967 13 p refs Presented at the Am. Gas Assoc. Distribution Conf., St. Louis, 1–4 May 1967

(NASA-TM-X-52282) CFSTI: HC$3.00/MF$0.65 CSCL 21D

Current jet airplanes utilize kerosene or gasoline-type fuels. Liquid methane, however, is superior in terms of heating value, cooling capacity, and possibly cost. When it is applied to the difficult supersonic transport mission, payload capacity is estimated to increase by 30 percent, with a similar reduction in direct operating cost. Many problems must be solved before the concept can be considered to be feasible. If it is actually adopted, the airlines would consume up to six trillion cubic feet of natural gas per year. Author

N67-23985 Weapons Research Establishment, Salisbury (Australia).

THE PROPERTIES AND SPECIFICATION TESTING OF UNSYMMETRICAL-DIMETHYL HYDRAZINE

N. V. Ayres and L. A. Pearson Dec. 1965 26 p refs

(WRE-TN-CPD-107) CFSTI: $3.00

This note summarises the chemical and physical properties of unsymmetrical dimethyl hydrazine (U.D.M.H.) and discusses the methods to be used in testing U.D.M.H. to ensure conformity to the relevant American and French Specifications for rocket fuels. Laboratory sampling techniques have been developed to ensure that U.D.M.H. is not contaminated by the atmosphere during testing. The test methods are modified, where necessary, to conform to standard laboratory practice and to use equipment conforming to British Standards for fuel testing equipment. The properties of a pure sample of U.D.M.H. have been determined by these methods and the results obtained were consistent with the specified properties. The results obtained show that there should be no difficulty in testing U.D.M.H. to specifications. Author

N67-25331# Aerospace Medical Div. Aeromedical Research Lab. (6571st), Holloman AFB, N. Mex.

THE EFFECT OF MONOMETHYLHYDRAZINE WITH AND WITHOUT PYRIDOXINE ON OPERANT BEHAVIOR OF PRIMATES

Thomas L. Wolfle, Glayde D. Whitney, and Paul Y. Batson Feb. 1967 33 p refs

(ARL-TR-67-6; AD-648547) CFSTI: HC$3.00/MF$0.65

Ten macaque monkeys were trained on a complex behavioral program containing both aversively and appetitively rewarded tasks. A two-phase experimental design was utilized. During Phase I all subjects were repeatedly exposed at one of two dose levels of monomethylhydrazine and pyridoxine HCl. The monomethylhydrazine (i.p.) and pyridoxine HCl (i.m.) injections were administered simultaneously. Phase II was a replication without pyridoxine HCl. Data included behavior on a Sidman avoidance schedule, FR(100:1) and three-stimulus oddity for food, as well as discrete avoidance with both visual and auditory cues. Gross clinical signs were noted. Dose-response and temporal relationships were investigated. Appetitive responding was found to be most sensitive and the differences between Phase I and Phase II provide some evidence that pyridoxine HCl may be effective as a therapeutic agent in situations involving exposure to low levels of monomethylhydrazine. Author (TAB)

N67-25845*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

HIGH-ENERGY FUELS FOR SUPERSONIC TRANSPORT RESERVES

Joseph D. Eisenberg Washington, NASA, May 1967 36 p refs

(NASA-TN-D-3987) CFSTI: HC$3.00/MF$0.65 CSCL 21D

The reserve fuel requirements of the supersonic transports are expected to be about 10 percent of the gross weight of the aircraft, an amount approximately equal to that of the payload consisting of both passengers and baggage. This analysis shows that the reduction in the reserve fuel resulting from the use of high-energy fuels leads to significant increases in payload and reductions in direct operating costs. The results are presented as a function of the fraction of main-fuel reserve energy replaced by high-energy fuels. The sensitivity of the results to fuel-system weight is shown, and the direct operating costs are given for a spectrum of fuel prices. For aircraft designed to use the high-energy reserves on the design range mission, the gains made with liquid-hydrogen reserves in the basic JP aircraft are the most interesting. The calculated direct operating cost improvement is nearly 10 percent and, associated with it, is a gain in passengers of over 15 percent when compared with the all-JP-fueled aircraft. If ranges in excess of the aircraft design range are required, the decrease in number of passengers and the increase in direct operating cost that results may be reduced by the use of ethyldecaborane in the JP supersonic transport. However, this possible gain does not include any adverse effects on engine performance due to boric oxide deposits. Author

N67-25999* General Applied Science Labs., Inc., Westbury, N.Y.
DIFFUSION CONTROLLED COMBUSTION FOR SCRAMJET APPLICATION. PART I: ANALYSIS AND RESULTS OF CALCULATIONS
R. Edelman Dec. 1965 115 p refs Prepared for Marquardt Corp., Van Nuys, Calif.
(Contract NAS1-5117)
(NASA-CR-66363; TR-569) CFSTI: $3.00 CSCL 21B

A description of the analysis, the method of solution and the results of calculations for diffusion controlled, equilibrium combustion of hydrogen are presented. Calculations include two-dimensional and axisymmetric turbulent flows with constant and variable axial pressure distributions. The investigation was conducted for ramjet combustion chamber inlet conditions which includes the flight Mach number regime of 3 to 8 and the altitude range from 50,000 to 120,000 feet. The results are presented in terms of flow deflections, combustion lengths and detailed property profiles in the mixing and combustion region. Flow deflections in the vicinity of the fuel injection points from 9° to 30°, and combustion lengths from 15 to 40 fuel jet diameters are indicated. Flow reversal, shockless subsonic burning and pressure interaction due to flow deflection, are predicted and an example of a multiple injection system is presented. Author

N67-26221# San Francisco Univ., Calif. Inst. of Chemical Biology.
EFFECT OF HYDRAZINES ON VITAMIN B6 LEVELS IN THE MOUSE BRAIN Final Report, Mar. 1965–Feb. 1966
Arthur Furst and Waldemar R. Gustavson Wright-Patterson AFB, Ohio, AMRL, Sep. 1966 46 p refs
(Contract AF 33(615)-2332)
(AF-IF; AMRL-TR-66-135; AD-647192) CFSTI: HC $3.00/MF $0.65

The effects of administered 1,1-dimethylhydrazine (UDMH) and monomethylhydrazine (MMH) on vitamin B6 levels in mouse brain have been studied. Separation of the B6 group (pyridoxol, pyridoxal, pyridoxamine, and the respective 5-phosphates) by means of paper chromatography revealed that the R sub F values obtained are dependent upon the pH of the developing solvent. To obtain the time lag just prior to convulsions induced by UDMH and MMH, a dose-lag time study was conducted; included were pyridoxal and (its 5-phosphate) hydrazones of UDMH and MMH. Graphs of log dose vs lag time are given. The bioassay procedure, though not completed, permits detection of some of the B6 congeners to a limit of 0.5 nanograms. Author (TAB)

N67-27224*# National Aeronautics and Space Administration, Washington, D. C.
HIGH ENERGY PROPELLANTS—A CONTINUING BIBLIOGRAPHY WITH INDEXES
Apr. 1967 146 p refs
(NASA-SP-7002(03)) CFSTI: HC $3.00/MF $0.65 CSCL 21H

Presented is a selection of annotated references to unclassified reports and journal articles announced in *Scientific and Technical Aerospace Reports (STAR), International Aerospace Abstracts (IAA),* and *Aerospace Medicine and Biology* (NASA SP-7011). Emphasis is given to references which are concerned with research and development studies on solid, liquid, and hybrid propellants and oxidizers, but the bibliography also provides extensive coverage of propellant handling and storage, combustion characteristics, toxicity, hazards, and safety measures. Each entry in the bibliography consists of a citation and an abstract. All reports and articles cited were introduced into the NASA Information System during the period January through December, 1966. A subject index and a personal author index are included. Author

N67-27254 Deutsche Versuchsanstalt fur Luft- und Raumfahrt, Stuttgart (West Germany). Institut fuer Raketentreibstoffe.
RESEARCHES ABOUT THE SYSTEM HYDRAZINE–AMMONIA [UNTERSUCHUNGEN AM SYSTEM HYDRAZIN–AMMONIAK]
Fritz Bachmaier and Jose Jiminez-Barbera Mar. 1967 27 p refs In GERMAN; ENGLISH summary
(DLR-FB-67-21; DVL-616)

Some qualities of hydrazine ammonia mixtures are investigated with regard to their use as rocket fuels. By means of conventional measuring methods being adapted to the problems of these systems, vapor pressures, densities and viscosities of such mixtures are determined as functions of compositions. The findings of these studies show vapor pressure and density deviations from ideal behavior which are a disadvantage, but should not rule out using this system as fuel for rocket engines. Author

N67-29154*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
LIQUID PROPULSION
In its Space Programs Sum. No. 37–44, Vol. IV 30 Apr. 1967 p 171–191 refs

Developments in the areas of gas supply system, impinging sheet injectors, and components in liquid propellant systems are reported. Problems relating to large numbers of pulses and filter contamination in the reaction control system are discussed, and it was concluded that the feasibility of hydrazine plenum warm gas attitude control system was demonstrated. Recent advances in material compatibility with hydrazine and hydrazine/hydrazine nitrate mix propellants, and in heat sterilization of ethylene–propylene elastomeric material with hydrazine and hydrazine stability are described. Details are given on the experiments on a 100-lb impinging sheet injector element with variable spacing between the deflectors and using N_2O_4/N_2H_4 propellants to investigate the degradation in efficiency of the larger injector compared with a 25-lb injector. N.E.N.

N67-30037*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
METHANE-FUELED PROPULSION SYSTEMS
Richard J. Weber, James F. Dugan, Jr., and Roger W. Luidens Washington, NASA, 1966 36 p refs Presented at the 2d Joint Propulsion Specialist Conf., Colorado Springs, 13–17 Jun. 1966 Sponsored by AIAA
(NASA-TM-X-52199) CSCL 21D

Liquid methane fuel is superior to JP or kerosene in terms of heating value, cooling capacity, and (possibly) in cost and availability. When it is applied to the difficult commercial supersonic transport mission, it is estimated that the payload capacity can be increased by about 30 percent and the direct operating cost reduced a like amount. Because methane is a good thermodynamic working fluid, there exists the possibility of making further gains in aircraft performance by employing special engine cycles. The cryogenic nature of liquid methane poses unusual problems in handling, storage, and engine and airframe design. However, the magnitude of the potential gains warrants further analysis and experimental work to substantiate the merits of the concept. Author

N67-31330*# Lockheed Missiles and Space Co., Sunnyvale, Calif.
A STUDY OF HYDROGEN SLUSH AND/OR HYDROGEN GEL UTILIZATION. VOLUME II: SYSTEMS OPTIMIZATION AND VEHICLE APPLICATION STUDIES Final Report
11 Mar. 1967 236 p refs
(Contract NAS8-20342)
(NASA-CR-85822; K-11-67-1) CFSTI: HC $3.00/MF $0.65 CSCL 21I

The study of hydrogen slush and/or hydrogen gel utilization constitutes the first formal investigation of subcooled liquid and slush hydrogen fuels for space vehicle applications. Results of this study program are reported. Complete property data from the triple-point to the critical point are included. All the details of the technical effort are presented, including parametric analysis of effects on vehicle systems and application of sub-cooled hydrogen to three study vehicles. Author

N67-31455*# General Applied Science Labs., Inc., Westbury, N. Y.
COMPUTER PROGRAMS FOR THE MIXING AND COMBUSTION OF HYDROGEN IN AIR STREAMS
D. Siegelman and O. Fortune Jul. 1966 89 p refs
(Contract NAS8-20066)
(NASA-CR-85823; GASL-TR-618) CSCL 21B

Details are presented on programs developed to aid those interested in combustion chamber design, cryogenic hydrogen venting, and exhaust plumes. Programs, discussions of specific features, and input-output formats are presented for: (1) a finite difference method solution of the free jet problem for plane two-dimensional and axisymmetric configurations, (2) a finite difference method solution for laminar axisymmetric two phase free mixing with hydrogen—air chemistry, (3) a finite difference method solution for the finite rate evaporation of cryogenic hydrogen in two-phase air, (4) a finite difference method solution for two-dimensional turbulent compressible boundary layers in the absence of pressure gradients, and (5) an approximate method of solution for the combustion of a uniform axisymmetric jet of pure gaseous hydrogen mixing with a partial, a parallel air stream. N.E.N.

N67-31532*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EXPERIMENTAL BEHAVIOR OF COMBUSTION PRODUCTS OF HEF-2 AND AIR DURING EXPANSION IN EXHAUST NOZZLES
J. R. Branstetter, W. B. Kaufman, and A. L. Smith Washington, NASA, Dec. 1960 61 p refs
(NASA-TM-X-381) CSCL 21B (Declassified)

The performance of HEF-2 (largely propylpentaborane) combustion products was investigated in exhaust nozzles with 4- and 12-inch/diameter throats. Specific-fuel-consumption data agreed well with ideal values (assuming B_2O_3 as the only boron combustion product) when the B_2O_3 was either completely liquid or completely vapor. In the two-phase region (3200° to 3500°R) the fuel consumption was 11 percent to 20 percent higher than the ideal. However, when the vaporized combustion product was assumed to be HBO_2 rather than B_2O_3, the ideal values for a frozen-expansion process agreed very well with the test data. No effect of combustor or nozzle size on performance was observed. Author

N67-31544*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ALTITUDE PERFORMANCE OF A FULL-SCALE HIGH-TEMPERATURE TURBOJET ENGINE USING PENTABORANE FUEL AND HEF-2
Joseph N. Sivo and John P. Wanhainen Washington, NASA, Jan. 1959 41 p refs
(NASA-MEMO-12-31-58E) CFSTI: HC $3.00/MF $0.65 CSCL 21E (Declassified)

A full-scale high-temperature turbojet engine was run on both pentaborane and HEF-2 at a simulated altitude of 50,000 feet at a flight Mach number of 0.8. As a result of the high-temperature operation, the boric oxide deposits that occurred were within acceptable limits. The specific fuel consumption was improved 22 percent with pentaborane fuel and 10 percent with HEF-2 as compared with hydrocarbon fuel. Author

N67-31731*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EXPERIMENTAL INVESTIGATION OF BASE HEATING AND ROCKET HINGE MOMENTS FOR A SIMULATED MISSILE THROUGH A MACH NUMBER RANGE OF 0.8 TO 2.0
Bruce G. Chiccine, Alfred S. Yalerino, and Arthur M. Shinn Washington, NASA, Oct. 1959 29 p refs
(NASA-TM-X-82) CFSTI: HC $3.00/MF $0.65 CSCL 16D (Declassified)

The effects of jet and stream interactions were investigated with a 1/13-scale ballistic missile using a liquid oxygen–JP-4 fuel rocket. Nozzle extension ratios were studied at angles of attack of 0° and 5° with 0° and 4° motor gimbal angles and several combustion chamber pressures over the Mach number range. Base region temperatures were reduced from as high as 1200°F to tunnel stagnation values by increasing the rocket extension from 0.32 to 0.78 body diameter. Aerodynamic hinge moments were generally found to decrease with decreasing nozzle extension, flight Mach number, and increasing jet pressure ratio. Author

N67-32112*# Aerojet-General Corp., Downey, Calif. Research Div.
EVALUATION OF THE BLAST PARAMETERS AND FIREBALL CHARACTERISTICS OF LIQUID OXYGEN/LIQUID HYDROGEN PROPELLANT Final Report
R. E. Pesante and M. Nishibayashi 7 Apr. 1967 138 p refs
(Contract NAS9-4355)
(NASA-CR-65651; Rept.-0954-01(01)FP) CSCL 21B

The basic parameters of liquid oxygen/liquid hydrogen propellant are examined, the blast characteristics are compared with LOX/RP-1 and nitrogen tetroxide/Aerozine-50 propellant systems. Specific characteristics considered in evaluating the propellant systems were peak overpressure, shock wave velocity, positive pressure impulse and duration, fragment velocity, thermal radiation and temperature, initial fireball growth rate, and fireball size and duration. Cryogenic and hypergolic propellants were tested to evaluate the explosive and thermal characteristics. The overpressure tests indicated that the explosive yield of LOX/LH_2 increased as the distance from the event increased. Analysis of test films revealed that most of the fireball's growth occurred during the first 20 msec after propellant initiation. Examination of the initial fireball growth rate data from test to test indicated a similarity of growth rates for the LOX/LH_2 propellant. The maximum fireball diameters varied from 64 to 91 ft and the maximum height ranged from 38.5 to 73 ft. S.P.

N67-32461# Aerospace Medical Div. Aerospace Medical Research Labs. (6570th), Wright-Patterson AFB, Ohio.
TOXICOLOGY AND PATHOLOGY OF REPEATED DOSES OF MONOMETHYLHYDRAZINE IN MONKEYS Final Report, Apr.–Jul. 1964
Kenneth C. Back and Mildred K. Pinkerton Feb. 1967 20 p refs
(AMRL-TR-66-199; AD-652846) CFSTI: HC $3.00/MF $0.65

The effects of daily repeated doses of monomethylhydrazine (MMH) were studied in monkeys. Groups of monkeys were given from 2.5 to 5 mg/kg MMH i.p. for a total of 23 doses. Other monkeys were given from 7 to 10 mg/kg MMH i.p. for up to 4 days. Baseline and weekly clinical laboratory measurements studied were complete blood count, serum glucose, alkaline phosphatase, and glutamic oxaloacetic transaminase. At the end of the exposures, necropsies were performed on all animals. Special studies included fat stains of fresh cryostat sections of heart, liver, and luxol fast blue stains of pons, cerebellum, basal ganglia, and insular cortex. Results of the experiments have delineated the limits of toxicity for MMH in primates, as evaluated by clinical chemistry, symptomatology, and pathological examination. Repeated doses of 5 mg/kg cause emesis and some convulsions when a total of 15 mg/kg was reached. Animals tolerated daily doses of 2.5 mg/kg for a total of 23 injections with no significant effects. Other animals tolerated 12 doses of 5 mg/kg per day after having received 5 mg/kg each day for 3 days and 2.5 mg/kg for 8 days or 95 mg/kg for a 4-week period. This experiment tends to negate a tolerance phenomenon. The most significant conclusions from the experiments are the relative lack of pathological (either anatomical or clinical) alterations seen in the acute intoxications and the extremely narrow limits between a no-effect and lethal dose level. Of extreme interest is the absence of kidney malfunction or renal

pathology in these studies as contrasted by results seen in dogs at these dose levels. MMH causes marked renal damage in dogs. Author (TAB)

N67-32644# School of Aerospace Medicine, Brooks AFB, Tex.
TOXICITY OF MONOMETHYLHYDRAZINE ON THE FROG CORNEA Progress Report 15 Apr.–15 Sep. 1966
Walter N. Scott Mar. 1967 14 p refs
(SAM-TR-67-22; AD-652204) CFSTI: HC $3.00/MF $0.65

The effect of monomethylhydrazine (MMH) on the in vitro frog cornea was studied. Parameters examined were corneal transparency, membrane potential difference (P.D.), and chloride transport as evidenced by the short-circuit current. MMH caused a diminution in the transparency, a decrease in the short-circuit current, and a fall in the tissue P.D. These effects were slightly ameliorated by subsequent treatment of the tissue with arginine. Author (TAB)

N67-32874# Magna Corp., Anaheim, Calif.
THIN FILM PERSONAL DOSIMETERS FOR DETECTING TOXIC PROPELLANTS Final Report, 15 Apr. 1964–15 Apr. 1965
C. R. Townsend, G. A. Giarrusso, and H. P. Silverman Wright-Patterson AFB, Ohio, AMRL, Feb. 1967 71 p
(Contract AF 33(615)-1751)
(TRW-6302-6001-R0000; AMRL-TR-66-231; AD-652849) CFSTI: HC $3.00/MF $0.65

The subject of this report is the development of a portable system for the detection of low concentrations of nitrogen tetroxide (N_2O_4), fluorine (F_2), and unsymmetrical dimethylhydrazine (UDMH) in air. The detection system is based upon the change of electrical resistivity of thin metal films when exposed to these gases. Silver metal films coated with appropriate salts proved to be applicable to the detection of all three gases; however, the following sensitized metal films were found to be optimum: for N_2O_4, silver; for F_2, copper; and for UDMH, gold. Using the best film and salt combinations found to date, N_2O_4 could be monitored over the range of 0.1 to 50 ppm, F_2 over the range 1.0 to 50 ppm, and UDMH over the range 10 to 100 ppm, with a standard deviation of about 20 percent. The effects of temperature over the range 50 to 90°C and of humidity from 10 to 90 percent on the response characteristics of the thin film sensors were found to be significant but within the tolerance limits. Means for reducing these effects were suggested which, if successful, would, in effect, make this detection system practically independent of changes in the environment. A portable breadboard readout instrument was designed and fabricated for use with the sensors to form an integrated detection system for personal protection. Author (TAB)

N67-33290# Air Force Systems Command, Wright-Patterson AFB, Ohio. Foreign Technology Div.
THE TOXICOLOGICAL CHARACTERISTIC OF HYDRAZINE
N. K. Kulagina 20 Jan. 1967 26 p refs Transl. into ENGLISH from Akad. Nauk SSSR, Toksikologiya Novykh Promyshlennykh Khim. Veshchestv, no. 1, 4, 1962 p 65–81
(FTD-HT-66-306; AD-653346) CFSTI: HC $3.00/MF $0.65

Lethal concentrations of hydrazine vapors are of the order of 1.0 to 2.0 mg/liter. Concentrations of the order of 0.5 to 0.8 mg/liter are abreactive though they result in pronounced distrubances. A threshold concentration of hydrazine which produces minimal disturbances of the higher nervous activity of animals with a one-time application is a concentration of 0.02 mg/liter. It produces an increased irritability of the central nervous system. The clinical picture of acute hydrazine poisoning includes an irritating effect upon the mucuous membranes of the eyes, upper respiratory tracts and a general excitation, sometimes accompanied by convulsions. The morphological changes of the inner organs include extensive vascular disturbances, lung edema, and necrobiotic changes of the liver and kidneys. Prolonged exposure to hydrazine vapors in small concentrations may cause a chronic poisoning. The capability of hydrazine to penetrate the body through the skin and to produce a heavy and even lethal poisoning, as well as its capability to cause an acute skin irritation, and of the mucous membranes of the eye make it necessary to protect the skin and eyes from direct contact with hydrazine. TAB

N67-33449*# Dynamic Science Corp., Monrovia, Calif.
INVESTIGATION OF THE FLAME STRUCTURE OF A THERMALLY UNSTABLE FUEL Final Report
Stuart Hersh, B. R. Lawyer, R. J. Hoffman, and B. P. Breen 30 Jun. 1967 42 p refs
(Contract NAS7-442)
(NASA-CR-72261; DS-SN81B) CFSTI: HC $3.00/MF $0.65 CSCL 21B

An investigation of the hydrazine/nitrogen tetroxide droplet flame is reported. The results of the experimental work are the temperature and stable species concentration profiles. It is concluded that a hydrazine decomposition flame exists at the droplet surface causing a large temperature gradient which results in much higher burning rate than found for thermally stable fuels. Author

N67-34203# Cornell Aeronautical Lab., Inc., Buffalo, N. Y. Hypersonic Facilities Dept.
SIMULATION OF EARTH-STORABLE LIQUID PROPELLANTS WITH GASEOUS REACTANTS
W. Sheeran Jun. 1967 21 p refs Supersedes AHRD-PS-65-8 (HFD-PS-67-5; AHRD-PS-65-8)

From thermodynamic considerations it was shown that to exactly duplicate the combustion products of earth-storable liquid propellants, a gaseous fuel/oxidizer combination at the same initial temperature must have the same atomic composition and initial energy as the liquid propellant mixture. On the basis of these two requirements, a gaseous reactant combination of $N_2/O_2/H_2/C_2H_4$ was determined which, when combusted, was shown through the usual equilibrium composition calculations to duplicate the exhaust products and temperature from the combustion $N_2O_4/50/50N_2H_4$–UDMH liquid propellants. Author

N67-34758*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EVALUATION OF SPEECH SUPPRESSION CONCEPTS IN A 20,000-POUND-THRUST HYDROGEN–OXYGEN ROCKET
John P. Wanhainen, Ned P. Hannum, and Louis M. Russell Washington, NASA, Aug. 1967 36 p refs
(NASA-TM-X-1435) CFSTI: HC $3.00/MF $0.65 CSCL 21B

An experimental investigation was conducted to determine the effects of (1) propellant injection radial distribution, (2) fluorine additive to the liquid oxygen, (3) extended oxidizer tubes, (4) porous injector faceplate, (5) nozzle area radial distribution, and (6) chamber wall film cooling on acoustical mode stability characteristics. Stability data were obtained at a chamber pressure of 300 pounds per square inch absolute and over a range of oxidant-fuel ratios from 3.5 to 6.5. Hydrogen injection temperature was used to rate the stability of the various designs. The combustor with the lowest self-triggering temperature was considered to be the most stable design. Concentrating the propellant injection radial distribution had a detrimental effect on longitudinal mode stability. Addition of fluorine to the oxygen to an amount of 30 percent by weight had no significant effect on stability; however, characteristic exhaust velocity efficiency was improved by 1 to 3 percentage points. The combustor stability characteristics were significantly improved by the wagon wheel nozzle, the porous faceplate, and the extended oxidizer tubes. Chamber wall film cooling produced no major change in the hydrogen temperature stable operating

limits. Performance, however, decreased 2 to 3 percentage points for each 10 percent of hydrogen flow diverted for film cooling. Author

N67-34912*# Lockheed Missiles and Space Co., Sunnyvale, Calif.
HANDBOOK OF PHYSICAL AND THERMAL PROPERTY DATA FOR HYDROGEN. TRIPLE POINT REGION TO CRITICAL POINT REGION. VOLUME 1: A STUDY OF HYDROGEN SLUSH AND/OR HYDROGEN GEL UTILIZATION
11 Mar. 1967 72 p refs
(Contract NAS8-20342)
(NASA-CR-87655; LMSC-K-11-67-1, Vol. I) CFSTI: HC $3.00/MF $0.65 CSCL 21I

Physical and thermal property data for hydrogen in the regions between the triple point and the critical point are tabulated and illustrated in both the English and International systems of units in this handbook for space vehicle designers. Nearly all of the data presented are for parahydrogen, since this is the major component of low temperature equilibrium mixtures. Properties, such as the solubility of helium in hydrogen, that are significantly different for parahydrogen and orthohydrogen are presented for the case of equilibrium mixtures. Property data in the solid, liquid, and vapor states near the triple point temperature of 13.803°K (24.85°R) were taken from this handbook for a hydrogen slush utilization study. M.W.R.

N67-34996*# Republic Aviation Corp., Farmingdale, N. Y.
A SUPERSONIC COMBUSTION TEST PROGRAM UTILIZING GAS SAMPLING, OPTICAL AND PHOTOGRAPHIC MEASURING TECHNIQUES Final Report
Anthony Casaccio and Richard L. Rupp [1967] 115 p refs
(Contract NAS1-6314)
(NASA-CR-66393) CSCL 21B

Effects of certain parametric variations on the supersonic combustion of hydrogen in air were investigated. The test program was performed in a one-megawatt arc-jet facility at a Mach number of 2.35 and an air static pressure of 0.5 atm. Free-jet testing of single, three-point and peripheral (ring) injection geometries were conducted for controlled variations in air static temperature, fuel total temperature, fuel-to-air velocity ratio, fuel-air equivalence ratio and fuel–air spacing. Two segmented combustor contours were also tested for various air static temperatures (2100°R, 2700°R, 2900°R and 3100°R), fuel stagnation temperatures of 600°R and 1000°R and fuel–air equivalence ratios of 0.5 and 1.0. Spectroscopic and photographic techniques were employed to measure combustion stream temperatures and to note general flame characteristics. Gas samples were extracted from the combustion stream for each of the test runs and analyzed in a gas chromatograph. Wall pressures and temperatures were recorded for each of the segmented combustor test runs in the series. Results show that changes in air static temperature, equivalence ratio and fuel–air velocity ratio have, in general, a more pronounced effect on combustion characteristics than changes in fuel stagnation temperatures. Slight effects due to variation in fuel–air spacing were also noted. Author

N67-35022# Entwicklungsring Nord, Bremen (West Germany).
THE DETERMINATION OF THE THERMAL CONDUCTIVITY OF THE SPECIFIC HEAT AND THE DENSITY (GROSS DENSITY) OF INSULANTS FOR ROCKET TANKS FILLED WITH LIQUID HYDROGEN. PART 1: DESCRIPTION OF MEASURING METHOD [DIE BESTIMMUNG DER WAERMELEITFAEHIGKEIT DER SPEZIFISCHEN WAERME UND DES RAUMGEWICHTS (ROHDICHTE) VON ISOLATIONEN FUER MIT FLUESSIGEM WASSERSTOFF GEFUELLTE RAKETENTANKS. TEIL 1: BESCHREIBUNG DER MESSVERFAHREN]
B. Koglin and W. F. Zimni *In* European Space Vehicle Launcher Develop. Organ. ELDO Tech. Rev., Vol. 2, No. 1 1967 26 p refs In GERMAN; ENGLISH summary (See N67-35021 20-31)

In addition to a brief general study of the insulation of tank walls for cryogenic high-energy rocket stages, the description and discussion of various measuring methods for determining thermal conductivity, specific heat, and density in insulating materials, together with a comprehensive review of the literature are given. Author (ESRO)

N67-35259 Bolkow Entwicklungen K. G., Munich (West Germany).
ABOUT ROCKET TRANSMISSION AND GAS GENERATOR WITH HYDRAZINE AS MONERGOL [UEBER RAKETENTRIEBWERKE UND GASERZEUGER MIT HYDRAZIN ALS MONERGOL]
Helmut Hopmann 1967 38 p In GERMAN Presented at the DGRR Symp. on Chem. Rocket Transmission, Munich, 21 Mar. 1967
(TR-714-O; Rept.-67-010)

A brief survey on the advantages and disadvantages in optimal utilization of hydrazine as monergol rocket fuel is given. The most important hydrazine efficiency values for rocket technology and gas generators are presented and followed by a description of the catalytic decomposition and gas producing processes. Transl. by G.G.

N67-35368*# Pratt and Whitney Aircraft, West Palm Beach, Fla. Research and Development Center.
INVESTIGATION OF LIGHT HYDROCARBON FUELS WITH FLUORINE–OXYGEN MIXTURES AS LIQUID ROCKET PROPELLANTS Final Report, 22 Jun. 1965–15 Jun. 1967
J. C. Matheson et al 15 Sep. 1967 149 p refs
(Contract NAS3-6296)
(NASA-CR-72147; PWA-FR-2227) CSCL 21I

Performance and cooling analyses were made to determine the highest performing light hydrocarbon fuels for use with flox in regeneratively cooled and transpiration cooled pressure-fed thrust chambers. Sea level and simulated-altitude rocket firings were made at nominal 100-psia chamber pressure and 5000-lb vacuum thrust in uncooled, transpiration cooled, and regeneratively cooled chambers using flox with methane, propane, and butene-1. Based on the data obtained in these tests, predicted performance was calculated for these propellants over a range of thrust levels. Author

N67-35642*# Union Carbide Corp., Bound Brook, N. J.
SATURATED HYDROCARBON POLYMERIC BINDER FOR ADVANCED SOLID PROPELLANT AND HYBRID SOLID GRAIN Quarterly Report, Feb. 1–Apr. 30, 1967
James E. Potts, ed. 19 May 1967 34 p refs Prepared for JPL
(Contracts NAS7-100; JPL-951210)
(NASA-CR-88018; QR-6) CSCL 21I

Several chain transfer agents are being investigated as to their suitability for placing desirable functional groups at the ends of ethylene–neohexene copolymer chains. Symmetrical disulfides, such as dimethyl dithioglycolate were not very effective as telogens for ethylene/neohexene copolymers. Much more promising results have been obtained with telogens containing the carbon–halogen bond. Carbon tetrachloride gave telomers containing –Cl and $-CCl_3$ as polymer end groups. Conversion of these groups to –COOH has proven to be unexpectedly difficult. Telomers have been obtained from each of these telogens, and the analytical data thus far received are quite favorable. In particular, the first BBIB telomer analysed contains .95 ester groups and .84 bromine atoms per molecule. Model compound studies on 11-bromohendecanoic acid have demonstrated the feasibility of this approach for preparing dicarboxylic acids. Author

N67-36106 Deutsche Versuchsanstalt für Luft- und Raumfahrt, Munich (West Germany). Institute fuer Raketentreibstoffe.
CHEMICALLY HEATED HYDROGEN THROUGH TRIBRIDE COMBUSTION [CHEMISCHE WASSERSTOFFAUFHEIZUNG DURCH TRIBRIDE VERBRENNUNG]
1967 13 p Presented at DGRR Symp. Chem. Raketentriebwerke, Munich, 21 Mar. 1967
CFSTI: HC $3.00/MF $0.65

Metal combustion is examined as a chemical means for increasing the combustion temperature and propulsion efficiency of hydrogen. Problems connected with the combustion of pure metals in high-energy propellant systems of the oxidizer/metal/hydrogen type are reviewed. Unconventional solutions such as powder combustion and cryogenic solid propellants are considered in addition to tribrid combustion in the presence of binders with specific properties. The use of lithium as a high-energy binder for beryllium is discussed, and the performance of other tribrid systems is briefly compared with pure metal combustion. Transl. by K.W.

N67-36282*# Chrysler Corp., New Orleans, La. Space Div.
RELIEF VALVE, 6 BY 8 INCH, MANNING, MAXWELL, AND MOORE PART NUMBER TYPE 1905 QC/L3, NASA DRAWING NUMBER 75M12930 LRV-7 Test Report
Donald R. Hardwick 24 Mar. 1967 55 p
(Contract NAS8-4016)
(NASA-CR-88111; TR-RE-CCSD-FO-1027-3) CSCL 13K

The valve is used at Launch Complex 37 of the John F. Kennedy Space Center to prevent overpressurization of the inner LOX tank. Three specimens of the valve were tested for the following: (1) receiving inspection; (2) functional; (3) high temperature; (4) flow; (5) surge and response; (6) cycle; and (7) proof pressure. The specimens met operational and environmental requirements and performed according to specifications. K.W.

N67-37424# National Bureau of Standards, Washington, D. C.
CALCULATION OF THE HEATING VALUE OF A SAMPLE OF HIGH PURITY METHANE FOR USE AS A REFERENCE MATERIAL
George T. Armstrong 15 Dec. 1966 23 p refs
(NBS-TN-299) GPO: $0.25

The heat of combustion of CH_4 has been recalculated in kJ $(mol)^{-1}$ Btu $(mol)^{-1}$, Btu $(cu\ ft)^{-1}$ (dry basis) and Btu $(std.\ cu\ ft)^{-1}$ (saturated basis), using the best available experimental determinations of the heat of combustion and other measured quantities and the most recent generally accepted physical constants and defined physical units. The calculations are outlined in detail. The resulting quantities are applied to calculation of the heat of combustion of a reference sample of CH_4 submitted for analysis of composition and certification of heating value by the Institute of Gas Technology. Author

N67-39539# California Univ., Berkeley. Coll. of Engineering.
THE EFFECT OF NON-EQUILIBRIUM COMBUSTION ON PROPELLANT PERFORMANCE
Robert F. Sawyer Jul. 1967 15 p refs
(Grant AF-AFOSR-1256-67)
(TS-67-3; AFOSR 67-2004; AD-657791)

Most calculations of propellant performance, including those considering kinetic nozzle flows, are based on equilibrium composition in the combustion chamber. Departures from equilibrium combustion are cited and the effect of non-equilibrium or kinetic combustion upon propellant performance for the hydrazine/nitrogen tetroxide combination is reported. Non-equilibrium combustion may yield performance either greater than or less than equilibrium combustion. Author (TAB)

N67-39723*# Rocket Research Corp., Seattle, Wash.
MONOPROPELLANT HYDRAZINE THRUSTER SYSTEM Final Report, 12 Feb.–27 Nov. 1965
27 Nov. 1965 75 p
(Contract NAS5-9137)
(NASA-CR-89570; Rept.-66-R-72) CFSTI: $3.00 CSCL 21H

A program is summarized for the development and delivery of a 0.5 lbf monopropellant hydrazine thruster system intended for use as a laboratory test model. Design and testing of a developmental hydrazine reactor are covered, along with the design, prequalification, testing, and acceptance testing of the complete hydrazine propulsion system including a propellant tank/bellows assembly, propellant valves, lines, filter, and hydrazine reactor. The hydrazine reactor utilizes Shell 405 spontaneous catalyst for the decomposition of anhydrous hydrazine. The hydrazine reactor is used with a blowdown-pressure feed system providing nominal vacuum total impulse of 350 lbf-sec. Areas of interest in the development of the hydrazine reactor were injection methods, chamber geometry, and catalyst bed packing techniques. During the program approximately 100 tests were conducted in which major effort was placed on injector optimization. Author

N67-39948# California Univ., Berkeley. Thermal Systems Div.
PERFORMANCE OF AMMONIA-FIRED GAS-TURBINE COMBUSTORS
D. T. Pratt Aug. 1967 35 p refs
(Contract DA-04-200-AMC-791(X))
(TS-67-5; TR-9; AD-657585)

A theoretical and experimental program was undertaken to investigate scaling and combustion in gaseous ammonia-fired gas turbine combustors. Theoretical analysis of performance and scale test data previously performed strongly indicates that the final size chosen for an operating gas turbine is performance-limited almost equally by chemical reaction kinetics (residence time) and by turbulent diffusion or mixing processes (velocity or Reynolds number). Experimental results confirmed that a small-diameter combustor is chemically rate-limited at pressures very slightly less than the minimum previously reported, and becomes limited almost equally by chemistry and mixing at higher pressures. The fundamental problem with utilizing gaseous ammonia as a turbine fuel is certainly the relatively slow (compared to hydrocarbon fuels) chemical reaction between ammonia and air. As air flow is reduced, to allow sufficient residence time for the reaction to progress, diminished Reynolds number effects lead to less efficient mixing. This in turn leads to decreased combustion efficiency. The only apparent solutions (apart from chemical enrichment by cracking or use of additives) are to use a smaller fuel nozzle orifice to create a more vigorous fuel jet in the primary zone, and to use two or more combustors in parallel rather than build a single larger combustor. TAB

N67-40212# Mine Safety Appliances Co., Pittsburgh, Pa.
COLORIMETRIC PERSONAL DOSIMETER FOR HYDRAZINE FUELS Final Report, Jun. 1965–Aug. 1966
Charles A. Plantz Wright-Patterson AFB, Ohio, AMRL, May 1967 12 p refs
(Contract AF 33(615)-2929)
(AMRL-TR-66-152; AD-658442)

A research program was initiated to develop a personal colorimetric dosimeter for hydrazine fuels. An extensive literature survey was conducted to ascertain the most appropriate colorimetric reactions applicable to such a device. Many reagents were found which formed a color upon contact with various hydrazine vapors; however, most of these colored reaction products proved unstable during accelerated aging tests. Bindone, (delta 1,2 -- Biindan)--1, 3,3 -- Trione, uniformly dispersed on Eastman Chromagram Sheet (Type K301R2) was selected for incorporation as the sensing element in the dosimeter badge, because its response to

hydrazine, unsymmetrical dimethylhydrazine (UDMH), and monomethylhydrazine (MMH) was both linear and readily observable. Synthetic color standards were developed and included in the dosimeter to provide the user with a means of estimating accumulated exposure within the range of 100-1800 ppm-minutes.
Author (TAB)

IAA ABSTRACTS

A67-16073
ORGANIC CHEMISTRY OF HYDRAZINE [ORGANICHESKAIA KHIMIIA GIDRAZINA].
A. P. Grekov.
Kiev, Izdatel'stvo Tekhnika, 1966. 235 p. In Russian.

This monograph gives a nomenclature of hydrazine derivatives and describes their chemical and physical properties, uses, reactions with electrophilic agents, and methods of analyzing them. Among the subjects covered are hydrazine-based polymers, hydrazine-based reducing agents for organic compounds, and uses of hydrazine derivatives as chemical reagents. The reactions in which hydrazine or its derivatives are used are (1) the reduction of nitro, nitro-azo, azo, carbonyl, ethylene, and acetylene compounds, alkyl and aryl halides, and nitriles, and (2) the determination of I, Br, ferrocyanide, bichromate, permanganate, sulfides, sulfites, nitrates, nitrites, phosphites, vanadates, H_2O_2, Cu, Ag, Au, Zn, Cd, Hg, Al, Tl, Pb, P, Se, Zr, MnO_2, Tc, Re, Fe, and Co. The methods of hydrazine analysis include iodometry, iodatometry, bromometry, bromatometry, chlorometry, permanganometry, mercurimetry, vanadometry and determinations with potassium ferrocyanide, sodium nitrite, copper salts, chloramine-T, and aldehydes. Uses of hydrazine and its derivatives in physiologically active preparations, insecticides, and in plant growth control are also described. The monograph is addressed to engineers and scientists of the chemical, pharmaceutical, and textile industries and to agricultural and medical researchers. V. Z.

A67-19014
PROPULSION BY LIQUID OXYGEN AND LIQUID HYDROGEN.
J. Dardare (Société d'Etude de la Propulsion par Réaction, Villejuif Seine, France).
IN: PURE AND APPLIED CRYOGENICS. VOLUME 5 - LIQUID HYDROGEN.
Oxford, Symposium Publications, Division of Pergamon Press, Ltd. 1966, p. 135-157. In English and French.

Consideration of the use of oxygen and hydrogen as propellants to obtain the high performance which results from their high reaction temperature and especially from the small molecular mass of hydrogen. Following a brief review of the performance and principal properties of the propellant, the problem of its application in rocket engines is discussed. Present designs are described with particular stress on the SEPR engines developed in France. A summary of future prospects is presented. F.R.L.

A67-18308 * #
MIXING AND REACTION STUDIES OF HYDRAZINE AND NITROGEN TETROXIDE USING PHOTOGRAPHIC AND SPECTRAL TECHNIQUES.
Marshall C. Burrows (NASA, Lewis Research Center, Cleveland, Ohio).
American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 5th, New York, N.Y., Jan. 23-26, 1967, Paper 67-107. 10 p. 14 refs.
Members, $0.75; nonmembers, $1.50.

Distances required to atomize, mix, and react N_2H_4 and N_2O_4 were experimentally determined for a quadlet injector element at 19 atm and an oxidant-fuel weight ratio of 1.0. Streams of like propellants were diagonally opposite at an impingement angle of 90°. Silhouette photographs showed that atomization of the propellant streams occurred in less than 1 in., and vaporizing pockets of NO_2 extended downstream for 4 in. or less. Thermocouple measurements showed that the hottest gases were in the oxidant-rich zones; fuel-rich gases appeared to be influenced by the decomposition reaction of hydrazine. Temperatures approached steady-state values 11 in. or more from the injector. Spectral radiation bands of NH, OH, and NH_2 were most intense in the fuel-rich and well-mixed zones; pyrometer measurements of H_2O radiation were highest in the oxidizer-rich and well-mixed zones. Concentration profiles of H_2O were determined from measured radiation and gas temperature and plotted as a function of axial distance. The resulting curves compared favorably with H_2O concentrations calculated for combustion profiles limited by either fuel or oxidant vaporization. (Author)

A67-18387 *
TURBULENT TRANSPORT COEFFICIENTS IN SUPERSONIC FLOW.
John H. Morgenthaler and Joseph M. Marchello (Johns Hopkins University, Applied Physics Laboratory, Silver Spring; Maryland, University, College Park, Md.).
(American Institute of Chemical Engineers, Annual Meeting, 58th, Symposium on Fundamentals of Fluid Dynamics, Philadelphia, Pa., Dec. 6-9, 1965, Paper.)
International Journal of Heat and Mass Transfer, vol. 9, Dec. 1966, p. 1401-1418. 19 refs.
NASA-sponsored research.

Hypersonic ramjets employing supersonic combustion of hydrogen fuel have attractive potentialities for future aircraft or launching systems. The object of the present work was to study quantitatively the effects of fuel injection parameters on the mixing of gaseous hydrogen fuel with a supersonic air stream confined within a cylindrical duct, to provide some of the fundamental background needed for the design of supersonic combustors for high-performance engines. Hydrogen was injected at sonic velocities into Mach 2 and Mach 3 air streams, at overall equivalence ratios of 0.17 to 0.50, in both radial and axial (downstream) directions from circumferential wall slots. Results showed that considerably better mixing occurred in the case of radial injection, although the decrease in stagnation pressure also was greater for this case. The eddy diffusivity of mass, E_d (turbulent diffusion coefficient) and radial velocity, $\bar{V}_r$, were determined by differentiating experimental concentration, velocity and density profiles, obtained at various axial distances from the injection station. For the radial injection case, with a 1-in. ID test section, a simple model in which E_d varied only in the radial direction and $\bar{V}_r$ varied only in the axial direction, allowed reasonable correlation of the experimental results. The validity of the trends obtained in E_d and $\bar{V}_r$ were ckecked by numerical integration of the diffusion equation, and simultaneous solution of the diffusion and momentum equations; computed profiles agreed reasonably well with downstream experimental concentration and velocity profiles. A method for solving turbulent mixing problems by simultaneous solution of the diffusion, momentum and energy equations is presented. (Author)

A67-18869 #
COMPOSITE SOLID PROPELLANT IGNITION - IGNITION OF AMMONIA AND OTHER FUELS BY PERCHLORIC ACID VAPOR.
G. S. Pearson and D. Sutton (Ministry of Aviation, Rocket Propulsion Establishment, Research Div., Westcott, Bucks., England).
AIAA Journal, vol. 5, Feb. 1967, p. 344-346. 10 refs.

Study designed to determine whether ignitions are still obtained with (1) solid fuels with very small vapor pressures and (2) gaseous fuels in the presence or absence of a solid surface. The ignition delays of gaseous fuels with perchloric acid vapor with and without a catalyst are tabulated. It was found experimentally that perchloric acid-ammonia-catalyst mixtures ignited faster than perchloric acid-solid fuel mixtures. Since in the practical case of an ammonium perchlorate propellant the ammonia and perchloric acid are vaporized together, it seems probable that, with the catalyzed propellant, ignition occurs as a result of heterogeneous reactions between the ammonia and perchloric acid vapor on the surface of the catalyst. M.F.

A67-19313 #
STUDY OF THE NORMAL RATE FOR METHANE-AIR MIXTURE FLAMES AT HIGH PRESSURES [ISSLEDOVANIE NORMAL'NOI SKOROSTI PLAMENI METANO-VOZDUSHNYKH SMESEI PRI VYSOKIKH DAVLENIIAKH].

V. S. Babkin and L. S. Kozachenko.
Fizika Goreniia i Vzryva, no. 3, 1966, p. 77-86. 8 refs. In Russian.

Experimental determination of normal flame propagation rates for methane-air mixtures with 6 to 13% methane, at 50 to 200°C and 1 to 70 atm. It is shown that the baric exponent n is a function of the methane-air ratio, temperature, and pressure and that the temperature exponent m is a function of the methane-air ratio and pressure. The latter has a minimum value of ~2 when the composition of a mixture approaches a stoichiometric proportion. The values of n and m are calculated from the relations of the Lovachev flame propagation theory. The calculated results are in qualitative (and in some cases in quantitative) agreement with the experimental results. V.Z.

A67-19365 * #
LOW-THRUST PROPULSION FOR THE MORL.
Milton Goodman (Douglas Aircraft Co., Inc., Advance Propulsion Dept., Santa Monica, Calif.).
(American Institute of Aeronautics and Astronautics, Electric Propulsion Conference, 5th, San Diego, Calif., Mar. 7-9, 1966, Paper 66-226.)
Journal of Spacecraft and Rockets, vol. 4, Feb. 1967, p. 183-187. 5 refs.
Contract No. NAS 1-3612.

A67-19385 ≠
IGNITION OF HYPERGOLIC PROPELLANTS IN A SIMULATED SPACE ENVIRONMENT.
Raymond L. Chuan and Paul C. Wilber (Celestial Research Corp., South Pasadena, Calif.).
(AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, INSTITUTE OF ENVIRONMENTAL SCIENCES, AND AMERICAN SOCIETY FOR TESTING AND MATERIALS, SPACE SIMULATION CONFERENCE, HOUSTON, TEX., SEPTEMBER 7-9, 1966, TECHNICAL PAPERS, p. 236-241.)
Journal of Spacecraft and Rockets, vol. 4, Feb. 1967, p. 282-284. 6 refs.

A67-23132 #
IGNITION OF THE HYDROGEN-OXYGEN PROPELLANT COMBINATION BY MEANS OF CHLORINE TRIFLUORIDE.
R. Sandri and R. Billingham (National Research Council, Ottawa, Canada).
AIAA Journal, vol. 5, Apr. 1967, p. 770-773. 5 refs.

A large number of experiments were conducted in a 100-lb-thrust uncooled rocket chamber firing into a vacuum tank. A special automatic system was used for the precise timing of the injection of the three components, and reliable and repeatable testing conditions were established. The optimum timing was determined, and three different ignition delays could be measured which characterized the hypergolic ignition of the hydrogen and the subsequent ignition of the main propellants. Ignition proved to be very reliable, and only very small quantities of igniter liquid were required. Some insight was gained into the mechanism of the process. (Author)

A67-24792 #
THE INFLUENCE OF TAILPIPE LENGTH ON FLAME STABILITY.
Louis G. Palermo (Boeing Co., New Orleans, La.) and John R. O'Loughlin (Tulane University, New Orleans, La.).
American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Houston, Tex., Mar. 5-9, 1967, Paper 67-GT-4. 8 p. 9 refs.
Members, $0.75; nonmembers, $1.50.
Army-supported research.

The influence of tailpipe length on the stability of a flame anchored in a high-velocity propane-air stream contained in a 2-in. pipe test section has been experimentally examined. Two flameholders were studied; a bluff body and a reverse-jet. A satisfactory correlation of the bluff-body data was obtained by plotting (blowoff velocity) (tailpipe length) 0.31 vs equivalence ratio. For the reverse-jet, the correlation procedure yielded a value of 0.64 for the exponent on tailpipe length but the correlation was poorer. A better correlation of the bluff-body data was obtained when the exponent on tailpipe length was taken as a function of equivalence ratio. (Author)

A67-26259
CALCULATION OF IGNITION DELAYS IN THE HYDROGEN-AIR SYSTEM.
K. N. Bascombe (Ministry of Aviation, Explosives Research and Development Establishment, Waltham Abbey, Essex, England).
Combustion and Flame, vol. 11, Feb. 1967, p. 2-10. 22 refs.

The calculation of ignition delays of hydrogen-air mixtures between the limits of temperature 800 and 2000°K, pressure 0.01 and 10 atm, and stoichiometric ratio 0.2 and 2.5 is considered. The simple model chosen involves instantaneous mixing of the preheated gases, which are assumed initially in chemical equilibrium. The criterion taken for the end of the ignition delay period is that the hydroxyl concentration shall have reached 10^{-6} mole liter; this condition was used in an earlier theoretical treatment by Momtchiloff and also in an experimental study by Schott and Kinsey. A method of determining the ignition delays under the range of conditions given above is presented, and the results are compared with those of Momtchiloff (which were obtained by computer analysis of a much more complicated model) and with the experimental data (which were obtained using dilute mixtures of hydrogen and oxygen in argon). In view of the uncertainties in the reaction kinetic data and the difference between the model chosen for the calculations and the experimental conditions the agreement between the values arrived at by the two methods is satisfactory, and evidently only the three chemical reactions considered are significant during the ignition delay period. This falls from about 10^{-3} sec at 800°K to about 10^{-6} sec at 2000°K for a stoichiometric mixture at 1 atm. A graph of log (ignition delay) against log (pressure) is approximately linear, with a slope numerically slightly greater than unity; the effect of changing the stoichiometric ratio is comparatively small, there being, however, a shallow minimum in the curve at a ratio of approximately unity. (Author)

A67-27439 * #
LIQUEFIED NATURAL GAS AS A FUEL FOR SUPERSONIC AIRCRAFT.
Richard J. Weber (NASA, Lewis Research Center, Mission Analysis Branch, Cleveland, Ohio).
American Gas Association, Distribution Conference, St. Louis, Mo., May 1-4, 1967, Paper. 12 p.

Review of several recent articles dealing with the application of liquefied natural gas to the SST. The positive and negative aspects of the concept are indicated, and values indicating the characteristics of a conventional jet aircraft fuel and of such possible fuels as propane, methane, ethane, and hydrogen are tabulated. The improvement in turbojet engine performance when changing from conventional fuel to methane is plotted. B.B.

A67-27637 #
EXPERIMENTS ON THE SATURN S-IB STAGE TO DETERMINE THE LOX DENSITY.
H. T. deBooy (Chrysler Corp., Space Div., New Orleans, La.).
IN: ADVANCES IN CRYOGENIC ENGINEERING. VOLUME 12 - PROCEEDINGS OF THE TWELFTH ANNUAL CRYOGENIC ENGINEERING CONFERENCE, BOULDER, COLO., JUNE 13-15, 1966.
Conference supported by the National Science Foundation, NSF Grant No. GK-1116.
Edited by K. D. Timmerhaus.
New York, Plenum Press, Division of Plenum Publishing Corp., 1967, p. 49-55. 5 refs.

Study of LOX density fluctuations, heat transfer, and boil-off rate in the Saturn S-IB-stage fuel system. The boiling density and the heat transfer rate to each LOX tank were measured a total of nine times prior to the static tests of the three S-IB stages. The weather conditions during these tests covered a fairly wide range of wind speed, humidity, and temperatures. The wind effect on the

average heat flux of an uninsulated tank filled with LOX is shown graphically. Also shown is the drag coefficient and Nusselt number vs Reynolds number for a cylinder in cross flow, and the average heat flux to the center LOX tank on the S-IB stage as a function of the humidity of the air. R.B.S.

A67-27687 #
COMPATIBILITY OF ATLAS MATERIALS WITH FLUORINE PROPELLANTS.
A. Bleich and J. Hertz (General Dynamics Corp., General Dynamics/Convair, San Diego, Calif.).
IN: ADVANCES IN CRYOGENIC ENGINEERING. VOLUME 12 - PROCEEDINGS OF THE TWELFTH ANNUAL CRYOGENIC ENGINEERING CONFERENCE, BOULDER, COLO., JUNE 13-15, 1966.
Conference supported by the National Science Foundation, NSF Grant No. GK-1116.
Edited by K. D. Timmerhaus.
New York, Plenum Press, Division of Plenum Publishing Corp., 1967, p. 762-770.

Investigation of the oxidizers fluorine (F_2), oxygen difluoride (OF_2) and a mixture of liquid fluorine and oxygen (FLOX) with a view to upgrading the Atlas booster. The compatibility of Atlas materials with these oxidizers was studied, and the following conclusions are reached: (1) the Atlas tank skin material and ducting material are compatible with F_2, OF_2, and FLOX; (2) miscellaneous metallic parts used in Atlas are compatible with FLOX; (3) most nonmetallic materials used in the Atlas with the exception of the fluorosilicone rubber were usable for short times in FLOX; and (4) conversion of the Atlas to a 30% FLOX oxidizer system presents no apparent materials difficulties. M.M.

A67-28551
THE DEFLAGRATION OF HYDRAZINE DIPERCHLORATE.
E. T. Mchale, S. J. Adams, G. Von Elbe, and J. B. Levy (Atlantic Research Corp., Kinetics and Combustion Div., Alexandria, Va.).
Combustion and Flame, vol. 11, Apr. 1967, p. 141-149. 12 refs.
Contract No. AF 49(638)-1169.

Experimental studies encompassing the following aspects of the self-deflagration of the solid oxidizer hydrazine diperchlorate have been carried out: deflagration rate as a function of pressure and the effects of catalysts; flame temperature and temperature profile through the combustion wave; and thermal decomposition and quenching of the deflagration. The results suggest that the deflagration process is defined by three pressure regimes: a low-pressure regime, below approximately 20 atm; a high-pressure regime, above approximately 100 atm; and a region of transition. At high pressures, "normal" deflagration occurs - i.e., a flame is stabilized above the oxidizer, and heat from this exothermic reaction zone is transmitted back to the condensed material causing gasification. Reactants enter the flame and thus continue the cycle. At pressures below 20 atm, the oxidizer is mainly consumed by a rapid, self-sustaining decomposition. Condensed-phase chemical reactions are the primary mode of combustion and heat transfer from a stable flame makes a secondary contribution to the process. (Author)

A67-29437 #
DEVELOPMENT OF A FACILITY FOR SUPERSONIC COMBUSTION SIMULATION.
Norman E. Scaggs and Robert G. Dunn (USAF, Office of Aerospace Research, Aerospace Research Laboratories, Fluid Dynamics Facilities Research Laboratory, Wright-Patterson AFB, Ohio).
(American Institute of Aeronautics and Astronautics, Aerodynamic Testing Conference, Los Angeles, Calif., Sept. 21-23, 1966, Paper 66-743.)
Journal of Spacecraft and Rockets, vol. 4, June 1967, p. 803-805.

A67-30705 *
THE PERFORMANCE OF GASEOUS PARAHYDROGEN AS A MONOPROPELLANT FOR AUXILIARY PROPULSION.
I. Millett and C. R. Nelson (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.).
(International Astronautical Federation, International Astronautical Congress, 16th, Athens, Greece, Sept. 13-18, 1965, Paper.)
IN: PROPULSION AND RE-ENTRY; INTERNATIONAL ASTRONAUTICAL FEDERATION, INTERNATIONAL ASTRONAUTICAL CONGRESS, 16TH, ATHENS, GREECE, SEPTEMBER 13-18, 1965, PROCEEDINGS. VOLUME 5. [A67-30701 16-28]
Congress supported by the United Nations Educational, Scientific and Cultural Organization.
Edited by Michał Łunc.
Paris, Gauthier-Villars, Dunod; New York, Gordon and Breach; Warsaw, Państwowe Wydawnictwo Naukowe, 1966, p. 37-53. 7 refs.
Contract No. NAS 8-9500.

A67-31519
COMBUSTION OF HYDROGEN AND HYDRAZINE WITH NITROUS OXIDE AND NITRIC OXIDE - FLAME SPEEDS AND FLAMMABILITY LIMITS OF TERNARY MIXTURES AT SUB-ATMOSPHERIC PRESSURES.
P. Gray, R. Mackinven, and D. B. Smith (Leeds University, Dept. of Physical Chemistry, Leeds, England).
Combustion and Flame, vol. 11, June 1967, p. 217-226. 23 refs.

Measurement of flame speeds relative to the burnt gas at subatmospheric pressures over the whole range of flammability for the ternary systems $N_2H_4 + N_2O + NO$ and $H_2 + N_2O + NO$, and for a number of $H_2 + N_2O + N_2$ mixtures. Measurements were made in a closed vessel, using a schlieren technique in conjunction with a rotating-drum camera. Composition limits of flammability (at 50 and 70 mm Hg) have also been determined. The maximum flame speed (S_B = 3470 cm/sec) occurred in a slightly fuel-rich mixture (53% hydrogen) of hydrogen plus nitrous oxide from which nitric oxide was absent. The effects of adding nitric oxide were more like those caused by adding an inert diluent than those caused by adding a second oxidant. Composition limits of flammability for $H_2 + N_2O + N_2$ and for $H_2 + N_2O + NO$ were very similar. In the combustion of hydrazine, nitric oxide supported combustion better than nitrous oxide. In lean ternary mixtures, the mixed oxides enhanced each other's reactivity and flame speeds were greatest when both were present. T.M.

A67-31537
THE SIGNIFICANT STRUCTURE AND PROPERTIES OF LIQUID HYDRAZINE AND LIQUID DIBORANE.
Mu Shik Jhon (Virginia, University, Dept. of Chemistry and Center for Advanced Studies in the Sciences, Charlottesville, Va.), Joe Grosh, and Henry Eyring (Utah, University, Dept. of Chemistry, Salt Lake City, Utah).
Journal of Physical Chemistry, vol. 71, June 1967, p. 2253-2258. 15 refs.
Research supported by the University of Virginia; NSF Grant No. GP-3698.

Demonstration that the significant-structure theory of liquids is applicable to rocket fuels, such as liquid hydrazine and liquid diborane, over the entire liquid range. The following properties were calculated and compared with experiment: vapor pressure, molar volume, entropy, the critical constants, heat capacity at constant volume and constant pressure, thermal coefficient of expansion, and compressibility. The surface tensions of the liquids were computed in the generalized manner developed by Chang et al. Also, the dielectric constant of the liquid hydrazine was calculated in a manner similar to that developed by Hobbs, Jhon, and Eyring. The results show good agreement with experimental observations. R.B.S.

A67-31811
PRODUCTION, HANDLING, AND SHIPPING OF ELEMENTAL FLUORINE.

J. M. Siegmund (Allied Chemical Corp., Morristown, N.J.). Chemical Engineering Progress, vol. 63, June 1967, p. 88-92.

Discussion of the production, handling, and shipping of fluorine, the most reactive element known and of considerable interest in rocket engine propulsion. The current production process consists of electrolyzing HF from a melt of KF·2HF to form crude fluorine product and hydrogen waste. Fluorine is considered to be no more difficult to handle than other reactive or toxic chemicals. Materials of construction are carbon steel for pipe and fittings in gaseous fluorine service, and stainless steel for liquid fluorine service. Comments are made on health and safety precautions, the use of fluorine in the aerospace industry, and the toxicity of fluorine as it affects that industry. F.R.L.

A67-31978

MEANS FOR REDUCING BYPASS FLOW REQUIREMENTS IN LIQUID HYDROGEN AND LIQUID OXYGEN TANK MOUNTED BOOST PUMPS ON CENTAUR VEHICLE.

A. V. Pradhan, G. H. Caine, and J. F. DiStefano (Borg-Warner Corp., Pesco Products Div., Bedford, Ohio).

IN: SOCIETY OF AUTOMOTIVE ENGINEERS, AEROSPACE SYSTEMS CONFERENCE, LOS ANGELES, CALIF., JUNE 27-30, 1967, PROCEEDINGS.

New York, Society of Automotive Engineers, Inc., 1967, p. 159-168.

Analysis for minimizing bypass flow on the Centaur boost pumps, considering that cryogenic centrifugal pumps cannot be operated at extremely low flow rates without internal boiling of the fluid. Effects due to recirculation, cavitation, inlet vortex, and pump mounting position are discussed in detail. The temperature-pressure relationships in the liquid hydrogen boost pumps are evaluated in relation to bypass flow requirement to determine if this flow rate can be reduced or eliminated. The minimum quantity of flow without any bypass was analytically estimated, and it was observed that it compared closely with the test results. P.v.T.

A67-33459

ROCKET ENGINES AND GAS GENERATORS USING HYDRAZINE AS A SINGLE-COMPONENT FUEL [ÜBER RAKETENTRIEBWERKE UND GASERZEUGER MIT HYDRAZIN ALS MONERGOL].

H. Hopmann (Bölkow GmbH, Ottobrunn, West Germany).

(Deutsche Gesellschaft für Raketentechnik und Raumfahrt, Symposium über Chemische Raketentriebwerke, Munich, West Germany, Mar. 21, 1967, Vortrag.)

Luftfahrttechnik Raumfahrttechnik, vol. 13, June 1967, p. 136-140. In German.

Description of the advantages in using hydrazine as a single-component fuel for rocket engines. Some of these advantages are: simple handling, greater reliability, simplified fuel production, a simple energy-conversion process, low temperatures, engine cooling, and low manufacturing costs. The most important performance values for this rocket fuel are given, and the process of gas production by catalytic decomposition of the fuel is described and explained by means of test results. P.v.T.

A67-33792

DENSITY INDUCTION TIMES IN VERY LEAN MIXTURES OF D_2, H_2, C_2H_2, AND C_2H_4, WITH O_2.

Donald R. White (General Electric Co., Research and Development Center, General Physics Laboratory, Schenectady, N.Y.).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF., AUGUST 14-20, 1966, PROCEEDINGS.

Symposium supported by the British Section of the Combustion Institute, U.S. Army and U.S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.

Pittsburgh, Pa., Combustion Institute, 1967, p. 147-154. 21 refs. USAF-supported research.

Measurement of the induction time for shock-wave induced exothermic reaction in lean O_2-D_2, O_2-H_2, O_2-C_2H_2, and O_2-C_2H_4 mixtures in a constant-area shock tube, using optical interferometry. For fuel/oxygen ratios of a few percent and for $1100 < T < 2200^{\circ}K$, the gas time from the shock to the first decrease in density is given by three relationships in moles/liter, seconds, and $^{\circ}K$. Essentially the same activation energy is shown by H_2, C_2H_2, and C_2H_4, but that of D_2 appears to be slightly less. With respect to H_2, the induction times for D_2, C_2H_2, and C_2H_4 are about 1.5, 0.5, and 0.4, respectively. The more nearly stoichiometric mixtures show induction times inversely proportional to the geometric mean reactant concentration, while the dependence on the fuel concentration increases with decreasing fuel/O_2 ratio, the dependence on $[O_2]$ vanishing for the leanest O_2-C_2H_4 mixtures. M.M.

A67-33804

IONIZATION IN ETHYLENE-AIR-NITRIC OXIDE FLAMES.

G. A. McD. Cummings (Ministry of Technology, Rocket Propulsion Establishment, Westcott, Bucks., England) and E. Hutton (Manchester, University, Dept. of Chemistry, Manchester, England).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF., AUGUST 14-20, 1966, PROCEEDINGS.

Symposium supported by the British Section of the Combustion Institute, U.S. Army and U.S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.

Pittsburgh, Pa., Combustion Institute, 1967, p. 335-339; Comments, K. J. Mathews (Leeds University, Leeds, England), T. Kinbara (Sophia University, Tokyo, Japan), and A. Fontijn (AeroChem Research Laboratories, Inc., Princeton, N.J.), p. 340, 341. 16 refs.

Using ethylene as fuel, a range of flames was studied at atmospheric pressure in which the oxidizer was a mixture of nitric oxide and air. The degree of ionization in these flames was measured by means of an electrostatic probe, scanning through the reaction zone of the flame. Emission intensities from the flames at selected wavelengths were measured using a Jarrell-Ash scanning spectrometer. The wavelengths (Å units) selected were 5165 (C_2), 4312 (CH), 3584 (CN), and 3360 (NH), in addition to the Q_2 12, Q_1 13, Q_2 13, and Q_1 15 lines of the 3064 band of OH. As nitric oxide was added to the ethylene-air flame, there was a decrease in the positive-ion concentration which was comparable with the observed decrease in the intensity of the C_2 and OH emission. It is concluded that this reduction in ion concentration was due to the reduction of CH radical and O atom concentrations on addition of nitric oxide. The high level of ionization observed in the ethylene-nitric oxide flame was of the order of that predicted by the Saha equation, but the variation of ion density with composition suggests that a chemi-ionization reaction is important. (Author)

A67-33836

A SHOCK-TUBE STUDY OF THE AMMONIA-OXYGEN REACTION.

Tetsu Takeyama and Hajime Miyama (Toyo Rayon Co., Ltd., Basic Research Laboratories, Kamakura, Japan).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF., AUGUST 14-20, 1966, PROCEEDINGS.

Symposium supported by the British Section of the Combustion Institute, U.S. Army and U.S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.

Pittsburgh, Pa., Combustion Institute, 1967, p. 845-851; Comments, R. F. Sawyer (California, University, Berkeley, Calif.) and R. I. Soloukhin (Novosibirskii Gosudarstvennyi Universitet, Novosibirsk, USSR), p. 851, 852. 25 refs.

Investigation of the three different stages of the ammonia-oxygen reaction over the temperature range from 1500 to $2800^{\circ}K$. The measurements of induction periods for the appearance of OH absorption at 3067 Å and the time relations among concentrations of OH, NH, NO, and NH_2, which were identified spectrophotometrically, led to a reaction mechanism for the induction period in which

the reaction $NH_2 + O_2 \rightarrow NH + HO_2$ is rate-controlling. The rate of ammonia consumption immediately after the induction period was measured by monitoring the absorption by ammonia at 2245 Å. A weak emission of OH was found to follow a spike, which was observe at the end of the induction period, and to persist at constant level up to 500 μsec. This weak emission is demonstrated to be chemiluminescence, the mechanism of which is discussed in connection with that claimed for the hydrogen-oxygen reaction. M.M.

A67-33837

GAS-PHASE REACTIONS OF HYDRAZINE WITH NITROGEN DIOXIDE, NITRIC OXIDE, AND OXYGEN.

R. F. Sawyer (California, University, Berkeley, Calif.) and I. Glassman (Princeton University, Princeton, N.J.).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF., AUGUST 14-20, 1966, PROCEEDINGS.
Symposium supported by the British Section of the Combustion Institute, U.S. Army and U.S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.
Pittsburgh, Pa., Combustion Institute, 1967, p. 861-868; Comments, K. W. Michl (Göttingen, Universität, Göttingen, West Germany) and L. Daverman (New York University, New York, N.Y.), p. 869. 19 refs.
NSF Grant No. GP-579; Grant No. AF AFOSR 62-90.

Investigation, in an adiabatic flow reactor, of the homogeneous gas-phase reactions of hydrazine with nitrogen dioxide, nitric oxide, oxygen, and a mixture of oxygen and nitric oxide. Reaction rates, overall activation energies, and reaction orders were obtained under comparable experimental conditions for the four reactions. The results obtained demonstrate that hydrazine oxidation can occur both with and without prior decomposition of the hydrazine and depends on the particular oxidizer. M.M.

A67-33838

THE STRUCTURE OF THE REACTION ZONES OF AMMONIA-OXYGEN AND HYDRAZINE-DECOMPOSITION FLAMES.

D. I. MacLean and H. Gg. Wagner (Göttingen, Universität, Göttingen, West Germany).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF., AUGUST 14-20, 1966, PROCEEDINGS.
Symposium supported by the British Section of the Combustion Institute, U.S. Army and U.S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.
Pittsburgh, Pa., Combustion Institute, 1967, p. 871-878. 13 refs.
Research supported by the Alexander von Humboldt Foundation.

Investigation of the reaction zones of 40%, 57%, and 65% ammonia-oxygen flames at 20 mm Hg on an 8-cm-diam burner. Mass-spectrometric analyses, employing a specially designed dynamic sampling system, yielded concentration profiles of NO, H_2O, N_2, NH_3, H_2, and N_2O in the reaction zones. Optical spectrophotometric analyses gave OH-concentration and NH-absorption profiles, as well as emission profiles of the excited species NH_2, NO, NH, and OH. Temperature profiles were measured with thermocouples, by sodium-line reversal or by means of the OH-rotation spectra. End products of the reaction were, in order of importance, H_2O, N_2, H_2, and NO. Intermediate products measured were N_2O, OH, and NH. Maximum temperatures of 2200°K were observed in near-stoichiometric flame. M.M.

A67-33843

AMMONIA COMBUSTION PROPERTIES AND PERFORMANCE IN GAS-TURBINE BURNERS.

F. J. Verkamp, M. C. Hardin, and J. R. Williams (General Motors Corp., Allison Div., Applied Research Dept., Indianapolis, Ind.).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF AUGUST 14-20, 1966, PROCEEDINGS.
Symposium supported by the British Section of the Combustion Institute, U. S. Army and U. S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.
Pittsburgh, Pa., Combustion Institute, 1967, p. 985-991; Comments, R. M. Fristrom (Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.) and A. C. Nixon (Shell Oil Co., Shell Development Co., Houston, Tex.), p. 991, 992. 11 refs.
Contracts No. DA-20-113-AMC-05553(T); No. AF 33(657)-13687.

Experimental studies were conducted to determine the minimum ignition energy, quenching distance, flame-stability limits, and gas-turbine-burner performance of ammonia-air mixtures. The minimum ignition energy of ammonia was 8 mjoules compared to less than 0.5 mjoules for propane. At stoichiometric conditions, the quenching distance for ammonia-air was 0.275 in. The corresponding reported value for propane-air is 0.08 in. In the flame stability experiments, ammonia would burn at only one-half the air-flow velocity possible with hydrocarbon fuels, and the range of equivalence ratios for stable flame was much narrower than for hydrocarbon fuels. These characteristics were essentially substantiated in gas-turbine-burner testing. It was concluded that neat ammonia cannot be used as a substitute fuel for hydrocarbons in conventional gas-turbine burners unless the ignition-system energy is increased, the combustion liner diameter is increased by a factor of approximately 2, and the ammonia injected in the gaseous state. Two approaches were investigated for improving the combustion properties of ammonia. These were to use additives or to partially predissociate the ammonia. Additives were tested in the flame-stability apparatus in concentrations of 5% by volume of the total fuel. At this concentration, none of the additives improved the flame-stability properties to the extent required. The minimum ignition energy, quenching distance, and flame-stability properties of 28% dissociated ammonia were approximately equal to these same properties of methane. Partially dissociated ammonia was also tested in the gas-turbine burner. It was concluded that 28% dissociated ammonia could be used as a substitute fuel in gas-turbine-combustion systems optimally sized for hydrocarbon fuels. (Author)

A67-33844

FLAME-PROPAGATION RATES IN AMMONIA-AIR COMBUSTION AT HIGH PRESSURE.

E. S. Starkman and G. S. Samuelsen (California, University, College of Engineering, Berkeley, Calif.).

IN: SYMPOSIUM (INTERNATIONAL) ON COMBUSTION, 11TH, UNIVERSITY OF CALIFORNIA, BERKELEY, CALIF., AUGUST 14-20, 1966, PROCEEDINGS.
Symposium supported by the British Section of the Combustion Institute, U.S. Army and U.S. Air Force, Grant No. DA-ARO(D)-31-124-G841, NASA, Grant No. NGR 39-003-005, National Science Foundation, NSF Grant No. GP-5734.
Pittsburgh, Pa., Combustion Institute, 1967, p. 1037-1044; Comments, M. L. Brown (Caterpillar Tractor Co., Peoria, Ill.), J. L. Laver (Sun Oil Co., Marcus Hook, Pa.), F. Verkamp (General Motors Corp., Allison Div., Indianapolis, Ind.), and W. Cornelius (General Motors Corp., GM Defense Research Laboratories, Goleta, Calif.), p. 1044, 1045. 15 refs.

Investigation of the reluctance of ammonia to be easily ignited and of the necessity to advance the spark for optimum performance in combustion engines. Ionization-gap techniques showed that long induction times and slow flame speed were both contributors to the phenomena observed. The most important factor in determining the combustion characteristics of ammonia was found to be the extent of predissociation prior to attempted ignition. There was evidence from combustion gas analysis that NO^+ was the probable most abundant ion contributing to successful application of the ionization-gap techniques and the NO^+ was probably produced in the pyrolysis of ammonia rather than by equilibrium reactions. M.M.

A67-33937 * #

EFFECTS OF USING SUBCOOLED LIQUID AND SLUSH HYDROGEN FUELS ON SPACE VEHICLE DESIGN AND PERFORMANCE.

C. W. Keller (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Sunnyvale, Calif.).

American Institute of Aeronautics and Astronautics, Propulsion Joint Specialist Conference, 3rd, Washington, D.C., July 17-21, 1967, Paper 67-467. 7 p.

Members, $0.75; nonmembers, $1.50.
Contract No. NAS 8-20342.

Study of significant system-design modifications and resulting performance gains for three typical space vehicles fueled with triple-point hydrogen. It was found that propellant management, propulsion, insulation, venting, and pressurization vehicle systems optimize and operate differently when subcooled liquid and slush hydrogen fuels are used, rather than atmospheric-saturated liquid hydrogen. Substantial performance gains can be achieved by the use of subcooled hydrogen when a vehicle originally optimized for a particular mission duration is subjected to a more severe thermal environment. For example, the payload of a Saturn V/S-IVB Lunar Logistics Vehicle is increased 32% by using initially triple-point liquid, and 40% by using initially 50% slush, compared to the payload when using initially saturated liquid. Payload gains also accrue.
F.R.L.

A67-33951 * #
THE EFFECT OF ADDITIVES ON DROPLET HYDRAZINE BURNING.
B. R. Lawver and B. P. Breen (Marshall Industries, Dynamic Science Corp., Monrovia, Calif.).
American Institute of Aeronautics and Astronautics, Propulsion Joint Specialist Conference, 3rd, Washington, D.C., July 17-21, 1967, Paper 67-482. 4 p.
Members, $0.75; nonmembers, $1.50.
Contracts No. AF 04(611)-11616; No. NAS 7-442.

Results of an experimental and analytical investigation of the effect of additives on the N_2H_4 - N_2O_4 droplet flame structure and burning rate. The approach taken was to define experimentally the neat hydrazine flame structure by concentration and temperature probes, then to select additives the effects of which were then experimentally measured. It was found that the burning rate of hydrazine droplets varies linearly with the droplet diameter and that the addition of 10% water to hydrazine reduced the burning by about 15%.
F.R.L.

A67-33963 * #
GAS-CORE REACTOR WORK AT NASA/LEWIS.
Robert G. Ragsdale and Frank E. Rom (NASA, Lewis Research Center, Cleveland, Ohio).
American Institute of Aeronautics and Astronautics, Propulsion Joint Specialist Conference, 3rd, Washington, D.C., July 17-21, 1967, Paper 67-499. 12 p.
Members, $0.75; nonmembers, $1.50.

The feasibility of using a fissionable gas to heat the hydrogen propellant in a nuclear rocket reactor has been under investigation for a number of years. Evaluation of various proposed concepts has led to research into fluid mechanics, radiant heat transfer, and reactor physics problems. A review of current projects is presented, and work underway at NASA/Lewis and contract-supported studies are covered. Recent results are presented for turbulent gas mixing, thermal radiation between gases, and critical mass measurements in a cavity reactor. The current status of these problem areas is discussed. The fluid mechanics problems are complex, but are yielding to combined analytical and experimental studies. Radiant heat transfer problems still require work but do not appear insurmountable. Reactor physics appears as the most challenging area; comparisons between theory and experiment will define the direction of future gas-core work.
(Author)

A67-33973 #
COMPARATIVE CAPABILITIES OF ADVANCED PROPULSION SYSTEMS - UPPER STAGE PROPULSION.
Richard Simms (TRW Systems Group, Power Systems Div., Redondo Beach, Calif.).
American Institute of Aeronautics and Astronautics, Propulsion Joint Specialist Conference, 3rd, Washington, D.C., July 17-21, 1967, Paper 67-509. 11 p.
Members, $0.75; nonmembers, $1.50.
AEC Contract No. AF (04-3)-517.

Demonstration that a new type of advanced propulsion system using radio-isotope-heated hydrogen thrusters appears to provide additional benefits and should be considered for propelling a high-energy upper stage for the performance of a variety of potential scientific missions. The performance of the radioisotope stage is compared to the performance of the high-energy kick stage (HEKS) which utilizes hydrogen-fluorine propellants. The boost vehicles considered include the Saturn IB and Saturn V, with either the Centaur or a hypothetical nuclear-reactor intermediate stage. The result of this comparison indicates that radioisotope propulsion offers substantial payload advantages over alternative high-energy upper stages for a broad range of demanding scientific missions.
P.v.T.

A67-33979 * #
PREIGNITION PHENOMENA IN SMALL A-50/NTO PULSED ROCKET ENGINES.
H. E. Perlee, T. Christos, Y. Miron, and H. K. James (U.S. Bureau of Mines, Explosives Research Center, Pittsburgh, Pa.).
American Institute of Aeronautics and Astronautics, Propulsion Joint Specialist Conference, 3rd, Washington, D.C., July 17-21, 1967, Paper 67-516. 5 p. 5 refs.
Members, $0.75; nonmembers, $1.50.
NASA-supported research.

Demonstration that the accumulation of an explosive material - hydrazine nitrate - may be contributing to the often observed ignition-spike phenomena of low-thrust Aerozine-50/nitrogen tetroxide rocket engines. Residues taken from the MSC (Manned Spacecraft Center) engines and analyzed by the U.S. Bureau of Mines, following pulsed operation at about 0.005 psia, contained approximately equal parts by weight of hydrazine nitrate and water. Work continued at the Bureau revealed that hydrazine and monomethylhydrazine react with nitrogen tetroxide in these engines during the preignition period to form the respective fuel nitrate. Unsymmetrical dimethylhydrazine, in combination with nitrogen tetroxide, on the other hand, reacts to form ammonium nitrate, rather than its fuel nitrate. The accumulation of these nitrates on the engine walls with each successive pulse eventually reaches proportions capable of sustaining permanent engine damage, if initiated to detonation.
P.v.T.

A67-35012 * #
EFFECT OF ADDITIVES ON THE IGNITION DELAY TIME OF HYPERGOLIC PROPELLANTS.
Mario R. Stevens, H. Dwight Fisher, Harold G. Weiss, and Bernard P. Breen (Marshall Industries, Dynamic Science Corp., Monrovia, Calif.).
Combustion Institute, Western States Section, Spring Meeting, University of California, La Jolla, Calif., Apr. 24, 25, 1967, Paper 67-22. 20 p. 5 refs.
Contract No. NAS 7-438.

The low temperature ignition behavior of the N_2O_4/N_2H_4 propellant system was studied for condensed phase hydrazine contacted with nitrogen tetroxide vapor at temperatures ranging between 25 and 100°C, and for condensed phase nitrogen tetroxide contacted with hydrazine vapor at 25°C. Experimental results are presented in terms of minimum ignition pressure and corresponding ignition delay time. Solidification of the oxidizer inhibited the ignition process; hydrazine vapor condensed upon the solid oxidizer surface with no visible reaction occurring.
(Author)

A67-35014 * #
MEASUREMENT OF THE FLAME STRUCTURE OF A THERMALLY UNSTABLE FUEL IN AN OXIDIZING ATMOSPHERE.
Stuart Hersh, B. R. Lawver, R. J. Hoffman, and B. P. Breen (Marshall Industries, Dynamic Science Corp., Monrovia, Calif.).
Combustion Institute, Western States Section, Spring Meeting, University of California, La Jolla, Calif., Apr. 24, 25, 1967, Paper 67-24. 25 p.
Contracts No. NAS 7-442; No. AF 04(611)-11616.

The flame structure of a 2500 μ hydrazine drop burning in nitrogen tetroxide was determined experimentally by measuring the temperature and specific contractions at a plane 90° from the stagnation point. The hydrazine drop diameter was maintained constant by suspending it on the end of a water cooled hypodermic needle attached to a constant flow rate syringe. Nitrogen tetroxide was fed into the burner, establishing a thermal convective flow field around the drop. The flame was probed with a shielded 0.002-in. platinum-platinum/10% rhodium thermocouple as well as a concentration sampling probe. The experiments indicate that hydrazine

decomposes very close to the liquid drop surface, producing a steep temperature gradient which thus controls the burning rate.
(Author)

A67-35766 * #
MIXING AND REACTION OF HYDRAZINE AND NITROGEN TETROXIDE AT ELEVATED PRESSURE.
Marshall C. Burrows (NASA, Lewis Research Center, Chemistry and Energy Conversion Div., Physical Chemistry Branch, Cleveland, Ohio).
(American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 5th, New York, N.Y., Jan. 23-26, 1967, Paper 67-107.)
AIAA Journal, vol. 5, Sept. 1967, p. 1700, 1701.
[For abstract see issue 06, page 1072, Accession no. A67-18308]

A67-35956 #
PARAMETRIC SYNTHESIS AND PERFORMANCE ANALYSIS OF DUAL-FUEL HYPERVELOCITY CRUISE VEHICLES.
H. Glenn Ball and E. L. Gomez (General Dynamics Corp., Fort Worth Div., Aerospace Technology Dept., Fort Worth, Tex.).
American Institute of Aeronautics and Astronautics, Guidance, Control and Flight Dynamics Conference, Huntsville, Ala., Aug. 14-16, 1967, Paper 67-559. 12 p.
Members, $0.75; nonmembers, $1.50.

The dual-fuel concept is an effective method for decreasing the size of hypervelocity vehicles. The results of previous studies have defined vehicles with enormous fuel volumes due to the low density of LH_2. A method for decreasing the volume of these vehicles is to use a dual-fuel concept (e.g., high-density hydrocarbon fuels in combination with LH_2). For a 4500-n-mi, Mach-8 cruise mission, Digital Computer Program HYSYN (HYpervelocity Vehicle SYNthesis) was used to define (1) vehicle size variations with several modes of dual-fuel operation, (2) design parameters (acceleration and wing loading at various points in a mission) which yield minimum-size vehicles, and (3) vehicle-size sensitivity to off-optimum values for the design parameters. (Author)

A67-36540 * #
VISUALIZATION OF HYDROGEN FIRES.
R. L. Proffit (North American Aviation, Inc., Rocketdyne Div., Canoga Park, Calif.).
Canaveral Council of Technical Societies, Space Congress on the Challenge of the 1970's, 4th, Cocoa Beach, Fla., Apr. 3-6, 1967, Paper. 6 p.
Contract No. NAS 8-19.

Results are presented of an experimental program to develop techniques for the visualization of hydrogen fires in the presence of strong background illumination. The techniques investigated include the application of photography, television, and image-converter tubes in the infrared and ultraviolet regions of the spectrum. A single-camera, closed-circuit infrared television system has proved to be the most versatile and successful visualization method. The use of optical filters to provide good contrast and definition of both flame and backgrounds is discussed. The application of infrared and ultraviolet television for visualization of high-altitude hydrogen flames is treated. A short kinescope film of test results was made. (Author)

A67-36732 #
VARIABLE-THICKNESS MODE OF INSULATION FOR HYDROGEN SPACE STORAGE TANKS.
Clarence A. Schalla (Lockheed Aircraft Corp., Lockheed Missiles and Space Co., Research and Development Div., Sunnyvale, Calif.).
American Society of Mechanical Engineers and American Institute of Chemical Engineers, Heat Transfer Conference and Exhibit, Seattle, Wash., Aug. 6-9, 1967, ASME Paper 67-HT-50. 11 p.
Members, $0.75; nonmembers, $1.50.

Evaluation of a variable-thickness insulation system for the more efficient transport of propellant into earth orbit for subsequent docking transfer to lunar and interplanetary mission vehicles. Thicker-than-average wall insulation for ullage wall surfaces are introduced in order to preclude the compromising of higher thermal conductivities in a constant-thickness insulation design. The heat-leak attenuation aspects of delivering 174,000 to 793,000 lb of hydrogen payload into docking orbit standby periods up to 120 days for extended-lunar program and interplanetary-mission vehicles are analyzed. Based on ascent heating as the criterion for optimization, a basic 1-in.-thick, helium-purged multilayer insulation without a substrate but with meteoroid bumper standoff is selected. B.B.

A67-37797 • #
MARINER IV MIDCOURSE PROPULSION SYSTEM IMPULSE AND ACCURACY PREDICTION.
James H. Kelley (California Institute of Technology, Jet Propulsion Laboratory, Liquid Propulsion Section, Pasadena, Calif.).
(American Institute of Aeronautics and Astronautics, Annual Meeting, 3rd, Boston, Mass., Nov. 29-Dec. 2, 1966, Paper 66-948.)
Journal of Spacecraft and Rockets, vol. 4, Sept. 1967, p. 1217-1223.

A67-37798 #
COMBUSTION CHARACTERISTICS OF CONDENSED-PHASE HYDRAZINE-TYPE FUELS WITH NITROGEN TETROXIDE.
Theodore Christos, Yael Miron, Harry James, and Henry Perlee (U.S. Bureau of Mines, Explosives Research Center, Pittsburgh, Pa.).
Journal of Spacecraft and Rockets, vol. 4, Sept. 1967, p. 1224-1229. 18 refs.

METALS, UPTON, N.Y., SEPTEMBER 19-23, 1966, PROCEEDINGS. PART 1.
Conference sponsored by the U.S. Atomic Energy Commission, and the International Union of Pure and Applied Physics.
Advances in Physics, vol. 16, Apr. 1967. 216 p.

CONTENTS:
PREAMBLE, v, vi.
APPLICATION OF A STRUCTURE FACTOR-POTENTIAL RELATIONSHIP TO THE ELECTRICAL RESISTIVITY OF THE LIQUID ALKALI METALS. Arthur Paskin (Brookhaven National Laboratory, Upton, N.Y.), Ralph J. Harrison (U.S. Army, Watertown, Mass.), and P. Ascarelli (Brookhaven National Laboratory, Upton, N.Y.; U.S. Army, Philadelphia, Pa.), p. 263-269. 11 refs. [See A67-39102 21-26]

A67-38716 * #
LOW ENVIRONMENTAL PRESSURE MPD ARC TESTS.
Denis J. Connolly, Ronald J. Sovie, Charles J. Michels, and James A. Burkhart (NASA, Lewis Research Center, Cleveland, Ohio).
American Institute of Aeronautics and Astronautics, Electric Propulsion and Plasmadynamics Conference, Colorado Springs, Colo., Sept. 11-13, 1967, Paper 67-685. 11 p. 13 refs.
Members, $0.75; nonmembers, $1.50.

Tests of lithium and ammonia magnetoplasmadynamic (MPD) arc thrustors were conducted in a 15-ft-diam, 65-ft long vacuum tank. The tank pressure was maintained at 3×10^{-6} torr during lithium-performance testing. The thrust efficiency varied from 10% at a specific impulse of 1000 sec to 70% at 5000 sec, in good agreement with previously published results at three decades higher environmental pressure. The overall efficiency of the thrustor, using ammonia propellant, was found to improve with increasing mass flow rate and was almost as high as that of the lithium thrustor for specific impulse less than 2500 sec. The degree of ionization of the ammonia MPD arc was studied both by spectroscopic means and by estimating the power available for frozen-flow losses. At approximately constant specific impulse the degree of ionization, and hence frozen flow losses, correlated with arc voltage and less strongly with magnetic field. The current distribution of the discharge of an ammonia MPD thrustor was studied by means of Rogowski coils. It was found that, under a wide range of conditions, the arc current was concentrated into spokes rotating at a frequency in the hundreds-of-kHz range. Under the conditions studied, the frequency increased with increasing magnetic field or increasing arc current and decreased with increasing propellant flow rate. (Author)

A67-41319
UPPER LIMITS OF THE PERFORMANCE OF LIQUID HYDROGEN/LIQUID OXYGEN SYSTEMS AS A ROCKET-PROPULSION COMBINATION [OBERE GRENZEN DER LEISTUNGSFÄHIGKEIT DES FLÜSSIGWASSERSTOFF-FLÜSSIGSAUERSTOFF-SYSTEMS ALS RAKETENTREIBSTOFFKOMBINATION].
Irene Sänger-Bredt (Bölkow GmbH, Ottobrunn, West Germany).
(Deutsche Gesellschaft für Raketentechnik und Raumfahrt and Wissenschaftliche Gesellschaft für Luft- und Raumfahrt, Jahrestagung, Bad Godesberg, West Germany, Oct. 4-8, 1966, Vortrag.)
IN: WISSENSCHAFTLICHE GESELLSCHAFT FÜR LUFT- UND RAUMFAHRT, ANNUAL REPORTS 1966 [WISSENSCHAFTLICHE GESELLSCHAFT FÜR LUFT- UND RAUMFAHRT, JAHRBUCH 1966].
Edited by Hermann Blenk and Werner Schulz.
Braunschweig, West Germany, Friedrich Vieweg und Sohn GmbH, 1967, p. 338-358. 24 refs. In German.

Detailed examination of the manifold possibilities for the improvement of liquid-fuel rocket-engine performance through the optimization of the liquid hydrogen/liquid oxygen mixtures and of the engine itself. A survey of the numerical relations between the accessible specific impulses of liquid-propellant rocket engines is presented, as well as a discussion of the accompanying operational conditions, such as the initial chemical state of the propellant constituents, their mixture ratio, the pressure and temperature in the combustion chamber, the expansion ratio, and the nozzle-area ratio. Hydrogen-oxygen mixtures were chosen as energy sources and as working fluid for this investigation, because such mixtures represent the most advantageous propulsion media with regard to energetic and technological qualities. The fuel mixtures discussed have been proposed for application to the most advanced European space rocket-engine projects. R.B.S.

A67-41443
PRODUCTION OF THE BORANES AND RELATED RESEARCH.
R. L. Hughes, I. C. Smith, and E. W. Lawless (Midwest Research Institute, Kansas City, Mo.).
Edited by R. T. Holzmann (Aerojet-General Corp., Azusa, Calif.).
New York, Academic Press, Inc., 1967. 541 p.
$22.
ARPA-supported research.

This book presents for the first time unpublished research work conducted on borane chemistry from 1950 to 1965 with the aim of developing high-energy fuels for air-breathing engines. The chemistry of the carbothermic and ferrothermic reduction of sodium salts to prepare sodium is outlined as a means of promoting boron from a low-energy state to the B-H bond. Detailed treatment is given to the preparation, properties, kinetics, and mechanisms of the borane, alkylboranes, carboranes, and boron-nitrogen compounds, and to the compilation of physical properties and spectra. Toxicology and safety, the analytical chemistry, and separation and purification of boranes are treated in detail. Reviews of widely scattered information on toxicology, IR spectra, the physical properties of boranes and their derivatives and of carborane derivatives are included. An attempt was made to make the work as comprehensive as possible; every effort was made to secure and review all published reports. V.P.

A67-41602 #
METHEMOGLOBINEMIA AS AN INDICATOR OF EXPOSURE TO MONOMETHYLHYDRAZINE.
Dale A. Clark and Sidney R. Fortney (USAF, Systems Command, Aerospace Medical Div., School of Aerospace Medicine, Biosciences Branch, Physiological Chemistry Section, Brooks AFB, Tex.).
IN: AEROSPACE MEDICAL ASSOCIATION, 1967 ANNUAL SCIENTIFIC MEETING, WASHINGTON, D.C., APRIL 10-13, 1967, PREPRINTS OF SCIENTIFIC PROGRAM.
Washington, D.C., American Medical Association, 1967, p. 178, 179. Abridged.

Review of the known metabolic effects of monomethylhydrazine (MMH) to identify one or more effects that could provide an index to the size of the dose received and the severity of symptoms to be expected. Because it had been observed that MMH produces significant methemoglobinemia in anesthetized dogs, it was thought possible that methemoglobin production might serve as such an index. Observations of tests on human blood support the conclusion that man would also develop methemoglobinemia if exposed to MMH. F.R.L.

A67-42532
DEVELOPMENT OF A FAMILY OF LIGHT WEIGHT SHORT DURATION TURBO-ALTERNATOR POWER SUPPLIES.
D. J. Hucker, R. L. Semlow, and T. F. Glennon.
IN: ADVANCES IN ENERGY CONVERSION ENGINEERING; AMERICAN SOCIETY OF MECHANICAL ENGINEERS, INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE, MIAMI BEACH, FLA., AUGUST 13-17, 1967, PAPERS.
New York, American Society of Mechanical Engineers, 1967, p. 517-526.

The paper describes the development of a family of small totally self-contained electrical/hydraulic power supplies suitable for aircraft or missile applications. The units described are turbo-alternators with multiple output windings to supply a range of ac and dc voltages from a few volts to several thousand volts at power levels from 1 kw upward, along with hydraulic and shaft power if desired. The 5-kw unit has demonstrated its endurance with repeated runs of over 20 min duration at rated load. The family of units is designed for use with a variety of storable high energy propellants, to suit a wide range of applications. The scope of the paper includes discussion of the design considerations pertinent to such a unit and the development testing performed for design verification.
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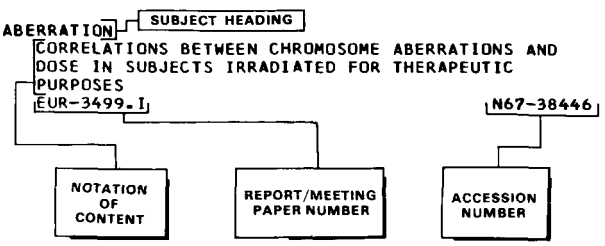

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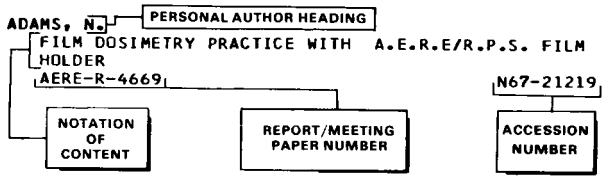

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