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HYDROGEN ENERGY

CUMULATIVE VOLUME 1953 THROUGH 1973

ENERGY INFORMATION CENTER
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO 87131

A Cooperative Effort of
The Technology Application Center and
The College of Engineering

HYDROGEN ENERGY

N74-29411

A BIBLIOGRAPHY WITH ABSTRACTS

CUMULATIVE VOLUME

January 1, 1974

TECHNICAL EDITOR
KENNETH E. COX

COMPILED BY THE
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THE COLLEGE OF ENGINEERING

and

THE TECHNOLOGY APPLICATION CENTER

THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO

NOTICE

FOREWORD

Our modern world presents an ever increasing number of new technical problems, many of which have potential solutions embodied in reports of previous research. Recognizing the fact that some of these problems may be solved by designs, techniques, and technology already in existence, NASA's Technology Utilization Program developed a system of six centers for disseminating the results of existing research, both aerospace and nonaerospace. The Technology Application Center (TAC) of the University of New Mexico is one of these centers; its primary mission is to promote the timely and beneficial use of new technology.

One of TAC's major efforts has focused on the identification of new high-interest areas of technology, and the assembling and updating of references on these subjects. A typical subject area of increasing worldwide interest and concern is the broad field of energy. The voluminous amount of both technical and nontechnical information on this subject—now scattered among a growing number of announcement and publishing mediums—necessitated, in TAC's view, a comprehensive compilation of such information. To fulfill that need, the College of Engineering and TAC joined resources to establish the Energy Information Center of the University of New Mexico.

As a corollary to compiling such an information base, one of the goals of the Energy Information Center is to publish a number of reference works, each centered on a specific energy source, conversion system, or carrier. This abstract bibliography on hydrogen as a carrier and secondary energy source is the first such product to be published through the Center.

William A. Shinnick
Director
Technology Application Center
The University of New Mexico
January 1974

ACKNOWLEDGMENTS

The volume HYDROGEN ENERGY was conceived by the technical editor, Dr. Kenneth E. Cox, during his participation in the 1973 NASA/ASEE Summer Design Program on "Hydrogen as an Energy Carrier." A precursor document was provided for use at this summer program through a cooperative experiment between Dr. John F. Harvey, Dean of the University of New Mexico General Library, and the Technology Application Center. This document served as a catalyst for HYDROGEN ENERGY.

Encouraging and extending these efforts was the Energy Information Center, recently established through the joint auspices of the College of Engineering, under Dean R. C. Dove, and TAC. HYDROGEN ENERGY is the first document to be published by the Center.

Thanks are further extended to Zanier Lane of the UNM General Library who assisted in the first literature search; Eugene Burch, Assistant Director of TAC who worked with the graduate student compilers, John Leffler and Mani Natarajan; and to Lee Doswell who typed most of the original manuscript.

Also acknowledged are the untiring efforts of John Nowak who programmed the computerized indexes; and Virginia Burt who compiled the final master copy.

This publication was further made possible by the Technology Utilization Program of NASA from which both the Energy Information Center and the Technology Application Center derive the majority of their support.

Walter W. Long Thomas K. Feldman, Ph.D.

Co-Directors

Energy Information Center

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The use of hydrogen, either in gaseous or liquid form, will necessitate the development of a large-scale transmission and distribution system. A hydrogen gas pipeline system, similar to or partially integrated with existing natural gas pipelines, appears to be the most practical solution. In a nuclear economy, hydrogen is to be preferred as the energy carrier over electricity for most purposes. This is due to its ready substitution and usage for all energy needs, as well as its low transmission costs. Siting of nuclear plants in a nuclear-hydrogen scenario could be far distant from cities thus obviating one of today's most pressing problems. Hydrogen can also provide for the storage capacity needed to meet both daily and seasonal peaking requirements. These requirements may be satisfied most economically by large-scale underground storage in depleted natural gas formations.

Recent high interest in the area of the hydrogen economy has been shown by the increasing number of conferences, study groups, and meetings being held on this topic. Among the latest and most outstanding of these were the "Cornell International Symposium and Workshop on the Hydrogen Economy" held August 20-22, 1973, the earlier "Working Symposium on Liquid-Hydrogen-Fueled Aircraft" held at NASA's Langley Research Center on May 15-16, 1973, and the NASA-ASEE 1973 Systems Design Institute held on the topic of "Hydrogen as a Future Energy Carrier" at Johnson Space Center from June through August 1973.

The growth of information on the above concept, known as "Hydrogen Energy" or as the "Hydrogen Economy," has been both rapid and diffuse in the years since 1968 when interest and work developed in this field. At the present time, publications on the "Hydrogen Energy" concept average about 100 per year. Consequently, a number of important references may not be widely known and may be difficult to obtain. Examples of these include government reports, industrial contractor reports, university research reports, journal articles, and recent papers given at technical society meetings that are not yet abstracted.

Recognizing the need for complete and up-to-date information on energy in general, and particularly on the "Hydrogen Energy" concept, the ENERGY INFORMATION CENTER was recently established at the University of New Mexico under the auspices of the College of Engineering and the Technology Application Center.

INTRODUCTION

A conservative study of the demand for energy in the United States indicates a doubling of the consumption of energy from the present to the year 2000. Most of today's energy needs are met by fossil hydrocarbons that have finite reserves and are becoming in short supply throughout the world. To conserve these fossil sources and ensure a high standard of living, a synthetic nonpolluting fuel derived from a renewable primary energy source must be used. Hydrogen, a recyclable fuel that can be produced from water, appears to be one answer embodying great potential.

Hydrogen is compatible with most of today's fuel requirements with one exception; certain on-board storage difficulties for automotive-type vehicles are foreseen. Industry can, however, use hydrogen as a fuel in most applications where fossil fuels are now used. The industrial-chemical use of hydrogen will not be radically altered; in fact, hydrogen could find many more applications such as its use in the direct reduction of metallic ores. Residential and commercial use of hydrogen appears both feasible and practical, especially in new buildings. However, the changeover of existing structures does present some problems due to cost and safety considerations. Finally, the use of hydrogen as a fuel in electrical power generation appears to be not only feasible, but may provide higher efficiencies than presently possible in conventional generating plants.

The handling and safety considerations for gaseous hydrogen appear to be no more complex than for existing gaseous fuels such as natural gas; and society can adapt to the use of hydrogen as a fuel with a reasonable time period for information, education, and guidance.

It should be stressed at this point that hydrogen, per se, is not a primary energy source but a synthetic fuel or "energy carrier." A source of energy such as nuclear, solar, or wind energy must be utilized in order to produce hydrogen. Methods commercially available today to produce hydrogen are the electrolysis of water and possibly the gasification of coal with steam. Closed-cycle water/thermochemical decomposition methods are rapidly being developed, both in Europe and in this country, due to their promise of high conversion efficiencies.

The most modern computerized literature search techniques, as well as the assistance of many workers in this exciting field, have been used to compile this extensive bibliography with abstracts on all aspects of the "Hydrogen Economy." In addition to publishing this initial bibliography, the Energy Information Center will publish a quarterly update on the same subject and provide copies of selected references upon request.

This bibliography seeks, as its main goal, to cover the topic of hydrogen as an energy carrier. However, other aspects of hydrogen have not been neglected.

The technical editor has added some technical and personal bias to the abstracts by identifying certain articles with an asterisk (*). These articles are considered to have leading merit and give the user greater familiarity with the field.

Although a considerable effort has been made to ensure that the bibliography is substantially complete, readers and researchers in the field are asked to notify the Technical Editor of any omissions and to supply the missing articles or reports.

Kenneth E. Cox, Ph.D.
Technical Editor
Technology Application Center, and
Associate Professor, Department of
Chemical and Nuclear Engineering
The University of New Mexico

GUIDE TO USE OF THIS PUBLICATION

A number of features have been incorporated to help the reader use this document. These consist of:

- A TABLE OF CONTENTS listing general categories of subject content and the indexes available. Locations of these within the document are indicated by black edge tabs. More specific coverage by subject terms or title can be located through the appropriate index.

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- An INDEX OF CORPORATE SOURCES, where identified.

- An INDEX OF PERMUTED TITLES to afford access through any major word in the title.

- An INDEX OF PERMUTED SUBJECT TERMS to provide access through any terms assigned as being indicative of the major subject content of each citation.

  NOTE: COORDINATE TERM SEARCHING of subject content is inherently available through the user's consideration of associated terms in this subject term permutation.

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* To use, bend book to fan open the page fronts. Locate desired section keyed to index mark along right edge of this page.

** Citation numbers appear on upper right corner of each page.

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** Citation numbers appear on upper right corner of each page.

I. GENERAL

H73 10000* THE HYDROGEN ECONOMY
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), Scientific American, V 228:13-21 N1 Ja 73, Avail:TAC

As the fossil fuels run out, they will become more expensive, making the direct use of nuclear electrical energy relatively more economical. In this situation a case can be made for utilizing the nuclear-energy sources indirectly to produce a synthetic secondary fuel that would be delivered more cheaply and would be easier to use than electricity in many large-scale applications.

In many respects hydrogen is the ideal fuel. Although, it is not a "natural" fuel, it can be readily synthesized from coal, oil or natural gas. More important, it can be produced simply by splitting molecules of water with an input of electrical energy derived from an energy source such as a nuclear reactor. Perhaps the greatest advantage of hydrogen fuel, however, at least from an environmental standpoint, is the fact that when hydrogen burns, its only combustion product is water.
(HYDROGEN, FUEL, ENERGY, TRANSMISSION, STORAGE, USE)

H73 10001 "THE ECOLOGY FUEL" THE HYDROGEN ECONOMY CONCEPT
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), IGT Gas Scope, V 2 N5 May 73, Cryogenic Information Report, Avail:TAC

"As the United States' supply of nonpolluting fossil fuels begins to dwindle, the gas industry has begun a search for alternative sources of clean-burning energy, such as the gasification of coal and importation of LNG .... Nuclear and solar energy are the only effectively abundant energy sources that can be considered to fill the country's long-term energy gap. But almost all work to harness these energy forms is directed toward using them to produce electric power....... An all-electric economy is undesirable for a number of reasons....... For the past 10 years, IGT has been studying a synthetic chemical fuel than can easily be produced from nuclear or solar energy and other readily available sources: Hydrogen."

The article discusses not only the production of hydrogen, but the storage, transmission and safety aspects.

"Although years of research and work are ahead of us, we feel that the great potentiality of such a system justifies time and effort."
(HYDROGEN, ENERGY, FUEL, ECONOMY, PRODUCTION, STORAGE, TRANSMISSION, USE)

√ H73 10002* A HYDROGEN-ENERGY SYSTEM
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), American Gas Association, Rep No L21173, Aug 72, Avail:TAC

Because of the limited supplies of fossil fuels available, our energy supply pattern will undergo some radical changes in the near future. One change is that energy in any form is going to cost more in proportion to the other things we can buy. Another change is that the sources of energy which we use will have to change and relatively "inexhaustible" supplies such as nuclear energy will have to play an increasing part. These changes will precipitate a number of other radical changes, which themselves will be tempered by our increasing desire to avoid "pollution" or to minimize the effects of our technological progress upon our environment.

One of the changes that is possible is the development of a fuel system based upon a synthetic chemical fuel derived from nuclear energy and fully recycable materials such as air and water. Of the various fuels that can be considered, the most likely to come into use is hydrogen. An energy industry based upon hydrogen for energy storage, distribution and utilization has been termed "The Hydrogen Economy." There is growing interest in such a concept on the part of various industrial companies, the U.S. Government, the Atomic Energy Commission, the American Gas Association, and others.

In the "Hydrogen Economy," hydrogen will be produced from nuclear energy by today's known technology using water electrolysis. Direct-current electric power from a nuclear power station can be used to electrolyze water into hydrogen and oxygen at efficiencies of about 100% (in comparison to today's figures of between 60 and 70%). New methods will also be developed for water-splitting using the nuclear reactor heat directly.

Hydrogen will be used for all the present applications of natural gas and more. Burners can be designed to handle hydrogen in heating, cooking and industrial operations. Gas turbines and piston engines will operate better on hydrogen. Fuel cells that use hydrogen as a fuel are simpler and cheaper than those that use hydrocarbon fuels. As we have already mentioned, hydrogen is an extremely clean fuel, the controlled burning of which produces only water. The benefit of such a clean fuel on the environment will be considerable.

Hydrogen will be transmitted from the remote, possibly offshore, power stations in underground high-pressure pipelines similar to those used for natural gas today. In many instances, the same lines can be used, with modifications to the compressor stations. There appear to be no insurmountable problems in doing this. Hydrogen will be distributed in networks similar to those used for today's natural gas. Some extra safety considerations are necessary, but appear to be acceptable. (HYDROGEN, ECONOMY, ENERGY, FUEL, STORAGE, TRANSMISSION, USE, SYSTEMS, STUDY, COST)

H73 10003 GAS INDUSTRY'S ROLE IN THE NUCLEAR AGE
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), ASHRAE Journal, V 13:38-40 Sept 71, Avail:TAC

Moving to a nuclear age, the problems of electricity transmission, distribution and storage become increased. Hydrogen is the simplest conceivable synthetic fuel that exists as an alternative to electricity. A hydrogen energy system has benefits in transmission and distribution costs over electricity, additionally hydrogen is an ideal fuel in many respects for combustion or for reconversion to electricity via the fuel cell. (HYDROGEN, ENERGY, ECONOMY, FUEL, STORAGE, TRANSMISSION, USE, ELECTROLYSIS)

H73 10004 A NEW CONCEPT IN ENERGY TRANSMISSION
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), Public Utilities Fortnightly, V 89:21-29 Fe 3 '72, Avail:TAC

As we move from a fossil fuel economy toward a nuclear power age to meet the burgeoning energy demands of this country, the problems of electricity transmission, distribution and storage become accentuated. An alternative exists to the growing number of overhead power lines ap-

pearing around our cities. Hydrogen is a synthetic fuel that could be made from water and electricity at the power stations and used as a means of underground energy transmission. It is an ideal fuel in many respects for combustion to obtain heat or for reconversion to electricity near the user. Economically, transmission of a gas is far cheaper than transmission of electric power, especially underground. This concept is not without its problems; nevertheless, it surely deserves detailed consideration in the future.
(HYDROGEN, ENERGY, FUEL, ECONOMY, STORAGE, PRODUCTION, TRANSMISSION, USE, ELECTROLYSIS)

H73 10005* "THE HYDROGEN ECONOMY"
Gregory, D.P., D.Y.C. Ng, and G.M. Long, Electrochemistry of Cleaner Environments, J.O'M. Bockris, Ed., Plenum Press, New York, 72, Chap. 8, Avail:TAC

This chapter sets out to study the impact on industry and society of a transition from fossil fuels to hydrogen as our basic source of stored energy. Some speculative assumptions have had to be made, among them the basic one that hydrogen will indeed be accepted as a fuel and will take the place of methane in the natural-gas industry. Having made these assumptions, we will attempt to discuss real effects and not to speculate further. We will consider future hydrogen production techniques, problems, and its characteristics in pipeline transmission; means for storing hydrogen to provide short-term energy reserves; the use of hydrogen as a conventional fuel for cooking, heating, vehicle propulsion, and the generation of electricity locally; the storage of electrical energy using hydrogen fuel cells; and the expanded use of hydrogen as a chemical raw material. In line with the theme of this book, electrochemical aspects will be emphasized and the impact of our assumptions on the pollution of the environment will be discussed.
(HYDROGEN, ENERGY, FUEL, USE, SAFETY, ELECTROLYSIS, ENVIRONMENT)

H73 10006 PRODUCTION AND DISTRIBUTION OF HYDROGEN AS A UNIVERSAL FUEL
Gregory, D.P. and J. Wurm, 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Aug 72, Avail:TAC

As we deplete our fossil fuels, their cost will in-

crease until alternative energy sources become competitive. The cost of providing an energy supply is strongly influenced by the cost of delivering or transmitting the energy from its source to its point of use. Modern technology leans toward electrical energy as a means of supplying our increasing energy needs and toward nuclear-electric power as an ultimate substitute for fossil fuel. Electric power, however, is a most expensive energy form to transmit and deliver and cannot readily be stored. A synthetic chemical fuel could be storable and cheaper to transmit. When we consider the various synthetic chemical fuels that could be made from nuclear power, hydrogen appears as the cleanest and simplest candidate for an energy-distribution medium. Its combustion products are compatible with the atmosphere. Hydrogen could, in principle, be distributed as universally as natural gas is today, using most of the same technology, But its use would present some new technological problems. It could do all of the jobs done by natural gas, and more. Its universal availability would give rise to new technological opportunities. Transition to a "hydrogen economy" would have to be a well-planned, nationwide operation. Since hydrogen can easily be made today from conventional fossil fuels, it could bridge the gap between the fossil age and the nuclear age by a well-thought-out conversion program.
(HYDROGEN, PRODUCTION, FUEL, ENERGY, TRANSMISSION, USE, SAFETY, ENVIRONMENT)

H73 10007 WHEN HYDROGEN BECOMES THE WORLD'S CHIEF FUEL
Anon, Business World, p 89+ Sept. 23 '72

The sea is full of it. It doesn't pollute. And it returns to the sea after it's burned.
(HYDROGEN, FUEL)

H73 10008 HYDROGEN: LIKELY FUEL OF THE FUTURE
Anon, Chemical and Engineering News, V 50:14-17, Je 26 '72, Avail:TAC

By now almost everyone must know that there are serious problems relating to energy fuels. Many ways out of the "energy crisis" have been proposed. One route, however, has until recently received relatively little attention. That route is a fuel economy based on hydrogen, a concept that shows promise of becoming a major subject in energy discussions of the future.

In this article, the first of a three-part series, C & EN considers arguments and actions relating to hydrogen's use as an energy carrier in a hydrogen fuel economy of the future. For hydrogen ever to achieve large-scale use, there must be large-scale production. Part two of the series, to be published July 3, will survey present and future hydrogen production technology. Large-scale production of hydrogen implies the ready availability of cheap hydrogen in large quantity. Part three, to be published July 10, considers the implications of such hydrogen availability on the industrial sector in general.
(HYDROGEN, ENERGY, FUEL, ECONOMY, CARRIER, USE)

H73 10009 "HYDROGEN: CANDIDATE FOR UNIVERSAL FUEL"
Anon, Chemical and Engineering News, v 50:34-5, Ap 17 '72, Avail:TAC

In the push for alternatives to fossil fuels to reduce the threat of an energy crisis, most attention has been focused on nuclear power generation and synthetic gas and oil. However, in the urgency to provide alternatives, those involved may be overlooking the virtues of hydrogen as a universal fuel.
(HYDROGEN, FUEL, ENERGY, ECONOMY, USE)

H73 10010 "THE H_2INDENBURG SOCIETY"
Anon, Chemical and Engineering News, V50:3, May 29 '72, Avail:TAC

This society was founded in Boston in April, 1972 and is "dedicated to the safe utilization of hydrogen as a fuel." (For information, contact the Secretary W.J.D. Escher, Escher Technology Associates, St. Johns, Mich.)
(HYDROGEN, SAFETY)

H73 10011 HYDROGEN-ENERGY SYSTEM
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), American Chemical Society, Division Fuel Chemistry, Preparation, V 16:88-94 N4, Ap 10-14 '72, Avail:TAC

This is a review of economic, technological and ecological aspects of production, transportation and utilization of hydrogen as one of the most important sources of energy in the future. The following highlights are detailed - energy supply; nuclear electric power; nuclear chemical power, hydrogen fuel; and hydrogen production, transmission and production cost. The benefits of the system described are indicated. 7 refs. (HYDROGEN, ENERGY, ECONOMY, NUCLEAR, PRODUCTION, TRANSMISSION, STORAGE, USE, COST)

H73 10012* STUDY, COST, AND SYSTEM ANALYSIS OF LIQUID HYDROGEN PRODUCTION FINAL REPORT
Hallett, N.C., (Air Products and Chemicals, Inc., Allentown, Pa.), N68-28227 (Contract NAS2-3894) (NASA-CR-73226) CFSTI: HC $3.00/MF $0.65 CSCL 07A, 323 p, Je 68, refs, Avail:TAC

This report contains information related to contemplated large-scale liquid hydrogen systems. Descriptions of feasible processes and equipment are presented. Information concerning availability and cost of required raw materials and energy are projected. Composite system analyses based on preliminary NASA hypersonic transport (HST) liquid hydrogen requirements indicate estimated average product cost of 7.7 to 8.8 cents per pound. (HYDROGEN, STUDY, PRODUCTION, LIQUID, COST, SYSTEM ANALYSIS)

H73 10013* HYDROGEN: TOMORROW'S FUEL?
Chopey, N.P., Managing Editor, Chemical Engineering, P 23-26 Dec 25 '72, Avail:TAC

It isn't going to happen soon, but hydrogen derived from water could eventually supplant all fossil fuels, as well as all electrical distribution networks. (HYDROGEN, WATER, FUEL)

H73 10014 "SECOND THOUGHTS ON THE HYDROGEN ECONOMY"
Anon, Science News, V 104:9 Sept 1 '73, Avail:TAC

A major problem facing proponents of the various so-called "exotic" energy sources is whether or not such sources can be made socially and economically feasible - issues theoretically inclined scientists sometimes have trouble judging. The idea of using hydrogen as the basic fuel of the future, for example, has recently gained popularity and a conference last week at Cornell University offered a rare opportunity for multidisciplinary debate on the subject. (HYDROGEN, ECONOMY, ENERGY)

H73 10015 "HYDROGEN-HEATED TOWNS PLACED ON ENERGY CRISIS SOLUTION LIST."
Anon, Albuquerque Journal, Sept 11 '73, Avail:TAC

New American towns which would operate solely on hydrogen power could be one solution to the energy crisis, a University of New Mexico professor, Dr. Kenneth Cox, believes.
(HYDROGEN, ENERGY)

H73 10016 ANOTHER HYDROGEN CAR OUT WEST
Anon, Industrial Resources, V 14:25 Oct 72, Avail:TAC

Los Angeles -- In recent months, a number of experts have suggested the future energy needs of the U.S. may be met by a "hydrogen economy."

The references were mainly to the use of hydrogen fuel in the utility field. However, a group of engineering students at the University of California at Los Angeles have built a modified automobile that again raises the possibility of using hydrogen to power tomorrow's cars.

The revamped automobile built at UCLA was penalized by the weight of the storage container for the gaseous hydrogen. Although the car was a prizewinner in the recent nationwide Urban Vehicle Design Competition, the container design restricted the car's range before refueling to only to 96 km (60 miles).
(HYDROGEN, ENERGY, ECONOMY, TRANSPORTATION)

H73 10017 HYDROGEN AND POWER: A LETTER
Cook, C.S., Science, V 180:370 N4084 Ap 27 '73, Avail:TAC

In this letter, C. Sharp Cook discusses the "hydrogen-energy" concept on a commercial basis.
(HYDROGEN, ENERGY)

H73 10018 HYDROGEN PRODUCTION FOR BETTER NUCLEAR UTILIZATION
Thornton, R.M., (Georgia Institute of Technology, Atlanta), Transactions of the American Nuclear Society, V 15:27-28 N2 72, From Conference on nuclear power for tomorrow; Atlantic City, N.J. Aug 22 '72, See CONF-720817, Avail:TAC

One of the foremost restrictions placed on the rapid growth of nuclear power has been the economic necessity of using it as a base-load network. If the base load could be raised enough to "flatten" a utility's power demand curve, then nuclear systems could become the sole power-generation source for society. To promote this,

a study into the feasibility of using off-peak electrical power from nuclear plants to produce hydrogen by electrolysis was made.
(HYDROGEN, NUCLEAR, OFF-PEAK, ELECTROLYSIS)

H73 10019 SOLAR SEA POWER
Zener, G., Physics Today, V 26:48-53 Ja 73, Avail:TAC

Heat engines operating in the tropical oceans, capitalizing on the temperature differential between upper and lower levels, could provide a source of economical, pollution-free electricity.
(HYDROGEN, ECONOMY, ENERGY, ELECTROLYSIS, FUEL, VEHICLE, OXYGEN)

H73 10020 CRYOGENIC H_2 AND NATIONAL ENERGY NEEDS
Hord, J., Cryogenic Engineering Conference, Atlanta, Ga., Aug 8 '73, Avail:TAC

C

Our impending fossil fuel shortage is a clear challenge to the cryogenics industry and government to provide efficient and economical means of satisfying specific national fuel requirements. Large scale production of liquid hydrogen was stimulated by the U.S. space exploration program. Now, civilian demands for synthetic fuels beckon cryogenic hydrogen.

National and world energy shortages are briefly summarized to demonstrate the relevance of synthetic fuels in satisfying future energy markets. A perspective of national energy needs, as they relate to cryogenic hydrogen fuel, is given. Hydrogen and alternate synthetic fuels are briefly reviewed and potential applications for cryogenic hydrogen are described. Technical research and development efforts, required to satisfy specific current and future national needs, are identified. The mechanism for implementation of synthetic fuels and the indistinct timetable for transition to these fuels are discussed.
(HYDROGEN, ENERGY, USE, CRYOGENIC, FUEL, SYNTHETIC)

H73 10021 IS HYDROGEN THE FUEL OF THE FUTURE?
Trotter, R.J., Science News, V 102:46-47 Jl 15 '72, Avail:TAC

Shrinking fossil-fuel resources and rising environmental concerns have made imperative, as all the world must now be aware, the development of new power sources. Alternatives such as nuclear, hydroelectric, solar, geothermal, tidal and meteorological power will all be used to produce nonfossil chemical fuels.

One such fuel, hydrogen, is being examined with increasing interest as a possible major fuel of the future.
(HYDROGEN, FUEL, FUTURE)

H73 10022 HYDROGEN AND POWER: A LETTER
Bockris, J. O'M., Science, 180:370 N4084 Ap 27 '73

In this letter, the writer discusses the commercial feasibility of hydrogen economy compared with conventional energy sources.
(HYDROGEN, POWER, ECONOMY)

H73 10023 HYDROGEN FIGURES IN MANY ENERGY PROPOSALS
Anon, Chemical and Engineering News, V 50:33-34 Oct 2 '72, Avail:TAC

It is no longer necessary to justify use of hydrogen as an energy storage medium. Most of the technical and scientific communities that are wrestling with concepts for restructuring the national energy system accept hydrogen, although they also have become acutely aware of the packaging and transportation problems that remain to be solved. Hydrogen now figures in many alternative energy systems proposed.
(HYDROGEN, ENERGY, STORAGE, MEDIUM, SYSTEM, TRANSPORTATION)

H73 10024 HYDROGEN FUEL ECONOMY; WIDE-RANGING CHANGES
Anon, Chemical and Engineering News, V 50:27-28+ Jl 10 '72, Avail:TAC

It's difficult to predict the shape of private or industrial life in a hydrogen fuel economy, but parts of the outline can be penciled in. Transportation technology would be affected. Changes would take place in domestic and commercial uses of fuel. Probably one of the major impacts in the industrial area would stem from availability of large quantities of low-priced hydrogen. Transport and storage of hydrogen are yet another part of the picture.

The feasibility of using hydrogen as a fuel in internal combustion engines has been demonstrated (C&EN, June 26, page 16), and fuel cells based on hydrogen are another possibility for powering vehicles. But hydrogen's

reach could extend beyond just surface transportation.
(HYDROGEN, FUEL, ECONOMY, USE, TRANSPORTATION, STORAGE, INTERNAL COMBUSTION, FUEL CELL)

H73 10025 HYDROGEN FUEL USE CALLS FOR NEW SOURCE
Anon, Chemical and Engineering News, V 50:16-18 Jl 3 '72, Avail:TAC

The replacement of hydrocarbon fuels by hydrogen in the long term would require a new source of hydrogen and a new technology to produce, transmit, and distribute it. The only "endless" source of hydrogen is the sea. However, until present supplies of gas, oil, and coal become economically unattractive, they will remain the best source of hydrogen, fuels, and chemicals.

In the not-too-distant future, coal conversion probably will take up most of the slack left by depletion of natural gas deposits, During the same time, it's possible that electrolytic hydrogen will influence the gasification era.
(HYDROGEN, FUEL, ECONOMY, COAL, CONVERSION, ELECTROLYSIS)

H73 10026* A HYDROGEN ECONOMY
Bockris, J. O'M., Science, V 176:1323 N4041 Je 23 '72, Avail:TAC

The medium of energy transport from an atomic reactor to sites at which energy is required should not be electricity, but hydrogen. The term "hydrogen economy" applies to the energetic, ecological and economic aspects of this concept.

The concept envisages atomic reactors held on platforms floating on water. They are in water sufficiently deep to make heat dissipation easy. The electricity they make would be converted on site to hydrogen and oxygen by electrolysis. The hydrogen would be piped to distribution stations and thereafter sent to factory and home. Reconversion to electricity would take place in on-site fuel cells, the only side product being pure water.

The main difficulties which we would face in getting started toward a hydrogen economy are (i) conservatism; (ii) the absence of education or training in electrochemical engineering; and (iii) the public's fear of hydrogen.

//

(HYDROGEN, NUCLEAR, ENERGY, FUEL, FUEL CELLS, OXYGEN, ELECTROLYSIS)

H73 10027 HYDROGEN - FUEL OF THE FUTURE?
Armagnac, A.P., Popular Science, V 128:64-67 Ja 73, Avail:TAC

Teamed with atomic power, element No. 1 might be the prime answer to air pollution and our "energy crisis."
(HYDROGEN, FUEL, FUTURE)

H73 10028 HYDROGEN GETS TOP BILLING AS FUTURE "CLEAN FUEL"
Burgess, Eric, Christian Science Monitor, Boston, Mass., V 2: Oct 28 '72, Avail:TAC

Hydrogen offers a cleaner source of energy than fossil fuels and provides the consumer with a single fuel than can be derived equally well from fossil fuels and sea water, allowing for flexibility of energy system usage. Oil importation from overseas will reach a crisis stage by 1980, making a search for feasible alternatives imperative. Hydrogen is cheaper to produce and transport and easier to store than fossil fuels.
(HYDROGEN, FOSSIL FUELS, ECONOMICS)

H73 10029 A HYDROGEN-ELECTRIC UTILITY SYSTEM WITH PARTICULAR REFERENCE TO FUSION AS THE ENERGY SOURCE
Tanner, E.C. and R.A. Huse, 7th Intersociety Energy Conversion Engineering Congerence, San Diego, Calif., Aug '72

The use of hydrogen for large-scale energy storage, transmission, and distribution is discussed. A numerical example is given for one specific configuration -- a fusion reactor linked to an electrolyzer plant. The advantages lie in the abundance of hydrogen, the low cost and high reliability of transmitting energy by pipeline, and the elimination of many constraints on plant siting. Problems arise from inefficiencies in electrolysis and in the reconversion of hydrogen to electricity. These inefficiencies result in more waste heat and drive up costs to the customers. Technological improvements can be expected which will lead to more efficient performance.
(HYDROGEN, USE, STORAGE, TRANSMISSION, ELECTROLYSIS)

H73 10030 "THE CLEANING OF AMERICA"
Williams, L.O., Astronautics and Aeronautics, V 10:42-51 N2 Fe 72, Avail:TAC

Automobiles, airplanes, powerplants, and steel mills will turn into models of ecological virtue, and we can rejuvenate rivers, and ... more, when we switch to a nuclear-hydrogen energy system.
(HYDROGEN, ENERGY, FUEL, ENVIRONMENT, NUCLEAR, ECOLOGY)

H73 10031* HYDROGEN AND OTHER SYNTHETIC FUELS ✓
Michel, J., Chairman, Synthetic Fuels Panel, Doc. No. TID-26136, Avail:TAC C

An assured long-term supply of energy is essential for the growth and maintenance of a modern industrial nation such as the United States. The current energy crisis this country is facing is well documented. Therefore it seems highly appropriate to investigate alternative energy systems which could provide the U.S. with the means of overcoming these problems. By 1985, the U.S. would be importing over one-half its petroleum and would have a shortfall in natural gas supply of about one-half of demand.

Synthetic fuels from nonfossil sources appear to be the most likely alternative for supplying the long-term needs for gaseous and liquid fuels.

Hydrogen is a particularly attractive synthetic fuel for the following reasons:

1. It is essentially clean burning, the main combustion product being water.
2. It may be substituted for nearly all fuel uses.
3. It can be produced from domestic resources.
4. It is available from a renewable and universal raw material--water.
5. Nearly all primary energy sources, nuclear, solar, etc., may be used in its production.

The main obstacles to the use of hydrogen as a universal fuel are its high cost relative to the current low prices for fossil fuels and, for some applications, the unresolved problems of handling a low-density or a cryogenic fluid. Safety considerations, while important, are not believed to present a serious technical obstacle to its widespread use.
(HYDROGEN, ENERGY, SYNTHETIC, FUEL, SYSTEM, SAFETY, CRYOGENIC, ELECTROLYSIS)

H73 10032* HYDROGEN--A CLEAN FUEL FOR URBAN AREAS
Winsche, W.E., T.V. Sheehan, and K.C. Hoffman, Intersociety Energy Conversion Engineering Conference, Boston, Mass., Aug 71, Avail:TAC

The use of hydrogen as a clean general-purpose fuel for the more densely populated sections of an urban area is studied as a means of reducing air pollution and to provide for the effective utilization of off-peak electric power. A forecast of the 1985 electric power supply for the entire metropolitan New York City region, including suburban counties, indicates that sufficient hydrogen could be produced by the electrolysis of water, using the off-peak electrical power available throughout the region, to provide over half of the energy required for transportation or, alternatively, nearly all of the space heat requirements within the New York City limits where the environmental problems are most severe. Additional hydrogen could be produced from coal and delivered to the City by pipeline to provide the balance of the energy needs for transportation as well as for household, commercial, and industrial use. A combined hydrogen and electrical energy supply would eliminate all of the CO_2, CO, hydrocarbon, SO_2, and particulate emissions from energy conversion devices located within the City. The by-product oxygen produced along with the hydrogen in the electrolysis operation provides an ample supply throughout the metropolitan region for the treatment of sewage and industrial wastes, for use as the oxidizer to eliminate NO_x emission from incinerators and for the treatment and revitalization of polluted bodies of water. (HYDROGEN, FUEL, ENVIRONMENT, URBAN, ENERGY, ELECTROLYSIS)

H73 10033* "HYDROGEN AND SYNTHETIC FUELS FOR THE FUTURE"
Michel, J.W., American Chemical Society Symposium on "Chemical Aspects of Hydrogen as a Fuel," Chicago, Ill., Aug 73, Avail:TAC

Early in 1972 the Energy R&D Goals Committee of the Federal Council on Science and Technology organized a study to assess a number of basic energy technologies which could favorably influence the U.S. future energy supplies. Various federal agencies sponsored eleven technical panels to perform this assessment and to prepare R&D plans for developing the priority technologies. The findings of one of these panels, "Hydrogen and Synthetic

Fuels," sponsored by the USAEC, is the primary subject of this paper.

While there are currently serious problems in providing adequate electricity, the longer-term energy problems seem to be more associated with providing an assured supply of environmentally acceptable portable fuels. The importance of this supply is apparent when it is realized that electrical energy only meets one-tenth of our end-energy needs today - the remainder is supplied from fossil fuels, mainly petroleum and natural gas.

While production of synthetic fuels requires thermal or electrical energy and thus may appear to complicate an already difficult problem, this energy can be obtained from domestic and, for the most part, clean sources, e.g., nuclear or solar. Further, because of low transport costs, synthetic fuels can be produced at remote, well-regulated plants and thus would not contribure to the primary pollution problems that exist in our urban centers. An additional consequence of such a system is that of conservation of our limited fossil fuel resources, particularly petroleum, so that they may be used as valuable chemical product feedstocks and in metallurgical processes. The synthetic fuels, especially hydrogen, may be consumed with very little or no air pollution as well as with higher conversion efficiencies and thus could be more attractive for urban uses than the fossil fuels in current use.

The intent of this paper is to summarize the findings of the Synthetic Fuels Panel which evaluated the major aspects of new fuels systems, i.e., production, storage and transportation, end uses and an overall systems analysis. While the emphasis was on hydrogen and other fuels from nonfossil sources, a section on the use of coal to produce hydrogen and methanol is also included to help define the interim time period before our dependency on nonfossil fuels occurs.
(HYDROGEN, ENERGY, SYNTHETIC, FUEL, ASSESSMENT, POLLUTION, PRODUCTION, STORAGE, METHANOL)

H73 10034* HYDROGEN: SYNTHETIC FUEL OF THE FUTURE
Maugh, T.H., Science, V 178:849 Nov 24 '72, Avail:TAC

Nuclear fission and fusion -- and perhaps solar energy -- will almost certainly be the major energy sources and should, in theory, be capable of supplying all our energy needs. Most developmental work on these sources has emphasized the production of electricity, however, while only 10 percent of energy and use is supplied by electricity. The remainder is supplied by the combustion of fuels to produce heat energy that is used in industry, homes, and transportation. It is likely both that electricity will play a larger role in applying future energy demands and that heat energy from nuclear reactors will be utilized in large nuclear/industrial complexes, or nuplexes. Nonetheless, there will remain a strong demand for portable, fluid fuels, particularly for applications in transportation, and the most likely response to this demand will be vastly increased production of hydrogen.

Hydrogen, of course, is not an alternative primary energy source, because large amounts of energy will be required to produce it. Rather, it holds promise of being a highly efficient energy carrier that would prove valuable in situations where transfer of energy as electricity is inefficient, impractical, or impossible. It is this potential that has generated such widespread interest in the possibility of a "hydrogen economy."

In many ways, hydrogen is virtually an ideal fuel. When it is burned in air, the only possible pollutants are nitrogen oxides derived from the air itself, and concentrations of these are generally lower than concentrations produced by other fuels.
(HYDROGEN, SYNTHETIC, FUEL, FUTURE, ENERGY, NUCLEAR, CARRIER, ECONOMY)

H73 10035* HYDROGEN AND ENERGY
Marchetti, C., Chemical Economy & Engineering Review, V 5 Nl Ja 19 '73, Avail:TAC

The challenge of the century for chemical engineers ---thermochemical cycles to produce hydrogen---may bring a revolution in the technology and management of energy and food.

Hydrogen has a peculiar position in nature:
-it is the most abundant element;
-it plays a key role in fueling the universe;
-it is the first chemical product in photosynthesis i.e. the chemical mediator between sunlight and the biosphere.

Hydrogen can become the main energy mediator between the newly harnessed nuclear energy and human society, so avoiding most of the political, ecological, long-term

procurement problems connected with the use of fossil fuels. Via proper microorganisms it can be employed to produce "primary" food, easing the pressure on agriculture. This fact will have even more revolutionary consequences.
(HYDROGEN, ENERGY, NUCLEAR, FOOD, ECOLOGY)

H73 10036 HYDROGEN, MASTER-KEY TO THE ENERGY MARKET
Marchetti, C., Euro Spectra , V 10:117-130 N4 Dec 71, Avail:TAC

An analysis of the potential uses of hydrogen shows that practically the whole of the energy market can be served by this "clean" energy medium.
(HYDROGEN, ENERGY, MARKET, ENVIRONMENT)

H73 10037 THE HYDROGEN ECONOMY--AN ULTIMATE ECONOMY? A PRACTICAL ANSWER TO THE PROBLEM OF ENERGY SUPPLY AND POLLUTION
Bockris, J. O'M., (Flinders Univ. of South Australia, Bedford Park) and A.J. Appleby, (CNRS, Laboratoire d'Electrolyse et Service d'Electrophorese, Bellevue, Fr.), Environment This Month. The International Journal of Environmental Science, Lancaster, Eng. V 1:29-35 N1 Jl 72

The use of H_2 as the medium of energy between remote energy producing sites and population centers is considered. Hydrogen could be used to generate electricity at the site or could be used directly as a fuel. Production of H_2 by water electrolysis and radiolysis is described, and the consequences of a H_2 economy on all aspects of human life requirements are discussed. A H_2 economy would be entirely nonpolluting and would make high energy densities possible for all regions of the world, hastening the spread of uniform high living standards.
(HYDROGEN, ECONOMY, ENVIRONMENT, ENERGY, ELECTROLYSIS, POLLUTION, FUEL)

H73 10038 THE MASTER OF A NEW AGE
Lessing, L., Fortune, V 63:152-156+ N5 May 61, Avail:TAC

The first and lightest chemical element, hydrogen, runs like an invisible stream through many of the most portentous developments of the age. It is rising by improved processes to ever greater volume in the oil and chemical industries. It is powering, later this

year, the upper stage of the Atlas-Centaur rocket, first in a line of new liquid-hydrogen vehicles that will finally give the U.S. thrust to go ahead in space. It also provides the working fluid for the nuclear rocket, an advanced engine for space. Finally, by various chemical and thermonuclear means, hydrogen is on the verge of yielding within limitless sources. Quite aside from its ominous accomplishments in the bomb, therefore, hydrogen appears to be the master fuel of a new age.
(HYDROGEN, ENERGY, VEHICLE, NUCLEAR)

H73 10039 THE COMING HYDROGEN ECONOMY
Lessing, L., Fortune, V 86:138-142 N5 Nov 72, Avail:TAC

The vision involves moving by stages from an economy based on the hydrocarbons -- coal, oil, and natural gas-- to a pure hydrogen economy. Hydrogen, by far the most abundant, energetic, and the cleanest of all the elemental fuels in the universe, "may well be decisive technology of this century."
(HYDROGEN, FUEL, HYDROCARBON, ECONOMY)

H73 10040* HYDROGEN: KEY TO THE ENERGY MARKET
de Beni, G. and C. Marchetti, Euro Spectra, V 9:46-50 N2 Je 70, Avail:TAC

The conclusions arrived at in this study, which are shortly to be published, are that hydrogen can be an extremely flexible intermediate which would make it possible to penetrate the whole of the market without any sudden changes in technology being necessary. In certain cases the substitution is a straightforward matter; town gas, for example, already contains 50-90% hydrogen. In other cases it would seem to be a more complex operation, but in keeping with the normal course of technological development.
(HYDROGEN, ENERGY, MARKET, STUDY, INTERMEDIATE)

H73 10041 HYDROGEN: THE NEW FUEL
Jones, W., Saturday Evening Post, V 244:54+ Spr 72, Avail: TAC

The world is running out of gas, as well as coal, gasoline, and fuel oil.

There is another fuel. We don't use it much, but it is as abundant as water, potentially as cheap as gasoline or natural gas, and it does not pollute our environment.

Hydrogen is the other fuel of our future.

In fact, the scientific, technological, and industrial bases exist now to make hydrogen the fuel of our future rather soon.

(HYDROGEN, FUEL, FOSSIL, WATER, ENERGY, FUTURE, POLLUTION, ENVIRONMENT)

H73 10042* HYDROGEN AS AN ENERGY VECTOR: NEW FUTURE PROSPECTS FOR APPLICATIONS OF NUCLEAR ENERGY

Beghi, G., (European Atomic Energy Community, Ispra, Italy, Joint Nuclear Research Center), N73-15699 (EUR-4838), May 72 20 p refs, Avail:TAC

In view of a wider penetration of nuclear energy in the energy field and therefore of a diversification of its applications, the usefulness of an intermediary energy vector is pointed out. Therefore hydrogen is examined as to its present potential uses in the future. Among the hydrogen production processes, the method of dissociation of water with a closed cycle of chemical reactions and utilizing nuclear heat seems particularly promising.

(HYDROGEN, ENERGY, FUTURE, NUCLEAR, APPLICATION, USE, PRODUCTION, HEAT, WATER, DECOMPOSITION)

H73 10043* HYDROGEN SYSTEMS FOR ELECTRIC ENERGY

Hausz, W., G. Leeth, D. Lueck, and C. Meyer, (TEMPO - General Electric Company Center for Advanced Studies, Santa Barbara, Calif.), Report GE 72TMP-15 Ap 72

Synthetic fuels, particularly hydrogen, can have an important role in future electric energy systems. An attractive "Eco-Energy" system, both ecologically and economically sound, would be based on nuclear reactor heat (fission or fusion) at remote sites, which may be offshore islands or floating platforms. Water would be decomposed into hydrogen and oxygen. Pipelines would deliver the hydrogen and oxygen to small generating units dispersed throughout the electrical load area, and at distribution substations. The dispersed generation used to convert the fuel energy to a-c suitable for underground distribution would be efficient gas turbines and/

or fuel cells of advanced design.

Such a system is completely devoid of the pollutants of fossil fuel systems including nitrogen oxides, because oxygen rather than air is used. It completely eliminates overhead transmission lines, requires less land for corridors, and makes multiple right-of-way use more feasible. The low cost of underground pipeline transmission alleviates nuclear siting problems and hazards. By-product heat from fuel manufacture and electrical power generation could be disposed of in deep waters or used for beneficial purposes in this ultimate system.

In 1985 the cost of energy generated by present types of fission and fossil fuel plants with overhead EHV transmission would be roughly 14 mills/kWh for present technology and 16 to 50 mills/kWh for the alternative systems, at the point of retail sales. However, pressures to locate nuclear plants remotely, to put transmission lines underground, and to use clean fossil fuels (which are becoming much more expensive), would move the reference system upward in cost to 20 to 30 mills/kWh. Improvements in the Eco-Energy system that can be foreseen on a no-surprise basis will both improve the efficiency of many components and reduce the unit cost of manufacture, potentially achieving costs in the year 2000 (1972 dollars) of under 15 mills/kWh.
(HYDROGEN, SYNTHETIC, FUEL, ECOLOGY, ENERGY, SYSTEM, STUDY, COST, POLLUTION, TRANSMISSION)

H73 10044 HYDROGEN MAY EMERGE AS THE MASTER FUEL TO POWER A CLEAN-AIR FUTURE.
Clark, W., Smithsonian, Washington, D.C., 72-1GA-00018, V 3:12-19 N5 Aug 72

Recent experimentation in the use of H_2 as a nonpolluting alternative to gasoline in internal-combustion engines is reported. Four examples of H_2 conversion systems in automobiles are described; all use gaseous or liquid H_2 alone or combined with O_2 or CO_2, with a reduction of NO_x, the only emissions produced. One engine uses exhaust water vapor as an engine coolant. Methods under consideration for the circumvention of H_2-power drawbacks, particularly fuel weight and explosiveness, are discussed. Means of transporting and producing large quantities H_2, including nuclear power reactors to produce both electricity and photons, are also explored.
(HYDROGEN, FUEL, AUTOMOBILE)

H73 10045* LIQUID HYDROGEN AS A FUEL FOR THE FUTURE.
Jones, L.W., Science, V 174:367-370 N4007 Oct 22 '71,
Avail:TAC

The use of liquid hydrogen as a long-term replacement for hydrocarbon fuel for land and air transportation seems technically feasible. It is an ideal fuel from the standpoint of a completely cyclic system, serving as a "working substance" in a closed chemical and thermodynamic cycle. The energy-per-unit-weight advantage (a factor of 3) over gasoline or any other hydrocarbon fuel makes liquid hydrogen particularly advantageous for aircraft and long-range land transport. As a pollution-free fuel, it must be seriously considered as the logical replacement for hydrocarbons in the 21st century.
(HYDROGEN, LIQUID, HYDROCARBON, FUEL, TRANSPORTATION, POLLUTION, ENVIRONMENT)

H73 10046* HYDROGEN: ITS FUTURE ROLE IN THE NATION'S ENERGY ECONOMY
Winsche, W.E., K.C. Hoffman, and F.J. Salzano, Science, V 180:1325-1332 N4093 Je 29 '73

Hydrogen fuel derived from water could extend nuclear power and reduce dependence on imported oil. In the near future, large scale economical sources of energy derived from nuclear fission or from other domestically available primary sources such as solar or geothermal energy will be needed. Because of its complex nature, and for reasons of safety, nuclear energy clearly cannot be utilized directly in small scale transportation systems such as the automobile. Thus the original promise that nuclear power will eventually supply all the nation's energy needs can only be effectively fulfilled by supplying the energy in the form of electricity or some storable, portable fuel.

Hydrogen has the necessary properties and can fulfill the role of a secondary source of energy that can be derived from the primary source by the decomposition of water. It can be substituted for petroleum and coal in almost all industrial processes which require a reducing agent, such as in steel manufacturing and other metallurgical operations. Further, hydrogen can easily be converted to a variety of fuel forms such as methanol, ammonia, and hydrazine. Thus, it is essential that the analysis and technological feasibility of a hydrogen energy system be considered now. It is of vital importance to the nation to develop some general-purpose fuel that can be produced from a variety of domestic energy sources and reduce our dependence on imported oil. (HYDROGEN, FUEL, WATER, STUDY, ENERGY, ANALYSIS, ALTERNATIVE, NUCLEAR, SAFETY, TRANSPORTATION)

H73 10047* HYDROGEN PRODUCTION FOR ECO-ENERGY
Kerns, G.P., (TEMPO - General Electric Company - Center for Advanced Studies, Santa Barbara, Calif.), Report GE72TMP-53 Nov 17 '72

This report is one of a series related to a study done on the "Eco-Energy Project." The preferred system uses hydrogen as the major means of transport of energy from remote sites.

The objective of the project was to identify and analyze the critical aspects of Eco-Energy. In this regard a major problem area was the evaluation of the cost of hydrogen production using nuclear power sources.

The objective of this report is to determine the economics of hydrogen production.
(HYDROGEN, COST, NUCLEAR, ECONOMICS, TRANSPORTATION)

H73 10048 ECO-ENERGY STUDIES AT TEMPO
Hausz, W. and others, Nuclear Engineering, V 17:942-945 Nov 72, Avail:TAC

At the present state of the art, Eco-Energy is far more costly than the present-day electric utility system using fossil-steam plants, overhead transmission lines, and some fraction of total capacity as peaking combustion turbines or pumped storage. The Eco-Energy system may be viewed as an ultimate, permanent goal to be approached as it becomes viable. Estimating the performance and costs of technological alternatives that are foreseeable by the end of the century, as well as the transition problems of meshing with present electric energy system requirements and load growth requirements, has been the subject of study at TEMPO for about two years. These studies have been partially supported by the Southern California Edison Company and the Oak Ridge/AEC.
(HYDROGEN, STUDY, ENERGY, ECOLOGY, FOSSIL, STORAGE, ALTERNATIVE, ELECTRICITY)

H73 10049* NUCLEAR POWER PLANTS FOR HYDROGEN PRODUCTION
Leeth, G.G., (TEMPO - General Electric Company - Center for Advanced Studies, Santa Barbara, Calif.), Report GE72TMP-52 Nov 1 '72

Several previous TEMPO documents have assumed the use of nuclear power plants as the primary energy sources. In these cases no determination was made as to the types of power plants best suited for such applications. This document is a comparison of various kinds of nuclear reactors and an evaluation of their suitability for hydrogen production by water splitting.
(HYDROGEN, ENERGY, NUCLEAR, WATER, DECOMPOSITION)

H73 10050* ECO-ENERGY
Hausz, W., G.G. Leeth and C. Meyer, 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Aug 72, Avail:TAC

To study our future national electrical energy needs and means of supplying them, a system analysis must give balanced attention to ecological, economic and societal factors. A parametric analysis of post-1990 systems and transitional modes identified a promising candidate system: the use of efficient gas turbines or fuel cells, at distribution level, which burn pipeline-delivered hydrogen generated at large, remotely-located energy centers.
(HYDROGEN, ENERGY, ECOLOGY, ELECTRICITY, ANALYSIS, FUTURE, SYSTEM, ALTERNATIVE)

H73 10051 FEDERAL PANEL REPORTS ON HYDROGEN
Anon, Chemical and Engineering News, Sept 10 '73, Avail:TAC

The panel's main conclusion was that synthetic fuels, particularly hydrogen, can have a significant and beneficial effect over the long term. The main obstacles to use of hydrogen as a universal fuel are high cost relative to present fuels and unresolved problems of handling a low-density or cryogenic fluid. The panel believes that safety considerations will present no serious obstacle to use of hydrogen.
(HYDROGEN, SYNTHETIC, FUEL, CRYOGENIC, SAFETY)

H73 10052* THE INFLUENCE IN AN ENERGY MARKETPLACE
Hausz, W., (TEMPO - General Electric Company - Center for Advanced Studies, Santa Barbara, Calif.), International Symposium and Workshop on The Hydrogen Economy, Cornell University, Ithaca, N.Y., Aug 20-22 '73, Avail:TAC

Where does hydrogen fit in the energy scenario for the rest of this century? This depends on how it compares to its competition -- in price, cleanliness, convenience and other advantages or disadvantages either hydrogen or the alternatives may have.

Hydrogen competes at several levels. As a chemical used to add hydrogen to other molecules it is unique. This market was $0.6 \cdot 10^{15}$ Btu in 1968, mostly for making ammonia and petrochemicals. About 8 percent growth rate to the year 2000 is forecast. Next, as a reducing agent, it will compete with coke and carbon monoxide as the means of reducing metallic ores, and in many organic and inorganic reactions. Hydrogen is an ideal gaseous fuel, for residential and commercial distribution; here, its competitor is natural gas and synthetic methane. More broadly, it can compete with industrial fuels, gaseous or otherwise, as a clean fuel. Perhaps the toughest market to penetrate is that in which storability, transportabiliy and portability are important requirements: the transportation market and to a lesser extent the market for dispersed electric generation (where electric transmission is the competitor).
(HYDROGEN, ENERGY, MARKET, FUEL, COST, STORAGE, TRANSMISSION, ELECTRICITY)

H73 10053 HYDROGEN AND THE ELECTRIC ECONOMY
Deen, J.L., and R.J. Schoeppel, (Mechanical and Aerospace Engineering, Oklahoma State University), Frontiers of Power Technology Conference Proceedings, p 10-11 71

Electricity, a secondary form of energy, has played a dominant role in the evolution of an advanced civilization. Its rate of growth currently exceeds that in the competitive industrial, residential and transportation sectors. This increasing trend is expected to continue until a near-total electric economy is achieved.

The transition to the electric economy is expected to involve the "electric auto" in a number of ways: 1) electrically generated hydrogen for use in internal combustion engines; 2) stored electricity in the form of batteries for use in providing vehicle propulsion; 3) elec-

trically generated hydrogen for use in fuel cell engines. The expected role for each of these means of energy conversion, and the transition to the electric economy, is predicted to occur in this order. Various ramifications of such evolutionary changes, including the influences of the energy crisis and environmental degradation, are presented.
(ELECTRICITY, ENVIRONMENT, ENERGY)

√ H73 10054 HYDROGEN ENERGY SYSTEMS AND VEHICULAR PROPULSION
Stuart, A.K., (The Electrolyser Corporation Ltd., 122 The West Mall, Etobicoke, Toronto, Canada), The International Conference on Automobile Pollution, The Association of Professional Engineers of the Province of Ontario, Toronto, Je 27 '72, Avail:TAC

Hydrogen is suggested as the ultimate recycable fuel with many advantages as an engine fuel. Nuclear energy systems are discussed with off-peak electric power providing a low cost source of hydrogen. Attention is given to the storage, handling and safety aspects of hydrogen. Gradual conversion to a hydrogen energy system is proposed.
(FUEL, ENGINE, POLLUTION, OXYGEN, NUCLEAR, STORAGE, SAFETY)

√ H73 10055 THE ENERGY LABYRINTH
Anon, Union Carbide Corp., Linde Division, 270 Park Ave., New York, N.Y., 10017, Avail:TAC

Hydrogen, the fuel of the future from the standpoint of .... ecology, the national economy, engineering feasibility.
(HYDROGEN, FUEL, ECONOMY, ENERGY, ECOLOGY, SAFETY, NUCLEAR, COAL)

√ H73 10056 THE HYDROGEN ECONOMY
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), A.G.A. Monthly, p 4-9, Je 72, Avail:TAC

Energy from the ocean .... by the year 2000 hydrogen produced from water may prove to be an answer to the nation's shortage of clean energy.
(HYDROGEN, ECONOMY, ENERGY)

H73 10057 HYDROGEN AS A FUEL
Anon, Petroleum Press Service, Jl 72, Avail:TAC

The Commission of the European Communities has proposed that research into using nuclear energy to extract hydrogen from water should be continued by the Ispra establishment of the EEC's Joint Research Centre. The aim of Ispra is to perfect its Mark I process invention for the production of hydrogen, so that it can be applied on an industrial scale and quickly become an important source of energy in Western Europe.
(ENERGY, NUCLEAR, OXYGEN, REACTOR, DECOMPOSITION, HEAT, GASIFICATION, COAL, POLLUTION, USE)

H73 10058* HEAT-STORAGE WELLS FOR CONSERVING ENERGY AND REDUCING THERMAL POLLUTION
Meyer, C.F., (TEMPO - General Electric - Center for Advanced Studies, Santa Barbara, Calif.), and D.K. Todd, (Univ. of Calif., Berkley, Calif.), 8th Intersociety Energy Conversion Engineering Conference, Philadelphia, Pa., Aug 73, Avail:TAC

The motivation for investigating heat storage arose from TEMPO's investigations of Eco-Energy and the hydrogen economy.

One advantage of hydrogen as a fuel is the high efficiency that can be obtained in hydrogen-oxygen combustion turbines, used to drive electric generators. The exhaust from hydrogen-oxygen turbines is pure steam. The steam and the energy it contains can be used in various ways. An attractive alternative is to design the system to produce steam and hot water at temperatures of 180° to 340° F, for district heating: i.e., space heating, aborption-cycle air conditioning, water heating, and process heat. Exhaust heat is thus exported and utilized, and no cooling facilities are required.

Storing large amounts of useful heat in groundwater appears feasible. Preliminary analysis shows that more than three-fourths of the stored heat can be recovered after 90 days; heat-storage wells cost less than the cooling facilities they replace; and the necessary underground formations are widely available.
(COMBUSTION, HYDROGEN, OXYGEN, STEAM, FUEL, ECONOMY)

H73 10059 CONSERVING ENERGY WITH HEAT STORAGE WELLS
Meyer, C.F., (TEMPO - General Electric Co., Santa Barbara, Calif.), and D.K. Todd, (Univ. of Calif., Berkley, Calif.), Environmental Science & Technology, V 7:512-516 N7 Je 73, Avail:TAC

Electric and gas utilities have embarked upon major compaigns to promote conservation of energy because of public pressure and the short supply of clean fuels,

Recent studies at Genera; Electric's Center for Advanced Studies (TEMPO) show that thermal pollution could be greatly reduced and substantial energy conservation could resutl from large-scale application of a total-energy approach under which utilities would produce and market both electricity and useful heat.

A more advanced system would employ hydrogen-oxygen turbines. That a "hydrogen economy" will evolve within the next one or two decades, due to the shortage of fossil fuels and other considerations, has been postulated by a number of investigators. Hydrogen and oxygen would be manufactured by splitting water.

The exhaust from a hydrogen-oxygen turbine would be pure steam. The turbine can be designed to exhaust at whatever temperature is dictated by heat-energy requirements. Since full thermodynamic credit can be taken for the heat in the exhaust, the effective efficiency of the hydrogen-oxygen turbine is very high. For energy conservation this approach is extremely attractive. (ELECTRIC, EFFICIENCY, POLLUTION, TURBINE, HYDROGEN, OXYGEN, CONSERVATION)

H73 10060 HYDROGEN: IT'S CLEAN, BUT IS IT A PRACTICAL FUEL?
Anon, Cornell Chronicle, Sept 6 '73, Avail:TAC

It's the most abundant element in the universe, it will be plentiful on earth long after this planet's supplies of fossil fuels are exhausted, and it makes a clean fuel which burns to give off harmless water vapor, but some 80 internationally known scientists and engineers meeting at Cornell Aug 20-22 are still questioning whether hydrogen will be the fuel of the future.

Cornell's International Symposium and Workshop on the Hydrogen Economy was a gathering of specialists who spoke in technical terms about the way the utilization of hydrogen, the simplest of the elements, could affect economics and energy stores on a worldwide basis.

Organized and chaired by Simpson Linke, professor of electrical engineering at Cornell, the conference brought a number of distinguished visitors to the campus.
(HYDROGEN, ECONOMY, MEETING)

H73 10061* PROSPECTS FOR HYDROGEN AS A FUEL FOR TRANSPORTATION SYSTEMS AND FOR ELECTRICAL POWER GENERATION
Escher, W.J.D., (Escher Technology Associates), Report No. ORNL-TM-4305, Oak Ridge National Laboratory, Oak Ridge, Tenn., Sept 72, Avail:TAC

The potential application of hydrogen, produced from non-fossil domestic sources, is examined for applicability to the transportation and electrical generation sectors. The characteristics of hydrogen as a gas and as a cryogenic liquid are noted; cost trends are presented.

Ground, water, and air transportation modes and systems are individually examined with respect to a potential conversion to hydrogen fuel. Electrical generation systems, both conventional and unconventional, are assessed similarly. Hydrogen's potential for transmission and storage of electrical energy is cited.

From these findings, a detailed list of recommended study, research and development, and demonstration system topics is given toward implementing an eventual conversion of transportation and the electrical utilities to hydrogen fuel.
(HYDROGEN, FUEL, TRANSPORTATION, POWER, GENERATION)

H73 10062 C&EN TALKS WITH.......
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), Chemical and Engineering News, Oct 1 '73

A coal-fired airplane? Not literally -- but chemically speaking it may not be far away. Dr. Derek P. Gregory, assistant director for engineering research at the Institute of Gas Technology, is a firm believer in the future of hydrogen fuels.

Dr. Gregory's interest in hydrogen isn't a narrow preoccupation. It is one aspect of a much broader concern with organizing national resources to meet future energy needs. There is little doubt in his mind that the principal elements in the energy business of the future will be nuclear reactors, coal, and water.

The chief reason for the current energy bind, says Dr. Gregory, is the lack of a national energy policy.

Two essentials of a valid national energy policy, Dr. Gregory says, are a firm conservation program and a consistent method of allocating resources. Neither is popular but both are required.
(HYDROGEN, FUEL, ENERGY, POLICY)

H73 10063* "HYDROGEN SYNTHETIC FUEL OF THE FUTURE"
Hammond, A.L., W.D. Metz, and T.H. Maugh II, Energy and the Future, Chapt 18, American Association for the Advancement of Science, Washington, D.C., 73, Avail:TAC

It may take 50 years, 100 years, or longer, but the time is approaching when gas, oil, and coal will no longer be available for use as fuels. Possibly, reserves of these fuels will be depleted by then. Probably, production will not be able to keep pace with demand. But most likely, the remaining reserves will become far too valuable as feedstocks for chemical production to be burned simply for their energy content. It is likely both that electricity will play a larger role in supplying future energy demands and that heat from nuclear reactors will be utilized in large nuclear/industrial complexes, or nuplexes. Nonetheless, there will remain a strong demand for portable, fluid fuels, particularly for applications in transportation, and the most likely response to this demand will be a vastly increased production of hydrogen.

Hydrogen, of course, is not an alternative primary energy source, because large amounts of energy are required to produce it. Rather, it holds promise of being a highly efficient energy carrier that can be used in situations where transfer of energy as electricity is inefficient, impractical, or impossible. It is the potential that has generated such widespread interest in the possibility of a "hydrogen economy."

In many ways, hydrogen is an ideal fuel. When it is burned in air, the only possible pollutants are nitrogen oxides derived from the air itself, and concentrations of these are generally lower than concentrations produced by other fuels. When it is burned in pure oxygen, the only product is water and there are no pollutants at all. (HYDROGEN, SYNTHETIC, FUEL, FUTURE)

H73 10064 SYNTHETIC FUELS FOR TRANSPORTATION AND NATIONAL ENERGY NEEDS
Gregory, D.P., (Institute of Gas Technology, Chicago, Ill.), and R.R. Rosenberg, Paper presented at SAE National Meeting, Symposium on Energy and the Automobile, Detroit, Mich., May 15 '73, Avail:TAC

The United States petroleum supplies cannot keep up with the demands made upon them by the use of automobiles. Increased importation of oil is not a satisfactory long-tem solution. U.S. supplies of coal, nuclear,

and solar energy, however, are abundant. We suggest that "clean" fuels could be synthesized from these resources by using these abundant materials. This paper examines the possibilities of making methanol, ethanol, hydrogen, and ammonia for use as vehicle fuels. In the short term, methanol and methanol-gasoline blends appear attractive. In the long term, hydrogen is ideal if its handling problems can be solved.
(HYDROGEN, FUEL, SYNTHETIC, TRANSPORTATION)

√ H73 10065* CLEAN ENERGY VIA CRYOGENIC TECHNOLOGY
Williams, L.O., (Martin Marietta Aerospace, Denver, Colo.), Advances in Cryogenic Engineering, Chapt. L-8, V 18 72; and Paper A-5, Cryogenic Engineering Conference, Boulder, Colo., Aug 72

Consideration of the total problem of air pollution leads to the conclusion that, for a permanent solution, the open-loop combustion of fossil fuel must eventually be stopped. Only nuclear power sources, particularly those using fusion, have the potential of producing the power required by the economy with a minimum of air pollution. For mobile (portable) requirements, a fuel combusted with air remains unexcelled as a power source. Examination of the chemical fuels that could be used for mobile power without producing air pollution lead to hydrogen as the only possible zero-pollution fuel. Hydrogen provides more energy per unit weight than any other fuel. It and its combustion products, hydrogen and water, are totally nontoxic.

In the technology of converting the economy to the use of zero-pollution hydrogen, two broad problems are of significance:

1. Can sufficient low-cost hydrogen be produced?
2. Can the hydrogen be handles and distributed in an economic and safe manner?

The first question can be answered by the use of electrolysis of sea water with nuclear-produced electricity. In this process an electric current is passed through water decomposing it into its constituents - hydrogen and oxygen. Water is the starting material for this process and the hydrogen burns to water when it is used as fuel, thus closing the material transport loop used in the energy system. The answer to the second question is also clearly yes. For safety, cooling, and availability of water, the very large generating plants could be located very near or, possibly better, on the oceans. The hydrogen and oxygen produced could be transmitted by existing and new pipelines to all parts of the country. At various regional locations large liquefaction facilities could convert the hydrogen to liquid for storage and supply to the various local mobile transport supply facilities would provide service and fuel in a manner indistinguishable from that used in today's filling station. (ENERGY, HYDROGEN, LIQUID, CRYOGENIC)

H73 10066 POLLUTION-FREE CAR ENGINES THAT BURN A GASOLINE-HYDROGEN MIXTURE
Anon, Chementator, Chemical Engineering, V 80:17 N22 Oct 1 '73

Pollution-free car engines that burn a gasoline-hydrogen mixture are under study at the U.S. National Aeronautics and Space Administration's laboratories in Pasadena, Calif. Project researchers are looking toward a car that would not only meet future auto-emission limits (without catalytic or other add-on devices) but also offer fuel economy and the ability to operate on relatively low-grade hydrocarbons.

In the scheme, hydrogen is generated from gasoline and water in a thermal reactor, then fed to an "atomizer" that the engine employs in place of a carburetor. The atomizer blends the hydrogen with gasoline, and the mixture goes to a standard internal-combustion engine.

The researchers have operated an experimental car in which the hydrogen was supplied by a gas cylinder; they hope to have ready within two months an automobile equipped with the hydrogen generator. They claim that cars using the new approach, once it is fully developed, will produce zero or near-zero emissions of hydrocarbons, carbon monoxide, and nitrogen oxides. (HYDROGEN, GASOLINE, POLLUTION-FREE, AUTOMOBILE)

H73 10067* A HYDROGEN BASED ENERGY ECONOMY
Fein, E., (The Futures Group, Glastonbury, Conn.), Report No. 69-08-10, Oct 72, Avail:TAC

This report explores the area of production, transportation and storage, and the potential market for hydrogen. These provide the background for a discussion of growth and future projections.

Two utility systems, which represent possible stages of evolvement toward an ultimate system, are analyzed. While projected costs are meant to be as realistic as pos-

sible, the competitiveness of hydrogen as a fuel will depend very much on the assigned costs of pollution constraints for fossil fuels and on the geopolitics of supply. The pattern of possible system evolution leads to the identification of promising research and development areas.
(PRODUCTION, TRANSPORTATION, STORAGE, MARKET, CHEMICAL, REFINING, UTILITY, ELECTRIC, RESEARCH, FOSSIL, FUEL)

H73 10068* A HYDROGEN ENERGY CARRIER
Savage, R.L., L. Blank, T. Cady, and K.E. Cox, Eds., 1973
NASA-ASEE Systems Design Institute, University of Houston, Rice University, NASA-Johnson Space Center, Houston, Tex., V I: Summary, NASA Grant NGT 44-005-114

Hydrogen as an energy carrier is almost ideal from an environmental viewpoint. It is made from water and its product of combustion is water. Hydrogen can be used as a fuel in all conventional areas of energy use, including industrial chemical, industrial fuel, electric power generation, residential and commercial, and transportation. A primary source of energy such as fossil fuel, nuclear energy or solar energy must be used to produce hydrogen. The cost of hydrogen will depend on the cost of the primary source of energy and the efficiency of the process used to produce the hydrogen. Projected costs of gaseous hydrogen at the producing plant range from $1.00 to $3.00 per million Btu. Pipeline transmission of gaseous hydrogen will add only a few cents per million Btu to the cost of hydrogen fuel delivered to the customer.

Initial large scale methods of production of hydrogen will be from the gasification of coal. Nuclear energy will also be used to produce hydrogen. The established process is by electrolysis of water but the overall efficiency is low. Depending on the cost of electric power, the cost of hydrogen gas produced by electrolysis will range from $100 to $5.00 per million Btu. There is very little cheap power available, even at off-peak periods and the cost of most of the hydrogen produced by electrolysis will be from $3.00 to $5.00 per million Btu.

If needed technology is developed, direct thermal decomposition of water or thermo-chemical decomposition of water to produce hydrogen, using nuclear heat rather than electricity, will produce hydrogen at a cost of $1.00 to $1.50 per million Btu. These processes are not expected to be operational before 1985. For the period after the year 2000, solar energy may replace nuclear energy for the production of hydrogen from water, but the cost is forecast to be in the range of $2.00 to $3.00 per million Btu.

Hydrogen can be transported most economically by pipeline. Special attention must be directed to designing the pipeline to avoid conditions which may cause hydrogen environment embrittlement.

There are no non-technical aspects of the hydrogen economy which cannot be met. Safety problems with hydrogen are similar to and probably no worse than safety problems with other hazardous fuels. Environmental, social, legal, economic and political factors have been examined. No insurmountable problems are anticipated in converting to a hydrogen economy.
(HYDROGEN, ENERGY, ENVIRONMENT, SOCIETY, LEGAL)

H73 10069* A HYDROGEN ENERGY CARRIER
Savage, R.L., L. Blank, T. Cady, and K.E. Cox, EDs., 1973
NASA-ASEE Systems Design Institute, University of Houston, Rice University, NASA-Johnson Space Center, Houston, Tex., V II: Systems Analysis

see preceding item

A systems analysis of hydrogen as an energy carrier in the United States indicated that it is feasible to use hydrogen in all energy use areas except some types of transportation. These use areas are industrial, residential, and commercial, and electric power generation. Saturation concept and conservation concept forecasts of future total energy demands were made. Projected costs of producing hydrogen from coal or from nuclear heat combined with thermochemical decomposition of water are in the range $1.00 to $1.50 per million Btu of hydrogen produced. Other methods are estimated to be more costly. The use of hydrogen as a fuel will require the development of large-scale transmission and storage systems. A pipeline system similar to the existing natural gas pipeline system appears practical, if design factors are included to avoid hydrogen environment embrittlement of pipeline metals. Conclusions from the examination of the safety, legal, environmental, economic, political and societal aspects of hydrogen fuel are that a hydrogen energy carrier system would be compatible with American values and the existing energy system.
(HYDROGEN, SYSTEMS, STUDY, ENERGY, COSTS, ECONOMICS)

H73 10070 OUR SOLAR ENERGY OPTIONS: PHYSICAL AND BIOLOGICAL
Tamplin, A.R., (Lawrence Livermore Lab., Livermore, Calif.), Report No. UCRL-51315, Ja 2 '73

This report discusses various schemes that have been proposed for the utilization of solar energy. These schemes would have to include an energy storage system. One storage system would involve the electrolysis of water and storage of hydrogen. The first section will discuss physical systems and the second section will treat biological systems. The major focus of the report will be to present a means of comparison; consequently the technical description will be somewhat brief. More detailed technical discussions can be found in the cited references.
(TERRESTRIAL, SPACE, MARINE, HEAT, ALGAE, EFFICIENCY, WASTE, FUEL, PYROLYSIS, COST)

H73 10071 INFLUENCE OF HYDROGEN IN AN ENERGY MARKETPLACE
Jones, L.W., (University of Michigan, Ann Arbor, Mich.), Cornell International Symposium and Workshop on the Hydrogen Economy, Cornell University, Ithaca, N.Y., Aug 73

We must explore every reasonable option and solution to the energy problem and explore them soon and intensively. Towards the end of finding the best solutions, the author includes hydrogen as an essential element. Further, a balanced program containing the three elements: pursuit of research, high stakes in investment and long technological lead-time for implementation of new, large-scale energy systems are required.
(USE, ECONOMY, CARRIER, CONSERVATION)

H73 10072* LARGE-SCALE CONCENTRATION AND CONVERSION OF SOLAR ENERGY
Hildebrandt, A.F., G.M. Haas, W.R. Jenkins, and J.P. Colaco, (University of Houston, Houston, Tex.), EOS Trans. AGU, V 53:684-692 N7 Jl 72

There is a source of energy which is totally pollution-free and easily available but which has been considered too intermittent and expensive to be of value - solar energy. Proposals have been made to collect solar energy with solar cells spread over large areas, but solar cells have a low (3% - 10%) conversion efficiency and are not economically attractive. We find that a much higher conversion efficiency

is possible by first concentrating the solar energy and then using a thermodynamic conversion cycle. We propose a concentrator consisting of a large number of individual movable mirrors that reflect the solar energy onto a single collector atip a large tower. The concentrated energy can then be converted to electrical power either by means of a steam cycle, using liquid metals for heat transfer down the tower, or by a closed cycle magneto-hydrodynamic generator. The intermittent nature of the solar energy can be overcome by electrolyzing water into hydrogen and oxygen gas and storing the energy either in the form of compressed hydrogen and oxygen gas or as cryogenic liquids. Energy storage in the form of hydrogen is especially attractive since it offers the possibility of a pollution-free fuel for the internal combustion engine.
(HYDROGEN, ELECTROLYSIS, OXYGEN, STORAGE, INTERNAL COMBUSTION, MAGNETOHYDRODYNAMIC, COST, SOLAR, ENERGY, CONVERSION)

H73 10073* A HYDROGEN ECONOMY?
Anon, Mechanical Engineering, Oct 73, p 50

As the United States' supply of nonpolluting fossil fuels begins to dwindle, the gas industry has begun a search for alternatuve sources of clean-burning energy.

For the past 10 years, IGT, says Derek Gregory, assistant director, engineering research, has been studying a synthetic chemical fuel that can easily be produced from nuclear or solar energy sources: hydrogen.

Hydrogen can be produced from water by the addition of energy and can be oxidized back to water to give up this energy as heat or electric power directly. So, while hydrogen is not a naturally occurring fuel or a primary source of energy, it is an attractive medium for storage and transmission of an energy source. It is a means of making such energy sources as nuclear, solar, and low-grade fossil fuels available to the consumer in a clean, convenient, and flexible way.

According to Gregory, if we chose to make hydrogen rather than electricity from our supplemental energy sources, it can, unlike electricity, be stored near the load center and its lower transmission cost would allow greater freedom in siting generating stations. Gaseous fuels are relatively cheap to transmit in underground pipelines; hydrogen is no exception. Existing natural gas lines could carry the same energy content as natural gas for only a small penalty in pumping costs.

The use of hydrogen as a fuel presents both some problems and some distinct advantages. There seems to be no reason why pure hydrogen could not be used for all purposes served by natural gas today: it burns smoothly and easily when mixed with air, and it can be burned in domestic and industrial appliances similar to those used for natural gas. In addition, because hydrogen burns without noxious exhaust products, it can be used in an unvented appliance without hazard; thus, a home heating furnace could conceivably operate without a flue, thereby saving the cost of a chimney and adding as much as 30 percent to the efficiency of a gas-fired home-heating system.

√ H73 10074 HYDROGEN - THE KEY TO ABUNDANT CLEAN ENERGY
Billings, R.E., and F.E. Lynch, (Energy Research, Inc., Provo, Utah), Publication No. 73003, Apr 73, Avail:TAC

Hydrogen is an ideal fuel for the internal combustion engine. Automobiles being tested at Energy Research and at other facilities perform well and are virtually pollution-free, the only significant by-product being water vapor. More important, however, is the fact that hydrogen-powered engines show significantly higher operating efficiencies than engines powered by the other fuels synthesizable from coal. This means that less of our coal reserve is consumed for each vehicle mile driven on hydrogen.

Since hydrogen combustion generates 1000 times less particulates than hydrocarbon fuels, there is less abrasive action on engine parts resulting in longer engine life, fewer repairs, and less frequent oil changes. The difference in power between the hydrogen and gasoline is negligible, and the pollution from the exhaust of a well designed hydrogen engine is so low that under some conditions it is cleaner than the air the engine is breathing in.
(FUEL, INTERNAL-COMBUSTION, ENGINE, POLLUTION, HYDROCARBON)

√ H73 10075* ECONOMIC COMPARISON OF TWO SOLAR/HYDROGEN CONCEPTS
McCulloch, W.H., R.B. Pope, and D.O. Lee, (Sandia Labs., Albuquerque, N.M.), Report No. SLA-73-0900, Oct 73, Avail:TAC

This report describes two concepts for producing hydrogen from solar energy. The two systems are then compared

on the basis of performance and costs.
(ECONOMICS, SOLAR, ENERGY, ELECTROLYSIS, THERMOCHEMICAL, WATER, DECOMPOSITION)

H73 10076 PLAN FOR THE ELIMINATION OF POLLUTION
Williams, L.O., (Martin Marietta Corp., Denver, Colo.), Environmental Awareness, Institute of Environmental Sciences, Malcolm and Martin, Cassandra (Eds.), Los Angeles, Calif., Apr 26-30 '71

Products of open-loop combustion of fossil fuel cause most atmospheric pollution and must be stopped. A chemical fuel reacted with the ambient atmosphere is the most efficient means of handling energy. Only one portable fuel, hydrogen, produces no pollution. Tests indicate virtually all fuel-consuming devices, including automobiles, can operate on hydrogen. Hydrogen can be produced from fossil fuels but for a true long-term solution a closed-loop system based on electrolysis of sea water to hydrogen, followed by combustion of hydrogen back to water, can be visualized. Hydrogen and byproduct oxygen could be produced by extremely large (thus economical) nuclear fusion or fission reactors floated at sea by electrolysis of local sea water. The oxygen can be used to reduce non-fuel pollution and repair some existent environmental damage. A cursory analysis indicated that 10 to 15 years would be required to apply this solution to the nation.
(POLLUTION, CONTROL, HYDROGEN, FUEL, NUCLEAR, ELECTROLYSIS)

X H73 10077* HYDROGEN FUTURE FUEL, (A LITERATURE SURVEY ISSUED QUARTERLY)
Anon, (Cryogenic Data Center, National Bureau of Standards, Boulder, Colo.), Aug 73, Issue No. 1, Avail:TAC

This first issue concentrates on providing a bibliography on hydrogen as a cryogen. Future issues will look at the possibilities of hydrogen, particularly liquid hydrogen, as a primary synthetic fuel.
(HYDROGEN, FUEL, CRYOGENIC, PROPERTY, SAFETY, TRANSPORTATION, STANDARDS, APPLICATIONS)

H73 10078* NSF-RANN ENERGY ABSTRACTS
Guthrie, M.P., Ed., (Oak Ridge National Lab., Oak Ridge, Tenn.), NSF-RANN Energy Abstracts, (A Monthly Abstract Journal of Energy Research), Ja 73, Issue No. 1, Avail:TAC

"NSF-RANN Energy Abstracts" is sponsored by the National Science Foundation--Research Applied to National Needs Program and is published monthly by the ORNL-NSF Environmental Program and the Environmental Information System of Oak Ridge National Laboratory. Computer-generated indexes will be prepared twice a year.

The purpose of this bibliography is to disseminate as rapidly as possible the published results of work performed under the Energy Research and Analysis category of RANN. Other energy research results will also be covered as far as possible. This bibliography, in general, will cover research on energy sources, electric power (generation, supply and demand, transmission, environmental effects, and use), and energy (production, consumption, supply and demand, and policy). The research publications cited are technical journal articles, popular or semi-technical magazine articles, topical reports, progress reports, symposium papers and proceedings, monographs, and books published within the past two years.
(ENERGY, SOURCE, ELECTRICITY, USE, GENERATION, SUPPLY, DEMAND, TRANSMISSION, ENVIRONMENT, PRODUCTION, CONSUMPTION, POLICY)

H73 10079* ENERGY TRANSMISSION VIA HYDROGEN
Johnson, J.E., (Linde Div., Union Carbide Corp., New York, N.Y.), Cornell Hydrogen Symposium, Aug 73, Avail:TAC

The "hydrogen economy" is already operating in macrocosm. All the technology that is required to transmit energy via hydrogen has been developed in the course of placing man on the moon. What is yet to be determined is the scale of operation that will be required to economically produce and distribute the hydrogen energy this country will eventually require. The major challenges to implementing hydrogen energy transmission systems are clear. The demonstration of the improved efficiency of hydrogen fueled energy conversion devices are essential in developing a credible argument for overcoming the "why change syndrome" and technology for improving storage capabilities is essential to permit early application of hydrogen energy transmission systems.
(ENERGY, TRANSMISSION, STORAGE, LIQUID, ECONOMICS, CRYOGENIC, SAFETY)

H73 10080 HYDROGEN FUEL FROM WATER BY A NUCLEAR ROUTE
Anon, Chemical & Engineering News, p 13, Nov 5 '73, Avail:TAC

Hydrogen fuel from water by a nuclear route is being sought at Gulf General Atomic Co. The research is sponsored by Southern California Edison and Northeast Utilities. Gulf General's high-temperature gas-cooled reactor technology may provide an alternative to costly electrolytic technology for obtaining ecologically clean hydrogen fuel from water.
(FUEL, WATER, NUCLEAR)

H73 10081* THE METHANOL ECONOMY - A PRACTICAL VERSION OF THE HYDROGEN ECONOMY
Reed, T.B., and R.M. Lerner, (Lincoln Lab., M.I.T., Lexington, Mass.), Report No. DS-14457, Nov 73, Avail:TAC

We believe that methanol is the most versatile synthetic fuel available to stretch, or eventually substitute for, disappearing reserves of low-cost petroleum resources. Starting now, methanol can be used to market economically natural gas that is otherwise going to waste in remote locations. Starting now, methanol can be used as a beneficial additive at the 5 percent to 15 percent level in internal combustion-engine fuel. The result appears to be lower polluting emissions and less need for lead in the fuel, both without adverse effect on performance.

With increasing production of fuel-grade methanol from coal and other sources, we foresee the increasing use of methanol for electrical power plants, for heating, and for other fuel applications. We hope that a practical methanol fuel cell may become a reality by the time that methanol becomes plentiful for fuel purposes.

Finally, methanol offers a particularly attractive form of solar-energy conservation, since agricultural and forest waste products can be used as the starting material. Indeed, at 1 percent conversion efficiency the forest lands could supply the entire present U.S. energy requirement.
(METHANOL, ECONOMY, ENGINE, FUEL, ENERGY)

H73 10082 THE WONDERFUL FUEL
Anon, Newsweek, Nov 12 '73, p 75, Avail:TAC

The fuel of the future, many scientists now think, is hydrogen.

Recently, scientists at the Jet Propulsion Laboratory in Pasadena, California, unveiled an automobile engine that runs on a mixture of hydrogen and gasoline - and whose operation is so clean that it meets almost all of the strict Federal emission standards set for 1977-model cars. At the Atomic Energy Commission's Brookhaven Laboratory on Long Island, engineers are testing the German Wankel engine as the major component of another hydrogen-powered automobile; and as long ago as last year, hydrogen-powered cars took first and second places in the intercollegiate urban-vehicle design competition, which stressed both speed and pollution-free operation.

To hydrogen enthusiasts, who think hydrogen-powered cars could be mass-produced in ten years or less, the automobile is just one beneficiary of the future hydrogen economy. In time, they believe, hydrogen will be used to heat homes, drive turbines for production of electricity and store power produced in off-peak periods for later use.
(AUTOMOBILE, FUEL, FUTURE, GASOLINE, POLLUTION)

H73 10083 SOLAR POWER
Ford, N.C., and J.W. Kane, Bulletin of Atomic Science, Oct 27-31 '71, Avail:TAC

We would like to propose a possible method of producing energy from solar radiation at a reasonable cost..... By using plastics presently available it may be possible to solve the economic problems of collection.....and the energy may be converted via thermal dissociation of water into hydrogen, an efficient, nonpolluting fuel.
(HYDROGEN, WATER, THERMAL, PRODUCTION, ENERGY, PLASTICS)

7 ✓ H73 10084 ENERGY SOURCES ON A POST-INDUSTRIAL SOCIETY
Bockris, J. O'M., (Flinders University of South Australia), Australian Quarterly, Sept 73, p 32-41, Avail:TAC

Fossil fuels will be expensive to use by the mid-80s and dangerous not long after 2000. Breeder reactors appear too pollutively dangerous to develop upon a large scale. We are left with the prospect of developing solar energy, with the further speculative possibility of being able to control atomic fusion. The transmission of energy via hydrogen over very long distances improves the possibilities of utilizing the solar energy which is available abundantly in certain parts of the world. Countries having such solar energy would in the future be permanently rich in a way analogous to the temporary richness of, for example, the Arab States.
(FOSSIL, FUEL, BREEDER, REACTOR, SOLAR, ENERGY, HYDROGEN, TRANSMISSION)

H73 10085 THE HYDROGEN ECONOMY - AN ULTIMATE ECONOMY?
Bockris, J. O'M., and A.J. Appleby, The Environment - This Month, V 1:29, Ja 72, Avail:TAC

After surveying the present world situation, the authors conclude that our present technology will make affluent life increasingly difficult to maintain from about 2000 AD. A totally new energy medium is required. In this expertly reasoned article the authors convincingly present the case for using hydrogen as the medium of energy between remote energy producing sites and population centres - the hydrogen then being used to generate electricity on site of use or alternatively being used directly as a fuel. The effects of a hydrogen economy on all aspects of our life requirements are discussed in detail. A hydrogen economy would be entirely non-polluting and would make high energy-densities possible for all regions of the world, thus hastening the spread of uniform high living standards. J. O'M. Bockris is a Professor in Flinders University, South Australia, and A.J. Appleby is form the Laboratoire d'Electrolyse (CNRS), France.
(HYDROGEN, ECONOMY, ENERGY, SOURCE, PRODUCTION, TECHNOLOGY, WATER, USE)

✓ H73 10086 THE COMING ENERGY CRISIS, AND SOLAR ENERGY
Bockris, J. O'M., (Flinders University of South Australia), Unpublished paper, Nov 73, Avail:TAC

The nature of the present (pseudo) and the coming (real) energy crises are discussed. Post 1971 evidence suggests that pollutive dangers from fission plants are larger than had been guessed. The resuscitation upon a large scale of coal as an energy source would give pollutive dangers, including climatic changes due to excess carbon dioxide. Solar energy systems, earlier impossibly expensive, are now predicted to have the same capital cost range as have atomic reactors. Cheap high purity silicon; coatings which adsorb at less than 1μ, but do not emit at more than 1μ; thin film photovoltaics; thermoelectrics; and photosynthesis are areas of immediate solar energy research interest. Roof-top energy collection may be a permanent part of the future, but will not avoid the necessity of large solar farms to collect energy for industry and transportation. Storage will be in hydrogen: there are advantages of developing cheap hydrogen as a general clean fuel, e.g., for transportation. Australia's position in respect to the yearly average receipt of solar energy, and the

possession of suitable collecting areas, is unrivalled. The massive export of hydrogen fuel could be made. Relatively small areas of Central Australia could supply energy needed for the entire, e.g., Japanese, economy. A brief review of attitudes observed to a massive Australian solar energy development program is given.
(ENERGY, CRISIS, SOLAR, COAL, FISSION, HYDROGEN, STORAGE, TRANSMISSION, EXPORT, REVIEW)

H73 10087 POWER WITHOUT POLLUTION
Bockris, J. O'M., (Flinders University of South Australia), Hemisphere, Sept 73, p 21-5, Avail:TAC

The article examines the implications of cheap solar power for Australia and Asia.

The concept described involves converting solar energy into electricity for the electrolysis of brackish water to produce hydrogen. Hydrogen is reconverted to electricity at the point where the energy is needed by a fuel cell.
(POLLUTION, POWER, FUEL CELL, ELECTROLYSIS, SOLAR, ENERGY)

H73 10088 ENERGY ALTERNATIVES: SUN, WIND, EARTH, WATER
Anon, Colorado Business, Nov 1 '73, p 36-7, Avail:TAC

Western scientists have stepped up their search for alternative sources of energy as a way of making the nation self-sufficient.

Coal development appeared to be the most promising in the immediate future, but great interest centered on new and untapped sources - solar energy from the heavens; geothermal energy from the hot, fiery core of the earth; hydrogen from its waters, and winds from the skies.

The use of hydrogen as an energy carrier is under study. Dr. Kenneth Cox, worked on the project last summer at the Johnson Space Center in Houston. He called for development of a hydrogen energy program and noted there are many advantages to such a system:

"First," he said, "it comes from water, and when burned, its main product is water, so environmentally speaking that is a real plus. We can transmit hydrogen over long distances with existing natural gas lines. Or we could liquefy it and transport it in tankers." He added hydrogen could be compressed and stored in gaseous state in depleted natural gas fields. Cox said hydrogen costs two to three times more than natural gas, but is no more expensive than Middle East natural gas

will be in the future.
(ENERGY, ALTERNATIVE, SOLAR, ENERGY, CARRIER, COAL)

✓ H73 10089* A TOWER TOP FOCUS SOLAR ENERGY COLLECTOR
Hildebrandt, A.F., and L.L. Vant-Hull, (Physics Dept., University of Houston, Houston, Tex.), ASME Winter Annual Meeting, Detroit, Michigan, Nov 73, ASME Paper 73-WA/Sol-7, Avail:TAC

Solar energy can be usefully concentrated onto a central receiver by a large array of independently steered flat mirrors. In order that the reflected radiation all be intercepted, the central receiver must be elevated well above the mirror field. A receiver atop a 450-meter tower can effectively collect the radiation reflected from a 2.6 km square field of mirrors. By judiciously spacing mirrors over 45 percent of the area, such a system at 35 deg N latitude could collect 2700 Mw-Hr-Thermal/day in midwinter and about twice this energy in midsummer. We propose that this heat be used to replace part of the fossil fuel burned in a conventional electrical plant during sunlit hours. Eventually, overnight storage of heat, e.g., in an eutectic salt, could reduce fuel usage to a standby basis. An alternative approach is to use solar energy to generate hydrogen through decomposition of water. The influence of factors to produce the most economical energy from this capital intensive system, including thermodynamic efficiency, receiver temperature, and heliostat steering accuracy, are considered.
(ENERGY, SOLAR, WATER, DECOMPOSITION, RADIATION, EFFICIENCY, TEMPERATURE, SYSTEM)

II. PRODUCTION

H73 20000 EXTRATERRESTRIAL PROPELLANT RESUPPLY FOR ADVANCED MANNED MISSIONS
Heppenheimer, T. A., bibliog il diags Astronautics & Aeronautics V 10:60-7 Nov 72, Avail:TAC

Converting water to hydrogen propellant at the landing site offers a potential means to keep down the size of interplanetary spacecraft and to permit mission operations out to Jupiter's system.
(HYDROGEN, WATER, SPACECRAFT, PROPELLANT)

H73 20001 PERFORMANCE STUDIES ON AN ELECTROLYSER FOR THE PRODUCTION OF HYDROGEN ✓ ?
Seshadri, N., (Meteorological Instruments Workshop, New Delhi, India), Indian J Technol, V 8:65-70 N2 Fe 70

One of the most common means of producing hydrogen gas used in meteorological work for inflating rubber balloons for carrying aloft radiosonde/Rawin transmitters, the radar targets used in the upper air soundings for temperature and upper wind measurements, is by electrolysis. The performance of a modified electrolyzer for hydrogen generation has been studied under different operating conditions.
(HYDROGEN, ELECTROLYSIS, PRODUCTION, PERFORMANCE)

H73 20002 ELECTROLYTIC PRODUCTION OF HYDROGEN AND OXYGEN
Rhodes, William A., (Henes Manufg. Co.), 56552y U. S. 3,394,062 (Cl. 204-129), 2p Jl 23 '68, Appl Mar 14 '63-Je 30 '64 ✓

H and O are produced from an aq. electrolyte contg. electrolyte in concn. greater than that required for max. ionization. The soln. is electrolytically decompd. at a temp. below the b.p. of water.
(ELECTROLYSIS, OXYGEN)

H73 20003 ELECTROLYSIS APPARATUS FOR PRODUCTION OF PURE GASES
Moritz, Jean, 76820d Fr. 1,536,290 (Cl. C 01b), 4 p Aug 16 '68, Appl. Je 21 '67

Electrolytic cells for producing gases, such as H_2 and O_2, employ electrodes with wavy surfaces or surfaces with zig-zag or trapezoidal conformations. These configurations reduce the min. p.d. required. (ELECTROLYSIS, APPARATUS, GAS)

H73 20004 AUTOMATIC LABORATORY APPARATUS FOR OBTAINING HYDROGEN AND OXYGEN
Guseinov, N. M.; Ismailov, I. A.; Lyutfaliev, K. A., Teregulov, S. Kh.; Polyakov, Yu. G., Mamedaliev, Yu. G., (Institute of Petrochemical Processes, Academy of Sciences, Azerbaidzhan S.S.R.), 89649n U.S.S.R. 298,373 (Cl. B 01k, C 01b), Mar 16 '71, Appl. Je 19 '68; From Otkrytiya Izobret., Prom. Obraztsy, Tovarnye Znaki 1971, 48(11), 32

To increase the purity of the gases produced and for regulating the electrolyte level in the anode and cathode spaces, the cylindrical, nonconducting holder for one of the electrodes is placed on the insulated bottom of the electrolyzer and perforated around the circumference in its lower half.
(ELECTROLYSIS, APPARATUS)

H73 20005 OPERATION OF ELECTROLYTIC INSTALLATIONS FOR THE PRODUCTION OF HYDROGEN AND OXYGEN
Goldshtein, A. B.; Serebryanskii, F. Z., 80 p May 21 '70, Joint Publications Research Service, Washington, D. C., Trans. of mono. Ekspluatatsiya Elektroliznykh Ustanovok dlya Polucheniya Vodoroda i Kisloroda, Moscow, 1969 89 p JPRS-50566 HC $3.00/MF $0.65

The electrolysis of water is a process that involves the risk of explosion, since the basic product, hydrogen, forms explosive mixtures with oxygen or air. Therefore it is particularly important that the personnel operating the electrolyzer observe the safety rules described in the last section of this brochure.
(WATER, ELECTROLYSIS, HYDROGEN, OXYGEN, MANUFACTURING METHODS, OPERATION, COSTS, SAFETY)

H73 20006* PRODUCTION OF HYDROGEN BY ELECTROLYSIS
Chapman, E. A., Chem & Process Eng V 46:387-93 N8 Aug 8 '65, Avail:TAC

Under right circumstances, electrolysis can be favorable source of very pure hydrogen; due to high cost of electricity, use of electrolytic methods is

limited in England to few specialized applications, but availability of off-peak power may alter this situation in future; increasing world demand for ammonia may be partially met in some underdeveloped countries by using hydroelectric power for hydrogen production; design and construction of electrolyzers for industrial production of hydrogen and oxygen are reviewed.
(PRODUCTION, HYDROGEN, ELECTROLYSIS, OFF-PEAK POWER, AMMONIA, OXYGEN)

H73 20007* ELECTROLYTIC HYDROGEN--ITS MANUFACTURE AND APPLICATIONS
Silman, H., Chem Age V 93:126-7 N2375 Ja 16 '65, Avail: TAC

Electrolytic hydrogen generating plant producing 100 cu ft/hr of hydrogen manufactured by Efco-Stuart Electrolyser Co, Ltd; it is used where pure hydrogen is required in moderate quantities; simple and automatic in operation, it is available as packaged installation; voltage and current required are 2 v and 100 amp/sq ft; this type of installation can reduce cost of transport and equipment for hydrogen.
(PRODUCTION, HYDROGEN, ELECTROLYSIS, TRANSPORT, EQUIPMENT)

H73 20008 ELECTROLYSIS CELL FOR GENERATING HYDROGEN AND OXYGEN
Proskuryakov, L. M.; Zizin, V. G., (Bashkir Scientific-Research Institute of Petroleum Refining) 32528u Ger. 1,268,602 (Cl. C 01b), May 22 '68, Appl Fe 8 '66, 4 p

An app. for continuous generation of H or O by decompn. of H_2O under pressure consists of an electrolyte vessel (electrode) and a H_2O tank placed on top of it, both being surrounded by cooling coils.
(ELECTROLYSIS, OXYGEN)

H73 20009 ELECTROLYSIS APPARATUS
Haas, Georg, 27549a Ger. Offen. 1,909,852 (Cl. B 01k, C 01b), Sept 17 '70, Appl. Fe 27 '69, 99 p

In an electrolysis app. for production of H_2 and O_2 from water, the lower part of the separator between the anode chamber and the cathode chamber, which normally is open, is closed by a porous, ion-permeable curtain.

Thus, a curtain, e.g. of glass fiber netting with mesh size which allows passage of H ions and O ions but hinders the passage of H_2 bubbles evolved into the anode chamber and O_2 bubbles into the cathode chamber, is used in this way to avoid the formation of explosive mixts.
(ELECTROLYSIS, APPARATUS)

H73 20010 HYDROGEN-OXYGEN CELL PRODUCING ELECTRICITY DURING ELECTROLYSIS
Bruneau, Jean L. G. 83678w Fr. 1,511,568 (Cl. H 01m), Fe 2 '68, Appl. Jl 18 '66, 3 p

H_2 and O_2, electrolytically generated at Pb electrodes in one cell by an external storage battery, are bubbled through holes in a pair of "special" Pb electrodes in another cell, producing elec. power to light an elec. bulb. The electrolyte is aq. H_2SO_4. Designs of an exptl. and a practical system are given.
(ELECTROLYSIS, ELECTRICITY)

H73 20011 ELECTROLYTIC HYDROGEN PLANT
Anon, Engineer, V 222:721, Nov 11 '66, Avail:TAC

A plant producing electrolytic hydrogen from Stuart cells has recently been installed in works of Fine Tubes Ltd., Plymouth, by Efco-Stuart Electrolyser Ltd., Sheerwater, Woking, Surrey. The hydrogen so produced is used as a protective atmosphere to maintain a specular finish on stainless steel tubes during heat treatment. With the present installation of six Stuart cells the plant can produce up to 500 ft^3 of hydrogen per hour but the capacity is to be increased to 750 ft^3/hour by adding three extra cells.
(HYDROGEN, ELECTROLYSIS, STUART CELL)

H73 20012 PRESSURE-RESPONSIVE CONTROL CIRCUIT FOR AN ELECTROLYSIS-TYPE HYDROGEN GENERATOR
Anon, (National Distillers and Chemical Corp.), British 1,165,512 (Cl. G 05d), Oct 1 '69, U.S. Application May 10 '67

An electronic circuit is designed for controlling current supply to the electrodes of an electrolysis-type H generator in response to the generated gas pressure.
(ELECTROLYSIS, CONTROL)

H73 20013* CHEAP HYDROGEN FOR BASIC CHEMICALS
Juda, W., and D.M. Moulton, Chem. Eng. Progr., V 63:59 Ap 67 Avail:TAC

To improve the economics of the electrolytic generation of hydrogen, it is suggested that sulfur dioxide be used to depolarize the oxygen electrode. This substantially reduces the electrolysis voltage and produces commercially valuable sulfuric acid. Two fertilizer schemes based on this procedure using low-cost nuclear power are examined.
(PRODUCTION, HYDROGEN, OXYGEN, SULFURIC ACID, WATER, AMMONIA, ELECTROLYSIS, NUCLEAR, CURRENT DENSITY)

H73 20014* MODERN ELECTROLYSER TECHNOLOGY
Stuart, A.K., Paper presented at the American Chemical Society Symposium on Non-Fossil Fuels, Boston, Ap 13 '72 Avail:TAC

Electrolysis of water is familiar to high school students of chemistry throughout the world; but the extent of its application in industry today may come as a surprise to many. One reads statements in the technical literature such as "the electrolytic process for producing hydrogen is now generally considered too costly for practical purposes." Such statements apply to large plants, except in low-cost power areas, but do not adequately reflect what has in fact been happening in the field. Total figures are not available but there are many hundreds of electrolytic plants in operation today throughout the world and a considerable number are being built every year.

The capacities in industrial use range from as little as 500 cubic feet per day, absorbing perhaps 3 kw, to over 40 million cubic feet per day, absorbing 240 thousand kw. The sizes most common in metallurgical and chemical processing are between 10 thousand and 500 thousand cubic feet per day. The very large installations exist at low-cost hydro-electric sites where hydrogen is used for the manufacture of synthetic ammonia for nitrogen fertilizer. Examples of such plants are in Norway, India, Egypt, Japan, Peru, Korea, Canada and Australia.
(HYDROGEN, ELECTROLYSIS, SYNTHETIC, AMMONIA, NITROGEN, FERTILIZER)

H73 20015 MAKING HYDROGEN AND OXYGEN
Anon, Compressed Air Magazine, V 11:10, Ja 73, Avail:TAC

Hydrogen is becoming more important throughout industry. Of the various known processes for producing high-purity hydrogen and oxygen, the most popular is the electrolytic breakdown of water. The article describes Brown, Boveri electrolyzers.
(OXYGEN, ELECTROLYSIS, HYDROGENATION, FERTILIZERS, METAL, SEMICONDUCTOR)

? ✓ H73 20016 STATUS OF THE LIFE SYSTEMS' STATIC FEED WATER ELECTROLYSIS SYSTEM
Schubert, F.H., (Life Systems, Inc., Cleveland, O.), SAE/ASME/AIAA Life Support and Environmental Control Conference, Jl 12-14 '71, San Francisco, Calif.

The Static Feed Water Electrolysis System (SFWES) is reviewed as developed for an Aircrew O_2 System including cell components, module, and hardware. The control used to match O_2 generation rate with use rate is discussed. The 1967-1969 SFWES's performance status is reviewed including the effect of current density (0 to 350 ASF), operating time (0 to 10,000 hr), and temperature (75 to 180 F) on voltage for various electrochemical cell sizes. The ability to operate without degassing is reviewed; 50 hr in 1967, 100 hr in 1968, and 300 hr in 1969. The anode contributes 89 percent to the increase in cell voltage above the theoretical value initially. All materials of construction demonstrated satisfactory operation for more than 400 days but improvements can be made at the anode.
(ELECTROLYSIS, WATER, STATIC)

1 ✓ H73 20017 LONG-TERM OPERATION OF A WATER ELECTROLYSIS MODULE
Schubert, F.H., (TRW, Inc.), SAE Paper No. 690643

TRW, under NASA sponsorship, has developed a water electrolysis module (WEM) designed to provide 3.6 lb/day of oxygen at a current density of 100 amps/sq ft and at a pressure level of 80 psia. Although designed for aircraft application, the concepts employed in the design of the module make its use in other life support systems possible.

One of the ten-cell water electrolysis modules fabricated, and designed as WEM No. 1, has been successfully operated for 7525 hr. The endurance test program is being conducted at a current density of 80 amps/sq ft, a temperature of 175 F, and a pressure level of 30 psia.

This paper describes the cell and module configurations and the materials of construction selected. Results of the parametric and cyclic test programs are presented and cell performance and servicing and maintenance requirements are discussed.
(ELECTROLYSIS, WATER, MODULE)

H73 20018 REGENERATIVE FUEL CELL STUDY
Wynveen, R.A. and F.H. Schubert, (Life Systems, Inc., Cleveland, O.), Final Report ER-151-2, Nov 72

The objectives of the study were to evaluate the MSS energy storage requirement and the application of the Regenerative Fuel Cell Subsystem (RFCS) to it. This involved identifying the pacing technologies which turn out to be the Water Electrolysis Subsystem (WES) and the hydrogen (H_2)-Oxygen (O_2) Fuel Cell Subsystem (FCS). The expression "fuel cell" as used in this report always refers to the H_2-O_2 fuel cell.
(FUEL CELL, REGENERATIVE)

H73 20019 SIX-MONTH TEST PROGRAM OF TWO WATER ELECTROLYSIS SYSTEMS FOR SPACECRAFT CABIN OXYGEN GENERATION
Gillen, R.J. (NASA Manned Spacecraft Center, Houston, Tex.), B.M. Greenough (Lockheed Missiles and Space Co., Sunnyvale, Calif.), E.S. Mills (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.), W.G. Sanderson (The Boeing Co., Houston, Tex.), and F.H. Schubert (Life Systems, Inc., Cleveland, O.), ASME Paper 72-ENAV-5 72

The water electrolysis systems used in the space-station simulation 99-day manned test of a regenerative life support system at the McDonnell Douglas Astronautics Company were refurbished as required and subjected to a six-month test program. The test objectives and management of the test are described. The test configurations and preliminary findings are summarized and discussed. Problems encountered during testing and the remedial actions taken are defined.
(ELECTROLYSIS, SPACECRAFT, OXYGEN)

H73 20020 SELECTION OF ELECTROLYTES FOR ELECTROLYSIS CELLS: ALKALINE OR ACID

Schubert, F.H., (Life Systems, Inc., Cleveland, O.), Space Technology and Heat Transfer Conference, Los Angeles, Calif., Je 21-24 '70

The paper quantitatively illustrates the effect of the electrolyte nature on a Water Electrolysis System (WES) design. The objective was to select either an acid or a base electrolyte for use in the WES for a space station life-support system. Selection of an alkaline electrolyte was based on a comparison of system equivalent weights. The system, using the Alkaline electrolyte at 190 F, presents a 15- to 21-percent savings in equivalent weight when compared to a 190 F acid system. A 34- to 46-percent savings results when compared to an 80 F acid system. The major (50 to 85 percent) contributor to the system equivalent weight results from the power penalty.

(ELECTROLYTE, CELL, ACID, ALKALINE)

H73 20500 GE PROCESS COULD MAKE CHEAPER HYDROGEN
Anon, Chemical and Engineering News, V 46:48-9 N4 Nov 4 '68, Avail:TAC

Electrochemical process produces hydrogen by dissociating steam with solid zirconium oxide electrolyte cells.
(HYDROGEN, ELECTROCHEMICAL, STEAM, PRODUCTION, ZIRCONIUM OXIDE)

H73 20501* "ENERGY DEPOT ELECTROLYSIS SYSTEMS STUDY"
Schade, C.W., (Allison Division of General Motors), Report EDR 3714, Washington, D.C.: U.S. Atomic Energy Commission, V 1 Final Report TID 20441 Je 64, Avail:TAC

A number of advanced technical concepts for electrolyzer design and construction, which have not yet reached commercial application, but which promise to reduce the likely cost of hydrogen have caused an increase of interest in electrolyzer technology within the last decade in the United States.

The primary military application was the "energy depot program." Because of logistics, the cost of energy on the battlefield is high. In this concept, a nuclear power plant, an electrolytic hydrogen plant, an air liquefaction plant, and an ammonia plant would be flown in and assembled behind the lines to chemically manufacture ammonia to be used as a fuel for internal combustion engines, fuel cells, and heaters. As electrolytic hydrogen manufacture was an integral part of this program, and improved electrolyzers should be possible as a spin-off from advanced fuel cell technology, a significant effort was expended in advancing electrolyzer technology.
(ELECTROLYZER, DESIGN, HYDROGEN, COST, AMMONIA)

H73 20502 PREPARATION OF PURE HYDROGEN
Anon, Matsushita Electric Industrial Co., Ltd. Fr., 92685y, 1,517,243 (Cl. C 01b), Mar le 68, Japan. Appl. Mar 30 66; 7 p.

An aqueous solution of NH_4Cl or NH_4NO_3 is electrolyzed in which solution a powder semiconductor is suspended, having a band width of the forbidden band $\leqq 0.5$ ev., such as Bi_2Te_3, Te, InAs, CdSb, Ge, Si, CdTe, or ZnS.
(ELECTROLYSIS, PRODUCTION)

H73 20503* ELECTROLYSIS AS A SOURCE OF HYDROGEN AND OXYGEN
Costa, R.L., and P.G. Grimes, Chemical Engineering Progress, V 63:56 Apr 67, Avail:TAC

By the application of fuel cell technology, high-efficiency electrolytic cells have been built and extensively tested. An economic study using low-cost nuclear power shows water electrolysis to be competitive for ammonia plants in areas where natural gas is not available and for hydrogen and oxygen supply to other segments of the chemical industry.
(PRODUCTION, HYDROGEN, OXYGEN, WATER, AMMONIA, ELECTROLYSIS)

H73 20504* ELECTROLYTIC HYDROGEN FUEL PRODUCTION WITH SOLID POLYMER
Titterington, W.A. and A.P. Fickett, Electrolyte Technology, 8th Intersociety Energy Conversion Conference, Philadelphia, Pa., Aug 13 '73, Avail:TAC

The General Electric Company water electrolysis technology, which is based on a solid polymer electrolyte (SPE) concept, is presented for applicability to large-scale hydrogen production in a future energy system. High cell current density operation is selected for the application, and supporting cell test performance data is presented. Demonstrated cell life data is included to support the adaptability of the SPE system to large-size hydrogen generation utility plants as needed for bulk energy storage or transmission. The inherent system advantages of the acid SPE electrolysis technology are explained. System performance predictions are made through the year 2000, along with plant capital and operating cost projections.
(ENERGY, PRODUCTION, STORAGE, TRANSMISSION, PERFORMANCE, COST)

H73 20505 WATER ELECTROLYSIS - PROSPECT FOR THE FUTURE.
Wydeven, T., (NASA, Ames Research Center, Moffett Field, Calif.) and R.W. Johnson, (NASA, Langley Research Center, Hampton, Va.), (Aviation and Space: Progress and Prospects; Proceedings of the Annual Aviation and Space Conference, Beverly Hills, Calif., Je 16-19 '68, p 93-102.) ASME, Transactions, Series B - Journal of Engineering for Industry, V 90:531-540 Nov 68, 13 refs, Avail:TAC

A survey of oxygen generators for spacecraft based

on water electrolysis is presented. The water electrolysis cells surveyed are predominantly prototype units including both liquid and vapor feed cells. Cell design, operational performance, gas purity, and problems encountered during testing are discussed. Suggestions are given as to where future research might be concentrated in order to solve some of the more general problems associated with water electrolysis.
(OXYGEN, PRODUCTION, ELECTROLYSIS, SPACECRAFT, DESIGN)

H73 20506* "DESIGN STUDY OF HYDROGEN PRODUCTION BY ELECTROLYSIS"
Anon, Allis-Chalmers Manufacturing Company, Publication No. ACSDS 0106643, Milwaukee, Oct 66, Avail:TAC

The present program, a design study of hydrogen production by electrolysis, was centered around low capital investment as the primary goal, with other factors, such as high efficiency, long life, simple, trouble-free operation, maintenance and down time also influencing the conceptional system. Only uncatalyzed porous nickel electrodes were considered.
(HYDROGEN, PRODUCTION, ELECTROLYSIS, DESIGN, COST)

H73 20507* "THE ECONOMICS OF HYDROGEN AND OXYGEN PRODUCTION BY WATER ELECTROLYSIS AND COMPETITIVE PROCESSES"
Mrochek, J.E., in W.W. Grigorieff, Ed., Abundant Nuclear Energy, Washington, D.C.: U.S. Atomic Energy Commission, V 107:22 69, Avail:TAC

The manufacturing costs of hydrogen and oxygen are estimated for water-electrolysis plants using two types of advanced electrolytic cells: porous-electrode cells and high-temperature vapor-phase cells. Electrolytic plants producing 40 million standard cubic feet of hydrogen and 860 tons of oxygen per day are compared with fossil-fuel plants that use steam reforming and partial-oxidation processes at the same hydrogen-production rates. The cost of electricity required for the electrolytic process using a porous-electrode cell to break even with the fossil-fuel processes ranged from 0.8 to 2.3 mills/kWh. If an oxygen credit of $4/ton was assumed, this break-even power cost range increased to 1.5 to 3 mills/kWh. The use of electrolytic hydrogen plants as load-leveling devices for power is discussed briefly.

(HYDROGEN, OXYGEN, PRODUCTION, ELECTROLYSIS, COST, STEAM REFORMING, PARTIAL OXIDATION)

H73 20508 OXYGENHYDROGEN GENERATOR
Spengler, H.H,, T.J. Kempher (Allis-Chalmers Manufacturing Co.), FR. 1,514,487 (Cl. C olb), Fe 23 '68, US Appl. Fe 25 '68; 4 p

An O-H generator consists of a porous electrolyte matrix, such as polypropylene or asbestos fibers, between 2 porous sintered Ni electrodes. Between the matrix and the electrodes are interposed noble metal, preferably Pt or Pd, screens. The screens may be 0.25-mm. thick with 0.3-mm. openings.
(ELECTROLYTE, NICKEL, MATRIX)

H73 20509 SOLID ELECTROLYTES OFFER ROUTE TO HYDROGEN
Anon, Chemical and Engineering News, Aug 27 '73, Avail:TAC

Electrolysis systems to generate hydrogen may result from solid polymer electrolytes originally designed for fuel cells.
(HYDROGEN, PRODUCTION, ELECTROLYSIS, POLYMER)

H73 20510* HYDROGEN GENERATION BY SOLID POLYMER ELECTROLYTE WATER ELECTROLYSIS
Russell, J.H., L.J. Nuttall and A.P. Fickett, American Chemical Society Meeting, Hydrogen Fuel Symposium, Chicago, Aug 73, Avail:TAC

The most common water electrolysis units in the past used a liquid caustic (potassium hydroxide) electrolyte and were relatively inefficient and required frequent maintenance. During the past five years, however, the General Electric Company has developed a unique solid polymer electrolyte (SPE) water electrolysis technology The SPE system combines high efficiency with exceptionally long, maintenance free life (over three years of continuous operation have been accumulated to date on one of the early single-cell units). While this development was prompted primarily by requirements for oxygen generation in aerospace and submarine life support systems, the design can readily be adapted and scaled to large-size hydrogen generation plants.

It is the purpose of this paper to summarize the present and projected capabilities of the SPE water

electrolysis technology, and to consider the applicability of the SPE technology as a generator of hydrogen for use as a fuel, for energy transmission, and for energy storage.
(HYDROGEN, PRODUCTION, ELECTROLYSIS, POLYMER, FUEL, ENERGY, TRANSMISSION, ENERGY STORAGE)

H73 20511* "NUCLEAR ENERGY CENTERS, INDUSTRIAL AND AGRO-INDUSTRIAL COMPLEXES"
Anon, Oak Ridge National Laboratory, ORNL 4290, Washington, D.C.: U.S. Atomic Energy Commission, Nov 68, Avail:TAC

The cost of hydrogen production by electrolysis is markedly dependent on the cost of electric power. Oak Ridge National Laboratory carried out a design study for large-scale electrolyzers in 1966, and derived a cost for a 44,000 lb/hr plant (about 1000 MW input) of about $40 million. This is about 10% of the cost of the nuclear power stations required to supply it. Their hydrogen production cost was based upon some rather unorthodox financing assumptions and a very low cost of electric power (2.5 mills/kWhr, compared to an average cost of over 9.0 mills prevailing in 1970). This gives a hydrogen production cost of $1.03/million Btu.
(HYDROGEN, PRODUCTION, COST, ELECTROLYSIS, ELECTRICITY, NUCLEAR POWER)

H73 20512* "SYSTEM STUDY OF HYDROGEN GENERATION BY THERMAL ENERGY"
Funk, J.E. and R.M. Reinstrom, Final Report TID 20441, Allison Division of General Motors Report EDR 3714, Washington, D.C.; U.S. Atomic Energy Commission, V 2 Supplement A Je 64, Avail:TAC

The results presented in this report show that the ideal efficiency of a constant temperature and pressure chemical process which produces hydrogen from water is exactly the same as the ideal efficiency of an electrolysis process operated at the same temperature and pressure. It is further shown that there are inefficiencies in a chemical process which cannot be avoided. The fact is established that the reactions in a chemical process cannot be run at a single temperature if the process is to be more efficient than electrolysis.

Specifications for compounds which would yield

efficient two-reaction chemical processes have been developed. They appear in the form of free energy of formation and absolute entropy difference between the hydride or oxide of the compound and the compound itself. The absolute entropy change that occurs when either an oxygen atom or two atoms of hydrogen are added to a molecule can be determined semiempirically. These semiempirical correlations indicate that only certain gaseous compounds can meet the entropy specification. Whether these gaseous compounds meet the free energy specification, or whether they exist, has not been determined. Such determination, along with further study of the developed specifications and an extension of the specifications to include phase changes, are recommended for future work.
(HYDROGEN, PRODUCTION, ELECTROLYSIS, FREE ENERGY, ENTROPY, THERMAL EFFICIENCY)

H73 20513 ELECTROLYTE HYDROGEN BY PRESSURE ELECTROLYSIS IN THE ZDANSKY-LONZA ELECTROLYTOR
Anon, Lurgi Gesellschaft fur Warmetechnik, MBH, Frankfurt, Main, 72, Avail:TAC

The pressure electrolysis process has been technically applied in the Zdansky-Lonza Electrolytor, this being the first unit in the history of water electrolysis making hydrogen and oxygen at 30 atmospheres gauge pressure on an industrial scale, giving an output range of between 100 and 700 std. cu. m. of hydrogen per hour per unit.
(ELECTROLYSIS, OXYGEN, POWER, PRESSURE, CELL, VOLTAGE)

H73 21000 THERMODYNAMICS OF MULTI-STEP WATER DECOMPOSITION PROCESSES
Funk, J.E., (University of Kentucky, Lexington), American Chemical Society, Division Fuel Chemistry, V 16:79-87 N4 Apr 10-14 '72, (Paper for Meeting), Avail:TAC

Brief description of the process in which hydrogen is produced from water by thermal treatment in three or four steps in presence of such catalysts as tantalum-, bismuth-, mercury-, or vanadium-chloride is followed by thermodynamic calculations. The following topics are discussed in detail -- second law limitations; multistep processes; work of separation; and the vanadium chloride process. Technological data are included.
(HYDROGEN, PRODUCTION, CATALYST, THERMAL)

H73 21001 OBTAINING HYDROGEN BY MEANS OF REACTOR HEAT
Dorner, S., (Kernforschungszentrum, Karlsruhe, West Germany; Institut fuer Neutronenphysic und Reaktortechnik), NSA 33122 (NP-19322), 66 p. Oct 71 (In German), Dep. NTIS

Known methods used in the decomposition of water by means of reactor heat are discussed. Theoretical considerations on the development of new methods show that closed-circuit processes with gas components require relatively high temperatures and, therefore, seem to be not very promising. The production of hydrogen by dissolution of the metal and the subsequent conversion into oxide call for a low decomposition temperature of the oxide. Experiments were made with reactions in the molten state in order to convert into oxides the halogenides formed in the closed-circuit process. With a view to complete the closed-circuit processes, exchange reactions and separations through evaporation of some alkaline and alkaline earth halogenides, respectively, and the metals in the Vb-group of the periodic system were checked experimentally. Some considerations were made with respect to economy.
(DECOMPOSITION, WATER, CLOSED, REACTION, OXIDE, HALOGEN)

H73 21002* THERMOCHEMICAL HYDROGEN GENERATION
Wentorf, R.H., Jr. and R.E. Hanneman, (Corporate Research and Development, Schenectady, N.Y.), Report No.-73CRD222, Jl 73, Avail:TAC

The basic concepts for thermochemical hydrogen generation are described along with useful criteria for the

selection of potentially viable, multistep, closed-cycle processes. Three partially tested, new closed-cycle thermochemical hydrogen production processes, based on nuclear heat and water input, are presented with overall, potential thermal efficiencies ranging from 40% to 60%. Closed-cycle hydrogen processes are compared briefly to electrolytic and open-cycle (carbon fed) thermochemical methods for hydrogen generation.
(NUCLEAR, WATER, CYCLE, THERMAL, EFFICIENCY)

H73 21003* *"ENERGY REQUIREMENTS IN THE PRODUCTION OF HYDROGEN FROM WATER"*
Funk, J., and R. Reinstrom, Industrial and Engineering Chemistry Process Design Development, V 5:336-42 Jl 66, Avail:TAC

The energy requirements for the production of hydrogen from water are discussed from a theoretical point of view. A Carnot, or temperature, limitation on the efficiency of producing hydrogen from water using thermal energy is developed. The theoretical energy requirements, as both useful work and heat, for various processes which decompose water are determined -- electrolysis, direct decomposition, and multi-reaction chemical processes -- to find processes and conditions for which the useful work requirement is minimized. Lowering the useful work requirement increases the hydrogen yield per unit of thermal energy -- i.e., increases the process efficiency. Specifications for compounds to be operated in efficient two-reaction chemical processes are developed and their use is discussed. While a water decomposition process more efficient (on a thermal energy basis) than electrolysis is highly desirable, none is available at present.
(ELECTROLYSIS, DECOMPOSITION, CHEMICAL, ENERGY, USE, THERMAL)

H73 21004 HYDROGEN PRODUCTION CYCLIC PROCESS
DeBeni, G., (Europaeische Atomgemeinschaft (EURATOM) Europazentrum Kirchberg) Ger. Offen. 2,005,015 (Cl. C 01b), Sep 10 '70, Appl. Fe 19 '69; 7 p

A cyclic process for the production of H from Hg and H_2O is described. Thus, 0.15 ml Hg and 2.4 ml 48% HBr were heated in a 40 ml reaction vessel within 2 hr up to 200° to give after cooling H at a pressure of 2 atom and 20% of the stoichiometric amt. $HgBr_2$.
(HYDROGEN, CYCLE, WATER, PRODUCTION)

H73 21005* "HYDROGEN PRODUCTION FROM WATER USING NUCLEAR HEAT"
Marchetti, C., Ispra, Italy: Euratom, Joint Nuclear Research Center, Progress Report No. 1, Dec 70, Avail:TAC

Multistep chemical processes for the decomposition of water, using nuclear heat, are studied in view of producing hydrogen as intermediate energy vector.

The results of the work performed at the Centre of Ispra up to December 1970 are reported: the main object of the research is the Mark-I cycle, the first patented of these chemical cycles.

The studies are principally related to the chemistry (equilibria and kinetics studies and physico-chemical properties), to the corrosion of construction materials, to the preliminary flow-sheet determination for the coupling with a nuclear reactor.

A general hydrogen market evaluation is also included.
(CHEMICAL, CORROSION, ENERGY, CYCLE, COST, THERMAL, DECOMPOSITION)

H73 21006 "A LOW TEMPERATURE THERMAL PROCESS FOR THE DECOMPOSITION OF WATER"
Abraham, B.M., and F. Schreiner, Science, V 180:959 73, Avail:TAC

The following three reactions, each of which has been shown to proceed at the temperature indicated, are suggested as a cycle for the thermal decomposition of water:

$$LiNO_2 + I_2 + H_2O \dashrightarrow LiNO_3 + 2HI,\ 300^{o}K$$

$$2HI \dashrightarrow I_2 + H_2,\ 700^{o}K$$

$$LiNO_3 \dashrightarrow LiNO_2 + \tfrac{1}{2}O_2,\ 750^{o}K$$

(HYDROGEN, OXYGEN, PRODUCTION, CYCLE, REACTION)

H73 21007* "HYDROGEN SOUGHT VIA THERMOCHEMICAL MEANS"
Anon, Chemical and Engineering News, Sept 3 '73

Especially promising are several reaction schemes that can produce hydrogen by thermal cracking of water in closed system. The article reviews several closed-cycle processes that have been devised at General Electric.
(THERMAL, WATER, CLOSED, SYSTEM, REACTION, PRODUCTION)

H73 21008 THERMOCHEMICAL CRACKING OF WATER
Pangborn, J.B., (Institute of Gas Technology, Chicago, Ill.), Cornell Symposium and Workshop on "The Hydrogen Economy," Cornell University, Ithaca, N.Y., Aug 20-22 '73, Avail:TAC

Major objectives in developing thermochemical cycles to split water into hydrogen and oxygen are a cyclical set of chemical reactions and products that are easily and efficiently separated. Few thermochemical cycles proposed to date would exceed an energy efficiency of 50% when operating as a process. A final conclusion is that economics will govern final choices of cycles, and efficiency only partly determines the economics.
(HYDROGEN, OXYGEN, DECOMPOSITION, CYCLE, CHEMICAL, REACTION, EFFICIENCY, ECONOMICS)

H73 21009 CHEMICAL PROCESS TO DECOMPOSE WATER USING NUCLEAR HEAT
De Beni, G., (C.C.R.), Euratom-Ispra-Varese, Italy; C. Marchetti, American Chemical Society, Division Fuel Chemistry, Preparation, V 1:110-133 N4, Paper for Meeting Apr 10-14 '72, Avail:TAC

This is a description of a process of water conversion into hydrogen and oxygen by using the nuclear heat for operating some endothermal chemical reactions in a closed cycle, i.e. with nominal consumption of chemicals. In this method a four-step chemical cycle, christened Mark I, is employed with catalysts containing reaction studies involved in the Mark-I are presented, optimal structure of catalyst is elucidated, and economic considerations are included.
(PRODUCTION, HYDROGEN, OXYGEN, CYCLE, MARK I, CATALYST, ECONOMY)

H73 21010 MOLLIER DIAGRAMS FOR THE EVALUATION OF NUCLEAR HEAT PROCESSES FOR WATER DECOMPOSITION
Glaser, H., VDI-Forschungsh, V 38:17-24 N549, 72

Some non-electrolytic water decomposition processes for the production of hydrogen gas fuel by using nuclear heat are discussed, including the two-stage process involving reactions of metals with metal oxides, the multiple-stage process by G. de Beni based on reactions between $CaBr_2$ and Hg, and the multiple-stage Fe-Cl process. Mollier's enthalpy vs entropy diagrams are presented for

the appraisal of these processes.
(HYDROGEN, PRODUCTION, FUEL, NUCLEAR)

H73 21011 PROCEEDINGS ROUND TABLE ON DIRECT PRODUCTION OF HYDROGEN WITH NUCLEAR HEAT
Anon, C.C.R. Euratom, Ispra, Italy, Dec 12 '69, EUR/C-IS/1026/1/69e, Avail:TAC

A conference on the idea of using nuclear energy to make hydrogen from water without recourse to other raw materials.
(WATER, DECOMPOSITION, CYCLE, ENERGY, PROCESS, FUEL)

H73 21012* HYDROGEN PRODUCTION FROM WATER USING NUCLEAR HEAT
Marchetti, C., Euratom, Joint Nuclear Research Center, Ispra, Italy, Progress Report No. 3, Dec 72, Avail:TAC

Research on methods of hydrogen production by chemical decomposition of water is based on the interest in extending the utilization of nuclear energy by using a flexible and clean "energy vector."

Even more than during 1971, in 1972 the scientific and industrial worlds have turned their attention to hydrogen as a possible basis for a future "energy system."

Work performed at the J.R.C., Ispra has been oriented to:

- -exploring the possibilities of chemical cycles which could bring about the decomposition of water (within the above mentioned temperature limits).
- -obtaining sufficient information on these possible chemical cycles to make comparisons, and to make a technico-economic evaluation of the relative industrial processes.

The research now being performed is still in its earliest stage, the object of which is to obtain sufficient elements to design a pilot plant.

At the end of this first stage (three - five years long, according to the effort available to devote to it), the evaluations will have to be sufficient to decide:

(a) whether it is possible to develop an industrial process,
(b) whether it is worthwhile to construct a pilot plant for the most promising looking cycle.

Parallel to the laboratory research work, and in support of the decisions to be taken, studies will be carried out in close collaboration with industry on the development of the hydrogen market, its role and impact on the energy system, and on all the relative technical and economical assessments.

In conclusion it can be said that the research is at the beginning of an important phase, in which the number of cycles is increasing significantly and showing interesting diversification. Knowledge of several of these cycles will be, in the next future sufficiently advanced to make some preliminary evaluations and comparisons.
(ENERGY, CYCLE, DECOMPOSITION, CHEMICAL, STUDY, ECONOMICS, KINETICS, THERMODYNAMICS, DESIGN, PLANT)

H73 21013* THERMAL DECOMPOSITION OF WATER THROUGH CHEMICAL CYCLES USING A Fe-Cl_2 FAMILY
Herdy-Grena, C., (Commission of the European Communities, Joint Nuclear Research Centre - Ispra Establishment, Materials Department, Italy), Je 73

The thermal decomposition of water through chemical cycles is considered under a theoretical point of view. From the specified thermochemical conditions (upper limit of the temperatures, limitation of the reaction free energy changes, etc.), it is ascertained that only chlorine is suitable, as an element, to decompose water, in the first reaction of a multistep process.

Therefrom a Fe-Cl_2 family was worked out. This family uses iron and chlorine compounds and offers the advantage to involve common elements and to bring on few corrosion and pollution problems.
(IRON CHLORIDES, THERMODYNAMICS, CHEMICAL, REACTION, KINETICS)

H73 21014* FUNDAMENTALS OF THERMOCHEMICAL CYCLIC PROCESSES
Barnert, H., (Nuclear Research Center, Juelich, Germany), Report No. JUL-967-RG, Institute for Reactor Development, KFA Juelich, Germany, Je 73, Avail:TAC

Relations between heat and work and thermodynamic data of chemical reactions are given. They are derived with the theory of the thermodynamic of irreversible processes using a number of homogeneous regions. There are considered several sorts of entropy production and their effects on the efficiency Hereby statements are possible on thermochemical cyclic processes, especially on the thermochemical cyclic process for

the production of hydrogen and oxygen from water.
(THERMODYNAMICS, CYCLE, PROCESS, NUCLEAR, HEAT, WATER, SPLITTING, THERMOCHEMICAL, EFFICIENCY)

H73 21015* NUCLEAR WATERSPLITTING
Barnert, H., (Nuclear Research Center, Juelich, Germany), Atomwirtschaft, Aug-Sept 73, p 408-410, (In German), Avail:TAC

The energy system "Nuclear energy as primary energy source and hydrogen as carrier for energy, produced from water in an thermochemical cyclic process" opens up new aspects of future energy supply. Particularly for this application, the High Temperature Reactor (HTR) with Pebble Bed Core (PBC) and Once Through Than Out (OTTO) fueling fits excellently as the nuclear heat source.
(ENERGY, REACTOR, HEAT, WATER, SPLITTING, CYCLE, PROCESS, THERMOCHEMICAL)

H73 21016 THERMOCHEMICAL AND NUCLEAR TECHNOLOGY FOR NUCLEAR WATER SPLITTING
Barnert, H., (Nuclear Research Center, Juelich, Germany), Cornell International Symposium and Workshop on "The Hydrogen Economy", Cornell University, Ithaca, N.Y., Aug 73, Avail:TAC

With regard to nuclear power used for thermochemical water splitting, the author makes the following three points:

1) The production of hydrogen should be done on a large scale with large size units.
2) It seems to be economical to make use of the potentially high efficiency of the "thermochemical cyclic process."
3) Chemical engineering experience (expressed as "space-time") should be used to a wide extent.

(NUCLEAR, THERMOCHEMICAL, WATER, SPLITTING, TECHNOLOGY, EFFICIENCY, HEAT, PROCESS)

H73 22000* PRODUCTION OF HYDROGEN FROM COAL CHAR IN AN ELECTROFLUID REACTOR
Pulsifer, A. H., (Iowa State University, Ames), T. D. Wheelock, Industrial and Engineering Chemistry, Process Design Development, V 11:229-37 N2 Ap 72, Avail:TAC

The characteristics of electrofluid reactor are reviewed, and a reaction model which appears to fit experimental results is proposed. Product gas compositions and energy requirements predicted by the model for the gasification process are presented for various possible operating conditions. The present state of development of the reaction system and foreseeable problems which must be worked out are reviewed. In addition, the adaptation of the process to the production of various products such as hydrogen, methane, and methanol is discussed.
(REACTION, GASIFICATION, METHANE, METHANOL, SYNTHESIS GAS, ENERGY)

H73 22001 PRODUCTION OF HYDROGEN FROM COAL CHAR IN AN ELECTROFLUID REACTOR
Pulsifer, A. H., (Iowa State University, Ames), T. D. Wheelock, (American Chemical Society, Division Petroleum Chemistry), Preparation V 16:C5-C19 N2 for meeting Los Angeles, California, Mar 28 - Apr 2 '71

The characteristics of electrofluid reactor are reviewed, and a reaction model which appears to fit experimental results is proposed. Product gas compositions and energy requirements predicted by the model for the gasification process are presented for various possible operating conditions.
(REACTION, GASIFICATION, METHANE)

H73 22002 COAL PROCESSING BY ELECTROFLUIDICS, PHASE II
Anon., Iowa State University of Science and Technology, Ames, Report for May 11 '65-Ap 1 '67, Ap 1 '67, 123 p Contract 14-01-0001-479, PB-174927, HC $3.00/MF $0.65

The purpose of the investigation was to develop coal utilization processes which can be carried out advantageously in an electrofluid bed reactor. The first process studied was the manufacture of hydrogen by the steam-carbon reaction. The electrofluid bed reactor consists of an electrically heated fluidized bed of conducting solids. The report contains a

summary of the experimental data collected on the gasification of coal char using steam and the results of a study on the contact resistance between a fluidized bed and an electrode placed in it. A preliminary economic evaluation of a process for producing hydrogen is also included as are preliminary economic evaluations of processes for producing carbon disulfide and hydrogen cyanide.
(FLUIDIZED BED, COAL, HYDROGEN, INDUSTRIAL, GAS, CHARCOAL, STEAM, DECOMPOSITION, ECONOMICS, STUDY)

H73 22003 PRODUCTION OF A MIXTURE OF HYDROGEN AND STEAM
Benson, Homer E., (Con-Gas Service Corp.), 89189j, U. S. 3,421,869 (Cl. 48-197), Ja 14 '69, Appl Je 1 '64, 4 p

In the steam-Fe process for prepg. a mixt. of H_2 and steam, steam and air are caused to react with carbonaceous material to prep. a gas mixt. contg. 22% CO, 6% CO_2, and 20% H_2 (producer gas) which is then used to reduce Fe_3O_4 to FeO and Fe. The reduced Fe is then oxidized with steam to prep. H and the cycle is repeated.
(STEAM, IRON, CYCLE, HYDROGEN)

H73 22004 UNIFORM FLOW OF FLUIDIZED COKE TO THE REHEATING ZONE DURING HYDROGEN GENERATION BY COKING
Oldweiler, Morcy E. (Esso Research and Engineering Co.) 62842a, Fr. 1,533,265 (Cl. C 10b) Jl 19 '68, U. S. Appl. Je 30 '66, 7 p

During the prepn. of H from hydrocarbons by coking, bubbling and large variations in pressure are prevented in the conduit in which powd. coke is transported upward to the reheater as a fluidized solid in a gas. The pressure variations are prevented by injecting the fluidizing gas through several inlets located along an initial section of the conduit.
(FLUIDIZED, COKE, HYDROGEN, GENERATION)

H73 22005 CHAR OIL ENERGY DEVELOPMENT
Jones, John F., Michael R. Schmid, Martin E. Sacks, Yung-Chuan Chen, and Charles A. Gray (FMC Corp., Princeton, New Jersey), U. S., Clearinghouse Federal Science and Technical Information, PB 173916, 83733y, 239 p (1967) (Eng.), Avail:CFSTI

The multistage fluidized-bed pyrolysis of high-

volatile bituminous coals to product oil, gas, and char was studied. Catalytic hydrotreating of the oil yields a synthetic crude oil suitable as a petroleum-refinery feedstock. The product gas can be reformed to produce a high-Btu. pipeline gas or H. The char product is used as boiler fuel for power generation.
(FLUIDIZED, COAL, CATALYST, CHAR, POWER)

H73 22006 HYGAS PROGRAMS
Papamarcos, John, Power Engineering, Fe 73, p 33-38, Avail:TAC

This article presents the incentive to develop the most economical gasification process.

HYGAS Programs Among the new gasification processes being developed, the HYGAS programs are furthest advanced. The Institute of Gas Technology started work on coal gasification in 1944 and over a period of years developed two processes, both of which were incorporated into the HYGAS process. One process gasified powdered coal in suspension with oxygen and steam to produce a mixture of carbon monoxide and hydrogen. This mixture was then upgraded by passage over a nickel catalyst. The second process was direct hydrogenation of pretreated coal. In this process the coal was pretreated at elevated temperatures with an oxygen-bearing gas to destroy its caking tendency. The coal was then fed into a reactor maintained at a temperature of about 1300 to 1500 F and a pressure between 1000 and 1500 psi. Hydrogen was injected into this reactor to maintain the powdered coal in a fluid-like condition and to react with it to produce methane.

Synthane Process Basic process steps are (1) coal pretreatment to destroy caking properties; (2) carbonization plus steam-oxygen gasification of the pretreated coal in a fluidized bed; (3) shift conversion of synthesis gas to ratio of 3:1 for hydrogen and carbon monoxide; (4) purification of shifted product gas; and (5) catalytic methanation of the hydrogen plus carbon monoxide.
(COAL, GASIFICATION, HYDROGEN, PRODUCTION, METHANE)

H73 22007 HOW PRESSURE AND OXYGEN/METHANE RATIO AFFECT PARTIAL OXIDATION
Wellman, P. and S. Katell, Hydrocarbon Processing

& Petroleum Refiner, V 43:106-8 Dec 64

At the Morgantown Coal Research Center of the Bureau of Mines, economic evaluations of well-known processes for hydrogen production have been made to compare with cost evaluations of systems using coal as a basic raw material. Included in these comparative studies are evaluations of the steam-methane reforming and partial oxidation of methane systems to produce the synthesis gas with subsequent upgrading to produce hydrogen.

The partial oxidation of methane to produce hydrogen for ammonia synthesis is particularly attractive, since part of the nitrogen (a byproduct of the oxygen plant) may be used to synthesize the product.
(HYDROGEN, PRODUCTION, COST, COAL, SYNTHESIS GAS, AMMONIA, NITROGEN)

H73 22008 DISTRIBUTION OF GASEOUS PRODUCTS FROM LASER PYROLYSIS OF COALS OF VARIOUS RANKS
Karn, F. S., R. A. Friedel, and A. G. Sharkey, Jr.
(Pittsburgh Coal Research Center, Pittsburgh, Pa.)
97315e, Carbon (Oxford) 5(1), 25-32(1967) (Eng.)

Irradiation of coal by laser energy pyrolyzes coal rapidly at high temps. Gaseous products from coals of various ranks were analyzed by mass spectrometry. The total gas yield varied inversely with coal rank, showing a 4-fold increase between anthracite and lignite. The at. C-H ratio for the gases was lower than for the corresponding coal. Yields of C_2H_2, H_2, CO, and CO_2 generally increased between anthracite and lignite.
(LASER, PYROLYSIS, COAL)

H73 22009* GASIFICATION; A REDISCOVERED SOURCE OF CLEAN FUEL
Maugh, Thomas H., Science 178:4056, p 44-45 Oct 6 '72
(Q/1/S28), Avail:TAC

The basic chemistry of gasification is simple. Carbon from coal or naphtha--the petroleum fraction with a boiling point between 175° and 240°C--is combined with water to form "synthesis gas"--a mixture of methane, hydrogen, and carbon monoxide--and carbon dioxide. This gas is then combined to form methane, the principal constituent of natural gas. The overall reaction requires several steps, however, and is much more complex.

Naphtha gasification is considerably simpler than coal gasification and is in a much more advanced state of development. Three different naphtha processes have been commercialized: the catalytic rich gas (CRG) process developed by the British Gas Council, the methane rich gas (MRG) process developed by Japan Gas Company, and the Gasynthan process developed by West Germany's Lurgi Mineraloeltechnik GmbH and Badische Anilin-und Soda-Fabrik AG. These processes are very similar in concept. The main difference is in the catalysts used.
(COAL, HYDROGEN, PRODUCTION, CATALYST, SYNTHESIS GAS, METHANE)

H73 22010 IGT GETS $18-MILLION OCR CONTRACT TO MAKE HYDROGEN GAS FROM COAL CHAR WASTE
Anon, Energy Resources Report, Jl 13 '73

An $18,160,000 contract to develop process for producing hydrogen gas from coal char waste--an intermediate step in production of pipeline quality gas from coal--was awarded July 6 to Institute of Gas Technology, Chicago, Ill., by Interior Department's Office of Coal Research.
(GASIFICATION, COAL, CHAR)

H73 22011 GASIFICATION OF SOLID FOSSIL FUELS IN A MICROWAVE DISCHARGE
Fu, Y.C., B.D. Blaustein, and I. Wender, (Pittsburgh Energy Research Center, (Bureau of Mines, Pittsburgh, Pa.), Chemical Engineering Progress, Symposium Series, V 67:47-54 N112 71

Gasification of solid fuels (lignite, high-volatile A bituminous coal, oil shale, kerogen, gilsonite, tar sands) in a microwave discharge in argon gave H, CO, and gaseous hydrocarbons. The extent of gasification depended on the C content of the solid. High initial rates of production of various composnents of gases decreased rapidly in the early stages of reaction. In a CO_2 discharge, the product species were oxidized to CO; in a H discharge, the formation of hydrocarbons was enhanced.
(GASIFICATION, FOSSIL, FUEL, MICROWAVE)

H73 22012 GASES FROM LASER PYROLYSIS OF ORGANIC MATERIALS
Karn, F.S., R.A. Friedel, and A.G. Sharkey, Jr., (Pittsburgh Coal Research Center, Bureau of Mines, Pittsburgh, Pa.), Chemistry and Industry, (London), V 7:239-40 70

Laser irradiation of coal, petroleum, and rubber in a He atmosphere produced simple gas mixture containing mainly H and C_2H_2. With coal, CO and CO_2 were also major products. Use of the method in refuse disposal was suggested, since usable C_2H_2 would be produced.
(LASER, PYROLYSIS)

H73 22013 WHAT HYDROGEN FROM COAL COSTS
Katell, S. and J.H. Faber, (The U.S. Department of Interior, Bureau of Mines, Morgantown, W. Va.), Hydrocarbon Process Petro Refiner, V 43:3 Mar 64

These economics indicate that hydrogen can be produced from coal for about $0.38 per 1,000 cubic feet using coal gasification, steam-iron process or nuclear heat gasification.
(COST, ECONOMICS, HYDROGEN, COAL)

H73 22100 EMPHASIS ON H_2 STRENGTHENED
Anon, Oil and Gas Journal, V 70:87-8 Fe 14 '72, Avail:TAC

Hydrogen is on the way to becoming as fundamental for the modern U.S. refinery as crude oil, equipment, and catalysts.

The primary routes to hydrogen are steam reforming and partial oxidation.

Both processes entail some form of feed preparation followed by the generation of raw gases and their purification to yield the desired hydrogen product. Substitute natural gas from liquid hydrocarbons or coal will also be a product of this technology.
(STEAM REFORMING, PARTIAL OXIDATION, HYDROCARBONS, COAL, ENERGY)

H73 22101 APPARATUS FOR PRODUCING AND COOLING GASEOUS MIXTURES OF HYDROGEN AND CARBON MONOXIDE
Ter Haar, L.W., (Shell Internationale Research Maatschappij N.V.), 131435s, Ger. Offen. 2,102,370 (Cl. C 01b), Jl 29 '71, Neth. Appl. Ja 21 '70, 14 p

To prevent excessive C formation and settling of C on cooling surfaces in a CO-H reactor by partial oxidation of hydrocarbons with O or O-enriched air and steam at 5-150 atmosphere, a cooling medium such as H_2O is introduced through a jet nozzle, into a series of spiral shaped tubes, which surround the center of the reactor, and where the cooling medium is recirculated to control the pressure and temperature in the reaction.
(HYDROGEN, CARBON MONOXIDE, PROCESS)

H73 22102 HYDROGEN, STEAM REFORMING; FOSTER WHEELER CORPORATION
Anon, Hydrocarbon Process, V 51:222 Sept 72

The basic steps for the steam-hydrocarbon reforming process are desulfurization, reforming, CO conversion, CO_2 removal and methanation.

The desulfurization of the hydrocarbon feed is necessary in order to prevent catalyst deactivation or poisoning. Depending on the type of feedstock and the nature of the sulfur contaminants, desulfurization methods can vary from ambient temperature adsorption on activated carbon, to high temperature reaction with zinc oxide (as illustrated), to catalytic hydrogenation followed by zinc oxide.

(DESULFURIZATION, REFORMING, CONVERSION, METHANATION, CATALYSIS, POISONING)

H73 22103 INTEGRATED REFORMER UNIT
Sederquist, R.A., (United Aircraft Corp.), 126470d, U.S. 3,531,263 (Cl. 48-61; C 01b, B 01j), Sept 29 '70, Appl. Aug 5 '68, 5 p

A fuel processing unit for use in fuel cells consists of a cylindrical structure which houses the reaction components for converting hydrocarbon feedstock. The feed passes through a reactor cavity where the hydrocarbon fuel stream reacts to produce a H-rich stream. The converted stream is air-cooled, then passes into a shift-conversion cavity where CO is converted to CO_2 + H_2. The H_2-rich effluent is directed to the fuel cell or other process equipment.
(FUEL CELL, REFORMER, CARBON MONOXIDE)

H73 22104 MANUFACTURE OF HYDROGEN BY REFORMING OF NAPHTHA
Nakamura, Sokuhiko, Kagaku Kojo, V 11:69-72 N4 67 (Japan).

Preparation of H gas from S-free naphtha, reaction of naphtha with water vapor, and elimination of CO and CO_2 by-products by methanation were reviewed.
(REFORMING, NAPHTHA)

H73 22105 HIGH PURITY HYDROGEN FROM HYDROCARBON-CONTAINING CHARGED MATERIAL BY USE OF AN ELECTROCHEMICAL PROCESS
Shalit, H., (Atlantic Richfield Co.), 27543u, Ger. Offen. 1,958,359 (Cl. C 01b), Sept 24 '70, U.S. Appl. Mar 17 '69, 17 p

Pure H_2 is obtained from hydrocarbons with 100% coulombic yield at 150-200 mA/cm^2 in a cell at 0.2-0.3 V having a hollow Pd anode containing a steam-reforming catalyst in 90% NaOH-10% KOH electrolyte at 475°.
(FUEL CELL, HYDROCARBON, PROCESS)

H73 22106 HYDROGEN FROM EXCESS REFINERY STREAMS RANGING FROM C_6 TO HEAVY OILS
Hepp, H.J., (Phillips Petroleum Co.), 89508v, U.S. 3,552,924 (Cl. 23-212; C 01b), Jan 5 '71, Appl. Aug 15 '66, 4 p

Refinery streams are subjected to hydrocracking, steam reforming of the C_6 fraction formed, and reaction of the CO-CO_2-H mixture with H_2O.
(HYDROCRACK, REFORMING, STEAM)

H73 22107 CATALYTIC PROCESSES FOR HYDROGEN MANUFACTURING
Comley, E.A., and R.M. Reed, World Petroleum Congress, 6th-Processing and Refining of Oil and Gas-Proc Sec 3, 63, p 147-58

Two catalytic processes used commercially for producing hydrogen from hydrocarbons are steam reforming of hydrocarbons and autothermal catalytic process; major emphasis is on steam reforming process including chemical reactions, commercial developement and present status and design procedures; pilot plant data on steam reforming at high pressures.
(PRODUCTION, STEAM, REFORMING, HYDROCARBON, CHEMICAL DESIGN)

H73 22108 STEAM REFORMING PARAFFINIC HYDROCARBONS
Pupko, S., (Office National Industriel de l'Azote), 21632t, U.S. 3,408,171 (Cl. 48-214), Oct 29 '68, Appl. Jun 12 '67, 2 p

Paraffinic hydrocarbons are steam reformed to H-rich gases by contact of 5 moles of hydrocarbons and 2 moles of steam with a catalyst containing 3-35% NiO on MgO and 3 $MgO.4SIO_2.H_2O$ (I).
(STEAM, REFORMING, HYDROCARBON)

H73 22109 DESTRUCTIVE DEHYDROGENATION OF THE AROMATIC RING
Appell, H.R., (U.S. Department of the Interior, Bureau of Mines, Pittsburgh, Pa.), R. Raymond, I. Wender; (American Chemical Society, Division Petroleum Chemistry), Preparation V 16:C24-C30 N2 for meeting Los Angeles, Calif., Mar 28-Apr 2 '71

Results of an experimental program evaluating the possibility of obtaining hydrogen from aromatic hydrocarbons with the ultimate objective of applying this method to low cost hydrocarbons or bituminous materials such as residua, pitches and coal fractions.
(HYDROGEN, PRODUCTION, HYDROCARBONS, COAL, RESIDUE)

H73 22110 HYDROGEN FROM LIQUID HYDROCARBONS FOR FUEL CELLS
Meek, J., B.S. Baker, C.H. Eckert, and F. Todesca, SAE Journal-Paper 935A for meeting Oct 19-23 '64, 12 p

Aspects of high-temperature steam reforming, partial

oxidation, and low-temperature steam reforming processes are discussed for hydrogen generation from liquid hydrocarbons; for each process, examples of possible hydrogeneration-fuel cell systems are selected and theoretical overall efficiency calculations made; calculations are based on n-hexane; results indicate that overall efficiencies higher than 40% are unlikely; method for hydrogen generation employed at Institute of Gas Technology, Chicago, Ill.; typical overall system efficiencies expected from approach lie between 25 and 35%.
(STEAM REFORMING, PARTIAL OXIDATION, HYDROCARBONS)

H73 22111 LOW-TEMPERATURE REFORMING FOR HYDROGEN
Anon, Oil and Gas Journal, V 62:88-9 N51 Dec 21 '64
Avail:TAC

Low-temperature reforming of liquid-hydrocarbon feedstocks appears to offer attractive route to hydrogen to be used in low-temperature acid-fuel cells; method, followed by CO shift and CO methanation process steps, has been operated experimentally for more than 3000 hr; gas produced, essentially stoichiometric hydrogen and CO_2 and 10 to 20 ppm CO, has been used to energize fuel cells for more than six months without noticeable poisoning effects; overall efficiency of synthesis method is not expected to exceed 40%.
(HYDROCARBON, FUEL CELL, PROCESS, METHANATION, POISONING)

H73 22112 DESIGN VARIABLES AND PRODUCTION COSTS IN LARGE-SCALE MANUFACTURE OF HYDROGEN
Twist, D.R., K.J. Sagar, Chemical Engineering, N192 Oct 65, p CE252-9, Avail:TAC

Recent developments in large-scale hydrogen manufacture are reviewed, together with possible methods of producing 95+% hydrogen, and it is concluded that steam reforming of hydrocarbons is economic method in most cases; typical process employing steam reforming is described, and mechanical and process variables for reforming stage are listed and discussed, with graphs illustrating interrelationships.
(STEAM REFORMING, HYDROCARBONS, CHEMICAL, PROCESS, DESIGN)

H73 22113 EIN NEUES VERFAHREN ZUR REINSTWASSERSTOFFER-ZEUGUNG DURCH DAMPFREFORMIEREN VON KOHLENWASSERSTOFFEN
Anon, Brennstoff-Chemi V 49:T60 N7 Jl 68

New method of high-purity hydrogen manufacture by steam cracking of hydrocarbons; sulfur-free liquid or gaseous hydrocarbons are catalytically cracked at 25 to 30 atmosphere; hydrogen was then extracted from gas obtained in cracking in diffusion cells; hydrogen obtained by this method is absolutely dry and impurities are below 99.9999 vol %. (In German).
(HYDROCARBON, CATALYSIS, PRESSURE, CRACKING)

H73 22114 JET FUEL AS FEEDSTOCK
Khan, A. R., J. Meek, and B. S. Baker, Chemical Engineering Progress, V 62:74-6 N5 May 66, Avail:TAC

Presented is production of hydrogen by steam reforming from such commercially available fuels as gasoline and JP-4; operating conditions, reactor design, gas conversions, and fuel cell performance are discussed.
(HYDROGEN, STEAM REFORMING, PRODUCTION, DESIGN, CONVERSION)

H73 22115 HYDROGEN SUPPLY FOR FUEL CELLS
Anon, (Texas Instruments Inc.), British 1,182,499 (Cl. C 10g), Fe 25 '70, U.S. Appl. Dec 15 '66, 9 p

A hydrocarbon fuel, e.g., kerosine or C_3H_8, is partially steam reformed to produce a feed containing H and at least 10 mole % unreacted hydrocarbon. This is fed to the electrodes where more H is produced by further reformation reaction between the unreacted hydrocarbon and water produced by the cell reaction. Reformation in the cell is catalyzed by the molten salt electrolyte (Na, Li, K/CO_3 at 350-850°).
(FUEL CELL, STEAM, REFORMING)

H73 22116 EXPERIENCE WITH LIQUID HYDROCARBON FUELS
Frysinger, G. R., 19th Annual Power Sources Conference-Proc, U.S. Army Electronics Laboratories, Fort Monmouth, N.J., May 18-20 '65, p 11-13

Feasibility of utilizing existing liquid hydrocarbon fuel types (JP-4, unleaded gasoline, diesel fuel) in fuel cell power plants, particularly of indirect type; conversion of liquid hydrocarbons to hydrogen in

external reformer, partial and direct oxidation of liquid fuels, and protection of reformer and electrode catalysts from harmful effects of sulfur in fuels are discussed.
(FUEL CELL, CONVERSION, REFORMER, OXIDATION, CATALYST)

H73 22117 HYDROGEN IN PETROLEUM AND CHEMICAL INDUSTRIES APPLICATION AND MANUFACTURE. (WATERSTOF IN DE PETROLEUM EN CHEMISCHE INDUSTRIE. TOEPASSING EN FABRICAGE)
ter Haar, L. W., Ingenieur, V 81:M1-10 N17 Apr 25 '69
Survey of methods and raw materials for manufacture of synthesis gas; increasing demand of hydrogen for refining of petroleum products is discussed; influence of process pressure, of plant size and of other factors on economics of hydrogen making; it is shown that for partial oxidation process optimal process pressure is 55 bar and for steam-reforming about 20-bar; it is concluded that partial oxidation of oil residue is competitive with steam-reforming of naphtha at price differential of about 9 dollars per ton feedstock. (In Dutch).
(PETROLEUM, PARTIAL OXIDATION)

H73 22118 HYDROGEN, PARTIAL OXIDATION
Anon, Hydrocarbon Process, V 51:220 Sept 72, Avail:TAC
For the manufacture of hydrogen needed for refining operations such as hydrodesulfurization, hydrocracking or petrochemicals.
(HYDROCRACK, PARTIAL OXIDATION)

H73 22119 PRODUCTION OF HYDROGEN FROM LIQUID HYDROCARBONS AT ELEVATED PRESSURES
Anon, (Texaco Development Corp.), French 1,572,582 (Cl. C 01b), Je 27 '69, Appl. May 31 '68, 10 p
H is produced economically by the direct partial oxidation of liquid hydrocarbons at >70 $kg.cm^2$ in the presence of O and steam.
(PARTIAL OXIDATION, HYDROCARBON)

H73 22120 PREPARATION OF HYDROGEN FROM HYDROCARBONS
Hockstra, J. and V. Haensel, (to Universal Oil Products Co.), 92417a, U. S. 3,340,010 (Cl. 23-212), Sept 5 '67, Appl. Dec 16 '63, 4 p
H is prepared by passing a hydrocarbon vapor at

$\geq 1300^{o}F$ over a catalyst supported on anhydrous Al_2O_3 and containing >2% by weight of a salt of an alkaline earth metal to improve the hardness and attrition resistance and >5% of a Ni salt to provide the catalytic activity.
(HYDROCARBON, CATALYST)

H73 22121 HYDROGEN FROM HIGH-BOILING HYDROCARBON FUELS
Becker, P.D., (Metallgesellschaft A.-G.), German Offen. 1,811,381 (Cl. C 01b, B 01j), Jl 2 '70, Appl. Nov 28 '68, 13 p

H was manufactured from high-boiling kerosine fractions by decomposing the hydrocarbons in exothermic reactions to CH_4, which was steam-reformed to CO and H. The catalytic multistage processes were heated by He from a He-cooled atomic reactor.
(HYDROCARBON, NUCLEAR, CATALYST)

H73 22122 LOW-TEMPERATURE REFORMING; A GOOD ROUTE TO FUEL-CELL HYDROGEN
Anon, Oil and Gas Journal, V 62:88-9 Dec 21 '64

Low-temperature reforming of liquid-hydrocarbon feedstocks appears to offer an attractive route to hydrogen to be used in low-temperature acid-fuel cells, Institute of Gas Technology studies show.

The method followed by carbon monoxide shift and carbon monoxide methanation process steps, has been operated experimentally for more than 3,000 hours. The gas produced, essentially stoichiometric hydrogen and carbon dioxide and 10-20-ppm carbon monoxide, has been used to energize fuel cells for more than 6 months without noticeable poisoning effects.
(REFORMING, FUEL CELL)

H73 22123 SYNTHETIC GAS FROM HEAVY FUELS
Kuhre, C. J., and C. J. Shearer, Hydrocarbon Process, V 50:113-117 Dec 71

As air pollution restrictions become more severe and natural gas prices increase, take a look at partial oxidation of high-sulfur fuels for your hydrogen and synthesis gas needs.
(POLLUTION, GAS, SYNTHESIS)

H73 22124 HYDROGEN PLANTS TAKING NEW STATURE IN REFINING OPERATIONS
Anon, Oil and Gas Journal, V 63:82-3 Mar 22 '65

Refiners in increasing numbers are finding it worthwhile to include a hydrocracking unit in their processing schemes, either for upgrading residual fractions or for converting surplus distillate fuels into motor gasoline.

Virtually all require a companion hydrogen-manufacturing plant. In some instances the units will be required to furnish as much as 60% of the total hydrogen needed. Capital cost of the unit could represent a third of the entire project.
(HYDROCRACK, COST, FUEL)

H73 22125 INNOVATIONS IN HYDROGEN PRODUCTION
Ring, T. A. and others, Chemical Engineering Progress, V 66:59-64 Dec 70

Recent innovations in hydrogen plant design enables the refiner to accommodate his economic philosophy, as well as his preference in gas compression schemes.
(GAS, REFINING)

H73 22126 IMPROVING RELIABILITY OF STEAM REFORMERS
Anon, Chemical and Process Engineering, V 52:3+ Oct 71

The worldwide acceptance of hydrocracking as a means of increasing refinery flexibility has created a demand for hydrogen "utility" plants capable of producing up to 100 million scfd (2.8 million m^3/day) hydrogen at purities from 95-98%, and with maximum reliability and supply. Most hydrogen production is by the steam reforming of hydrocarbons ranging from naphtha to hydrogen-rich offgas. Shutdown of the hydrogen plant means that the hydrocracker, carrying an investment of three or four times that of the hydrogen plant, is also shut down. An on-stream factor of at least 90-95% is therefore aimed at, and this level of reliability is now feasible if the design, construction and operation of the hydrogen plant is of the highest quality.
(STEAM, REFORMING, HYDROCARBON)

H73 22127 HYDROGEN, STEAM REFORMING
Anon., (C&I/Girdler, Inc.), Hydrocarbon Process, V 49:270 Sept 70

For producing high purity hydrogen such as needed for

hydrogenation and hydrodesulfurization.
(PRODUCTION, HYDROGENATION, HYDRODESULFURIZATION, PURITY)

H73 22128 HYDROGEN, PARTIAL OXIDATION
Anon, Hydrocarbon Process, V 49:269 Sept 70
For the manufacture of hydrogen needed for refining operations such as hydrodesulfurization, hydrocracking or petrochemicals.
(HYDRODESULFURIZATION, HYDROCRACKING, PETROCHEMICALS, REFINING)

H73 22129 REFINING PROCESS DEVELOPMENTS; IMPROVEMENTS IN MAKING HYDROGEN
Voogd, J. and J. Tielrooy, Hydrocarbon Process, V 46:115-20 Sept 67
New developments in hydrogen manufacture result in higher hydrogen purity, lower hydrogen costs and *higher reformer pressures.*
(MANUFACTURE, PURITY, COST, PRESSURE, REFORMER)

H73 22130 PRODUCTION OF HYDROGEN AND SYNTHESIS GAS
Solbakken, A., (Inst. Ind. Kjemi, Nor. Tek. Heogsk., Trondheim, Norway), Kjemi, V 31:18-21 N2 71, 23452m, (Norweg)
A review.
(HYDROGEN, SYNTHESIS, GAS)

H73 22131 JET FUEL AS A FEEDSTOCK
Khan, A.R., J. Meek, and B.S. Baker, (Institute of Gas Technology, Chicago), 75065s, Chemical Engineering Progress, V 62:74-7 N5 67, (English), Avail:TAC
Natural gasoline, C_6H_{14}, and JP-4 jet fuel were successfully steam reformed at 437-522^o with H yields of up to 65%. The products were suitable for use with low-temperature acid fuel cells, giving overall efficiencies estimated at 30-40% with low current drains.
(STEAM, REFORMING, FUEL CELL)

H73 22132 HYDROCARBON STEAM REFORMING, IN TUBES, FOR PRODUCTION OF SYNTHESIS GAS OR HYDROGEN
Roche, A., J. Lemaire, 31985v, (French) Stud. Petrochem., U.N. Interreg. Conference, 1st 64 (Pub. 66), 1,339-44 (English), United Nations: New York, N.Y.

Steam reforming in tubes is reviewed as an alternative to cracking with O. The production of synthesis gas from natural gas and from light oil, and of H from light oil, are briefly described.
(STEAM, REFORMING, GAS)

H73 22133 INTEGRATE HYDROGEN PRODUCTION WITH REFINERY OPERATIONS
Buividas, L.J., H.R. Schmidt, and C.H. Viens, Chemical Engineering Progress, V 61:88 May 65, Avail:TAC

Important planning and design variables are discussed and evaluated for the integration of hydrogen supply with petroleum refining operations. Results of an optimization study are given for a typical hydrogen plant/hydrocracker installation.
(DESIGN, OPERATION, REFORMER, REACTOR, COST)

H73 22134 HYDROGEN FROM LIQUID HYDROCARBONS FOR FUEL CELLS
Meek, J., B.S. Baker, C.H. Eckert, and F. Todesca, (Illinois Institute of Technology, Institute of Gas Technology, Chicago, Ill.), A65-11413, Society of Automotive Engineers, National Transportation, Powerplant, and Fuels and Lubricants Meeting, Baltimore, Md., Oct 19-23 '64, Paper 935A, 13 p

Description of high-temperature steam reforming, partial oxidation, and low-temperature steam reforming processes for hydrogen generation from liquid hydrocarbons. For each process, examples of possible hydrogeneration fuel-cell systems are selected and theoretical overall efficiency calculations are made. For convenience, the calculations are based on n-hexane. Results indicate that overall efficiencies higher than 40% are unlikely. A system is described that can provide an efficiency between 25 and 35%.
(HYDROCARBON, STEAM, REFORMING)

H73 22135 PREPARATION OF HYDROGEN BY CATALYTIC RE-FORMING OF HYDROCARBONS
Anon, United Aircraft Corp., 92418b, Netherlandish Appl. 6,610,510 (Cl. C 01b), Fe 6 '67m U.S. Appl. Aug 3 '65, 13 p, cf., CA 67:55690 p

Before the gas stream is led into the H purifier, the unreacted hydrocarbons and the H_2O vapor are separated in a condenser, thus improving the efficiency of the process and the capacity of the purifier, the H having a higher partial pressure in the impure gas.
(CATALYST, HYDROCARBON)

H73 22136 EXPLORATORY DEVELOPMENT MODEL MINIATURE HYDROGEN GENERATOR
Rothfleisch, J.E., Report No. 2 (Final), Nov 1 '66-Oct 31 '67, (Union Carbide Corp., Parma, O.), ECOM-0114-F Contract DAAB07-67-C-0014, AD-665, HC $3.00/MF $0.65

Two exploratory development model miniature hydrogen generators were designed, fabricated, tested, and delivered to the United States Army Electronics Command. The two units are fully operative generator systems designed to produce sufficient hydrogen by thermal cracking JP-4 jet fuel to supply 200-watt hydrogen/air fuel cell systems for intermittent twelve-hour operating periods. Qualification tests of the completed systems demonstrated the technical feasibility of man-portable generators based on the thermal cracking principle, and indicated that fully qualified, reliable field units can be developed without any major technological advances.
(SYSTEM, FUEL CELLS, GAS, FUEL)

H73 22137 PREPARATION OF HYDROGEN OR HYDROGEN-CONTAINING GAS MIXTURES
Anon, (Shell Internationale Research Maatschappij N.V.), 51755m, Netherlandish Appl. 6,603,481 (Cl. 10g), Sept 18 '67, Appl. Mar 17 '66, 17 p

Hydrocarbons were converted with vapor in the presence of a Re catalyst on a carrier containing $\geqq 1$ metals from the right column of Group I and (or) metals from Group VIII and $< 2\%$ of $\geqq 1$ alkali metals. Thus, the influence of the alkali metal content on the stability of the catalyst was shown.
(HYDROCARBON, CATALYST)

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H73 22138 CRACKING OF HYDROCARBONS TO ACETYLENE, ETHYLENE, METHANE, AND HYDROGEN WITH HYDROGEN HEATED IN AN ELECTRIC ARC
Sennewald, K., K. Gehrmann, L. Strie, L. Bender, E. Schallus, and H.W. Stephan, (Knapsack A.-G.), 4766p, German 1,468,159 (Cl. C 07c, C 01b), Je 11 '70, Appl. Aug 5 '64, 9 p

H (1350 m^3 hourly) is heated in a H_2O cooled arc chamber with 3 graphite electrodes of 5280 kW consumption. The H is divided into several streams of which part is conducted along the electrodes and the rest into the arc chamber.
(ELECTRIC, CRACKING)

H73 22139 MANUFACTURE OF HYDROGEN IN IMPURE STATE
Anon, Shell Internationale Research Maatschappij N.V., 55686s, Netherlandish Appl. 6,511,884 (Cl. C 01b), Mar 14 '67, Appl. Sept 13 '65, 15 p

A hydrocarbon source is combusted under pressure with O and (or) air to form a H + CO mixture, in which, by further catalyzed reaction with steam, the H is augmented producing a CO_2 admixture. The process is made economically sound by recovery of useful heat of combustion as high pressure steam, and adiabatic cooling using the pressure reduction to operate a turbine, which in turn is used to operate the final gas compression.
(HYDROCARBON, STEAM, PRESSURE)

H73 22140 MANUFACTURE OF HYDROGEN FROM PETROLEUM AND NATURAL GAS
Svaton, J., 80094a, Ropa Uhlie, V 9:303-7 N11 67, (Slo)

A review summarizing essential information on the development of H manufacture by reforming hydrocarbons with steam (e.g., the endothermic reaction $CH_4 + H_2O \rightarrow CO + 3\ H_2$, with simultaneous and (or) subsequent exothermic conversion $CO + H_2O \rightarrow CO_2 + H_2$) and by partial oxidation of hydrocarbons, e.g., $CH_4 + \frac{1}{2}\ O_2 \rightarrow CO + 2\ H_2$, either catalytic or uncatalyzed, which is thermally more balanced. The methods for removal of carbon oxides and final purification of the H gas obtained are briefly indicated.
(REFORMING, STEAM, HYDROCARBON)

H73 22141 HYDROGEN FROM THE PARTIAL OXIDATION OF HYDROCARBONS
West, B.R., F.L. Gray, (Texas Instruments, Inc.), 92652k, French 1,517,644 (Cl. C 01b, H 01m), Mar 15 '68, U.S. Appl. Apr 6 '66, 6 p

H-rich gas for a fuel cell is generated in an apparatus where an ejector uses the flow of the fuel and of the reactants to pump primary air and to recycle used fuel from the fuel cell into the apparatus.
(PARTIAL OXIDATION, FUEL CELL)

H73 22142 PROCESS FOR PRODUCTION OF HYDROGEN
Marshall, W.H., Jr., 87349e, U.S. 3,297,408 (C. 23-212), Ja 10 '67, App. Fe 28 '62, and Apr 5 '65, 5 p

Fifty to 85% of the hydrocarbons were converted to H, CO, CO_2 by steam reforming at a steam to carbon ratio of 4.0, a pressure of 500 psia., and a temperature sufficient to give such conversion, followed by a catalytic shift conversion with steam of the product from the catalytic reforming to convert most of the CO to CO_2 and additional H. The product from the shift conversion was cooled to condense the steam and remove the CO_2.
(STEAM, REFORMING, HYDROCARBON)

H73 22143 HYDROGEN FROM LIGHT DISTILLATES FOR FUEL CELLS
Khan, A.R., J. Meek, and B.S. Baker, Chemical Engineering Progress Symposium, Serial No. 75, 63, 31 p (67), Avail:TAC

This paper deals with the production of hydrogen by steam reforming from such commercially available fuels as gasoline and JP-4. Operating conditions, reactor design, gas conversions, and fuel cell performance are discussed.
(PRODUCTION, GENERATION, SUPPLY, REFORMING, VOLTAGE, TEMPERATURE, EFFICIENCY, YIELD)

H73 22144 THE I.C.I. STEAM NAPHTHA REFORMING PROCESS AND OTHER TECHNIQUES
Gard, N.R., 51606p, Kem. Teollisuus, V 24:786-92 N10 67, (English)

The I.C.I. steam naphtha reforming process produces H for NH_3 synthesis by causing naphtha to react with steam over a Ni catalyst at high temperature. In addition to permitting the use of high-molecular-weight hydrocarbon feedstocks, the process was designed to operate

with small quantities of steam and at high pressures. In spite of these adverse factors, C laydown on the catalyst is completely inhibited. Adequate feedstock desulfurization is of great importance for continuing maximum activity of the S-sensitive Ni reforming catalyst.
(STEAM, REFORMING, CATALYST)

H73 22145 MINIATURE HYDROGEN GENERATORS
Rothfleisch, J.E., and L.M. Litz, (Union Carbide Corp., New York, N.Y.), Proceedings, Annual Power Sources Conference, 100957y, V 20:28-31, (66), (English)

Supplying H_2 for fuel cells in the power range of 10-200 watts from field-available hydrocarbon fuel calls for a miniature generator. A small thermal cracking unit in which gasoline or jet propulsion fuel is decomposed at 900-1100^{o} to give a gas product containing 80-90% H_2 is described. The product composition was not affected by fuel used.
(HYDROGEN, GENERATOR, FUEL CELL)

H73 22146 HYDROGEN FOR HYDROCRACKING
Stormont, D.H., Oil and Gas Journal, V 65:92-4 N10 67, (English), 97163d, Avail:TAC

The 1st complete plant is under construction for producing high-purity H for hydrocracking operations by partial oxidation of vacuum-tower bottoms. The refinery will use the Texaco partial oxidation process and the Rectisol process(MeOH wash) to give a H purity of 98%+. Improvements in the partial oxidation process, which has been in use for 14 years, permit H or synthesis gas to be produced without a compression stage at $\geq$1500 psi.
(HYDROCRACK, PARTIAL OXIDATION)

H73 22147 CATALYTIC STEAM REFORMING OF LIQUID HYDROCARBONS
Bongiorno, S.J., W.H. Nebgen, (Chemical Construction Corp.), 26821n, German Offen. 2,039,383 (Cl. C 01b), Mar 4 '71, U.S. Appl. Aug 21 '69, 17 p

Fuel savings are achieved in catalytic reformation plant by compressing the synthesis gas in a compressor driven by steam turbine. The steam from the turbine is reheated by indirect heat-exchange with the waste

gases in the convection zone of the reformer and is used to drive other steam turbines that provide the power for the reformation plant.
(STEAM, REFORMING, CATALYST)

H73 22148 HYDROGEN AND CARBON MONOXIDE CONTAINING GASES FROM FUEL GASIFICATION COLUMNS
Howorka, S., A. Koener, and L. Tretner, 87203c, German Offen. (East) 51,383 (Cl. C 10j), Sept 5 '66, Appl. Jl 26 '65, 4 p

H_2 and CO are obtained from fuel gasifying columns by reaction, in a turbulent stream with O_2 and steam. The gas stream is injected tangentially to the reaction medium.
(GASIFICATION, FUEL, STEAM)

H73 22149 HYDROGEN GENERATOR ASSEMBLIES
Engdahl, R. and E.S. Tillman, Jr., (Energy Research Corp., Bethel, Conn.), Final Report, Mar 70-Mar 71, Sept 71, 65 p, ECOM-0153-F, Contract DAAB07-70-C-0153, AD-733 931, PC $3.00/MF $0.95

The objective of the work was to evaluate design criteria for a simplified hydrogen generator for a 500 watt fuel cell. The hydrogen is produced by the catalytic steam reforming of vaporized JP-4 fuel with subsequent purification through a palladium-silver separator. The experimental studies were performed on a breadboard type system. This system contained all of the major subcomponents required in an actual portable unit for field use.
(SYSTEM, FUEL CELLS, GAS, HYDROCARBONS, DESIGN, PURIFICATION, CATALYST)

H73 22150 HYDROGEN MANUFACTURE
Smith, C.S. and W.J. McLeod, (El Cerrito, Calif., assignors to Chevron Research Co., San Francisco, Calif.), 3,577,221, Dec 31 '68, Serial No. 788,300, Int. (Cl. Colb), 1/02, 1/18, U.S. (Cl. 23-213), 7 Claims

According to the present invention a process is provided for producing high pressure hydrogen which comprises:

(a) generating a hydrogen-rich gas stream containing CO and CO_2;

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(b) removing CO_2 from the hydrogen-rich gas stream to obtain a CO_2 lean, hydrogen-rich gas stream;

(c) centrifugally compressing the CO_2-lean, hydrogen-rich gas stream to a pressure of above about 400 p.s.i.g.; and

(d) reacting CO contained in the CO_2-lean, hydrogen-rich gas stream with H_2O at a pressure of above about 400 p.s.i.g.

Preferably CO_2 is removed from the hydrogen obtained after step (d) and the purified compressed hydrogen is used in a hydroconversion process.
(PRESSURE, PURITY, HYDROCONVERSION, CHEMICAL, PROCESS)

H73 22151 HYDROGEN STEAM REFORMING: C & I/GIRDLER INC.
Anon, Hydrocarbon Process, V 47:235 Sept 68, Avail:TAC

The steam-hydrocarbon reforming process includes the basic steps of desulfurization, reforming, conversion, CO_2 removal and methanation.
(PROCESS, PRODUCTION, REFORMING, CONVERSION, DESULFURIZATION, METHANATION)

H73 22152 SYNTHESIS GAS, CITY GAS, AND REDUCING GAS
Topsoe, H.F.A., 114946j, France 1,551,065 (Cl. C 01b), Dec 27 '68, Danish Application Sept 27 '66, 7 p

The title gases can be prepared,from hydrocarbons with molecular weights greater than that of CH_4, or gaseous hydrocarbon mixtures containing H_2O vapor (and (or) other O-containing gas) at 550-1000° and 1-250 kg./cm.^{2} in the presence of a metallic catalyst and an activator.
(HYDROCARBON, GAS, METHANE, WATER, CATALYST, ACTIVATOR)

H73 22153 EXAMPLES OF PRACTICAL APPLICATIONS OF THE PURIFICATION AND SEPARATION OF GASES
Reichel, H., (Linde A.-G., Hoellriegelskreuth, Germany), 113808r, Tech. Mitt., V 63:267-72 N6, 1970 (German)

A review is presented of the various manufacturing steps involved in the production of olefins from petroleum hydrocarbons, NH_3 from synthesis gas, and CO and H_2 from petroleum hydrocarbons. Various separation and purification techniques are discussed.
(PRODUCTION, HYDROCARBON, OLEFIN, PETROCHEMICAL, HYDROGEN, PURIFICATION)

H73 22154 PRESSURE CONTROL IN THE MANUFACTURE OF A GAS MIXTURE CONTAINING HYDROGEN AND CARBON MONOXIDE
Vogel, J.E., (Shell Internationale Research Maatschappij N.V.), 131204r, German Offen. 2,107,904 (Cl. C 01b), Sept 2 '71, Netherlandish Appl. Fe 20 '70, 12 p

The manufacture of the title mixture in a reactor by combustion of hydrocarbons with O or O-enriched air at 5-80 atmosphere and the subsequent water cooling from 1300-500^{o} to 260-340^{o} in a flue gas boiler is controlled by measuring the differential pressure between the steam (50-150 atmosphere) in the cooling system and the gas mixture before and after cooling response.
(CONTROL, PRESSURE, COMBUSTION)

H73 22155 CATALYTIC REFORMING
Anon, (Toyo Engineering Corp.), French 1,571,927 (Cl. C 10g), Je 20 '69, Japanese Appl. Jl 10 '67, 12 p

A two stage catalytic hydrocarbon reforming process to obtain a gas essentially composed of hydrogen is described. In the first stage, a mixture of hydrocarbons and steam is reformed catalytically using external heat. In the second stage, the first stage product is reformed catalytically by combustion with the O of preheated compressed air introduced into the reactor.
(CATALYST, HYDROCARBON, REFORMING)

H73 22156 APPARATUS FOR PRODUCING HYDROGEN-CARBON MONOXIDE GAS MIXTURES
Ter Haar, L.W., (Shell Internationale Research Maatschappij N.V.), 99422x, German Offen. 2,102,368 (Cl. C 01b), Aug 5 '71, Netherlandish Appl. Ja 21 '70, 14 p

An apparatus is described for the manufacture of H-CO mixtures by partial combustion of hydrocarbons with O or air-containing O.
(PARTIAL, COMBUSTION, HYDROCARBON)

H73 22157 CATALYTIC STEAM REFORMING OF NAPHTHA
Mayland, B.J., C.R. Trimarke, R.L. Harvin, and C.S. Brandon, (Girdler Corp.), 23224b, U.S. 3,477,832 (Cl. 48-213; C 10k), Nov 11 '69, Appl. Je 5 '64, 7 p

H and crude synthesis gas are prepared by steam reforming naphtha. Unsaturated hydrocarbons (I) and S-containing compounds are vaporized and mixed with H in the presence of a Co-Mo supported hydrodesulfurization catalyst.
(STEAM, REFORMING, CATALYST)

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H73 22158 HYDROGEN PRODUCTION FOR FUEL CELL MODULES
Anon, (Texas Instruments Inc.), British 1,182,499 (Cl. C 10g), Fe 25 '70, U.S. Appl. Dec 15 '66, 7 p.

The performance of fuel cell anodes in fused salt electrolytes decreases along the flowline when the units receive the H fuel in a series arrangement. This is due to a reduction in H concentration caused by reaction and dilution with reaction products. The difficulty can be overcome by using as fuel a mixture of steam and hydrocarbon which is converted to a mixture of H and unreacted hydrocarbon in an internal reformer.
(FUEL CELL, HYDROCARBON, REFORMING)

H73 22159 PURIFICATION OF HYDROGEN IN HYDROCONVERSION PROCESSES
Anon, (Texas Development Corp.), French 1,562,026 (Cl. C 10g), Apr 4 '69, Appl. Ja 8 '68, 10p

Oil and excess H are preheated to 461° and reacted with additional H in a degassing tower, from which the heavy residue is removed. The vapor portion is cooled to 438-49° and reacts with recycled H in a catalytic hydrogenation reactor at 427°.
(PURIFICATION, CATALYST)

H73 22160 GAS MIXTURE CONTAINING HYDROGEN AND CARBON MONOXIDE
Arakawa, T., M. Oka, (Mitsubishi Chemical Industries Co., Ltd.), 99753f, Japan 71 00,802 (Cl. C 01b, C 10g), Ja 9 '71, Appl. Dec 17 '66, 5p

A naphtha (b. 36-141°) was cracked over an SiO_2-Al_2O_3-NiO catalyst at 850°, 146 cm^3/cm^3-hr, and 1 kg/cm^2 gage in the presence of steam.
(CATALYST, NICKEL, STEAM)

H73 22161 HYDROGEN GENERATOR FOR FUEL CELL USE IN SUBMARINES
Seymour, C.S., (to Hydrocarbon Research, Inc.), 17315n, U.S. 3,306,706 (Cl.23-212), Fe 28 '67, Appl. Oct 17 '62, 4 p

Hydrocarbons readily dehydrogenated, such as cyclohexane to yield C_6H_6, are proposed as H sources for restricted uses. Thus, the catalytic reaction yields H for fuel cell use and C_6H_6 as a nongaseous coproduct which a submarine can store and return to base for rehydrogenation. The H produced provides feed for power generation via fuel cells.
(HYDROCARBON, FUEL CELL)

H73 22162 STEAM REFORMING OF HEXANE WITH CRYSTALLINE ALUMINOSILICATE CATALYSTS
Leaman, W.K., C.J. Plank, and E.J. Rosinski, (Mobil Oil Corp.), 7920e, U.S. 3,523,772 (Cl. 48-214; C 01b, B 01j), Aug 11 '70, Appl. Dec 20 '66, 4 p

Hexane is steam-reformed to town gas or hydrogen at low steam-hydrocarbon ratios over crystal aluminosilicates (particles $<0.5-1\ \mu$) impregnated with Ni or rare earths.
(STEAM, REFORMING, CATALYST)

H73 22163 SIMULTANEOUS PRODUCTION OF OXO SYNTHESIS GAS AND HYDROGEN
Staege, H., (H. Koppers, G.m.b.H.), 89479m, German Offen. 1,917,568 (Cl. C 07c, C 01b), Nov 5 '70, Appl. Apr 5 '69, 27 p

A portion of a hydrocarbon is steam-reformed and passed through a CO converter, a CO_2 scrubber, and a demethanizer to give a stream containing $>95\%$ H.
(GAS, SYNTHESIS)

H73 22164 HYDROGEN-RICH GASES
Anon, (Esso Research and Engineering Co.), 36334n, French 1,565,873 (Cl. C olb), May 2 '69, Appl. May 15 '68, 8 p

A gas with elevated H/CH_4 ratio was prepared by treating naphtha with steam in the presence of a $Ni-Al_2O_3$ catalyst and $Ba(NO_3)_2$ as promoter.
(CATALYST, STEAM)

H73 22165 PRODUCING HYDROGEN OR AMMONIA SYNTHESIS GAS AT MEDIUM PRESSURE
Kapp, E., P. Becker, (Metallgesellschaft A.-G.), 78676t, German Offen. 1,958,033 (Cl. C 01b, B 01j), Je 3 '71, Appl. Nov 19 '69, 20 p

H or a N-H mixture is prepared by treating a liquid or solid S-containing fuel with O and H_2O, removing S compounds by washing with a solution of an organic base or of an alkali-metal salt of a weak acid, converting CO to CO_2 by reaction with H_2O in the presence of a Fe_2O_3-Cr_2O_3 catalyst at 350-450°.
(AMMONIA, SYNTHESIS, GAS)

H73 22166 FUEL-CELL HYDROGEN FROM HYDROCARBONS
Baker, B.S., J. Meek, A.R. Khan, and H.R. Linden, (Institute of Gas Technology), 74073j, U.S. 3,488,171 (Cl. 48-197; C 10k), Ja 6 '70, Appl. Ja 4 '65, 6 p

Hydrocarbons (maximum boiling point 500°F) (I) are

steam-reformed on a catalyst containing Ni 25-80, Al_2O_3 10-60 wt. % and Al the remainder at 1-5 atmosphere and 700-1100^oF and then methanated at 300-400^oF and one atmosphere on a Ru or Rh on Al_2O_3 catalyst.
(FUEL CELL, HYDROCARBON)

H73 22167 PRODUCTION OF HYDROGEN
Anon, (Esso Research and Engineering Co.), by W.F. Taylor, 57418j, France 1,452,728 (Cl. C olb), Sept 16 '66, U.S. Appl. Jl 29 '64, 8 p

H was obtained from a gaseous or liquid mixture of a hydrocarbon and water in the presence of a catalyst containing 10-75% Ni and 0.5-12% of a promoter such as La, Ba, Sr, Ce, Cs, K, Y, Fe, or Cu.
(CATALYST, WATER, HYDROCARBON)

H73 22168 VAPOR CONVERSION OF A GASOLINE RAFFINATE UNDER PRESSURE
Veselov, V.V., N.T. Meshenko, and N.N. Tsimbalistaya, (Institute Gaza, USSR), 102349z, Khim. Tekhnol. Topl. Masel, V 15:13-17 N2 70 (Russian)

During steam conversion of a dearomatized platformate gasoline, b. 43-136^o, introduced as a 1:5 gasoline-steam mixture at a volumetric rate of 1 hr^{-1} onto a 1:1 Ni-Cr catalyst at 320^o, an increase in pressure from 1 to 31 atmosphere reduced H content in the product from 62.0 to 31.5% and raised CH_4 content from 15.2 to 43.1% without substantially changing CO_2 content.
(STEAM, GASOLINE)

H73 22169 APPARATUS FOR REFORMING CARBONACEOUS MATERIAL INTO HYDROGEN
Anon, (United Aircraft Corp.), 55690p, Netherlandish Appl. 6,610,509 (Cl. C olb), Fe 6 '67, U.S. Appl. Aug 3 '65, 27 p

The material, such as saturated hydrocarbons with 6-10 C atoms (or mixture thereof), are mixed with H_2O, preheated to 205-510^o, brought into contact with a hydrogenating catalyst (Ni, Co, or Pt), where it is converted into a CH_4-rich gas stream at 370-650^o. This gas stream is heated to 700-990^o, at which temperature the CH_4 is converted into H, CO, CO_2 by a second dehydrogenating catalyst.
(REFORMING, HYDROCARBON)

H73 22170 HIGH-PRESSURE REFORMING OF HYDROCARBONS
Gignier, J., P. Lhonore, J. Quibel, and M. Senes, (Societe Chimique de la Grande Paroisse, Azote et Produits Chimiques), 4189r, France 1,492,926 (Cl. C 10j), Aug 25 '67, Appl. May 11 '66, 8 p

Reforming and, if needed for NH_3 synthesis gas, secondary reforming is carried out at pressures of ~100 bars to give an energy advantage over similar processes carried out at 1 bar.
(PRESSURE, REFORMING, HYDROCARBON)

H73 22171 HYDROGEN-RICH GAS MIXTURE
Quartulli, O.J., (Pullman Inc.), 41065j, German 1,293,133 (Cl. C 01b), Apr 24 '69, U.S. Appl. Sept 14 '61, 9 p

The title product is prepared by contacting hydrocarbons with steam in a 1st reforming zone at 14-49 atmosphere with an outlet temperature 705-870° and a residence time of 0.5 to 10 seconds. Sufficient steam is supplied to this zone to give a concentration of residual CH_4 in the effluent of 5-16 mole % (dry) and to provide a steam-C ratio of 2.5-7.5.
(REFORMING, STEAM)

H73 22172 MACROKINETICS OF THE PYROLYSIS OF SHALE OIL IN A FLUIDIZED BED
Elenurm, A., T. Laus, and M. Gubergrits, 92510a, Eesti NSV Tead. Akad. Toim., Reem., Geol. V 16:88-96 N2 67, (Russian)

The pyrolysis of 2 naphtha fractions from shale oil, b. up to 150 and 200°, response, was studied in a fluidized bed filled with quartz sand in 3 series of exports with varying temperatures, steam/oil ratios, and contact times. An increase in temperature decreases the yield of olefins and increases the proportion of H and CO. The yield of H and CO sharply increases above 750°.
(PYROLYSIS, KINETICS, FLUIDIZED)

H73 22173 NEW CONCEPTS AND TECHNIQUES FOR PREPARING PURE HYDROGEN STARTING FROM HYDROCARBONS
Cohn, J.G.E., (Engelhard Ind., Inc., USA), 51699h, World Petroleum Congress, Proceeding, 7th V 5:175-185 67 (Pub. 68), (English), Elsevier Publishing Co., Ltd.: Barking, England

Production of H or of H-containing gases by steam oxygenolysis of naphtha is possible at low molar steam to C ratios over a wide range of temperatures, pressures,

and process conditions. Catalysts are Ni or Co on supports or precious metals alone or in combination with Ni or Co. Use of the latter catalysts appears indicated for feeds containing substantial concentrations of unsaturates or aromatics.
(STEAM, NAPHTHA, CATALYST)

H73 22174 HYDROGEN-RICH SYNTHESIS GASES
Strelzoff, S., H.C. Morgenstern, and J.M. Connor, (Chemical Construction Corp.), German 1,808,911 (Cl. C 01b) Jl 17 '69, U.S. Nov 14 '67, 21 p

An application is described in which the hydrocarbon, especially CH_4, naphtah, fuel oil, or residual oil, flows in the presence of steam through succeeding beds consisting of particulate SiO_2, MgO, Al_2O_3, or kaolin as carriers for catalysts such as reduced Ni or Co salts, NiO, metallic Ni or Co, ZrO_2, Cr_2O_3, or MoO_3.
(HYDROCARBON, STEAM CATALYST)

H73 22175 GENERATION OF HYDROGEN FROM HYDROCARBONS AND USE IN MOLTEN CARBONATE FUEL CELLS
Baker, B.S., and A.R. Kahn, (Institute of Gas Technology), U.S. 3,488,226 (Cl. 136-86; H 01m), Ja 6 '70, Appl. Nov 8 '65, 6 p

A process for the continuous production of H-rich gases for direct use in high temperature molten carbonate fuel cells is described.
(HYDROCARBON, FUEL CELL, CARBONATE)

H73 22176 WATER GAS SHIFT CONVERTER AND FUEL CELL SYSTEM
Hooper, T.N., (Texas Instruments, Inc.), U.S. 3,499,797 (Cl. 136-86; H 01m, C01b), Mar 10 '70, Appl. Apr 28 '66

Equipment is described comprising a partial oxidizer and a shift converter to convert a hydrocarbon fuel to H gas for use in operating an attached fuel cell. An inexpensive converter made with catalytic Cr-steel tubes is described which operates with a lower pressure drop, which can be used to preheat air fed to the partial oxidizer, and which required less steam for the shift reaction.
(HYDROCARBON, FUEL CELL, STORAGE)

H73 22177 HYDROGEN MANUFACTURE USING GAS TURBINE-DRIVEN CENTRIFUGAL COMPRESSORS
Smith, C.S., and W.J. McLeod, (Chevron Research Co.), U.S. 3,576,603 (Cl. 23-212; C 01b), Apr 27 '71, Appl. May 17 '68 - Apr 1 '69

Because of the low molecular weight of pure H,

centrifugal compressors are impractical for raising the pressure to desirable operating ranges. In the method described, a hydrocarbon is treated with steam in a reformer followed by shift conversion to produce H and CO_2. At least a portion (preferably all) of the H-CO_2 mixture is compressed to $\geq$900 psig in a centrifugal compressor prior to separating the CO_2 from the H.
(HYDROCARBON, STEAM, PRESSURE)

H73 22178 HYDROGEN GENERATION BY STEAM REFORMATION OF N-HEXANE OVER ZEOLITE CATALYSTS
Brooks, C.S., (United Aircraft Research Laboratory, East Hartford, Conn.), Advanced Chemistry Series, V 102:426-33, 71, (Molecular Sieve Zeolites-II), (English)

High-activity Ni and Co catalysts for H generation by the steam-hydrocarbon reforming reaction were prepared by ion exchange from synthetic zeolites.
(HYDROGEN, REFORMING, CATALYST)

H73 22179 CONTACT CATALYST FOR HYDROGEN-RICH GAS FROM HYDROCARBONS
McMahon, J.F., (Pullman Inc.), U.S. 3,417,029 (Cl. 252-455), Dec 17 '68, Appl. Mar 1 '60 - Apr 5 '63, 14 p, Division of U.S. 3,119,667 (CA 60: 11647b)

The disclosure is the same but the claims are dif--ferent.
(CATALYST, HYDROCARBON)

H73 22180 HYDROGEN PRODUCTION BY STEAM REFORMING
Johnson, J.E., T.L. Singman, and N.P. Vahldieck (to Union Carbide Corp.), 51893s, U.S. 3,361,534 (Cl. 23-210), Ja 2 '68, Appl. Mar 31 '65, 10 p

A process for producing and purifying H by using steam reforming of hydrocarbon feed streams is described. Process improvement is effected by: (a) providing 1.5-4 moles of steam/atom of C in feedstock, and reforming only 60-70 mole % of feed hydrocarbons, (b) cooling crude H to below the dewpoint of CH_4, (c) isenthalpically expanding CH_4 condensate to a lower pressure, (d) using heat exchange between CH_4 condensate and crude H for refrigeration, and (e) recycling vaporized CH_4 to the catalytic reaction step.
(STEAM, PURIFICATION, REFORMING)

H73 22181 METHOD OF PRODUCING HYDROGEN FROM A CARBON MONOXIDE-CONTAINING GAS STREAM AND HEAT RECOVERY
James, G.R., (to Chemical Construction Corp.), 47707p, U.S. 3,292,998 (Cl. 23-213), Dec 20 '66, Appl. Mar 22 '63, 5 p

For example, the residual gas stream from C_2H_2 synthesis which is rich in CO is recovered as a cool dry gas at 90°F. and 100 psig. This gas stream is heated to 280°F., saturated with H_2O vapor, and passed through a gas-to-gas preheater prior to catalytic H synthesis.
(CATALYST, HEAT)

H73 22182 PROTECTION OF A METHANATION CATALYST IN HYDROCARBON REFORMING
Gutmann, W.R. and R.A. Mascarich, (to Catalysts and Chemicals, Inc.), 106649n, U.S. 3,377,138 (Cl. 23-213), Apr 9 '68, Appl. J2 7 '66, 2 p

A desulfurized hydrocarbon vapor is reformed with steam at $>$1200°F. and with a catalyst to produce H and CO, then passed through a shift converter to change the CO to CO_2.
(METHANATION, HYDROCARBON, CATALYST)

H73 22183 SYNTHESIS-GAS MIXTURES FOR AMMONIA AND METHANOL
Pagani, G., (Montecatini Edison S.p.A.), 88859z, France 1,489,535 (Cl. C 01b), Jl 21 '67, Italian Appl. Aug 18 '65, 6 p

A high-pressure method for the steam reforming of liquid and gaseous hydrocarbons into H and CO is described.
(STEAM, REFORMING, CATALYST)

H73 22184 CATALYTIC CRACKING OF HYDROCARBONS
Anon, Badische Anilin - und Soda-Fabrik A.-G., 126962z, France 1,544,524 (Cl. C 01b), Oct 31 '68, Ger. Applic. Nov 16 '66, 3 p, Correction of CA 71:83384v

Hydrocarbons containing 2-30 C atoms are cracked, in 1 step, at $>$550° in the presence of a catalyst, containing little or no alkali metals, and comprising 35-55% Ni on a MgO support and 10-30% binder such as $MgAl_2O_4$.
(CATALYST, HYDROCARBON)

95

H73 22185 HYDROGEN FROM HYDROCARBONS: HYDRODESULFURIZATION OF THE FEED
Buswell, R.F., H.J. Setzer, and R.A. Sederquist, (United Aircraft Corp.), 4946x, U.S. 3,476,534 (Cl. 48-94; C 10g), Nov 4 '69, Appl. Sept 26 '67, 5 p

In producing H from hydrocarbons by steam reforming, hydrodesulfurization of the feedstock is integrated in the process. A portion of the product H is recycled and mixed with the feedstock. The mixture is then passed through a boiler that produces a mixture of superheated vaporized hydrocarbons and H.
(STEAM, REFORMING, HYDROCARBON)

H73 22186 SELECTED PROCESSES FOR THE PRODUCTION OF BASIC CHEMICALS AND INTERMEDIATES FROM PETROLEUM HYDROCARBONS
Soensken,H., (Bad. Anilin- und Soda-Fabrik A.-G., Ger.), 23410p, Stud. Petrochem;, U.N. Interreg. 1st Conference, 64 (Pub. 66), 1,345-58 (English), United Nations: New York, N.Y.

A review is given of licensed processes for production of H and NH_3, C_2H_2, and C_2H_4, recovery and purification of monoolefins, manufacture of butadiene from C_4 fractions, and manufacture of intermediates.
(REVIEW, PROCESS)

H73 22187 AVAILABLE HYDROGEN IN REFINERY
Menant, R., 23440f, Rev. Ass. Fr. Tech. Petrole, V 76 N205 71, (French)

H sources in a petroleum refinery are reviewed. Catalytic reforming, cracking, and dehydrogenation, steam cracking, and hydrocracking are discussed.
(REFINING, STEAM, HYDROCRACK)

H73 22188 HYDROGEN COMPRESSION BY CENTRIFUGAL COMPRESSORS IN HYDROCRACKING PROCESSES
Jackson, S.B., (Fluor Corp., Ltd.), 88612j, U.S. 3,401,111 (Cl. 208-108), Sept 10 '68, Appl. Jl 5 '66, 3 p

Centrifugal compressor stages are reduced when a H stream contains 1-12% of a hydrocarbon having a molecular weight of 30-80. Thus, in a hydrocracking process, a fraction containing mostly C_4H_{10} is recycled to the H compressor feed. For a discharge pressure of 1600 psig., the number of compressor stages is reduced from 6 to 3 by hydrocarbon addition.
(COMPRESSION, HYDROCRACK)

H73 22189 COMPACT REACTOR-BOILER COMBINATION FOR CONVERTING A MIXTURE OF A REFORMABLE FUEL AND STEAM TO A HYDROGEN-CONTAINING REFORMATE FEED STOCK SUITABLE FOR CONSUMPTION BY A FUEL CELL UNIT
Dantowitz, P., (General Electric Co.), 24087n, U.S. 3,541,729 (Cl. 48-94; C 01b, B 01j), Nov 24 '70, Appl. May 9 '68, 7 p

A fuel and steam were contacted in a reforming catalyst bed to produce a H-containing reformate, which could be used as a fuel for a fuel cell.
(REFORMING, FUEL CELL)

H73 22190 CATALYTIC COMPOSITIONS USED FOR THE STEAM REFORMING OF HYDROCARBONS TO GASES RICH IN HYDROGEN
van Hook, J.P. and T.H. Milliken, (Pullman, Inc.), 66338f, France 1,466,635 (Cl. B 01j, C 01b), Ja 20 '67, U.S. Appl. Dec 29 '64, 14 p

The catalyst comprises Co or CoO, or a mixture of the two, deposited on a support such as zirconia.
(CATALYST, STEAM, REFORMING)

H73 22191 USE OF HYDROGEN IN TOWN GAS PRODUCTION
Yaita, G., (Mitsubushi Co., Tokyo), 70848k, Kagaku Kojo V 11:53-7 N12 67 (Japan)

The reasons that town gas contains H, and the processes for producing H-rich town gas are reviewed. A H generator using naphtha as the raw material produces the cheapest H. Various H generators and processes are described.
(USE, GAS, PRODUCTION)

H73 22192 REDUCING GAS
Anon, Texaco Development Corp., 81227r, Britain 1,178,515 (Cl. C 10g), Ja 21 '70, U.S. Appl. Sept 19 '67, 8 p

A fuel oil and 95% O react in the absence of supplemental steam. Atomic O (oxidant)-C (fuel) ratio is 1-1.2:1. The main effluent gas is CO-H. Suitable feeds include light distillates, naphthas, heavy residuals, crudes, and heavy fuel oils. The smelting of iron ore in a blast furnace using this process is described.
(GAS, FEED, PROCESS)

H73 22193 SYNTHESIS GAS
Bongiorno, S.J., (Chemical Construction Corp.), 131483f, U.S. Re-Issue 26,990 (Cl. 252-373; B 01j, C01b, F 27d), Nov 24 '70, Appl. Nov 21 '69, 6 p, Reissue of U.S. 3,446,747 (See Neth. Appl. 6,510,457, CA 65: 2042c)

A synthesis gas containing CO and H was produced under high pressures by the catalytic primary steam reforming of a fluid hydrocarbon.
(PRESSURE, CATALYST, REFORMING)

H73 22194 HYDROGEN BY INCOMPLETE FLAMELESS CATALYTIC COMBUSTION OF HYDROCARBON OILS
Koch, C., (Siemens A.-G.), 78677u, German Offen. 1,964,810 (Cl. C 01b), Jl 15 '71, Appl Dec 24 '69, 10 p

The title process was carried out in sintered bricks containing ~65% open pores by volume. CO thus formed reacted with H_2O vapor at 150-500° in the presence of Cu-Zn catalysts.
(CATALYST, COMBUSTION, HYDROCARBON)

H73 22195 DESIGN AND CHARACTERISTICS OF H AND G TYPE HYDROGEN PRODUCTION EQUIPMENT BY HITACHI SHIPBUILDING COMPANY
Aoki, K., and Adachi, O., (Hitachi Shipyard, Hitachi, Japan), 119778y, Sekiyu to Sekiyu Kagaku, V 15:26-34 N7 71, (Japan)

H production equipment in petroleum refineries, design problems (gasification and desulfurizing of naphtha, steam reforming, CO conversion, and CO_2 separation), and structures and features of the H- and G-type H production equipment are given.
(DESIGN, PRODUCTION, PETROLEUM)

H73 22196 STEAM CONVERSION OF LIQUEFIED GAS AND ITS MIXTURES WITH HYDROGEN
Rozhdestvenskii, V.P., and V.I. Erofeeva, (USSR), 153536c, Tr. Inst. Giproniigaz, N8 319-35m 69, (Russian), from Ref. Sh., Khim. 70, Abstract No. 18B941

Steam conversion of liquefied gas and its mixtures with H were studied in an open system. Dependence of total conversion intensity of initial hydrocarbons and composition of converted gas on conditional contact time was established. Presence of H did not decrease the reaction rate, but increased the CH_4 and CO content in converted gas.
(STEAM, CONVERSION, GAS)

98

H73 22197 APPARATUS FOR CRACKING HYDROCARBONS TO PRODUCE HYDROGEN
Winters, C.E., (Union Carbide Corp.), 72665j, France 1,524,503 (Cl. C 01b, H 01m), May 10 '68, U.S. Appl. May 24 '66, 5 p

A compact, efficient apparatus is described which comprises a cracking chamber (25 mm. diameter, 12.5 mm. long) and a burner. The same hydrocarbon is fed to the cracking chamber and to the burner as fuel. The apparatus is useful for preparing H for reaction in a fuel cell to generate electric current.
(HYDROCARBON, APPARATUS)

H73 22198 HYDROGEN FROM HYDROCARBON REFORMING
Khan, A.R., (Institute of Gas Technology), 49215h, U.S. 3,416,904 (Cl. 48-214), Dec 17 '68, Appl. Nov 22 '65, 4 p

A H-rich stream is produced by reforming feedstocks b. $<500^{\circ}$F., and containing relatively high proportions of olefins and aromatics, at 1-5 atmosphere and 700-1100°F. in the presence of an $Al-Al_2O_3-Ni$ catalyst.
(REFORMING, CATALYST)

H73 22199 BURNER FOR THE PARTIAL OXIDATION OF HYDROCARBONS FOR SYNTHESIS GAS
Auer, W., K. Buschmann, and H. Heinz, (Badische Anilin- und Soda-Fabrik A.-G.), 89678e, German Offen. 1,905,604 (Cl. C 01b), Aug 20 '70, Appl. Fe 5 '69, 7 p

Synthesis gas (CO + H) was prepared in a burner consisting of 2 concentric tubes leading into a burning chamber by passing a mixture containing hydrocarbon with steam and (or) CO_2 through the outer tube and O containing 1.0-3.0% steam through the inner tube.
(BURNER, OXIDATION, CATALYST)

H73 22200 SYNTHESIS GAS AND HYDROGEN FROM LIQUID HYDROCARBONS
Schlinger, W.G., W.L. Slater, and R.M. Dille, (Texaco Inc.), 44113w, U.S. 3,545,926 (Cl. 23-213; C 01b), Dec 8 '70, Appl. Nov 26 '65 - May 29 '68, 5 p

Synthesis gas was produced by partial oxidation of a fuel oil (9.70° API) with O and steam at 2400 psig and 2377°F for a residence time of 3.32 sec followed by the water gas-shift reaction.
(HYDROCARBON, OXIDATION)

H73 22201 CATALYTIC CONVERSION OF HYDROCARBONS TO HYDROGEN AT LOW TEMPERATURE AND HIGH PRESSURE
Taylor, W.F., F.S. Pramuk, and B.N. Heimlich, (Esso Research and Engineering Co.), 30770f, France 1, 443,096 (Cl. C 01b), Je 24 '66, U.S. Appl. Ja 20 '64, 5 p

A feedstock containing mainly paraffinic C_5-C_{10} compounds is premixed with a 1.5-3:1 excess by weight of steam, pressurized to 5-100 atmosphere, and passed at high space velocity through a catalyst (I) at 288-482° (preferably 427°). The product, predominantly H, also contains CH_4, CO_2, and CO.
(CATALYST, HYDROCARBON)

H73 22202 HIGH PRESSURE HYDROGEN PRODUCTION
Baillie, R.A., (Sun Oil Co.), 27315a, U.S. 3,514,260 (Cl. 23-213; C 01b), May 26 '70, Appl. Oct 20 '67, 3 p

H is produced by high-pressure steam-hydrocarbon reforming over a catalyst to give CO and H, followed by a shift reaction on the CO over an appropriate catalyst at high pressure.
(PRESSURE, REFORMING)

H73 22203 STEAM PHASE CRACKING OF HYDROCARBONS WITH STEAM TO OBTAIN HYDROGEN-CONTAINING GASES
Kanzler, K.H. and P. Guenther, (Girdler-Suedchemie Katalysator G.m.b.H.), 48061k, German 1,230,963 (Cl. C 10j), Dec 22 '66, Appl. Fe 16 '65; 2 p, Addition to German 1,220,466 (CA 63, 17766d)

Previous work is extended from hydrocarbons in the b. range of gasoline to hydrocarbons with C_{1-5} atoms, such as CH_4 to propane, ethylene to pentylene, butadiene, pentadiene, and acetylene.
(HYDROCARBON, STEAM)

H73 22204 HYDROGEN-RICH GAS BY PARTIAL OXIDATION OF LIQUID HYDROCARBONS AT HIGH PRESSURES
Schlinger, W.G., W.L. Slater, and R.M. Dille, (Texaco Development Corp.), 27361n, S. African 68,05,802, Dec 10 '69, Appl. Sept 9 '68, 19 p

Liquid hydrocarbons, steam, and O react at 1800-3000°F and 1000-3000 psig, in a gas generation zone, the effluent gas is contacted directly with preheated H_2O and passed into a water gas shift zone containing a catalyst to yield a H-rich stream at 1000-3000 psig.
(OXIDATION, HYDROCARBON)

100

H73 22205 SELECTIVE CONVERSION OF NAPHTHA HYDROCARBONS TO HYDROGEN
Taylor, W.F., and J.H. Sinfelt, (Esso Research and Engineering Co.), 62844c, British 1,156,766 (Cl. C 10g), Jl 2 '69, Appl. May 15 '68, 4 p

The title process is conducted over a Ba-promoted, low Ni, Ni-Al_2O_3 catalyst.
(NAPHTHA, CATALYST)

H73 22206 HYDROGEN BY STEAM REFORMING
Voogd, J., (Int. Selas Corp. Am., Neth.), 142339q, Chemical Process. Eng. (Bombay), V 5:27-33 N9 71, (English)

A review with 3 references on the steam-hydrocarbon reforming process for production of H for use in refineries. Improvements in technology, engineering and construction materials are discussed.
(HYDROCARBON, REFORMING)

H73 22207 PRODUCTION OF HYDROGEN
Spielman, M., G.P. Baumann, and B. Hering, (Esso Research and Engineering Co.), 69653c, British 1,138,257 (Cl. C 10g), Dec 27 '68, Appl. Je 19 '67, 9 p

H gas is produced by a catalytic steam reforming process of hydrocarbons. The reforming is carried out at 1000-1700°F. and 400-600 psig. in 2 stages, the first with steam and the 2nd with air and steam, so that the final effluent gas contains 3 moles H/mole N.
(CATALYST, REFORMING)

H73 22208 REFORMING OF LIQUID HYDROCARBONS TO GASEOUS FUEL
Mayland, B.J., and C.S. Brandon, (Girdler Corp.), 14826b, U.S. 3,442,632 (Cl. 48-215; C 10kg), May 6 '69, Appl. Oct 26 '64, 5 p

Naphtha and related liquid hydrocarbons are converted to gaseous fuel (H_2, CO_2, CO, and CH_4) suitable for industrial use by passing them in a reformer furnace first through a catalyst bed of high activity, for a time insufficient to produce complete reformation, and then through a catalyst bed of lesser activity for a longer time, to form chiefly methane, condensed naphthas, and aromatic compositions.
(REFORMING, HYDROCARBON)

H73 22209 RANEY NICKEL CATALYSTS FOR HYDROGEN PREPARATION BY REFORMING HYDROCARBONS
Anon, Siemens-Schuckertwerke A.-G., Netherlandish Appl. 6.601,850 (Cl. C 01b), Sept 14 '66, German Appl. Mar 13 '65, 6 p

Chips of an alloy of Al and 45-55% Ni (particle size 1-5 mm.) are treated during a short time with an aqueous or alc. 2-6N KOH solution to form on each particle a thin activated layer of Ni, the core composed of the Al-Ni alloy acting as a support. The catalyst is suitable for reforming C_{2-10} hydrocarbons at 600-800^{o} or alcs. 300-400^{o} and is useful in mobile equipments used to supply H to fuel cells.
(CATALYST, REFORMING)

H73 22210 HYDROGEN MAY BECOME UTILITY AND BE PIPED TO CONSUMERS THROUGH GRID SAY BIPM SPOKESMAN
Anon, Chemical Age, Sept 25 '70

The main driving forces that have enabled hydrogen to become a bulk commodity should maintain their impetus and may eventually lead to hydrogen becoming a utility centrally produced in industrial areas and distributed through a pipeline as now happens with electricity, water, steam, and oxygen.
(HYDROGEN, UTILITY, DISTRIBUTION)

H73 22211 THERMO-CATALYTIC HYDROGEN GENERATION FROM HYDROCARBON FUELS
Callahan, M.A., (U.S. Army, Engineer Research and Development Center, Fort Belvoir, Va.), In: From electrocatalysis to fuel cells, Proceedings of the Seminar, Seattle, Wash., Dec 9-11 '70, (A72-33876 16-03) Seattle, University of Washington Press, 72, p 189-204, 13 refs

The catalyzed pyrolysis of liquid hydrocarbon fuels is shown to be a feasible method of generating high-purity hydrogen. The advantages of this method over other hydrogen production systems, such as steam reforming, are notably its simplicity, its tolerance to fuel additives, and the purity of the product. The cracking reaction can be made to be close to 100% efficient in hydrogen yield, with a stream purity of greater than 95% hydrogen. The problems associated with this method of hydrogen generation are the high temperatures needed and undesired side reactions.
(CATALYST, HYDROCARBON)

112

H73 22212 COMMERCIAL EXPERIENCE WITH HYDROGEN MANUFACTURING CATALYST
Cromeans, J.S., (Catalyst Consulting Services, Inc., Louisville, Ky.), H.W. Fleming, American Chemistry Society, Division of Petroleum Chemistry, Preparation V 16:C38-C44 N2, Meeting Los Angeles, Calif., Mar 28-Apr 2 '71

Review of catalysis used in the production of hydrogen by the steam-hydrocarbon reforming process and by the partial-oxidation process.
(HYDROGEN, PRODUCTION, HYDROCARBON, STEAM REFORMING, PARTIAL OXIDATION)

H73 22213 THERMODYNAMIC STUDY OF THE INCOMPLETE COMBUSTION (GASIFICATION) OF LIQUID FUELS AT HIGH PRESSURE
Baikov, A.M., V.M. Maslennikov, and A.K. Mukhamedzyanov, (USSR), Fiz. Goreniya Vzryva, V 6:128-30 N1 70

The thermodynamics of steam reforming is studied for the model crude fraction $C_nH_mO_kN_lS_p$ under conditions preventing the formation of C deposits. The effects of air excess, C-H ratio, steam volume, and pressure are discussed.
(THERMODYNAMICS, COMBUSTION)

H73 22214 HYDROGEN FROM HEAVY TAILINGS (WASSERSTOFF AUS SCHWEREN RUECKSTAENDEN)
Reinmuth, E., (Bataaise Int Petroleum Mij, N.V., Hague, Holland), Erdoel u Kohle-Erdgas-Petrochemie, V 22:378-84 N7 Jl 69

Various techniques for manufacture of hydrogen from heavy petroleum refineries tailings are analyzed and their economics compared.
(PETROLEUM, ECONOMICS)

H73 22215 PLANTS FOR HYDROGEN MANUFACTURE INCREASE LITTLE IN COST
Nelson, W.L., (Technical Editor and Petroleum Consultant), The Oil and Gas Journal, Je 5 '72

Enough information has become available to permit computation of the productivity attained in the design and construction of hydrogen-generating plants. Little or no change in investment costs occurred between 1962 (the basis) and 1966-1968, but inflation then resulted in increased costs during 1969-1971.
(DESIGN, COST)

H73 22216 MINIATURE HYDROGEN GENERATORS
Rothfleisch, J.E., and L.M. Litz, (U.S. Army Electronics Laboratories, Fort Monmouth, N.J.), 20th Annual Power Sources Conference - Proceedings, May 24-26 '66, p 28-31

Simple thermal cracking system operating at atmospheric pressure for generation of hydrogen directly usable in alkaline fuel cells without further purification; chemistry based on equation in which heat applied to hydrocarbon results in molecular degradation into component H_2 and C; electric tube furnace, feed metering apparatus, and reactor temperature control equipment using thermocouples comprised experimental arrangement; reaction temperature over 1100 C required for 85% or better H_2 yield; cumulatively higher H_2 percentage with increasing duration of run was observed; portable field furnace cracking unit described.
(HYDROCRACK, FUEL CELL)

H73 22217 HYDROGEN - KEY FACTOR IN REFINING'S FUTURE
Bery, R.N., (Foster Wheeler Corp.), Heat Engineering, 49-57, Jl 71

The use of hydrogen in hydrocracking and other refining processes is increasing the demand for hydrogen. A block flow diagram shows the various processes involved in converting hydrocarbons to hydrogen. The steam reforming and partial oxidation processes are described. Purification of the raw hydrogen and design criteria for hydrogen plants are also discussed.
(HYDROCRACKING, HYDROCARBON, PURIFICATION, REFORMING, OXIDATION)

H73 22218 HYDROGEN FROM HEAVY RESIDUES
Berg, G.J. van den, and others, Chemical & Engineering Process, V 52:49-55, Oct 71

The economics of hydrogen production by partial oxidation of heavy residues at 55 and 90 atma (Shell gasification process) have been studied and compared with the catalytic steam reforming of light naphtha (Recatro process). It is found that when the price of naphtha exceeds the price of hydrogen plant and ($10·00/t for a 100t/day plant, it is more economic to use the partial oxidation route. It was also seen that for an oil gasification process including a waste heat boiler, there is no incentive to increase the partial oxidation pressure above 55 atma because both the capital and operating costs increase.
(PARTIAL OXIDATION, RESIDUE, STEAM, REFORMING, PRODUCTION, PROCESS)

H73 22219 PARTIAL OXIDATION. A MINIMUM POLLUTION ROUTE FOR HYDROGEN MANUFACTURE
Schlinger, W.G., (Texaco, Inc., Montebello, Calif.), W.L. Slater, American Chemical Society, Division of Petroleum Chemistry, Los Angeles, Calif, Mar 28-Apr 2 '71, p C45-50

Description of hydrogen manufacturing process which develops the major portion of the energy required for hydrogen generation by internal partial combustion of atmospheric contaminants from the combustion products, thereby minimizing the discharge of pollutants into the atmosphere.
(PARTIAL OXIDATION, POLLUTION, PROCESS)

105

H73 22600 INNOVATIONS IN HYDROGEN PRODUCTION
Ring, T.A., W.L. Mann, and Y.S. Tse, (Bechtel Corp., San Francisco, Calif.), Chemical Engineering Progress, V 66:59-64 Dec 70, Avail:TAC

Recent innovations in hydrogen plant design enables the refiner to accommodate his economic philosophy, as well as his preference in gas compression schemes.
(COST, DESIGN, REFINING, GAS)

H73 22601 METHANATION CATALYSTS
Vahala, J., (Research for Inorganic Chemistry, Usti nad Labem, Czechoslovakia), International Chemical Engineering, V 12:60-8 N1, Ja 71, Avail:TAC

The preparation of catalysts used in the purification of hydrogen by methanation was studied by saturation of the carriers (silica or alumina), by precipitation of active substances on their surfaces, and by the coprecipitation of nickel salts and silicon and aluminum compounds.
(HYDROGEN, PURIFICATION, CHEMICAL, PROCESS)

H73 22602 LOW TEMPERATURE FORMATION OF HYDROGEN FROM $CO + H_2O$
Allen, D.W., SAE-Paper 935D for Meeting Oct 19-23 '64, 3 p

Advantages of low-temperature CO conversion catalysts over conventional iron-chrome, high-temperature CO conversion catalysts when used to produce hydrogen for fuel cell use; production of hydrogen from methane and from propane is considered and reforming conditions indicated.
(CONVERSION, CATALYST, PRODUCTION, FUEL CELL, GAS, REFORMER)

H73 22603 PRODUCTION AND DISTRIBUTION OF LIQUID HYDROGEN
Baker, C.R., and L.C. Matsch, Advances in Petroleum Chemistry and Refining, V 10:36-81 65

Chemical nature and properties of liquid hydrogen; hydrogen is produced from water and hydrocarbons, especially by steam reforming process; temperature, operating conditions, gas stream compositions of hydrogen; hydrogen purification with emphasis on cryogenic absorption process; liquefaction of hydrogen by refrigeration tech-

niques; calculation of ortho and para hydrogen proportion, stage conversion, and production of slush hydrogen; storage and distribution.
(HYDROCARBONS, STEAM REFORMING, PURIFICATION, CRYOGENIC, LIQUEFACTION, STORAGE, DISTRIBUTION)

H73 22604 PRODUCTION OF HIGH-PURITY HYDROGEN FROM BUTANE WITH SPECIAL REFERENCE TO MATERIALS OF CONSTRUCTION AND OPERATING PROBLEMS
Hack, K.M., and B.B. Hall, Chemical Engineering, N193 p CE282-8 Nov 65, Avail:TAC

Problems met within 6 yr operation of low-pressure plant for continuous production of high-purity hydrogen (99.6% H_2), based on steam reforming of butane; reference is made to reformer-tube failures, corrosion of heat exchangers, and general operating performance.
(PRESSURE, STEAM REFORMING, REFORMER, CORROSION, PERFORMANCE)

H73 22605 CHEAP HYDROGEN BY REGENERATIVE COKE-OVEN GAS SEPARATION
Karwat, E., Chemical Engineering, N193 p CE294-301, CE304 Nov 65, Avail:TAC

Process for regenerative separation of hydrogen from hydrogen-containing gas mixtures like coke-oven gas, for production either of ammonia-synthesis gas or of practically carbon-monoxide-free pure hydrogen; manufacturing costs of hydrogen and ammonia are given and compared with those for natural gas or naphtha as raw materials.
(AMMONIA, PRODUCTION, SEPARATION, COST, NATURAL GAS, NAPHTHA)

H73 22606 PARTIAL-OXIDATION PROCESS
Anon, (Texas Development Corp.), Oil and Gas Journal, V 63:108 Apr 5 '65, Avail:TAC

The Texaco partial-oxidation process is a highly versatile method for producing hydrogen and synthesis gas from hydrocarbon fuels ranging from natural gas to unmerchantable fuel oil.
(HYDROGEN, PRODUCTION, SYNTHESIS GAS, HYDROCARBON, FUEL, OIL)

H73 22607 STEAM-METHANE REFORMING
Anon, (Foster Wheeler Corp.), Oil and Gas Journal, V 63:111 Apr 5 '65, Avail:TAC

Hydrogen required for hydrocracking and hydro-desulfurization, and for the production of petrochemicals, may be obtained by the steam-methane-reforming process.

Feedstocks used in generating hydrogen for refinery use include natural gas, refinery gas, propane, and butane. In typical applications where a single shift converter is used, hydrogen at a purity in excess of 95% is produced. Carbon-oxides content is less than 10 ppm.
(HYDROGEN, PRODUCTION, HYDROCRACKING, HYDRO-DESULFURIZATION, CONVERTER)

H73 22608 HYDROGEN PRODUCTION AND LIQUEFACTION
Newton, C.L., Chemical and Process Engineering, V 48:51-8, Dec 67

Reduced cost of liquid hydrogen production has resulted through the integration of the plant into a complex of various related products, which takes advantage of the efficient use of equipment, personnel, distribution systems, land area, etc. The supply of hydrogen as recovered from refinery off-gas or from improved steam-reforming generators has also contributed to cost reductions. This article discusses process developments concerned with liquid hydrogen process including hydrogen gas production, purification, liquefaction, ortho-to-para conversion, related products, liquid hydrogen distribution, and safety.
(REFINERY, STEAM REFORMING, COST, PROCESS, PURIFICATION, CONVERSION, DISTRIBUTION,SAFETY)

H73 22609 PRODUCTION OF PURE H_2 AND CO BY METHANE WASH
Anon, Chemical and Process Engineering, V 53:5 Mar 72

A process for the production of pure hydrogen and carbon monoxide from natural gas, refinery gas, LPG, naphtha, etc. -- and which could be used for adjustment of the CO/H_2 stoichiometric ratio for oxo syngas plants -- has been developed by Linde.
(NATURAL GAS, NAPHTHA, PROCESS, PURITY)

H73 22610* ACETYLENE AND HYDROGEN FROM THE PYROLYSIS OF METHANE
Happel, J. and L. Kramer, Industrial and Engineering Chemistry, V 59:39-50 Ja 67, Avail:TAC

Though direct synthesis of acetylene has been pursued for many years, undesirable product impurities have prevented general adoption of the synthesis. In this report, the authors show that high yields of relatively uncontaminated mixtures of acetylene and hydrogen are possible.
(SYNTHESIS, PURITY, PROCESS, YIELD)

H73 22611* OPTIMIZE HYDROGEN PRODUCTION BY MODEL
Grover, S.S., Hydrocarbon Process, 49:109-11, Apr 70, Avail:TAC

Handling heat transfer, mass transfer and reaction kinetics, this model finds optimum operating conditions for hydrogen production by steam-methane reforming which closely agree with pilot plant and commercial data.
(STEAM REFORMING, METHANE, KINETICS)

H73 22612 CASE HISTORY: FAILURES IN A STEAM-METHANE REFORMER FURNACE
Nisbet, D.F., Hydrocarbon Process, 50:103-5 May 71, Avail:TAC

After 4½ years operation producing 64 MMcfd of hydrogen, pigtail and subheader failures presented the most problems.
(HYDROGEN, PRODUCTION, PROCESS)

H73 22613 PRODUCTION OF CONCENTRATED HYDROGEN FROM THE METHANE-HYDROGEN FRACTION OF PYROGAS
Guseinova, Z.D., Ya.R. Veliev, and Yu.G. Kambarov, Chemical Technology Fuels and Oils, N7-8:574-5 Jl-Aug 71

The present work is devoted to obtaining hydrogen from the methane-hydrogen fraction of pyrogas by the absorption method. The work was performed on an experimental unit with a capacity of 10 cu m. hr of the gas produced. The starting feed was the methane-hydrogen fraction from an experimental gas separation unit. The schematic of the concentrated-hydrogen production unit is shown. Technological conditions for the process are presented and methods of analysis for gases concerned

are suggested.
(ABSORPTION, SEPARATION, PROCESS, ANALYSIS)

H73 22614 TECHNICAL HYDROGEN PRODUCTION FOR FERTILIZER INDUSTRY IN INDIA
Mukherjee, N.L., Chemical Age India, V 21:166-73 Nl Ja 70

Commercial hydrogen production for the fertilizer industry is discussed with special reference to the techno-economical aspects and the future growth in India. In the present circumstances of low capital reserve, it is unreasonable to install new coke oven plants only for fertilizer production. Alternatives are to switch to the continuous oxidation process of water gas production from coal or coke, to find any other suitable process of cheap and bulk scale hydrogen production from indigenous raw meterial, or to materialize the steam-iron process based on the fluidized bed technique.
(ECONOMY, OXIDATION, WATER, GAS, COKE, PROCESS)

H73 22165 SYNTHESIS GAS PRODUCTION
Anon, (Texaco Development Corp.), French 2,032,726 (Cl. C 01b), Nov 27 '70, German Appl. Fe 5 '69, 7 p

This application minimizes oxidative erosion of the burner and superheating of the gas mixture at the nozzle. The burner consists of a number of concentric tubes. An O-containing gas is introduced through the central tube and a combustible hydrocarbon through the annular space between the outer concentric tubes. Partial oxidation of the hydrocarbon occurs in the space between the 2 outlets to give a mixture of CO and H. In an example, the oxidation is conducted at 1350° and 85 atmosphere.
(OXIDATION, SYNTHESIS)

H73 22616 HYDROGEN AND CARBON MONOXIDE
Linde, Hydrogen Process, V 50:164 Nov 71, Avail:TAC

A process for the production of pure hydrogen and pure carbon monoxide from natural gas, refinery gas, liquid gas, naphtha, and other hydrocarbons.
(PURITY, NATURAL GAS, NAPHTHA, HYDROCARBONS)

H73 22617 POLUCHENIE VODORODA METODOM KATALITICHESKOI KONVERSII BUTANA POD DAVLENIEM
Leibush, A.G., E.D. Shorina, and B.D. Agranat, Khimicheskaya Promyshlennost N7:20-5 Jl 65, (In Russian)

Production of hydrogen by catalytic conversion of butane under pressure; laboratory investigations under pressure ranging from 2 to 21 atmosphere; effects of mixture of water vapor and oxygen are also considered in this process; emphasis is on factors affecting carbon black formation during conversion; these factors are --prevention--of butane decomposition before it contacts catalyst and rapid heating of mixture over 750 C, as soon as mixture is in contact with catalyst.
(CATALYST, PRESSURE, BUTANE)

H73 22618 CENTRIFUGAL COMPRESSORS USED
McLeod, W.J., and C.S. Smith, (Standard Oil Co. of Calif.), and N.J. Haritatos, (Chevron Research Co., Richmond, Calif.), The Oil and Gas Journal, Je 5 '72

First application of a new design--direct production of high-pressure, high-purity hydrogen using centrifugal compressors coupled with CO_2 removal by physical absorption--is currently under construction at Standard Oil Co. of California's El Segundo, Calif., refinery.

Called Chevron high-pressure hydrogen production (CHPHP), the process was incorporated into that refinery's new hydrogen plant based on specifications prepared by Chevron Research Co.

The technique is applied to the synthesis gases produced by the partial-oxidation process and to the twin steam-methane reforming unit.
(PRESSURE, OXIDATION, REFORMING)

H73 22619 HYDROGEN: SELAS CORP. OF AMERICA
Anon, Hydrogen Process, V 48:187, Nov 69, Avail:TAC

A process for the manufacture of high-purity hydrogen from natural gas, refinery gas, propane, butane, naphtha, and similar hydrocarbons.
(PRODUCTION, PURITY, NATURAL GAS, NAPHTHA, HYDROCARBON)

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H73 22620 MATHEMATICAL DESCRIPTION OF THE THERMAL CONTACT PROCESS FOR THE PRODUCTION OF HYDROGEN
Oprishko, A.A. (Grozny Brancn of the Scientific-Research Institute for the Automation of the Petrochemical Industry, Soviet Union), B.K. Amerik, Yu.M. Zhorov, L.A. Pashukskaya, and O.V. Yukunin, Chemical Technology Fuels and Oils, N3-4:206-8 Mar-Apr 70

The aim of the present article is the development of a mathematical model of a new process in which hydrocarbon vapors (methane, ethane, ethylene, and acetylene), rising upwards in the reactor, encounter a descending flow of grains of a heat-transfer agent (aluminum oxide) having a temperature of 1400 to 1000 C. With high-temperature decomposition, hydrogen is formed and coke is deposited on the heat-transfer medium.
(HYDROCARBON, DECOMPOSITION, COKE, MODEL)

H73 22621 HYPRO; UNIVERSAL OIL PRODUCTS CO.
Anon, Hydrocarbon Process and Petroleum Refiner, V 44:227 Nov 65

For production of hydrogen from refinery and/or natural gas streams.
(REFINING, GAS)

H73 22622 HYPRO PROCESS: UNIVERSAL OIL PRODUCTS CO.
Anon, Oil and Gas Journal, V 63:110 Apr 5 '65, Avail:TAC

The Hypro Process offers a catalytic method for converting refinery or natural-gas streams into hydrogen assaying a minimum purity of 93 vol %.

Hypro increases the hydrogen-to-carbon ratio of the remaining petroleum fractions in a refinery when refinery gas, the product most often consumed as a plant fuel, is charged to it. This conserves the remaining petroleum fractions for conversion into other, more valuable products or for direct sale. Hypro burns carbon, the least valuable fuel in the refinery.
(PRODUCTION, HYDROGEN, CATALYST, NATURAL GAS, REFINERY)

H73 22623 HYDROGEN PRODUCING SYSTEM
McCartney, D.E. and H.A. Hauser, (to Universal Oil Products Co.), U.S. 3,314,761 (Cl. 23-213), Apr 18 '67, Appl. Jl 5 '63, 5 p

A continuous catalytic H producing system by the decomposition or cracking of CH_4 is described.

(CATALYST, DECOMPOSITION, CRACKING, METHANE)

H73 22624 AIR AND GAS SEPARATION PLANTS
Griesheim, M., (GmbH, Cryogenics Div., Frankfurt am Main, 300 Hanauer Landstrasse, West Germany).

Air and gas separation plants .... for manufacture of pure gases in both the liquid and gaseous state are described in a 71-page book. Numerous photographs and drawings show many schemes for processing crude gases such as air, refinery gases, crack gas, natural gas, water gas, and residual gas into pure helium, hydrogen, nitrogen, methane, acetylene, ethylene, ethane, etc. In addition to the process descriptions, technical data related to pure gases is presented. Key physical data is tabulated, vapor pressure curves are shown and temperature enthalpy data are diagrammed for the principal gases.
(SEPARATION, PROCESS)

H73 22625 MATHEMATICAL DESCRIPTION OF THE THERMAL-CONTACT PREPARATION OF HYDROGEN
Oprishko, A.A., B.K. Amerik, Yu.M. Zhorov, L.A. Paskudskaya, O.V. Yakunin, (Grozn. Filial NIPI "Neftekhimavtomat," Grozny, USSR), Khim. Tekhnol. Topl. Masel, V 15:38-40 N3 70, (In Russian)

The process of decomposition of a CH_4-C_2H_6-C_2H_4-C_2H_2 mixture in contact with Al_2O_3 heat carriers was described by 11 equations including material and thermal balances. The equations were resolved by the Runge-Kutta method at various temperatures of the heat carrier in the lower part of the reactor as a function of the reactor temperature.
(DECOMPOSITION, HYDROCARBON, HEAT, REACTOR, EQUILIBRIUM, METHANE, TEMPERATURE)

H73 22626 AUTOMATIC CONTROL OF COMBINED METHANE AND CARBON MONOXIDE CONVERSION SECTION AT THE RUSTAVI CHEMICAL PLANT
Sergeeva, S.L., G.A. Tugushi, and E.V. Portugimov, (USSR), Avtomat. Nar. Khoz., 66, (Pub. 69), p 185-94, (In Russian), from Ref. Zh., Khim. 69, Abstract No. 20I238

Consumption, d., pressure, and flow temperatures of vapor, gas, O, H_2O, and air and their mixtures in various phases are the physical parameters characterizing the oxidative production of H or H-N from natural gas. (CONTROL, CONVERSION)

H73 22627 PRODUCTION OF ACETYLENE, ITS HOMOLOGS, AND TECHNICAL HYDROGEN FROM NATURAL GAS BY PLASMA JET SYNTHESIS
Valibekov, Yu.V., and G.M. Bolotov, (Inst. Khim., Dushanbe, USSR), Izv. Akad. Nauk Tadzh. SSR, Otd. Fiz.-Mat. Geol.-Khim. Nauk, V 2:47-55 68, (in Russian)

A mixture of natural gas (90% CH_4 and 6.4% C_2H_6) and Ar was passed through an electric arc and cooled with an Ar stream to give a gas mixture containing H 42-70, CH_4 4-42. Operating conditions leading to formation of C_2H_2 simple homologs were studied.
(GAS, PLASMA, SYNTHESIS)

H73 22628 PRODUCTION OF REDUCING GAS
Milner, G., (Power-Gas Corp., Ltd.), British 1,149,114 (Cl. C 10g), Apr 16 '69, Appl. Fe 24 '67, 8 p

A gas mixture containing H, CO, and $\leq$12% volume CO_2 and H_2O vapor is prepared by catalytic steam reforming of natural gas in a cyclic process.
(GAS, PROCESS, REFORMING)

H73 22629 STEAM REFORMING OF HYDROCARBON FEEDSTOCKS
Talbert, S., (Lummus Co.), German Offen. 2,022,076 (Cl. C 10g), Nov 19 '70, U.S. Appl. May 8 '69, 14 p

Gas containing 82-94% H + CO at a 3:1 to 4:1 H-CO molar ratio is obtained and the formation of C minimized by stagewise reforming of natural gas at a steam-feedstock C ratio of less than 2:1 at the first stage and below this proportion in the overall balance. The preferable ratios are 2.2-2.6:1 and 1.2-1.5:1, respectively.
(STEAM, REFORMING, HYDROCARBON)

H73 22630 SYSTEM EMPLOYING COAL AS FUEL IN A STEAM REFORMER
Stotler, H.H., (Hydrocarbon Research, Inc. and United States Dept. of the Interior), U.S. 3,551,123 (Cl. 48-94; B 01j, C 01b, F 23i), Dec 29 '70, Appl. Oct 18 '68, 4 p

Coal-derived hot flue gas is used as the heating gas in a H-producing steam reformer.
(COAL, FUEL, REFORMING)

114

H73 22631 DEVELOPMENT OF HYDROGEN PREPARATION PROCESSES
Stezhenskii, A.I., I.A. Makarov, and Yu.G. Prazhennik, (Inst. Gaza, Kiev, USSR), Neftepererab, Neftekhim, Kiev, N3:107-16 69, (in Russian)

The mechanism of high temperature (1250-70^{o}) oxidation of CH_4 with O is discussed on the basis of calculations from existing data. The effect of pressure and conditions for the nondeposition of C during the reaction were determined and are considered with reference to the performance of internal-combustion engines and gas turbines.
(TEMPERATURE, COMBUSTION)

H73 22632 CATALYTIC PREPARATION OF HYDROGEN AND CARBON BLACK FROM NATURAL GAS IN A BALL MILL
Patrikeev, V.V., N.Z. Kotelkov, and O.G. Khteranovich, (Saratov. Sel'skokhoz. Inst., Saratov, USSR), Zh. Prikl. Khim., Leningrad, V43:1377-80 N6 70, (in Russian)

H and carbon black were prepared from natural gas in a 1.5-l. cylindrical steel ball mill heated by an electric muffle furnace and rotated by the electric motor.
(CATALYST, GAS)

H73 22633 SIMULTANEOUS MANUFACTURE OF HYDROGEN AND OF A HYDROGEN-CARBON MONOXIDE MIXTURE
Anon, (Selas of America, Nederland) N.V. French 1,559,142 (Cl. C 01b), Mar 7 '69, Netherlandish Appl. Ja 12 '68, 7 p

A mixture of steam, CO_2, and hydrocarbons is subjected to catalytic reforming and the gas mixture obtained is divided into 2 streams. The 1st stream is partially liquefied to give a gas phase of H, and a liquid phase of CO, thus producing technically pure H. The CO fraction is mixed with the 2nd stream to give technically pure CO-H.
(STEAM, CATALYST, REFORMING)

H73 22634 HYDROGEN
Anon, (United Aircraft Corp.), Netherlandish Appl. 6,609,376 (Cl. C 01b), Fe 6 '67, U.S. Appl. Aug 3 '65, 14 p

Nearly pure H is made catalytically from hydrocarbons and H_2O vapor. Ni, Co, or Pt are used as catalysts. A mixture of the hydrocarbons and H_2O vapor contacted with the catalyst, thus producing CO_2, CO, and H.
(PURITY, CATALYSIS, HYDROCARBON, WATER, MEMBRANE, TEMPERATURE)

H73 22635 SYNTHESIS GAS MANUFACTURE
Garvie, J.H., Chemical Process Engineering, V 48:55-62 N11 67, (in English)

The economically feasible methods for the preparation of synthesis gas for the production of NH_3 are evaluated. The N is obtained from air separation or introduced as air in the preparation of H. The methods of H production include the reforming of desulfurized gaseous hydrocarbon feedstocks in the C_{3-4} range, the CO conversion of any C-containing feedstock, and the partial oxidation of feedstocks ranging from natural gas to fuel or crude oil. Reforming is more economical than partial oxidation for the same feedstock, but the advantages of the price differential from the use of heavier feedstocks may give the partial oxidation an economic advantage. (AMMONIA, STEAM REFORMING, HYDROCARBON, CONVERSION, PARTIAL OXIDATION, ECONOMY)

H73 22636 HYDROGEN BY STEAM-METHANE REFORMING
Habermehl, R.H., and K.A. Atwood, (Catalysts and Chemicals Inc.), U.S. 3,382,045 (Cl. 23-213), May 7 '68, Appl May 10 '65, 6 p

In the title process, 2 stages of shift conversion are used without intervening CO_2 removal.
(STEAM, REFORMING, CONVERSION)

H73 22637 PRODUCTION OF HYDROGEN-RICH GASES
Hebden, D., and K.J. Humphries, (Gas Council), British 1,063,464 (Cl. C 10g), Mar 30 '67, Appl. Mar 13 '64, 4 p
Addition to British 895,038 (CA 57, 2520d)

H-rich gases are prepared by treatment of a C_3 hydrocarbon vaporizable at atmospheric pressure and 250° with steam.
(HYDROCARBON, STEAM)

H73 22638 REACTIONS OF N-BUTANE, ETHYLENE, AND 1-BUTENE WITH STEAM OVER A SILICA-SUPPORTED NICKEL CATALYST IN THE TEMPERATURE RANGE 370-450
Morita, Y., M. Saito, and M. Tokuno, (Dep. Appl. Chem., Waseda Univ., Tokyo, Japan), Mem. Sch. Sci. Eng., Waseda Univ. N34:125-36 70, (in English)

Steam reforming of 8.4:1 H_2O-C_4H_{10} mixture at 370° over a Ni/silica gel catalyst gave CH_4, H, and CO_2 in essentially theoretical distribution.
(REACTION, STEAM, REFORMING)

H73 22639* HYDROGEN GENERATION FROM NATURAL GAS WITH HEAT FROM NUCLEAR REACTOR
Kugeler, K., Berlin Kernforschungsanlage Juelich 68, JUEL-557-RG, 27 p, (German), Avail:Germany

Using the heat from a nuclear reactor, a method for production of H by the reaction of CH_4 with steam is described. The reactants were fed into the reactor at 70 atmosphere and 750-950^{o}. The overall pressure in the chamber dropped to 30 atmosphere and the temperature to 400-750^{o}. Thermodynamic considerations of the energy balance of the system are given. The CH_4 diffusion rate was 2.45 X 10^5 m.^{3}/hr., the CH_4 use rate was 1.60 X 10^5 m.^{3}/hr., and the H production rate was 7.12 X 10^5 m.^{3}/hr. (yield: 69.5%). Statistical data from the viewpoint of the production cost are discussed.
(NUCLEAR, HEAT, REFORMING)

H73 22640 HIGH-TEMPERATURE HYDROCARBON REFORMING FURNACE
Von Wiesenthal, P., (Alcorn Combustion Co.), French 1,538,588 (Cl. C 01b), Sept 6 '68, Appl. Jl 21 '67, 4 p

In the reforming of hydrocarbon mixtures with H_2O and (or) CO_2 to produce H and CO, combustion air is preheated by indirect exchange with a com. heat transfer fluid which has been circulated through tubes in the convection section of the furnace.
(TEMPERATURE, REFORMING)

H73 22641 HYDROGEN FROM METHANE
Hayes, J.C., (to Universal Oil Products Co.), U.S. 3,379,504 (Cl. 23-212), Apr 23 '68, Appl. Mar 26 '65, 5 p

In the production of H by catalytic decomposition of CH_4 with a fluidized bed of Ni-Al_2O_3 as catalyst, clinker formation during start-up is inhibited by preheating and drying the catalyst, and initially subjecting the dry catalyst to reduction with a gas mixture containing less than or equal to 25% free H, e.g. CH_4 + N.
(METHANE, CATALYST)

H73 22642 GENERATION OF HYDROGEN FROM HYDROCARBON GASES BY STEAM-OXYGEN CONVERSION IN A FLUIDIZED BED UNDER PRESSURE
Sechenov, G.P., V.S. Al'tshuler, and L.D. Leonova, (Inst. Goryuch. Iskop., Moscow, USSR), Neftepererab, Neftekhim., Moscow, N7:21-4 68, (in Russian)

Laboratory study of 2-stage generation of H from CH_4 (natural gas) was carried out in 2 fluidized bed reactors.
(STEAM, OXYGEN)

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H73 22643 PREPARATION OF HYDROGEN
Morida, Y., (Wasenda Univ., Tokyo), Kagaku Kojo, V 11:11-17 N12 67, (Japan)

Preparation of H_2 by partial oxidation of hydrocarbons is discussed. In the contact process, natural gas and naphthas are used as feeds in the presence of a catalyst (e.g., Ni) at 750-900°. In the thermal process, heavy oils and crude oils are used as feeds without catalysis at 1300-1500°. The I.C.I. process and the Texaco process are described with flow diagrams to illustrate contact and thermal processes, respectively.
(PARTIAL OXIDATION, HYDROCARBON, NATURAL GAS, NAPHTHA, CATALYST, HEAT)

H73 22644 THE MANUFACTURE OF HYDROGEN BY REFORMING REFINERY GASES
Radancevic, M., (Petroleum Refinery Bosanski Brod, Brosanski Brod, Yugoslavia), Nafta, Zagreb, V 18:529-32 N11 67 (Croatian)

The production of pure H is achieved by the catalytic steam reforming of a mixture of H 41.09, $CH_4$25.82, C_2H_6 27.54, $C_3H_8$5.31, and C_4H_{10}0.24 vol. %.
(CATALYST, REFORMING)

H73 22645 AMMONIA SYNTHESIS GAS
Green, R.V., (du Pont de Nemours, E.I., and Co.), U.S. 3,584,998 (Cl. 23-199; C 01cb, B 01j), Je 15 '71, Appl. Jl 3 '68, 4 p

The usual primary reformer used in preparing NH_3-synthesis gas is eliminated by preheating the air, steam, and natural gas to 1500-2000°F and causing them to react in a secondary type reformer containing a conventional Ni-base catalyst. The reformer is operated at 1500 psig; usually 300-500 psig.
(AMMONIA, REFORMING)

H73 22646 CATALYTIC DECOMPOSITION OF METHANE FOR THE PRODUCTION OF HYDROGEN
Veselov, V.V., V.T. Kharlambova, N.A. Kovalenko, K.M. Proshcheruk, and P.S. Savchuk, (Inst. Gaza, Kiev, USSR), Neftepererab, Neftekhim, Kiev, N2:137-48 67, (Russian)

A series of catalysts suitable for the decomposition of CH_4 to H was evaluated in tests using a natural gas containing $CH_4$93-5, N 3.5-4.5, and C_2H_6 1.5-2.5%.
(CATALYST, METHANE, DECOMPOSITION)

H73 22647 HYDROGEN FROM METHANE AND WATER
Guerrieri, S.A., (Lummus Co.), French 1,503,018 (Cl. C 01b, H 01m), Nov 24 '67, U.S. Appl. Nov 12 '65, 6 p

A portable H generator for use in connection with fuel cells is described. The H is prepared by steam-reforming of practically S-free hydrocarbons, which are mixed with H_2O and heated 760-870°. The reaction products are utilized to reheat the mixture and pure H is separated in a diffusion cell based on Pd alloys. Suitable hydrocarbons are CH_4, natural gas, liquid petroleum gases, etc.
(WATER, GENERATOR, HYDROCARBON)

H73 22648 CATALYTIC DISSOCIATION OF HYDROCARBONS
Anon, (Badische Anilin- und Soda Fabrik A.-G.), French 1,548,421 (Cl. C 01b), Dec 6 '68, German Appl. Sept 5 '66, 5 p

CO and H are produced from gaseous or vaporizable hydrocarbons by a flameless catalytic process without formation of carbon black and without abnormal increase of temperature of the catalyst, by using a two-step process, with a catalyst comprising a mech. Pt-Ni mixture.
(CATALYST, GAS)

H73 22649 KINETICS OF PROPANE CRACKING IN FLUIDIZED BED REACTORS
Bach, G., and S. Nowak, (Deut. Akad. Wiss. Berlin), Chemical Tech., Berlin, V 19:161-6 N3 67, (in German)

The pyrolysis of pure propane was determined in a vacuum apparatus (diagram given) with a uniform quartz sand reactor. Curves are given for the decrease in C_3H_8 concentration and increase in C_2H_4, CH_4, H, and C_3H_6.
(KINETICS, PYROLYSIS)

H73 22650 PRODUCTION OF HYDROGEN-CONTAINING GASES FROM HYDROCARBONS
Vorum, D.A., (to Pullman Inc.), U.S. 3,278,452 (Cl. 252-376), Oct 11 '66, Appl. Dec 24 '59, 8 p

Previous processes used to produce H from CH_4 and higher hydrocarbons generally involve partial oxidation (as shown in reactions 1, 2, and 3), steam-reforming process (4 and 5), or a combination method. Combined partial-oxidation and steam-reforming processes have advantages over either process alone by virtue of using

heat evolved in partial-oxidation to supply at least part of the heat required for steam-reforming, thereby cutting fuel costs and permitting operation with feeds containing relatively large amounts of hydrocarbons.
(HYDROCARBON, REFORMING)

H73 22651 ECONOMICS OF PRODUCING HYDROGEN FROM GASEOUS FEEDSTOCK
Chernyi, Yu.I., Chemical Technology Fuels & Oils, V 7:673-677 N9-10, Sept-Oct 71

Existing methods of producing hydrogen are analyzed from economic point of view. The most economical process of hydrogen production from gaseous feed at a refinery has been shown to be the thermal decomposition on fixed packing. However, this process cannot be recommended at present for wide use, since it has not been sufficiently developed industrially, the most effective is conversion with steam, which is more advantageous in terms of energy consumption, investment, and production cost than conversion with oxygen. In terms of the current consumption characteristics and investment, the process of metal-steam conversion in a moving contact bed is most advantageous.
(ECONOMICS, HYDROGEN, GAS, THERMAL, DECOMPOSITION)

H73 23000* PROCESS FOR PRODUCING HYDROGEN FROM WATER USING AN ALKALI METAL
Miller, A.R., H. Jaffe, U.S. Pat. 3.490.871 Ja 20 '70, Avail:TAC

A process for producing hydrogen gas from water involving the reaction of an alkali metal, preferably cesium and coater to produce hydrogen gas and an alkali metal-oxygen compound and thereafter the alkali metal-oxygen compound is regenerated and recycled for reduction of a further quantity of water.
(REDUCTION, REGENERATION, RECYCLE)

H73 23001 PROCESS OF SUPPLYING HYDROGEN TO A FUEL CELL WITH BOROHYDRIDE ADDUCT
Hogsett, J.N., (to Union Carbide Corp.), U.S. 3,374,121 (Cl. 136-86), Mar 19 '68, Appl. Nov 27 '64, 14 p

H is generated for fuel cells by contacting adducts of metal borohydride and organic N compounds (diamino-alkanes, polyalkylenes, polyamines, triazines, tetrazenes, heterocyclics).
(PROCESS, HYDRIDE)

H73 23002 METHOD OF AND PLANT FOR THE UTILIZATION OF NUCLEAR ENERGY
Anon, (to Kernforschungsanlage Julich Gesellschaft Mit Beschrankter Haftung), British Patent 1,225,014, Mar 17 '71, Priority date Fe 17 '67, Germany

Hydrogen production by process heat reactor, method for design with means for production of hydrogen by reaction of metal oxide, steam and carbon monoxide.
(HYDROGEN, PRODUCTION, DESIGN, STEAM, REACTOR, PROCESS, HEAT)

H73 23003 HYDROGEN GENERATION FOR FUEL CELLS
Lafyatis, P.G., and J.E. Rothfleisch, (Union Carbide Corp.), U.S. 3,458,288 (Cl. 23-282; B 01j), Jl 29 '69, Appl. Dec 28 '65, 5 p

A portable, self-contained apparatus for H_2 generation for fuel cells by the hydrolysis of a metal borohydride by an inorganic acid is described.
(FUEL CELL, HYDRIDE)

H73 23004 EVALUATION OF STORABLE PROPELLANT REFORMING FOR USE IN EMERGENCY LIFE SUPPORT SYSTEM DESIGN
Wright, L.O., (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), N71-29903, (NASA-TM-X-2321: E-5520), Avail:NTIS CSCL 06K, Washington, Jl 71, 35 p, refs

The storable propellants Aerozine-50 and nitrogen tetroxide (N204) are evaluated as sources of hydrogen, oxygen, potable water, and heat for use in an emergency life support system. Results of these laboratory studies indicate the feasibility of steam reforming Aerozine-50 to obtain hydrogen rich gas.
(HYDROGEN, PRODUCTION, STEAM-REFORMING, PURITY, CRYOGENIC, OXYGEN)

H73 23005 HYDROCYANIC ACID AND HYDROGEN FROM ACETONITRILE AND AMMONIA
Anon, (Deutsche Gold- und Silber-Scheideanstalt vorm. Roessler), French Demande 2,014,523, Apr 17 '70, German Appl. Jl 6 '68

MeCN and NH_3 are passed over a catalyst containing 50-80 atmospheric % Al or Mg and Pt deposited on Al_2O_3 at 1100-1300^o in a sintered Al_2O_3 tubular reactor. The mixture is rapidly heated and rapidly cooled to give a mixture containing HCN and H. The yield of HCN is about 150 weight % based on MeCN.
(AMMONIA, REACTION)

H73 23006 SELF-REGULATING HYDROGEN GENERATOR
Harm, R.L., (General Electric Co.), U.S. 3,453,086, Jl 1 '69, Appl. Oct 12 '65

This application uses the contacting of a liquid reactant with a solid one.
(LIQUID, GENERATOR)

H73 23007 PROCESS FOR SUPPLYING HYDROGEN AND OXYGEN TO FUEL CELLS
Vahldieck, N.P., (Union Carbide Corp.), French 1,482,628, May 26 '67, U.S. Appl. Je 10 '65

Exhaust H from the anode is burned to provide part or all of the heat required to operate an NH_3 cracking unit or a hydrocarbon reformer to make crude H.
(ELECTROLYSIS, HEAT, AMMONIA, CRACKING, HYDROCARBON, REFORMER, OXYGEN)

H73 23008 PORTABLE HYDROGEN GENERATOR
Knorre, H., and K. Stephan, (Deutsche Gold- und Silber-Scheideanstalt vorm. Roessler), German 1,251,723, Oct 12 '67, Appl. Dec 2 '64

The generator is composed of a cylindrical capsule containing hydride in the lower half and a drying agent in the upper.

(GENERATOR, HYDRIDE)

H73 23009 HYDROGEN PRODUCTION FOR FUEL CELLS
Bocard, J.P., R.L. Harvin, and B.J. Mayland, U.S. 3,469,944, Sept 30 '69, Appl. Ja 31 '64 - May 13 '68

A process for preparing H suitable for use in fuel cells comprises catalytic reforming of MeOH at 700-800°F under nonadiabatic conditions.

(CATALYSIS, METHANOL, DIFFUSION, PALLADIUM, REFORMER, HEAT)

H73 23010 PORTABLE HYDROGEN GENERATOR
Costa, R.L., Intersociety Energy Conversion Engineering Conference - Technical Papers for meeting Aug 13-17 '67, P 401-5

Compact, portable unit generates high purity hydrogen from liquid ammonia; unit is based on off-the-shelf hardware; generator has volume of 3.5 cu ft. and weighs 130 lb; it produces 140 scfh of 99.99% pure hydrogen at 3 psig; generator has change in rate response time of less than 30 sec; thermal efficiency is 72% at rated output; generator system consists of ammonia dissociator, hydrogen purifier and liquid ammonia of storage, transfer and control subsystem.

(AMMONIA, GENERATOR)

H73 23011 HYDROGEN PRODUCTION
Normand, A., (Societe Chimique de la Grande Paroisse, Azote et Produits Chimiques), French Addition 95,172, Jl 31 '70, Appl. May 30 '68, Addition to French 1,564,814

Pure H was prepared by catalytic oxidation of NH_3 in a reactor consisting of 2 compartments.

(PURITY, CATALYSIS, OXIDATION, AMMONIA, REACTOR, DECOMPOSITION, NITROGEN)

H73 23012 METHOD OF OBTAINING PURE HYDROGEN FOR FUEL CELL FEEDING OUT OF METHANOL
Bloch, O., (Institut Francais du Petrole, Rueil-Malmaison, France), C. Dezael, and M. Prigent, Third International Symposium on Fuel Cells, Proceedings, Je 16-20 '69, Brussels, Belgium, by SERAI and COMASCI

Characteristics of a complete converter-separator device for feeding alkali electrolyte hydrogen fuel cell are presented. The device is based on the principle of absorption-desorption, an analog to devices which are currently used in the industries for gas treatment.
(FUEL CELL, METHANOL)

H73 23013 HYDROGEN FROM METHANOL FOR FUEL CELLS
Rothfleisch, J.E., (Union Carbide Corp., Development Dept., South Charleston, W.Va.), Society of Automotive Engineers, National Transportation, Powerplant, and Fuels and Lubricants Meeting, Baltimore, Md., Oct 19-23 '64, Paper 935C

Bench scale studies of the production of hydrogen from an equimolar methanol-water mixture in a single bed of a precious-metal catalyst or a base-metal catalyst. In either case, the catalyst proved effective both in dissociating the methanol and in promoting the water gas shift reaction to a significant degree. With a base-metal catalyst, yields in excess of 90% of theoretical were obtained at 100 psig and 700^{o}F, based on the total hydrogen content of the feed. It was further demonstrated that, by lining the reaction chamber with a supported silver-palladium alloy membrane, ultrapure hydrogen suitable for direct use in fuel cells could be produced in a compact integral reactor-purification system.
(FUEL CELL, METHANOL)

H73 23014 GENERATING HYDROGEN
Gluckstein, M.E., (to Ethyl Corp.), U.S. 3,313,598, Apr 11 '67, Appl. Mar 13 '62 and Je 7 '65

A portable source of small amounts of H, e.g. for use in fuel cells, consists of reacting $NaAlH_4$ with H_2O. The rate of evolution of the H can be decreased by using aqueous solutions of lower alcs. or inorganic acids or salts.
(FUEL CELL, GENERATOR)

H73 23015* METHOD FOR UTILIZING NUCLEAR ENERGY IN THE PRODUCTION OF HYDROGEN
Wolfgang, H., and G. Wolff, (to Kernforschungsanlage), U.S. Patent 3,535,082, Oct 20 '70

Nuclear energy is utilized in the production of H_2 by heating $CaCO_3$ or $MgCO_3$ so as to form the respective metal oxide and CO_2, using a portion of the thus obtained CO_2 for conversion thereof in contact with C to CO, heat-omg the thus obtained metal oxide and CO in the presence of steam so as to form H_2 gas and metal carbonate, the latter being reused for producing metal oxide and CO_2 and the H_2 gas being recovered, and supplying the heat required for these reactions and for the production of the needed steam by indirect heat exchange with a heat exchange medium such as He which passes in a closed cycle between a high temperature nuclear reactor in which the heat exchange medium is heated and the above described reaction mixtures which are heated by the heat exchange medium under simultaneous cooling of the latter.
(NUCLEAR, ENERGY, CARBONATE)

H73 23016 REACTION OF ALUMINUM WITH SODIUM HYDROXIDE SOLUTION AS A SOURCE OF HYDROGEN
Belitskus, D., (Aluminum Co. of America, Alcoa Research Laboratories, New Kensington, Pa.), Journal of the Electrochemical Society, Aug '70

Generation of hydrogen for fuel cells by reaction of hydrides with water or aqueous solutions reduces storage weight or volume over high pressure or cryogenic storage but is expensive. Reaction of aluminum in aqueous solutions provides an inexpensive, compact source of hydrogen. While 100^{o}-500^{o}F is required for useful rates with mercuric chloride solution, room temperature is satisfactory with sodium hydroxide solution.

Hydrogen generation rates from massive aluminum in sodium hydroxide solutions are inconveniently slow for fuel cell use, even in 10M NaOH. Compacts of atomized aluminum powder in sodium hydroxide solutions yield hydrogen at suitable rates without external heating and with a start-up time in the range of 1 minute.
(ALUMINUM, GENERATOR)

H73 23017 HYDROGEN GENERATION BY MEANS OF THE ALUMINUM/WATER REACTION
Smith, I.E., (Cranfield Institute of Technology, Cranfield, Beds., England), Journal of Hydronautics, V 6:106-109 Jl 72

An aluminum amalgam will react with water at ordinary temperatures with the formation of aluminum hydroxide and the liberation of free hydrogen. In the case of a block or sheet of the metal having an amalgamated surface, this reaction will continue until all the aluminum has been consumed. The reaction rate is observed to be temperature dependent, and this affords a simple means of regulating the output of hydrogen. If the supply of water and disposal of waste is discounted the reaction is shown to be superior, on a volumeric basis, to all other common means of producing hydrogen, and furthermore is competitive on a weight and cost basis with other chemical production methods. The inherent simplicity of such a scheme for hydrogen generation offers attractive advantages in terms of reliability.
(ALUMINUM, GENERATOR)

H73 23018 PROCESS AND EQUIPMENT FOR THE WORKING OF NUCLEAR ENERGY
Anon, (to Kernforschungsanlage, Julich GmbH), French 1,572,233, May 19 '69

A procedure for utilizing energy produced by a nuclear reactor is described. A refrigerant circulating through pipes transfers the heat produced by the reactor to vessels containing substances destined to participate in a particular chemical reaction. In the production of hydrogen, water vapor is passed over a metal oxide in a CO atmosphere. The metal carbonate formed is dissociated with regeneration of the oxide and evolution of CO_2, some of which is passed over finely divided carbon, producing CO, which is returned to the reaction vessel. Products of the reaction are hydrogen gas and CO_2.
(PROCESS, NUCLEAR)

H73 23019 STUDY OF MULTIPLE RESERVE ELECTROCHEMICAL POWER SOURCE
Ciprios, G., (Government Research Laboratory, Esso Research and Engineering Co., Linden, N.J.), NASA Contract Rep. 69, NASA-CR-100657, Avail:CFSTI, from Sci. Tech. Aerosp. Rep., V 7:2027 N12

Neat hydrazine and 98 wt. % H_2O_2 are used as storable

reactants. Appropriate high temperature reactors, containing propellant decomposition catalysts, are used to generate H and O feed gases for the fuel cell. Allis-Chalmers fuel cell modules were selected for the centerline design on the basis of low specific weight and demonstrated bootstrap start-up capability.
(HYDROGEN, HYDRAZINE, OXYGEN, FUEL CELL, CATALYST)

H73 23020 LOW TEMPERATURE FORMATION OF HYDROGEN FROM $CO + H_2O$
Allen, D.W., (Chemetron Corp., Chemetron Chemicals Div., Chicago, Ill.), Society of Automotive Engineers, National Transportation, Powerplant, and Fuels and Lubricants Meeting, Baltimore, Md., Oct 19-23 '64, Paper 935D

Discussion of several applications illustrating the advantages of "low-temperature" CO conversion catalysts over conventional iron-chrome "high-temperature" conversion catlaysts are indicated: operation at a lower temperature level results in a higher purity product for a one-stage system, and a greater yield of hydrogen per unit of hydrocarbon feed; operation at a lower temperature level gives greater freedom in efficient recovery of heat.
(CONVERSION, CATALYST, PURITY, HYDROCARBON, EFFICIENCY, REACTOR)

H73 23021 MODIFICATION OF A HYDROGEN GENERATOR ML-539/TM TO PRODUCE PURE HYDROGEN
Ryan, J.R., and M.F. Collins, (Engelhard Industries, East Newark, N.J., Instruments and Systems Dept.), Final Report Dec 4 '67 - Dec 14 '69

A hydrogen generator ML-539/TM which was originally designed to produce 400 scfh of dissociated ammonia (75% hydrogen and 25% nitrogen), was modified to produce 400 to 450 scfh of pure (99%) hydrogen. The major changes in the generator were the adding of two palladium alloy diffusion chambers for purification of the dissociated ammonia.
(DISSOCIATION, AMMONIA, PURIFICATION, TEMPERATURE, PRESSURE, DESIGN, CATALYST, PERFORMANCE)

H73 23022 PRODUCTION OF HYDROGEN FOR DEUTERIUM EXTRACTION
Dirian, G., D. Leger, and J. Pauly, (to Commissariat a l'Energie Atomique), French Patent 2,098,623, Mar 10 '72

Water vapor is passed over a metal in the bulk state (Fe, Ni, or Cr), which reduces the water to hydrogen. The hydrogen formed is sent to a plant that extracts the deuterium. The metal is then regenerated by the deuterium-depleted hydrogen. Reduction of the water vapor and the regeneration of the metal are effected in two adjacent tubes. Heat exchange occurs between these tubes, a sensibly constant temperature being established in these tubes. The metal is brought to a temperature between 600 and 900°C.
(WATER, REDUCTION, REGENERATION, TEMPERATURE, HEAT)

H73 23023 COMPACT HIGH PURITY HYDROGEN GENERATORS
Kurpit, S.S., (Engelhard Industries) - Technology Bulletin, V 6:5-9 Nl Je 65

High purity hydrogen for industrial and military applications can be obtained by use of Englehard hydrogen generators, which are more economical and compact than merchant cylinders; generators can operate on variety of feedstocks such as relatively sulfur-free liquid or gaseous hydrocarbon fuels in combination with demineralized water, ammonia, aqueous methanol solutions, or other special compounds; in most cases, some auxiliary electric power is required.
(HYDROCARBON, FUEL, WATER, AMMONIA, METHANOL, POWER)

H73 23024 DISPOSABLE HYDROGEN GENERATOR
Brewer, J.N., and D.L. Allgeier, Science, V 147:1033-4 N3661 Fe 26 '65

Hydrogen gas is produced by chemical action of magnesium metal, zinc chloride, sodium chloride, and water within unique plastic and aluminum foil envelope contained in anaerobe jars in quantity of about 2 liters; absence of excessive buildup of hydrogen reduces hazard of explosion; gas-producing units are simple to activate and may be discarded after use.
(GENERATOR, HYDROGEN)

H73 23025 PRODUCTION OF HYDROGEN TO SATISFY SMALL INDUSTRIAL DEMANDS
Charlesworth, P.L., and G. Schmidt, Chemical Engineering N192:CE259-65 Oct 65, Avail:TAC

Production of hydrogen to satisfy industrial demands up to 500 normal cu m/hr is discussed; types of processes available are described, with particular reference being made to cracking of ammonia and methanol, and to steam reforming of hydrocarbons; details of available purification techniques are given to illustrate how different hydrogen purities might be achieved; operating-cost data are presented for three processes.
(CRACKING, AMMONIA, METHANOL, STEAM REFORMING, HYDROCARBON, PURIFICATION, COST)

H73 23026 COMPACT H_2 GENERATORS FOR FUEL CELLS
Geissler, H.H., (Englehard Industries, East Newark, N.J.), in Army Signal Research and Development Laboratory Proc., 17th Annual Power Sources Conference, p 75-77, 63

A portable 107-liter-per-hour hydrogen generator to supply a 200-watt hydrogen-oxygen fuel cell power package is described. This miniaturized device catalytically dissociates ammonia to yield nitrogen and hydrogen. The hydrogen gas is separated by diffusion elements of palladium-silver alloy, and the residual gas is used as fuel to supply the total energy requirements, including heat losses of the process.
(DISSOCIATION, CATALYSIS, NITROGEN, DIFFUSION, METHANOL, HYDROCARBON)

H73 23027 FREE HYDROGEN IN GENESIS OF PETROLEUM
Hawkes, H.E., American Association of Petroleum Geologists Bulletin, V 56:2268-70 Nov 72

A model is proposed that postulates (1) a free-hydrogen source in the deep-seated environment, resulting from dissociation of water in the presence of minerals containing ferrous iron; (2) a continuous upward percolation of elemental hydrogen into the surface environment as a consequence of its high rate of diffusion relative to other constituents; and (3) a hydrogen sink near the surface formed by biologically catalyzed chemical reactions of free hydrogen with organic matter, ferric iron, sulfates, and atmospheric oxygen. It is suggested that the

hydrogenation of biogenic organic matter in sedimentary rocks by free hydrogen of deep-seated origin should be investigated as a factor in the genesis of petroleum.
(DISSOCIATION, WATER, DIFFUSION, CATALYSIS, CHEMICAL, OXYGEN)

H73 23028 FUEL CELL SYSTEM USING LITHIUM AND LITHIUM HYPOCHLORITE TO PRODUCE HYDROGEN AND OXYGEN
Honeycutt, S.C., (Lithium Corp. of America, Inc.), U.S. 3,578,501, May 11 '71, Appl. Nov 13 '68

A regenerative fuel cell system operating on H_2 and O_2 is described. The H_2 is obtained by the reaction of Li with H_2O and the O_2 by heating an aqueous solution of LiOCl.

The system requires a minimum of vessels to carry out the reactions. No by-products are formed, since all products are again used in the operations.
(FUEL CELL, REGENERATIVE)

H73 23029 MOBILE HYDROGEN GENERATORS AND MEAN TEMPERATURE FUEL CELLS
Laroche, J., F. Lalanne, and R. Combelles, Entropie N14:46-51 67

Discussed are com. H_2 generators developed in the U.S. using hydrocarbons or NH_3 as starting material. Autothermal cracking of hydrocarbons and reforming of hydrocarbons with steam were investigated as processes for H_2 generators.
(HYDROCARBONS, AMMONIA, CRACKING, STEAM REFORMING, CATALYST, HEAT)

H73 23200 ENERGY GENERATION AND UTILIZATION IN HYDROGEN BACTERIA
Bongers, L., NASA Report 1596, Ja 69, Avail:TAC

This progress report on Contract NASW-1596 covers the reporting period from 23 September 1968 through 22 January 1969. In this report the efficiency of growth by hydrogen bacteria and the definition of growth-rate limiting factors on efficiency of energy conversion are considered.

Some previously reported observations and data from the open literature are included to provide a balanced and interpretive discussion. The present report deals with the effect of the growth environment on gas consumption characteristics of autotrophically growing H. eutropha. The data presented here suggest that the variation in efficiency of energy conversion is due to a lack of an obligatory coupling between energy-donating and energy-utilizing processes in hydrogen bacteria.
(EFFICIENCY, GROWTH, CONVERSION, EUTROPHA)

H73 23201 BIOREGENERATION IM GESCHLOSSENEN SYSTEM MIT HILFE VON ELEKTROLYSEGAS UND BAKTERIEN
Schlegel, H.G., (Institut fur Mikrobiologie der Universitat Gottingen), N86-35667, Je 68, Avail:TAC

The growth parameters for Hydrogenomonas strain H 16 were determined under conditions of continuous culture with formation of H_2-O_2 mixture by direct electrolysis of the culture medium. Using this method, a cell concentration of 3 g dryweight/l was achieved, whereas with an external gas supply the cell concentration reached 28 g dryweight of bacteria/l. Further topics to be reported on are: the development of new culture vessels, the isolation and characterization of new species and strains of hydrogen-oxydizing bacteria, the determination of polysaccharide content, the production of bacterial mutants and metabolic regulation. The future development of an electrolysis-bacterial system for bio-regeneration accompanied by oxygen and protein production is favourably viewed.
(HYDROGEN, PRODUCTION, GROWTH, CULTURE, ELECTROLYSIS, BACTERIA)

H73 23202 VARIABLE PHOTOSYNTHETIC UNITS, ENERGY TRANSFER AND LIGHT-INDUCED EVOLUTION OF HYDROGEN IN ALGAE AND BACTERIA
Gaffron, H., (Florida State University, Tallahassee, Fla.), European Biophysics Congress, 1st, Baden, Austria, Sept 14-17 '71, Proceedings, Vienna, Wiener Medizinische Akademie, 71, p 19-22

The present state of knowledge regarding the truly photo-chemical reactions in photosynthesis is considered. Nine tenths of the available knowledge is of a biochemical nature. Questions regarding the activities of the chlorophyll system are examined. The simplest photochemical response observed in living hydrogen-adapted algal cells is the release of molecular hydrogen, which continues even after all other known natural reactions have been eliminated either by heating or the action of poisons.
(PHOTO-CHEMICAL, REACTION, BIOCHEMICAL, CHLOROPHYLL)

H73 23203 HYDROGEN FORMATION BY ANAEROBIC DECOMPOSITION
Deutsch, I., Gas, V 42:66-8 N2 Fe 66

Procedure used to generate hydrogen-carbon dioxide gas mixture experimentally in more than trace quantities of anaerobic metabolism; hydrogen concentration of 40% was shown by chromatographic ratio of peak heights; mechanism of hydrogen formation; formation of this hydrogen takes place in sugar and confectionery wastes and certain soils.
(CARBON DIOXIDE, METABOLISM, MECHANISM, SUGAR)

H73 23204 BACTERIAL METHANE FUEL CELL
van Hees, W., Journal of the Electrochemical Society, V 112:258-62 N3 Mar 65

Study of methane bio-anode using strain of Pseudomonas methanica (Soehngen); physical contact between bacteria and anode is necessary for removal of electrons into external circuit; if methane is replaced by nitrogen, anode potential is not changed at first; however, bacteria begin to die out; actual fuel species is hydrogen removed from flavoprotein; hydroxyl ions are immediate source of oxygen at anode; prolonged periods of open-circuit condition and also very high current drain should be avoided; both are detrimental to bacteria.
(BACTERIA, ANODE, NITROGEN, OXYGEN, HYDROGEN, CURRENT)

H73 23205 BIOCHEMICAL HYDROGEN GENERATORS
May, P.S., G.C. Blanchard, and R.T. Foley, 18th Annual Power Sources Conference - Proc, (U.S. Army Electronics Laboratories, Fort Monmouth, N.J.), May 64, p 1-3

Generation of hydrogen using micro-organisms for fuel cell batteries is discussed; hydrogen generation rates of various micro-organisms are given; hydrogen production of growing and resting cells are compared using 10-liter fermenter system.
(MICRO-ORGANISM, FUEL CELL, BATTERY)

H73 23206 BIOCHEMICAL FUEL CELLS
Perry, H., Jr., and J. Christopulos, 19th Annual Power Sources Conference - Proc, (U.S. Army Electronics Laboratories, Fort Monmouth, N.J.), May 18-20 '65, p 19-23

Direct and indirect biochemical fuel cell systems utilizing plant vegetation and human waste as fuels with aid of micro-organisms for military applications; hydrogen, ethanol, formic acid, ammonia, and methane are produced from fuels by fermentation; operation of indirect fuel cell system which delivers 60-w at 28-v.
(HYDROGEN, GENERATOR, MICRO-ORGANISM, METHANE, AMMONIA)

H73 23207* BIOLOGICAL FORMATION OF MOLECULAR HYDROGEN
Gray, C.T., and H. Gest, Science, V 148:186-92, 65, Avail:TAC

A "hydrogen valve" facilitates regulation of anaerobic energy metabolism in many microorganisms.
(ANAEROBIC, ENERGY, METABOLISM, MICRO-ORGANISM)

H73 23208 THE MECHANISM OF HYDROGEN PHOTOPRODUCTION BY SEVERAL ALGAE II. THE EFFECT OF INHIBITORS OF PHOTOPHOSPHORYLATION.
Stuart, T.S. and H. Gaffron, Planta, V 106:91-100, 72, Avail:TAC

In order to come to a more firmly based conclusion on the mechanism of hydrogen photoproduction in green algae, we have compared two additional genera of green algae, i.e., Ankistrodesmus and Chlorella, with the previously tested Chlamydomonas and Scenedesmus. None of the algae tested required photo-system II for H_2 photoproduction, since this reaction still occurred in the preence of 10^{-5} M DCMU. Photophosphorylation was also not required since two potent inhibitors of this process, Cl-CCP and SAL, almost always stimulated H_2 photoproduction.

Cl-CCP gave very little if any stimulation of this reaction in autotrophically grown cells of this alga, but stimulated H_2 photoproduction by photoheterotrophically grown cells approximately 450%. Chlamydomonas cells were found to be about ten times as sensitive as the other cells to both poisons. We conclude that all of the algae tested are able to photoproduce H_2 via non-cyclic electron flow through photosystem I to hydrogen.
(HYDROGEN, MECHANISM, PHOTOPRODUCTION)

H73 23209 THE MECHANISM OF HYDROGEN PHOTOPRODUCTION IN SEVERAL ALGAE II. THE CONTRIBUTION OF PHOTO-SYSTEM II. Stuart, T.S. and H. Gaffron, Planta, V 106:101-12 72, Avail:TAC

The contribution of PS II to H_2 photoproduction by several unicellular green algae was measured both when O_2 evolution and photophosphorylation were umimpaired and also when these processes had been eliminated by Cl-CCP. As judged by the effects of DCMU, a PS II contribution was found under both sets of experimental conditions for several strains of Chlorella, Ankistrodesmus and Scenedesmus. However, H_2 photoproduction by Chlamydomonas moewusii was insensitive to DCMU and thus was entirely due to PSI.
(HYDROGEN, PHOTOPRODUCTION)

H73 23400 NEW DEVELOPMENTS IN HYDROGEN GAS GENERATION MOLECULAR SIEVES
Priddy, M.H., Journal of the American Oil Chemists' Society, V 48:sup46A+, Fe 71, Avail:TAC

The use of molecular sieves as a means of purifying steam-reformed hydrocarbon fuel in the production of low cost hydrogen has been developed into a practical gas generator design. Conventional processes for producing hydrogen are reviewed, with a history of molecular sieves and how this dry desiccant material was applied to commercial equipment as an adsorbent for removal of CO_2 and water vapor. The molecular sieve type hydrogen gas generator is discussed with an outline of typical operating cost and gas purity capabilities.
(PURIFICATION, HYDROCARBON, FUEL, COST, PRODUCTION)

H73 23401 CRYOGENIC HYDROGEN UPGRADING
Anon, (Union Carbide Corp., Linde Division), Hydrocarbon Process, V 47:232 Sept 68, Avail:TAC

To recover and upgrade the hydrogen in refinery or petrochemical off-gas streams. Methane is refected to fuel, while hydrocarbons having chemical value are recovered as partially refined byproducts.
(RECOVERY, REFINERY, PETROCHEMICAL, HYDROCARBON, FUEL)

H73 23402 UPGRADING HYDROGEN VIA HEATLESS ADSORPTION
Alexis, R.W., Chemical Engineering Progress Symposium Ser, V 63:50-2 N74 67, Avail:TAC

Rapid adiabatic cycle, with desorption by pressure change only, is employed to separate hydrocarbons from hydrogen; tables list qualitative comparison of hydrogen upgrading processes, typical process economics for hydrogen upgrading by heatless adsorption, and operating cost comparison.
(SEPARATION, HYDROCARBON, PRESSURE, COST, ECONOMY)

H73 23403 RECOVERY OF HYDROGEN FROM INDUSTRIAL GAS MIXTURES
Charlesworth, P.L., Chemical Engineering, N187:CE87-90 Apr 65, Avail:TAC

Recovery of hydrogen from byproduct streams of chemical and petroleum industries, in form suitable for re-

turning to original process or for use in other processes, can be accomplished cheaply by low-temperature separation techniques; applicable to fields of ammonia synthesis and purification and upgrading of petroleum distillates to high-octane gasolines; typical operating costs for hydrogen.
(CHEMICAL, PETROLEUM, CRYOGENIC, SEPARATION, AMMONIA, PURIFICATION, COST)

H73 23404 ERZEUGUNG VON REINST-WASSERSTOFF IN DIFFUSIONSANLAGEN
Bosse, K.O., and F. Kohlmeyer, Institut Zeit fuer Gaswaerme, V 14:156-61 N4 Apr 65
Production of high-purity hydrogen in diffusion units; it is shown how high-purity hydrogen containing no more than 1 ppm of impurities can be produced with aid of diffusion units, core of which is formed by palladium-silver diffusion cells.
(PURIFICATION, DIFFUSION)

H73 23405 CO_2 REMOVAL BY HEATLESS PROCESS
Beavon, D.K. and others, Chemical and Process Engineering, V 53:32-3 Ja 72
The capital and operating costs of large-scale hydrogen and ammonia syngas plants can be considerably reduced by incorporating the Purisol "heatless" CO_2-removal process. This, combined with centrifugal instead of reciprocating compressors, also gives greatly increased reliability.
(COST, HYDROGEN, AMMONIA, CENTRIFUGAL, COMPRESSOR)

H73 23406 HYDROGEN, CRYOGENIC UPGRADING
Anon, Hydrocarbon Process, V 49:268 N9 Sept 70
Application: To recover and upgrade the hydrogen in refinery or petrochemical off-gas streams. Methane is rejected to fuel, while hydrocarbons having chemical value are recovered as partially refined byproducts.
(RECOVERY, REFINERY, PETROCHEMICAL, HYDROCARBON, FUEL)

H73 23407
Anon, Chemical Week, Mar 25 '70
A new way to separate hydrogen and to concentrate synthesis gas is being introduced by Du Pont. It's based

on a new line of Permasep permeators the company is making in a new unit at Glasgow, Del. Du Pont sees a potential for the technique in two big areas. It can be used to concentrate carbon monoxide in synthesis gas by removing as much as 95% of the hydrogen. Or, it can be used to recover hydrogen from high-pressure hydro-desulfurization units in oil refineries. The process has been put to work in a commercial plant and has been operating since Oct 68. It boosts carbon monoxide concentration from about 30% to more than 80%, turns out hydrogen in 90%-plus concentration.
(SEPARATION, GAS)

H73 23408 SEPARATION OF BINARY MIXTURES OF CO AND H_2 BY PERMEATION THROUGH POLYMERIC FILMS
McCandless, F.P., Industrial and Engineering Chemistry Process Design, V 11:470-8 Oct 72, Avail:TAC

The pure gas permeability coefficients of various polymeric materials to carbon monoxide and hydrogen were determined, and the most promising of these were tested as separation membranes using binary mixtures of the gases.
(SEPARATION, MEMBRANE)

H73 23409 ULTRA-PURE HYDROGEN OBTAINED BY STEAM REFORMING AND MOLECULAR SIEVE ADSORPTION
Anon, Process Engineering, Nov 72, p 11

The process is conventional, with desulphurizarion followed by reforming in a cylindrical furnace, quenching and shift conversion. After cooling, the impurities (CO, CO_2, CH_4, and N_2) are removed by passing the gas over a fixed bed containing a combination of adsorbents - mainly of the molecular sieve type.
(DESULPHURIZATION, REFORMING, CONVERSION)

H73 23410 HYDROGEN RECOVERY PROCESS
Anon, (Petrocarbon Developments Ltd.), Hydrocarbon Process & Petroleum Refiner, V 44:226 Nov 65

Process for recovering hydrogen contained in off-gas streams such as those occurring in the ammonia synthesis, petroleum refining and petrochemical industries.

The process may also be adapted to alloy the recovery of very high purity argon from ammonia synthesis purge gas.
(AMMONIA, REFINERY, PETROCHEMICAL, PURITY)

H73 23411 NEW HYDROGEN RECOVERY ROUTE
McBride, R.B., and D.L. McKinley, Chemical Engineering Progress, V 61:81-5 N3 Mar 65, Avail:TAC

Large-scale hydrogen recovery units, based on diffusion through palladium barriers, are in operation; detailed description of several of these units and of their costs, as well as research, development and engineering activities in this field are given.
(DIFFUSION, PALLADIUM, COST)

H73 23412* HYDROGEN PURIFICATION USING A MODIFIED FUEL CELL PROCESS
McEvoy, J.E. and others, Industrial and Engineering Chemistry Process Design and Development, V 4:1-3 Ja 65, Avail:TAC

A new technique for purifying H_2 streams to obtain high purity H_2, an outgrowth of fuel cell research, is based on the use of electrochemical cells using highly efficient catalytic electrodes. Impure hydrogen is consumed at the anode of the cell and purified hydrogen generated at the cathode. By the application of a small potential across the electrodes of this cell, it is possible to ionize H_2, and only H_2, at the anode and simultaneously to produce an equivalent amount of H_2 at the cathode. The impurity gases pass over the anode unreacted and are discharged from the system. Data show the polarization characteristics of the electrodes in the presence of pure hydrogen, as well as the effect of gaseous diluents from which the "efficiency" of H_2 removal from the charge stream can be calculated. H_2S and CO are electrode poisons, although the effect of CO is transient.
(ELECTROCHEMICAL, CATALYST, ANODE, POLARIZATION, EFFICIENCY)

H73 23413 HYDROGEN PURIFICATION
Anon, (Linde Division of Union Carbide), Hydrocarbon Process, V 48:188 N11 Nov 69

A pressure swing adsorption process for applications requiring an ultrahigh purity hydrogen product (99.999+%), from any hydrogen bearing stream containing any or all of the following impurities: NH_3, A, H_2O, CH_4, CO, CO_2, H_2S, N_2, C_2s, C_3s, C_4s and C_5s. A minimum feed pressure of 150 psig is required for operation. Pressures above

600 psig become uneconomical. Feed temperatures are in the range of $40^{o}F$ to $100^{o}F$.
(ADSORPTION, AMMONIA, HYDROCARBON, PRESSURE, TEMPERATURE)

H73 23414 HYDROGEN PURIFICATION PLANT FOR BENZENE MANUFACTURE
Kimura, S., and A. Numata, Hitachi Review, V 19:415-20 N11 70

The hydrogen purification plant supplied to the Mizushima Works of Kawatetsu Chemical Industry Company is designed to recover hydrogen by low-temperature separation using off-gas from a benzene manufacturing plant.
(DESIGN, RECOVERY, CRYOGENIC, SEPARATION)

H73 23415 FULLY INTEGRATED HYDROGEN DIFFUSION SYSTEM
Matlack, G.L., Platinum Metals Review, V 13:26-7 N1 Ja 69

Principle of hydrogen diffusion through silver-palladium alloy membrane, developed by Matthey Bishop Inc., over past few years, is now being applied to complete systems for processing steam-reformed hydrocarbons and hydrogen-rich gas mixtures as well as commercial purity hydrogen; unit consists of ammonia dissociator, dissociated ammonia compressor and diffusion system with controls, with anhydrous ammonia bulk storage system provided by ammonia supplier.
(PALLADIUM, MEMBRANE, STEAM REFORMING, HYDROCARBON, AMMONIA, DISSOCIATION, STORAGE)

H73 23416 LOW PURITY HYDROGEN UPGRADER
Anon, (Linde division of Union Carbide), Hydrocarbon Process & Petroleum Refiner, V 44:236 Nov 65

A process to recover and upgrade the hydrogen in refinery or petrochemical off-gas streams. Hydrogen product purities can range from 90 to 98 percent.
(RECOVERY, REFINERY, HYDROCARBON, PETROCHEMICAL)

H73 23417 HYDROGEN PRODUCTION AND PURIFICATION BY DIFFUSION PROCESS
Serfass, E.J., and H. Silman, Chemical Engineering, N192:CE266-71 Oct 65, Avail:TAC

Ultrapure hydrogen can be separated from gases containing hydrogen by diffusion through palladium silver

alloy tubes at temperatures of 350 to 400 C and differential pressures of about 180 psi; alloy used contains about 25% silver, which has effect of preventing phase transformation leading to breakdown of pure palladium membranes in presence of hydrogen; combined electrolysis-diffusion cells can also be used for separation of hydrogen in ultrapure form by diffusion through palladium membrane which acts as electrode during electrolysis.
(SEPARATION, PALLADIUM, PRESSURE, TEMPERATURE, MEMBRANE, ELECTROLYSIS)

H73 23418 TRENNUNG UND REINIGUNG VON WASSERSTOFF DURCH PERMEATION AN MEMBRANEN AUS PALLADIUM-LEGIERUNGEN
Darling, A.S., Chemie-Ingenieur-Technik, V 37:18-27 N1 Ja 65

Separation and purification of hydrogen by permeation through membranes made of palladium alloys; pure hydrogen can be separated from mixtures of gases by diffusion through membranes made of palladium or palladium/silver alloys; construction, efficiency, and output of diffusion cells intended for commercial use, and of electrolytic diffusion cells used for production of fairly small quantities of hydrogen are discussed; process is also suitable for separating hydrogen/deuterium mixtures.
(DIFFUSION, ELECTROLYTIC, EFFICIENCY, PRODUCTION, DEUTERIUM)

H73 23419 FRACTIONATION OF AIR OR HYDROGEN-CONTAINING GAS MIXTURES
Kessler, G. and W. Scholz, (Linde A.-G.), British 1,073,570, Je 28 '67, German Appl. May 19 '65

In the fractionation of air with the associated fraction of a H-containing gas mixture, a portion of the gaseous N withdrawn from a rectification column used for the fractionation of air was compressed to a high pressure at room temperature. Upon cooling to room temperature, it was used to wash the H-containing gas mixture (the constituents which are not easily condensed), and a portion of this was also compressed to a high pressure at room temperature and then cooled down and made to expand into a rectification column.
(NITROGEN, PRESSURE, SEPARATION, FRACTIONATION)

H73 23420 RESEARCH STUDIES ON SOLID HYDROGEN PURIFICATION MEMBRANES
Jewett, D., and A.C. Makrides, (Tyco Labs Inc., Waltham, Mass.), Interim Technical Report No. 2, May 15 - Nov 15 '66, Mar 67

The permeation rate of hydrogen through tantalum coated with a thin film of palladium was measured over the temperature range 400-600C and at pressures up to 175 psia. The permeation rate is substantially greater than that through pure palladium membranes of the same thickness under the same conditions.
(PURIFICATION, MEMBRANE, METAL FILM, CATALYSIS, ADSORPTION, DIFFUSION, PERMEABILITY)

H73 23421 HYDROGEN PURIFICATION AT LOW TEMPERATURES
Foerg, W., (Linde AG, Werksgruppe, Munich, West Germany), Chemical Process Engineering, V 52:57-9, 61, 63, 68,

The extraction and purification of hydrogen from process gas streams containing hydrogen - e.g., dealkylation recycle gas, synthesis gas, hydrogen/helium mixtures - are most efficiently carried out at low temperatures. Process techniques employed include partial condensation, absorption, and scrubbing with nitrogen or liquid methane.
(EXTRACTION, SYNTHESIS GAS, HELIUM, TEMPERATURE, CONDENSATION, ABSORPTION, NITROGEN)

H73 23422 PALLADIUM DIFFUSION YIELDS HIGH-VOLUME HYDROGEN
Anon, Chemical Engineering, V 72:36+ Mar 1 '65, Avail:TAC

Breakthrough in diffuser design puts palladium separation into large-scale, high-purity hydrogen recovery for the first time.
(SEPARATION, DIFFUSION)

H73 23423 CRYOGENIC RECOVERY OF HYDROGEN FROM AMMONIA SYNTHESIS GAS
Markbreiter, S.J., (Edison, N.J.), I. Weiss, (Brooklyn, N.Y.), (assignors to American Messer Corp., New York, N.Y.), U.S. Patent No. 3,553,972

The recovery of ammonia and hydrogen-enriched gas from ammonia synthesis purge gas at high pressure may be achieved without the use of external refrigeration. The purge gas is cooled to nearly the freezing point of

ammonia to condense and thus separate ammonia from the purge gas. The refrigeration for condensing ammonia is produced by work-expanding the purge gas after ammonia condensate has been removed therefrom. Thereafter, the purge gas is further cooled so that gaseous impurities such as methane and argon are condensed and separated to leave a hydrogen-enriched gas suitable for recycling to the ammonia synthesis. The refrigeration for condensing the gaseous impurities is produced by work-expanding the product hydrogen-enriched gas.
(REFRIGERATION, SEPARATION, CONDENSATION, METHANE, RECYCLE)

H73 23424 HYDROGEN PURIFICATION
Meisler, J., (Teaneck, N.J.), G.C. Banikiotes, (Seaford, N.Y.), and E.H. Van Baush, (Pearl River, N.Y.), (Assignors to Hydrocarbon Research, Inc., New York, N.Y.), U.S. Patent No. 3,691,779

A high purity, 97 to 99.9 percent hydrogen product is obtained by using a separation process consisting of a low temperature refrigeration system operating below 120^{o}R, and an adsorption system operating on an adiabatic pressure-swing principle within the temperature range of 200^{o} to 140^{o}R.
(ADSORPTION, SEPARATION, HYDROCARBON, CONDENSATION, REGENERATION)

H73 23425 PURIFICATION OF HYDROGEN BY MEANS OF LOW TEMPERATURES
Foerg, W., (Linde Representative), Science Technology, V 15:18-26 70

Low-temperature techniques are eminently suitable for recovering hydrogen of high purity from gas mixtures containing hydrogen. Three processes are available; condensation, absorption and freezing-out.
(CHEMICAL, CONDENSATION, ABSORPTION, ADSORPTION, REGENERATION, REFRIGERATION)

H73 23426 BLEED BURNING HYDROGEN PURIFIERS
Rubin, L.R., Engelhard Industries - Technology Bulletin, V 9:10-13 N1 Je 68

Needs for laboratory hydrogen purifiers in 1 to 2 cu ft/hr range are presently being met by using scaled

down versions of larger commercial permeation units; units described are distinguished from other commercially available small purifiers in their fast start-up and independence from electrical power.
(PURIFICATION, PERMEATION)

H73 23427 HYDROGEN RECOVERY TAKES ON NEW LUSTER IN SOME PLANTS
Stormont, D.H., Oil & Gas Journal, V 63:125-8 Mar 8 '65, Avail:TAC

Waste gases may be the most economical source when extra hydrogen is required.
(RECOVERY, WASTE, GAS)

H73 23428 PRESSURE-SWING ADSORPTION
Stewart, H.A., and J.L. Heck, Chemical Engineering Progress, V 65:78 Sept 69, Avail:TAC

Details of a newly-developed "pressure-swing" process which can process hydrogen-bearing streams to provide a high-purity hydrogen product containing 1 to 2 ppm total impurities.
(PURIFICATION, HYDROGEN, AMMONIA, WATER, METHANE, DIFFUSION, PALLADIUM)

H73 23429 NEW ADSORPTION PROCESS PRODUCES HIGHER-PURITY HYDROGEN
Anon, Iron & Steel Engineering, V 45:127 Fe 68

Pressure-swing adsorption produces 2,500,000 cu ft/day of hydrogen.
(ADSORPTION, PROCESS)

H73 23430 SEPARATION PLANT FOR PURE HYDROGEN
Anon, Engineering, V 198:646 Nov 20 '64

Heated palladium-silver alloy membranes produce 3000 cu ft/hr of hydrogen.
(SEPARATION, PALLADIUM)

H73 23431 PERMEATION METHOD RECOVERS HYDROGEN
Anon, The Oil and Gas Journal, Mar 23 '70

A possible commercial breakthrough in synthesis-gas processing and hydrogen recovery has been announced by Du Pont.

The process basically filters gases through bundles of polyester fibers to recover hydrogen and/or carbon monoxide.

The process, called Permasep, will separate hydrogen from carbon monoxide, nitrogen, methane, and heavier hydrocarbons.
(SEPARATION, PERMEATION)

H73 23432 HYDROGEN PURIFICATION
Anon, (Union Carbide Corp., Linde division), Hydrocarbon Process, V 51:221 Sept 72
For commercial production of hydrogen product of any purity level from a hydrogen bearing stream. It may be used to remove impurities of : NH_3, A, H_2O, CH_4, CO, CO_2, H_2S, N_2, C_2-C_5.
(PURIFICATION)

H73 23433 HYDROGEN RECOVERY FROM REFINERY WASTE GASES
Zeller, H. and W. Scholz, Erdoel Kohle, Erdgas, Petrochem., V 20:200-3 N3 67
Rather pure H is recovered from mixtures containing chiefly H and CH_4 together with significant amounts of C_{2-3} hydrocarbons and small amounts of higher hydrocarbons. The process involves stepwise condensation of the hydrocarbons.
(PURITY, HYDROCARBON, CONDENSATION, CRYOGENIC)

H73 23434 SEPARATION OF CONCENTRATED HYDROGEN FROM A METHANE-HYDROGEN FRACTION OF PYROLYSIS GAS
Guseinova, Z.D., Ya.R. Veliev, and Yu.G. Kambarov, (VNIIolefin, Baku, USSR), Khim, Tekhnol. Topl. Masel, V 16:13-14 N8 71
H was separated at -80° and 30 atmosphere from gas containing H 23, CH_4 73.9, and C_2H_4 2.3 mole %, using liquid C_2H_6 as absorbent.
(SEPARATION, PYROLYSIS)

H73 23435 PROCESS FOR SEPARATING GASEOUS COMPONENTS FROM GASEOUS MIXTURES
Anon, (Esso Research and Engineering Co.), Netherlandish Appl. 6,602,141, Aug 22 '66, U.S. Appl. Fe 19 '65
A cyclic process is described for separating and purifying H and (or) N gas, used in NH_3 synthesis, from components more soluble in water such as NH_3, H_2O, CO_2, CO, and CH_4.
(PURIFICATION, NITROGEN, AMMONIA, WATER, METHANE)

H73 23436 PROCESS AND APPARATUS FOR PURIFYING LOW-BOILING GASES IN GAS MIXTURES
Baldus, W., (Linde A.-G.), British 1,105,925, Mar 13 '68, German Appl. Je 5 '64

Purification of gases such as H, He, or Ne from impurities such as N, CO, and CH_4 is accomplished by a series of adsorbing chambers containing silica gel. In addition, the gas is cooled in various stages in the process.
(PURIFICATION, ADSORPTION)

H73 23437 PROCESS AND APPARATUS FOR REMOVING IMPURITIES FROM HYDROGEN-CONTAINING GASES
Becker, R., (to Linde A.-G.), U.S. 3,372,555, Mar 12 '68, German Appl. Aug 21 '63

A low-temperature process for the fractionation of H-containing gases containing substantial quantities of H, CH_4, and high-boiling gases having m. ps. higher than the boiling point of CH_4 has been developed.
(TEMPERATURE, PURIFICATION)

H73 23438 CONCENTRATION OF HYDROGEN BY CRYOGENIC PROCESSES
Streich, M., (Messer Griesheim G.m.b.H., Frankfurt/M., Germany), DECHEMA Monograph, V 58:195-204 N1027-1044, 68

The preparation of H of varying purity from H-bearing gases from refineries and petrochemical plants is described. Cost figures for the production of H at 95 mole % purity are given.
(PRODUCTION, PURITY, REFINERY, PETROCHEMICAL, COST)

H73 23439 SEPARATION OF HYDROGEN FROM OTHER GASES
Hope, J., (International Nickel Ltd.), British 1,152,283, May 14 '69, Appl. May 17 '67, Addition to British 1,090,479

A high-pressure absorption/low-pressure desorption cycling technique is described for the separation of H_2 from a gaseous mixture containing at least 50% H_2, e.g. a 75% H_2 + 25% N_2 mixture.
(PRESSURE, ABSORPTION, DESORPTION, AMMONIA, PALLADIUM)

H73 23440 LOW-TEMPERATURE REGENERATION OF HYDROGEN FROM INDUSTRIAL GASES
Charlesworth, P.L., and M. Ruehemann, (Petrocarbon Dev., Manchester, England), Chem. Prumysl, V 16:601-3 N10 66

The exit gases from NH_3 synthesis and catalytic reforming of petroleum fractions contain up to 50% volume

H. To recover the H either as a fuel or for the recycle gas, a low-cost separation process is essential. (AMMONIA, CATALYST, REFORMING, RECYCLE, COST, FUEL, SEPARATION)

H73 23600 FORMATION OF HOT HYDROGEN OR DEUTERIUM ATOMS BY PHOTOLYSIS OF ORDINARY OR DEUTERATED WATER VAPOR
Cottin, M., C. Vermeil, and J. Masanet, (Inst. Radium, Lab. Chem. Phys., Paris), C.R. Academie Science, Paris, Series V 263:753-6 N12, 66

A study was made of photodecomposition of water vapor with radiation of 1850, 1470, and 1236 A. The effects of the additions of H or O were determined. Mixtures of H_2O + D_2 and D_2O + H_2 were irradiated. The ratios H_2/HD or D_2/HD are a linear function of $1/D_2$ or $1/H_2$, respectively. The slopes of these functions are dependent on time for the isotopic system considered and on the phonon energy. The variations observed are attributed to changes in the rate constants. Therefore, it is concluded that the atoms formed have significant kinetic energies which are a function of the wavelength of the radiation. Only radiation at 1236 A. is energetically capable of causing the reaction H_2O (or D_2O) + hv = H_2 (or D_2) + O. Higher O pressures are needed at 1236^{o} A. to reduce the H_2 pressure formed directly upon decomposition.
(PHOTODECOMPOSITION, ENERGY, RADIATION, PRESSURE)

H73 23601 PRIMARY PRODUCTS OF LIQUID WATER PHOTOLYSIS AT 1236, 1470, AND 1849 A.
Getoff, N., G.O. Schenck, (Max-Planck Inst. Kohlenforsch., Muelheim/Ruhr, Germany), Photochemistry Photobiology, V 8:167-78 N3, 68

Liquid H_2O at 25-8^{o} was irradiated in the vacuum uv at different wavelengths. A Kr resonance lamp (1 mm. pressure), whose gas discharge was produced by a microwave generator was equipped with a CaF_2 window and a liquid N_2 trap to give radiation at 1236 A. For 1470 A., a Xe resonance lamp, similar to the above lamp, was used with a liquid O_2 trap and a sapphire window. A low-pressure Hg lamp was used for 1849 A. emission. At 1236 and 1470 A., e^{-}_{aq} was probably formed in addition to H and OH radicals. H· and OH· were scavenged by formate and e^{-}_{aq} and H_2O* by CO_2. Quantum yields are given and reaction mechanisms are discussed.
(HYDROGEN, PRODUCTION, RADIATION, MECHANISM)

H73 23602* INVESTIGATION FOR THE PURPOSE OF IMPROVING THE EFFICIENCY OF UTILIZATION OF SOLAR ENERGY BY THE DECOMPOSITION OF WATER INTO HYDROGEN AND OXYGEN

West, R.E., H. Mahmoud, D.G. Burkhard, H. Ito, and R.S. Kirk, (P.E.C. Corp., 1001 Mapleton Ave., Boulder, Colo.), N63-19875,
Report No. AFCRL-63-666, May 63, Avail:TAC

The sensitized photo-decomposition of water has been studied, with the purpose of improving its efficiency as a means of solar energy conversion. A number of metallic cations and other materials were tested for sensitizer activity and of these only ceric, thallic, ferrous, iodide, and chromous ions do sensitize the reaction; the former two to yield oxygen, the latter three, hydrogen. In no case was the simultaneous production of hydrogen and oxygen observed. Quantum yields were determined, with substantial conversion of the sensitizer, and found to be the order of 10^{-2} to 10^{-4}. Initial yields were much higher. With the known sensitizers, this reaction does not utilize a sufficient fraction of the solar spectrum to be practical as a means of solar energy conversion.

Several mixtures of ions and also various solid materials as additives to sensitizer solutions were tested for their influence on sensitizer activity. In every case, it was found that the quantum yield was the same as or lower than with the sensitizer alone.

Ceric ions oxidize water to yield oxygen in the dark at elevated temperatures. The thermal reaction is catalyzed by platinized platinum whereas the photochemical reaction is not. Apparently the ceric-water reaction proceeds thermally and photochemically by different mechanisms.

An experimental study of the ultraviolet and visible absorption spectrum of ceric ions was undertaken to determine the nature of the species in solution and which species participate in the photochemical reaction. While no conclusions can be reached, the ceric spectrum was found to be very dependent upon ceric and acid concentrations, indicating that hydrolysis and other reactions occur.

The development of a theory to predict the energies and probabilities of ion-ligand electron transitions in aqueous solutions was begun. The theory has been successfully applied to the hydrogen and water molecules but was not sufficiently developed to apply it to solutions.

It is recommended that further studies should continue on the basic aspects, chemical species and mechanism, of the reaction.
(SENSITIZER, CONVERSION, OXIDATION, TEMPERATURE, CATALYST, PHOTOCHEMICAL, MECHANISM)

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H73 23603 ELECTROCHEMICAL PHOTOLYSIS OF WATER AT A SEMICONDUCTOR ELECTRODE
Honda, K., Nature, V 238, Jl 7 '72

Although the possibility of water photolysis has been investigated by many workers, a useful method has only now been developed. Because water is transparent to visible light it cannot be decomposed directly, but only by radiation with wavelengths shorter than 190 nm.

For electrochemical decomposition of water, a potential difference of more than 1.23 V is necessary between one electrode, at which the anodic processes occur, and the other, where cathodic reactions take place. This potential difference is equivalent to the energy of radiation with a wavelength of approximately 1,000 nm. Therefore, if the energy of light is used effectively in an electrochemical system, it shold be possible to decompose water with visible light. Here we describe a novel type of photoelectrochemical cell which decomposes water in this way.
(DECOMPOSITION, RADIATION, ENERGY, VOLTAGE, ANODE)

H73 23604 CONVERSION OF SUNLIGHT INTO CHEMICAL ENERGY AVAILABLE IN STORAGE FOR MAN'S USE
Heidt, L.J., and A.F. McMillan, (Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.), Science, V 117, Ja 53

It has been established that the key reactions in the simple photochemical process can take place concurrently in a water solution of cerous and ceric ions - namely, the production of hydrogen gas by that part of the light absorbed by the cerous ions thereby oxidized to ceric ions, and oxygen gas by that part of the light absorbed by the ceric ions thereby reduced to cerous ions.

No attempt was made in the experiments reported there to determine the main reaction or the details of the mechanisms of the reactions in the system or the efficiency of the process, or to collect all the gas produced or to carry out the process under the most favorable conditions. Work on these problems, especially the last one, in sunlight is under way.
(HYDROGEN, PRODUCTION, OXYGEN, OXIDATION, ENERGY)

H73 23605 "PHOTOCHEMISTRY"
Heidt, L.J., McGraw-Hill Encyclopedia of Science and Technology, McGraw-Hill Book Co., Inc., New York, 60, p 153-155

A general treatment of photochemistry in which terms

such as quantum yield, photochemical reactions, light absorptions are defined.
(QUANTUM, YIELD, PHOTOCHEMISTRY, LIGHT)

H73 23606 GROSS AND NET QUANTUM YIELDS AT 2537 A. FOR FERROUS TO FERRIC IN AQUEOUS SULFURIC ACID AND THE ACCOMPANYING REDUCTION OF WATER TO GASEOUS HYDROGEN
Heidt, L.J., M.G. Mullin, W.B. Martin, Jr., and A.M. Johnson Beatty, (Chemistry Department, Massachusetts Institute of Technology, Cambridge, Mass.), Journal of Physics and Chemistry, V 66:336-341, 62

Gross, ϕ_g, and net, ϕ_n, quantum yield measurements have been made for the photochemical conversion by light of 2537 A. of up to 1.4% of the ferrous to ferric sulfate and of the accompanying production of gaseous hydrogen in aqueous sulfuric acid at 25 . In each solution ϕ_g decreased as the reaction progressed but ϕ_n remained constant. In the different solutions ϕ_n remained at 0.4 between 0.1 and 0.8 M ferrous sulfate in 2 M H_2SO_4 but increased from 0.16 to 0.74 between 0.15 and 6.0 M sulfuric acid. The data support the hypothesis that in 2 M and more dilute sulfuric acid ferrous sulfate exists mostly as ion pairs which in 6.0 M sulfuric acid are partly replaced by contact ferrous sulfate complexes.
(QUANTUM, YIELD, REDUCTION, WATER)

H73 23607 PHOTOCHEMISTRY OF CERIUM PERCHLORATES IN DILUTE AQUEOUS PERCHLORIC ACID
Heidt, L.J., "Solar Energy Research," F. Daniels, and A. Duffie, eds., University of Wisconsin Press, Madison, Wis., 55, p 203-219

The photochemistry of cerium perchlorates in dilute aqueous perchloric acid is of interest in connection with the problem of the utilization of solar energy because it has led to the discovery of a way to decompose water photochemically into hydrogen and oxygen, thereby converting light into chemical energy available in storage. The purpose of this article is to record the steps which led to the discovery of this process and to present the over-all reactions, the nature of the photochemical and thermal reduction of ceric to cerous ions in these solutions whereby water is oxidized to oxygen gas, and the nature of the photochemical oxidation of cerous to ceric ions whereby water is reduced to hydrogen gas.
(PHOTOCHEMISTRY, OXIDATION, SOLAR, REDUCTION, WATER)

III. UTILIZATION

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H73 30000 RECENT NASA EXPERIENCE WITH HYDROGEN ENGINES
Belew, L.F., F.M. Drummond, and R.D. Stewart, (NASA, Marshall Space Flight Center, Huntsville, Ala.), American Institute of Aeronautics and Astronautics, Annual Meeting, 1st, Washington, D.C., Je 29 - Jl 2 '64, Paper 64-270, Avail:TAC

Review of experience obtained to date in the development program of the liquid hydrogen J-2 and RL10 rocket engines. The configuration, performance, and operation of each engine are discussed. Progress in areas unique to hydrogen-burning engines, and to cryogenic engines in general, which must operate in a space environment, is described.
(LIQUID, ENGINE, SPACE)

H73 30001 3-KILOWATT CONCENTRIC TUBULAR RESISTOJET PERFORMANCE
Page, R.J., C.R. Halbach, and R.A. Short, (Marquardt Corp., Van Nuys, Calif.), Journal Spacecraft Rockets, V 3:1669-74 N11 66

The design and fabrication are described for a resistojet, the performance of which, during a 25-hr. test with H as a propellant, was a vacuum sp. impulse of 840 seconds and a thrust of 66.5 g force for 3.0-kw. electrical power input.
(JET, PERFORMANCE)

H73 30002 EXPERIMENTAL INVESTIGATION OF ACOUSTIC LINERS TO SUPPRESS SCREECH IN HYDROGEN-OXYGEN ROCKETS
Wanhainen, J.P., H.E. Bloomer, D.W. Vincent, and J.K. Curley Washington, (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), N67-17504, NASA-TN-D-3822, Fe 67, CFSTI: HC $3.00/MF $0.65, Avail:TAC

An investigation of suppression of high frequency combustion instability using Helmholtz type acoustic damping devices was conducted in a hydrogen-oxygen rocket of nominally 20,000-pound thrust size.
(ROCKET, COMBUSTION)

H73 30003 COMPARISON OF SMALL WATER-GRAPHITE NUCLEAR ROCKET STAGES WITH CHEMICAL UPPER STAGES FOR UNMANNED MISSIONS
Clark, M.R., G.D. Sagerman, G.P. Lahti, (Lewis Research Center, NASA, Cleveland, O.), NASA Tech. Note 68, Tech. Aerospace Report, V 6:3910 N22, 68, Avail:TAC

Payload performance and the radiation environment

characteristics of this small reactor type (200-600 Mw.) in a nuclear upper stage are considered. Payload dose criteria indicate that any shielding requirement would be based on propellant heating considerations. Several approaches to propellant heating, including subcooled or slush H propellant and shielding, are compared.
(NUCLEAR, ROCKET)

H73 30004 GAS CORE NUCLEAR REACTOR
Rom, F.E., (United States National Aeronautics and Space Administration), U.S. 3,574,057, Apr 6 '71, Avail:TAC

This reactor design provides improved and simplified means for injecting coolant into the core while cooling the moderator. The energy generated by the fissioning process is thermally-radiated to H which flows around this U mass. The H is introduced through pervious walls with seed material entrained so as to render the H opaque to the thermal radiation emanating from the fissioning gas. The heated H passes through a nozzle to produce thrust.
(GAS, NUCLEAR, REACTOR)

H73 30005 INVESTIGATION OF GASEOUS NUCLEAR ROCKET TECHNOLOGY
McLafferty, G.H., (United Aircraft Corp., East Hartford, Conn.), Summary Technical Report, Sept 15 '63 - Nov 15 '69, N70-17470, NASA-CR-107869, Avail:CFSTI, Avail:TAC

A feasibility study was made of a gaseous nuclear rocket engine concept: the closed-cycle nuclear light bulb engine. This engine is based on the transfer of energy by thermal radiation from gaseous nuclear fuel suspended in a neon vortex through an internally cooled transparent wall to seeded hydrogen propellant.
(GAS, NUCLEAR, ROCKET)

H73 30006 POODLE RADIOISOTOPE PROPULSION TECHNOLOGY
Jones, I.R., and G.E. Austin, (TWR System, Redondo Beach, Calif.), Proceedings Symposium Radioisotope Application Aerospace, 1st, Dayton, Ohio, V 2:385-408 66

The operating characteristics and applications of Poodle, a low thrust propulsion device which utilizes an alpha- or beta-emitting radioisotope to heat H to high temperatures and exhaust velocities, are discussed.
(ROCKET, TEMPERATURE)

H73 30007 ANALYSIS OF TOPPING AND BLEED TURBOPUMP UNITS FOR HYDROGEN-PROPELLED NUCLEAR ROCKETS
Evans, D.G., and J.E. Crouse, (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), N66-39615, NASA-TM-X-384, Washington, Je 60, CFSTI: HC $2.00/MF $0.50, Avail:TAC

The turbopump units analyzed were a bleed, a hot-topping (full-flow turbine), and a cold-topping unit. The types of configuration required and their effect on rocket gross weight were investigated. The scope of the analysis did not include the effects of the turbopump configurations on the weights of associate components, such as the reactor.
(NUCLEAR, ROCKET)

H73 30008 INVESTIGATION OF THE EIGHT-STAGE BLEED-TYPE TURBINE FOR HYDROGEN-PROPELLED NUCLEAR ROCKET APPLICATIONS. 1: DESIGN OF TURBINE AND EXPERIMENTAL PERFORMANCE OF FIRST TWO STAGES
Rohlik, H.E., (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), N66-39613, NASA-TM-X-475, Washington, May 61, CFSTI: HC $2.00/MF $0.50, Avail:TAC

Design information includes work division among stages, aerodynamic design, and blade geometry. Turbine performance is presented in terms of specific work, speed, weight flow, and efficiency with the effect of the second stage on first-stage performance at design operation included.
(TURBINE, NUCLEAR, ROCKET)

H73 30009 INVESTIGATION OF EIGHT-STAGE BLEED-TYPE TURBINE FOR HYDROGEN-PROPELLED NUCLEAR ROCKET APPLICATIONS. 11: EXPERIMENTAL OVERALL AND STAGE GROUP PERFORMANCE DETERMINED IN COLD NITROGEN
Rohlick, H.E., (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), N66-39612, NASA-TM-X-481, Washington, Mar 62, CFSTI: HC $2.00/MF $0.50, Avail:TAC

Over-all performance of four- and six-stage assemblies as well as the complete eight-stage turbine is presented in terms of efficiency, specific work, torque, and weight flow. Performance of the four two-stage groups within the eight-stage assembly is shown for design overall conditions. Also included is a description of design modifications that could be made to improve performance

over that obtained.
(TURBINE, NUCLEAR, ROCKET)

H73 30010 HYDROGEN-OXYGEN FIRED THERMIONIC GENERATORS AND THERMIONIC DIODES
Anon, (Thermo Electron Corp., Waltham, Mass.), N69-30871, NASA-CR-101745, Apr 3 '69, Avail:CFSTI, Avail:TAC

The hardware described in this paper served to evaluate the state-of-the-art of thermionic flame-heated devices for use in a short (a few hours to a few days) space mission. The reactants available as fuel and oxidant in the mission were expected to be hydrogen and oxygen, and these same reactants were employed in this work. Two hydrogen-oxygen 50 watt generators and two spare thermionic diodes were built. Although the generators were successfully operated their efficiency was far below that initially expected.
(GENERATOR, THERMIONIC)

H73 30011 HYDROGEN-OXYGEN SPACE POWER INTERNAL-COMBUSTION ENGINE
Morgan, N.E., (Sperry Rand Corp., Vickers, Inc., Aerospace Division, Torrance, Calif.), A65-13080, American Society of Mechanical Engineers, Winter Annual Meeting, New York, N.Y., Nov 9-Dec 4 '64

Discussion of the effects of fuel characteristics, oxidizer characteristics, and storage conditions on the operating cycle and power-plant configuration of a hydrogen-oxygen internal-combustion piston engine under development for space power applications. The development program and problems are reviewed, including descriptions of experimental engines, design philosophy, and test methods, equipment, and results.
(SPACE, ENGINE)

H73 30012 EXPERIMENTAL RESEARCH ON ELECTRIC PROPULSION. NOTE VII: ANALYSIS OF THE PERFORMANCE OF AN ARCJET DRIVEN BY HYDROGEN AND NITROGEN
Robotti, A.C., and M. Oggero, (National Aeronautics and Space Administration, Washington, D.C.), Ric. Sci. Anno 35, Ser. 2 Rend., Rome, V 8:894-901 N4 65, Oct 66, Avail:TAC

Description of experiments performed on a new type of arcjet, characterized by composite electromagnetic and vortex stabilization and propelled by hydrogen and nitrogen in turn. Particular attention was devoted to the electrical characteristics of the arc and to the loss of

heat through electrodes.
(ELECTRIC, ARCJET)

H73 30013 STABILIZING EFFECTS OF SEVERAL INJECTOR FACE BAFFLE CONFIGURATIONS ON SCREECH IN A 20,000 POUND-THRUST HYDROGEN-OXYGEN ROCKET
Hannum, N.P., H.E. Bloomer, and R.R. Goelz, (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), N68-21679, NASA-TN-D-4515, CFSTI: HC $3.00/MF $0.65, Apr 68, Avail:TAC

Experimental tests were conducted to assess the worth of injector face baffles as screech suppression devices. Hydrogen injection temperature was used to rate the stability of the various baffles.
(ROCKET, INJECTION)

H73 30014 SPACE SHUTTLE ENGINE
Stewart, F.M., (National Aeronautics and Space Admininstration, Marshall Space Flight Center, Huntsville, Ala.), Presented at the ELDO/NASA Space Transportation Systems Briefing, Bonn, Jl 7-8 '70, N71-18432, NASA-TM-X-66896, Avail:NTIS, Avail:TAC

The rocket engines for both the booster and orbiter elements of the space shuttle will be throttleable high performance hydrogen/oxygen engines. Depending on the design, the orbiter may use two or three engines while the booster may require ten or more. As is the case with most space vehicle launch systems, the pacing item is the engine. The space shuttle main engine requirements and concepts, and the approach to development as presently envisioned are described.
(SHUTTLE, SPACE, ENGINE)

H73 30015 HYDROGEN-OXYGEN SPACE SHUTTLE ACPS THRUSTER TECHNOLOGY REVIEW
Gregory, J.W., and P.N. Herr, (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), Presented at 8th Propulsion Joint Specialists Conference, New Orleans, La., Nov 29 - Dec 1 '72, sponsored by AIAA and SAE, N73-10744, NASA-TM-X-68146, Avail:NTIS, Avail:TAC

The generation of technology for injectors, cooled thrust chambers, valves, and ignition systems is discussed. The thrusters are designed to meet a unique and stringent set of requirements, including: long life for 100 mission reuses, high performance, light weight, ability to pro-

vide long duration firings as well as small impulse bits, ability to operate over wide ranges of propellant inlet conditions and to withstand reentry heating. The program has included evaluation of thrusters designed for ambient temperature and cold gaseous propellants at the vehicle interface.
(SPACE, SHUTTLE, ENGINE)

H73 30016 HYDROGEN-OXYGEN AUXILIARY PROPULSION FOR THE SPACE SHUTTLE. VOLUME 2: LOW PRESSURE THRUSTERS
Anon, (Aerojet Liquid Rocket Co., Sacramento, Calif.), N73-18801, NASA-CR-120896, Final Report, Ja 30 '73, Avail:NTIS, Avail:TAC

An abbreviated program was conducted to investigate igniter, injector, and thrust chamber technology for a 10.3 N/cm2 (15 psia) chamber pressure, 6660 N (1500 lbf) gaseous H2/O2 APS thruster for the Space Shuttle Vehicle. Successful catalytic igniter tests were conducted with ambient and cold propellants. Injector testing with a heat sink chamber (MR = 2.5, area ratio = 5.0) gave a measured specific impulse of 386 sec with 11% of the fuel used as film coolant. This coolant flow rate was demonstrated to be more than adequate to cool a spun adiabatic wall, flightweight thrust chamber.
(SPACE, SHUTTLE, ROCKET)

H73 30017 SPACE SHUTTLE HIGH PRESSURE AUXILIARY PROPULSION SUBSYSTEM DEFINITION STUDY
Kelly, P.J. and W.W. Regnier, (McDonnell-Douglas Astronautics Co., St. Louis, Mo.), N71-25068, NASA-CR-103115, Summary Report, Fe 12 '71, Avail:NTIS, Avail:TAC

Effort in support of the high pressure H2/O2 auxiliary propulsion subsystem, the preliminary design, and the study approach and results are summarized.
(SPACE, SHUTTLE, PROPULSION)

H73 30018 SPACE SHUTTLE AUXILIARY POWER UNIT (APU)
Beremand, D.G., and H.M. Cameron, (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, O.), Space Transportation System Technology Symposium, V 6:361-371, Jl 70, Avail:NTIS, N70-40975, Avail:TAC

A program to develop the technology of a hydrogen-oxygen fueled auxiliary power unit (APU) for the space shuttle vehicle is discussed.
(SPACE, SHUTTLE, POWER)

H73 30019 PRELIMINARY DESIGN OF AN AUXILIARY POWER UNIT FOR THE SPACE SHUTTLE. Volume 1: SUMMARY
Hamilton, M.L., and W.L. Burriss, (AiResearsch Mfg. Co., Los Angeles, Calif.), N72-19058, NASA-CR-1993, Washington, NASA Mar., 72, Avail:NTIS, Avail:TAC

Numerous candidate APU concepts are considered, each meeting the space shuttle APU problem statement. Evaluation of these concepts indicates that the optimum concept is a hydrogen-oxygen APU incorporating a recuperator to utilize the exhaust energy and using the cycle hydrogen flow as a means of cooling the component heat loads.
(DESIGN, POWER, SHUTTLE)

H73 30020 AN H2-O2 AUXILIARY POWER UNIT FOR SPACE SHUTTLE
Beremand, D.G., J.P. Joyce, and H.M. Cameron, (NASA, Lewis Research Center, Cleveland, O.), 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Proceedings - Sept 25-9 '72, Washington, D.C., American Chemical Society, 72, p 403-8, Avail:TAC

Auxiliary power units operating on hydrogen and oxygen have the potential for significantly improved performance and payload for the Space Shuttle vehicles.
(POWER, SPACE, SHUTTLE)

H73 30021 PERFORMANCE ESTIMATES FOR SPACE SHUTTLE VEHICLES USING A HYDROGEN OR A METHANE FUELED TURBORAMJET POWERED FIRST STAGE
Knip, G., Jr., and J.D. Eisenberg, (NASA, Lewis Research Center, Cleveland, O.), N72-14879, NASA-TN-D-6634, Washington, Ja 72, Avail:NTIS, Avail:TAC

Two- and three-stage (second stage expendable) shuttle vehicles, both having a hydrogen-fueled, turboramjet-powered first stage, are compared with a two-stage, VTOHL, all-rocket shuttle in terms of payload fraction, inert weight, development, cost, operating cost, and total cost.
(SPACE, SHUTTLE, JET)

H73 30022 COMPARATIVE STUDY OF FUELS FOR THE FIRST STAGE OF AN ATMOSPHERIC BOOSTER
Huet, C., Rech. Aerospace, N119:3-12 67

Complete thermodynamic calculations for theoretically preselected fuels (kerosine, pentaborane, N_2H_4, symdimethylhydrazine, liquid H, Al, Mg, B, Be, Li, and LiH) permitted performance prediction.
(FUEL, ROCKET)

H73 30023 ELDO FUTURE PROGRAM STUDY 3.2 ON AN ELDO B LAUNCHING SYSTEM WITH A STANDARD ENGINE OF 6-8 TONS OF THRUST
Anon, (Entwicklungspring Nord, Bremen, West Germany), N67-14266, Aug 31 '64, Avail:TAC

An investigation was conducted on the influence which the selections of a standard engine with 6 to 8 tons of thrust exerts on the performance of an ELDO B launch vehicle with two H_2/O_2 upper stages totalling 23 tons upper stage weight, including propellants and payload.
(ENGINE, THRUST)

H73 30024 ELDO FUTURE PROGRAMS, PRELIMINARY PROJECT LAUNCHERS B1 AND B2. STUDY NO. 3.5: A DETAILED DESCRIPTION OF THE CRYOGENIC STAGES
Anon, (Societe Pour l'Etude et la Realisation d'Engins Balistiques, Courbevoie, France), N68-28533, Dec 22 '65, Avail:TAC

This report describes a project of liquid hydrogen/ liquid oxygen stages for ELDO B1 and B2 launchers.
(ENGINE, THRUST)

H73 30025 HIGH ENERGY UPPER STAGES FOR ELDO VEHICLES
Childs, G.W., and D. Stott, (Hawker Siddeley Dynamics, Ltd., Stevenage, England, Space Division), N68-20307, ELDO Symposium on Propulsion, Paris, Oct 10-12 '67, Avail:TAC

Describes the design characteristics and performance of high energy liquid hydrogen/liquid oxygen engines and considers their application as upper stages to possible future ELDO launch vehicles. Reviews work already done and outlines a development program.
(DESIGN, ENGINE)

H73 30026 THEORETICAL PERFORMANCES OF THE TRIERGOLIC ROCKET FUEL SYSTEM FLUORINE-LITHIUM HYDRIDE-HYDROGEN
Dadieu, A., and R. Lo, (Deut. Versuchsanst. Luft-und Raumbahrt, Stuttgart-Vaihingen), Raumfahrtforschung, V 12:135-8 N3 68

Theoretical performances in the system F_2-LiH-H_2 were calculated.
(ROCKET, FUEL)

H73 30027 LITHIUM-FLUORINE-HYDROGEN PROPELLANT STUDY
Arbit, H.A., R.A. Dickerson, S.D. Clapp, and C.K. Nagai, (Rocketdyne, Canoga Park, Calif.), N68-16788, NASA-CR-72325, Fe 22 '68, CFSTI: HC \$3.00/MF \$0.65, Avail:TAC

Results of a program encompassing an analytical, design, and experimental effort to establish the fundamental feasibility of the fluorine/lithium/hydrogen tripropellant combination are reported.
(PROPELLANT, STUDY)

H73 30028 INVESTIGATION OF INJECTORS FOR A LOW-CHAMBER-PRESSURE HYDROGEN-FLUORINE ROCKET ENGINE
Price, H.G., Jr., R.J. Lubick, and A.M. Shinn, Jr., (NASA, Lewis Research Center, Cleveland, O.), N66-33333, NASA-TM-X-485, Jl 62, Washington, CFSTI: HC \$2.00/MF \$0.50, Avail:TAC

Characteristic velocity efficiencies as high as 99 percent were obtained with gaseous hydrogen and liquid fluorine in short combustion chambers.
(INJECTION, ROCKET, ENGINE)

H73 30029 FLUORINE-HYDROGEN PERFORMANCE EVALUATION. PHASE 1, PART 1: ANALYSIS, DESIGN, AND DEMONSTRATION OF HIGH PERFORMANCE INJECTORS FOR THE LIQUID FLUORINE-GASEOUS HYDROGEN COMBINATION
Arbit, H.A., and S.D. Clapp, (Rocketdyne, Canoga Park, Calif., Research Dept.), N66-32923, NASA-CR-54978, Final Report, Aug 66, CFSTI: HC \$3.75/MF \$1.25, Avail:TAC

Two injectors were designed for use with an uncooled, segmented, calorimetric thrust chamber designed for 2500-pound thrust at the midpoint of the experimental matrix. One was a triplet pattern in which LF_2 doublets impinged upon a central showerhead GH_2 jet: and the other employed self-impinging LF_2 doublets, with showerhead GH_2 jets on each side of the spray fan. Particular attention was given to the procedures used to obtain the experimental data, and analyses were presented covering their reliability and precision.
(INJECTION, THRUST)

H73 30030 EXPERIMENTAL PERFORMANCE OF A HYDROGEN-FLUORINE ROCKET ENGINE AT SEVERAL CHAMBER PRESSURES AND EXHAUST NOZZLE EXPANSION AREA RATIOS
Jones, W.L., C.A. Aukerman, and J.W. Gibb, (NASA, Lewis Research Center, Cleveland, O.), N66-33348, NASA-TM-X-387, Washington, Oct 60, CFSTI: HC $2.00/MF $0.50, Avail:TAC

The performance of a nominal-5000-pound-thrust hydrogen-fluorine rocket engine was evaluated over a range of mixtures from 6 to 20 percent fuel at chamber pressures from 60 to 725 pounds per square inch absolute with exhaust-nozzle area ratios of 3.7, 25, and 100. Performance near the theoretical maximum (97 percent) and stable combustion were obtained down to a chamber pressure of 60 pounds per square inch absolute at mixtures between 10 and 20 percent fuel.
(ROCKET, ENGINE, FUEL)

H73 30031 EXPERIMENTAL HYDROGEN-FLUORINE ROCKET PERFORMANCE AT LOW PRESSURES AND HIGH RATIOS
Aukerman, C., and B.E. Church, (NASA, Lewis Research Center, Cleveland, O.), N66-33325, NASA-TM-X-724, Washington, CFSTI: HC $2.00/MF $0.50, Sept 63, Avail:TAC

The performance of hydrogen and fluorine was evaluated in an altitude test facility at low chamber pressures in rocket engines having area-ratio-100 exhaust nozzles of three lengths.
(ROCKET, EXHAUST)

H73 30032 RESONANCE TUBE IGNITION OF HYDROGEN-OXYGEN MIXTURES
Phillips, B.R., and A.J. Pavli, (NASA, Lewis Research Center, Cleveland, O.), N71-26913, NASA-TN-D-6354, Washington, May 71, Avail:NTIS, Avail:TAC

A method was found to render the rocket engine igniter system independent of ambient pressures by enclosing the nozzle gap in a can.
(IGNITION, MIXTURE)

H73 30033 EVALUATION OF SPEECH SUPPRESSION CONCEPTS IN A 20,000-POUND-THRUST HYDROGEN-OXYGEN ROCKET
Wanhainen, J.P., N.P. Hannum, and L.M. Russell, (NASA, Lewis Research Center, Cleveland, O.), N67-34758, NASA-TM-X-1435, Washington, Aug 67, CFSTI: HC $3.00/MF $0.65, Avail:TAC

An experimental investigation was conducted to determine the effects of (1) propellant injection radial dis-

tribution, (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. 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.
(ROCKET, NOZZLE)

H73 30034 LONGITUDINAL INSTABILITY LIMITS WITH A VARIABLE LENGTH HYDROGEN OXYGEN COMBUSTOR
Morgan, C.J., and D.E. Soko, (NASA, Lewis Research Center, Cleveland, O.), N71-23713, NASA-TN-D-6328, Washington, Apr 71, Avail:NTIS,

An experimental investigation determined the longitudinal-mode instability characteristics of a 10,000 pound thrust, 300 psi chamber pressure, hydrogen-oxygen engine that could be continuously stroked in length from 19 to 65 inches during operation. A baffle was used to inhibit the transverse modes. Increasing baffle length stabilized the longitudinal mode of instability. Decreasing the hydrogen-injection temperature was destabilizing.
(THRUST, INSTABILITY)

H73 30035 PERFORMANCE OF COAXIAL INJECTORS IN LIQUID OXYGEN-GASEOUS HYDROGEN
Sternfeld, H.J., (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Lampoldshausen, West Germany, Institut fuer Chemische Radketenantriebe), N73-16779, Je 71, Avail:NTIS, Avail:TAC

Results of an experimental program for investigating combustion performance of variable thrust liquid oxygen/gaseous hydrogen rocket engines with coaxial injectors are presented.
(PERFORMANCE, ROCKET)

H73 30036 EFFECT OF THRUST PER ELEMENT ON COMBUSTION STABILITY CHARACTERISTICS OF HYDROGEN OXYGEN ROCKET ENGINES
Salmi, R.J., J.P. Wanhainen, and N.P. Hannum, (NASA, Lewis Research Center, Cleveland, O.), N68-36515, NASA-TN-D-4851, Washington, Oct 68, CFSTI: HC $3.00/MF $0.65, Avail:TAC

The results obtained with a series of coaxial injectors on a oxygen-hydrogen rocket engine operated at a chamber pressure of 300 psia were analyzed to deter-

mine the effects of injector thrust per element on the combustion stability. The thrust per element ranged from about 20 to 2500 pounds. Based on the minimum hydrogen temperature for stable combustion, the combustion stability increased with increasing thrust.
(THRUST, COMBINATION)

H73 30037 EFFECT OF COMBUSTOR PARAMETERS ON THE STABILITY OF GASEOUS HYDROGEN-LIQUID OXYGEN ENGINE
Feiler, C.E., (NASA, Lewis Research Center, Cleveland, O.), N68-11043, NASA-TM-X-52360, Washington 67, 4th Combustion Conference, Menlo Park, Calif., Oct 2-13 '67, sponsored by the Interagency Chemical Rocket Propulsion Group, CFSTI: HC $3.00/MF $0.65, Avail:TAC

Stability limits from the response factor model have been obtained for variations in chamber pressure, flow rate, throat area, and oscillation frequency for a fixed injector element geometry, and are compared with experimental data.
(COMBUSTION, STABILITY)

H73 30038 EFFECT OF CHAMBER PRESSURE, FLOW PER ELEMENT, AND CONTRACTION RATIO ON ACOUSTIC-MODE INSTABILITY IN HYDROGEN-OXYGEN ROCKETS
Wanhainen, J.P., C.E. Feiler, and C.J. Morgan, (NASA, Lewis Research Center, Cleveland, O.), N68-30518, NASA-TN-D-4733, Washington, Aug 68, CFSTI: HC $3.00/MF $0.65, Avail:TAC

An experimental investigation of a 20,000-lb. thrust engine with a single coaxial-type injector was conducted to determine the effect of variations in chamber pressure, weight flow per element, and contraction ratio, by changing nozzle throat diameter on tangential-acoustic-mode stability characteristics of hydrogen-oxygen rocket engines.
(PRESSURE, FLOW, ROCKET)

H73 30039 AIR PRECOOLING BEFORE COMPRESSION EFFECT ON THE AIR BREATHING ENGINES OF A SPACE-CRAFT LAUNCH VEHICLE
Kuenkler, H., (Technische Hochschule, Aachen, West Germany), N73-13785, DGLR-Paper_72-60, 5th Annual DGLR Meeting, Berlin, Oct 4-6 '72, Avail:NTIS, HC $3.75

The effect of air precooling before compression on the propulsive efficiency of liquid hydrogen turbojet engines with afterburning was investigated for space shuttle applications. Precooling was reached by heat exchange with the liquid hydrogen fuel flow. The efficiency of this

type of engine was determined for the accelerated flight of an aerodynamic space shuttle with regard to the limiting Mach number, the thrust behavior, the thrust/engine weight ratio and the specific fuel consumption.
(COMPRESSION, SPACECRAFT)

H73 30040 AN EVALUATION OF LOX/HYDROGEN ENGINE TECHNOLOGY FOR ADVANCED MISSIONS
Anon, (California Univ., Riverside, Calif.), N71-36111, NASA-CR-121864, Je 1 '71, Avail:NTIS, Avail:TAC
The importance of engine and stage design criteria on the sizing requirements of the complete stage are quantitatively defined. They include engine parameter (i.e. chamber pressure, area ratio, and mixture ratio) optimization analyses for two engine cycles as a function of stage size and mission profile.
(ENGINE, DESIGN)

H73 30041 PERFORMANCE AND COMBUSTION CHARACTERISTICS OF CONTROLLABLE HIGH-ENERGY ROCKET PROPULSION SYSTEMS
Sternfeld, H.J., and J. Reinkenhof, Astronautik, V 9:5-11, Ja - Mar 72
Results of an experimental investigation program describing combustion performance of variable thrust rocket engines with emphasis on the liquid oxygen/gaseous hydrogen propellant combination and coaxial injector are presented. The performance parameters investigated are mixture ratio, combustion pressure, characteristic chamber length, number of injection elements, injection area ratio, and injection velocity ratio.
(COAXIAL, INJECTOR, VARIABLE THRUST)

H73 30042 OXYGEN/HYDROGEN COMPONENT TECHNOLOGY STATUS
Fulton, D.L., J.R. Lauffer, G.R. Smith, and A.T. Zachary, (North American Rockwell Corp., Rocketdyne Div., Canoga Park, Calif.), American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Joint Propulsion Specialist Conference, 8th, New Orleans, La., Nov 29 - Dec 1 '72, AIAA Paper 72-1156, Avail:TAC
The advanced technology applicable to oxygen/hydrogen systems for auxiliary propulsion systems and other high energy upper stage applications is being developed.
(OXYGEN, ENERGY)

H73 30043 ORBITAL INVESTIGATION OF PROPELLANT DYNAMICS IN A LARGE ROCKET BOOSTER
Buchanan, H.J., and F.M. Bugg, (NASA, Marshall Space Flight Center, Huntsville, Ala.), N67-14910, NASA-TM-X-53542, Dec 1 '66, CFSTI: HC $3.00/MF $0.65

Experimental data on the dynamics of liquid hydrogen in the 6.6 m diameter tank of an S-IVB stage during boost, at S-IVB stage cutoff, and in orbit are presented.
(TANK, SLOSHING, OSCILLATION)

H73 30044 DEVELOPMENT OF PULSABLE ATTITUDE CONTROL ENGINES FOR HYDROGEN AND OXYGEN
Pulkert, G., (Messerschmitt-Boelkow-Blohm G.m.b.H. Ottobrunn, West Germany), Presented at the 5th DGLR Annual Meeting, Berlin, Oct 4-6 '72, 19 p, Avail: NTIS HC $3.00, Avail:TAC

Two hydrogen-oxygen engines have been developed for space shuttle attitude control, and stationary or pulsed operation. The main characteristics of combustion chamber, injector head, spark igniter, and pulse valve, are described.
(ENGINE, OXYGEN, COMBUSTION)

H73 30045 DYNAMIC PERFORMANCE OF LOW-THRUST, COLD-GAS REACTION JETS IN A VACUUM
Greer, H., and D.J. Griep, (Aerospace Corp., El Segundo, Calif.), Journal of Spacecraft Rockets, V 4:983-90 N8, 67,

The pulsed propulsive performance of low-thrust reaction jets, typical of those used for attitude control of small spacecraft, is analyzed and compared with the results of laboratory experiments on H, N, NH_3, Freon-12, and Freon-14 by using a 48:1 expansion-ratio nozzle. The transient processes that dominate the short-pulse or limit-cycle mode of thruster operation are formulated. These relations show good correlation with the data.
(PERFORMANCE, JET, SPACECRAFT)

H73 30046 PRATT & WHITNEY PICKED TO BUILD CRYOGENIC ROCKET ENGINE FOR LATE '70S USE
Taylor, H., Aerospace Technology, V 21:15 Ja 15 '68

The Air Force has initiated development of a high-pressure, high-energy reuseable liquid hydrogen engine for flights in the 1975-'80 time period.

The engine will power both first and second stages, according to Air Force spokesmen. In its first stage configuration, it will be used in conjunction with large solid motor strap-ons to increase payload capability.
(ROCKET, ENGINE, CRYOGENIC)

H73 30047 THE SEPR ROCKET ENGINE - HM4 WITH LIQUID OXYGEN AND HYDROGEN - DESIGN AND OPERATION
de Claviere, G., (Association Francaise des Ingenieurs et Techniciens de l'Aeronautique et de l'Espace), Congres International Aeronautique, 9th, Paris, France, Je 2-4 '69

Description of a 40-kN cryogenic-propellant engine developed for the Diogenes rocket. The engine consists of four propulsion chambers fed by a single turbopump. The results of tests of the different parts (pump, propulsion chambers, and entire engine) are summarized. Problems arising from the nature of the fuel, the low temperature, and heat exchange are discussed. It is concluded that the results obtained allow the development of engines of any thrust for the European space program.
(DESIGN, ROCKET, ENGINE)

H73 30048 THEORETICAL PERFORMANCE OF ROCKET ENGINES USING GASEOUS HYDROGEN IN THE IDEAL STATE AT STAGNATION TEMPERATURES UP TO 200,000° R
Roback, R., (United Aircraft Corp., East Hartford, Conn.), AEC Accession No. 2868, Report No. NP-16339, 215 p, 66

Theoretical performance parameters for rocket engines utilizing normal gaseous H in the ideal state were calculated using 2 different assumptions: first, that the chemical compound remained in equilibrium during the isentropic expansion through the engine exhaust nozzle; and 2nd, that the chemical compound remained fixed (frozen) during the expansion.
(ROCKET, ENGINE, PERFORMANCE)

H73 30049 THE DEVELOPMENT OF THE S.E.P.R. HM4 ENGINE: A 40 KN THRUST LIQUID OXYGEN AND HYDROGEN ENGINE
Dardare, J., N68-15939, Presented at the ELDO Symposium on Propulsion, Paris, Oct 10-12 '67, CFSTI: HC \$3.00/MF \$0.65, Avail:TAC

Describes a liquid hydrogen/liquid oxygen rocket motor of 40 kN thrust with a tubular chamber is being

developed to increase the performance of the French Diogene launch vehicle. Principal stages in its development and the testing facilities employed are discussed.
(THRUST, ROCKET)

H73 30050 LARGE HYDROGEN-OXYGEN ABLATIVE CHAMBER TEST PROGRAM
Kovach, R.J., J.A. Mellish, and R.W. Michel, (Aerojet-General Corp., Sacramento, Calif.), Final Report N69-20193, NASA-CR-72512, Mar 14 '69, Avail: CFSTI, Avail:TAC

A large-scale silica phenolic, ablative-lined combustion chamber with a coaxial element injector having baffles, was tested to ascertain duration capability using the propellant combination of liquid hydrogen/liquid oxygen.
(ABLATION, TEST)

H73 30051 ACOUSTIC SCALE-MODEL TESTS OF HIGH-SPEED FLOWS
Smith, E.B., (Martin Co., Denver, Colo.), Final Report N66-24587, NASA-CR-74596, Mar 66, 104 p, CFSTI: HC $4.00/ MF $0.75

The purpose of this contract was to conduct a scale model test program to determine the acoustical field generated by high-chamber-pressure, hydrogen-fueled engines in various cluster configurations.
(TEST, FLOW, ENGINE)

H73 30052 ADVANCED PRESSURIZATION SYSTEMS FOR CRYOGENIC PROPELLANTS
Anderson, J.E., O.L. Scott, and H.F. Brady, (Martin Co., Denver, Colo.), Final Report Nov 20 '63 - Je 25 '65, N67-16605, NASA-CR-54467; Martin-CR-65-75, Ja 67, CFSTI: HC $3.00/MF $0.65, Avail:TAC

The purpose of this program was to select an optimized pressurization system for a vehicle using cryogenic propellants. Improvements in the method of analysis were also developed and incorporated in the program. The vehicle for study was an Apollo-type service module using liquid hydrogen and liquid oxygen as propellants. Systems of both pump-fed and pressure-fed engines were considered during the study with a final selection completed for the pump-fed engine system.
(CRYOGENIC, PROPELLANT)

H73 30053 ANALYSIS OF A SUPERSONIC-COMBUSTION ROCKET CONCEPT
Franciscus, L., (NASA, Lewis Research Center, Cleveland, O.), N72-24810, NASA-TM-X-68020, Fe 72, Avail: NTIS

A preliminary analysis has been made of a supersonic combustion rocket engine concept using hydrogen and oxygen propellants. The ejector action of a separate small rocket motor is employed to pump the propellants to high stagnation pressures and supersonic velocities.
(EJECTOR, SPECIFIC IMPULSE, TURBOPUMP)

H73 30054 FEASIBILITY STUDIES OF ROTATING DETONATION WAVE ROCKET MOTOR
Nicholls, J.A., R.E. Cullen, and K.W. Ragland, Journal of Spacecraft and Rockets, V 3:893-8 N6 Je 66

Paper considers, analytically and experimentally, feasibility of rocket motor using detonation wave rotating in annular combustion chamber wherein propellants are introduced continuously through injectors and expelled through annular nozzle; experiments utilizing gaseous hydrogen and oxygen and gaseous methane and oxygen were conducted in annular rocket motor.
(STUDY, ROCKET, MOTOR)

H73 30055 DESIGN AND FABRICATION OF SMALL H_2/O_2 ENGINES
Domokos, S.J., and G.L. Falkenstein, SAE Paper 700803 for meeting Oct 5-9 '70, 15 p

Candidate thrust chamber designs include channel wall, tubular or film-cooled single wall, with copper alloy for the chamber walls and nickel alloy or stainless steel for nozzle extensions. Injector designs that maximize thrust chamber performance while providing compatible heat transfer characteristics are necessary.
(DESIGN, ENGINE)

H73 30056 DESIGN AND MANUFACTURE OF LIQUID HYDROGEN THRUST CHAMBER
Steer, T.E., Spaceflight, V 10 135-42 N4 Apr 68

Efforts made by Rolls-Royce Ltd in development and manufacture of two experimental liquid hydrogen thrust chambers, based on designs submitted under study contract in course of which engine thrust was uprated to 70 kN; general description and overall performance of complete thrust chamber unit comprising combustion chamber and nozzle assembly, injector and ignition source; major feature of chamber unit requiring most design effort has been tubular cooling jacket, which extends from injector plane to below throat; other components and problems encountered. (DESIGN, THRUST)

H73 30057 PROPULSION BY LIQUID OXYGEN AND LIQUID HYDROGEN
Dardare, J., (Societe Etude Propulsion Reaction, Villejuif, France), Pure Application Cryogenic, V 5:135-57 66

A brief review of the properties of liquid H-O propellant mixtures, applied to a discussion of the design of rocket engines in the U.S. and in France.
(REVIEW, ROCKET, ENGINE)

H73 30058 EXPERIMENTS WITH HYDROGEN AND OXYGEN IN REGENERATIVE ENGINES AT CHAMBER PRESSURES FROM 100 to 300 POUNDS PER SQUARE INCH ABSOLUTE
Tomazic, W.A., E.R. Bartoo, and R.J. Rollbuhler, (NASA, Lewis Research Center, Cleveland, O.), N66-33344, NASA-TM-X-253), Washington, Apr 60, CFSTI: HC $2.00/MF $0.50, Avail:TAC

Tests were made with hydrogen and oxygen in regenerative thrust chambers of lightweight construction designed to give 20,000-pound thrust at a chamber pressure of 300 lb/sq in absolute.
(THRUST, ROCKET, ENGINE)

H73 30059 DEVELOPMENT OF A HYDROGEN-OXYGEN SPACE POWER SUPPLY SYSTEM
Morath, W.D., (Vickers, Inc., Torrance, Calif., Aerospace Div.), N66-26747, NASA-CR-75177; PR-91570-510-12, CFSTI: HC $2.00/MF $0.50, Avail:TAC

Prototype component development and engine endurance tests are reported. The design, fabrication, and assembly of the engine are mentioned, and design diagrams of components are included. The endurance tests are reported, and tables of component and engine failures are presented.
(SPACE, POWER, DESIGN)

H73 30060 DEVELOPMENT OF A 1,500,000-LB-THRUST (NOMINAL VACUUM) LIQUID HYDROGEN/LIQUID OXYGEN ENGINE
Anon, (Aerojet-General Corp., Sacramento, Calif.), N68-15861, NASA-CR-91903; Rept - 2555-M-I-F, Final Report Apr 30 '62 - Aug 4 '66, CFSTI: HC $3.00/MF $0.65, Aug 30 '67

The M-1 engine configuration is one of opposed oxidizer and fuel turbopumps fed by two 19-in. suction lines located 180 degrees apart. The turbopumps are supported by tubular members with primary attachment points on thrust chamber injector flange and fuel distribution torus. Use of these support locations reduces engine weight but compromises thrust chamber design due to imposition of high unit loads. A major factor in the M-1 engine design was dynamic load predictions.
(THRUST, LOAD, ENGINE)

H73 30061 DEVELOPMENT OF LIQUID OXYGEN/LIQUID HYDROGEN PROPULSIVE UNIT WITH 300 N VACUUM THRUST
Seidel, A., (Boelkow G.m.b.H., Ottobrunn/Munich, Germany), Raumfahrtforschung, V 11:177-82,N4, 67

The development of a high-energy propulsive unit using liquid oxygen and liquid hydrogen is described. Theoretical calculations concerning propellants, burning efficiency of H-O and H-F combinations and the cooling effects were carried out electronically. Details of the exptl. set up and the development of the prototype from 1962 to 1966 are given.
(PROPULSION, ENGINE)

H73 30062 PROTECTIVE COATING SYSTEM FOR A REGENERATIVELY COOLED THRUST CHAMBER
Carpenter, H.W., (Rocketdyne, Canoga Park, Calif.), N69-35125, NASA-CR-72569, Final Report, Je 30 '67 - Ja 31 '69, Avail: CFSTI

A ceramic coating system is desired for thermal protection of the thrust chamber wall in a high performance, liquid hydrogen/liquid oxygen fueled rocket engine. This heat barrier coating is intended to reduce the heat flux through the chamber wall, reduce the metal wall temperature to less than 1600^{o}F, operate with a 4000^{o}F surface temperature, and survive multiple engine starts.
(COATING, PROTECTION, THRUST)

H73 30063 DEVELOPMENT OF LO_2/LH_2 GAS GENERATORS FOR THE M-1 ENGINE
Anon, (Aerojet-General Corp., Sacramento, Calif., Liquid Rocket Operations), N66-27739, NASA-CR-54812; AGC-8800-59, Je 1 '66, CFSTI: HC $3.00/MF $0.75, Avail:TAC

The current technology for a 120,000 horsepower liquid oxygen/liquid hydrogen gas generator that was successfully designed and tested for the M-1 engine program is summarized.
(GENERATOR, ENGINE)

H73 30064 EVALUATION AND DEMONSTRATION OF THE USE OF CRYOGENIC PROPELLANTS (OXYGEN/HYDROGEN) FOR REACTION CONTROL SYSTEMS. VOLUME 2: EXPERIMENTAL EVALUATIONS AND DEMONSTRATION
Rodewald, N., G. Falkenstein, P. Herr, and E. Prono, (Rocketdyne, Canoga Park, Calif.), Final Report, Je 68, N69-10397, NASA-CR-72244; R-6838-2)

The feasibility of a catalytically ignited spacecraft reaction control system using cryogenic (hydrogen-oxygen) propellants was experimentally demonstrated. The system studied utilized propellant conditioners to prepare the incoming propellants to a temperature and pressure acceptable to the thrustor.
(PROPELLANT, THRUST)

H73 30065 INVESTIGATION OF THRUSTERS FOR CRYOGENIC REACTION CONTROL SYSTEMS, VOLUME 1
Johnson, R.J., (TRW Systems Group, Redondo Beach, Calif.), N71-12096, NASA-CR-72784, Final Report, Je 68 - Oct 69, Nov 13 '70, Avail:NTIS, Avail:TAC

An experimental and analytical program was conducted to evaluate the ignition characteristics and delivered performance of gaseous hydrogen oxygen reaction control thrusters. Specific goals were to establish design criteria for a pilot bed catalytic igniter and to define an operating map for reliable thruster ignition at two chamber pressure levels.
(THRUST, CRYOGENIC)

H73 30066 EXPERIMENTAL INVESTIGATION OF COMBUSTOR EFFECTS ON ROCKET THRUST CHAMBER PERFORMANCE
Anon, (Rocketdyne, Canoga Park, Calif.), N72-33738, NASA-CR-128318, Interim Report, Je 72, Avail: NTIS HC $8.00, Avail:TAC

A design and experimental program to develop special

instrumentation systems, design engine hardware, and conduct tests using LOX/GH2 propellants in which the propellant flow stratification was controlled is described.
(ROCKET, THRUST)

H73 30067 DESIGN OF LIQUID PROPELLANT ROCKET ENGINES
Huzel, D.K., and D.H. Huang, (National Technical Information Service, Springfield, Va.), Avail:TAC

This book intends to build a bridge for the student and the young engineer: to link the rocket propulsion fundamentals and elements (which are well covered in the literature) with the actual rocket engine design and development work as it is carried out in industry. The book attempts to further the understanding of the realistic application of liquid rocket propulsion theories, and to help avoid or at least reduce time and money consuming errors and disappointments. It also attempts to digest and consolidate numerous closely related subjects.
(DESIGN, ROCKET, ENGINE)

H73 30068 NUCLEAR HEATING AND PROPELLANT STRATIFICATION
Duke, E.E., AIAA Journal, V 3:760-2 Apr 65, Avail:TAC

In order to obtain maximum vehicle performance for a nuclear system employing liquid hydrogen (H_2l), the vehicle must be designed to obtain optimized propellant utilization while minimizing system weight. A major problem encountered in this endeavor is caused by propellant heating.
(PERFORMANCE, OPTIMIZATION, WEIGHT)

H73 30069 EVALUATION AND DEMONSTRATION OF THE USE OF CRYOGENIC PROPELLANTS (OXYGEN/HYDROGEN) FOR REACTION CONTROL SYSTEMS. II. EXPERIMENTAL EVALUATIONS AND DEMONSTRATION
Rodewald, N., G. Falkenstein, P. Herr, and E. Prono, (Rocketdyne, Canoga Park, Calif.), NASA-CR-72244, from Scientific and Technical Aerospace Report, V 7:161 N1 69, Avail:CRSTI, Avail:TAC

The feasibility of a catalytically ignited spacecraft reaction-control system using cryogenic (H-O) propellants was demonstrated exptl. The system studied utilized propellant conditioners to prepare the incoming propellants for a temperature and pressure acceptable to

the thrustor. A portion of the propellants at a mixture ratio of 1.0 was passed through a catalyst bed. Additional O was injected into the hot fuel-rich gas. Exptl. results for the thrustor and conditioner subsystems and a system demonstration are presented. Design criteria for the ultimate development of an operational system are also presented.
(CATALYSIS, THRUST, DESIGN)

H73 30070 CATALYSIS OF HYDROGEN-ATOM RECOMBINATION IN ROCKET NOZZLES
Lordi, J.A., R.E. Mates, NASA-CR-393 Mar 66, Avail:TAC

Use of gas-phase catalysis was suggested as means of enhancing hydrogen-atom recombination and hence performance of nuclear or electrically powered rocket engines; in present study use of oxygen and oxygen-nitrogen mixture as catalysts has been examined; results of calculations indicate that gas-phase catalysis leads to marginal increase in specific impulse; results of present studies and those of hydrogen-carbon system are used to establish minimum requirements which additive must satisfy to yield gain in specific impulse.
(RECOMBINATION, PERFORMANCE, SPECIFIC IMPULSE)

H73 30071 COMBUSTION AND HEAT TRANSFER IN A SMALL ROCKET CHAMBER BURNING LIQUID AND GASEOUS HYDROGEN
Jeffs, A.T., C. Ramshaw, and B.W.A. Ricketson, (Ministry of Aviation, Rocket Propulsion Establishment, Westcott, Bucks., England), Spaceflight, V 8:172-84 May 66

Results from a test program to study the practicability of gaseous hydrogen as a rocket fuel. Liquid oxygen and gaseous hydrogen were burnt in a chamber giving a nominal thrust of 450 lb. The construction of the motor and the analytical methods used are described. The test results are plotted and discussed.
(COMBUSTION, ROCKET)

H73 30072 DEVELOPMENT OF HYDROGEN-OXYGEN FUELED 3-KILOWATT INTERNAL-COMBUSTION ENGINE
Cameron, H.M., and N.E. Morgan, (Vickers, Inc., Torrance, Calif.), (NASA, Lewis Research Center, Cleveland, O.), N64-28410, AIAA 3rd Biennial Aerospace Power Systems Conference, Philadelphia, Pa., Sept 1-4 '64, AIAA Paper-64-756, Avail:TAC

The objective of this program was to convert the high energy released by the combination of hydrogen and oxygen to useful power in a powerplant that had been well developed in conjunction with hydrocarbon fuels. The power package includes a single-cylinder engine, generator, gas compressor, and recuperator for transferring heat from the exhaust gases to the gaseous cryogenic propellants. The approach has been to design the test engine and other test components based on available engine technology and to proceed with experimental development based on the analysis of test results. Current developement work on the engine is concerned with improving fuel consumption rates. Power levels from 1 to 5 hp have been achieved. (COMPRESSOR, RECUPERATOR, POWER)

H73 30073 DEVELOPMENT OF A HYDROGEN-OXYGEN INTERNAL COMBUSTION ENGINE SPACE POWER SYSTEM
Morgan, N.E., and W.D. Morath, (Vickers, Inc., Detroit, Mich.), Washington, N65-28954, NASA-CR-255, Jl 65, CFSTI: HC $6.00/MF $1.25, Avail:TAC

The prototype engine development effort consisting of design studies, hardware, modifications, performance and endurance test evaluation, and the fabrication and procurement of new test equipment and instrumentation is discussed. Major cesign effort was concentrated on the oxygen injector, the hydrogen valve, the piston and cylinder, and the combustion chamber. Engine performance development resulted in a marked reduction in specific propellant consumption compared with past experience. (ENGINE, SPACE, POWER)

H73 30074 HIGH ENERGY ROCKET PROPELLANT RESEARCH AT THE NACA/NASA LEWIS RESEARCH CENTER, 1945-1960
Sloop, J.L., (NASA, Washington, D.C.), 7th International History of Astronautics Symposium, Baku, U.S.S.R., Oct 73, Avail:TAC

History of rocket propellant research describing the use of hydrogen peroxide, oxygen, fluorine, diborane, hydrzine as rocket propellants. The final work used liquid hydrogen as a fuel with fluorine and oxygen as oxidizers. (HISTORY, ROCKET, LIQUID, HYDROGEN, OXYGEN, FLUORINE, PROPELLANT, FUEL)

H73 30075* ROCKETRY IN THE 1950'S
Braun, W. von, et al., NASA Historical Report No. 36, Oct 71, Avail:TAC

The report is a transcript of an AIAA Panel Discussion by leading men in the field of rocketry describing their experiences in the 1950's. A 196 reference bibliography by John L. Sloop is included.
(ROCKET, LIQUID, HYDROGEN, ENGINE)

H73 31000* AEROENERGY; A NEW FRONTIER
Vansant, C.A., (Operations Res., Inc., Silver Spring, Md.), IAA Accession No. A66-34443, 66, Avail:AIAA, Avail:TAC

The current status of the technology of utilizing liquid H in manned aircraft systems was surveyed. The progress in the development of hardware for liquid H propulsion systems, achieved in the past decade is outlined, as are the advantages which accrue from the use of liquid-hydrogen fuel. The economic and military considerations involved are examined.
(AIRCRAFT, PROPULSION, COST)

H73 31001* CRYOGENIC FUELS FOR AIRCRAFT
Esgar, J.B., (Lewis Research Center, Cleveland, O.), N71-19463, Avail:TAC

Exploratory research on the use of cryogenic fuels for airbreathing gas turbine engines is presented. The possible applications of liquid methane to a supersonic transport type aircraft and the application of liquid hydrogen to the airbreathing engines for recoverable boosters and orbiters for the space shuttle are discussed.
(SUPERSONIC, GAS TURBINE, SPACE, SHUTTLE)

H73 31002* HYDROGEN FUELED COMMERCIAL AIRCRAFT
Escher, W.J.D., (Escher Technology Associates), Astronautics & Aeronautics, Dec 72

Emerging as possibly the first transportation candidate to "get off the fossil-fuel standard" and use hydrogen is commercial aviation, if pilot studies NASA and airframe manufacturers have underway prove valid. For it now appears that liquid hydrogen fuel, with 2.75 times the gravimetric heating value of standard hydrocarbon fuels, will remarkably improve airplane performance, both subsonic and supersonic.
(STUDY, SUBSONIC, SUPERSONIC)

H73 31003 A CARBON DIOXIDE PURGE AND THERMAL PROTECTION SYSTEM FOR LIQUID HYDROGEN TANKS OF HYPERSONIC AIRPLANES
Jackson, L.R., and M.S. Anderson, (NASA Langley Research Center, Hampton, Va.), Advances in Cryogenic Engineering, V 12 66

Various thermal protection systems can be designed to give acceptable fuel heat load and prevent cryopumping of air. However, the weight and reliability of these systems vary greatly. Two possible approaches are being considered - gas-purging the system and sealing the system to exclude air from the tank walls.

It would appear desirable to have a thermal protection system that prevents large fuel loads and cryogenic pumping of air, but has neither the high weight of the helium-purged system nor the leak-free requirement of the evacuated systems. A study of structural concepts for hydrogen-fueled hypersonic vehicles at the Langley Research Center has provided a carbon dioxide concept that may offer such a thermal protection system.
(PURGE, AIRPLANE, HYPERSONIC)

H73 31004 AN EXPERIMENTAL AND ANALYTICAL EVALUATION OF THE THERMAL BEHAVIOR OF LIQUID HYDROGEN IN A TANK DESIGNED AND INSULATED FOR USE IN A HYPERSONIC VEHICLE
Yates, G.B., (General Dynamics/Convair, San Diego, Calif.), Advances in Cryogenic Engineering, V 12, 66

Attention has been focused in recent years on hypersonic flight. Numerous synthesis and systems studies have been conducted to define and optimize various airframe and propulsion concepts. Liquid hydrogen almost always evolves as the most desirable fuel because of its two inherent advantages, i.e., high heat capacity which provides needed coolant and high energy content per unit mass.

The overall program, from which the data presented are taken, is the development of a procedure for selecting an optimum tank installation in a hypersonic vehicle, and the design, fabrication and testing of an insulated flightweight liquid-hydrogen tank. The final test article will be a 6000-gal LH_2 tank of "double-bubble" intersecting cylinder construction. The basic tank structural material is 0.016-in. Inconel 718 alloy. The insulation is Microquartz, a high-silica fiber. It is used in a helium environment to prevent cryopumping. Insulation for the 6000-gal tank was optimized and resulted in a variable thickness around the circumference. The optimum operating pressure is 30 psia.

Tests are complete on a small scale, 2-ft-diameter 130-gal tank using the optimum insulation and operating pressure for the large tank. These test results are presented and compared with an analytical analysis developed

to support the tank optimization.
(SUPERSONIC, OPTIMUM, STUDY, ENERGY)

H73 31005 LIQUID HYDROGEN AS A SUPERSONIC TRANSPORT FUEL
DuPont, A.A., (Garrett Corp., Los Angeles, Calif.), Advanced Cryogenic Engineering, V 12:1-10 67

The title subject was discussed with consideration of the effect of H properties on aircraft performance, high Mach number capability, the effect of fuel costs on operating economics, the effect of H on engine design and performance, H storage in aircraft tankage, design features of a H-fueled aircraft to achieve safety during normal operation, and the relative hazard of H fuel in a crash landing. H showed high potential as a fuel.
(PERFORMANCE, COST, STORAGE, SAFETY)

H73 31006 DETERMINATION OF THE CRUISE RANGE OF A HYDROGEN-FUELED, AIR-BREATHING HYPERSONIC AIRCRAFT
Krouse, J.R., (David Taylor Model Basin, Washington, D.C., Aerodynamics Lab.), N65-31895, DTMB-2010; AERO-1089; AD-467687, May 65, Avail:TAC

The cruise range of a typical hydrogen-fueled, air-breathing, hypersonic aircraft is obtained for both a simple and a modified Breguet flight path. The analysis indicates that the modified Breguet flight path, in which the restriction of constant specific fuel consumption is relaxed (realistic variation with Mach number and altitude is permitted), results in a cruise range that is approximately three percent greater than that predicted by the simplified Breguet range equation. In either case, virtually semi-global range is obtained when the cruise range is superimposed upon the additional distance covered during climb and descent.
(SUPERSONIC, FUEL, ANALYSIS, CONSUMPTION)

H73 31007* PRELIMINARY APPRAISAL OF HYDROGEN AND METHANE FUEL IN A MACH 2.7 SUPERSONIC TRANSPORT
Whitlow, J.B., Jr., R.J. Weber, and K.C. Civinskas, (NASA, Lewis Research Center, Cleveland, O.), N73-22711, NASA-TM-X-68222, 72, Avail:NTIS HC $4.75, Avail:TAC

The higher heating value of hydrogen relative to JP fuel is estimated to reduce fuel weight by three fold and gross weight by 40 percent for comparable designed air-

planes of equal payload and range. Engine design parameters were varied to determine the influence of lower noise goals on gross weight and direct operating cost. At current fuel prices, the DOC of a hydrogen airplane would be much higher than that of a JP airplane. A methane airplane could offer an 8.5-percent lower KOC than JP. But future shortages may escalate the prices of both JP and methane, whereas the price of hydrogen manufactured hydrolytically could be reduced from present levels. If in the future all three fuels are postulated to have equal costs per unit of energy, the DOC for hydrogen could be as much as 20 percent below that for JP on the reference 4000-nautical-mile mission. Longer ranges or lower noise requirements would improve the advantage of hydrogen.
(PAYLOAD, RANGE, COST, NOISE)

H73 31008 THERMAL FEASIBILITY OF USING METHANE OR HYDROGEN FUEL FOR DIRECT COOLING OF A FIRST-STAGE TURBINE STATOR
Colladay, R.S., (NASA, Lewis Research Center, Cleveland, O.), N70-42326, NASA-TN-D-6042, Washington, Oct 70, Avail:NTIS, Avail:TAC

The feasibility of cooling the first-stage turbine stator directly with cryogenic fuels was investigated based on a numerical heat transfer analysis of methane and hydrogen-cooled vanes. An insulation barrier between the fuel cooling passages and the external vane surface was required to prevent adverse cooling conditions. The cooling configuration analyzed was that of tubular cooling passages embedded in insulation material surrounded by an outer vane shell. The results indicate that the turbine stator vanes could be adequately cooled with methane or hydrogen fuel at a 2490 F (1639 K) local-hot-spot gas temperature.
(HEAT, TRANSFER, GAS TURBINE)

H73 31009* KEY TECHNOLOGY FOR AIRBREATHING HYPERSONIC AIRCRAFT
Nagel, A.L., and J.V. Becker, (NASA, Langley Research Center, Hampton, Va.), American Institute of Aeronautics and Astronautics, Annual Meeting and Technical Display, 9th, Washington, D.C., Ja 8-10 '73, Paper 73-58, Avail:TAC

This paper reviews recent progress in the key hyper-

sonic technologies, which has been good despite a relatively low priority. Successful hypersonic research engine tests have been made. Active cooling system analyses have shown potential for weight savings, alleviation of structural design problems, and long airframe life. Maturing computerized flow field theories permit optimizing engine-airframe performance. Adequate progress in the future requires an expanded technology program emphasizing hydrogen usage. A hydrogen fueled hypersonic research airplane is essential, providing critical flight data and operational experience.
(COOLING, OPTIMIZATION)

H73 31010 EFFECT OF COMBUSTION GAS PROPERTIES ON TURBOJET-ENGINE PERFORMANCE WITH HYDROGEN AS FUEL
English, R.E., (National Advisory Committee for Aeronautics, Lewis Flight Propulsion Lab., Cleveland, O.), N63-12509, NACA-RM-E55J17a, Washington, Apr 10 '56, Avail:TAC

Simple adjustment of turbojet engine cycle calculations based on JP-4 fuel for the increase in heating value when hydrogen is substituted for JP-4 resulted in the following errors: Fuel specific impulse was as much as 3 percent high; thrust per unit airflow was as much as 5 percent low; and airflow per unit of turbine frontal area was as much as 1 percent low.
(SPECIFIC IMPULSE, THRUST, AIRFLOW)

H73 31011 DOD, AIRLINES FACE ENERGY CRISIS
Yaffee, M.L., Aviation Week & Space Technology, Nov 20 '72, Avail:TAC

Defense Dept. and U.S. airlines face a grim and growing fuel shortage for which there are no short-term solutions other than paying higher prices or importing more. U.S. government agencies and industry belatedly are marshaling their forces to find suitable solutions for the long term.

Most fuel people think the energy crisis will worsen. However, there are sources of energy other than oil and gas. All indigenous energy resources that can be developed should be developed and will be needed.

Liquid hydrogen appears to be the most promising aircraft fuel for 1990 and beyond, from energy, availability and environmental viewpoints. Electricity produced by future nuclear reactors will be used to generate the hydrogen by electrolysis of water or some other process.

Large cargo aircraft with gross weights above 1 million lb. should be used to introduce the use of liquid hydrogen as an aircraft fuel.

Use of liquid hydrogen will not require any significant changes in powerplants that are expected to be high bypass ratio turbofans. Biggest changes will be in the aircraft fuel system design and in storage procedures.
(COST, AIRCRAFT, ECONOMIC, FUEL)

H73 31012* POTENTIALS AND PROBLEMS OF HYDROGEN FUELED SUPERSONIC AND HYPERSONIC AIRCRAFT
Witcofski, R.D., (NASA Langley Research Center, Hampton, Va.), 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Sept 72

Current and projected air passenger travel trends, the growing concern over environmental protection, and the potential depletion of our fossil fuel reserves, when combined with the results of recent aeronautical research programs, leads to the consideration of liquid hydrogen fuel for transport aircraft. The use of liquid hydrogen fuel is shown to give superior range and/or payload capability as compared to JP fueled aircraft, at speeds from Mach 3 to 8. Supersonic combustion ramjet engines, having low cooling requirements, make available a large portion of the heat-sink capacity of liquid hydrogen fuel for active cooling of the entire airframe, opening the door to the use of conventional aircraft materials and construction experience to speeds as high as Mach 8 or 10. This paper discusses the characteristics of hydrogen fueled aircraft engines from supersonic to hypersonic speeds. Structural aspects of both "hot" and actively cooled aircraft are discussed, including the problem of insulating the hydrogen fuel. The effects on aircraft performance of the strong interaction between the propulsive, structural, and aerodynamic aspects of hypersonic aircraft are considered. The implications of the possible use of slush hydrogen are also covered. Environmental and economic aspects are considered and operational aspects needing further attention are also discussed.
(RANGE, PAYLOAD, COOLING, SLUSH, ECONOMIC)

H73 31013* THE ECONOMICS OF LIQUID HYDROGEN SUPPLY FOR AIR TRANSPORTATION

Johnson, J.E., (Union Carbide Corp., New York, N.Y.), Paper Q-1, Cryogenic Engineering Conference, Atlanta, Ga., Aug 73

The prospects for utilizing liquid hydrogen to provide future fuel requirements for air transportation industry segments is examined. An economic analysis for supply of 2,500 T/D of liquid hydrogen is developed based on producing the fuel from our extensive domestic coal and nuclear fuel reserves. Depending on the degree of aircraft operating cost savings achievable by removal of the environmental constraints and fuel weight limitations imposed by hydrocarbon jet fuels, the projected liquid hydrogen costs of $2.50 per million BTU could already be attractive to power the next generation of aircraft to be developed. As the best alternative to continued over-dependence on increasingly costly imported hydrocarbon liquid fractions, a liquid hydrogen alternative fuel strategy for air transportation offers a significant opportunity to economically contribute toward easing our energy crisis through utilization of our lowest cost domestic energy resources in an environmentally acceptable manner. The Apollo program has provided a significant technological base to develop the capability required to meet the high standards of safety and performance required by the air transport industry. The immediate requirement to prove the viability of liquid hydrogen fueled air transportation is the demonstration of the projected aircraft performance improvements possible that are attributable to hydrogen fuel.

(COST, AIRCRAFT, PRODUCTION)

H73 31014* THE CASE FOR A HYDROGEN-FUELED SUPERSONIC TRANSPORT

Brewer, G.D., (Lockheed-California Co., A Division of Lockheed Aircraft Corp.), Report No. LR 25511, Oct 23 '72

The report was written to review the conceptual arguments, pro and con, concerning the practicability of using liquid hydrogen as the fuel for a supersonic transport. The foreseeable shortage and attendant increasing cost of kerosene in the time period when an SST fleet can become operational makes the subject of prime interest.

Since the capability to manufacture liquid hydrogen

in the quantities necessary to satisfy anticipated demands hinges on availability of large amounts of electric power, a brief review is presented of the outlook for energy need in the United States in the 1990 - 2000 decade, along with a forecast of the most likely ways in which these needs will be met.
(MANUFACTURE, ENERGY, AIRCRAFT)

H73 31015 WORKING SYMPOSIUM ON LIQUID HYDROGEN-FUELED AIRCRAFT
Anon, NASA, Langley Research Center, Hampton, Va., May 15-16 '73
A compendium of written and visual material that is not a formal NASA document.
(AIRCRAFT, LIQUID, CRYOGENIC, FUEL, HYPERSONIC)

H73 31016* HYPERSONIC TRANSPORTS
Becker, J.V., F.S. Kirkham, (NASA, Langley Research Center, Hampton, Va.), NASA SP-292, Nov 2 '71
The paper projects current technology into the development and operation of hypersonic transports using hydrogen as a fuel. Considered in the projection are costs, structural problems, heating, and the use of shuttle derived technology.
(AIRCRAFT, HYPERSONIC, CRYOGENIC, COST)

H73 31017* THE CASE FOR HYDROGEN FUELED TRANSPORT AIRCRAFT
Brewer, G.D., (Lockheed-California Company, Burbank, Calif.), AIAA Paper No. 73-1323, AIAA/SAE 9th Propulsion Conference, Las Vegas, Nev., Nov 73, Avail:TAC
The case for using liquid hydrogen as the fuel for commercial aircraft of the future rests on the following arguments:

1) Petroleum is fast becoming a critically short commodity in the United States. World-wide, it will reach a peak of availability in less than 20 years, declining rapidly thereafter.
2) In the United States, the need to import the tremendous quantities of oil which are forecast for the future will lead to unacceptable dependence on a small number of foreign nations. This will cost the U.S. heavily in terms of deficit balance of payments; economic, commercial, and diplomatic independence; and national security.

3) Commercial aviation is at present a comparatively small but rapidly growing consumer of petroleum in the U.S. Development of an alternate fuel for commercial transport aircraft will eliminate a significant fraction of the future petroleum needs of the nation.
4) Hydrogen, as a candidate alternate fuel, offers significant potential advantages ween used in aircraft, viz., performance, pollution, noise and cost. Accordingly, it is recommended for initial and early use in aircraft, with its use in other economic sectors growing as its availability increases.

Each of these arguments is developed to explore its merit. Examples of commercial aircraft, both subsonic and supersonic, are examined to determine the potential, and some of the problems, of using liquid hydrogen as a fuel. (FUEL, TRANSPORT, AIRCRAFT, LIQUID, FUTURE, PETROLEUM, PERFORMANCE, POLLUTION)

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H73 32000* THE HYDROGEN-AIR FUELED AUTOMOBILE
Swain, M.R., and R.R. Adt, Jr., (University of Miami, Coral Gables, Fla.) 7th Intersociety Engineering Conference on Energy Conversion, San Diego, Calif., 72, Avail:TAC

The paper describes the research and development effort required to convert a 1970 Toyota 1600 station-wagon to run on a hydrogen-air fuel mixture. The unique engine design modifications involve only minor changes to the Otto cycle engine and will not require extensive manufacturer's retooling. In addition a high pressure source of hydrogen is not needed. Total engine cost is expected to be less than that of a similar gasoline fueled low emission engine. An approximately 50% increase in efficiency over that of the gasoline fueled engine is realized. Nitric oxide emissions, the only exhaust gas constituents of concern, are expected to meet the 1975 emission standards. The 1976 and later standards are expected to be met with minor modifications.
(MODIFICATION, COST, EMISSION, POLLUTION, ENVIRONMENT)

H73 32001* THE HYDROGEN - AIR FUELED AUTOMOBILE ENGINE (PART I)
Adi, R.R., D.L. Hershberger, T. Kartage, and M.F. Swain, (University of Miami, Coral Gables, Fla.), 8th Intersociety Engineering Conference on Energy Conversion, Philadelphia, Pa, 73, Avail:TAC

This paper describes the progress made on the development of the hydrogen-air fueled automobile engine described at last year's IECEC. Since that time a 4 cylinder, 195 cu in Pontiac engine has been redesigned, incorporating an improved version of the Hydrogen Induction Technique, to run on hydrogen and vaporized gasoline. Performance curves and emission data for the engine fueled by hydrogen are given.
(PERFORMANCE, EMISSION)

H73 32002* ON THE UCLA HYDROGEN CAR
Bush, A.F., and W.D. Van Vorst, (UCLA, Los Angeles, Calif.), Presented at 1973 Cryogenic Engineering Conference, Atlanta, Ga., Aug 10 '73, Avail:TAC

The features of the UCLA hydrogen car are reviewed and conclusions drawn from its development. Hydrogen has yielded higher brake thermal efficiency than gasoline, and a fuel economy of 10 miles per pound of hydrogen has been obtained consistently. Exhaust emission pollutants are well below the 1976 Federal standards. Safety aspects seem no more stringent than with gasoline, methane, or propane.

The major problems remaining have to do with storage of hydrogen, and the control system for feeding it to the engine. A hydride bed is suggested, and major design variables indicated. Attention is called to the problems of large scale distribution of hydrogen potentially required in a "hydrogen economy."
(EFFICIENCY, SAFETY, STORAGE, HYDRIDE, EMISSION, POLLUTION, ENVIRONMENT)

H73 32003 PERRIS SMOGLESS AUTOMOBILE ASSOCIATION
Anon, Industrial Resources, Sept 72

The Perris Smogless Automobile Association, is a group of individuals - Paul B. Dieges, Dwight B. Minnich, Fredric F. Nardecchia, and Patrick L. Underwood - in Perris, Calif., who, using a cryogenic hydrogen/oxygen fueling system, have arrived at a solution to the problem of automobile air pollution. The article tells how they conceived, built, and ran a pollution-free internal combustion vehicle.
(CRYOGENIC, OXYGEN, INTERNAL COMBUSTION, POLLUTION)

H73 32004* THE HYDROGEN ENGINE IN PERSPECTIVE
Murray, R.G., and R.J. Schoeppel, (Oklahoma State University), and C.L. Gray, (Environmental Protection Agency, Ann Arbor, Mich.), 7th Intersociety Engineering Conference on Energy Conversion, San Diego, Calif., 72, Avail:TAC

This paper has two basic purposes; first, to report the latest performance and emission characteristics of the Oklahoma State University air breathing, hydrogen burning engine and second, to place this engine in perspective in the future total energy picture. Since the production of energy and creation of air pollution are interrelated aspects of the same problem a discussion of one must give consideration to the effects of the other.

Four years ago development started on the first of a series of hydrogen fueled engines at Oklahoma State University. Early data indicated that a hydrogen fueled engine should yield torque, power, and efficiency values comparable to an equivalent spark ignition engine. The performance outlook of this first engine was so optimistic that the Air Pollution Control Office, Environmental Protection Agency funded an effort to study further design improvements and to test its emission characteristics.

Data from recent tests has indicated that it should be possible with today's technology to fabricate a reliable engine to power an automobile or truck. It is expected that this vehicle would have adequate range, normal size, and would fall within a complexity and reliability range similar to today's gasoline counterpart. In addition, it would emit no measurable hydrocarbons, organic, or sulfur compounds. Oxides of nitrogen emission below 1976 standards would be expected.

The successful conversion of four single-cylinder gasoline engines to run on hydrogen, along with very encouraging performance and emission measurements, has led to the conceptual design of an energy management system aimed at a permanent solution to the energy/ecology dilema. It is the purpose of this paper to place in perspective the outlook for the use of hydrogen as a motor fuel as one facet of this system. Involved is an impending energy crisis which is on a collision course with ecological standards because of a natural inter-relationship.

The probability of the global energy/ecology management system being hydrogen-centered will also be discussed. (EMISSION, ENERGY, INTERNAL-COMBUSTION, POLLUTION)

H73 32005* THE HYDROGEN I.C. ENGINE - ITS ORIGINS AND FUTURE IN THE EMERGING ENERGY-TRANSPORTATION-ENVIRONMENT SYSTEM

Weil, K.H., (Stevens Institute of Technology, Hoboken, N.J.), 7th Intersociety Engineering Conference on Energy Conversion, San Diego, Calif., 72, Avail:TAC

It is not the I.C. engine that pollutes our air, but its present fuels. Lower efficiency cycle automotive engines and catalytic exhaust treatment are technically unsound and waste remaining hydrocarbon reserves.

The Hydrogen Internal Combustion Engine's multi-fuel version is the key component of the evolving comprehensive Electricity - Hydrogen energy system, controlling air pollution and the electric utilities' predicament with low load factors, transmission and energy storage.

Any pragmatic transition rate in time and regional geography may be programmed with this engine - not excluding other promising approaches.

To make sound decisions, in time, about realistic compromises based on facts, preparations should begin now. (POLLUTION, EMISSION)

H73 32006* ON THE HIGHER ENERGY FORM OF WATER (H_2O*) IN AUTOMOTIVE VEHICLE ADVANCED POWER SYSTEMS
Escher, W.J.D., (Escher Technology Associates, St. Johns, Mich.), 7th Intersociety Engineering Conference on Energy Conversion, San Diego, Calif., 72, Avail:TAC

The hydrogen-oxygen (stoichiometric) bireactant combination, separately tanked and fed to an advanced-design automotive powerplant is addressed. This "higher energy form" of water is compared in terms of: onboard vehicle stored energy, volume, mass and cost with conventional systems employing gasoline- and hydrogen-fueled internal combustion engines.

The higher energy form of water, H_2O*, will be produced in abundance in future water-splitting hydrogen production facilities using nuclear or solar energy as being envisioned for the post fossil-fuel age "Hydrogen Economy." However, the majority of hydrogen energy conversion system studies so far have addressed hydrogen's reaction with air, not oxygen.

Relating heavily to a number of papers presented at the previous IECEC, the paper attempts to make the point that: not only H_2- airbreathing systems, but also H_2O* nonairbreathing energy conversion systems should be considered for future automotive vehicle propulsion. Particularly, if high-temperature H_2O* - fueled power cycles (3000-4000 $^\circ$F) can be developed, a savings in national energy resources of the order of 50 percent of that needed for present gasoline-fueled automobiles, and future hydrogen-fueled, but conventionally powered vehicles is technically possible.

Additionally, since the sole effluent in H_2O* combustion is the lower energy form of water, viz., H_2O, this has strikingly positive environmental ramifications. Clearly, a bold new opportunity is presented to the engineering community as it strives for energy conversion systems of the future which must adhere to the precept of benign

environmental interaction.
(OXYGEN, EFFICIENCY, POLLUTION, TEMPERATURE)

H73 32007 HYDROGEN-FUELED INTERNAL COMBUSTION ENGINE
Anon, Mechanical Engineering, V 93:40 Nov 71, Avail:TAC

University of Miami engineers are embarking on a research program to perfect a hydrogen-fueled internal-combustion automobile engine developed by a Hollywood, Fla., businessman.
(ENGINE, COMBUSTION)

H73 32008 LIQUID HYDROGEN AS A MOTOR FUEL
Anon, Chemistry, V 45:26 Ja 72, Avail:TAC

At one time, liquid hydrogen was merely a laboratory curiosity. But now, because of its use in atomic research and the space program, production in this country has reached an estimated 150 tons per day. Consequently, cost of production has declined - a liter of liquid hydrogen costs about the same as a liter of gasoline.

Some day, liquid hydrogen might be used as a fuel for motor vehicles. Environmental pollution from internal combustion engines would be completely eliminated because water is the sole combustion product.
(PRODUCTION, COST, POLLUTION)

H73 32009* SURVEY OF HYDROGEN'S POTENTIAL AS A VEHICULAR FUEL
Austin, A.L., (California University, Livermore, Calif., Lawrence Livermore Laboratory), N73-16766, UCRL-51228, Je 72, Avail:NTIS, Avail:TAC

The problems and potential of various hydrogen-based mobile fuel systems and the likely economic impact of a nationwide conversion to hydrogen are examined. The basic technical problem is to store enough hydrogen per vehicle in a small enough volume. The prospects of using gaseous and liquid hydrogen with air, liquid hydrogen with liquid oxygen, and hydrogen stored in metal hydrides in an internal combustion engine are analyzed. The practical feasibility is found to be marginal but with enough potential to justify an ongoing research program.
(STORAGE, IMPACT, ECONOMIC, HYDRIDE, ENGINE)

H73 32010 CLEAN AUTOMOTIVE FUEL: ENGINE EMISSIONS USING NATURAL GAS, HYDROGEN-ENRICHED NATURAL GAS, AND GAS MANUFACTURED FROM COAL (SYNTHANE)
Eccleston, D.B., and R.D. Fleming, (Bureau of Mines, Bartlesville, Okla., Energy Research Center), N72-18761, TPR-48, Fe 72, Avail:NTIS, Avail:TAC

Natural gas and mixtures of natural gas and hydrogen were used as fuels in a laboratory engine to determine the relationship of emissions to air-fuel ratio and to establish practical lean limits for air-fuel ratio. Synthetic gas manufactured from coal (Synthane) and natural gas were used as fuels in a vehicle to obtain comparative data on emissions and performance. Results showed that lean limits for air-fuel ratio when using hydrogen-enriched natural gas were extended significantly beyond that of natural gas. Synthane produced exhaust that was significantly less reactive than exhaust from nautral gas. With lean air-fuel ratios, the acceleration performance of a vehicle fueled with Synthane was improved over its performance when fueled with natural gas.
(PERFORMANCE, MIXTURE, POLLUTION)

H73 32011* ALTERNATIVE FUELS FOR CONTROL OF ENGINE EMISSION
Starkman, E.S., R.F. Sawyer, R. Carr, G. Johnson, and L. Muzio, (University of California, Berkeley, Calif.), Journal of Air Pollution Control Ass., V 20:87-92 N2 70

Theoretical and exploratory investigation has shown that spark ignition engine fuel compound can have a profound effect on exhaust content of potential air pollutants. CO and NO are 2 of these products of engine combustion which were studied. Considered were alcs., H, NH_3, so-called reformed hexane, and a few selected representative hydrocarbons. Energy content and C to H ratio both are influential in determining CO and NO concentrations at peak equilibrium conditions, and thus how much is exhausted to the atmosphere. Neither H nor NH_3 can produce CO (or unburned hydrocarbons) and theoretically should also give less NO, at most conditions, than do hydrocarbons. Measurement of the exhaust, while burning NH_3, shows that there is actually an increase in NO compared to hydrocarbons.
(POLLUTION, INTERNAL COMBUSTION, AMMONIA)

H73 32012 HYDROGEN AS A FUEL AND THE FEASIBILITY OF A HYDROGEN-OXYGEN ENGINE
Karim, G.A., (University of Calgary, Alta), and M.E. Taylor, SAE Preparation, N730089 for Meeting Ja 8-12 '73

A preliminary investigation was made into the use of hydrogen-oxygen mixtures in spark ignition engines. Following a literature survey regarding the combustion characteristics of hydrogen, a computer program based on a constant-volume combustion engine cycle was used to evaluate the overall performance of an engine. Another program, which considered chemical reaction kinetics, was used to predict the onset of autoignition in mixtures undergoing compression in an engine. The system would be supplied with a stoichiometric hydrogen-oxygen mixture while excess hydrogen would be circulated within to provide a rich mixture to the engine. Trim supplies of hydrogen and oxygen could be used to make adjustments to the equivalence ratio as required. Water would be removed from the system at the condenser and would be the only exhaust product.
(POWER, INTERNAL COMBUSTION, COMPUTER)

H73 32013 CONVERTED IC ENGINE RUNS ON HYDROGEN
Anon, Industrial Resources, V 14:35 Je 72

Successful and safe conversion of engines from gasoline to hydrogen fuel has been achieved by a group of scientists at Oklahoma State University.

The advance was reported by Dr. Roger J. Schoeppel, chairman of the energy resources program at Oklahoma State, who claims that it provides a means of killing two birds with one stone - the birds being the automobile pollution problem and the nation's energy crisis.
(ENGINE, CONVERSION)

H73 32014* EMISSION AND PERFORMANCE CHARACTERISTICS OF AN AIR-BREATHING HYDROGEN-FUELED INTERNAL COMBUSTION ENGINE
Murray, R.G., and R.J. Schoeppel, Intersociety Energy Conversion Engineering Conference, Boston, Mass., Aug 71, Avail:TAC

The paper reports on the performance and emission characteristics of a standard production gasoline engine which has been converted to run on an unconventional fuel: hydrogen.

Three years of development efforts at Oklahoma State

University, with support from Environmental Protection Agency during the last year, have culminated in the design of an internal combustion engine which appears to have the capability of meeting current and 1975 Federal Emission Standards. Not only is the engine capable of operating over a wider range of conditions and with lower NOX emissions than its gasoline counterpart, but it is also capable of exceeding the manufacturer's maximum power rating. Performance data and emission characteristics are presented to support these claims. Details of the engine's design are also included.
(POWER, STANDARD, POLLUTION)

H73 32015* DESIGN CRITERIA FOR HYDROGEN BURNING ENGINES
Schoeppel, R.J., (Oklahoma State University, Stillwater, Okla., School of Mechanical and Aerospace Engineering), Final Report APTD-0901, Oct 71, Avail:TAC

Laboratory experiments have demonstrated hydrogen not only to be an excellent substitute for conventional hydrocarbon fuels in internal combustion engines but also to have the inherent qualities necessary for a permanent solution to the air pollution problem. This conclusion was reached after extensive tests were conducted with an air-cooled single-cylinder gasoline engine converted to run on hydrogen. The engine's operational characteristics compared favorably with those of its gasoline counterpart. Furthermore, the NOX content of the exhaust was an order of magnitude lower than that expected from a gasoline engine. Trace amounts of unburned hydrocarbons and carbon oxides, also present, originated from the lubricating oil. It was concluded from these experiments that a multi-cylinder automotive engine converted to run on hydrogen should be able to meet the 1975/76 Federal Emission Standards.
(INTERNAL COMBUSTION, FOSSIL, FUEL, POLLUTION, EXHAUST)

H73 32016 PROSPECTS FOR HYDROGEN-FUELED VEHICLES
Schoeppel, R.J., (Oklahoma State University, Stillwater, Oklahoma), Chemical Technology, V 2:476-80 N8 Aug 72, Avail:TAC

The conversion of vehicles from conventional fuels to hydrogen is forecast to fulfill a more viable long-range solution to the air pollution problem than any previously proposed. The prospects for development of a

total energy system that produces hydrogen from an abundant natural resource, water, and replenishes this supply upon combustion in an engine whose emissions are pollution-free, appears to be a worthwhile effort to pursue.
(AUTOMOBILE, ENERGY, POLLUTION)

H73 32017* THE UCLA HYDROGEN CAR: DESIGN, CONSTRUCTION, AND PERFORMANCE
Finegold, J.G., F.E. Lynch, N.R. Baker, R. Takahashi, and A.F. Bush, (University of California, Los Angeles, Calif.), Automobile Engineering Meeting, Detroit, Mich., May 14-18 '73, Paper No. 730507, Avail:TAC

In order to offer a reasonable solution to environmental problems, a vehicle was built for entry in the 1972 Urban Vehicle Design Competition. The heart of this alternative to today's vehicles is a standard V-8 engine modified to use hydrogen as a fuel. This vehicle easily beats the 1976 federal exhaust emissions standards. Novel features of the modified 1972 Gremlin include a roll cage that lies above the roof and doubles as a luggage rack; foam between inside and outside body panels for body stiffness and impact absorption; proved 5 mph (2.2 m/s) crash bumpers utilizing popcorn as the energy-absorbing material; an engine parameter monitoring system; and improved visibility, lighting, braking, handling, and driver safety. The vehicle continues to be tested, is driven frequently, and interacts well in the urban environment with the myriad of traffic situations encountered in Los Angeles.
(ENVIRONMENT, AUTOMOBILE, EMISSION)

H73 32018 HYDROGEN-POWERED CARS MAY BEAT POLLUTION STANDARDS
Anon, The Albuquerque Tribune, Sept 18 '73, p A-1, from 1973 New York Times News Service, Avail:TAC

A radical system aimed at meeting the legal limitation on auto engine emissions is being developed by the National Aeronautics and Space Administration.

The concept involves the use of hydrogen as an additive to gasoline in modified versions of standard internal combustion engines.

It has shown "promising" results in laboratory tests but will not help power an auto for another two months.

The development is being carried out by the space

agency's Jet Propulsion Laboratory whose Ranger and Surveyor vehicles scouted the moon as a prelude to the manned lunar landings.
(AUTOMOBILE, EMISSION)

H73 32019   LOS ALAMOS LAB MAKING HYDROGEN-POWERED TRUCK
Anon, The Albuquerque Tribune, Sept 22 '73, p A-1, Avail:TAC

Scientists at Los Alamos Scientific Laboratory (LASL) here hope to put a hydrogen-powered pickup truck on the road by November.

The Atomic Energy Commission has given permission to Dr. Fred Edeskuty of LASL and several of his colleagues to proceed with necessary modifications on a 1972 Dodge half-ton pickup truck for conversion from gasoline to hydrogen fuel.
(INTERNAL COMBUSTION, RESEARCH)

H73 32020*   LOGISTICS, ECONOMICS, AND SAFETY OF A LIQUID HYDROGEN SYSTEM FOR AUTOMOTIVE TRANSPORTATION
Stewart, W.F., and F.J. Edeskuty, (Los Alamos Scientific Laboratory, Los Alamos, N.M.), Intersociety Conference on Transportation, Denver, Colo., Sept 23-27 '73, Avail:TAC

A hydrogen powered automobile plays a prominent role in many of the proposed solutions for the energy crisis. The development of a hydrogen powered automobile involves the development of a hydrogen fueled engine, a hydrogen storage system on board the vehicle, and a hydrogen production and distribution system. Several design aspects, cost estimates, and safety considerations are discussed for a liquid hydrogen production and distribution system. The amount of liquid hydrogen that must be produced annually to replace the gasoline consumed by automobiles is estimated. This estimate includes boiloff, cooldown, and transfer losses from the production plants, transport trailers, service stations, and automobiles.
(INTERNAL COMBUSTION, POLLUTION, EFFICIENCY, STORAGE)

H73 32021* PARTIAL HYDROGEN INJECTION INTO INTERNAL COMBUSTION ENGINES EFFECT ON EMISSIONS AND FUEL ECONOMY
Breshears, R., H. Cotrill, and J. Rupe, (Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif.), Environmental Protection Agency, The First Symposium on Low Pollution Power Systems Developement, Ann Arbor, Mich., Oct 14-19 '73

A High-Efficiency Low-Emission Engine Development Project is currently underway at the Jet Propulsion Laboratory of Caltech, sponsored by NASA as part of the Technology Applications and Aeronautics Programs. This report describes the concept and current status for the first 5 months of a 7-month feasibility demonstration initial project phase.

The system under development has the potential of meeting the EPA 1977 Standards, while improving fuel economy as compared with uncontrolled engines. It uses current fuels and engines, will have similar response characteristics to current engines, and will be low in cost considering both initial cost and fuel savings.

Basically, the concept is to use small amounts of hydrogen to allow burning of gasoline at ultra-lean conditions. The hydrogen is generated aboard the vehicle by feeding gasoline, water, and air to a hydrogen generator which produces hydrogen and carbon monoxide.

The most critical development of this system is the hydrogen generator. The design chosen is similar to that used for commercial production of hydrogen from hydrocarbons. (The process is called steam reforming.) In this process gasoline and water are heated to 1500 to 2000^{o} F, forming hydrogen, carbon monoxide, plus various hydrocarbons and diluents. Heat is supplied by pumping air into the generator and burning a portion of the gasoline. The reaction takes place in a thermal reactor without the use of catalysts. This design allows rapid start-up since the thermal inertia can be made small, allows the use of low-cost materials since the container need not operate at reaction temperatures, and avoids potential catalyst poisoning problems. The maximum theoretical hydrogen yield for this type of generator is 29% as compared with current generators which yield 15-20% hydrogen output. An operating condition has been found where soot is not produced. Future development will be directed toward completely eliminating the need for water. When the current generator is operated without water, large quantities of soot are produced. The current generator has a conversion efficiency of about 67%.

The overall status of the JPL system is:

1) V-8 engine tests show high efficiency, low NO_x and CO emissions.
2) Hydrogen generation by partial oxidation has been demonstrated.
3) V-8 engine operation on hydrogen generator products has been demonstrated.

Future plans include:

1) Completing the bottled hydrogen car buildup and testing.
2) Hydrogen generator car buildup and testing.
3) Reduction of hydrocarbon emissions.
4) Reduction in hydrogen generator size and complexity.

Current plans call for completion of the feasibility phase by December 15, 1973 and final Project completion in December 1975.

Other areas of application for hydrogen injection include gas turbines, atmospheric pressure continuous combustors, and increasing the flammability of fuels for a wide range of engines.
(HYDROGEN, INJECTION, INTERNAL COMBUSTION, ENGINE, EMISSION, FUEL)

H73 32022* HISTORY OF HYDROGEN-FUELED INTERNAL COMBUSTION ENGINES
Billings, R.E., and F.E. Lynch, (Energy Research Inc., Provo, Utah), Publication No. 73001, Apr 73, Avail:TAC

A survey of historical and current work with hydrogen fuel in internal combustion engines points the way to avoidance of the operating difficulties often encountered with this fuel. Hydrogen engines with proper carburetion and ignition systems are capable of remarkable efficiencies and negligible emissions without the use of complex auxiliary equipment but require more displacement than gasoline engines for equal power. Conventional engines may be converted to hydrogen fuel without significant loss of power through the use of water induction and near-stoiciometric mixtures for full throttle operation.
(HISTORY, ENGINE)

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H73 32023* PERFORMANCE AND NITRIC OXIDE CONTROL PARAMETERS OF THE HYDROGEN ENGINE
Billings, R.E., and F.E. Lynch, (Energy Research Inc., Provo, Utah), Publication No. 73002, Apr 73, Avail:TAC

The performance and nitric oxide emission characteristics of a 4-cycle engine at varying equivalence ratio are shown for hydrogen and for iso-octane under identical test conditions except for spark advance. Important results of earlier studies of hydrogen engines are discussed and the independent effects of exhaust recirculation, water induction and ignition timing on nitric oxide emission are reported for hydrogen operation at a fixed equivalence ratio.
(PERFORMANCE, NITRIC OXIDE, ENGINE)

H73 32024 NASA TESTING HYDROGEN INJECTION ENGINE CONCEPT
Anon, (NASA, Washington, D.C.), Press Release No. 73-184, Sept 73

NASA has initiated an experimental program to demonstrate the feasibility of an internal combustion engine concept which appears to significantly reduce pollution emissions while increasing engine efficiency.

The hydrogen injection system, using a mixture of hydrogen gas, air and gasoline vapor to power internal combustion engines, could eliminate the need for treating exhausts with catalytic mufflers. The Jet Propulsion Laboratory automotive project has been funded by NASA.
(AUTOMOBILE, POLLUTION, INJECTION ENGINE)

H73 32025 THE DEPARTMENT OF TRANSPORTATION HAS GRANTED $60,000 FOR HYDROGEN-FUELED-CAR RESEARCH
Anon, (Chementator), Chemical Engineering, Nov 12 '73, Avail:TAC

The Department of Transportation has granted $60,000 for hydrogen-fueled-car research, to help support a one-year study of the concept at the University of California, Los Angeles. There has already been considerable delving into hydrogen as an automotive fuel, by researchers at UCLA and elsewhere. But the federal government has up to now shown little interest in the idea, apart from some partially related work at Atomic Engergy Commission laboratories. Thus, the $60,000 grant is the first in this field by DOT; and, as far as DOT knows, by any federal agency.
(AUTOMOBILE, RESEARCH, FUEL)

H73 32026 CITY CAR WITH H -AIR FUEL CELL/LEAD BATTERY (ONE YEAR OPERATING EXPERIENCES)
Kordesch, K.V., (Union Carbide Corp., Cleveland, O.), 1971 Intersociety Energy Conversion Engineering Conference Proceedings, p 38, SAE Paper 719015, Aug 71, Avail:TAC

An urban automobile powered by a hybrid system consisting of a 33-kWh fuel cell battery and a secondary battery of 25-kW peak power output is described.

This 2000-lb., four-passenger car has a driving range of 200 miles, and can be refueled in three minutes. The power system was designed to give the vehicle the acceleration of a conventional small car in stop-and-go traffic and also extend 50-mph driving ability.

Performance data collected during actual operation of the vehicle in summer and winter weather, hill climbing, and long-distance driving will be presented.

Maintenance needs, cost of fuel cell operation, reliability, and life-expectancy questions relating to the prime power source and the secondary battery system will also be discussed.

(AUTOMOBILE, FUEL CELL, PERFORMANCE, POWER, BATTERY)

H73 33000 ANALYSIS OF THE SELF-IGNITION OF A TURBULENT GAS JET IN A STREAM OF OXIDIZING AGENT
Strokin, V.N., (USSR), Inzh.-Fiz. Zh., V 22:480-7 N3 72

An approximate method is proposed for calculating the ignition point of a free turbulent boundary layer formed by a hot-gas jet and concurrent oxidizing-agent flow. Calculated and exptl. data are compared on gasoline-air and H-air mixtures.
(JET, ANALYSIS)

H73 33001 HYDROGEN-OXYGEN CHEMICAL REACTION KINETICS IN ROCKET ENGINE COMBUSTION
Hersch, M., (NASA, Lewis Research Center, Cleveland, O.), N68-11642, NASA-TN-D-4250, Washington, Dec 67, HC $3.00/ MF $0.65, Avail:TAC

Hydrogen-oxygen reaction times and concentration histories of chemical species during reaction were calculated for rocket combustor conditions. Calculations were made for oxidant-fuel weight ratios of 1 and 10 and initial reactant temperatures of 1200° to $2500^{\circ}K$ at a chamber pressure of 20 atmospheres. The reaction time varied from about 0.01 second at $1200^{\circ}K$ to a few microseconds at $2500^{\circ}K$. Calculations were made by using a numerical integration program and an analytical solution. The reaction mechanism used included five chain branching reactions and three recombination-type reactions.
(NUMERICAL SOLUTION)

H73 33002* ANALYTICAL CHEMICAL KINETIC STUDY OF THE EFFECT OF CARBON DIOXIDE AND WATER VAPOR ON HYDROGEN-AIR CONSTANT-PRESSURE COMBUSTION
Erickson, W.D., and G.F. Klick, (NASA, Langley Research Center, Langley Station, Va.), N70-23548, NASA-TN-D-5768, Washington, Apr 70, Avail:TAC

Numerical solutions have been obtained for the finite-rate constant-pressure combustion of stoichiometric hydrogen-air mixtures in the presence of small to moderate amounts of carbon dioxide CO_2 and water vapor H_2O. Computations have been carried out for initial mixture temperatures of 1150 K, 1250 K, and 1500 K at a pressure of 1 atmosphere with additional computations for pressures of 0.5 atmosphere and 2 atmosphere at an initial mixture temperature of 1250 K. This study suggests that although all the conditions for hydroburning hypersonic ramjet engine tests in a combustion-heated wind tunnel cannot be matched to clean-air flight conditions, the chemical kinetic effects of CO_2 and H_2O are

small enough to allow useful interpretation of test results for initial temperatures of 1250 K or higher and pressures near 1 atmosphere or less.
(REACTION, TEMPERATURE, NUMERICAL SOLUTION)

H73 33003 REDUCTION OF DRAG OF A PROJECTILE IN A SUPERSONIC STREAM BY THE COMBUSTION OF HYDROGEN IN THE TURBULENT WAKE
Baker, W.T., T. Davis, and S.E. Matthews, (Johns Hopkins Univ., Silver Spring, Md., Applied Physics Lab.), Report No. CM-673, Je 4 '51, Avail:TAC

An experimental evaluation was made of the effect of combustion of hydrogen with the wake air on the drag of a projectile. The base drag was reduced by about two-thirds, and hence total drag of a flight unit may possibly be reduces one-third, by the use of a minimum of 6.4 percent of the stoichiometric requirement of the air swept by the maximum cross-sectional area.
(DRAG, TURBULENCE)

H73 33004 SPECIFIC HEAT RATIOS AND ISENTROPIC EXPONENTS FOR CONSTANT-VOLUME COMBUSTION OF STOICHIOMETRIC MIXTURES OF HYDROGEN-OXYGEN DILUTED WITH HELIUM HYDROGEN
Benoit, A., (Toronto Univ., Ontario, Canada, Institute for Aerospace Studies), Report No. UTIAS-TN-102, Ja 67, Avail:TAC

The report includes the calculation of the equilibrium specific heats, the equilibrium specific heat ratios, the isentropic exponents, and the corresponding values of the speeds of sound. For convenience, the final-to-initial temperature ratio and the final-to-initial pressure ratio are also included in the tables. The results are presented for helium and hydrogen dilution respectively.
(THERMODYNAMICS)

H73 33005 SOME FUNDAMENTAL PROBLEMS ON THE COMBUSTION OF LIQUID OXIDIZERS IN HYDROGEN
Tarifa, C.S., and P. Perez del Notario, (Instituto Nacional de Tecnica Aeroespacial, Madrid, Spain), Report No. AFOSR-68-1165, International Astronautical Federation Congress, 27th, Madrid, Spain, Mar 68, HC $3.00/MF $0.65, Avail:TAC

The object of the paper is the study of the basic process of combustion of single oxidizer droplets in a quiescent hydrogen atmosphere. This case cannot be included in a general theoretical study of droplet combustion owing to the specific properties of the hydrogen. Its low density and low molecular weight make diffusion conditions especially critical and the assumption of taking average values

for gas density and for transport coefficients regardless of mixture composition, which is normally admitted in droplet combustion studies, may introduce important errors for the case of hydrogen and it is shown in the paper.
(DROPLET, DIFFUSION)

H73 33006* THERMAL RADIATION FROM BURNING HYDROGEN PLUME
Martin, P.E., ISA-20th Annual Conference, Oct 4-7 '65

Liquid hydrogen passes through nuclear reactor, is ejected skyward, and ignited; its thermal radiation pattern is to be studied so that expected heat radiations may be calculated for locations near test pad; several sensors, commercial and homemade, are used to determine thermal radiation received at discrete points; from measured radiation, range, assumed plume height, and sensor orientation and height, average thermal emitting power per unit distance along vertical plume is calculated.
(HEAT, TEMPERATURE, EMISSION)

H73 33007 THERMODYNAMIC AND TRANSPORT PROPERTIES OF FUEL-OXYGEN COMBUSTION SYSTEMS
Davies, R.M., H.E. Toth, (Midland Research Station, Gas Council, Solihull, England), Proc. Symposium Thermophysics Prop., 4th, 68, p 350-9, edited by Moszynski, J.R., (American Society of Mechanical Engineers, New York, N.Y.)

Thermodynamic and transport properties for the stoichiometric combustion products of H, CH_4, C_3H_8, C_2H_2 and CO when burned with pure O at 1-atmosphere pressure are presented in the temperature range 400-3500 K. The values of any given temperature are in sequence from H to CO. Thermodynamic data are in good agreement with previously published results. The effectiveness of Lewis numbers based solely on H-atom diffusion was compared with that of the generalized Lewis number.
(THERMODYNAMICS, COMBUSTION)

H73 33008 UPPER SELF-IGNITION LIMIT OF HYDROGEN IN OXYGEN
Vedeneev, V.I., Iu.M. Gershenzon, and O.M. Sarkisov, Fizika Goreniia i Vzyva, V 8:403-408, Sept 72, Avail:TAC

Theoretical considerations are given to explain the available experimental data concerning the upper self-

ignition limit of hydrogen in oxygen. A set of 10 chemical reactions and a system of differential equations with a variable HO2 function are used to develop a kinetic scheme accomodating both qualitatively and quantitatively the results of various authors.
(REACTION, THERMODYNAMICS)

H73 33009 COMPUTER PROGRAMS FOR THE MIXING AND COMBUSTION OF HYDROGEN IN AIR STREAMS
Siegelman, D., and O. Fortune, (General Applied Science Labs., Inc., Westbury, N.Y.), N67-31455, NASA-CR-85823, Jl 66, Avail:TAC

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.
(CHAMBER, VENT, EXHAUST, NUMERICAL SOLUTION)

H73 33010 INVESTIGATION OF THE REACTION OF INCOMPLETE OXIDATION OF METHANE CATALYZED BY A HYDROGEN FLAME
Gudkov, S.F., (Foreign Technology Division Wright-Patterson, AFB, O.), Report No. FTD-MT-24-1823-71, Ja 25 '72, PC $3.00/MF $0.95, Avail:TAC

A method has been proposed for the initiation of the reaction of incomplete oxidation of methane by free radicals which are formed during the burning of hydrogen. A hypothetical reaction mechanism has been given for the incomplete oxidation of methane, catalyzed by the free radicals which are formed at the moment of the burning of hydrogen.
(COMBUSTION)

H73 33011 ACTIVATION ENERGIES AND RATE CONSTANTS COMPUTED FOR THE COMBUSTION OF HYDROCARBON AND HYDROGEN FUELS
Mayer, S.W., and L. Schieler, (Aerospace Corp., El Segundo, Calif., Lab Operations), Report No. TR-0158(9210-02)-3 SAMSO-TR-68-188, Mar 68, HC $3.00/MF $0.65, Avail:TAC

A method is described for computing activation energies and rate constants of bimolecular combustion reactions of atomic oxygen and molecular oxygen with hydrocarbon and inorganic fuels. The procedure is a modification of the transition-state bond-energy method previously applied in this series of investigations of rate data prediction for propellant performance and reentry nonequilibrium computer programs. Modification of the method was necessary in the investigation of combustion by O or O2 in order to include the effect of the triplet ground states on quantum-mechanical repulsion. The modified procedure provided much better agreement with experiment than did the method that neglects the triplet nature of ground-state O or O2. Computations of activation energies and rate constants were also made for combustion reactions of fuels with excited electronic states of oxygen that are likely to be more significant in high-temperature reactions.
(ACTIVATION, KINETICS, HYDROCARBON)

H73 33012 KINETICS OF HYDROGEN-OXYGEN AND HYDROCARBON-OXYGEN REACTIONS
Baldwin, R.R., and R.W. Walker, (Hull Univ., Dept. of Chemistry, England), Report No. AFOSR-68-2666, Oct 68, HC $3.00/MF $0.65, Avail:TAC

This report summarizes progress made on three main areas: (1) Further experimental studies of the hydrogen-oxygen and deuterium-oxygen reaction, together with the developemnt of computer programs to interpret the results. (2) Studies of the addition of ethane, propane, n- and isobutane, neopentane, tetraethylsilane and tetramethyl silane to slowly reacting hydrogen-oxygen mixtures. (3) The oxidation of acetaldehyde, propionaldehyde and butyraldehyde in aged boric-acid-coated vessels in the temperature range 400-500 C. These studies have provided valuable information on the mechanism of the oxidation, and on the reactions of H atoms, OH and HO2 radicals, and alkyl radicals.
(KINETICS, HYDROCARBON, REACTION)

H73 33013 A PRELIMINARY INVESTIGATION OF OXIDIZER-RICH OXYGEN-HYDROGEN COMBUSTION CHARACTERISTICS
Bailey, C.R., (NASA, Marshall Space Flight Center, Huntsville, Ala.), N67-11812, NASA-TN-D-3729, Washington, Dec 66, HC $2.00/MF $0.50, Avail:TAC

The operating characteristics of oxygen-hydrogen combustion were investigated over a propellant mixture ratio (O/F) band of 20 to 150. Firings were conducted in a 3600 pound thrust combustor at a chamber pressure of 1000 psia. Wedges fabricated from Inconel-X, Rene-41, and Waspalloy were placed in the exhaust of the combustor and subjected to the hot gases ranging in mixture ratio from 75 to 150. There were no significant heating problems with any of the combustor components.
(COMBUSTOR, EFFICIENCY)

H73 33014 CALCULATION OF IGNITION DELAYS IN THE HYDROGEN-AIR SYSTEM
Bascombe, K.N., (Explosives Research and Development Establishment, Waltham Abbey, England), Combustion and Flame, V 11:2-10 N1 Fe 67

The calculation of ignition delays of hydrogen-air mixtures between the limits of temperature 800 and 2000K, pressure 0.01 and 10 atmosphere and stoichiometric ratio 0.2 and 2.5 is considered. The simple model chosen involved 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 0.000001 mole/litre; this condition was used in an earlier theoretical treatment by Momtchiloff and also in an experimental study by Schott and Kinsey.
(MODEL, COMPUTER, REACTION)

H73 33015 CHEMICAL TRANSFORMATIONS IN A HYDROGEN-AIR MIXING LAYER
Leuchter, O., (NASA), Report No. ONERA-TP-981, NASA-TT-F-14633, Washington, Dec 72, (In French), HC $3.00, Avail:TAC

Chemical evolution in an air-hydrogen mixing layer was investigated. The confluence of two parallel flows of air and hydrogen was examined numerically in order to determine the conditons of self-ignition in the mixing layer. The calculations showed that the reaction zone is

limited to the stoichiometric region. For the two streams at the same temperature, the ignition length can be evaluated by neglecting the effects of lateral diffusion.
(COMPUTER, SELF-IGNITION)

H73 33016 COMBUSTION LIMITS OF HYDROGEN-OXYGEN-NITROGEN-STEAM MIXTURES
Greer, J.S., and R.L. Rankin, (MSA Research Corp., Evans City, Pa.), Final Report No. MSAR-68-109, Je 11 '68, Avail:TAC

The combustion limits of steam-diluted hydrogen-oxygen mixtures were determined at 1150 psig in a 0.5 cu ft stainless steel test cell.
(COMBUSTION, STEAM)

H73 33017 CONDITION OF THE MEDIUM BEFORE THE FLAME FRONT DURING THE INITIAL PHASE OF A COMBUSTION PROCESS
Salamandra, G.D., Thermophysical properties and gas-dynamics of high-temperature materials, Moscow, Izdatel'stvo Nauka, 72 p 122-130, Avail:TAC

High-speed photographic investigation of the combustion process in hydrogen-oxygen mixtures (with molecular ratios of 2:1 and 1:2) in a channel with circular cross section. The Topler schlieren method was used for medium motion visualization before the oncoming flame front. It was found that the gas flow rates in front of the oncoming flame were proportional to the flame surface area and that the distribution of gas flow parameters before the flame front was consistent with that of a simple wave in an ideal gas.
(OXYGEN, FLOW)

H73 33018 INVESTIGATION OF GH2-GO2 COMBUSTION
Calhoon, D.F., (Aerojet Liquid Rocket Co., Sacramento, Calif.), N72-20916, NASA-CR-125886, Ja 15 '72, Avail:TAC

Data from prototype GO2-GH2 injection elements were obtained and analyzed. The bulk of the testing was conducted with nonreacting propellants. N2 to simulate the O2 and H2. A limited number of tests were conducted in combusting environment, with the purpose of this testing being to evaluate the effects of combustion on cold flow mixture ratio and mass profiles.
(INJECTION, COMBUSTION)

H73 33019 NONEQUILIBRIUM CLUSTER FORMATION IN ROCKET EXHAUSTS
Oman, R.A., and V.S. Calia, (Grumman Aerospace Corp., Bethpage, N.Y.), N73-22893, RM-571, Mar 73, HC $3.00, Avail:TAC

The formation of large polymers in the vacuum plumes of large rocket engines was investigated. Monatomic species scaling concepts are applied to the molecular parameters of the water molecule in order to estimate its clustering behavior. The calculations indicate that the products of adiabatic combustion of hydrogen and oxygen will form clusters of several thousand water molecules if allowed to expand freely to vacuum. Experiments to define the basic cluster forming rates, cluster size distribution, and scaling relationships are described.
(POLYMER, WATER)

H73 33020 PHOTOCHEMICAL INDUCTION TIMES IN FLOWING MIXTURES OF HYDROGEN, OXYGEN, AND CHLORINE
Lawrence, L.R., (Ohio State Univ. Research Foundation, Columbus, O.), Journal of Astronautics Acta, V 17:763-70, 72, Avail:TAC

The objective of the presented work is to examine the properties of photochemical initiation of combustion in subsonic flows. This is a prelude to the study of photochemical initiation of supersonic combustion in hydrogen-oxygen-chlorine mixtures. It is felt that photochemically active ingredients might eventually be added to hydrogen-air mixtures such that the use of a proper light source could initiate supersonic combustion in SCRAMJET engines. The hydrogen-oxygen-chlorine mixture was chosen for this study since this mixture has been extensively researched, statically, in the past. A study was undertaken of the mixture under flowing conditions, starting with slow subsonic flows at 1 atmosphere. The mathematical approach derived in this paper may be applied for an analysis of the necessary condition in any flow, as a function of absorbed intensity and photochemical activity of the mixture.
(SUBSONIC, COMBUSTION)

H73 33021 QUANTITATIVE ANALYSIS OF LIQUID OXYGEN-LIQUID HYDROGEN COMBUSTION PRODUCTS
Boyd, G., and D.E. Kuivinen, (NASA, Lewis Research Center, Cleveland, O.), 24th Meeting of the Interagency Chemical Rocket Propulsion Group, Canoga Park, Calif., May 23-25 '67, N68-27610, NASA-TM-X-52304, HC $3.00/MF $0.65, Avail:TAC

A method was developed for the quantitative analysis of the combustion products obtained from the firing of a liquid oxygen-liquid hydrogen rocket engine. The fixed gases hydrogen, oxygen, nitrogen, and helium were determined by use of an analytical mass spectrometer.
(ANALYSIS, COMBUSTION)

H73 33022 EVALUATION OF HYDROGEN FUEL IN A FULL-SCALE AFTERBURNER
Groesbeck, D.E., W.R. Prince, and C.C. Ciepluch, (NASA, Lewis Research Center, Cleveland, O.), N65-12709, NACA-RM-E57H06, Washington, Sept 24 '57, Avail:TAC

A performance investigation using hydrogen fuel in a full-scale afterburner was conducted with particular study of fuel-injector configurations and afterburner length. A total of seven fuel-injector configurations, grouped by type as concentric ring or radial bar, were investigated at a burner-inlet velocity of approximately 600 ft/sec over a range of burner-inlet total pressure from 330 to 950 pounds per square foot absolute.
(PERFORMANCE, INJECTOR)

H73 33023 PERFORMANCE OF A 28-INCH RAMJET UTILIZING GASEOUS HYDROGEN AT A MACH NUMBER OF 3.6 ANGLES OF ATTACK UP TO 12°, AND PRESSURE ALTITUDES UP TO 110,000 FEET
Musial, N.T., J.J. Ward, and J.F. Wasserbauer, (NASA, Lewis Research Center, Cleveland, O.), N65-12712, NACA-RM-E58A23, Washington, May 19 '58, Avail:TAC

An investigation was conducted in the NACA Lewis 10- by 10-foot supersonic wind tunnel to evaluate the performance of a shrouded injector burner with perforated domes employed in a 28-inch ramjet using gaseous hydrogen as fuel.
(WIND TUNNEL, TRANSIENT)

H73-33024 LOW-PRESSURE PERFORMANCE OF A TUBULAR COMBUSTOR WITH GASEOUS HYDROGEN
Jonash, E.R., A.L. Smith, and V.F. Hlavin, (NASA, Lewis Research Center, Cleveland, O.), N65-33264, NACA-RM-E54L30a, Washington, May 9 '55, Avail:TAC

An investigation was conducted to determine the combustion performance characteristics of gaseous hydrogen fuel in a single tubular turbojet combustor.
(COMBUSTION, JET)

H73 33025 EXPERIMENTAL INVESTIGATION OF HOT-GAS SIDE HEAT-TRANSFER RATES FOR A HYDROGEN-OXYGEN ROCKET
Schacht, R.L., R.J. Quentmeyer, and W.L. Jones, (NASA, Cleveland, O.), N65-26412, Report No. NASA-TN-D-2832, Avail:TAC

The hot-gas side heat-transfer rates in a rocket nozzle were determined exptl. Transient temperature measurements were made at 5 axial locations in a Cu heat-sink nozzle having expansion and contraction area ratios of 4.64 with gaseous H and liquid O as propellants.
(NOZZLE, TRANSIENT)

H73 33026 COOLANT-SIDE HEAT-TRANSFER RATES FOR A HYDROGEN-OXYGEN ROCKET AND A NEW TECHNIQUE FOR DATA CORRELATION
Schacht, R.L., and R.J. Quentmeyer, (NASA, Lewis Research Center, Cleveland,O.), N73-18968, NASA-TN-D-7207, Mar 73, HC $3.00, Avail:TAC

An experimental investigation was conducted to determine the coolant-side, heat transfer coefficients for a liquid cooled, hydrogen-oxygen rocket thrust chamber. Heat transfer rates were determined from measurements of local hot gas wall temperature, local coolant temperature, and local coolant pressure. A correlation incorportating an integration technique for the transport properties needed near the pseudocritical temperature of liquid hydrogen gives a satisfactory prediction of hot gas wall temperatures.
(ROCKET, HEAT, TRANSFER)

H73 33027 COMBUSTION OF HYDROGEN AND METHANE TO SIMULATE EXPANSION OF STORABLE PROPELLANTS
Friedman, R., R.E. Gaugler, and E.A. Lezberg, (NASA, Lewis Research Center, Cleveland, O.), N68-33996, NASA-TM-X-52434, Washington 68, 4th Propulsion Joint Specialist Conference, Cleveland, O., Je 10-14 '68, AIAA, Avail:TAC

An experimental investigation of exhaust-nozzle temperature for the storable system 50% UDMH-50% hydrazine/nitrogen tetroxide was conducted using hydrogen and methane fuel burned in oxygen-enriched air to provide the same atomic constituents as the storable propellants.
(COMBUSTION, METHANE)

H73 33028 COMBUSTION OF FUEL-LEAN MIXTURES IN ADIABATIC, WELL-STIRRED REACTORS
Kydd, P.H., and W.I. Foss, (General Electric Co., Research Laboratory, Schenectady, N.Y.), Symposium (International) on Combustion, 10th, University of Cambridge, Cambridge, England, Aug 17-21 '64, Avail:TAC

Experimental investigation of a hitherto-unused combustion regime beyond the lean flammability limit, using a well-insulated, well-stirred reaction volume as a combustor. The combustion of H_2, CO, CH_4, C_2H_4, C_3H_8, and mixtures of these has been studied in this regime at pressures up to 2 atmospheres in three quite different reactors. A qualitative explanation of the results in terms of the currently accepted mechanism of hydrogen combustion is presented.
(COMBUSTION, REACTOR)

H73 33029 BRIEF STUDIES OF TURBOJET COMBUSTOR AND FUEL-SYSTEM OPERATION WITH HYDROGEN FUEL AT -400° F
Straight, D.M., A.L. Smith, and H.H. Christenson, (NASA, Lewis Research Center, Cleveland, O.), N65-12708, NACA-RM-E56k27a, Washington, Mar 7 '57, Avail:TAC

A single J-33 combustor and an experimental tubular combustor incorporating a fuel vaporizer were operated with gaseous hydrogen at temperatures slightly above the boiling point of the fuel. Data were obtained to explore possible effects of the fuel temperature on combustor performance and on the control and measurement of fuel flow.
(EFFICIENCY, VAPOR)

H73 33030 AXIAL AND CIRCUMFERENTIAL VARIATIONS OF HOT-GAS-SIDE HEAT-TRANSFER RATES IN A HYDROGEN-OXYGEN ROCKET
Schacht, R.L., and R.J. Quentmeyer, (NASA, Lewis Research Center, Cleveland, O.), N71-30738, NASA-TN-D-6396, Jl 71, Avail:TAC

An experimental investigation was conducted to determine the axial and circumferential variations of heat transfer coefficients in two rocket thrust chambers.
(HEAT, ROCKET, TRANSFER)

H73 33031 AN INTRODUCTION TO HEAT TRANSFER IN HYDROGEN/OXYGEN ROCKET COMBUSTION CHAMBERS
Ziebland, H., (Explosives Research and Development Establishment, Waltham Abbey, England), N68-22816, ERDE-1/S/66, Apr 29 '66, HC \$3.00/MF \$0.65, Avail:TAC

A brief introduction to heat transfer processes between the combustion gases and the surrounding cooled walls of a hydrogen/oxygen rocket engine is presented. A fairly comprehensive review is given of known compilations of thermodynamic and transport property data for the hydrogen/oxygen propellant. Effects of undeveloped flow conditions and of physico-chemical phenomena (recombination) on convective heat transfer are discussed, and some recent, yet unpublished results on radiative heat transfer, and on aerodynamic effects on convection in hydrogen/oxygen combustion chambers are presented. In view of these recent experimental observations the importance of extending heat transfer research to the mixing and reaction zone (non-equilibrium areas) of a combustion chamber is pointed out.
(TRANSPORT, CONVECTION, FLOW)

H73 33032 SUPERSONIC COMBUSTION AND BURNING IN RAMJET COMBUSTORS
Edse, R., (Ohio State University Research Foundation, Columbus, O.), Report No. OSURF-2153-3, Je 70, Avail:TAC

Induction distances, transient pressures, and wave propagation rates were determined in cylindrical tubes for detonation waves in stoichiometric hydrogen-oxygen mixtures initially at one atmosphere and temperatures ranging from 300K down to 123K.
(TRANSIENT, INDUCTION, SHOCK)

H73 33033 STEADY-STATE ROCKET COMBUSTION OF GASEOUS HYDROGEN AND LIQUID OXYGEN. PART II: ANALYSIS FOR COAXIAL JET INJECTION
Combs, L.P., and M.D. Schuman, (Rocketdyne, Canoga Park, Calif.), N66-14456, AFOSR-65-1319, Mar 65, Avail:TAC

Simultaneous equations describing rocket propellant injection, atomization, mixing, vaporization, and combustion are formulated for a cylindrical liquid oxygen jet surrounded by an annual gaseous hydrogen stream.
(ROCKET, COMBUSTION)

H73 33034 AN EXPERIMENT ON PARTICULATE DAMPING IN A TWO-DIMENSIONAL HYDROGEN-OXYGEN COMBUSTOR
Heidmann, M.F., and L.A. Povinelli, (NASA, Lewis Research Center, Cleveland, O.), N68-11044, NASA-TM-X-52359, 4th Combustion Conference, Menlo Park, Calif., Oct 2-13 '67, Avail:TAC

Aluminum particles (5μ mean diameter) were injected into a small circular combustor by a secondary flow process used for transverse mode stability rating. Small mass concentrations of aluminum were found to be effective in suppressing instability. A critical concentration of 2/100 percent was noted below which the effect was destabilizing.
(STABILITY, CONCENTRATION)

H73 33035 CHEMICAL KINETICS CONSIDERATIONS DURING CALCULATION OF THE NOZZLE FLOW OF PRODUCTS OF THE COMBUSTION OF HYDROGEN IN AIR
Khailov, V.M., Teplofiz. Vys. Temp., V 6:863-9 N5 68

The special case of thermophysics processes, accompanied by a chemical reaction, of expansion in a nozzle of dissocd. products of combustion of H_2-O_2-N_2 mixtures was analyzed theoretically.
(KINETICS, NOZZLE)

H73 33036 COMBUSTION AND HEAT TRANSFER IN SMALL ROCKET CHAMBER BURNING LIQUID OXYGEN AND GASEOUS HYDROGEN
Jeffs, A.T., C. Ramshaw, B.W.A. Ricketson, Spaceflight, V 8:172-84 N5, May 66

In 1960, program was initiated at Rocket Propulsion Establishment, Westcott, England, to provide design information for liquid oxygen-liquid hydrogen combustion chamber; report covers first phase of program, in which liquid oxygen and gaseous hydrogen were burnt in chamber giving nominal thrust of 2 kN (450 lb.).
(COMBUSTION, OXYGEN)

H73 33037 COMBUSTION INSTABILITY IN STEEL AND ABLATIVE ROCKET CHAMBERS
Goelz, R.R., (NASA, Lewis Research Center, Cleveland, O.), N68-15644, NASA-TM-X-1511, Washington, Fe 68, Avail:TAC
An investigation was conducted to compare the effects of ablative chambers and steel chambers on combustion instability in a hydrogen-oxygen rocket engine.
(COMBUSTION, ROCKET)

H73 33038 COMBUSTION OF GASEOUS HYDROGEN AT LOW PRESSURES IN A 35^{o} SECTOR OF A 28-INCH-DIAMETER RAMJET COMBUSTOR
Kerslake, W.R., (NASA, Lewis Research Center, Cleveland, O.), N66-39530, NACA-RM-E58A21a, Washington, Apr 22 '58, Avail:TAC
Gaseous-hydrogen fuel was burned in a connected-pipe combustor with a cross section equal to 35^{o} sector of a 28-inch diameter.
(COMBUSTION, JET)

H73 33039 TESTS WITH HYDROGEN FUEL IN A SIMULATED AFTERBURNER
Kerslake, W.R., and E.E. Dangle, (NASA, Lewis Research Center, Cleveland, O.), N65-33266, NACA-RM-E56D13a, Jl 2 '56, Avail:TAC
An investigation was conducted in a 16-inch-diameter simulated afterburner using gaseous hydrogen fuel.
(INJECTOR, EFFICIENCY)

H73 33040 THEORETICAL COMBUSTION PERFORMANCE OF RAMJET FUELS: HYDROGEN
Renich, W.T., (Johns Hopkins Univ., Silver Spring, Md.), Report No. CF-2601, Dec 13 '56, Avail:TAC
The report is the first of a series prepared as a compilation of available data on theoretical combustion performance of various fuels. The performance parameters to be given primary consideration are flame temperature and air specific impluse; others, including fuel specific impulse, mole change and expansion ratio are also included.
(COMBUSTION, JET)

H73 33041 PERFORMANCE ANALYSIS OF COMPOSITE PROPULSION SYSTEMS
Wrubel, J.A., (Rocketdyne, Canoga Park, Calif.), N69-27912, NASA-CR-101402, Apr 69, Avail:TAC
The improved understanding of gas stream turbulent mixing is contingent upon obtaining a more comprehensive

description of the resultant flow field and a more precise evaluation of the turbulent transport properties. The flow field being experimentally studied is the two dimensional mixing of fuel-rich supersonic hydrogen-oxygen combustion products and a subsonic heated airstream.
(MIXING, TRANSPORT, SUBSONIC)

H73 33042 PROBLEMS OF MIXING AND SUPERSONIC COMBUSTION OF HYDROGEN IN HYPERSONIC RAMJETS
Leuchter, O., (Office National d'Etudes et de Recherches Aerospatiales, Paris, France), N73-18962, ONERA-TP-973, May 11 '71, DGLR Sci. Comm. for Air Breathing Propulsions and for Chemical Propulsions, Traven, Avail:TAC

The mixing and ignition of hydrogen jets injected normally into a supersonic two-dimensional flow are discussed. The specific application is to investigate the combustion performance of a hypersonic ramjet engine. An analysis of experimental results obtained at Mach 1.5 has shown empirical relations for the jet penetration and crosswise distribution of fuel with respect to thermal blockage. Mixing of hydrogen and air was examined in optimal penetration conditions to establish the length necessary to obtain complete mixing. A significant reduction of ignition lengths, as compared to the theoretical values corresponding to the thermal conditions of the steady upstream flow, was shown to occur.
(HYPERSONIC, COMBUSTION)

H73 33043 MIXING OF HYDROGEN INJECTED FROM MULTIPLE INJECTORS NORMAL TO A SUPERSONIC AIRSTREAM
Rogers, R.C., (NASA, Langley Research Center, Langley Station, Va), N71-34274, NASA-TN-D-6476, Sept 71, Avail:TAC

The mixing of hydrogen downstream from a row of sonic injectors normal to a Mach 4 airstream was investigated to determine the effect of injector spacing.
(INJECTOR, BOUNDARY LAYER, CONCENTRATION)

H73 33044 FUNDAMENTAL ASPECTS OF SUPERSONIC COMBUSTION
Swithenbank, J., and M. Jaques, (Sheffield Univ., England), Report No. AFOSR-70-1934TR, Je 70

The application of turbulence theory to the design of supersonic combustors has been investigated both experimentally and theoretically.
(TURBULENCE, INJECTOR, VORTEX)

H73 33045 BURNING VELOCITIES IN HYDROGEN-BROMINE AND DEUTERIUM-BROMINE MIXTURES
Cooley, S.D., and R.C. Anderson, (Texas Univ. Defense Research Lab, Austin, Tex.), Report No. DRL-333, Jl 53, Avail:TAC

Measurements were made of flame velocities in straight tubes for hydrogen-bromine and deuterium-bromine mixtures. From these the burning velocities were determined.
(VELOCITY)

H73 33046 CALCULATIONS OF BURNING VELOCITIES FOR HYDROGEN-BROMINE MIXTURES. IV. EQUATION OF SEMENOV AND FRANK-KAMENETSKY AND MANSON EQUATIONS. V. ADDITIONAL CALCULATIONS BY MALLARD-LE CHATELIER EQUATION
Anderson, R.C., (Texas Univ., Defense Research Lab., Austin, Tex.), Report No. DRL-317, Mar 53, Avail:TAC

Calculations of burning velocities in hydrogen-bromine mixtures were extended to include values based on the equation developed by Semenov, Frank-Kamenetsky and others and that developed by Manson. Additional exploratory calculations using the Mallard-Le Chatelier equation are also summarized.
(VELOCITY, EQUATION)

H73 33047 EFFECT OF DILUENTS ON BURNING VELOCITIES IN HYDROGEN-BROMINE MIXTURES
Huffstutler, M.C., J.A. Rode, and R.C. Anderson, (Texas Univ., Defense Research Lab., Austin, Tex.), Report No. DRL-334, Aug 3 '53, Avail:TAC

Experiments on the effects of diluents on burning velocities in H_2-Br_2 mixtures were made using N_2, A, and He as diluents, with 10 percent and 25 percent of diluent and at 50C and 200C. The predominant trend is for a decrease in burning velocity with the magnitude of the effect varying in the order He less than A less than N_2. With the lesser amounts of helium, burning velocities were actually increased somewhat on occasion. The region of stable flame was shifted toward higher bromine percentages when diluents were added.
(STABILITY)

H73 33048 FEASIBILITY STUDY OF OXYGEN/HYDROGEN POWDERED METAL IGNITION
Lee, W.B., (Marquardt Corp., Van Nuys, Calif.), N67-31967, NASA-CR-68773, Sept 1 '65, Avail:TAC

Theoretical and experimental studies were performed

on the subject of producing low temperature H_2/O_2 ignitions by the use of catalytic and/or pyrophoric powdered metals. Interest centered on the use of Raney nickel powder, which is both catalytic for H_2/O_2 ignition, and pyrophoric with oxygen. It was demonstrated that Raney nickel powder, stored under an atmosphere of hydrogen, should have indefinite shelf life in the activated state, being able to produce ignitions at any time upon contact with oxygen.
(CATALYST, PYROPHORIC)

H73 33049 EXPERIMENTAL INVESTIGATIONS ON SUPERSONIC COMBUSTION IN THE FLOW FIELDS OF BODIES OF REVOLUTION AND NEAR A FLAT PLATE IN TANGENTIAL FLOW
Maurer, F., F.J. Niezgodka, and H. Post, Bundesmin, fuer Verteidigung, N71-22129, DLR-FB-70-64, Dec 70, Avail:TAC

Supersonic combustion of hydrogen in the flow field of a flat plate in tangential flow and near bodies of revolution was studied in the Mach number range from 1.8 to 3.2. In the flat plate experiments a secondary air jet from a crosswise slot was used to stabilize the flame. Hydrogen was injected upstream of the slot. Flame stabilization on bodies of revolution was obtained due to a small annular cavity near the thickness maximum. In all cases spark ignition was used. The changes of pressure distribution near the flat plate as well as changes of drag of the bodies of revolution due to heat addition were considerable.
(STABILITY, IGNITION, DRAG)

H73 33050 STUDY OF CATALYTIC REACTORS FOR HYDROGEN-OXYGEN IGNITION
Kesten, A.S., (United Aircraft Corp., East Hartford, Conn., Research Labs.), N69-41244, NASA-CR-72567, Jl 69, Avail:TAC

An analytical study of a catalytic ignition system to promote hydrogen-oxygen combustion was performed in order to establish procedures capable of predicting the steady-state behavior of the system. Included is the development of a computer program which is used to calculate the steady-state axial temperature and reactant concentration profiles in typical reaction chamber configurations.
(COMPUTER, CONCENTRATION)

H73 33051 TRANSIENT MODEL OF HYDROGEN/OXYGEN REACTOR
Kesten, A.S., and J.S. Sangiovanni, (United Aircraft Corp., East Hartford, Conn.), N71-37557, NASA-CR-120799, Fe 71, Avail:TAC

The utility of a catalytic ignition system to promote hydrogen-oxygen combustion and the limits imposed by the transient response of the system are discussed. The transient behavior of a reactor packed with porous catalyst particles is a function of film and pore diffusion of heat and mass as well as the chemical kinetics of the catalytic reaction. A model has been developed which permits computation of cencentration and temperature profiles in the bulk gas phase and within porous catalyst particles are functions of time for given reaction rate expressions.
(TRANSIENT, CATALYST, COMPUTER)

H73 33052 DEVELOPMENT OF HYDROGEN-OXYGEN CATALYSTS
Jennings, T.J., W.E. Armstrong, and H.H. Voge, (Shell Development Co., Emeryville, Calif.), N67-19876, NASA-CR-72118, Jl 67, Avail:TAC

This report presents results of a program designed to develop catalysts of improved activity and thermal stability for catalytic ignition of an oxygen-hydrogen mixture at low temperatures.
(STABILITY, TEMPERATURE)

H73 33053 DEFLAGRATION IN THE COMBUSTION OF HYDROGEN-FLUORINE MIXTURES
Vanpee, M., K.D. Cashin, B.J. Falabella, and P.S.R.K. Chintapalli, (Massachusetts Univ., Amherst, Mass.), Combustion and Flame, V 20:443-444, Je 73

Investigation of the burning velocities in the combustion of hydrogen-fluorine mixtures at pressures around 2.4 mm Hg over a mixture composition range of 25 to 65% fluorine by volume. Determined by Gouy's method, the burning velocities are presented in tabular form and compared with theoretically predicted deflagration velocities. Possible errors in the experimental determination are discussed.
(VELOCITY, BURNING)

H73 33054 SUPERSONIC MIXING OF HYDROGEN AND AIR
Morgenthaler, J.H., (Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.), N67-22859, NASA-CR-747, Apr 67, Avail:TAC

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.
(INJECTOR, COMBUSTOR, RAMJET)

H73 33055 STUDIES LEADING TO THE REALIZATION OF SUPERSONIC COMBUSTION IN PROPULSION APPLICATIONS
Jacques, M.T., R. Payne, and J. Swithenbank, (Sheffield Univ., England, Dept. of Chemical Engineering and Fuel Technology), Report No. HIC-174 AFOSR-TR-72-1333, Je 72

The report discusses theoretical and experimental studies of hydrogen mixing and combustion in a high enthalpy (6000K) Mach 3.5 airstream carried out in a combustion driven hypersonic shock tunnel operating with a tailored primary shock Mach number of 10.2 - 10.6 Results obtained using wall static pressure measurements indicated that following injection there was a steep compression zone, followed by a re-expansion zone after which the static pressure gradually increased to approach that predicted by complete combustion at test conditions.
(MIXING, CONCENTRATION, SHOCK)

H73 33056 MIXING AND COMBUSTION OF HYDROGEN IN A SUPERSONIC AIRSTREAM
Jacques, M.T., (Sheffield Univ., Dept. of Fuel Technology and Chemical Engineering, England), Report No. HIC-170 AFOSR-TR-71-2636, Fe 71

The report is concerned with the mixing and combustion of hydrogen in a high enthalpy Mach 3.5 airstream, in which the conditions are such that the combustion process is mixing limited. The high enthalpy conditions are obtained using a combustion driven hypersonic shock tunnel.
(SHOCK, INJECTOR, TURBULENCE)

H73 33057 INVESTIGATION OF COMBUSTION OF HYDROGEN IN A HYPERSONIC AIR-STREAM
Slutsky, S., (General Applied Science Labs, Inc., Westbury, N.Y.), N66-12855, NASA-CR-68191, Mar 65, Avail:TAC

A detailed investigation of the problem associated with the venting of combustible hydrogen from launch vehicles is summarized. Problems associated with the kinetics of the hydrogen air system, including the two phase phenomena associated with cryogenic hydrogen, as well as the fluid mechanical mixing problems and the coupling of the two were considered.
(MIXING, VENTING, KINETICS)

H73 33058 HEAT ADDITION IN SUPERSONIC FLOW BY MEANS OF HYDROGEN COMBUSTION ON A FLAT PLATE IN TANGENTIAL FLOW
Maurer, F., (Cologne), DGLR 71, 4th DGLR Annual Meeting, Baden-Baden, West Germany, Oct 11-13 '71, Avail:TAC

The problem of external heat addition in supersonic flow for producing aerodynamic forces is studied, supplemented by a one dimensional momentum analyses for the flowfield of a flat plate in tangential flow. Secondary air injection through a slot nozzle is used for creating upstream and downstream recirculation zones. By adding hydrogen to the upstream flow and ingniting with a spark device, a stable flame is produced.
(SUPERSONIC, FLOW, COMBUSTION)

H73 33059 GENERATION OF HIGH STAGNATION TEMPERATURES BY PRECOMBUSTION OF HYDROGEN
Alvermann, W., DLR-FB-67-05, In German, Ja 67, Avail:TAC

For mixture of air and oxygen heated by precombustion of hydrogen and containing 21% oxygen by volume which can be used as a substitute for air in thermogasdynamic investigations with high Mach number, the temperature of the air before combustion, required for predetermined temperatures of the mixture, is calculated for several hydrogen contents. Furthermore the equilibrium compositions of the different air-oxygen-hydrogen systems are determined for various temperatures and pressures.
(GENERATION, COMBUSTION)

H73 33060 DIFFUSION FLAMES AND SUPERSONIC COMBUSTION
DaRiva, I., A. Linan, E. Fraga, and J. Urrutia, (Instituto Nacional de Tecnica Aeroespacial, Madrid, Spain), N70-11935, AD-693341, Je 69, Avail:TAC

The method of matched asymptotic expansions has been

used for the analysis of the H_2-Air reaction in the temperature and pressure range of interest to Supersonic Combustion.
(RATE, EXPANSION, REACTION)

H73 33061 AN ANALYSIS OF INTERNAL SUPERSONIC FLOWS WITH DIFFUSION, DISSIPATION AND HYDROGEN-AIR COMBUSTION
Dash, S., (Advanced Technology Labs, Inc., Jericho, N.Y.), N70-42160, NASA-CR-111783, May 70, Avail:TAC

Using a modified characteristic calculation accounting for diffusion normal to the streamlines and finite rate chemistry along them, with pressure variations both along and normal to the streamlines, a system of equations is presented which is of a hyperbolic-parabolic nature.
(COMPUTER, NOZZLE)

H73 33062 TWO-DIMENSIONAL, SUPERSONIC MIXING OF HYDROGEN AND AIR NEAR A WALL
Yates, C.L., (Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.), N71-20127, NASA-CR-1793, Mar 71, Avail:TAC

Parallel injection of hydrogen at Mach 1.19 from a rectangular wall-slot into a Mach 2.1 airstream was experimentally investigated using instream probes. The development of pressure, temperature, composition and velocity profiles was measured to a downstream distance of 30 slot heights for two values of the hydrogen-to-air mass flux ratio: 0.088 and 0.120. From the data, there are determined the growth rates of the turbulent species, energy, and momentum transfer layer thicknesses, and the decay rates of the composition, temperature and velocity maxima.
(PRESSURE, TURBULENCE, TEMPERATURE)

H73 33063 STUDIES OF HYDROGEN-AIR SUPERSONIC COMBUSTION AT LOW DENSITIES
Drewry, J.E., and R.G. Dunn, (USAF, Aerospace Research Labs., Wright-Patterson AFB, Ohio), R. Edelman, and O. Fortune (General Applied Science Labs., Inc., Westbury, N.Y.), Combustion Institute, Fall Meeting, Menlo Park, Calif., Oct. 28-29 '68, Paper 68-29, Avail:TAC

An investigation of supersonic combustion as related to propulsive systems for high Mach number, high-altitude

flight is described. A method of laboratory simulation is employed which is considered to be suitable for fundamental studies of diffusional-controlled supersonic combustion under conditions approaching those of actual flight.
(SIMULATION, COMPUTER, IGNITION, NUMERICAL SOLUTION)

H73 33064 COMPUTATIONAL STUDY OF THE KINETICS OF THE HYDROGEN-OXYGEN REACTION BEHIND STEADY STATE SHOCK WAVES, APPLICATION TO THE COMPOSITION LIMITS AND TRANSVERSE STABILITY OF GASEOUS DETONATIONS
Dove, J.E., and T.D. Tribbeck, (Toronto Univ., Ontario, Canada), Astronautica Acta, V 15:387-397, 70, Avail:TAC

The rate equations for the H_2-O_2 reaction have been integrated numerically under the conditions of steady flow in a Zeldovich-Doring-von Neumann detonation. The reaction kinetic behavior of the H_2-O_2 system under conditions close to the isothermal branched-chain explosion limits is considered. The application to detonability limit calculations is discussed.
(RATE, DETONATION, INDUCTION)

H73 33065 INITIATION OF DETONATION BY INCIDENT SHOCK WAVES IN HYDROGEN-OXYGEN-ARGON MIXTURES
Skinner, G.B., G. Mueller, U. Grimm, and K. Scheller, (Ohio State Univ. Research Foundation, Columbus, O.), Report No. ARL-68-9320, Ja 68, Combustion and Flame, V 12: 436-442 N1 Oct 68, Avail:TAC

A series of experiments was carried out to demonstrate in detail the steps by which a chemical reaction initiated by a shock wave couples to the wave. Shock speed, pressure, and heat transfer measurements gave complementary information on the process. The hydrogen-oxygen reaction that was studied is typical of many gaseous combustion reactions in having a temperature-dependent ignition induction time. Once reaction starts, energy is given to the incident shock wave so that induction times of successive elements of gas become shorter. During this period of decreasing induction time the shock wave is accelerated to a high transient value. Later the velocity falls off as the induction time reaches a short, constant interval and the reaction occurs close behind the shock wave.
(IGNITION, VELOCITY)

H73 33066 CHEMICAL KINETICS OF THE SHOCK-INTEGRATED COMBUSTION OF HYDROGEN AT HIGH PRESSURE AND LOW TEMPERATURES

Wakefield, C.B., D.L. Ripley, and W.C. Gardiner, (Texas Univ., Dept. of Chemistry, Austin, Tex.), Journal of Chemical Physics, V 50:325-332 N1 Ja 1 '69, Avail:TAC

The ignition mechanism of the hydrogen-oxygen explosion at temperatures near 1000K and pressures greater than 1 atmosphere was investigated theoretically using the complete analytic solution to the kinetic equations of an abbreviated, linearized mechanism and numerical integration of the full conventional mechanism for these conditions. It was found that the analytic solution of the simplified mechanism is capable of only a qualitative description of the second limit effect observed in reflected shock experiments on ignition delays, and cannot be forced to yield quantitative agreement.

(IGNITION, DETONATION, COMPUTER)

221

H73 34000 FUEL CELLS - PRESENT POSITION AND OUTSTANDING PROBLEMS
Barak, M., Advanced Energy Conversion, V 6:29-55 N1 Ja-Mar 66

Present state of development of fuel cells in United States, Europe and Great Britain, including static and portable systems; outstanding problems are discussed, which must be solved before real "breakthrough" is achieved, including properties of catalysts in electrochemical media, chemical processes of polarization and reaction mechanisms, particularly when complex organic substances are used as fuels, electrochemical factors causing "drowning" of electrodes whenever water is formed as product, production of cheap electrodes and simple engineering systems, and use of more effective catalysts to enable cheap fuels to be used.
(CATALYST, ELECTRODE, REACTION)

H73 34001 FUEL CELLS
Grubb, W.T., and L.W. Niedrach, (General Electric Co., Research and Development Center, Schenectady, N.Y.), Direct Energy Conversion, edited by G.W. Sutton, McGraw-Hill Book Co., New York, N.Y., 66, p 39-104

Discussion of fuel cells, defined as electrochemical devices that directly convert the chemical energy of a fuel oxidation reaction into electrical energy. Fuel cells are considered from the point of view of thermodynamics which sets the ultimate limitation on energy density, from the point of view of the kinetics of electrochemical reactions and transport processes which set practical limits on energy density and are subject to improvement, and from the point of view of the state of development of representative types of fuel cells. It is considered that fuel cells will always be very complex in the chemical sense, and there will be many types of possible fuel cells in keeping with the wide diversity of chemical reactions that may be involved. It is highly probable that some types of fuel cells will be successful in a practical way.
(FUEL CELL, ENERGY)

H73 34002 THE PRESENT AND FUTURE OF FUEL CELLS
Bagotskii, V.S., and A.M. Skundin, (Army Foreign Science and Technology Center, Charlottesville, Va.), Khimiya v Shkole N3:10-16 70, Avail:TAC

The operation of a fuel cell is briefly described, and the chemical reactions upon which the production of electricity is based are outlined. Possible applications of fuel elements in power engineering are also discussed. (REACTION, POWER)

H73 34003 DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY - BATTERIES AND FUEL CELLS
Lespinasse, B., Sciences et Industries Spatiales, V 1:63-8, N7-8 65

Discussion of hydrogen fuel cells, the only ones at present planned for space use. Cells derived from the Bacon cell, which essentially comprises two sintered nickel electrodes, of two different porosities, with a central compartment filled with an electrolyte (KOH), and with the lateral compartments being supplied with gaseous hydrogen and oxygen, are examined in terms of the reactions at the electrodes, the electromotive force, and current density. Membrane cells are similarly investigated. Comments are made on the decomposition of the polarization curve, the efficiency, and the heat to be disposed of. The Gemini and Apollo fuel cells are briefly described. (REACTION, MEMBRANE, NICKEL)

H73 34004 ELECTROCHEMICAL FUEL CELLS
Sandstede, G. (Battele- Institut, Frankfurt/Main, Germany), Fortschr. Chem. Forsch., V 8:171-221 N2 67

Electrochemical combustion reactions, H and hydrocarbon fuel cells, and the construction of fuel cell batteries are discussed.
(REACTION, CONSTRUCTION)

H73 34005 FUEL CELL AS ENERGY CONVERSION DEVICE
Gupta, C.P., (University of Roorkee, India), Journal of the Institution of Engineers, V 48:160-87 N10, Je 3 '68

The hydrogen-oxygen fuel cells are at present in the most advanced stage of development. Hydrogen-oxygen ion-exchange membrane fuel cell is in a relatively advanced stage of development. It operates at approximately atmospheric pressure, and the temperatures within the cell are 40 to 60 C. One version of a high temperature fuel cell, operating above 500 C uses molten alkali carbonates as electrolyte. The electrolyte is usually held in a

sponge-like ceramic matrix. More advanced cells may give power densities of 2 to 10 kw/cu ft at an overall efficiency of about 60%.
(MEMBRANE, ELECTROLYTE)

H73 34006 FUEL CELLS
Gregory, D.P., (Energy Conversion Ltd., Basingstoke, England), Endeavor, V 28:8-12 N103 Ja 69, Avail:TAC

Review of developments in various acid, alkaline, and molten salt systems, and applications; fuel cells allow reaction of two materials to occur in electrochemical process to provide electric current; it operates with no moving parts, which leads to noiseless and reliable operation; universal fuel of cell is hydrogen, and problems and methods of converting inexpensive hydrocarbon fuels to hydrogen in portable equipment are noted; modified Bacon-type fuel cell for Apollo spacecraft, internal reforming system with palladium foil anodes, electrovan with speed of 70 mph and 150-mi range, portable radio power supply, etc, are among systems discussed.
(ACID, ALKALINE, MOLTEN SALT)

H73 34007 FUEL CELLS - ELECTROCHEMICAL ENERGY CONVERTERS OF FUTURE
Doehren, H.H. von, Int Electronische Rundschau, V 19:63-7 N2 Fe 65

Principles of operation, design, economic considerations, and state-of-art report of fuel cells; thermodynamic fundamentals; review of various types of fuel; advantages of fuel cell with view to their application in future.
(COST, THERMODYNAMICS, DESIGN)

H73 34008 FUEL CELLS: MODERN PROCESSES FOR THE ELECTROCHEMICAL PRODUCTIONS OF ENERGY
Vielstich, W., (Bonn Universitat, Bonn, West Germany), Translation of Brennstoffelemente: Moderne Verfahren zur Elektrochemischen Energiegewinnung, Weinheim, West Germany, Verlag Chemie GmbH, 65, London and New York, Wiley-Interscience, 70, Avail:TAC

An attempt is made to present a comprehensive but concise account of research and development in the field of the direct generation of electrical energy by electrochemical processes, to the stage achieved in 1964. The results of extensive hitherto unpublished research are included. The electrochemical methods for storing electric energy are examined together with the separation of the iso-

topes of hydrogen accompanying the electrolysis of aqueous solutions. In conclusion, the whole field is briefly reviewed and possibilities of future applications of the new sources of energy are discussed. The book is intended not only for electrochemists but for all groups of research workers interested in energy conversion.
(ELECTRODE, CONSTRUCTION)

H73 34009 FUEL CELLS: THEORY AND APPLICATION
Hart, A.B., (Central Electricity Generating Board, Surrey, Eng.), and G.J. Womack, (Central Electricity Generating Board, Southhampton, Eng.), Barnes and Noble, Inc., N.Y., 67, Avail:TAC

Practical and experimental fuel cells are discussed in this text. Areas covered include the thermodynamics of galvanic cells, the kinetics of fuel cell processes, the limiting problems in fuel cells, the fuel cell as a supplier of large-scale industrial power, and the application of fuel cells to mechanical power plant systems and space exploration. Sources of voltage loss when current is drawn from a cell are related quantitatively to cell design characteristics. Performance characteristics of oxygen electrodes, porous metal electrodes as a function of their structure, and hydrocarbon gas electrodes are also examined.
(THERMODYNAMIC, GALVANIC, ELECTRODE)

H73 34010 MASS EXCHANGE IN A HYDROGEN-OXYGEN FUEL CELL WITH A CAPILLARY MEMBRANE
Bogotzsky, V.S., (Academy of Sciences of the USSR, Moscow, USSR), and Yu.M. Volfkovich, Journal Appl. Electrochem, V 2:315-325 N4, Nov 72, Avail:TAC

The concentration and potential gradients across an electrolyte-containing membrane of the hydrogen-oxygen fuel cell have been calculated taking into account the following processes: diffusion of all solution components, ion migration in the electric field, permeation flux of the solution, external water vapor flows, water vapor transport in gas bubbles. A theory of the self-regulation of water remaoval has been developed, which takes account of the mass exchange conditions in the membrane and in the whole fuel cell, as well as capillary membrane. The self-regualtion of water removal during changes of the current or during changes of parameters influencing the rate of water removal, as well as the self-regulation in the case of a non-uniform process distribution over the electrode surface have been considered.
(MIGRATION, BUFFER)

H73 34011 PHYSICAL AND TECHNICAL PROBLEMS OF DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL
Lidorenko, N.S., V.E. Dmitrenko, F.R. Yppets, G.F. Muchnik, and I.A. Zaidenman, (Akademiya Nauk, USSR), Energetika i Transport, N4:3-12 68, Avail:TAC

An analysis is made of the basic power aspects of the problem of developing fuel cells. From a physical energy point of view the system of electrochemical generators (ECG) is examined on the basis of an analysis of three components-the ECG itself and the systems of accessories and automatic adjustment, the creation of which is combined with the solving of a number of specific problems. The most important of these problems are examined and the necessity of their overall solution is brought out. As an example of practical realization of these problems, data are cited for an electrochemical generator with polymeric hydrophobic electrodes. This generator has promise for application in ground transport equipment. An analysis is made of the technology of manufacture of electrodes, design of battery, and volt-ampere characteristics. Photographs are shown of a Soviet ECG with ion-exchange membranes and cermet electrodes.
(POWER, ELECTRODE, MANUFACTURE)

H73 34012 THE FUEL CELL CONCEPT, A REVIEW OF BASIC PRINCIPLES
Henry, R.J., N71-15723, DLR-MITT-70-09, Jl 70, Avail:TAC

The discussion of single cell electrochemistry includes performance characteristics of the Apollo fuel cell using hydrogen-oxygen reactants. Modern applications of cells using air oxidant and hydrocarbon fuels are described and the relatively pollutant-free fuel cell exhaust is compared with that from commercial powerplants.
(FUEL CELL, REVIEW)

H73 34013 THE FUEL CELL - WHEN
Lioret, P., (Ecole Superieure d'Electricite, France), Science Progres Decouverte, 13-19, Je 70, Avail:TAC

Review of the state of the art and of recent French efforts in the field of fuel cells. An expensive source of power, the fuel cell has found so far hardly any other application than in space missions. Is it doomed to remain a lab curiosity or will it one day compete with conventional sources of power. At least one French group of researchers hope to be on a path leading to industrial

success.
(DESIGN, RESEARCH)

H73 34014 COMPLETE POWER SOURCES
Pearson, J.W., in An Introduction to Fuel Cells, edited by K.R. Williams, American Elsevier Publishing Co., Inc., N.Y., 66, p 284-309, Avail:TAC

Discussion of problems connected with the construction of fuel batteries. The principal materials suitable for low-temperature cells are summarized in a table. It is noted that a hydrogen generator/fuel cell system is unlikely to be a commercial competitor of the diesel electric generator, unless economics is not the sole consideration. One possible exception is the combination of a high-pressure electrolyzer and a vehicle powered by fuel cells. This is only likely to be economic in special circumstances, for example, if the electric vehicle is required for full-time (24 hr/day) operation. The fuel cell vehicle could be rapidly recharged with hydrogen and oxygen from storage fed by the electrolyzer. It is pointed out that if other considerations outweigh economics, then the hydrogen generator and fuel cell may find applications. Design studies for submarine plants suggest that military application are being seriously considered.
(COST, VEHICLE)

H73 34015 BRINGING THE FUEL CELL DOWN TO EARTH
Lessing, L., Fortune, 129-132, Sept 66

In essence, a fuel cell is a device for converting chemical energy directly into electrical energy. By bringing hydrogen and oxygen gas together in a controlled way on catalytic platinum electrodes, we could re-form water and in the course of the reaction tap off an electric current. The same principle applied to many chemical reactions. So far the fuel cell has proved to be useful only in very special circumstances, in space and military applications. Eventually, fuel cells may supply a new source of power for special vehicles, trucks, fast trains, even automobiles.
(POWER, VEHICLE)

H73 34016 CONCENTRATION CHANGES IN OPERATING FUEL CELLS
Lundquist, J.T., Jr. and W.M. Vogel, (Pratt & Whitney Aircraft, Middletown, Conn.), Journal of the Electrochemical Society, V 116:1066 N8 Aug 69

The high current densities at which fuel cells operate give rise to large concentration changes across the porous matrix employed in most of these cells. These changes were measured in cells especially constructed for these determinations using aqueous potassium hydroxide and phosphoric acid as electrolytes. Part of the resulting voltage losses of the fuel cells, due to pH changes and liquid junction potentials, were measured. A theoretical treatment is presented which accurately describes the experimental data.
(FUEL CELL, CURRENT DENSITY)

H73 34017 ELECTROCATALYTIC REACTIONS
Makrides, A.C., 20th Annual Power Sources Conference - Proceedings, (U.S. Army Electronics Labs, Fort Monmouth, N.J.), May 24-26 '66, p 5-8, Avail:TAC

Review of relationship, constituting basic principle of fuel cell electrolysis, between atomic composition and electrode properties for hydrogen, oxygen, and hydrocarbon oxidation reactions; rates of electrode reactions examined as functions of electron-exchange reactions; electrode composition determines interaction rate between reactants and electrode surface; hydrogen, oxygen, and hydrocarbon oxidation reactions considered in relation to electrode reactivity as determined either by intrinsic chemical property of individual surface atoms, or by electronic energy states of electrode material as whole.
(FUEL CELL, ELECTRODE, REACTION)

H73 34018 HYDROGEN SOURCES FOR FUEL CELLS
Singman, D., and A.F. Forziati, (Harry Diamond Labs., Washington, D.C.), N64-12661, AD-424580, Nov 1 63, Avail:TAC

Commercially available gas, liquid, and chemical sources of hydrogen for use with fuel-cell batteries are compared. Cryogenic storage is shown to be the most efficient on both weight and volume bases. Chemical generators are suitable for applications requiring moderate quantities of hydrogen gas at infrequent periods. Compressed-gas cylinders are convenient when small quantities of hydrogen are desired. A bibliography of selected pub-

lications of the past five years is included.
(FUEL CELL, BATTERY)

H73 34019 ENERGETICS: FUEL-CELL SYSTEMS
Cohn, E.M., Mechanical Engineering, p 22, Je 66

An idea that is well over 150 years old is finally becoming a reality - the conversion of fuel energy directly into electrical energy for use in functional power plants. This is the fuel cell, noted as the on-board power source for certain space missions. What is the fuel cell, and just where does it go from here?
(FUEL CELL, POWER)

H73 34020 FUEL CELLS FOR CENTRAL POWER GENERATION
Archer, D.H., Mechanical Engineering, p 42, Mar 68

Under research: Solid-electrolyte fuel cells which have the capability to produce electrical energy from coal at high efficiency in large-scale central station power plants.
(SOLID-ELECTROLYTE, POWER)

H73 34021 THE CONVERSION OF ENERGY
Summers, C.M., Scientific American, 149-159, Sept 71, Avail:TAC

This paper presents many energy conversion systems. One of them is the fuel cell which converts the energy in hydrogen or liquid fuels directly into electricity.
(FUEL CELL)

H73 34022 USE OF HYDROGEN IN FUEL CELLS
Nuttall, L.J., (General Electric Co., New York, N.Y.), Society of Automotive Engineers, International Automotive Engineering Congress, Detroit, Mich., Ja 11-15 '65, Paper 994A, Avail:TAC

Discussion of the technology of fuel cells. The fuel cell is termed an energy-conversion device which needs a supply of fuel and oxidant from an external source. It is stated that the greatest interest shown in the fuel cell to date is for use in marine propulsion; however, interest has been shown in its application to vehicle proplusion. This interest will probably grow as the life and reliability of fuel cells continue to improve and as manufacturing costs will be reduced. Many applications are expected to utilize hydrocarbon fuels directly. It

is noted that the extensive use of hydrogen cells, particularly outside the space power field, will depent very much on continuing improvements in the state of the art of the production, storage, and handling techniques for the hydrogen fuel.
(FUEL CELL, TECHNOLOGY)

H73 34023 THE FUEL CELL PROBLEM
Cohn, E.M., (NASA, Washington, D.C., Institute of Electrical and Electronics Engineers), International Convention and Exhibition, New York, N.Y., Mar 18-21 '68, Paper, Avail:TAC

Discussion of the historical background, development, and operation of fuel cells, with special attention devoted to the materials, applications, and engineering problems of fuel cells using hydrogen and oxygen (pure or as air). These problems involve the minimization of the amounts of precious platinum and palladium catalysts, the optimization of electrodes and cell structures, and the problem of high cost per kilowatt.
(HISTORY, APPLICATION, CATALYST)

H73 34024 TECHNOLOGY OF FUEL CELLS
Tantram, A.D.S., Proceedings of the Institution of Mechanical Engineers, V 178:137-43, 144-55 N5, (Automobile Division), 63-64, Avail:TAC

Review of technology and fundamental aspects; basic mechanisms, namely, oxygen concentration cells, hydrogen electrode cells, Redox cells, and others are considered to show fundamental requirements and limitations of different types of cells; structures of porous and of nonporous electrodes; advantages and disadvantages for various temperature ranges.
(REACTION, ELECTRODE, TEMPERATURE)

H73 34025 MASS TRANSFER IN ELECTROCHEMICAL FUEL CELLS WITH ION EXCHANGE MEMBRANES
Ivanov, A.M., Teplofizika Vysokikh Temperatur (USSR), V 8:615-621 N3, 70, Avail:TAC

Basic questions characterizing the problem of optimum mass and heat transfer in electrochemical fuel cells are discussed. The effect of mass-transfer conditions on the output characteristics of fuel cells is examined, in hydrogen-oxygen fuel cells with ion exchange membranes.

The inherent moisture content of ion exchange membranes and of the membrane-catalyst system are also described.
(FUEL CELL, ION EXCHANGE)

H73 34026 LOW-TEMPERATURE FUEL CELL SYSTEMS
Palmer, N.I., Chemical Engineering Progress Symposium, Series No. 75, 63, p 17, 67, Avail:TAC

Low-temperature fuel cells are reviewed. Three major hydrogen-oxygen systems are compared. A classification of the different types of hydrocarbon-air fuel cells is given. Construction and performance of representative systems are analyzed.
(FUEL CELL, TEMPERATURE)

H73 34027 HYDROCARBON - AIR FUEL CELL SYSTEMS
Peattie, C.G., IEEE Spectrum, V 3:69-76 N6, Je 66

Status of hydrocarbon-air fuel cell technology at present time is presented; basic principles of two types of hydrocarbon-air fuel cells, namely indirect-oxidation and direct-oxidation systems, are outlined; in direct-oxidation cells, hydrocarbon fuel is oxidized directly at fuel electrode; in indirect-oxidation cells, now in systems engineering development stage, hydrocarbon fuel is converted into impure hydrogen, which may then be purified to certain degree and injected into fuel cell modules; present situation in research, development, and technology in United States and Europe; future applications.
(OXIDATION, RESEARCH)

H73 34028 HYDROGEN-OXYGEN PRIMARY EXTRATERRESTRIAL (HOPE) FUEL CELL PROGRAM PHASE 1a
Chapman, L.E., (General Electric Co., Philadelphia, Pa.), N63-15187, AF-33(657)896C, Final Report, Je 62 - Oct 62, Jan 63, Avail:TAC

The activities conducted on the HOPE (hydrogen-oxygen primary extraterrestrial fuel system) Phase 1a program are described. Included are: research on electrochemical reactions, hydrogen ion diffusion through polymeric membranes, internal mass transport of water through capillary action, and mass transport of water vapor through an ambient of diatomic oxygen gas at 1 atmosphere pressure. Project HOPE's ultimate objective was the design of a 500-watt fuel-cell power-system, including cryogenic fuel supply, for orbital applications.
(REACTION, MEMBRANE, WATER)

H73 34029 FUEL CELLS - THEIR STATUS AND FUTURE OUTLOOK
Yeager, E., (Case-Western-Reserve University, Cleveland, O.), Chemical Engineering Progress, V 64:92-6, Sept 68

Examination of the state-of-the-art and future potential of fuel cells such as hydrogen-oxygen cells, hydrazine-oxygen cells, hydrocarbon-consuming cells, and sodium amalgam-oxygen cells. An H_2-O_2 type (by GE) has been used as nonpropulsive power siurce for orbital missions in the Gemini project; another (by Pratt and Whitney) will be applied in the Apollo project: and a third (by Allis Chalmers) is under study for later space projects. Voltage output under operating conditions is about 0.9 V for the hydrogen-oxygen type. Problems that remain to be overcome in all types are low power densities and short operating life. Some materials problems arise from the high operating temperatures required in the case of the hydrocarbon-consuming cell. In regions with high cost of electrical power the further development of the sodium amalgam-oxygen cell might be attractive.
(HYDROGEN, HYDRAZINE, HYDROCARBON, TEMPERATURE)

H73 34030 FUEL CELLS - PROBLEMS FOR CHEMICAL ENGINEERS
Barak, M., Chemical and Process Engineering, V 49:89-96, 100 N4, Apr 68 Avail:TAC

Fuel cells, which produce electricity through Redox reactions in electrolyte, are not subject to Carnot cycle limitations and can be made in units supplying power up to several kilowatts; article outlines principles of operation, and discusses choice of electrolyte, fuel, oxidant, catalyst, and electrode material for each particular application; cells for space vehicles, electric traction, stationary power plants and domestic purposes are described.
(ELECTROLYTE, CATALYST, ELECTRODE, APPLICATION)

H73 34031 FUEL CELLS - PRESENT POSITION AND FUTURE PROSPECTS
Barak, M., (Chloride Batteries, Ltd., Swinton, England), N68-28728, AFSC Performance Forecast of Selected Static Energy Conversion Devices, 67, p 496-526

The successful use of hydrogen-oxygen fuel cells in the Gemini spacecraft and their potential use in the Apollo spacecraft and lunar excursion module are reviewed. Other specialized fuel cell applications are discussed, such as an indirect hydrocarbon-air battery for field communication systems, hydrazine-oxygen system battery for submarines, and hydrogen-oxygen units for buoys and for electric traction. Also considered are the experiments on the direct use of cheap organic fuels, such as kerosene and methanol, without a preliminary reforming process. Various systems are being investigated such as medium temperature, molten salt electrolyte (300° to 600°C), high temperature, solid oxide electrolyte (800° to 1200°C); and low temperature, acid electrolyte systems. Summary information is included on the research being conducted in Great Britain, France, Germany, Switzerland, Sweden, Holland, Russia, and Japan. (APPLICATION, HYDRAZINE, HYDROCARBON, TEMPERATURE)

H73 34032 FUEL CELLS, A PROGRESS REPORT
Austin, L.G., B.C. Almaula, Chemical Engineering, V 76:85-91 N13, Je 16 '69

Many chemical engineering problems remain to be solved before the promising potential of fuel cells becomes a reality. This survey also points out the advantages and difficulties involved in the adaptation of fuel cells to electric cars, forklift trucks, and electrochemical processes. (APPLICATION, PROBLEM)

H73 34033 FUEL CELLS
Bacon, F.T., Journal of the Institute of Fuel, V 38:406-12 N296, Sept 65

Reviewing use of hydrazine, ammonia, cyclohexane, and compressed hydrogen with emphasis on additional difficulties which arise when attempts are made to produce complete units consuming hydrocarbon fuel and air; developments in fuel cell design, mainly hydrogen cells; use of compressed hydrogen in propulsion of short-range transport vehicles; relative merits and storage of fuel cells. (DESIGN, VEHICLE)

H73 34034 FUEL CELL TECHNOLOGY - A SURVEY OF ADVANCES AND PROBLEMS
Wynveen, R.A., (Allis-Chalmers Manufacturing Co., Milwaukee, Wis.), Proceedings of the Australian Conference of Electrochemistry, Sydney and Hobart, Australia, Fe 13-20 '63, edited by J.A. Friend and F. Gutmann, Oxford, Pergamon Press, Ltd., 65, p 611-633, Avail:TAC

Survey of recent progress in fuel cell technology,

with the object of evaluating the state of development of cells for various proposed applications. The cells considered are classified according to the range of fuel cost into (1) cells using zinc-oxygen, sodium-oxygen, hydrogen-oxygen, and hydrogen-air (expensive fuels), (2) cells using methanol-air and methanol-oxygen (medium-cost fuels), and (3) hydrogen-air fuel cells (low-cost fuels). The survey includes: hydrogen-oxygen fuel cells, cells employing carbon electrodes, high-temperature/high pressure cells, the Justi cell, solid electrolyte systems, organic and inorganic membranes, and the vehicle-held electrolyte system.
(APPLICATION, ELECTRODE, SOLID-ELECTROLYTE, TEMPERATURE)

H73 34035 FUEL CELLS, TODAY AND TOMORROW
Pouli, D., (Allied Chemical Corp., Morristown, N.J.), Heat, Piping and Air Conditioning, V 42:102-9 N9, Sept 70

Review of the state-of-the-art of new sources of energy conversion with respect to fuel cells deals with fuel cell components, modes of electrolyte retention, product removal, classification of fuel cells, cell reactions, voltage losses, and practical fuel cell systems.
(ELECTROLYTE, SYSTEM)

H73 34036 ELECTROCHEMICAL PROCESSES IN FUEL CELLS
Breiter, M.W., (General Electric Co., Schenectady, N.Y.), (Springer-Verlag New York, Inc.), Anorganische und allgemeine Chemie in Einzeldarstellungen, V 9, 69, Avail:TAC

An analysis of the fundamental electrochemical problems is presented without taking into consideration the practical approaches. Thermodynamic considerations and definitions are presented together with basic requirements for practical fuel cells. The basic concepts of transport process are briefly outlined. A review is presented of the effect of the nature of the electrode material on the kinetics of electrode reactions on homogeneous surfaces, taking into account mainly the primary effects.
(THERMODYNAMICS, ELECTRODE, CATALYST, MEMBRANE)

H73 34037 A MODEL FOR ANALYZING THE EXPERIMENTAL VOLTAGE-CURRENT CHARACTERISTICS OF A HYDROGEN-OXYGEN FUEL CELL BATTERY
Epps, C.M., (Texas Technological College, Lubbock, Tex.), N71-17675, Ph.D. Thesis, 69, Avail: Univ. Microfilms, No. 70-1469, Avail:TAC

A steady state model is developed for the voltage output of a hydrogen-oxygen fuel cell battery as a function of battery temperature, reactant pressure, electrolyte concentration, and average cell current. The model includes the effects of activation and concentration polarization in the porous electrodes and resistance polarization in the bulk electrolyte. The results of the mathematical model are fitted to experimental voltage-current data for a hydrogen-oxygen fuel cell battery and shown to be adequate for correlation and extrapolation of these data.
(MODEL, FUEL CELL)

H73 34038 FUEL CELLS
Austin, L.G., (Department of Chemical Engineering, North Carolina State University, Raleigh, N.C.), Report No. NASA-SP-120, Avail:TAC

A review of government-sponsored research, 1950-1964.
(FUEL CELL, REVIEW)

H73 34039* FUEL CELLS AND ELECTROLYZERS IN THE HYDROGEN ECONOMY
Appleby, A.J., (Laboratoires de Marcoussis, France), Cornell International Symposium on the Hydrogen Economy, Cornell University, Ithaca, N.Y., Aug 73, Avail:TAC

Conversion of water to hydrogen by electrolysis is advocated with reconversion of hydrogen to work by fuel cells. Fuel cells, electrolyzers and electrocatalysis schemes are described.
(FUEL CELL, ELECTROLYZER, CONVERSION, ELECTROCATALYSIS, ENERGY)

H73 34100 ULTRA-PURE HYDROGEN FOR FUEL CELLS
Pfefferle, W.C., SAE Paper 935B, Oct 19-23 '64

Engelhard Hydrogen Process (EHP) provides solution to problem of building efficient, compact hydrogen generators for fuel cell use; process simplification is achieved by integrating use of hydrogen producing reaction, removal of pure product hydrogen, utilization of residue as fuel to supply energy, and requirements of process; generators provide source of ultra-pure hydrogen, suited for fuel cell use, and are capable of achieving thermal efficiency approaching 100% for conversion of hydrocarbons into hydrogen; it should be possible to build small fuel cell power packages, as small as 500w, operating at thermal efficiencies greater than those of large power plants.
(UTILIZATION, ENERGY, PROCESS, GENERATOR, EFFICIENCY, CONVERSION, HYDROCARBON)

H73 34101 A NEW APPROACH TO HIGH-PRESSURE, HIGH-TEMPERATURE HYDROGEN-OXYGEN FUEL-CELL AND ELECTROLYSIS-CELL DESIGN
Allison, H.J., (Oklahoma State Univ., Stillwater, Okla.), N69-16772, Ph.D. Thesis, 67, Avail: Univ. Microfilms, No. 68-8357, Avail:TAC

The objective of this study is to present an approach to high-pressure high-temperature fuel-cell and electrolysis-cell electrode design which is based on the theory of conformal transformations. Electrode configurations resulting from a conformal transformation of the type considered in this study have electrostatic field characteristics similar to those associated with conventional parallel plate electrodes. Fuel cells and electrolysis cells which are operated at high pressures and temperatures can have electrical characteristics which are superior to those of cells which are operated at lower pressures and temperatures.
(PRESSURE, TEMPERATURE, FUEL CELL)

H73 34102 THE EFFECT OF DESIGN AND OPERATING FACTORS ON LIFE AND PERFORMANCE OF MATRIX FUEL CELLS
Wood, K.O., and W.F. Bell, (Pratt and Whitney Aircraft, South Windsor, Conn.), N71-31150, NASA-CR-72906; PWA-4145, Fe 28 '71, Final Report, Avail:TAC

The effect of design and operating factors on the performance and life of alkaline electrolyte, hydrogen/oxygen, matrix fuel cells was investigated. Full size single cells were operated on a simulated space shuttle load profile and were refurbished by flushing with fresh electrolyte to extend their useful life. A data base for the design

of fuel cells with a one year operating life is provided. Cell life of over 6400 hours at a potential of 0.945 volts with no net voltage decay was demonstrated while operating at a temperature of 176 F and a current density of 75 atmospheres sq ft.
(DESIGN, FUEL CELL)

H73 34103 COLD HYDROGEN AND BASIC ELECTROLYTE CELLS AT THE RESEARCH CENTER OF THE CGE
Edon, C., (Compagnie Generale d'Electricite de Paris, France), Electrochemical Generators for Space Applications: Centre National D'Etudes Spatiales, International Convention, Paris, France, Dec 4-7 '67, Proceedings, 68, Avail:TAC
Discussion of the development of fuel cells based on a study of the composite subsystems - e.g., single cell batteries, reagent chambers, and auxiliary control systems. The development of a cold hydrogen and basic electrolyte cell is described on the basis of the following parameters: (1) atonomy, weight, and reliability of the batteries, (2) low-power cells and operation in air, (3) power of the cell and regulation of the electrolyte concentration, and (4) reliability, output, and weight of the auxiliary control systems.
(WEIGHT, RELIABILITY, ELECTROLYTE)

H73 34104 FUEL CELLS, DESIGN & COMPONENTS
Anon, Engineering, N18:6-14, Sept 30 '68
History and general description of fuel cells; various types of dry cells, storage batteries and fuel cells are compared on basis of power-to-weight ratios; electrodes, electrolytes, fuel and applications are discussed.
(ELECTRODE, ELECTROLYTE)

H73 34105 HYDROGEN AND BASIC-ELECTROLYTE LOW-TEMPERATURE BATTERIES AT THE CGE RESEARCH CENTER
Edon, C., (Compagnie Generale d'Electricite de Paris, France), Sciences et Industries Spatiales, V 4:29-32 N9-10, 68
Discussion of the technical and economic requirements that influence the definition and design of a fuel cell. Fundamental design problems associated with low-temperature hydrogen cells and basic battery solutions are treated. Also treated is the regulation of the electrolyte concentration by elimination of the water formed.
(COST, DESIGN)

H73 34106 HYDROGEN-OXYGEN FUEL CELL SYSTEM WITH REACTANT-SUPERSATURATED ELECTROLYTE FEED
Zaromb, S., (Zaromb Research Corp., Passaic, N.J.), N68-32106, NASA-CR-96143, Jl 10 '67, Final Report Nov 21 '66-May 20 '67, Avail:TAC

A conceptual design analysis was performed for the purpose of evaluating the feasibility and advantages of a supersaturated feed fuel cell (SFFC) based on packing reactants into electrolyte solutions under high pressure followed by circulation of the loaded electrolytes through appropriate porous electrodes. This study was confined to low temperature alkaline H -O_2 fuel cells. Tentatively assumed normal operating conditions of 75 C at 10 atmosphere system pressure and 200 atmosphere reactant saturation pressures, 5 M KOH, and 0.25 amp/cm^2 apparent electrode area, yield a predicted output voltage of at least 1.10 v/cell for the SFFC as compared with only 0.90 v/cell or less for gaseous-diffusion type or for recently considered undersaturated flooded-flow systems. The SFFC system was shown to be stable and, in part, self-regulating.
(ALKALINE, TEMPERATURE)

H73 34107 PURGE DYNAMICS OF FUEL CELLS
Gidaspow, D., (Institute of Gas Technology, Chicago, Ill.), S. Sareen, AIChE Journal, V 16:560-8 N4, Jl 70

Fuel cell gas compartments are of two type - through-flow and dead-ended. Dead-ended anode and cathode compartments are used when pure reactants are available, such as hydrogen and oxygen in space vehicles. It appears that for rational design and improvement of dead-ended and nearly dead-ended fuel cells, one must have a good mathematical description of flow in the anode and cathode cavities.
(PURGE, FUEL CELL)

H73 34200 FEASIBILITY STUDY OF HIGH PERFORMANCE HYDROGEN-OXYGEN FUEL CELLS
Okrent, E.H., M. Lieberman, and C.E. Heath, (Esso Research and Engineering Co., Linden, N.J.), N68-22889, NASA-CR-94407, Dec 67, Avail:TAC

Two process concepts were examined to determine if decoupling the limiting cathodic process into its own reaction space could result in increased hydrogen-oxygen fuel cell efficiency and result in enhanced specific power. Although decoupling was successful with slurry catalyst and mediator systems, the anticipated performance improvements were not obtained.
(EFFICIENCY, POWER, CATALYST)

H73 34201 PURIFICATION OF FUEL CELL GASES
Bath, T.D., and A.D. McElroy, (Midwest Research Institute, Kansas City, Mo.), N66-21008, NASA-CR-65284, Fe 23 '66, Avail:TAC

Means of effecting purification in-flight of hydrogen and oxygen gases delivered to the Apollo fuel cell were evaluated and screened for suitability. The techniques which appeared to be workable were further studied. Purifications which were judged to be feasible are removal of carbon dioxide and carbon monoxide from oxygen, and separation of hydrogen from impurities by diffusion through metallic membranes.
(MEMBRANE)

H73 34202 ADVANCED ELECTROCHEMICAL TECHNOLOGY
Grohse, E.W., and P.C. Chen, (Alabama University Research Institute, Huntsville, Ala.), N68-21308, NASA-CR-94084, Ja 30 '68, Avail:TAC

An advanced fuel cell of the gas diffusion type is being studied, including the development of improved mathematical representation of the predominant, performance-controlling phenomena occurring within the active pores of the electrodes of such cells. Fabrications and installation of experimental facilities for the advanced basic study of fuel cells and related electrochemical systems are under development; and preliminary studies are being made of a new flow-through concept in which continuous circulation of an emulsified electrolyte is used to overcome limitations of presently-used flow-through systems because of the low

solubilities of hydrogen and oxygen in strong aqueous electrolytes at ordinary temperatures and moderate pressures.
(FUEL CELL, ELECTROLYTE)

H73 34203 CONSTRUCTION OF A HYDROGEN-OXYGEN FUEL CELL AND ITS PERFORMANCE WITHIN THE TEMPERATURE RANGE -20^{o}C TO +60^{o}C
Weidinger, K., (Bad Godesberg, West Germany), Bundesmin fuer Wiss. Forsch, N68-15248, BMWF-FB-W-67-04, May 67, Avail:TAC

In order to study the temperature influence on the mechanical and electrochemical properties of a fuel-cell-battery an investigation was carried out within the temperature range -20^{o}C to +60^{o}C. No mechanical defects due to differences in thermal expansion of metal-electrodes and plastics (used for framing) could be observed. There is a strong temperature influence, however, on the electrochemical performance. Nevertheless an operation of the fuel-cell below 0^{o}C is possible, as long as the power densities are low.
(FUEL CELL, TEMPERATURE, POWER)

H73 34204 EFFECT OF PRESSURE ON PERFORMANCE OF HYDROGEN FUEL CELLS
Gillibrand, M.I., F. Gibson, L.J. Pearce, and R.G.H. Watson, Electrochimica Acta, V 12:49-56 N1, Ja 67

Effect of environmental pressure on performance of multiplate hydrogen/oxygen fuel cell as been studied at 30 and 60 C; at each temperature, power obtained from cell increased with increasing pressure; for example, at working voltage of 0.6 v, increased power was 90 and 150% at 60 and 30 C respectively when environmental pressure was increased from 1 to 5 atmosphere; improved performance was due to reduction in polarization of both oxygen and hydrogen electrodes.
(FUEL CELL, PRESSURE, PERFORMANCE)

H73 34205 ELECTRIC CELLS WITH ELECTROCHEMICAL HYDROGEN COMBUSTION
Parisot, J., R. Vic, and R. Meyer, Review Inst. Fr. Petrole Ann. Combustion Liquides, V 22:1674-98 N11, 67

After a brief review of cells with carbon electrodes, with and without Pt-Ni catalyst, using H and O or air, the development of a specific cell using approximately 7N KOH and electrodes of wood charcoal, petroleum coke, or combinations of different forms of carbon, is discussed.
(ELECTRODE, CARBON)

H73 34206 FUEL CELLS
Schwartz, H.J., Chemical Engineering Progress Symposium Series No. 75, 63, P 3, 67

Three hydrogen-oxygen fuel cell systems are currently under development for aerospace applications. The three are described in terms of their basic operating parameters and construction features. A fuel cell may be considered to be an isothermal steady state reactor in which the conversion of hydrogen and oxygen to water is accomplished.
(AEROSPACE, HEAT, REMOVAL, WATER)

H73 34207 FUELS FOR FUEL CELLS
Bode, H., Chemie-Ingenieur-Technik, V 35:367-71, May 63, Avail:TAC

Discussion of the development of, and problems concerned with, hydrogen-oxygen fuel cells. Noted is research on the development of fuel cells which will use hydrogen produced by a generator or obtained from the combustion of hydrogen-containing compounds, such as methane, in order to avoid the bulk and weight penalties associated with high-pressure hydrogen-storage cylinders.
(GENERATION)

H73 34208 IMMOBILIZED PHOSPHORIC ACID INTERMEDIATE-TEMPERATURE FUEL CELL
Hamlen, R.P., E.J. Szymalak, Electrochem Technology, V 4:172-4 N3-4, Mar-Ap 66

Use of zirconium phosphate Teflon matrix for phosphoric acid cells operating at 125 to 175 C, using as fuel both hydrogen and propane; phosphoric acid system would be useful only for hydrocarbon system or where higher operating temperature is mandatory for other reasons; these electrolyte/electrode assemblies are useful where simplicity of assembly is more important than high performance; however, better mechanical properties are necessary for lifetimes greater than about 500 hr at 150 C.
(FUEL CELL, ELECTRODE, TEMPERATURE)

H73 34209 HYDROGEN-CHLORINE FUEL CELLS. V. DISCHARGE MECHANISM OF THE HYDROGEN-CHLORINE FUEL CELL AT HIGH TEMPERATURES.
Yoshizawa, S., Z. Takehara, and Y. Nakanishi, Denki Kagaku, V 35:225-30 N3, 67

The discharge mechanism of H-Cl fuel cell was investigated by using LiCl-KCl eutectic at 450-600^{o} as the electrolytic cell.
(FUEL CELL, DISCHARGE, CHLORINE)

H73 34210 HYDROGEN-OXYGEN ION-EXCHANGE MEMBRANE FUEL CELLS
Foulkes, F.R., W.F. Graydon, Canadian Journal of Chemical Engineering, V 47:171-6 N2, Apr 69

A hydrogen-oxygen cationic ion-exchange membrane fuel cell was operated at various temperatures, pressures, and electrolyte concentrations. The open circuit and discharge characteristics of the cell were explained in terms of the oxygen polyelectrode theory. Although discharge was limited by internal resistance, pressurization greatly reduced polarization.
(CATION)

H73 34211 OPERATION OF A FUEL CELL
Connor, J.E., Jr., A.F. D'Alessandro, and H. Shalit, (Atlantic Richfield Co.), French Appl. 1,534,466, Jl 26 '68

A mixture of H_2O/C-containing fuel in a ratio of 2 moles H_2O vapor/mole of C was passed into a reactor zone containing a catalyst to form CH_4 and H. The H passed out of the reactor zone towards an anode having a metallic membrane permeable to H, and through an electrolyte to produce current.
(MEMBRANE, GENERATION)

H73 34212 INTERMEDIATE TEMPERATURE FUEL CELL - OPERATION ON DILUTE HYDROGEN, CARBONACEOUS FUELS, AND DILUTE OXYGEN
Mather, W.B., Jr., and A.N. Webb, (Texaco, Inc., Beacon, N.Y.), I & EC - Industrial and Engineering Chemistry, Process Design and Development, V 7:15-21, Ja 68, Avail:TAC

A fuel cell using a phosphoric acid paste electrolyte with porous carbon and metal gauze electrodes has been operated at 200°C on dilute hydrogen and carbonaceous fuels with oxygen and air as oxidants. Dilute hydrogen, steam-reformed (at cell temperature) methanol, and shifted carbon monoxide give 70 to 90% the performance of pure hydrogen.
(FUEL CELL, TEMPERATURE, ELECTRODE)

H73 34213 METHANOL IN-SITU REFORMING FUEL CELLS
Hartner, A.J., and M.A. Vertes, (Leesona Moos Labs., Great Neck, N.Y.), Proceedings A.I.Ch.E. Joint Meeting, London, 65, N5:12-15

Considerable attention is currently being given to the development of fuel cells operating on carbonaceous fuels. The direct oxidation, although simple in over-all

concept, faces some severe development problems. In the alternative indirect approach, the carbonaceous fuel is steam reformed in a prereactor to produce H which can then be fed to a H fuel cell, the technology of which is considerably more advanced.
(EFFICIENCY)

H73 34214 PERFORMANCE OF COMPACT-DESIGN BUTANE-AIR FUEL CELL
Eisenberg, M., and B. Baker, Electrochem Technology, V 2:258-61, N9-10, Sept-Oct 64

Experiments were conducted on high-temperature, molten carbonate fuel cells to evaluate characteristics of hydrogen-air and butane-air systems; by use of reference electrode, it was possible to isolate anode and cathode performance; hydrogen electrode is almost independent of temperature over 500 to 750 C range.
(TEMPERATURE, ANODE, CATHODE)

H73 34215 PERFORMANCE OF REFORMED NATURAL GAS-ACID FUEL CELL SYSTEM
Meek, J., B.S. Baker, A.C. Allen, F.B. Leitz, W. Glass, and D.K. Fleming, American Chemical Society - Division of Fuel Chemistry, V 9:21-42 N3, Sept 12-17 '65

Development of hydrogen generator-fuel cell system in which feed from reformer is rich in hydrogen but unpurified, enrichment being achieved by conventional chemical processing techniques; this implies use of fuel cell of acid electrolyte type; it is unlikely that platinum will be replaced as catalyst, at least on oxygen side.
(FUEL CELL, CATALYST, NATURAL GAS, ACID)

H73 34216 PROBLEMS OF GASES MIXING IN H_2/O_2 FUEL CELLS IN WHICH GAS CIRCULATES THROUGH ELECTROLYTE
Telschow, C.G., Brown Boveri Review, V 53:18-20 N1-2, Ja-Fe 66

In fuel cells that are operated at low temperatures with liquid electrolyte and with oxygen and hydrogen, heteroporous electrodes may be used in which some gas is conveyed unused through electrolyte; for fuel cell to function properly, it is essential for barrier between two electrodes to allow electrolyte through, but not gases concerned; this article deals with some problems raised by mixing of gases and gives some results obtained with experimental model.
(FUEL CELL, ELECTROLYTE)

H73 34217 LOW TEMPERATURE FUEL BATTERIES
Williams, K.R., J.W. Pearson, and W.J. Gressler, International Symposium on Batteries, 4th-Proceedings, Sept 64, p 337-47

Development of low-temperature fuel battery with output capability of 250 w at 12 v, measuring 12X12X9 in. maximum; annular electrodes consisted of thin nonconducting porous plastic PVC substrate with applied silver conducting layer on one face; single electrode area estimated at .5 sq ft and number of cells for required 12 v equal to 20; electrolyte 6N KOH solution; H_2 and O_2 are reactant gases. (FUEL CELL, TEMPERATURE, ELECTRODE)

H73 34218 SELF-DISCHARGE OF A HYDROGEN-OXYGEN FUEL CELL
Kubokawa, M. and G. Takeshima, (Doshisha University, Kyoto, Japan), Denki Kagaku, V 34:883-7 N11, 66, In Japanese

The self-discharge of a H-O fuel cell with a porous carbon electrode was studied. The self-discharge was assumed to be caused by dissolved O and its convection in the vicinity of the H electrode, the maximum c.d. observed being 2.4 $ma./cm^2$. The self-discharge was more pronounced with a large quantity of Pd catalyst, by inadequate waterproofing of the electrode, and by increase of temperature. (CARBON, ELECTRODE)

H73 34219 ELECTROLYTIC REGENERATIVE HYDROGEN-OXYGEN FUEL-CELL BATTERY
Findl, E., and M. Klein, (Xerox Corp., Rochester, N.Y.), Proceedings, Annual Power Sources Conference 20, 49-52, 66

An electrolytically regenerative fuel cell developed for use as a secondary battery includes a H_2-O_2 primary fuel cell and a water electrolysis cell as a single unit. During charging, H_2O contained in an asbestos matrix separating the electrodes is electrolyzed to produce H_2 and O_2. As the gases are evolved, they are fed to storage tanks. During discharge, the stored gases are recombined at the electrodes to form H_2O which is absorbed by the matrix. (ELECTROLYSIS)

H73 34220 THE USE OF HYDROGENASE-METHYLENE BLUE SYSTEM IN A BIOCHEMICAL FUEL CELL (AN ANODE REACTION)
Mizuguchi, J., S. Suzuki, K. Kashiwaya, and M. Tokura, Kogyo Kagaku Zasshi, V 67:410 N2, 64, In Japanese, Avail:TAC

An electron carrier system similar to one found in living cells has been studied in vitro at the anode of a

biochemical fuel cell. The action of an electron carrier system, composed of methylene blue as an organic Redox compound and hydrogenase as an enzyme with hydrogen gas, has been analyzed at the anode of a biochemical fuel cell. A current of 0.16 mA/ (sq. cm.) has been shown using a hydrogenase solution obtained from E. coli. It gave evidence for general application of similar systems in biochemical fuel cells.
(FUEL CELL, BIOCHEMICAL)

H73 34221 PRESSURE OPERATION OF FUEL CELLS
Watson, R.G.H., and L.J. Pearce, International Symposium on Batteries, 4th-Proceedings, Sept 64, p 349-69

Thermodynamic and kinetic effects of gas pressure on fuel cell performance using gas at one or both electrodes; results for two hydrogen cells and changes caused by pressure variants recorded; oxygen electrode is apparently insensitive to pressure but for hydrogen electrode polarization is pressure-dependent; cause of this dependence as yet indeterminate.
(POLARIZATION)

H73 34222 A 5-kW HYDROGEN-AIR FUEL BATTERY WITH AN ALKALINE ELECTROLYTE
Jacquelin, J., J.P. Pompon, (Research and Development Non-Mechanical Electric Power Sources), Proceedings, International Symposium, 7th, 391-404, 70

Current progress in the development of H-air fuel batteries in the 5 kW range is discussed. The cells of the battery consist of a H chamber and sintered Ni electrodes containing nonprecious metal oxides as catalysts, an electrolyte chamber containing 8M KOH and an air chamber with sintered Ni electrodes.
(CATALYST)

H73 34223 A 1 KW HYDROGEN FUEL BATTERY
Gillibrand, M.I., and J. Gray, (Electric Power Storage, Ltd., England), Power Sources 1966: Research and Development in Non-Mechanical Electrical Power Sources; Proceedings of the Fifth International Symposium, Brighton, England, Sept 20-22 '66, Avail:TAC

A hydrogen fuel battery operating at normal temperature has been constructed and operated over an extended period.

The battery was assembled with 30 individual multielectrode cells. Full instrumentation was included to enable measurements to be made of each cell and electrode potential, temperatures, and the pressure and consumption of hydrogen and oxygen.
(INSTRUMENTATION)

H73 34224 DUAL CELL REGENERATIVE FUEL CELL INVESTIGATION
Stedman, J.K., and D. Baillieul, (Pratt and Whitney Aircraft, East Hartford, Conn.), N72-30041, AD-741839, Avail:TAC

An analytical and exploratory development program was conducted on an integrated dual cell design of a hydrogen-oxygen regenerative fuel cell. Discussed is a design which employs separate fuel cell and electrolysis cells in a single container which also acts as a reactant pressure vessel. The alkaline matrix cells are arranged on two concentric cylinders within the pressure vessel with water transport accomplished by vapor diffusion across the hydrogen gap separating the cell cylinders. The performance and endurance potential of the dual cell concept was evaluated. The fuel cell is being designed for use in satellites to overcome the problem of power generation during solar eclipse.
(ELECTROLYSIS, ALKALINE)

H73 34225 FUEL CELL TECHNOLOGY PROGRAM CONTRACT SUMMARY REPORT
Anon, (Pratt and Whitney Aircraft, East Hartford, Conn., South Windsor Engineering Facility), N72-30029, NASA-CR-128519, Avail:TAC

A fuel cell technology program which was established to advance the state-of-the-art of hydrogen-oxygen fuel cells using the P and WA PC8B technology as the base is reported. The major tasks of this program consisted of fuel cell system studies of a space shuttle powerplant conceptual design.
(SHUTTLE)

H73 34226 FUEL CELL TECHNOLOGY PROGRAM
Anon, (Pratt and Whitney Aircraft, East Hartford, Conn.), N72-30028, NASA-CR-128618, Apr 27 '72, Avail:TAC

A fuel cell technology program was established to advance the state-of-the-art of hydrogen oxygen fuel cells using low temperature, potassium hydroxide electrolyte technology as the base. Cell and component testing confirmed that low temperature, potassium hydroxide electrolyte

technology is compatible with the requirements of the space shuttle contractors.
(TEMPERATURE, SHUTTLE)

H73 34227 FUEL-CELL DESIGN BASED ON AIR AND REFORMABLE FUEL
Anon, (General Electric Co.), British 1,174,973, Dec 17 '69

A design of fuel cell is described, having the following special features: (1) the generation of H fuel by reaction between an organic fuel and H_2O in a reformer; (2) removal of CO from the reformate; (3) the use of H_2O, formed in the cell by reaction, in the reformer.
(FUEL CELL, AIR, FUEL)

H73 34228 HYDROGEN FOR FUEL CELL
Anon, (United Aircraft Corp.), Netherlandish Application 6.609,447, Ja 9 '67

The H is produced by a dehydrogenation catalyst in contact with an H-containing feed material. The H+ formed are led through an adsorbing porous carrier to a cathode, which contains a catalyst for the adsorption of these ions and their subsequent reduction on passage of an electric current.
(CATALYST, SEPARATION)

H73 34229 HYDROGEN GENERATION FOR FUEL CELLS
Kordesch, K.V., (Union Carbide Corp.), British 1,146,900, Mar 26 '69

H_2 is supplied to conventional fuel cell by a N_2H_4- or NH_3-decomposition cell employing acid or basic electrolytes, Pt-metal-catalyzed C, porous-Ni, or Raney-Ni electrodes. The necessary power is supplied from the fuel cell itself, generally producing approximately 900 mv. at c.d. 100 ma./cm^2.
(AMMONIA, HYDRAZINE)

H73 34230 PROCESS FOR SUPPLYING HYDROGEN AND OXYGEN TO FUEL CELLS
Vahldieck, N.P., Snyder, and L.C. Matsch, (Union Carbide, N.Y.), U.S. Patent 3,532,547

A process for operating a hydrogen-oxygen fuel cell in a closed system, hydrogen being obtained by dissociation of a hydrogen-containing compound and oxygen being obtained

from a liquid oxygen supply. Oxygen is used to burn various waste products. The resulting heat is used in the dissociation of the hydrogen-containing compound and the refrigeration value of oxygen and/or the hydrogen-containing compound is used to condense combustion products and other by-product materials.
(AMMONIA)

H73 34231 HYDROGEN PURIFICATION USING MODIFIED FUEL CELL PROCESS
McEvoy, J.E., R.A. Hess, G.A. Mills, H. Shalit, Industrial and Engineering Chemistry - Process Design & Development, V 4:1-3 N1, Ja 65

Technique for purifying H_2 streams to obtain high purity H_2 is based on use of electrochemical cells using highly efficient catalytic electrodes; impure hydrogen is consumed at anode of cell and purified hydrogen generated at cathode; by application of small potential across electrodes of this cell, it is possible to ionize H_2, and only H_2, at anode and simultaneously to produce equivalent amount of H_2 at cathode.
(FUEL CELL, PURIFICATION, ELECTRODE)

H73 34232 20 WATT-HOUR PER POUND REGENERATIVE FUEL CELL
Costa, R.L., and S.S. Tomter, (Electro-Optical Systems, Pasadena, Calif.), Report No. EOS-4058-FR, Mar 72, Avail:TAC

The electrolytically regenerative fuel cell is an electrochemical energy storage device, wherein the energy density per unit weight substantially exceeds present acceptable power sources. The report is concerned with a cylindrical regenerative hydrogen-oxygen fuel cell which is a basic electrochemical cell serving the dual function of a primary fuel cell and a water electrolysis cell.
(ELECTROLYSIS)

H73 34233 HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS
Astrin, R.F., and M.G. Klein, (Electro-Optical Systems, Inc., Pasadena, Calif.), N71-12253, NASA-CR-1683, Nov 70, Avail:TAC

The objectives of this program were to evaluate the processes, materials, and components that limit the cycle life of regenerative hydrogen-oxygen fuel cells. A composite capillary matrix was developed, tested, and demonstrated to be superior to fuel-cell-grade asbestos and

other more commonly used matrix materials.
(LIFE, MATRIX)

H73 34234 ELECTROLYTICALLY REGENERATIVE HYDROGEN-OXYGEN FUEL CELL
Wilner, B.M., H.A. Frank, E. Findl, and M.G. Klein, (Electro-Optical Systems, Inc., Pasadena, Calif.), N71-11052, U.S. Patent 3,507,704, Avail:TAC

A compact and electrolytically regenerative fuel cell with integral but separate storage for the electrolyte and each of the gases utilized is described. The fuel cell embodies bipolar plates possessing integral manifold means for conveying the fuel and oxidizing gases to and from the storage areas of the cell. It also embodies gas distribution means in the plates for effective and uniform exposure of the electrodes and reacting areas to the fuel and oxidizing gases.
(ELECTROLYSIS)

H73 34235 ELECTROLYTIC REGENERATIVE H_2-O_2 SECONDARY FUEL CELLS
Klein, M.G., and R.L. Costa, (Electro-Optical Systems, Inc., Pasadena, Calif.), Space systems and thermal technology for the 70's; American Society of Mechanical Engineers, Space Technology and Heat Transfer Conference, Los Angeles, Calif., Je 21-24 '70, Proceedings, Part I, New York, 70, Avail:TAC

The regenerative H_2-O_2 secondary fuel is rechargeable battery that uses pressurized hydrogen and oxygen gas as the reactants. It is expected that this new energy storage system will be used in communication satellites to replace conventional secondary batteries. During charge, water contained within a matrix separating the electrodes is electrolyzed to produce hydrogen at one electrode and oxygen at the other. During discharge the stored gases are reacted at the same electrodes to give electrical energy and form water, which is reabsorbed by the matrix.
(ELECTROLYSIS, MATRIX, DESIGN)

H73 34236 HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS
Klein, M. and R. Astrin, (Electro-Optical Systems, Inc., Pasadena, Calif.), N69-18885, NASA-CR-1244, Fe 69, Avail:TAC

A research and development program to develop an elec-

trolytic regenerative hydrogen-oxygen fuel cell concentrated on the development of a capillary matrix bipolar pile fuel cell stack with integral gas storage tankage. Tasks were undertaken to select and develop electrodes and matrix materials for the regenerative fuel cell. A cell stack employing an oxygen electrode, a potassium titanate matrix, and a hydrogen electrode consisting of a platinized sintered porous nickel plaque was found to comprise the best cell construction.
(ELECTRODE, MATRIX, ELECTROLYSIS)

H73 34237 HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS, 1 JULY-AUGUST 1966
Klein, M.G., (Electro-Optical Systems, Inc., Pasadena, Calif.), N67-12906, NASA-CR-80109, Aug 10 '66, Avail:TAC

This report reviews the progress made on the development of a hydrogen-oxygen regenerative fuel cell (secondary battery).
(FUEL CELL, REGENERATION)

H73 34238 HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS
Klein, M.G., (Electro-Optical Systems, Inc., Pasadena, Calif.), N66-22945, NASA-CR-71855, Nov 10 '65, Avail:TAC

This report reviews the progress made during this period on the development of a hydrogen-oxygen regenerative fuel cell. Primary emphasis was placed on processing and testing single cells with various electrode structures in order to improve the cycle life capabilities of the oxygen electrode.
(FUEL CELL, REGENERATION)

H73 34239 HYDROGEN-OXYGEN ELECTROLYTIC REGENERATIVE FUEL CELLS
Rowlette, J.J., (Electro-Optical Systems, Inc., Pasadena, Calif.), N64-11809, NASA-CR-55059, Oct 18 '63, Avail:TAC

Progress reported includes the following: (1) A system analysis of fuel cells was made by relating the cell-component weights to the fuel-cell electrode area, and then relating the latter to the pertinent operating parameters of the system. After this part of the analysis was completed, the weight relationships were programmed into an IBM computer, and all parameters pertinent to the problem were varied systematically.
(WEIGHT, CURRENT DENSITY)

H73 34240 ELECTRICALLY-REGENERATIVE HYDROGEN-OXYGEN FUEL CELL
Frank, H.A., (Electro-Optical Systems, Inc., Pasadena, Calif.), N63-10270, ARS Paper-2563-62, ARS Space Power Systems Conference, Santa Monica, Calif., Sept 25-28 '62, Avail:TAC

A description is presented of the status of electro-optical systems in the development of an electrically regenerative hydrogen-oxygen fuel cell for space application. The system performs the same function as a secondary battery in spacecraft, and shows potential advantages over batteries from standpoints of energy-to-weight ratio, cycle life, and operating temperature range.
(FUEL CELL, REGENERATION)

H73 34241 15-KW HYDROCARBON-AIR FUEL CELL ELECTRIC POWER PLANT DESIGN
Truitt, J.K., (Texas Instruments, Inc., Dallas, Tex.), AD-827-947, Ja 11 '68, Avail:TAC

Critical subsystems and components representing elements of a 15-kilowatt partial-oxidation molten-carbonate hydrogen-air fuel cell power generating system were designed, fabricated and tested to establish overall feasibility of the 15-kilowatt design.
(CARBONATE)

H73 34242 PERFORMANCE OF A MOLTEN CARBONATE FUEL CELL AND BATTERY SYSTEM
Peattie, C.G., I. Trachtenberg, and J.K. Truitt, (Texas Instruments, Dallas, Tex.), Proceedings, Australian Conference on Electrochemistry, 1st, Sydney and Hobart, Australia, Fe 13-20 '63, Avail:TAC

Investigation of the single-cell and multicell performance of a molten-carbonate fuel cell at 600°C. Hydrogen, reformed propane, and an equilibrium solution of methanol and water are used as fuels, with air as oxidant.
(FUEL CELL, CARBONATE)

H73 34243 MOLTEN-CARBONATE FUEL BATTERY PROGRAM
Truitt, J.K., (Texas Instruments, Inc., Dallas, Tex.), N64-15562, TI-08-63-108, 63, Avail:TAC

Power obtainable from single cells on hydrogen fuel using the 4 3/16-in. electrode diameter assembly has been increased from an average of 60 w to about 100 w/ft^2 at 0.7 v by improvements in the fuel electrode structure and

reduction in electrical resistance.
(OXIDATION)

H73 34244 MODIFIED PARTIAL OXIDATION OF HYDROCARBONS FOR USE IN ACID FUEL CELLS
Bannochie, J.G., and C.G. Clow, Energy Conversion, V 13:67-74, Pergamon Press, 73

The authors consider the problems of fuel cell systems capable both of running on logistic hydrocarbon fuels without the provision of an external water supply and of operating in the temperature range -40° to $+52^{\circ}C$. During this study they evolve a modification to partial oxidation and the paper describes this process and the advantages and limitations of fuel cell systems incorporating it.
(FUEL CELL, ACID, HYDROCARBON, OXIDATION)

H73 34245 EFFECT OF OXYGEN-SUPPLY IMPURITIES ON PERFORMANCE OF HYDROGEN-OXYGEN FUEL CELL
Jones, J.C., J.E. Cox, Energy Conversion, V 8:113-15 N3, Nov 68

Experimental method involved operation of single cells with three reactant oxygen supply purity levels; constant load was maintained and change in cell performance was measured as voltage degradation and change in cell performance was measured as voltage degradation with time during test run; after each test run, significant immediate voltage recovery was observed when oxygen electrode was purged.
(FUEL CELL, PERFORMANCE)

H73 34246 FACTORS AFFECTING LIFE OF FUEL CELLS
Gillibrand, M.I., G.R. Lomax, 20th Annual Power Sources Conference - Proceedings, U.S. Army Electronics Laboratories, Fort Monmouth, N.J., May 24-26 '66, p 24-8

Series of experiments to determine life of individual fuel cells; oxygen electrodes contained carbon, graphite, and Teflon-bonded Pt catalyst; discharge duration of six oxygen electrodes at 60 C and 50 ma/sq cm varied from 10,898 to 14,904 hr; at 100 ma/sq cm hours varied from 3368 to 12,488; similar performance data indicated for hydrogen electrodes; life-tests on 30 hydrogen-oxygen cells with KOH electrolyte gave operating histories ranging from 0 to 8960 hr.
(ALKALINE, ELECTRODE)

H73 34247 500-WATT INDIRECT HYDROCARBON SYSTEM
Bartosh, S.J., 20th Annual Power Sources Conference - Proceedings, (U.S. Army Electronics Labs, Fort Monmouth, N.J.), May 24-26 '66, p 31-5

Program and design of 500 w indirect hydrocarbon-air power plant consisting of converter for producing H_2 from fuel and water by steam reforming and fuel cell for generating electrical power.
(REFORMING)

H73 34248 5 KVA HYDROCARBON REFORMER - AIR FUEL CELL SYSTEM
Kirkland, T.G., M.L. Engle, and G.I. Cade, 18th Annual Power Sources Conference - Proceedings, (U.S. Army Electronics Laboratories, Fort Monmouth, N.J.), May 64, p 31-3

Construction, operation, and performance of 5-kva air fuel cell system using reformer for hydrogen generation from water and hydrocarbons; power-conversion efficiency of system is 24%; diagrams are given showing air-supply, thermal-control and moisture-control networks.
(FUEL CELL, AIR, HYDROCARBON)

H73 34249 APOLLO FUEL CELL SYSTEM
Morrill, C.C., 19th Annual Power Sources Conference - Proceedings, (U.S. Army Electronics Labs, Fort Monmouth, N.J.), May 18-20 '65, p 38-41

Status report on hydrogen-oxygen (air) fuel cell system for Apollo spacecraft; power plant requirements, development progress and status, and performance growth are discussed.
(FUEL CELL, SPACECRAFT)

H73 34250 FUEL CELLS PRESENT STATUS AND DEVELOPMENT PROBLEMS
Kirkland, T.G., D.J. Looft, SAE-Paper 660230, Apr 5-6 '66

Approaches taken at U.S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va., to develop fuel-cell power plants for application which uses hydrogen derived from liquid hydrocarbons and oxygen from ambient air; four systems are investigated, namely, direct oxidation, internal reforming, external reforming and partial oxidation-molten carbonate; major problem areas common to all systems are electrode reliability and noise, weight and reliability of auxiliary components; fuel-cell power-plant power density that has to be achieved to replace internal combustion engines in vehicles is between 10 and 13 lb/kw.
(REFORMING, OXIDATION)

H73 34251 OPERATING CHARACTERISTICS OF HIGH-PRESSURE MEDIUM-TEMPERATURE HYDROGEN-OXYGEN RECHARGEABLE FUEL CELLS
Ramakumar, R., Proceedings, Frontiers of Power Technology Conference, Oct 23- '69, Oklahoma State University, Stillwater, Okla.

This paper presents and discusses the experimental results obtained to study the effect of pressure and temperature on the electrolysis and fuel cell polarization curves of rechargeable hydrogen-oxygen fuel-cells employing porous zirconia membrane and aqueous potassium hydroxide electrolyte.
(POLARIZATION, ALKALINE)

H73 34252 GENERATING POWER IN A MOLTEN ELECTROLYTE (HYDROGEN-HALOGEN) FUEL CELL
Juda, W., D.M. Moulton, and H.L. Gruber, (Protech Inc, and Atlantic Richfield Co.,) U.S. 3,575,717, Apr 20 '71

Fuel cells employing an H_2 anode, a halogen cathode, and a molten electrolyte containing ions of the halogen can be operated at potentials much higher than their stated potentials if the H halide (HX) is not soluble in the electrolyte and if it is removed as formed.
(FUEL CELL, ELECTROLYTE)

H73 34253 STUDIES OF THE MOLTEN CARBONATE ELECTROLYTE FUEL CELL
Webb, A.N., W.B. Mather, Jr., and R.M. Suggitt, (Texaco Research Center, Beacon, N.Y.), Journal of the Electrochemical Society, V 112:1059 N11, Nov 65

Fuel cells with $NaLiCO_3$ electrolyte contained in a porous MgO matrix have been operated at 650^{o}C on synthetic, "realistic" fuels containing combinations of H_2, CO, CO_2, H_2O, and N_2. A mixture of air and CO_2 was used as the state of the electrode was avoided. H_2 and CO were oxidized at oxidized electrodes with 0.6v activation polarization. Carbon deposition from the disproportionation of CO occurred even during the oxidation of H_2. The disproportionation can be prevented by addition of H_2O or CO_2.
(FUEL CELL, CARBONATE)

H73 34254 HYDROGEN-OXYGEN PRIMARY EXTRATERRESTRIAL (HOPE) FUEL CELL PROGRAM
Anon, (General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa.), N63-15188, ASD-TDR-62-522, Je 62, Avail:TAC

Phase 1 of this program resulted in the development and test of a 25-watt fuel-cell module, and the design and fabrication of HOPE spacecraft compatible with the improved Blue Scout Booster.
(WATER, REMOVAL)

H73 34255 HYDROGEN-OXYGEN PRIMARY EXTRATERRESTRIAL (HOPE) FUEL CELL PROGRAM
Anon, (General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa.), N63-15188, ASD-TDR-62-522, Je 62, Avail:TAC

Phase I of this program resulted in the development and test of a 35-cell 25-watt/28-volt space configuration fuel-cell module. The HOPE spacecraft, fuel supply tanks, pneumatics, and thermal systems have been designed and fabricated to provide operating capability in orbit for 7 days at 50 watts, compatible with the Blue Scout launch vehicle.
(WATER, REMOVAL, HEAT, VIBRATION)

H73 34256 FUEL CELL TECHNOLOGY PROGRAM
Anon, (General Electric Co., Lynn, Mass.), N72-23053, NASA-CR-115572, Aug 25 '72, Avail:TAC

A program to advance the technology for a cost-effective hydrogen/oxygen fuel cell system for future manned spacecraft is discussed. The evaluation of base line design concepts and the development of product improvements in the areas of life, power, specific weight and volume, versatility of operation, field maintenance and thermal control were conducted from the material and component level through the fabrication and test of an engineering model of the fuel cell system.
(COST, SPACECRAFT)

H73 34257 A NEW HIGH-PERFORMANCE FUEL CELL EMPLOYING CONDUCTING-POROUS-TEFLON ELECTRODES AND LIQUID ELECTROLYTES
Niedrach, L.W., and H.R. Alford, (General Electric Co., Schenectady, N.Y.), Journal of the Electrochemical Society, V 112:117 N2, Fe 65

A low-temperature, aqueous electrolyte fuel cell employing new, "conducting-porous-Teflon electrodes" is described. The new electrodes show excellent performance characteristics with a variety of fuels (including hydrocarbons) and with both oxygen and air as the oxidant. Preparation methods are discussed, and performance data obtained with ambient temperature, hydrogen-oxygen and hydrogen-air cells are presented to illustrate their properties.
(FUEL CELL, ELECTRODE)

H73 34258 THE OPERATION OF AN ION-MEMBRANE FUEL CELL WITH MICROBIALLY-PRODUCED HYDROGEN
Blanchard, G.C., and R.T. Foley, (Veterans Administration Hospital, Boston, Mass.), Journal of the Electrochemical Society, V 118:1232 N7, Jl 71

A consideration of various methods of converting the energy associated with biochemical or microbiological reactions to electrical energy indicates that the most practical approach is the indirect whereby products produced by enzymatic reactions are fed to an electrochemical converter. Hydrogen can be produced by the action of Clostridium perfringens on glucose and natural product substrates in technologically significant quantity and purity. The hydrogen produced by the action of Clostridium perfringens on glucose and bananas (as an example of natural products) has operated an ion-membrane H_2-O_2 fuel cell for periods of 24-48 hr with no evidence of detrimental reactions. Such systems operate at power densities order-of-magnitude greater than direct biochemical fuel cells wherein the enzymatic reaction takes place on the electrode. They would offer advantages for operation in remote areas.
(FUEL CELL, ION, MEMBRANE, MICROBE)

H73 34259 PERFORMANCE STUDIES ON A RECHARGEABLE HYDROGEN-OXYGEN FUEL CELL
Hughes, W.L., R. Ramakumar, and H.J. Allison, (Oklahoma State University, Stillwater, Okla.), Proceedings of the Fifth Intersociety Energy Conversion Engineering Conference, Las Vegas, Nev., Sept 21-25 '70, Avail:TAC

Hydrogen-oxygen fuel cells employing a porous membrane made of calcia stabilized zirconia and sintered nickel electrodes with no noble metal catalysts of any kind have the potential for the developement of an economical energy storage system. In this paper, the effect of the porosity of the membrane on the polarization curves of electrolysis and fuel cell modes of operation are investigated experimentally and the results are presented and discussed.
(ELECTRODE, POLARIZATION, POROSITY)

H73 34260 ECONOMIC HIGH-PRESSURE HYDROGEN-OXYGEN REGENERATIVE FUEL-CELL SYSTEMS
Allison, H.J., (Oklahoma State Univ., Stillwater, Okla.), R. Ramakumar, W.L. Hughes, Proceedings of 4th Intersociety Energy Conversion Engineering Conference, Washington, D.C., Sept 22-26 '69, Paper 699129, p 1042-7

Experimental prototype units of high pressure (1000

to 3000 psi) moderate temperature (300 to 350 F) hydrogen-oxygen reversible fuel-cells using no noble materials of any kind have been successfully operated cyclically with encouraging results. The approach consists of using calcia stabilized porous zirconia as membrane and aqueous KOH as electrolyte with porous nickel electrodes sintered on to the membrane.
(TEMPERATURE, PRESSURE, POROSITY)

H73 34261 FUEL CELL RESEARCH AT OKLAHOMA STATE UNIVERSITY
Allison, H.J., (Oklahoma State University), Proceedings, Energy Conversion & Storage, 2nd, Oct 12-13 '64

Study for development of reversible hydrogen-oxygen fuel cells with electrodes which function at pressures as high as 3000 psi and which can be mass produced; conformal transformations of electrode configuration; construction and analysis of "magnet-hydrodynamic" hydrogen-oxygen cells using intense transverse magnetic field instead of conventional electrolyte to provide high resistance path between electrodes for ions and RF excitation to change fuel gases to nascent state.
(PRESSURE, ELECTRODE)

H73 34262 EXPERIMENTAL WORK TO DATE ON ENERGY CONVERSION AND STORAGE AT OKLAHOMA STATE UNIVERSITY
Allison, H.J., (Oklahoma State University), Proceedings, Conference on Energy Conversion and Storage, 63, p 65-80

Energy storage system under development is discussed that uses h-p electrolysis for production of hydrogen and oxygen gases, and fuel cells for subsequent recombination of gases to form water and electrical energy; most of experimental work concerns physical properties of fuel cells and pressure electrolysis units.
(ELECTROLYSIS, FUEL CELL)

H73 34263 HIGH PERFORMANCE FUEL CELL
Vannatta, D.W., (Allis-Chalmers, Milwaukee, Wis.), Report No. AFAPL-TR-70-42, Avail:TAC

The objective of this contract was to develop technology required for a high performance H_2/O_2 fuel cell power system for future Air Force space vehicle applications. Technical objectives for the system included: a specific energy of 1100 watt-hours per pound, a reliability of 0.998 for a

mission of 1500 hours duration, power requirements of 3 kW to 10 kW, and a system operating life goal of 3000 hours.
(SPACECRAFT)

H73 34264 RELIABILITY ASSESSMENT TESTING OF 2 KW. HYDROGEN-OXYGEN FUEL CELL STACKS
Bruno, R.P., J.R. Hurley, (Research Division, Allis-Chalmers, Milwaukee, Wis.), Intersociety Energy Conversion Engineering Conference, 67, p 415-22

The development of a 2 kw, H_2-O_2 alkaline fuel-cell power system has been undertaken. A reliability assessment testing program has been conducted to determine the capabilities and limitations of this system. Eight, 2-kw. fuel-cell stacks were constructed and tested to failure under this program.
(ALKALINE)

H73 34265 SEALING OF SILVER OXIDE-ZINC STORAGE CELLS
Anon, (McDonnel-Douglas Co., Newport Beach, Calif.), N69-12309, NASA-CR-97817, 67, Avail:TAC

The evaluation of the miniature fuel cells in controlling pressure in sealed silver oxide-zinc storage cells is summarized. These fuel cells are miniature electro-chemical devices composed of one solid battery electrode and one fuel cell gas consuming electrode. They are installed on or in a silver oxide-zinc storage cell and perform their pressure control function by electrochemically consuming evolved gases (H_2 and O_2) from the storage cells.
(FUEL CELL, PRESSURE)

H73 34266 INCREASED HYDROX FUEL CELL PERFORMANCE
Morgan, J.R., (NASA, Marshall Space Flight Center, Huntsville, Ala.), N72-22216, Research Achievements Review, V 4: 97-101, Fe 72, Avail:TAC

Research is being conducted to identify hydrogen-oxygen fuel cell system limitations and to investigate methods of reducing them. A method is proposed for improving cathodic efficiency.
(CATHODE, EFFICIENCY)

H73 34267 EXPERIMENTAL EVALUATION OF THE SINGLE-CELL CONCEPT FOR A LIGHTWEIGHT, RECHARGEABLE HYDROGEN-OXYGEN FUEL CELL
Stockel, J.F., (COMSAT Labs., Clarksburg, Md.), Proceedings of the Fifth Intersociety Energy Conversion Engineering Conference, Las Vegas, Nev., Sept 21-25 '70, V 1:5-95, 5-100, Avail:TAC

These are the first lightweight, rechargeable hydrogen-oxygen fuel cells built that demonstrate an attractive usable energy density (15 watt-hour/lb) and have good potential for increasing the energy density. The cells are rated at 24 ampere-hours, are cylindrical, and were operated between 230 and 600 psig. Utilized in the single-cell concept, these cells have the potential for good reliability and easy charge control. This work represents a significant step toward developing a rechargeable fuel cell for use on communications satellites.
(FUEL CELL, LIGHTWEIGHT, RECHARGEABLE)

H73 34268 HIGH POWER DENSITY FUEL CELL
Durante, B., (Wright-Patterson AFB, Ohio), J.K. Stedman, and C.L. Bushnell, (Pratt and Whitney Aircraft Div., South Windsor, Conn.), 4th Intersociety Energy Conversion Engineering Conference, Washington, D.C., Sept 22-26 '69, Proceedings, Avail:TAC

Interim results of an Air Force-sponsored experimental and analytical program conducted to investigate the feasibility of hydrogen-oxygen fuel cells for high-power short-duration applications such as missiles and satellite power systems. The concept being evaluated in this program includes a high-power-density hydrogen-oxygen fuel cell with open cycle heat and product-water removal subsystems, and reactant tankage. Results of a fuel cell test program are discussed.
(HEAT, REMOVAL, WATER, ENDURANCE)

H73 34269 ADVANCED SPACECRAFT FUEL CELL SYSTEMS
Thaller, L.H., (NASA, Lewis Research Center, Cleveland, O.), Power Sources Symposium, 25th, Atlantic City, N.J., May 23-25 '72, Avail:TAC

An evolutionary advanced technology program is described which is aimed at meeting the requirements of the next generation of fuel cell systems as well as providing technology fallout to ongoing mission oriented programs. The specific

goals of the system selected for development are for 10,000 hr of operation with refurbishment, 20 lb/kW at a sustained power of 7 kW, and 21 kW peaking capability for durations of two hours. The system is designed to operate on low pressure propulsion grade hydrogen and oxygen.
(PRESSURE)

H73 34270 SIMULATED HYDROGEN CROSS-LEAKAGE IN A LOW-TEMPERATURE, CONTAINED-ELECTROLYTE HYDROGEN-OXYGEN FUEL CELL
Hagedorn, N.H., (NASA, Lewis Research Center, Cleveland, O.), N69-17337, NASA-TM-X-52542, 69, Avail:TAC

A fuel cell was operated at temperatures of 120 , 135 , and 150 F, and current levels of 10, 25, and 50 amperes. A cathode feed stream mixture containing oxygen and 0 to 20 percent hydrogen (by volume) was metered to the fuel cell. There existed a minimum feed rate of this mixture which was required to sustain cell performance at each operating point. The hydrogen portion of the mixture was completely consumed by combustion in all cases.
(FUEL CELL, TEMPERATURE)

H73 34271 FUEL CELL TECHNOLOGY PROGRAM
Bell, D., (NASA, Manned Spacecraft Center, Houston, Tex.), N70-40974, Space Transportation System Technology Symposium, V 6:349-60, Jl 70, Avail:TAC

The advanced fuel cell program to support the primary electrical power requirements of space shuttle vehicles in the mid-1970's is discussed. The objective is to advance the technology of hydrogen-oxygen fuel cells through a rigorous and comprehensive program commencing at the lowest component and material level and progressing through the fabrication and test of an engineering model fuel cell and related components and assemblies.
(FUEL CELL, TECHNOLOGY, SPACECRAFT)

H73 34500 EVALUATION OF FUEL CELL WATER FOR HUMAN CONSUMPTION
Katchman, B.J., C. Linder, S.A. London, A. West, and G. Kitzes, (Miami Valley Hospital, Dayton, O.), AMRL-TR-66-141, AF-33(657)11716, Nov 66

Water obtained from a hydrogen-oxygen fuel cell was subjected to chemical, organoleptic, and microbiological analyses and found to be acceptable according to the U.S. Public Health Service Standards.
(FUEL CELL, WATER, HUMAN)

H73 34501 INVESTIGATION OF THE DYNAMICS OF WATER REJECTION FROM A HYDROGEN-OXYGEN FUEL CELL TO A HYDROGEN STREAM
Prokopius, P.R., and N.H. Hagedorn, (NASA, Lewis Research Center, Cleveland, O.), N67-38425, NASA-TN-D-4201, Oct 67, Avail:TAC

A water rejection dynamics study of a hydrogen-oxygen fuel cell was conducted using both experimental and analytical techniques. In the type of cell studied, water resulting from the fuel cell reaction diffuses as a vapor through a porous electrode and is removed by circulating gaseous hydrogen. The experimental investigation was conducted by introducing step transients in the rate of water production and in the inlet humidity of the water removal gas stream, while holding all other cell operating parameters constant. When the various dimensions and operating conditions of the cell tested were substituted for the corresponding constants of the mathematical model, its step response was calculated and was found to compare well, with the experimental data.
(HUMIDITY, TRANSIENT, MODEL)

H73 34502 EXPERIMENTAL INVESTIGATION OF THE DYNAMICS OF WATER REJECTION FROM A MATRIX TYPE OF HYDROGEN-OXYGEN FUEL CELL
Prokopius, P.R., and R.W. Easter, (NASA, Lewis Research Center, Cleveland, O.), N69-14518, NASA-TN-D-4956, Dec 68, Avail:TAC

An experimental study of water-rejection dynamics was conducted on a matrix type of hydrogen-oxygen fuel cell which employs a hydrogen stream to extract the product water.
(HUMIDITY, TRANSIENT)

H73 34503 IMPROVED WATER- AND HEAT-REMOVAL UNIT FOR H_2/O_2 FUEL CELL SYSTEMS
Klink, R., and H.G. Plust, Energy Conversion, V 8:191-2 N4 Dec 68

It is possible to increase H_2O-removal density in H_2O-removal units of fuel cell systems, by that system parameters, causing increase of temperature of evaporator wall; values are given for influence of thickness of removal cavity of asbestos, KOH-stream and material used as support plaque for evaporator wall.
(FUEL CELL, WATER, HEAT, REMOVAL)

H73 34504 500-WATT HYDROGEN-AIR CELL
Breelle, Y., and A. Grehier, (Institut Fr. Pet., France), Journees Int. Etude Piles Combustion, C.R., 3rd, 280-5, 69

Problems concerning the thermal balance and the elimination of the H_2O formed are discussed. The performance of these cells and their endurance yield an elec. battery compatible with industrial use.
(HEAT, REMOVAL, WATER, ENDURANCE)

H73 34505 STATIC MOISTURE REMOVAL CONCEPT FOR HYDROGEN-OXYGEN CAPILLARY FUEL CELL
Platner, J.L., and P.D. Hess, Chemical Engineering Progress Symposium Series, V 61:299-305 N57 65

Static moisture removal system; desired water-vapor pressure is maintained in cell through diffusion membrane associated with each cell; water will not be evaporated from cell electrolyte until electrolyte vapor pressure exceeds desired value; above this value, evaporation rapidly increases; evaluation for space power applications.
(FUEL CELL, MOISTURE, REMOVAL)

H73 34506 LOW TEMPERATURE FUEL CELL
Connors, J.W., R.A. Thompson, and R.A. Sanderson, Chemical Engineering Progress, V 62:68-9 N5, May 66

Discussed are analysis of heat and water removal subsystems, synthesis into power plant of these subsystems with reactant conditioning and control subsystems, and mutual interaction of all these subsystems for low temperature hydrogen/oxygen fuel cell power plant.
(HEAT, REMOVAL, WATER)

H73 34507 THE SEPARATION OF REACTION WATER FROM FUEL CELLS BY DIFFUSION AND CONDENSATION
Gutbier, H., Chem. Ing. - Tech., V 40:1209-14 N24 68, Avail:TAC

An evaporation method was developed for separating the reaction water from fuel cells, in which the opposing evaporation and condensation surfaces are separated only by a narrow gas-filled slit. The liquid surface is stabilized mechanically by a porous membrane. The rate of water separation is measured as a function of temperature and electrolyte concentration. The test results are discussed in conjunction with theoretical considerations. The technical application of the method is described for hydrogen-oxygen fuel cells.
(FUEL CELL, WATER, REMOVAL)

H73 34508 USE OF A FLUIDIC OSCILLATOR AS A HUMIDITY SENSOR FOR A HYDROGEN-STEAM MIXTURE
Prokopius, P.R., (NASA, Lewis Research Center, Cleveland, O.), N66-33487, NASA-TM-X-1269, Washington, Aug 66, Avail:TAC

A continuous-reading humidity sensor was developed for transient studies of a hydrogen-oxygen fuel-cell system in which the water produced is removed from the cells in vapor form by a recirculating hydrogen stream. The basis of the sensor is a fluidic oscillator that has an oscillation frequency sensitive to molecular weight and, hence, humidity of the hydrogen-steam mixture.
(FUEL CELL, TRANSIENT, STEADY-STATE, ANALOG)

H73 34509 ZIRCONIUM PHOSPHATE MEMBRANES FOR INTERMEDIATE TEMPERATURE FUEL CELLS
Berger, C., M.P. Strier, Journal of the Electrochemical Society, V 115:230-3 N3 Mar 68

New type of solid inorganic membrane for intermediate temperature hydrogen-oxygen fuel cell application is described; this is based on zirconium phosphate sintered with zeolite material "Zeolon-H;" zeolite material contributes to maintenance of water balance in membrane which is required especially at temperatures above 25 C.
(WATER, REMOVAL)

H73 34510 DEVELOPING ELECTRICALLY DRIVEN HYDROGEN BLOWER FOR VEHICULAR FUEL CELL POWERPLANT
Amann, C.A., and G.D. Skellenger, SAE Paper 670455, May 15-19 '67, Avail:TAC

Compact hydrogen blower was designed to facilitate removal of water from hydrogen loop of fuel cell system in Electrovan; it involved two radial flow states, driven by high-speed electric motor through flexible shaft coupling. (WATER, REMOVAL)

H73 34511 WATER AND HEAT BALANCE OF HYDROGEN-OXYGEN FUEL CELLS

Sprengel, D., Energy Conversion, V 10:7-11 N1, Mar 70

The author describes the reaction products of the H_2-O_2 fuel cell namely water and heat with regards to optimum energy conversion and system balance. (FUEL CELL, WATER, HEAT, BALANCE)

H73 34600 USE OF THE ADSORPTION HYDROGEN ELECTRODE AND THE OXYGEN FUEL-CELL ELECTRODE IN NICKEL-CADMIUM CELLS
Sizemore, K.O., (Goddard Space Flight Center, Greenbelt, Md.), N66-24926, NASA-TM-X-55469, Apr 66, Avail:TAC

The characteristics of two types of auxiliary electrodes are investigated. The essentially linear response of the adsorption hydrogen's electrode voltage as a function of oxygen pressure and its stability in potassium hydroxide electrolyte makes it an ideal electrode for charge control. Although the oxygen fuel-cell electrode is a very good gas recombination electrode and better by a factor of 20 over the adsorption hydrogen electrode, it is difficult to use as a charge-control electrode because of its high sensitivity to oxygen pressure.
(CONTROL)

H73 34601 RESEARCH ON HYDROGEN FEED MECHANISM OF FUEL CELL ON OPEN CIRCUIT
Edon, C., International Symposium on Batteries, 4th - Proceedings, Sept 64, p 257-63

Electrochemical method applied to verification of simple theory describing feed mechanism for open-circuited fuel cell using gas and porous electrode; experiments with KOH electrolyte, 99.999% pure H_2 gas, Pt counter-electrode, and Hg/HgO as reference electrodes indicate that electrode feeding mechanisms for open-circuit configurations are dissolution and diffusion; good agreement shown between calculated and observed values.
(ELECTRODE)

H73 34602 OXIDATION OF HYDROGEN ON A PASSIVE PLATINUM ELECTRODE
Schuldiner, S., (Naval Research Lab., Washington, D.C.), Report No. NRL-6659, Fe 27 '68

Under potentiostatic, steady-state conditions and at anodic potentials above 0.7 V (NHE), the rate of oxidation of molecular hydrogen decreases at a high-activity Pt electrode in 1M H_2SO_4. It is shown that this decrease is not owing to the formation of oxygen species on the electrode surface.
(AN ION)

H73 34603 LOW TEMPERATURE HYDROGEN CELLS OF C.G.E. EXISTING BATTERIES AND FUTURE PROSPECTS
Dubois, P., and C. Edon, AGARD Propulsion and Energy Panel, Je 12-16 '67, Liege, Belgium

Principal characteristics of electrodes used by French General Electric Co. for manufacture of low-temperature hydrogen cells are described; expected development is also outlined; means that may be selected for production or storage of hydrogen for different applications are reviewed, and some details are given of various types of fuel cell power generators now being studied or tested at Compagnie Generale d'Electricite Research Center.
(ELECTRODE)

H73 34604 LOW COST FUEL CELL ELECTRODES
Frysinger, G.R., 20th Annual Power Sources Conference - Proceedings, (U.S. Army Electronics Labs., Fort Monmouth, N.J.), May 24-26 '66, p 14-17, Avail:TAC

Review of recent advances in hydrocarbon-air fuel cell construction designed to minimize Pt electrocatalytic requirements expressed in grams of Pt/kw gross power; goal sought is about 20 to 25 g equivalent of Pt/kw.
(CATALYST, ALKALINE)

H73 34605 LIGHT-WEIGHT FUEL CELL ELECTRODES - 1, 2
Colman, W.P., D. Gershberg, J. DiPalma, R.G. Haldeman, and K.V. Kordesch, 19th Annual Power Sources Conference, Proceedings, (U.S. Army Electronics Labs., Fort Monmouth, N.J.), May 18-20 '65, p 14-19, Avail:TAC

Effects of catalyst loading, matrix materials, and operating variables on performance of fuel cells using light-weight electrodes; operating variables include temperature, current density, and pressure; electrodes are prepared from commerical platinum black and consist of mixture of three parts platinum black and on part Teflon supported on nickel screen. Operating characteristics of thin, light-weight carbon electrodes with porous metal support for hydrogen-air fuel cells using hydrocarbon converters; effect of surface tension on contact angle for typical repellency agents; polarization curves for thin electrodes in H_2-O_2 and H_2-air fuel cells.
(CATALYST, MATRIX, POLARIZATION)

H73 34606 CARBON FUEL CELL ELECTRODES
Clark, M.B., W.G. Darland, K.V. Kordesch, 18th Annual Power Sources Conference, Proceedings, (U.S. Army Electronics Labs., Fort Monmouth, N.J.), May 64, p 11-14, Avail:TAC

Performance of thin carbon-nickel composite electrodes for hydrogen-oxygen fuel cells is discussed; electrode construction is shown; graphs of temperature and pressure effects on electrode output, and long-time performance.
(FUEL CELL, CARBON, ELECTRODE)

H73 34607 TRANSPORT OF HYDROGEN TO CYLINDRICAL ANODES IN STIRRED ELECTROLYTES
Cairns, E.J., A.M. Breitenstein, Journal of the Electrochemical Society, V 114:349-51 N4, Apr 67

Transport-limited electrode reaction chosen was anodic oxidation of hydrogen dissolved in aqueous electrolytes; anode was smooth platinum cylinder; electrolytes and temperatures chosen were 1N $HClO_4$ at 25 C, 1N Cs_2CO_3 at 24 C, and 1N Cs_2CO_3 at 80 C; limiting currents were measured for anodic oxidation of dissolved hydrogen; relevant to design and fabrication of practical military fuel cell power plants for operation on ambient air and hydrocarbon fuels.
(ELECTRODE, ACID, CARBONATE)

H73 34608 SOME PROBLEMS IN USE OF HYDROCARBONS IN FUEL CELL POWER SYSTEMS
Williams, K.R., A.G. Dixon, (American Chemical Society - Division of Fuel Chemistry), V 11:294-300 N3, Papers for Meeting Sept 10-15 '67

Some of problems encountered in design of hydrocarbon-reforming system and electrodes for use on impure hydrogen are discussed.
(ELECTRODE, IMPURITY)

H73 34609 REACTION OF HYDROGEN WITH NONSTOICHIOMETRIC MANGANESE DIOXIDE
Brooks, C.S., Journal of Catalysis, V 4:535-45 N5, Oct 65

Kinetics of hydrogen oxidation at temperatures from 25 to 400 C over active nonstoichiometric manganese dioxide; oxidation rates, energy requirements, and reaction mechanisms to explain interactions at catalytic electrodes for fuel cells and removal of oxidizable contaminants from air; oxidation rates were of first order; activation energy for depletive hydrogen and removal of oxygen from oxide lattice. (ELECTRODE, OXIDATION, CATALYST)

H73 34610 PRESENT STATE OF SCIENTIFIC STUDIES ON ELECTRODE PROCESSES IN FUEL CELLS
Doehren, H. von, and G. Wolf, Electrochimica Acta, v 11:53-64 N1, Ja 66

Several important types of electrodes used in low temperature fuel cells are discussed; porous gas-diffusion electrodes made of carbon or of suitable sintered metals are most commonly used; more recent developments are pore-free palladium membrane electrode for hydrogen as fuel. (TEMPERATURE, POROSITY, MEMBRANE)

H73 34611 PERFORMANCE OF CARBON MONOXIDE IN LOW-TEMPERATURE FUEL CELLS CONTAINING OXIDE CATALYSTS
Niedrach, L.W., I.B. Weinstock, Electrochem Technology, V 3:270-5 N9-10, Sept-Oct 65

Number of oxides have been shown to be effective in promoting electro-oxidation of carbon monoxide on platinum electrodes in acid electrolyte fuel cells; polarization curves for carbon monoxide/oxygen cells incorporating mixed catalysts approach those for hydrogen/oxygen cells; impure hydrogen that contains carbon monoxide (e.g. reformer gas) also responds to mixed catalyst system. (ELECTRODE, POLARIZATION)

H73 34612 PAPER FUEL CELL ELECTRODES
Barber, W.A., and N.T. Woodberry, Electrochem Technology, V 3:194-8 N7-8, Jl-Aug 65

Fuel cell electrodes can be made from waterproofed and platinized acrylic paper; large-area, uniform electrode sheets are possible, whose performance in hydrogen-oxygen fuel cells is equivalent to platinum black on metal screen. (FUEL CELL, ELECTRODE, PAPER)

H73 34613 OPERATING CHARACTERISTICS OF PALLADIUM-SILVER ANODE ON IMPURE HYDROGEN STREAMS
Chodosh, S.M., N.I. Palmer, and H.G. Oswin, American Chemical Society - Division of Fuel Chemistry, v 9:151-63 N3 Pt3, Sept 12-17 '65

Suitably prepared palladium-silver anode can be used

efficiently to extract hydrogen from impure streams within certain limits; limits of operation are set by temperature (fixed in these studies at 200 C), required H_2 utilization i.e., exit hydrogen partial pressure and reversibility of chemisorption of various impurity species; H_2 utilization at fixed current density is function of hydrogen partial pressure flow rate, and extent of impurity adsorption.
(FUEL CELL, ANODE, OPERATION)

H73 34614 NEW METHODS OF OBTAINING FUEL CELL ELECTRODES
Despic, A.R., D.M. Drazic, C.B. Petrovic, V.L. Vujcic, Journal of the Electrochemical Society, V 111:1109-12 N10, Oct 64

Method of obtaining Raney nickel hydrogen electrodes was evaluated; electrodes were made by pressing aluminum-nickel powder mixture, followed by simultaneous sintering of Ni skeleton and alloying of surface layer of formed Ni skeleton with aluminum present in its pores; major advantages of this type of electrode lie in simplicity of its preparation as well as in its mechanical strength.
(NICKEL)

H73 34615 NEW AIR ELECTRODE FOR FUEL CELLS
Zeliger, H.I., Journal of the Electrochemical Society, V 114:236 N3, Mar 67

Details of electrode fabrication procedure; mix contained silica, graphite, Teflon suspension, wetting agent, chloroplatinic acid, and water; slurry was applied on alternate sides of 45 mesh platinum screen; excellent performances (0.8 v IR free at 350 ma/sq cm) were obtained on hydrogen with platinum loadings of 1.0 mg/sq cm; it was, however, as air electrodes that these electrodes showed superiority.
(FABRICATION)

H73 34616 RANEY-NICKEL CATALYSTS IN GALVANIC FUEL CELLS
Doehren, H.H. von, and A. Kalberlah, Chemie-Ingenieur-Technik, V 40:176-80 N4, Fe 26 '68, (In German)

Nickel catalysts prepared by earlier methods were pyrophoric and could be used only under greatest care; by careful partial oxidation of hydrogen and of surface of Raney nickel with alkali salts of halogen oxoacids or air in non-aqueous environment spontaneous inflammability could be reduced without affecting electrochemical properties of elec-

trodes; by addition of promoters, susceptibility to damage on interruption of hydrogen supply could be considerably reduced.
(ELECTRODE, DAMAGE)

H73 34617 HYDROGEN-OXYGEN THIN ELECTRODE FUEL CELL MODULE
Winters, C.E., and W.L. Morgan, SAE - Paper 670182 for meeting Ja 9-13 '67, Avail:TAC

Construction and operating characteristics of Union Carbide hydrogen-oxygen thin electrode module as incorporated into General-Motors Electrovan are described; interfaces between fuel cell module and its thermal and its fuel system are considered as well as interface with electrical load under range of steady-state and transient conditions; accessible state-of-art and next generation improvements are described.
(FUEL CELL, ELECTRODE, MODULE)

H73 34618 FUEL CELLS
Fukuda, M., C.L. Rulfs, P.J. Elving, Electrochimica Acta, V 9:1551-86 N12, Dec 64

Catalysts consisting of palladium reduced by hydrogen, and palladium reduced by formate, supported on four types of porous skeleton disks.
(CATALYST, PALLADIUM, ELECTRODE)

H73 34619 EXPERIMENTAL STUDY OF MODE OF OPERATION OF POROUS GAS-DIFFUSION ELECTRODES WITH HYDROGEN FUEL
Austin, L.G., and S. Almaula, Journal of the Electrochemical Society, V 114:927-33 N9 Sept 67

Current-polarization curves from zero current to limiting current have been obtained for anodic ionization of H_2 at Teflon-bonded, platinum-black, gas-diffusion electrodes in 1N H_2SO_4.
(POLARIZATION, ANODE)

H73 34620 ELECTROFORMED FUEL CELL ELECTRODE MATRICES
Botosan, R.A., and T. Katan, Electrochem Technology, V 5:315-18 N7-8, Jl-Aug 67

Use of electroformed metal matrices as catalyst support and for current collection provides possible variety of structures inherently having high specific area and low ohmic resistance; catalyst distribution is easily

attained in fabrication and maintained in operation of hydrazine-oxygen and hydrogen-oxygen fuel cells yielding promising performance.
(CATALYST, FABRICATION)

H73 34621 ELECTROCHEMICAL ENERGY CONVERSION IN PALLADIUM-HYDROGEN DIFFUSION ELECTRODE
Cleary, H.J., N.D. Greene, Electrochimica Acta, V 10:1107-15 N11, Nov 65
Sufficiently high current densities can be attained on Pd/H diffusion electrodes to make their use in fuel-cell applications feasible.
(FUEL CELL, DIFFUSION, ENERGY, CONVERSION)

H73 34622 EFFECTS OF HEAVY DISCHARGE PULSING ON FUEL CELL ELECTRODES
Kronenberg, M.L., and K.V. Kordesch, Electrochem Technology, V 4:460-4 N9-10, Sept-Oct 66
Experimental study; under certain conditions heavy discharge pulses significantly improve sustained performance level of hydrogen/oxygen fuel cells.
(CATALYST)

H73 34623 COBALT PHTHALOCYANINE AS FUEL CELL CATHODE
Jasinski, R., Journal of the Electrochemical Society, V 112:526-8 N5, May 65
It has been possible to form oxygen electrode with metal chelate, cobalt phthalocyanine, as active catalyst; sufficient electric conductivity was achieved by mechanically blending chelate with acetylene black; stable electrode structure was formed by Teflon-bonding mixture to metal screen; current densities sustained with H_2/O_2 cells were sufficiently high (60 to 120 ma/sq cm), to be considered for application in practical fuel cell systems.
(ELECTRODE, CATALYST)

H73 34624 CARBON-AIR ELECTRODES FOR LOW TEMPERATURE FUEL CELLS
Kordesch, K.V., American Chemical Society - Division of Fuel Chemistry, V 9:13-20, N3, Sept 12-17 65, Avail:TAC
Carbon-containing cathodes seem to be most desirable electrodes for high-power density, economical, air-fuel

cells; fuel source for such low temperature cells may be hydrogen from hydrocarbon reformer units, or hydrogen from alcohol or ammonia converters; at present, CO_2 removal is necessary during air operation in order to attain long life at high current densities.
(FUEL CELL, TEMPERATURE, CARBON, ELECTRODE)

H73 34625 COMPOSITE CARBON-METAL ELECTRODES FOR FUEL CELLS
Clark, M.B., W.G. Darland, K.V. Kordesch, Electrochem Technology, V 3:166-71 N5-6, May-Je 65

Thin, composite electrodes have been developed for hydrogen-oxygen (air) fuel cells; these constitute considerable weight and volume reduction, combine structural advantages of porous metal carrier with excellent performance characteristics of thin carbon layer, and are adaptable to large-scale production.
(POROSITY, FABRICATION)

H73 34626 DEVELOPMENT OF CATHODIC ELECTROCATALYSTS FOR USE IN LOW TEMPERATURE HYDROGEN/OXYGEN FUEL CELLS WITH AN ALKALINE ELECTROLYTE
Giner, J., J. Parry, and L. Swette, (Tyco Labs., Inc., Waltham, Mass.), N69-10585, NASA-CR-97624, Je 30 '68, Avail:TAC

A survey was carried out on the intrinsic activity of the transition metals, selected transition metal alloys and intermetallic compounds, and transition metal carbides, nitrides, borides and silicides for the electrochemical reduction of oxygen.
(ELECTRODE)

H73 34627 A STUDY OF THE DEGRADATION OF PLATINUM BLACK FUEL CELL CATHODES
Malachesky, P.A., C. Leung, and H. Feng, (Tyco Labs., Inc., Waltham, Mass.), AD-757-714, Oct 72, Avail:TAC

The report deals with a study of the mode of cathode electrocatalyst degradation in the H_2-air phosphoric acid matrix fuel cell.
(FUEL CELL, PLATINUM, CATHODE)

H73 24628 FUEL CELLS WITH ELECTROCHEMICAL HYDROGEN COMBUSTION
Anon, Revue de l'Institut Francais du Petrole et Annales des Combustibles Liquide, V 22:1674-98 N11, Nov 67

After a general review of active carbon electrodes using oxygen or air and hydrogen electrodes with a platinum-catalyzed-nickel or carbon base, the physical and electrochemical characteristics of carbon and nickel electrodes are given, and then the experimental parts with dissolved potassium hydroxide electrolyte are described.
(ELECTRODE, CARBON, ALKALINE, WATER)

H73 34629 MATRICES FOR H_3PO_4 FUEL CELLS
Camp, R.N., A. Nowotka, and B.S. Baker, (Energy Research Corp., Bethel, Conn.), N73-21966, AD-755206, Dec 72, Avail:TAC

The research was part of a program on the use of phosphoric acid fuel cells fueled by dirty hydrogen produced by thermocracking or steam reforming of a hydrocarbon.
(ACID, ANODE, ELECTRODE)

H73 34630 INEXPENSIVE CATHODE CATALYSTS
Camp, R.N., and B.S. Baker, (Energy Research Corp., Bethel, Conn.), Report No. ERC-6712F, Jl 14 '72, Avail:TAC

The report is a summation of the findings and developments aimed at the development of a low cost air cathode. The purpose was to lower the cost of air breathing fuel cells having moderate (125-135C) temperature phosphoric acid as the electrolyte.
(AIR, ACID, COST)

H73 34631 HIGH-PERFORMANCE LIGHT-WEIGHT ELECTRODES FOR HYDROGEN-OXYGEN FUEL CELLS
Gershberg, D., W.P. Colman, K.E. Olson, and E.W. Schmitz, (American Cyanamid Co., Stamford, Conn.), N69-14397, NASA-CR-1216, Dec 68, Avail:TAC

This report covers work done with electrodes in alkaline, matrix-type fuel cells operating on hydrogen and oxygen. The principal objective was to determine and recommend preferred matrix materials and operating conditions under which these electrodes would be capable of 2000-hour performance in a total module having a weight-to-power ratio substantially lower than those presently available for space environment.
(ALKALINE, MATRIX)

H73 34632 FUEL CELL ELECTRODES (HYDROGEN-AIR)
Salathe, R.E., (Whiteley Industries Inc., Wilmington, Mass.), Report No. ECOM-0127-F, May 72

The report describes the design and evaluation of a hydrogen-air fuel cell module for use in a portable hydrid fuel cell-battery system.
(ALKALINE, PORTABLE)

H73 34633 THIN FUEL CELL ELECTRODES
Clark, M.B., and K.V. Kordesch, (Union Carbide Corp., Parma, O.), N66-33621, ECOM-01344-F, 66, Avail:TAC

Fifteen, 100-watt (nominal), hydrogen-air batteries were built and subjected to various load and environmental conditions. The results now allow us to predict the performance and life expectancy of such batteries. Current densities as high as 100-ASF continuous loading could be supported without electrode damage. Of particular interest was the study of the interdependence of air humidity, gas flow rates, temperature, electrolyte concentration, and current density.
(FUEL CELL, ELECTRODE)

H73 34634 DEVELOPMENT OF FUEL CELL ELECTRODES; ELECTRODE IMPROVEMENT AND LIFE TESTING
Clark, M.B., R.L. Baum, J.D. Grigsby, and W.C. Thurber, (Union Carbide Corp., Parma, O.), N69-32642, NASA-CR-72576, Jl 31 '69, Avail:TAC

High-performance electrodes were developed for circulating-electrolyte type H_2-O_2 fuel cell systems for aerospace applications. The goals were an operating lifetime of 3000 hours, with an initial voltage above 09 volt and a voltage degradation less than 40 millivolts per 1000 hours, at a current density of 200 ASF. Major problem areas were elamination of cathodes and condensation of electrolyte in the oxygen gas passages.
(AEROSPACE, TEMPERATURE, CATHODE)

H73 34635 FUEL CELL WITH STABILIZED ZIRCONIA ELECTROLYTE AND NICKEL-SILVER ALLOY ANODE
Tragert, W.E., (to General Electric Co.), U.S. 3,296,030 (Cl. 136-86), Ja 3 '67

A high temperature fuel cell was constructed with a solid stable ZrO_2 electrolyte containing 15 mole % CaO. The cell was operated with H as fuel and O as the oxidant for 400 hours at 1040°, and c.d. of 20 ma./cm.^{2} was obtained at 0.6v.
(FUEL CELL, ELECTRODE, ZIRCONIA)

H73 34636 THE PERFORMANCE OF FLOODED POROUS FUEL CELL ELECTRODES
Brown, R., and J.A. Rockett, (Pratt & Whitney Div., United Aircraft Corp., East Hartford, Conn.), Journal of the Electrochemical Siciety, V 113:865 N9, Sept 66

The thin-meniscus model that is often applied to porous gas diffusion fuel cell electrodes has been found unsatisfactory for hydrogen reacting at nickel sinters in highly concentrated KOH electrolyte. The relative insensitivity of the performance to the gas-electrolyte pressure difference, which should have a strong influence on the active thin-meniscus area, requires the assumption that the flooded volume of the electrode is active. A model for a flooded pore is treated and the results of an approximate analytical solution compared with data.
(POROSITY, ALKALINE)

H73 34637 AN EXPERIMENTAL STUDY OF THE MODE OF OPERATION OF POROUS GAS-DIFFUSION ELECTRODES WITH HYDROGEN FUEL
Austin, L.G., and S. Almaula, (Pennsylvania State Univ., University Park, Pa.), Journal of the Electrochemical Society, V 114:927 N9, Sept 67

Current-polarization curves from zero current to limiting current have been obtained for anodic ionization of H_2 at Teflon-bonded, platinum-black, gas-diffusion electrodes in 1N H_2SO_4. Limiting currents were almost linearly proportional to hydrogen pressure and varied with pressure and temperature in approximately the same way as DC, the product of solubility and diffusivity of dissolved H_2. For an electrode containing 55 mg Pt-black/cm^2, the limiting current was 2.9 amp/cm^2 at 1 atmosphere H_2 and 25°C; polarization at 1 amp/cm^2 was 30 mv.
(POLARIZATION, ANODE, ACID)

H73 34638 POTENTIAL OF A PLATINUM ELECTRODE AT LOW PARTIAL PRESSURES OF HYDROGEN OR OXYGEN
Warner, T.B., and S. Schuldiner, (U.S. Naval Research Lab., Washington, D.C.), Journal of the Electrochemical Society, V 112:853 N8, Aug 65

The open-circuit potential on bright platinum in 1M H_2SO_4 was measured as a function of oxygen or hydrogen partial pressure from 10^{-2} to 10^{-7} atmosphere. The very low rates of H_2 or O_2 flow which were required were produced by a special gas generator. Based on the assumption that the resultant dissolved O_2 decreases the dissolved H_2 concentration in the solution at the electrode surface, an equation was developed for obtaining the effective H_2 partial pressure.
(FUEL CELL, PLATINUM, ELECTRODE)

H73 34639 FUEL CELL OXIDATION OF HYDROGEN ON MOVABLE, PARTIALLY SUBMERGED PLATINUM ANODES
Davitt, H.J., and L.F. Albright, (Purdue University, Lafayette, Ind.), Journal of the Electrochemical Society, V 114:531 N6, Je 67

The electrochemical oxidation of hydrogen was investigated potentiostatically at 30°C and atmospheric pressure using two movable flat-plate platinum anodes which were partially immersed in 1.0N H_2SO_4. The importance of meniscus formation, electrolyte film formed on the exposed portion of the anode, surface roughness, and hydrogen adsorption on the exposed portion of the anode is demonstrated by transient currents resulting from vertical movements of the anodes.
(ACID, TEMPERATURE)

H73 34640 THE EFFECT OF PREOXIDATION AND MENISCUS SHAPE ON THE HYDROGEN-PLATINUM ANODE OF A MOLTEN-CARBONATE FUEL CELL
Cobb, J.T., Jr., and L.F. Albright, (Purdue University, Lafayette, Ind.), Journal of the Electrochemical Society, V 115:2 N1, Ja 68

Electrochemical phenomena in a hydrogen-oxygen fuel cell were studied at 723°K for the three-phase region on smooth platinum anode sheets, partially immersed in a eutectic mixture of lithium, sodium, and potassium carbonates. Temporary increases in current were observed as the contact angle suddenly increased as the electrolyte film drained from the anode. The molten-carbonate film, obtained during raising the anode, was apparently relatively impermeable to hydrogen.
(FUEL CELL, PLATINUM, ANODE)

H73 34641* THE PLATINUM-ON-CARBON CATALYST SYSTEM FOR HYDROGEN ANODES. 1. CHARACTERIZATION OF THE CATALYST AND SUPPORT
Hillenbrand, L.J., and J.W. Lacksonen, (Battelle Memorial Institute, Columbus, O.), Journal of the Electrochemical Society, V 112:245 N3, Mar 65

A high degree of hydrogen electrode activity in alkaline media can be achieved with less than 1 mg Pt/cm^2 of electrode, if a properly chosen carbon support is used. For a complete description of the platinum-on-carbon catalyst systems, the physical and chemical states of both platinum

and carbon must be considered. In this paper the measurements of total electrode area, metal area and dispersion, pore size distribution, and the location of the Pt within the carbon structure are considered, and the importance of the choice of carbon is illustrated. The control of the chemical interactions between the platinum and the carbon is essential if high activity per unit weight of platinum is to be obtained.
(ELECTRODE, ALKALINE)

H73 34642 THE PLATINUM-ON-CARBON CATALYST SYSTEM FOR HYDROGEN ANODES. II. CHEMICAL REQUIREMENTS OF THE CARBON SURFACE
Hillenbrand, L.J., and J.W. Lacksonen, (Battelle Memorial Institute, Columbus, O.), Journal of the Electrochemical Society, V 112:249 N3, Mar 65, Avail:TAC
The large differences in the activity of platinum-on-carbon anodes that could be produced by the choice of carbon indicated that an important chemical interaction existed between the platinum and the carbon surface.
(FUEL CELL, CATALYST, ANODE)

H73 34643 THE NICKEL SKELETAL CATALYST BASED HYDROGEN ELECTRODE AND HOW IT WORKS
Burshtein, R.Kh., A.G. Pshenichnikov, F.Z. Sabirov, and V.N. Zhuravleva, (Naval Intelligence Command, Washington, D.C.), Report No. NIC-Trans-2617, Je 10 '68
The manner in which a porous gas electrode, activated by a skeletal catalyst, works is reviewed. The electrochemical activity in accordance with the composition of the active mixture and the thickness of active and barrier layers is studied.
(POROUS)

H73 34644 STUDIES ON ANODIC REACTION OF HIGH TEMPERATURE FUEL CELL
Sakikawa, N., and N. Kamiya, Journal of the Chemical Society Japan, V 70:874-7 N 6, Je 67
Reaction mechanism of molten alkali carbonate type fuel cell was studied; cathode used in all these experiments was made of silver gauze, and its conditions were kept constant throughout experiments; gauzes of different metals were used for anode, and several kinds of fuels were fed to these electrodes in temperature range of 400

to 500 C; when hydrogen is used, nickel electrode gives open circuit voltage of 1250 mv at 500 C.
(ALKALINE, ELECTRODE)

H73 34645 STUDY OF ELECTRODE - ELECTROLYTE INTERFACE FOR CASE OF OXYGEN-HYDROGEN CELL
Bihan, R. Le, Annales de Radioelectricite, V 23:82-6 N91, Ja 68, (In French)

Study is accomplished by means of energy diagram; variations of external potential due to absorption of oxygen, hydrogen, and potash on metal surfaces are measured by vibrating condenser method; results permit postulation of energy diagram for oxygen-hydrogen fuel cell using potash as electrolyte.
(FUEL CELL, ELECTROLYTE, INTERFACE)

H73 34646 PREPARATION AND BEHAVIOR IN CONTINUOUS SERVICE OF RANEY-CATALYSTS IN H_2- AND O_2-ELECTRODES
Cnobloch, H., M. Marchetti, H. Nischik, G. Richter, F. von Strum, 3rd International Symposium on Fuel Cells, Proceedings, Brussels, Belgium, Je 16-20 '69, by SERAI and COMASCI, p 203-9

Possibilities for improving I-V characteristics, behavior in continuous service, ease of operation, current density as well as reducing catalyst quantity for alkali H_2/O_2 fuel cells have been investigated to lower costs by increasing catalyst activity and also by suitable proportioning of electrode structure.
(CURRENT DENSITY, ALKALINE, COST)

H73 34647 EXTENDING THE DIMENSIONS OF AIR-HYDROGEN THIN ELECTRODES
Lucesoli, D., P. Degobert, (Division Appl., Inst. Fr. Petrole, Rueil-Malmaison, France), Journees Int. Etude Piles Combustion, C.R., 3rd, 69, p 325-36, (In French), Presses Acad. Eur., Brussels, Belgium

Theoretical and practical parameters to improve the design and performance of thin electrodes for air-H fuel cells were investigated. Permeability of the hydrophobic layer, the specific surface of catalyst, the support porosity, and the limiting diffusion current are optimized from polarization curves. A typical cell is described.
(PERMEABILITY, POROSITY, POLARIZATION)

H73 34648 ELECTROCHEMICAL STUDIES ON HIGHLY POROUS CARBON ELECTRODES
Bertsch, P., (Technische Hochschule, Munchen, West Germany), N70-15538, Ph.D. Thesis, Jl 2 '69, (In German), Avail:TAC

The electrochemical behavior of carbon electrodes with regulated pore distribution was studied and compared with other porous electrode materials for their application in hydrogen-oxygen fuel cells. Various electrochemical studies were performed to determine electrode kinetics and to calculate the potential time curve of the galvanostatic switch-on process.

(FUEL CELL, CARBON, ELECTRODE)

H73 34649 A LOW COST AIR ELECTRODE
Scarr, R.F., and K.V. Kordesch, (Union Carbide Corp., Cleveland, O.), 25th Annual Proceedings, Power Sources Conference, May 72, Avail:TAC

The overall simplicity of acid electrolyte fuel cells with respect to electrolyte containment, heat and water balances, and tolerance of impure reactants makes this fuel cell very attractive. Electrodes and operating characteristics are described.

(FUEL CELL, ELECTRODE, PLATINUM, ACID, PERFORMANCE, EFFICIENCY)

H73 34800 THE HYDROGEN-CHLORINE FUEL CELL
Bianchi, C., (Univ. Milan, Italy), Review Energie Primaire, V 1:60-3 N3, 65

A H-Cl fuel cell with a HCl electrolyte (10-30%), is described.
(FUEL CELL, CHLORINE)

H73 34801 USE OF HYDROGEN IN FUEL CELLS
Nuttall, L.J., SAE-Paper 994A, Ja 11-15 '65

Principle of operation of fuel cell; types of fuels employed ranging from hydrogen to liquid hydrocarbon fuels; hydrogen fuel cell is only one approaching practical use at present; status of types of fuel cells under development is indicated; examples of applications are described such as Gemini fuel cell, produced by General Electric Co., using acidic electrolyte in form of plastic ion-exchange membrane.
(ELECTROLYTE, ION-EXCHANGE, PLASTIC)

H73 34802 VEHICLE FUEL CELL SYSTEM
Wyczalek, F.A., D.L. Frank, G.E. Smith, SAE Paper 670181, Ja 9-13 '67

Fuel cell system was developed which can deliver peak power of 160 kw; it consists of 32 Union Carbide fuel cell modules together with electrical and fluid system auxiliary components needed to operate and control them in vehicle; reactants are hydrogen and oxygen and modules use circulating electrolyte, potassium hydroxide.
(FUEL CELL, VEHICLE)

H73 34803 THE BIOSATELLITE FUEL CELL/BATTERY POWER SYSTEM
Bruhin, A.C., and C.W. Bennett, (General Electric Co., Philadelphia, Pa.) N70-11022, NASA-CR-73376, 69, Avail:TAC

A power system was developed for the Biosatellite spacecraft which utilizes a hydrogen-oxygen fuel cell/silver-zinc battery combination to supply the mission electrical power. This system provides emergency modes of operation and insures uninterrupted power to the payload. A novel power controller was developed incorporating the capability of providing both peak load sharing and emergency power transfer in the event of a power source failure.
(BATTERY)

H73 34804 30-WATT METAL HYDRIDE/AIR FUEL CELLS SYSTEM
Malaspina, F.P., (Army Electronics Command, Fort Monmouth, N.J.), ECOM-3048, Nov 68, Avail:TAC

The use of ion exchange membrane fuel cell membrane fuel cell as developed for Army applications in a manpack hybrid 30-watt system is quantitatively investigated. The advantages of a unique solid fuel and Kipp generator type fuel system are shown in fuel economy and portability.
(ION EXCHANGE, HYBRID, HYDRIDE)

H73 34805 STUDY OF MULTIPLE RESERVE ELECTROCHEMICAL POWER SOURCE
Ciprios, G., (Esso Research and Engineering Co., Linden, N.J.), N69-23412, NASA-CR-100657, Ja 69, Avail:TAC

Neat hydrazine and 98 wt. % hydrogen peroxide are used as storable reactants. Appropriate high temperature reactors, containing propellant decomposition catalysts, are used to generate hydrogen and oxygen feed gases for the fuel cell. Allis-Chalmers fuel cell modules were selected for the centerline design on the basis of low specific weight and demonstrated bootstrap start-up capability.
(HYDRAZINE, HYDROGEN, PEROXIDE, FUEL CELL)

H73 34806 STORAGE OF SOLAR ELECTRICAL ENERGY BY ELECTROLYSIS OF WATER, SEPARATE STORAGE OF COMPRESSED HYDROGEN AND OXYGEN, AND SUBSEQUENT RECOMBINATION OF THESE GASES BY FUEL CELLS.
Justi, E., and W. Kalberlah, Cooperation Mediterraneenne pour l'Energie Solaire, Bulletin, N11:105-114, Dec 66, Avail:TAC

Discussion of the collection of solar energy by means of hydrogen fuel cells operating at ambient temperature and pressure, with high efficiency and power density, with water as the harmless final reaction product. Only such common metals as nickel and silver are used as catalysts, and methods have been found to increase their catalytic activity according to Raney's methods. The electrodes described have a double skeleton. A new three-electrode storage cell and an experimental demonstration model are described. The energy and efficiency of storing is considered.
(EFFICIENCY, NICKEL, SILVER, CATALYST)

H73 34807 SOME ENGINEERING ASPECTS OF HYDROGEN-OXYGEN FUEL CELL
Bacon, F.T., American Chemical Society - Division of Fuel Chemistry, V 9:1-6 N3, Sept 12-17 '65

Applications for fuel cells include possibility of storing electric energy; it is likely that, in foreseeable future, very cheap off-peak power will become available in United Kingdom; if practical power plants for short range road transport can be achieved.
(STORAGE, POWER, OFF-PEAK)

H73 34808 PRIMARY HYDROGEN-OXYGEN FUEL CELLS FOR SPACE
Cohn, E.M., (NASA, Washington, D.C.), 29th Meeting of the AGARD Propulsion and Energetics Panel, Belgium, Je 12-16 '67, N68-26788, NASA-TM-X-60277, Avail:TAC

By 1975, Grove-type fuel cells may reach 70% gross thermal efficiency. Cell-degradation rates should be 4 microvolts/hr or less, and system specific weight 60-80 lbs/kw of average load, with maintenance-free life up to 1 year. A better cathodic catalyst, optimized electrode structure, and inert matrices (if used at all) will be needed. Better solutions to chemical engineering problems are even more urgent. The best approach appears to be abandonment of the Grove cell and use of modern electrochemical knowledge in developing novel systems concepts.
(CATHODE, CATALYST, ELECTRODE)

H73 34809 STORAGE AND APPLICATIONS OF GALVANIC CELLS
Schneider, F.A., Electro-Techniek, V 44:268-71 N11, Je 2 '66, (In Dutch)

Explanation of why electrochemists, since 1890, try to use coal or methane as reductant and air as oxidant in galvanic cells, thus aiming at development of fuel cells; successful use of most expensive type of fuel cells based on hydrogen and oxygen in space flight is mentioned and cautious prognosis of future development of fuel cells cited; suggestion is made how to ban air pollution and noise from traffic in large cities by use of fuel cell batteries.
(FUEL CELL, POLLUTION, BATTERY)

H73 34810 STABILIZING THE NOMINAL POWER OF OXYGEN-HYDROGEN FUEL CELLS INTENDED FOR EMERGENCY POWER SUPPLY
Varta, A.G., French 1,536,877, Aug 16 '68

The O and H losses of the title cells during standby

are made up by electrolyzing water under pressure; the apparatus is described.
(ELECTROLYSIS, PRESSURE)

H73 34811 STORAGE BATTERY-FUEL CELL FOR CONVERTING ELECTRICITY TO HYDROGEN AND OXYGEN AND VICE VERSA
Siemens, A.G., and A.G. Varta, French 1,548,347, Dec 6 '68, Jl 66

A combination battery-fuel cell was developed consisting of a Raney-Ni valve electrode for H and 2 electrodes for O, a Ni gauze electrode for electrolytic release of O, and a Raney-Ni, Ag, or Cu valve electrode for dissolution of O gas. The use of an intermediate gauze ele - trode reduced corrosion of the O valve electrode owing to cycling of the cell.
(NICKEL, ELECTRODE, CORROSION)

H73 34812 MEGAWATT FUEL CELLS FOR AEROSPACE APPLICATIONS
Warnock, D.R., (USAF, Wright-Patterson AFB, O.), Proceedings-25th Power Sources Symposium, Atlantic City, N.J., May 23-25 '72, Avail:TAC

Description of a high power density fuel cell stack concept with an aqueous potassium hydroxide electrolyte contained in a capillary matrix of asbestos and potassium titanate. A porous sintered plate in partial contact with a hydrogen electrode forms a hydrogen flow field and serves as an additional container for the electrolyte. The high power density of the cells largely due to the low ohmic polarization capability of the thin matrix.
(POWER, ELECTROLYTE)

H73 34813 H_2-AIR FUEL CELLS AS ELECTRIC SUPPLY ON STRATOSPHERIC AIRSHIP
Balaskovic, P., and A. Rouscilles, (CRNS, Essonne, France), 4th International Symposium on Fuel Cells, Antwerp, Belgium, Oct 2-3 '72, Proceedings, V 1, Avail:TAC

The fuel cells considered can provide a stratospheric airship with propulsive energy. The airship is generally moving at an altitude of 22 km. It serves mainly as a relay for EM beams. The power system selected for the airship consists of the electric engine and fuel cells based on air and cryogenic hydrogen. It is pointed out that this system is the only power system of the systems

considered which meets the stringent requirements regarding a low weight for the airship power system.
(POWER, CRYOGENIC, WEIGHT)

H73 34814 HYDROGEN-OXYGEN FUEL CELLS: VARTA FUEL CELL SYSTEMS
Winsel, A., Performance Forecast Selec. Static Energy Conversion Devices, 29th meeting AGARD Propulsion Energy Panel, 67, p 575-94

The working principles, construction, and performance data of VARTA H-O fuel cells as well as electrolyzers, and gas generators for H and O are discussed. Electrodes were constructed of Raney-Ni or Ag on a skeleton of sintered carbonyl Ni. A 60-w. MeOH and a 50-w. H-O fuel cell are described.
(ELECTROLYZER, NICKEL)

H73 34815 OPEN CYCLE FUEL CELL SYSTEM FOR SPACE APPLICATIONS
Cheney, E.O., Jr., P.J. Farris, and J.M. King, Jr., (Pratt and Whitney, East Hartford, Conn.), American Society of Mechanical Engineers, Winter Annual Meeting, New York, N.Y., Nov 29-Dec 4 '64, Paper 64-WA/AV-15, Avail:TAC

Discussion of an open-cycle fuel-cell concept in which the heat capacity of cryogenically stored hydrogen is used to absorb wsste heat and water and reject them into space. Methods for analyzing and optimizing open-cycle systems incorporating modified Bacon cells are considered, and a parametric comparison is made between open closed-cycle systems for typical space requirements. It is suggested that open-cycle systems should be considered for missions which are less than one month in duration.
(CRYOGENIC, WASTE, HEAT, WATER)

H73 34816 PC8B-4-X562 FUEL CELL ELECTRICAL POWER SUPPLY. OPERATIONS MANUAL
Anon, (Pratt and Whitney Aircraft, East Hartford, Conn.), N72-15023, NASA-CR-115304, Jl 2 '70, Avail:TAC

The PC8B-4 fuel cell electrical power supply is an electrical powerplant designed to convert the chemical reaction of hydrogen and oxygen into electrical energy. It utilizes catalyzed electrodes with a potassium hydroxide electrolyte. The powerplant and test stand control unit

are described together with a specifications summary.
(REACTION, ENERGY, ELECTROLYTE)

H73 34817 HYDROCARBON-AIR FUEL CELL SYSTEM FOR MILITARY APPLICATION
Engle, M.L., Chemical Engineering Progress Symposium Series, V 63:41-4 N75, 67

Basic system consists of hydrogen generator that supplies pure hydrogen to fuel cell which electrochemically combines hydrogen with oxygen obtained from ambient air to produce 28 v d-c power.
(FUEL CELL, HYDROCARBON, AIR)

H73 34818 HYDROGEN-OXYGEN FUEL CELLS REQUIRING MINIMUM OF MAINTENANCE
Cnobloch, H., (Siemens AG, Erlangen, West Germany), H. Nischik, F.V. Sturm, Chemie-Ingenieur-Technik, V 41:146-54 N4, Fe 2 '69, (In German)

25-w battery made up of two sets of 17 individual cells and capable of functioning in temperature range minus 20 to plus 40 C has been developed to meet power requirements of television relay transmitter at Dollnstein, Germany.
(BATTERY, TEMPERATURE, POWER)

H73 34819 HYDROGEN GENERATOR MANPACK FUEL CELLS
Malaspina, F.P., (U.S. Army Electronic Command, Fort Monmouth, N.J.), Proceedings - Annual Power Sources Conference, 69, V 23:14-16

For advanced design model, improvements were made in the fuel cell power module, the power conditioning, the integral H generator, and the interchangeable fuel cell case. While incorporating these improvements, the military objective of lightweight equipment was considered.
(DESIGN, POWER, MILITARY)

H73 34820 FUEL CELLS
Schwartz, H.J., (NASA, Lewis Research Center, Cleveland, O.), N66-14769, NASA-TM-X-52149, 58th AIChE National Meeting, Philadelphia, Pa., Dec 5-9 '65, Avail:TAC

The flight of Gemini V marked the first demonstration of the use of fuel cells as spacecraft power systems. A fuel cell may be considered to be an isothermal steady-state

reactor on which the conversion of hydrogen and oxygen to water is accomplished. In order to maintain steady-state operation, heat and product removal techniques must be applied to the fuel cell.
(SPACECRAFT, POWER REACTOR, HEAT)

H73 34821 FUEL CELLS IN AEROSPACE
Starkey, G.E., (Air Force Dept., Washington, D.C.), N64-17401, Proceedings - 17th Annual Power Sources Conference, 63, p 84-5, Avail:TAC

Space missions for which primary (hydrogen-oxygen) fuel cells appear to be the optimum energy conversion method are surveyed. The criteria for selecting flight vehicle power supplies for space are listed, and the features that make fuel cells attractive for aerospace applications are outlined.
(ENERGY, CONVERSION, POWER)

H73 34822 FUEL CELLS IN ASTRONAUTICS
Jost, K., Luftfahrttechnik Raumfahrttechnik, V 16:300-304, Nov-Dec 70, (In German), Avail:TAC

Review of the design, operation, and merits of fuel cells used in astronautics. The technological maturity of fuel cells is shown to have been demonstrated by their performance record in the Gemini and Apollo manned mission series. Though their development and manufacturing costs exceed those of conventional energy sources, they still represent the most economical solution of the power supply problem for spacecraft.
(FUEL CELL, SPACECRAFT, DESIGN)

H73 34823 FUEL CELL POWERPLANT OPERATION IN APOLLO SPACECRAFT
Ching, A.C., A.P. Gillis, (Pratt and Whitney Aircraft, East Hartford, Conn.), and F.M. Plauche, Intersociety Energy Conversion Engineering Conference, 7th, San Diego, Calif., Sept 25-29 '72, Proceedings, p 368-72, Avail:TAC

Primary electrical power for loads in the Apollo Command and Service Modules is furnished by a system of three fuel cell powerplants. The powerplants convert cryogenic hydrogen and oxygen into direct current. Water formed in the fuel cell reactions is supplied to the spacecraft for crew use. Waste heat is rejected through a

coolant loop to a spacecraft radiator. The ability of the fuel cell to meet its voltage-power requirements and to control its own operating temperature under the environmental extremes of launch, ascent, earth orbit, translunar flight, and lunar orbit was demonstrated on successively more difficult missions leading up to the first lunar landing.
(ELECTRICITY, POWER, WATER, CRYOGENIC, LUNAR)

H73 34824 FUEL-CELL UNIT IN ELECTRIC VEHICLE
Winsel, A., Chemie-Ingenieur-Technik, V 40:154-9 n5, Fe 26 '68

Most of H_2O_2 fuel cells available at present are those with alkaline electrolytes; hydrogen must be carried in pressure bottles or be generated in small reformer useful for electric automobiles; improvements to be expected are possibility of regenerative braking, parallel operation between fuel-cell and lead battery, and utilization of rest-time of car for recovery of fuel in small electrolyzers.
(ELECTROLYTE, REFORMER, BATTERY)

H73 34825 FUEL CELLS AND FUEL BATTERIES - AN ENGINEERING VIEW
Liebhafsky, H.A., (General Electric Co., Schenectady, N.Y.), IEEE Spectrum, V 3:48-56, Dec 66, Avail:TAC

Discussion of the usefulness of fuel cells and fuel batteries, and of the problems relating to them. The conventional fuels for these devices - hydrogen, compromise fuels, and hydrocarbons - are investigated, and the efficiency, reliability and working life, and unit capital costs of fuel cells and batteries are studied. Electrical problems of the fuel battery and possible future applications (such as for central power stations) are considered.
(HYDROCARBON, COST, POWER)

H73 34826 GEMINI FUEL CELL SYSTEM
Cohen, R., Proceedings - 20th Annual Power Sources Conference, U.S. Army Electronics Labs., Fort Monmouth, N.J., May 24-26 '66, p 21-4

Description of design, operation, and performance of Gemini fuel cell system.
(FUEL CELL, SPACECRAFT)

H73 34827 FROM SHELL'S FUEL CELL - PORTABLE POWER.
Anon, Engineering, V 198:768-9 N5148, Dec 18 '64

Information on fully integrated fuel cell power system, developed by Shell Research Ltd., that can generate up to 5 kw of electrical power and can be run from methanol (methyl alcohol or wood alcohol), inexpensive petroleum derivative; in demonstration cell was mounted in utility truck and used to provide power for electric hammer for breaking concrete; fuel is converted into hydrogen by reaction with steam in presence of platinum catalyst; hydrogen is purified in diffuser, then enters battery of fuel cells.
(METHANOL, CATALYST, BATTERY)

H73 34828 FUEL CELL CONNECTED WITH A HYDROGEN GENERATOR
Dezael, C., M. Prigent, (Institut Francais du Petrole, France), French 1,549,206, Dec 13 '68

H, generated catalytically from a MeOH-H_2O mixture is utilized in an electric fuel cell. The catalytic burning of the residual gases eliminated from the cell, serves as an energy source for the H generator.
(METHANOL, CATALYST, ENERGY)

H73 34829 FUEL CELLS FOR IMPROVED ELECTRICAL POWER SUPPLY
Morril, C.C., (Pratt and Whitney Aircraft, East Hartford, Conn.), American Institute of Aeronautics, Washington, D.C., Ja 8-10 '73, Paper 73-82, Avail:TAC

Current commercial fuel cell technology and the requirements of utility applications lead to a fuel cell system design which is modular in configuration and is composed of three major subsystems. The subsystems include a fuel processor, a fuel cell power section, and an inverter. Fuel cell operational characteristics are discussed, giving attention to its high efficiency, its environmental characteristics, the load response, and the operational modes.
(DESIGN, MODULAR, LOAD)

H73 34830 5-KW HYDROCARBON-AIR FUEL CELL POWER SOURCE
Lodzinski, R.J., (Allis-Chalmers Manufacturing Co., Milwaukee, Wis.), in Space Power Systems Engineering, G.C. Szego and J.E. Taylor, Academic Press, Inc., N.Y., 66, p 1043-48, Avail:TAC

A fuel cell power source is described which utilizes

a reformer to supply the hydrogen and produces a net output of 5-kw electrical power at 110 v and 60 cps. Major emphasis is placed upon the fuel cell temperature and moisture control systems.
(TEMPERATURE, MOISTURE, REFORMER)

H73 34831 5 KW HYDROCARBON-AIR FUEL CELL POWER PLANT
Kirkland, T.G., Proceedings - 20th Annual Power Sources Conference, (U.S. Army Electronics Labs., Fort Monmouth, N.J.), May 24-26 '66, p 35-9

Operating data, auxiliary system operating data, and inverter operation for experimental 5 kva hydrocarbon fuel cell power plant.
(FUEL CELL, HYDROCARBON)

H73 34832 500 WATT HYDROCARBON AIR FUEL CELL SYSTEM
Buswell, R.F., Proceedings - 19th Annual Power Sources Conference, (U.S. Army Electronics Labs., Fort Monmouth, N.J.), May 18-20 '65, p24-26

Operation and performance of hydrogen generator-fuel cell system using liquid hydrocarbon fuels and oxygen (air) to produce 500 w at 32 v; system has specific weight of 140 lb/kw, specific volume of 5 cu ft/kw, and overall thermal efficiency of 30%.
(FUEL CELL, HYDROCARBON, AIR)

H73 34833 ELECTRICALLY COUPLED FUEL CELL AND HYDROGEN GENERATOR
White, D.W., (General Electric Co.), U.S. 3,607,427, Sept 21 '71

A solid O-ion electrolyte fuel cell electrode coupled directly to a solid O-ion electrolyte H_2O-dissociation cell (for H generation) is described. Hydrocarbon fuel is reacted with air, steam, or air and steam to produce a reducing gas mixture, which is admitted to the coupled cells to depolarize the anode of the dissociatoon cell and serve as fuel for the fuel cell.
(ELECTROLYTE, AIR, STEAM, ANODE)

H73 34834 EFFECTS OF CARBON DIOXIDE ON TRAPPED ELECTROLYTE HYDROGEN-OXYGEN, ALKALINE FUEL CELLS
Thaller, L.H., R.E. Post, and R.W. Easter, (NASA, Lewis Research Center, Cleveland, O.), N70-28121, NASA-TM-X-52812, 5th Intersociety Energy Conversion Engineering Conference, Las Vegas, Nev., Sept 21-4 '70, Avail:TAC

Trapped electrolyte alkaline fuel cells are presently

being used in aerospace applications. Low temperature versions of these systems appear to offer certain advantages over the Apollo-type fuel cell. However, the life characteristics of these low temperature cells have been somewhat disappointing.
(FUEL CELL, ELECTROLYTE, TEMPERATURE)

H73 34835 DEVELOPMENT OF UNDERSEA POWER
Yamamoto, T., Kagaku Kogyo, V 21:801-10 N6, 70, (In Japanese)

A review is given on the fuel cell as an undersea power source. The manufacture of H for the fuel cell from NH_3 and from MeOH, and the purification of H by adsorption are also reviewed.
(FUEL CELL, METHANOL, AMMONIA, ADSORPTION)

H73 34836 COLD HYDROGEN CELLS OF THE GENERAL ELECTRIC COMPANY AND THEIR ACCOMPANYING CIRCUITS
Dubois, P., Entropie No. 14, p 73-82, 67, (In French)

A definition of fuel cells is given, and the fundamental thermodynamic laws for transformation of chemical energy into electric energy are presented. General considerations about storage, supply, and control of the feed of the reactants into a battery, and control of the content of reaction products are given for batteries working with the systems H_2/O_2, N_2H_4/O_2, N_2H_4/H_2O_2, N_2H_4/KOCl, and Na-Hg/O_2. Cold cells with H_2 and O_2 as reactants are described.
(STORAGE, CONTROL, BATTERY)

H73 34837 CIRCULATING ELECTROLYTE HYDROGEN/AIR FUEL CELL SYSTEM
Clow, C.G., (Energy Conversion Ltd., Basingstoke, England), J.G. Bannochie, Proceedings - 4th Intersociety Energy Conversion Engineering Conference, Washington, D.C., Sept 22-26 '69, Paper 699132, p 1057-64, Avail:TAC

A hydrogen-air fuel cell system with a circulating alkaline electrolyte is described. Electrodes consist of a catalyzed hydrophobic layer supported on porous nickel. Special problems of water and electrolyte management associated with the hydrophobic electrodes are discussed and the problems of working with an electrolyte common to all the cells are analyzed.
(CATALYST, HYDROPHOBIC, ELECTRODE)

H73 34838 CIRCULATING ELECTROLYTE FUEL CELL POWERPLANT
Peak, W.R., and T.G. Schiller, (Pratt and Whitney Aircraft, East Hartford, Conn.), Report No. PWA-4073-ECOM-0125-F, Fe 1-Nov 30 '70, Avail:TAC

The technical feasibility of a hydrogen-air circulating alkaline electrolyte fuel cell system incorporating electrolyte regeneration capability has been demonstrated. The fuel cell design features four channels on the air side through which the potassium hydroxide electrolyte flows. The feasibility of this cell design was demonstrated by a 650 hour single cell test.
(DESIGN, TEST, REGENERATION)

H73 34839 A HYDROCARBON-AIR FUEL CELL
Engle, M.L., (Allis-Chalmers, Milwaukee, Wis.), Chemical Engineering Progress, V 62:77-9 N5, 67, Avail:TAC

The system described uses pure H_2, derived by reacting liquid hydrocarbon fuel with water using a reforming catalyst and extg. the product through a Pd-alloy diffusion element. The fuel cells were of the low temperature and pressure type with the alkaline electrolyte held in a matrix and the O_2 supply derived from compressed ambient air.
(WATER, REFORMING, CATALYST, ELECTROLYTE)

H73 34840 A 500 WATT HYDROGEN/AIR FUEL CELL WITH METHANOL REFORMER
Jacquelin,J., (Compagnie Generale d'Electricite, Paris, France), 4th International Symposium on Fuel Cells, Antwerp, Belgium, Proceedings, Oct 2-3 '72, V 1, Avail:TAC

The fuel cell stack described contains a number of subsystems, including the electrode package, an electrolyte circulation subsystem, a subsystem for the equilibration of electrolyte and gas pressures, the hydrogen circuit, and the air supply subsystem.
(ELECTROLYTE, PRESSURE)

H73 34841 A COMPACT HYDROGEN-OXYGEN CELL
Vic, R., and Y. Breelle, Electrochemical Generators for Space Applications; International Convention, Paris, France, Proceedings, Dec 4-7 '67, p 79-89, (In French), Avail:TAC

Description of an energy source designed for use in space environments and based on a cold hydrogen-oxygen fuel cell.
(FUEL CELL, SPACE, ENERGY)

H73 34842 AUTONOMOUS HYDROGEN/AIR FUEL CELL FOR LONG-LIFE MISSIONS
Breelle, Y., J. Cheron, A. Grehier, and R. Vic, (Institut Francais du Petrole, France), Proceedings - 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Sept 25-29 '72, p 1-6, Avail:TAC

Design and construction of an autonomous H_2/air fuel cell for the purpose of power feeding a 70-w radio-beacon for 5000 hr. The reliability required for this use led to the development of a cell operating at low specific power and with no rotating parts.
(DESIGN, POWER)

H73 34843 AUTOMATED ELECTRICAL START FOR JP4-AIR SYSTEMS
Greenwood, C.D., Proceedings, 22nd Annual Power Sources Conference, (U.S. Army Electronics Command, Fort Monmouth, N.J.), May 14-16 '68, p 13-16, Avail:TAC

Automatic startup and control system for hydrogen-oxygen fuel cells; system logic, major design considerations, and results of preliminary tests; block diagrams for control sequence.
(FUEL CELL, TEST, CONTROL)

H73 34844 STATUS OF SHUTTLE FUEL CELL TECHNOLOGY PROGRAM
Rice, W.E., and D. Bell, (NASA, Manned Spacecraft Center, Houston, Tex.), Proceedings - 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Sept 25-29 '72, p 390-95, Avail:TAC

The hydrogen-oxygen fuel cell has been proved as an efficient and reliable electrical power supply for NASA manned-space-flight vehicles. It has thus ensured a role in the Space Shuttle Program as the primary electrical power supply for the Orbiter vehicle.

H73 34845 ULTRA-PURE HYDROGEN FOR FUEL CELLS
Pfefferle, W.C., (Engelhard Industries, Inc., Newark, N.J.), Society of Automotive Engineers, Baltimore, Md., Oct 19-23 '64, Paper 935B, Avail:TAC

Description of a compact hydrogen generator suitable for integration into fuel-cell power systems. Such generators not only provide a source of ultrapure hydrogen especially suited for fuel-cell use, but also, in principle, can achieve thermal efficiencies approaching 100% for the conversion

of hydrocarbons into hydrogen.
(EFFICIENCY, HYDROCARBON)

H73 34846 THE FLYING H_2/O_2 STORAGE BATTERY
Costa, R.L., and L.S. Harootyan, Jr., Chemical Technology, V 2:163-66 N3, Mar 72

In view of the advanced hydrogen-oxygen primary fuel cell and electrolysis technology developed in the last decade, it is believed that a compact, lightweight, and reliable regenerative hydrogen-oxygen fuel cell can be developed by 1978. Performance goals for such a device are 20 to 30 watt-hours/pound and 7 years life at 0.95 system reliability. The attractiveness of the regenerative fuel cell is illustrated.
(FUEL CELL, REGENERATOR, ELECTROLYSIS)

H73 34847 IN SITU PREPARATION AND CONTROL OF HYDROGEN IN ELECTROCHEMICAL CELLS
Juda, W., (Prototech Inc.), U.S. 3,407,094

A fuel cell consists of molten electrolytic medium, a porous cathode, and an anode consisting of a porous support, which can be impregnated with reforming catalysts and coated with porous Ag and a 0.0001-0.005-in. thick Pd-containing layer, including Ag-Pd alloys. The partial pressure of H_2 produced in situ is maintained at below atmospheric pressure and at less than the pressure existing in the electrolytic medium by drawing current from the cell. The suction effect results in substantially complete electrochemical utilization of H.
(ELECTROLYTE, CATHODE, REFORMING, CATALYST)

H73 34848 FUEL CELL IS GOING COMMERCIAL
Bennett, K.W., The Iron Age, Nov 2 '67, p 50

With a growing number of stock model fuel cells available, there's prospect designers will incorporate them into new vehicles and machinery. Union Carbide will offer a unit that will operate on just hydrogen and air. However, market breakthrough is still 2 or 3 years away.
(AIR, MARKET, VEHICLES)

H73 34849 THE REVOLT AGAINST INTERNAL-COMBUSTION ENGINE
Lessing, L., Fortune, Jl 67, p 78

This paper introduces a G.M.'s Electrovan, employing a hydrogen-oxygen fuel cell developed by Union Carbide, to promote radically new alternative to the noisy, air-polluting gasoline engine.
(FUEL CELL, POLLUTION)

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IV. TRANSMISSION, DISTRIBUTION, & STORAGE

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H73 40000 FUEL FOR TOMORROW. LIQUID HYDROGEN. LOW-TEMPERATURE ENGINEERING TECHNOLOGY
Ohta, T., Bussei, V 13:405-9 N7, 72, (In Japanese)

A review with 6 references on possible application of liquid H as fuel and on the problem associated with low temperature engineering.
(HYDROGEN, FUEL, LIQUID, FUTURE)

H73 40001 USES OF CRYOGENIC FLUIDS IN INDUSTRY AND THE LABORATORY
Lafaurie, M., Chim. Ind., Genie Chim., V 99:583-92 N5, 68, (In French)

The applications of cryogenic fluids, especially liquid N, H, and He, are reviewed.
(CRYOGENIC, INDUSTRY, LABORATORY)

H73 40002* CRYOGENIC FLUIDS
Croft, A.J., (Oxford University, Oxford, Eng.), In: Advanced cryogenics, edited by C.A. Bailey, Plenum Press, London and New York, 71

Discussion of the properties and uses of the common liquid refrigerants. The substances considered include liquid nitrogen, liquid oxygen, liquid air, liquid neon, liquid hydrogen, liquid helium and liquid helium-3. General principles regarding the storage of the refrigerants are discussed together with the designs of vessels for specialized applications. Approaches for measuring the liquid level described include methods making use of liquid surface detection devices and hydrostatic methods. The design of transfer lines is also examined.
(CRYOGENIC, LIQUID, NITROGEN, OXYGEN, HYDROGEN)

H73 40003 LIQUID HYDROGEN
Anon, Pure & Applied Cryogenics, V 5, Pergamon Press, N.Y., 66

Volume comprises 12 chapters by different authors, representing lectures given in June 1965 at University of Grenoble, during course organized by Centre de Recherches sur les Tres Basses Temperatures under auspices of International Institute of Refrigeration; lectures treat physical properties and technological aspects of both production and utilization; latter includes space, electrical,

and nuclear applications.
(HYDROGEN, LIQUID, CRYOGENIC)

H73 40004* PUBLICATIONS AND SERVICES OF THE NATIONAL BUREAU OF STANDARDS, CRYOGENICS DIVISION
Mendenhall, J.R., V.J. Johnson, and N.A. Olien, (National Bureau of Standards, Boulder, Colo.), NBS-TN-639, Aug 73

This NBS Technical Note catalogs the publications of the Cryogenics Division, along with author and subject indexes, for the period 1953 through 1972. It also contains a listing of available thermodynamic properties charts, bibliographies, and miscellaneous reports of cryogenic interest.

A resume of the activities of and services provided by the Cryogenics Division is also included.
(PUBLICATION, THERMODYNAMICS, CRYOGENIC)

H73 40005 LIQUID HYDROGEN TECHNOLOGY
Parmley, R.T., (General Dynamics/Astronautics, San Diego, Calif.), Report No. GDA-AE62- 0774, Sept 62

This report contains information on liquid hydrogen as related to its use as a propellant for space vehicles. The following 14 areas are included: Manufacture, Transportation, Hydrogen safety, Materials compatibility, Cryogenic insulation, Transfer, Cryogenic measurements, Propulsion methods, Sloshing, Vortexing, Propellant heating, Zero-gravity behavior, Space storage, Properties.
(LIQUID, HYDROGEN, CRYOGENIC, SPACECRAFT)

H73 40006 TRENDS IN CRYOGENIC FLUID PRODUCTION IN THE UNITED STATES
Flynn, T.M., and C.N. Smith, Proceedings International Institute of Refrigeration, Tokoyo, Japan, 70, Bull. Suppl. Commission I, p 241-47

The cryogenic industry in the U.S. has changed dramatically in both scope and character during the last decade. It has progressed from a liquid hydrogen technology to a liquid helium technology to developing new technologies dependent upon both the upper and lower extremes of the cryogenic scale. Among these are practical applications of superconductivity and the use of liquefied natural gas as a major world energy source. This change in the nature of the industry, and some of its implications for the future,

is seen in this paper which traces the production of the economically significant cryogens over the last decade and gives the present status of cryogen production in the U.S.
(CRYOGENIC, LIQUID, INDUSTRY)

H73 40007 THE CRYOGENIC DATA CENTER, AN INFORMATION SERVICE IN THE FIELD OF CRYOGENICS
Olien, N.A., Cryogenics, V 11:11-18 N1, Feb 71, NBS-R-625

The Cryogenic Data Center is the major source of bibliographic information and data on the properties of materials at cryotemperatures in the United States and, to a lesser extent, serves the same function for the rest of the world. The Center also is a source of information for other areas of cryogenics such as metrology, instrumentation, processes and equipment, transport processes, safety, etc. An important output of the Cryogenic Data Center is the critical evaluation of property measurements and measurement techniques.
(CRYOGENIC, DATA, INFORMATION)

H73 40008* SURVEY OF THE PROPERTIES OF HYDROGEN ISOTOPES BELOW THEIR CRITICAL TEMPERATURES
Roder, H.M., G.E. Childs, R.D. McCarty, and P.E. Angerhofer, (Cryogenics Division, National Bureau of Standards, Boulder, Colo.), NBS Technical Note 641, Aug 73, Avail:TAC

The survey covers PVT, thermodynamic, thermal, transport, electrical radiative and mechanical properties. All isotopic as well as ortho-para modifications of hydrogen have been included. Temperatures are limited to those below the respective critical points, in general below 40 K. The pressure range is not restricted, that is solid, liquid, and gas phases are covered. However, with the exception of hydrogen, very little data exists at pressures other than saturation. The literature surveyed includes all references available to the Cryogenic Data Center up to June of 1972, and for several subjects, through March of 1973. The total number of documents considered was nearly 1500 of which about 10 percent contain pertinent information and are referenced in this report. The various properties are presented in the form of tables or graphs; if extensive tables have been published elsewhere, the reader is referred to the original sources.
(COMPILATION, DENSITY, DEUTERIUM, PROPERTY, ENTHALPY, ENTROPY, HYDROGEN, ELECTRICAL, MECHANICAL, OPTICAL, TRANSPORT)

H73 40100 LIQUEFACTION OF HYDROGEN AND HELIUM, OBTAINING ULTRALOW TEMPERATURES
Arkharov, A.M., K.S. Butkevich, A.G. Golovintsov, and B.M. Kulakov, Report No. FTD-MT-65-167, Ja 23 '67, Avail:TAC

Liquefaction of hydrogen and helium, and the usage and production of very low temperatures have been investigated. The authors investigated cascade methods of producing low temperatures and described certain cryogenic gases and liquids. Orthopara-transformation of hydrogen was considered in detail, and methods of obtaining this were investigated. Hydrogen and helium liquefiers were described and their usage was discussed. New low temperature cycles were discussed. Magnetic cooling, thermodynamics of demagnetization, and cryostats and magnets were investigated.
(LIQUEFACTION, CASCADE, HELIUM, HYDROGEN)

H73 40101 **MULTIPLE-UNIT HYDROGEN-HELIUM LIQUEFIER**
Batrakov, B.P., Kravchenko, V.A., Khim. Neft. Mashinostr., V 12:36-7 N12, 71, (In Russian)

High-pressure (140-50 atmospheres) H was passed through a heat exchanger, where it was cooled by low-pressure H and by-passed N vapor. After cooling by liquid N, H was cooled in another heat exchanger by low-pressure H and H vapor coming from H (1) heat exchanger of the He cycle. After throttling, part of H was liquefied, and the equilibrium gas phase formed the high-pressure H.
(LIQUEFACTION, COST, HEAT EXCHANGER)

H73 40102 LIQUEFACTION AND STORAGE OF HYDROGEN
Reiff, D.D., Chemical Engineering, V 72:191-8 N19, Sept 13 '65

Principles of liquefaction of gases and low-temperature heat transfer are basis for discussion of designs required for storage and handling of liquid hydrogen; in liquefaction of hydrogen there are two main considerations; first, low liquefaction-temperatures and safety require hydrogen to be pure; second, it is desirable that molecular variety, parahydrogen, be produced; in selecting insulation, balance must be achieved between considerations of economics, weight, volume, ruggedness and insulation effectiveness; in design of cryogenic storage vessels it is desirable to have simplest and lightest vessel, with minimum heat transfer, at lowest practical cost.
(LIQUEFACTION, HEAT TRANSFER, STORAGE, COST)

H73 40103 HYDROGEN-NEON LIQUEFACTION UNIT WITH A HELIUM EXPANSION COOLING CYCLE
Butkevich, I.K., V.M. Dobrov, Khim. Neft. Mashinostr., N3:42, 69, (In Russian)

The description, size, and technology and construction data are given for a liquefaction unit for H, Ne, or some other gas (capacity 11.5-20 and 6.5 l./hr, respectively), fitted with a compressor cooling system. The cooling medium is He, and preliminary cooling is attained by liquid N. The system permits obtaining a temperature down to -269^{o}, and a small modification of the apparatus renders possible the liquefaction of He in amounts of approximately 7l./hr.
(LIQUEFACTION, HELIUM, EXPANSION, COMPRESSION)

H73 40104 HYDROGEN LIQUEFIERS WITH EFFICIENT HEAT EXCHANGERS
Borovik, E.S., I.F. Mikhailov, and N.A. Kosik, Cryogenics, V 4:358-60 N6, Dec 64

Description of two liquefiers using heat exchangers formed of different diameter tubes soldered to one another for heat contact; single stage cooling of hydrogen by nitrogen boiling under reduced pressure is used in VO-10 hydrogen liquefier; two-stage cooling of hydrogen by liquid nitrogen is used in VO-50 unit; both designs are shown in diagrams.
(LIQUEFACTION, HEAT EXCHANGER, NITROGEN)

H73 40105 HYDROGEN LIQUEFIED WITH TWO-STAGE CONVERSION FOR PRODUCTION OF 98% PARAHYDROGEN
Fradkov, A.B., and V.F. Troitskii, Cryogenics, V 5:136-7 N3, Je 65

Report on operating principle and design of liquefier, which is shown in schematic diagram; refrigeration cycle is based on Joule-Thompson effect for normal hydrogen; parahydrogen is produced in line separate from refrigeration cycle by conversion at two temperature levels, these being temperature of liquid nitrogen (in gaseous phase), and temperature of liquid hydrogen; device has been in normal operation since 1961.
(LIQUEFICATION, PARAHYDROGEN)

H73 40106 DESIGN OF A CRYOGENIC EXPANSION ENGINE FOR TONNAGE HYDROGEN LIQUEFACTION
Morain, W.A., (Cooper-Bessemer Div., Cooper Inds., Mt. Vernon, O.), Advanced Cryogenic Engineering, V 12:585-94, 67

A large expansion engine with an nonlubricated cylinder, which has been in com. H liquefaction service, was discussed and was shown to be useful for tonnage H liquefaction.
(LIQUEFICATION, EXPANSION)

H73 40107 DESIGN OF A HYDROGEN LIQUEFIER
Schulze, M., W. Hoffmann, and W. Eichenauer, (Tech. Hochschule, Darmstadt, Germany), Glas-Instrum.-Tech., V 10:770-4 N9, 66, (In German)

A review is given of potential uses for liquid H and liquefaction of gases according to the Linde process. A detailed description of a liquefier with a capacity of 6l./hr. is given.
(LIQUEFICATION, PROCESS)

H73 40108 DEVELOPMENT OF A PRACTICAL THERMODYNAMIC CYCLE FOR A SPACE-BORNE HYDROGEN RELIQUEFIER
Benning, M.A., E.B. Kunkle, A.H. Singleton, Advanced Cryogenic Engineering, V 14:378-86, 68, Avail:TAC

Design studies were made to select and evaluate a practical thermodynamic cycle for a prototype. These studies established that a partial reliquefier capable of liquefying as much as 42% of its feed of 4 lb/hr could be built within the limitations of a 14 mo hardware development program. It is believed that this equipment is representative in design principle of later hardware capable of 10,000 hr maintenance-free operation.
(LIQUEFICATION, SPACECRAFT, THERMODYNAMICS)

H73 40109 PROCESS FOR PRODUCING LIQUEFIED HYDROGEN, HELIUM AND NEON
Garwin, L., (Oklahoma City, Okla.), U.S. Patent 3,609,984, Apr 25 '69

A process for liquefying hydrogen, helium and neon more efficiently and economically than by methods previously practiced, which process includes the steps of compressing

the gas (hydrogen, helium or neon) to a pressure such that, upon isobarically cooling the thus compressed gas, a temperature above the critical temperature of the gas is reached at which the gas can be isentropically expanded to yield substantially a single liquid phase at atmospheric pressure.
(LIQUEFICATION, COST, PATENT)

H73 40110 APPLICATION OF THERMOSIPHON FOR PRECOOLING APPARATUS
Bewilogua, L., R. Knoener, and G. Kappler, Cryogenics, V 6:34-5 Nl, Fe 66

Method for cooling large pieces of apparatus from room temperature down to 20 or 4 K is shown schematically; vessels for liquid nitrogen, for liquid hydrogen or neon, and for liquid helium are arranged in vaccum; measuring device is attached to helium vessel; first all three vessels are cooled to liquid nitrogen temperature; then hydrogen (or neon) vessel and helium vessel with measuring device are cooled to liquid hydrogen (or neon) temperature; finally helium vessel with measuring device is cooled to helium temperature.
(THERMOSIPHON, COOLING, APPARATUS)

H73 40111 PRODUCTION OF LIQUID HYDROGEN AT THE ROCKET PROPULSION ESTABLISHMENT
Bainbridge, R., and T.R. Horton, Cryogenics, V 11:456-68, Dec 71

The design, development, and operation of a liquid hydrogen plant with an hourly output of 100 litres of normal liquid hydrogen or 70 litres of 85-90% para-hydrogen are described. The liquid hydrogen produced was used for testing a rocket thrust chamber developed by Rolls Royce and for tank pressurization studies on behalf of ELDO. In a period of six months over 40,000 litres of liquid hydrogen were produced. The performance of a Linde cycle is briefly examined and the major design concepts required to ensure a safe and reliable production facility are discussed.
(LIQUEFICATION, PARAHYDROGEN)

H73 40112* JOULES-THOMSON LIQUEFACTION OF HYDROGEN-HYDROCARBON GAS MIXTURES
Bartlit, J.R., K.D. Williamson, Jr., F.J. Edeskuty, (Los Alamos Scientific Lab., Los Alamos, N.M.), Advanced Cryogenic Engineering, V 15:452-6, 69

A Joule-Thomson liquefier was operated with H_2-CH_4 or H_2-C_2H_6 as the feed gas. For CH_4, well-mixed streams containing concentrations less than the soly. limit passed through the liquefier without plugging and appeared quant. in the transferred product. CH_4 and C_2H_6 concentrations above their soly. limits (30 vol. ppm for CH_4; greater than 1 vol. ppm for C_2H_6) plugged the liquefier within minutes. The product formed was flowable as a homogeneous "milk," without phase separation.
(LIQUEFICATION, HYDROGEN, HYDROCARBON)

H73 40113 THE PRODUCTION OF LIQUID HYDROGEN
Rozhkov, I.V. et al., AD-693480, Ja 69, Avail:TAC

The production of liquid hydrogen, its liquefaction and its ortho-para-conversions, as well as specific features involved in the storage and transportation of this material are covered in detail in this report compiled from recent Soviet and other publications. The report deals specifically with the structural materials used in the fabrication of industrial installations, pumping and storage facilities. Cryogenic thermal insulation is covered, as are the rules of safety in connection with the handling of liquid hydrogen.
(LIQUEFICATION, STORAGE, TRANSPORTATION)

H73 40200* TECHNIQUES FOR DETERMINING AVERAGE DENSITY AND RELATED PARAMETERS IN TWO-PHASE CRYOGENIC FLOW SYSTEMS
Williamson, K.D., Jr., (Los Alamos Scientific Lab, Los Alamos, N.M.), Advances in Cryogenic Engineering, V 17, 71, Avail:TAC

Two-phase flow is difficult to avoid in cryogenic systems. Each time such systems are cooled to operating temperatures, two-phase flow is encountered unless the system pressure is maintained well above the critical pressure. In addition, many applications involve the low-pressure vaporization of cryogenic liquids in heat exchangers which must operate continuously in the two-phase region. In order to design such systems, a knowledge of the complicated distributions of gas and liquid must be known so that hydrodynamic and heat transfer analyses can be made. Both gross and detailed structure measurements are of interest. These include the average density, fluid quality (mass of vapor/total mass of fluid), void fraction (volume occupied by the gas/total volume), void distribution, flow regimes, and local velocities.
(DENSITY, TWO-PHASE, QUALITY, FLOW, CRYOGENIC)

H73 40201* CAVITATION IN LIQUID CRYOGENS. 1: VENTURI
Hord, J., L.M. Anderson, and W.J. Hall, (National Bureau of Standards, Boulder, Colo.), N72-24363, NASA-CR-2054, Avail:TAC

The results of continuing cavitation studies are reported, The cavitation characteristics of liquid hydrogen and liquid nitrogen flowing in a transparent plastic Venturi are discussed. Thermodynamic data, consisting of pressure and temperature measurements within fully developed hydrogen cavities, are reported. Details concerning test apparatus, test procedure, and data correlation techniques are given.
(CAVITATION, VENTURI, PRESSURE, TEMPERATURE)

H73 40202* COMPUTER PROGRAMS FOR THERMODYNAMIC AND TRANSPORT PROPERTIES OF HYDROGEN
Roder, H.M., R.D. McCarty, and W.J. Hall, (National Bureau of Standards, Boulder, Colo.), COM-72-51081, NBS-TN-625, Oct 72, Avail:TAC

The thermodynamic and transport properties of para and equilibrium hydrogen have been programmed into a series

of computer routines. Input variables are the pair's pressure-temperature and pressure-enthalpy. The programs cover the range from 1 to 5000 psia (34 MN/sq m) with temperatures from the triple point to 6000 R (3300 K) or enthalpies from - 130 BTU/lb (-623 J/mol) to 25,000 BTU/lb (117000 J.mol). Output variables are enthalpy or temperature, density, entropy, thermal conductivity, viscosity, velocity of sound, heat capacity at constant pressure, heat capacity at constant volume, the heat capacity ratio, and a heat transfer parameter.
(THERMODYNAMICS, TRANSPORT, COMPUTER, PROPERTY)

H73 40203 INCIPIENT AND NUCLEATE BOILING OF LIQUID
Coeling, K.J., and H. Merte, Journal of Engineering for Industry, V 91:513-20, May 69

Experimental data are presented for natural convection heat transfer and for the point of inception of vapor formation for liquid hydrogen and liquid nitrogen. Nucleate boiling results with liquid hydrogen are also presented, indicating the so-called hysteresis effect with increasing and decreasing heat flux. The variables covered include heater surface material, roughness, and orientation.
(BOILING, CONVECTION, NUCLEATE)

H73 40204* EQUATION OF STATE AND PHASE DIAGRAM OF DENSE HYDROGEN
Kerley, G.I., Physics of the Earth and Planetary Interiors, V 6:78-82 N1-3, Dec 72

The equation of state of hydrogen has been calculated for specific volumes ranging from .01 to 10,000 cu cm/mole and for temperatures ranging from 200 to 1,000,000 K. Three phases are considered: the molecular solid, the metallic solid and the fluid. Chemical equilibrium between molecules, atoms, ions and electrons is considered in calculating the properties of the fluid phase. Transitions between the three phases were discussed. The triple point, where the three phases coexist, is calculated to occur at 2.3 Mbar and 1679 K. At higher temperatures and pressures, the molecular solid is unstable.
(STATE, EQUATION, PHASE)

H73 40205   FINITE RATE EVAPORATION OF CRYOGENIC HYDROGEN IN TWO-PHASE AIR
Edelman, R., and H. Rosenbaum, (General Applied Sciences Labs., Inc., Westbury, N.Y.), N66-32644, NASA-CR-76978, Sept 63, Avail:TAC

A theoretical study of two-phase continuum flow of hydrogen and air for a given range of initial conditions is presented. Of special interest is the method employed in calculating the two-phase boundary and subsequent condensation of the air during the hydrogen evaporation process.
(TWO-PHASE, EVAPORATION, FLOW)

H73 40206   FLOW AND THERMAL CHARACTERISTICS OF HYDROGEN NEAR ITS CRITICAL POINT IN A HEATED CYLINDRICAL TUBE
Mahlon, W.T., (Los Alamos Scientific Lab., N.M.), Report No. LA-4172, Avail:TAC

The flow conditions and mechanism of hydrogen near its critical point in a heated cylindrical tube were investigated. A special boiling number was found to be effective in correlating temperature differences for pressures greater than the critical pressure. Correlations were also obtained as a function of reduced pseudocritical temperatures. With pseudocritical temperatures slightly less than one, dynamic pressure, temperature, and average hot wire current were more nearly constant with respect to radius than at other temperatures. "M" shaped velocity profiles were observed at pseudocritical temperatures above one.
(FLOW, CRITICAL POINT, PRESSURE, TEMPERATURE, BOILING)

H73 40207   FORCED CONVECTION HEAT TRANSFER TO SUPERCRITICAL CRYOGENIC HYDROGEN: PART 1. LITERATURE SURVEY
Beech, J.C., (Explosives Research and Development Establishment, Waltham Abbey, England), Report No. ERDE-1/S/69, Fe 28 '69, Avail:TAC

The published experimental data covering forced convection heat transfer to cryogenic hydrogen are reviewed, with special attention to the near-critical regions of temperature and pressure. Data for straight and curved tubes, of both circular and non-circular cross-sections, are covered; also the case of asymmetric peripheral heat flux through the walls. A number of theoretical and semiempirical treatments of the near-critical, variable fluid

property condition are discussed, and their effectiveness in correlation of near-critical heat transfer to cryogenic hydrogen considered.
(CONVECTION, CRYOGENIC, CRITICAL POINT, HEAT TRANSFER)

H73 40208 THERMODYNAMIC AND TRANSPORT PROPERTIES OF FLUIDS AND SELECTED SOLIDS FOR CRYOGENIC APPLICATIONS
Johnson, V.J., and D.E. Diller, (National Bureau of Standards, Boulder, Colo.), N71-20734, NASA-CR-117407; NBS-9782, Oct 31 '70 Avail:TAC

The activities and accomplishments for the data evaluation and compilation program are summarized in the description of the following tasks: (1) properties of hydrogen and related studies including curve fitting techniques and survey of temperature scales.
(THERMODYNAMICS, TRANSPORT, PROPERTY, FLUID)

H73 40209 HEAT TRANSFER TO CRYOGENIC HYDROGEN FLOWING TURBULENTLY IN STRAIGHT AND CURVED TUBES AT HIGH HEAT FLUXES
Anon, (Aerojet-General Corp., Sacramento, Calif.), N67-18156, NASA-CR-678, Fe 67, Avail:TAC

The forced convection heat transfer characteristics of cryogenic hydrogen were studied at pressures ranging from 800 to 1500 psi and fluxes from 8 to 27 Btu/in.^{2} sec. The tests were conducted under conditions simulating those predicted for the Phoebus-2 nozzle, in support of the nozzle development program.
(HEAT TRANSFER, TURBULENCE, CRYOGENIC, FLOW)

H73 40210 HEAT TRANSFER TO SUBLIMING SOLID-VAPOR MIXTURE OF HYDROGEN BELOW ITS TRIPLE POINT
Jones, M.C., T.T. Nagamoto, J.A. Brennan, A.I.Ch.E. Journal, V 12:790-5 N4, Jl 66

Experimental study; heat transfer coefficients are measured for solid vapor mixture of parahydrogen discharging through heated brass tube below triple point pressure.
(HEAT, TRANSFER, TRIPLE POINT, SUBLIMATION)

H73 40211 MECHANICAL PROPERTIES OF SOLID PARA-HYDROGEN AT 4.2K
Bol'shutkin, D.N., Yu.E. Stetsenko, Z.N. Linnik, Soviet Physics, Solid State, V 9:1952-5 N9, Mar 68

Ultimate strength, relative elongation, and hardening

coefficient, which depends on deformation rate, were determined; three characteristic regions of deformation curves were considered; low value of static Young's modulus of 29 kg/sq mm is to some extent, due to considerable contribution of zero-point vibrations to total lattice energy.
(SOLID, PARAHYDROGEN, PROPERTY)

H73 40212 NUMERICAL PROCEDURES FOR CALCULATING REAL FLUID PROPERTIES OF NORMAL AND PARAHYDROGEN
Goldberg, F.N., and A.M. Haferd, (NASA, Lewis Research Center, Cleveland, O.), N68-15798, NASA-TN-D-4341, Fe 68, Avail:TAC

The library of single function calls can be used efficiently without initial estimates. When physical conditions are known, engineering estimates of density may be included for additional speed in calculation.
(PROPERTY, PARAHYDROGEN, COMPUTER, FLUID)

H73 40213* TABLES OF PARAHYDROGEN DATA IN ENGINEERING UNITS FROM 36^{o} TO 5000^{o}R AT PRESSURES TO 5000 PSIA
Farmer, O.A., (Los Alamos Scientific Lab., N.M.), Report No. LA-3669, Fe 14 '67, Avail:TAC

Tables of thermodynamic-transport and related properties of parahydrogen are provided in engineering units for the temperature range 36 to 5000^{o}R and the pressure range 13 to 5000 psia.
(TABLE, PARAHYDROGEN, THERMODYNAMICS)

H73 40214 THERMAL BEHAVIOR AND MEASUREMENTS OF CRYOGENIC LIQUIDS
Jonke, R.J., Revue Scientifique et Technique CECLES/CERS, V 3:129-62, Apr-Je 71

The second stage of Europa III is powered by a liquid hydrogen and liquid oxygen engine. To minimize the amount of cryogenic propellants required - and thus optimize the payload - their behavior under operational conditions has to be studied. The present paper describes experimental work on the thermal behavior of cryogenic liquids carried out in Europe during 1967-1969 and the necessary measurement methods.
(CRYOGENIC, THERMAL, MEASUREMENTS)

H73 40300 CRYOGENIC FLOW-METERING RESEARCH AT NBS
Mann, D.B., Cryogenics, V 11:179-85, Je 71

An NBS program, which focuses attention on the problem, has as its objectives to (1) establish present state-of-the-art by evaluating existing measurement methods, (2) establish methodology to maintain precision and accuracy of field-measurement devices, and (3) establish a comprehensive program to develop new cryogenic fluid-measurement systems. The scope of this program includes a concerted effort to develop new mass-flow measurements for cryogenic fluids such as slush or liquid hydrogen.
(FLOW, CRYOGENIC, MEASUREMENT, SLUSH)

H73 40301 CRYOGENIC DENSITY PROBE
Anon, Instrumentation Technology, V 15:94, Oct 68

A sensor for local density of liquid hydrogen or oxygen provides 0.1 percent accuracy. The method is based on beta-ray absorption in a silicon surface-barrier detector.
(DENSITY, LIQUID, CRYOGENIC)

H73 40302 TEST OF LIQUID-LEVEL SENSORS AND FISSION COUPLES
McMillan, W.D., (General Dynamics, Fort Worth, Tex.), NASA-CR-2162, 21-47, Avail:TAC

Level sensors for gaging the height of liquid H in propellant tanks, comprised of a continuous capacitance probe 40-in. long and several each of point sensors of capacitance, thermal, and magnetostrictive types, were irradiated in a liquid H dewar to a dose exceeding that predicted for 10 missions.
(SENSOR, LIQUID-LEVEL)

H73 40303 LIQUID HYDROGEN FLOW BY NMR TECHNIQUE
Anon, Instruments & Control Systems, V 39:87, Aug 66

The purpose of the investigation is to explore the feasibility of using a nuclear magnetic resonance (NMR) technique to measure the flow rate of liquid hydrogen under conditions that are encountered in the fueling of rockets. The advantage of such a method, over conventional ones, is that no electrical or mechanical measuring device comes into contact with the liquid to introduce energy or heat into it. Although this technique has been successfully demonstrated in laboratory tests using ex-

perimental equipment, actual field tests are yet to be performed.
(FLOW, MEASUREMENT)

H73 40304 QUALITY DETERMINATION OF LIQUID-SOLID HYDROGEN MIXTURES
Daney, D.E., and D.B. Mann, Cryogenics, V 7:280-5, Oct 67

Current interest in liquid-solid mixtures of parahydrogen ('slush hyrogen') as a potential rocket propellant has lead to a theoretical and experimental investigation of one method of determining liquid-solid quality. Since knowledge of the quality is necessary to calculate such quantities as (1) the total mass in a container, (2) the storage time possible for these mixtures, and (3) the transport properties of such mixtures, it is desirable to have an accurate means of quality determination.
(LIQUID, SOLID, PARAHYDROGEN)

H73 40305* CRYOGENIC INSTRUMENTATION AT AND ABOVE LIQUID HYDROGEN TEMPERATURE: PRESENT AND FUTURE
Keller, W.E., (Los Alamos Scientific Lab., N.M.), N73-16743, LA-DC-72-855, 72, Avail:TAC

The instrumentation problems associated with present and possible future large scale cryogenic systems operating at or above liquid hydrogen temperatures were investigated. Cryogenic systems relevant to the energy problem, and the instrumentation problem for large scale usage of cryogens are discussed along with liquifaction and refrigeration systems, storage systems, and transportation of cryogens.
(INSTRUMENTATION, CRYOGENIC, TEMPERATURE)

H73 40306 DEVICE FOR MEASURING THE TEMPERATURE OF LIQUID AND GASEOUS HYDROGEN
Chandon, H.C., and A.R. Larson, (Aerojet-General Aerometrics, San Ramon, Calif.), N66-31701, NASA-CR-76417, Apr 66, Avail:TAC

A cryogenic temperature transducer which is extremely fast in response to changing temperature, has medium accuracy, and measures temperature over a wide range, was developed.
(TRANSDUCER, TEMPERATURE, CRYOGENIC)

H73 40307 LH_2 QUALITY METER
Anon, (Lockheed-Georgia Co., Marietta, Nuclear Lab.), N69-20539, NASA-CR-100356, Oct 68, Avail:TAC

Two engineering test models, fabricated from aluminum and from 347 stainless steel, were tested and calibrated in accordance with specified operating conditions and accuracy. The device was designed to indicate the ratio of dry vapor to wet vapor being vented through itself.
(VAPOR, CALIBRATION)

H73 40308 SMALL TURBINE-TYPE FLOWMETERS FOR LIQUID HYDROGEN
Warshawsky, I., H.F. Hobart, and H.L. Minkin, (NASA, Lewis Research Center, Cleveland, O.), N71-19703, NASA-TM-X-52984, 71, Avail:TAC

Statistical data are presented on the reproducibility and linearity of turbine-type sensors, in 2 to 5 cm sizes, with various types of bearings. Design principles; installation practices, and inspection procedures are suggested that are conducive to reliability.
(FLOW, CALIBRATION, DESIGN)

H73 40309 THIN-FILM HYDROGEN SENSOR
MacIntyre, J.R., (General Electric, Huntsville, Ala.), and T.N. Marshall, Jr., Instrumentation Technology, V 19:29-31 N8, Aug 72

A sensor is described which is characterized by very large resistance changes for relatively low amounts of hydrogen. Its simplicity makes it attractive for continuous monitoring applications.
(SENSOR, DETECTION)

H73 40400 PRESSURE VESSEL FOR USE WITH HYDROGEN
Long, C.A., (Struthers Scientific and International Corp.), British Patent 1,182,101, Fe 25 '70

The costs of such vessels may be reduced by using a laminated structure having vented layers of non H-resistant steel for all but the innermost liner. However, the welds are still susceptible to H embrittlement. Methods are described for overcoming this difficulty by using a number of constructions which eliminate continuous gas paths through the metal from the inner liner to the outer reinforcement.
(VESSEL, COST, PRESSURE)

H73 40401 HYDROGEN PRESSURE VESSEL WITH LAMINATED WALLS
Oto, Y., T. Yamazaki, T. Shinkawa, (Mitsubishi Heavy Industries, Ltd.), British Patent 1,182,142, Fe 25 '70

The diffusion of H through the welded joints of the innermost layer of the laminate is prevented by the welds being made onto a backing strip and not onto the inner-liner of the vessel.
(VESSEL, LAMINATED, PRESSURE, WELD)

H73 40402 THERMAL PROTECTION FOR LIQUID-HYDROGEN FUEL TANKS IN HIGH-SPEED, LONG-RANGE AIRCRAFT
Gosch, W.D., (Rand Corp., Santa Monica, Calif.), AD-625407, 65, Avail:TAC

Part of a continuing study of cryogenic fuel system is presented. An analysis is presented of requirements for thermal protection systems and of fuel boil-off for liquid-hydrogen tanks aboard hypersonic, long-range aircraft. From this analysis it should be possible to obtain preliminary approximations of the weights of fuel boil-off and thermal protection systems over a wide spectrum of tank sizes and heat inputs.
(AIRCRAFT, THERMAL, PROTECTION, LIQUID)

H73 40403 STRUCTURAL DESIGN CONSIDERATIONS FOR STORAGE OF LIQUID HYDROGEN IN SPACE VEHICLE
Sagata, J., SAE-Paper 994D, Ja 11-15 '65, Avail:TAC

Description of S-IV and S-IVB stages for Saturn, designed to use high specific impulse of liquid hydrogen-liquid oxygen propulsion system.
(INSULATION, STRUCTURE, DESIGN, LIQUID, SPACECRAFT)

H73 40404 STRUCTURAL CONCEPTS FOR HYDROGEN-FUELED HYPERSONIC AIRPLANES
Jackson, L.R., J.G. Davis, Jr., and G.R. Wichorek, (NASA, Langley Research Center, Langley Station, Va.), N66-16546, NASA-TN-D-3162, Fe 66, Avail:TAC

Two structural concepts have been identified and investigated to obtain a better insight into problems associated with structures for hydrogen-fueled hypersonic airplanes. One of these is the multiwall sandwich concept which combines the evacuated thermal protection, tankage, and load-carrying functions into a single component. The other concept is based on the use of an unsealed structure that does not require vacuum sealing, but rather utilizes carbon dioxide gas to purge the insulation space between the structure and tanks.
(AIRCRAFT, STRUCTURAL, HYPERSONIC)

H73 40405 OPEN-CELL CRYOGENIC INSULATION
Yates, G.B., (General Dynamics Corp., San Diego, Calif.), Advanced Cryogenic Engineering, V 16:128-37, 70

A completely open-cell insulation was feasible for a liquid H tank. The most efficient and the lightest weight material was the poly (phenylene oxide) foam. Very small pore sizes (1.5 mils in 400-mesh screen) effectively maintained an insulating gas layer.
(INSULATION, OPEN-CELL, CRYOGENIC)

H73 40406 NO-LOSS CRYOGENIC STORAGE ON THE LUNAR SURFACE
Bell, J.H., Jr., (Boeing Co., Huntsville, Ala.), NASA-SP-229, 70, p 23-30, Avail:TAC

A technique designed to store cryogenic O and H on the lunar surface with minimum heat leak is described.
(STORAGE, CRYOGENIC, SOLIDIFICATION)

H73 40407 LOW-DENSITY FOAM FOR INSULATING LIQUID-HYDROGEN TANKS
Sumner, I.E., (NASA, Lewis Research Center, Cleveland, O.), NASA-TN-D-5114, 69, Avail:TAC

Experiments were carried out to develop a light weight polyurethane foam insulation for liquid H tanks of space vehicles that could be foamed in place on the outside of the tank.
(FOAM, POLYURETHANE, SPACECRAFT)

H73 40408 LIQUID HYDROGEN TANK INSULATION FOR S-II BOOSTER
Hammond, M.B., Jr., Chemical Engineering Progress Symposium Series, V 62:213-18 N61, 66, Avail:TAC

S-II booster is first large airborne tank to have integrally bonded and sealed external insulation; all of design criteria and manufacturing aspects have been aimed at obtaining practical insulation with high reliability.
(INSULATION, RELIABILITY)

H73 40409 INITIAL WARMUP OF 500,000-GALLON LIQUID HYDROGEN DEWAR
Liebenberg, D.H., E. Murley, (Los Alamos Scientific Lab., N.M.), Report No. LA-3661, Mar 22 '67, Avail:TAC

A 500,000-gallon liquid hydrogen dewar was warmed to ambient temperature by breaking the annular space with a small quantity of gaseous nitrogen and using an installed 32.3-kW electric heater. Some previously reported hazards were not observed using this procedure.
(LIQUID, HAZARD)

H73 40410 HYDROGEN TANKAGE FOR HYPERSONIC CRUISE VEHICLES
Heathman, J.H., (General Dynamics Corp., San Diego, Calif.), and L.G. Kelly, American Institute of Aeronautics and Astronautics, 66, p 430-8

Study of nonintegral liquid-hydrogen tankage for hypersonic aircraft in all aspects affecting the total installation weight. Design criteria are established for vehicle mission requirements. Structural concepts and materials, insulation systems, and fuel system requirements are evaluated. Results of an optimization based on structural materials, insulation concept, insulation distribution and weight, boiloff and spray cooling, and tank operating pressure are given. Test results are given and compared with analytical predictions.
(TANK, HYPERSONIC, AIRCRAFT, DESIGN)

H73 40411 EXTERNAL PRESSURIZATION SYSTEMS FOR CRYOGENIC STORAGE SYSTEMS
Wapato, P.G., (Airesearch Manufacturing Co., Los Angeles, Calif.), N71-38527, NASA-CR-115205, Sept 10 '71, Avail:TAC

Recirculation-type external pressurization systems were investigated for use in pressure control of cryogenic hydrogen, oxygen and nitrogen storage systems.
(STORAGE, CRYOGENIC)

H73 40412 EXTERNAL PRESSURIZATION SYSTEMS FOR CRYOGENIC STORAGE SYSTEMS: DESIGN REFERENCE MANUAL
Wapato, P.G., A.W. Keeley, L.N. Jew, and C.F. Young, (AiResearch Mfg. Co., Los Angeles, Calif.), N71-38021, NASA-CR-115204, Sept 10 '71, Avail:TAC

The tools and techniques needed by system planners for estimation of the weight and cost of recirculation-type external pressurization systems for hydrogen, oxygen, and nitrogen storage are provided. Characterization information and design procedures are presented for all major system elements.
(STORAGE, CRYOGENIC, DESIGN)

H73 40413 EFFECT OF SIZE ON NORMAL-GRAVITY SELF-PRESSURIZATION OF SPHERICAL LIQUID HYDROGEN TANKAGE
Aydelott, J.C., and C.M. Spuckler, (NASA, Lewis Research Center, Cleveland, O.), N69-24188, NASA-TN-D-5196, May 69, Avail:TAC

A study was conducted to obtain a correlating parameter which would relate the rate of pressure rise to the volume of spherical liquid hydrogen tankage.
(TANK, VOLUME)

H73 40414 DEVELOPMENT OF A LIGHTWEIGHT EXTERNAL INSULATION SYSTEM FOR LIQUID-HYDROGEN STAGES OF THE SATURN V VEHICLE
Middleton, R.L., J.M. Stuckey, J.T. Schell, L.B. Mulloy, and P.E. Dumire, (NASA, Marshall Space Flight Center, Huntsville, Ala.), Advances in Cryogenic Engineering, V 10: 216-23, 64

A new insulation concept is discussed originating from this program having a weight of approximately 0.50 lb./ft.^{2} and a conductance of 0.33 Btu./hr. ft.^{2} ^{o}R. The double-seal insulation consists of an inner portion of individually sealed Mylar honeycomb cells and an outer He purge channel of glass-fiber-reinforced phenolic honeycomb.
(INSULATION, HONEYCOMB)

H73 40415 DEVELOPMENT OF ADVANCED MATERIALS COMPOSITES FOR USE AS INSULATIONS FOR LH2 TANKS
Lemons, C.R., C.R. Watts, and O.K. Salmassy, (McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.), N73-11547, NASA-CR-123928, Je 72, Avail:TAC

A study of internal insulation materials and fabrication processes for space shuttle LH2 tanks is reported.

Emphasis was placed on an insulation system capable of reentry and multiple reuse in the Shuttle environment.
(LIQUID, INSULATION, SHUTTLE, COST)

H73 40416 DETERMINATION OF THE THERMAL CONDUCTIVITY, THE SPECIFIC HEAT AND THE WEIGHT BY VOLUME OF INSULATIONS FOR ROCKET TANKS FILLED WITH LIQUID HYDROGEN
Oglin, B., and W.F. Zimni, (Techtran Corp., Glen Burnie, Md.), N68-15243, NASA-TT-F-11146, ELDO/CECLES Rev. Tech., V 2:3-28, 67, (In French), Avail:TAC

Experimental research into insulating foams at temperatures down to that of liquid hydrogen ($20^{o}K$) is reported. In addition to a general study of the insulation of tank walls for cryogenic high-energy rocket states, a description is given of various measuring methods of determining the thermal conductivity, the specific heat and the density of insulating materials, together with a comprehensive review of the literature.
(TANK, INSULATION, DENSITY, LIQUID)

H73 40417 A COMPUTER PROGRAM FOR THE CALCULATION OF THERMAL STRATIFICATION AND SELF-PRESSURIZATION IN A LIQUID HYDROGEN TANK
Arnett, R.W., and R.O. Voth, (National Bureau of Standards, Boulder, Colo.), N72-24362, NASA-CR-2026, May 72, Avail:TAC

An analysis and computer program are described for calculating the thermal stratification and the associated self-pressurization of a closed liquid hydrogen tank.
(STRATIFICATION, TANK, LIQUID)

H73 40418 A CARBON DIOXIDE PURGE AND THERMAL PROTECTION SYSTEM FOR LIQUID-HYDROGEN TANKS OF HYPERSONIC AIRPLANES
Jackson, L.R., M.S. Anderson, (NASA, Hampton, Va.), Advances in Cryogenic Engineering, V 12:146-56, 67, Avail:TAC

Structural studies showed that the CO_2-frost thermal protection concept may offer a practical purge and thermal protection system for H tanks.
(TANK, AIRCRAFT, HYPERSONIC)

H73 40419 LIQUID HYDROGEN POSITIVE EXPULSION BLADDERS
Wiederkarip, K.E., (Boeing Co., Seattle, Wash.), N69-10712, NASA-CR-72432, May 68, Avail:TAC

Liquid hydrogen expulsion tests performed using multi-ply bladders fabricated from Mylar, Kapton and an experimental polyester film.
(EXPULSION, LIQUID, TEST)

H73 40420 MULTILAYER INSULATION FOR LARGE VESSELS USED IN TRANSPORTING AND STORING CRYOGENIC LIQUIDS
Glaser, P.E., Mechanical Engineering, V 87:23-7, Aug 65

Investigating the thermal performance of multilayer insulations for large vessels used in transporting and storing cryogenic liquids - to make commonplace the large-scale use of these liquid fuels.
(INSULATION, MULTILAYER, STORAGE)

H73 40421 PAYLOAD OPTIMIZATION FACTORS FOR STORAGE OF LIQUID HYDROGEN IN A LOW-GRAVITY ENVIRONMENT
Sherman, A.L., Journal of Spacecraft and Rockets, V 7:216-19 N2, Fe 70

Many of the Apollo application missions and post-Apollo studies require orbital storage of cryogenic propellants. During these periods in orbit, it will be necessary to vent the excess tank pressures caused by pressurant, and auxiliary propellants.
(SPACECRAFT, STORAGE, LIQUID)

H73 40422 VENTING OF LIQUID-HYDROGEN TANKAGE
Aydelott, J.C., C.M. Spuckler, (NASA, Lewis Research Center, Cleveland, O.), NASA-TN-D-5263, 69, Avail:TAC

A 22-in. diameter spherical tank, 65% of which was filled with liquid H, was subjected to venting tests by uniformly heating the tank at 200-78°K, and top-heating at 311°K.
(VENT, LIQUID, TANK, ANALYSIS)

H73 40500 INVESTIGATION OF TWO-PHASE HYDROGEN FLOW IN PUMP INLET LINE
Urasek, D.C., P.R. Meng, and R.E. Connelly, (NASA, Lewis Research Center, Cleveland, O.), NASA-TN-D-5258, Jl 69, Avail:TAC

An investigation was conducted to evaluate the vapor-to mixture-volume ratio present in the inlet line of a pump when liquid hydrogen is pumped in a boiling condition from a sealed tank. Both an experimental and an analytical approach were used. The good agreement obtained between the experimental and analytical results indicated that the vapor- to mixture-volume ratio can be predicted with reasonable accuracy. These estimated values of vapor-to mixture-volume ratio, when used with previously reported results, may be useful in predicting pump inducer performance with two-phase flow.
(FLOW, TWO-PHASE, BOILING)

H73 40501 BEARINGS AND SEALS FOR CRYOGENIC FLUIDS
Scibbe, H.W., (NASA, Lewis Research Center, Cleveland, O.) N68-18124, NASA-TM-X-52415, 68, Avail:TAC

Bearings and seals in rocket engine turbopumps operate directly in the cryogenic propellant. Special design and lubricating techniques are required since ordinary oils and greases become glasslike solids at these extremely cold temperatures.
(BEARING, PUMP, CRYOGENIC)

H73 40502 HEAT TRANSFER COEFFICIENTS FOR LIQUID HYDROGEN TUROBPUMPS
Anon, (NASA, Washington D.C. Technology Utilization Division), Report No. PB-180-567, 68

An analytical study effort was undertaken to provide the basic criteria for hydrogen heat transfer coefficients as a function of the hydrogen thermodynamic state and heat transfer rate intensity, as applicable to liquid hydrogen turbopumps.
(LIQUID, PUMP, HEAT TRANSFER, BOILING)

H73 40503 THERMODYNAMIC IMPROVEMENTS IN LIQUID HYDROGEN TURBOPUMPS
Wagner, W.R., G.S. Wong, and E.B. Monteath, (Rocketdyne, Canoga Park, Calif.), N70-29705, NASA-CR-102722, Dec 69, Avail:TAC

The completed effort is described in the evaluation of

thermal conditioning problems of liquid hydrogen turbopumps to enhance mixed-phase operation and to minimize engine system constraints on starts and restarts.
(PUMP, HEAT TRANSFER, LIQUID)

H73 40504 PUMPS FOR LIQUID HYDROGEN
Carter, T.A., Jr., (Air Reduction Co., Inc.) Cryogenic Technology, V 3:172-5 N4, 67

The problems connected with pumping liquid and slush H are discussed. The characteristics and performance of pumps developed by 16 firms are described.
(LIQUID, SLUSH, PUMP, PERFORMANCE)

H73 40505 LUBRICATION AND WEAR OF BALL BEARINGS IN CRYOGENIC HYDROGEN
Scibbe, H.W., D.E. Brewe, and H.H. Coe, (NASA, Lewis Research Center, Cleveland, O.), N68-33065, NASA-TM-X-61165, 68, Avail:TAC

Several basic design and material requirements of ball bearings used in liquid hydrogen turbopumps are presented.
(PUMP, BEARING, WEAR, LUBRICATION)

H73 40506 HYDRAULIC DESIGN OF THE M-1 LIQUID HYDROGEN TURBOPUMP
Farquahr, J., and B.K. Lindley, (Aerojet-General Corp., Sacramento, Calif.), N66-32334, NASA-CR-54822, Jl 66, Avail:TAC

This report presents the design method and resulting design details as well as performance predictions for a ten-stage, axial flow, hydrogen pump for the M-1 oxygen/hydrogen liquid rocket engine.
(PUMP, DESIGN, PERFORMANCE)

H73 40507 EXPERIMENTAL STUDY OF LOW-SPEED OPERATING CHARACTERISTICS OF A LIQUID HYDROGEN CENTRIFUGAL TURBO-PUMP
Ribble, G.H., Jr., and G.E. Turney, (NASA, Lewis Research Center, Cleveland, O.), N69-33806, NASA-TM-X-1861, Aug 69, Avail:TAC

The low speed operating characteristics of a liquid hydrogen centrifugal turbopump are discussed. The turbo-

pump was operated at several speeds, ranging from 6.7 to 49 percent of the rated speed.
(PUMP, LIQUID, TEST, EFFICIENCY)

H73 40508 EXPERIMENTAL FINDINGS FROM ZERO-TANK NET POSITIVE SUCTION HEAD OPERATION OF THE J-2 HYDROGEN PUMP
Stinson, H.P., and R.J. Strickland, (NASA, Marshall Space Flight Center, Huntsville, Ala.), N72-29807, NASA-TN-D-6824, Aug 72, Avail:TAC

The results of a series of liquid hydrogen turbopump tests to demonstrate the feasibility of zero-tank net positive suction head are presented. A J-2 engine hydrogen pump and S-IVB stage fuel feed system were used for this investigation.
(TEST, PUMP, SUCTION)

H73 40509 ANALYSIS OF ROCKET-POWERED EJECTORS FOR PUMPING LIQUID OXYGEN AND LIQUID HYDROGEN
Franciscus, L.C., (NASA, Lewis Research Center, Cleveland, O.), N70-42421, NASA-TN-D-6033, Oct 70, Avail:TAC

A preliminary analysis of the use of rocket-powered ejectors for pumping liquid oxygen and liquid hydrogen in rocket engines was made. The drive gas is the exhaust gas of a smaller hydrogen-oxygen rocket engine. The analysis is one dimensional and does not include shock or friction losses.
(EJECTOR, PUMP, LIQUID, ANALYSIS)

H73 40510 COOLDOWN TIME FOR SIMPLE CRYOGENIC PIPELINES
Steward, W.G., R.V. Smith, and J.A. Brennan, (National Bureau of Standards, Boulder, Colo.), Report No. PB-180-981, 68, R-469

This paper offers a quick method by which cooldown time for a simple system can be estimated from a dimensionless parameter read from a graph. To use the method it is necessary to know the fluid and pipe enthalpy, density, and velocity of sound in the warm gas. The idealized model and closed form solution are described, and comparison with experimental results is shown.
(CRYOGENIC, PIPELINE)

H73 40511 A 14-M LIQUID-HYDROGEN LINE
Croft, A.J., (University of Oxford, England), Cryogenics, V 10:167-9 N2, 70

The 14-m liquid-H transfer line, between H and He liquefiers, is comprised of a ½-inch nominal bore Cu tubing, with wall thickness of 1.15 mm, concentrically insulated with a simple high-vacuum line made of 2-inch nominal bore Cu tubing.
(TRANSFER, PIPE, LIQUEFACTION)

H73 40512 ANALYSIS OF TWO-PHASE FLOW IN LH_2 PUMPS FOR O_2/H_2 ROCKET ENGINES
Bissell, W.R., (North American Rockwell Corp., Canoga Park, Calif.), G.S. Wong, T.W. Winstead, Journal of Spacecraft and Rockets, V 7:707-13 N6, Je 70

An analysis was made to determine the two-phase pumping capability of liquid-hydrogen pumps and to establish hydrodynamic design criteria to improve two-phase pump performance.
(PUMP, FLOW, TWO-PHASE, DESIGN)

H73 40600* MULTIPLE USE OF CRYOGENIC FLUID TRANSMISSION LINES
Bartlit, J.R., and F.J. Edeskuty, (Los Alamos Scientific Lab., Los Alamos, N.M.), Report No. LADC-72-341, 4th International Cryogenic Engineering Conference, The Netherlands, 72, Avail:TAC

Economic advantages accruing from transporting two energy sources concurrently through a single pipeline have been recently discussed. Proposed was the concurrent transport of electricity at liquid hydrogen (LH_2) temperatures, 20 K, (utilizing the greatly reduced resistivity of copper) and liquefied natural gas (LNG) at 110 K, (utilizing decreased pumping costs, thermal shielding, and energy for driving the hydrogen refrigerator offered by LNG). This idea is carried a step further by exploring environmental as well as economic advantages which may be realized by distributing three energy sources concurrently - LNG, LH_2, and electricity.
(COST, PIPELINE, ELECTRIC)

H73 40601* EXPERIENCE IN HANDLING, TRANSPORT AND STORAGE OF LIQUID HYDROGEN-THE RECYCLABLE FUEL
Bartlit, J.R., F.J. Edeskuty, and K.D. Williamson, Jr., (Los Alamos Scientific Lab., Los Alamos, N.M.), 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., 72, Report No. LADC-73-632, Avail:TAC

In the past where hydrogen has been used on a large scale, it has sometimes proved advantageous to use it in liquid form for ease in transport and storage. This existing cryogenic technology is found adequate to meet the needs of the most likely future applications for liquid hydrogen which are transportation facilities, remote sites not serviced by pipelines, peak-shaving, and superconducting power lines.

Existing liquefaction facilities, dewar and pipe sizes, flow capacities, design criteria and data, and safety are discussed and compared with future needs.
(TRANSPORTATION, STORAGE, LIQUID)

H73 40602 A 10,000-GPM LIQUID HYDROGEN TRANSFER SYSTEM FOR THE SATURN/APOLLO PROGRAM
Wybranowski, E., (NASA, John F. Kennedy Space Center, Fla.), Advance in Cryogenic Engineering, V 17, 71, Avail:TAC

Cryogenic loading of the huge Saturn V booster begins eight hours before the scheduled lift-off. The first three hours of fueling is the cold hydrogen gas conditioning of the S-II stage fuel tank. Then in one hour and thirty minutes approximately 340,000 gallons of liquid hydrogen is loaded into the S-II and S-IVB fuel tanks.

This report briefly describes the design and operation of the liquid hydrogen transfer system used to service the Saturn V launch vehicle.
(LIQUID, TRANSFER, SYSTEM)

H73 40603* THE STORAGE AND TRANSPORTATION OF SYNTHETIC FUELS
Johnson, J.E., (Union Carbide Corp., Linde Division), Report No. ORNL-TM-4307, Sept 72, Avail:TAC

This report summarizes various contributions by the technical staff of the Engineering and Research Departments of the Linde Division of Union Carbide Corporation. It includes a review of the problems associated with the storage and transportation of energy by the major candidate synthetic fuel systems - hydrogen and hydrogen-derived fuels, such as ammonia and methanol. Particular emphasis has been placed on the identification of limiting technologies and on areas in which research and development efforts should be undertaken to contribute solutions to the nation's growing problems of energy resources, transmission and conversion.
(STORAGE, TRANSPORTATION)

H73 40604 SHUTTLE: REACTION CONTROL SYSTEM. CRYOGENIC LIQUID DISTRIBUTION SYSTEM: STUDY
Akkerman, J.W., (NASA, Lyndon B. Johnson Space Center, Houston, Tex.), N73-16765, NASA-TM-X-68913, Ja 72, Avail:TAC

A cryogenic liquid distribution system suitable for the reaction control system on space shuttles is described. The system thermodynamics, operation, performance and weight analysis are discussed along with the design, maintanence and integration concepts.
(SHUTTLE, LIQUID, DISTRIBUTION)

H73 40605 CRYOGENIC PROPELLANT ACQUISITION AND TRANSFER
Tatro, R.E., (General Dynamics, San Diego, Calif.), NASA, Lewis Research Center Space Transportation System Technology Symposium, V 5:167-87, Jl 70, N70-39613, Avail:TAC

The technologies required to successfully design

acquisition and transfer systems for the shuttle are in the areas of storage tank fluid dynamics and thermal conditioning, pressurization and pumping system interfaces, and receiver tank thermodynamics.
(SHUTTLE, STORAGE, DESIGN)

324

H73 41000* A SUMMARY OF THE CHARACTERIZATION STUDY OF SLUSH HYDROGEN
Sindt, C., (National Bureau of Standards, Institute of Basic Standards, Boulder, Colo.), Cryogenics, V 10:372-80, Oct 70, Avail:TAC

Discussion of a study of slush hydrogen preparation, storage, transfer and equipment which is in progress at the Cryogenics Division of the National Bureau of Standards. A process of slush preparation by intermittent vacuum pumping is described. Observations of solid particle size and structure were made during a 100 h aging of slush, showing marked structural changes and insignificant size particle changes during aging. It was found that slush with over 0.5 solid content could be transferred and pumped with losses similar to losses in triple-point hydrogen when the Reynolds numbers are high.
(SLUSH, PREPARATION, STORAGE, TRANSFER, PUMP)

H73 41001 FLOW RESEARCH SYSTEM FOR LIQUID AND SLUSH HYDROGEN
Marshall, T.N., Jr., (NASA, Marshall Space Flight Center, Ala.), ISA Trans, V 10:117-20 N2, 71, Avail:TAC

This system is both a combination gravimetric calibration system for flow and quality instrumentation and a hydrogen slush generation system. Discussion focuses on the hydrogen slush flow and generation capability since the characteristics of the system for this use directly apply to liquid hydrogen flow research.
(LIQUID, SLUSH, FLOW, QUALITY, GENERATION)

H73 41002 HANDBOOK OF PHYSICAL AND THERMAL PROPERTY DATA FOR HYDROGEN. TRIPLE POINT REGION TO CRITICAL POINT REGION. VOLUME I: A STUDY OF HYDROGEN SLUSH AND/OR HYDROGEN GEL UTILIZATION
Anon, (Lockheed Missiles and Space Co., Sunnyvale, Calif.), N67-34912, NASA-CR-87655, Mar 11 '67, Avail:TAC

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.
(TRIPLE POINT, CRITICAL POINT, PROPERTY, SLUSH)

H73 41003 HYDROGEN-SLUSH DENSITY REFERENCE SYSTEM
Weitzel, D.H., C.F. Sindt, and D.E. Daney, (Cryogenic Division, NBS, Boulder, Colo.), Advances in Cryogenic Engineering, V 13:523-33, 67, Avail:TAC

Design considerations are given for a H-slush system for calibration of field-type instruments and (or) transfer standards. A method for slush measurement is described.
(SLUSH, INSTRUMENTATION, DENSITY)

H73 41004* INSTRUMENTATION FOR STORAGE AND TRANSFER OF HYDROGEN SLUSH
Weitzel, D.H., J.E. Cruz, L.T. Lowe, R.J. Richards, and D.B. Mann, (National Bureau of Standards, Boulder, Colo., Cryogenics Div.), Report No. NBS-R-673, 71, Advances in Cryogenic Engineering, V 16:230-40, Avail:TAC

A program for development and testing of density and flow instrumentation for use in hydrogen liquid and liquid-solid mixtures (slush) is reviewed. Performance criteria are indicated along with experimental and analytical results which provide some basis for choices among the various candidate systems. The density work is nearing completion; the flow studies have not yet provided data beyond the demonstration of feasibility.
(SLUSH, INSTRUMENTATION, TRANSFER, STORAGE, FLOW)

H73 41005* LIQUID-SOLID MIXTURES OF HYDROGEN NEAR THE TRIPLE POINT
Mann, D.B., P.R. Ludtke, C.F. Sindt, and D.B. Chelton, (National Bureau of Standards, Boulder, Colo., Cryogenics Div.), R-394, Advances in Cryogenic Engineering, V 11:207-17, 66, Avail:TAC

Interim results of a program to determine slush hydrogen properties are reported. The program is motivated by the desirability of using hydrogen in this state as a rocket fuel. A simplified production method was devised and data were secured on solid particle size distribution, aging effects, and terminal velocity of the solid particles in the liquid melt. Experimental data were also obtained on atmospheric pressure storage of the slush mixture.
(SLUSH, TRIPLE POINT, PROPERTY)

H73 41006 MELTING CHARACTERISTICS AND BULK THERMOPHYSICAL PROPERTIES OF SOLID HYDROGEN
Contreras, W., and M. Lee, (Grumman Aerospace Corp., Bethpage, N.Y.), Report No. AFRPL-TR-72-48, Jl 72, Avail:TAC

The experimental determination of the melting characteristics of solid hydrogen has been accomplished. This required the measurement of appropriate thermodynamic parameters, thermophysical properties and fluid flow rates required to characterize the melting of solid hydrogen in terms of an overall heat transfer coefficient, operating conditions and initial solid geometry.
(SOLID, PROPERTY, CONDUCTIVITY)

H73 41007* QUALITY DETERMINATION OF LIQUID-SOLID HYDROGEN MIXTURES
Daney, D.E., and D.B. Mann, (National Bureau of Standards, Boulder, Colo., Cryogenics Div.), Cryogenics, V 7:280-5 N5, Oct 67, Avail:TAC

Current interest in liquid-solid mixtures of parahydrogen ('slush hydrogen') as a potential rocket propellant lead to a theoretical and experimental investigation of one method of determining liquid-solid quality. It was found that measurement of the mass fraction pumped off during the freeze-thaw process provides a simple, nondestructive, and accurate method of quality determination.
(SLUSH, QUALITY, PARAHYDROGEN)

H73 41008 SLUSH AND SUBCOOLED PROPELLANTS FOR LUNAR AND INTERPLANETARY MISSIONS
Vaniman, J.L., A.L. Worlund, and T.W. Winstead, (George C. Marshall Space Flight Center, NASA, Huntsville, Ala.), Advances in Cryogenic Engineering, V 14:20-9, 68, Avail:TAC

The heat absorption capability of subcooled and slush H and O can extend the use of present space vehicles to future long duration missions.
(SLUSH, SPACECRAFT)

H73 41009* SLUSH HYDROGEN PUMPING CHARACTERISTICS USING A CENTRIFUGAL-TYPE PUMP (J-2)
Daney, D.E., P.R. Ludtke, and C.F. Sindt, (National Bureau of Standards, Boulder, Colo., Institute for Basic Standards), R-536, Advances in Cryogenic Engineering, V 14:438-44, Aug 68, Avail:TAC

The pumping characteristics of liquid-solid mixtures of

parahydrogen (slush hydrogen) are of considerable interest, since its use as a rocket propellant could require that it be pumped in ground installations and space vehicles. Extrapolation of relationships for pumping water slurries indicates that the pumping characteristics of liquid and slush hydrogen should be the same when the difference in density is considered.
(SLUSH, PUMP)

H73 41010* SLUSH HYDROGEN CHARACTERISTICS
Mann, D.B., C.F. Sindt, P.R. Ludtke, and D.B. Chelton, (National Bureau of Standards, Boulder, Colo., Cryogenics Div.), Report No. R-404, 66, Avail:TAC

The paper reviews the work accomplished to date by the NBS Cryogenics Division, and others, in the area of slush hydrogen production, handling, and characteristics.
(SLUSH, PRODUCTION, HANDLING, TRANSFER)

H73 41011 THE THERMODYNAMIC PROPERTIES OF PARAHYDROGEN FROM 1 TO 22K
Mullins, J.C., W.T. Ziegler, and S. Kirk, (Georgia Institute of Technology, Atlanta, Ga.), Report No. TR-1, Nov 1 '61, Avail:TAC

The thermodynamic properties of parahydrogen have been calculated at one degree intervals from 1 to 22K using existing thermal and equation of state data. The properties calculated include the vapor pressure, heats of vaporization and sublimation, enthalpy, and entropy.
(PROPERTIES, THERMODYNAMICS, PARAHYDROGEN)

H73 41012 THERMAL CONDUCTIVITY OF SOLID AND LIQUID PARAHYDROGEN
Dwyer, R.F., G.A. Cook, O.E. Berwaldt, Journal of Chemical & Engineering Data, V 11:351-3 N3, Jl 66, Avail:TAC

Measurements were made at pressures greater than saturation, and found to be essentially constant within experimental error over range of conditions covered; thermal conductivity of solid was 0.0092 plus or minus 0.0010 w/cm K over temperature range 15 to 17 K at pressures between 88 and 200 atmospheres; thermal conductivity of liquid was estimated from experimental measurements.
(CONDUCTIVITY, SOLID, LIQUID, PARAHYDROGEN)

H73 41013 METALLIC HYDROGEN: SIMULATING JUPITER IN THE LABORATORY
Metz, W.D., Science, V 180:398-9, Apr 27 '73, Avail:TAC

At pressures and temperatures found on the earth hydrogen is a gas and it becomes solid when cooled to temperatures below 14°K. But under extremely high pressures hydrogen may become a metal, and metallic hydrogen is commonly thought to consiitute as much as 40 percent of the mass of the planetary system - particularly in the massive planet Jupiter. Better information would improve the current models of Jupiter and Saturn. More pragmatic visionaries have suggested that metallic hydrogen could be a very useful rocket fuel, because of its expected high density. It is even possible that metallic hydrogen could be a superconductor at room temperature, and several utility companies are said to be closely watching attempts to produce it in the laboratory.
(METAL, PRESSURE, PLANET)

H73 41014 CORRELATION OF THEORY AND EXPERIMENT FOR HIGH-PRESSURE HYDROGEN
Hoover, W.G., M. Ross, C.F. Bender, F.J. Rogers, and R.J. Olness, (California University, Livermore, Calif.), Physics of the Earth and Planetary Interiors, V 6:60-4 N1-3, Dec 72, Avail:TAC

The magnitude of the forces with which hydrogen molecules interact are discussed in the light of recent mutually agreeing quantum calculations and high-pressure experiments. The agreement indicates the usefulness of a pari-potential description of dense hydrogen and suggests that pressures of at least 1.7 Mbar will be required to make metallic hydrogen. The expected lifetime of the metal at atmospheric pressure is very short.
(METAL, PRESSURE)

H73 41015 SOVIET AND US GROUPS SEEK HYDROGEN'S METALLIC PHASE
Lubkin, G.B., Physics Today, V 26:17, Mar 73, Avail:TAC

A group of Russian experimenters has recently reported that they may have produced metallic hydrogen at a pressure of 2.8 megabars, at the transition the density changed from 1.08 to 1.3 g/cm^3. Last year a Livermore group reported on an apparently similar experiment in which they observed

a pressure-volume point centered at 2 megabars and 1 cm^3/g. Some people have predicted that metallic hydrogen might be metastable, and others that it would be a room-temperature superconductor.
(METAL, DENSITY, SUPERCONDUCTOR)

H73 41016 'PRESSURE ON' TO MAKE METALLIC HYDROGEN
Anon, Industrial Research, Je 70

An unpublicized race to create metallic hydrogen apparently is underway between materials scientists at Cornell University, Ithaca, N.Y., and their Russian counterparts. The availability of metallic hydrogen could revolutionize rocketry and make it possible to divise a perfect room-temperature electrical conductor.
(METAL, CONDUCTOR)

H73 41017 PRODUCTION OF METALLIC HYDROGEN
Vereshchagin, L.F., and R.G. Arkhipov, (Joint Publications Research Service, Arlington, Va.), Trans. of Priroda, N3: 9-12, Mar 72, (In Russian), Avail:TAC

The report contains a discussion of predicted properties of metallic hydrogen. Ways of attaining the colossal pressures required to keep hydrogen in the metallic state at room temperature are examined.
(METAL, PRESSURE, PROPERTY)

H73 41018* SOLID HYDROGEN AS A SPACE STORABLE PROPELLANT--A PRELIMINARY STUDY
Hord, J., (Cryogenics Division, National Bureau of Standards, Boulder, Colo.), Unpublished NBS Report 10740, Mar 31 '72

The significant advantages of subcooled liquid, slush, and solid hydrogen, as space storable propellants, are made evident. Maximum storage duration of hydrogen propellant is obtained by using solid hydrogen and the maximum allowable tank vent pressure. Maximum "no-loss" storage duration is also obtained by using solid hydrogen. A comparison of storage durability of subcooled liquid, slush, and solid hydrogen is given.
(SLUSH, SOLID, STORAGE, SPACECRAFT)

H73 42000 HOW TO DESIGN PIPING SYSTEMS FOR HYDROGEN SERVICE
Cherrington, D.C., and A.R. Cuiffreda, (Esso Research & Engineering Co., Florham Park, N.J.), Oil & Gas Journal, V 65:102-6, 109 N21, 67, Avail:TAC

At ambient temperatures H_2 does not permeate steel readily except at extremely high pressures. At high temperatures and high pressures, H from dissociated H_2 can enter the steel and cause permanent damage either by physical action of H penetration into the crystal lattice and subsurface voids, or by chemical reaction with C and other elements.

(GAS, PIPE, DESIGN, SYSTEM)

H73 42001 HYDROGEN GAS PRESSURE VESSEL PROBLEMS IN THE M-1 FACILITIES
Laws, J.S., V. Frick, and J. McConnell, (Aerojet-General Corp., Sacramento, Calif.), NASA-CR-1305, Jl 68, Avail:TAC

This report delineates pertinent data and information related to a series of failures, or structural defects, experienced with high pressure, gaseous hydrogen storage receivers procured for, installed, and used as part of the M-1 Engine Development Program.

(GAS, PRESSURE, VESSEL, STORAGE, FAILURE)

H73 42002 HYDROGEN DISTRIBUTION TO PROCESS LABORATORIES
Hammersmith, J.W., and A.W. Larson, Chemical Engineering Progress, V 62:54, Dec 66, Avail:TAC

The American Oil Company's research staff has developed a system for supplying hydrogen to its process laboratories. The design facilitates safe handling of the increasing amounts of hydrogen demanded by petroleum and petrochemical process work. Pilot plants within the laboratories are supplied through individual distribution subsystems.

(GAS, DISTRIBUTION, PETROCHEMICAL)

H73 42003* TRANSPORTATION AND STORAGE OF HYDROGEN FOR ECO-ENERGY
Reynolds, R.A., and W.L. Slager, (TEMPO - General Electric Co., Santa Barbara, Calif.), Report No. GE-72-TMP-54, Dec 72, Avail:TAC

Primary emphasis is placed on comparison between the cost of pipeline transportation of natural gas and gaseous

hydrogen. These analyses indicated about a 40 percent higher cost for hydrogen under comparable conditions, but no significant operational problems were identified. Analysis of the costs of liquefaction and storage demonstrate that the low-energy density of hydrogen fuels is indeed a problem, but that several alternatives may offer reasonable solutions.
(PIPE, COST, TRANSPORT, STORAGE)

H73 42004* STANDARD FOR GASEOUS HYDROGEN SYSTEMS AT CONSUMER SITES
Anon, (Compressed Gas Association, Inc., New York, N.Y.), Pamphlet G-5.1, 70, Avail:TAC

This Standard covers the general principles recommended for the installation of gaseous hydrogen systems on consumer premises.
(GAS, STANDARD, CONSUMER, SAFETY)

H73 43000* METAL HYDRIDES AS A SOURCE OF HYDROGEN FUEL
Reilly, J.J., R.H. Wiswall, Jr., and K.C. Hoffman, (Brookhaven National Lab., Upton, N.Y.), Report No. BNL-14804, Division of Fuel Chemistry, American Chemical Society, Chicago, Ill., Sept 70, Avail:TAC

The use of hydrogen as a non-polluting fuel is desirable but the difficulties involved in using the cryogenic or compressed form are formidable. However, it appears that certain reversible metal hydrides can be used as a convenient, cheap and safe source of hydrogen fuel. The heat of dissociation can be supplied by the waste heat of the energy converter or, in certain cases, from the surrounding environment. When the hydride is exhausted it may be regenerated by supplying hydrogen at a pressure above its dissociation pressure. Metal hydrides of particular interest are VH_2, Mg_2NiH_4 and MgH_2. Vanadium dihydride contains approximately 2 wt % available hydrogen and at 25°C has a dissociation pressure ranging from 2 to 5 atmosphere, depending on its purity. Magnesium nickel hydride and magnesium hydride contain 3.6 wt % and more than 7 wt % hydrogen but both require higher decomposition temperatures. For Mg_2NiH_4 the dissociation pressure at 275°C is 1.9 atmosphere and for MgH_2 the dissociation pressure at 300°C is 1.8 atmosphere. These systems appear to be ideal for use as a hydrogen source for fuel cell power systems. They could also be used to supply hydrogen to modified internal combustion engines, gas turbines, etc.
(DISSOCIATION, DECOMPOSITION, PRESSURE, TEMPERATURE, ENERGY)

H73 43001 THE HIGHER HYDRIDES OF VANADIUM AND NIOBIUM
Reilly, J.J., and R.H. Wiswall, Jr., (Brookhaven National Lab., Upton, N.Y.), Inorganic Chemistry, V 9, 1678, 70, Avail:TAC

Vanadium dihydride and niobium dihydride were prepared by the direct reaction of hydrogen with the metal. Attempts to prepare tantalum dihydride were unsuccessful. Pressure-composition isotherms were determined for the systems $VH_{\sim0.9}$-$VH_{2.0}$ and $Nb_{\sim0.9}$-$NbH_{2.0}$. Pertinent thermodynamic data were calculated for each system. The phase diagrams for the vanadium-hydrogen system and the niobium-hydrogen system were extended to a composition corresponding to MH_2.
(HYDRIDE, REACTION, METAL, PRESSURE, VANADIUM, NIOBIUM)

H73 43002 A NEW LABORATORY GAS CIRCULATION PUMP FOR INTERMEDIATE PRESSURES
Reilly, J.J., A. Holtz, and R.H. Wiswall, Jr., (Brookhaven National Lab., Upton, N.Y.), The Review of Scientific Instruments, V 42 N10, Oct 71

A laboratory gas circulation pump has been built in which the pump driving force is obtained by the alternate decomposition and regeneration of vanadium dihydride (VH_2). This cyclic action is accomplished by alternately heating and cooling the hydride system using hot (50°C) and cold (18°C) water. The particular pump described is suitable for the circulation of gases in systems where the pressure range is between 7 and 24 atmospheres.
(GAS, PUMP, DECOMPOSITION, HYDRIDE)

H73 43003 THE REACTION OF HYDROGEN WITH ALLOYS OF MAGNESIUM AND NICKEL AND THE FORMATION OF MG_2NIH_4
Reilly, J.J., and R.H. Wiswall, Jr., (Brookhaven National Lab., Upton, N.Y., Inorganic Chemistry, V 7:2254m 68, Avail:TAC

In the Mg-Ni system two intermetallic compounds are formed: Mg_2Ni and $MgNi_2$. $MgNi_2$ did not react with H_2 at pressures up to 400 psia and temperatures to 350°; however, Mg_2Ni reacted readily with H_2 at 300 psia and 325°. The product of the reaction was a new ternary hydride with the formula Mg_2NiH_4. The reaction was reversible and upon decomposition the original starting material was regenerated. The X-ray diffraction pattern of the product was indexed. Several presuure-composition isotherms were obtained. The dissociation pressure of the hydride was found to obey the relationship $\log P_{sun} = (-3360/T) + 6.389$ from which thermodynamic data were calculated. In the presence of excess Mg the pressure-composition isotherm exhibited two plateaus; the lower plateau is attributed to the formation of MgH_2 as evidenced by X-ray diffraction data and thermodynamic considerations. The presence of Mg_2Ni appeared to have a catalytic effect on the formation of MgH_2.
(PRESSURE, TEMPERATURE, HYDRIDE, DISSOCIATION, THERMODYNAMIC)

H73 43004 THE REACTION OF HYDROGEN WITH ALLOYS OF MAGNESIUM AND COPPER
Reilly, J.J., and R.H. Wiswall, (Brookhaven National Lab., Upton, N.Y.), Inorganic Chemistry, V 6:2220, 67, Avail:TAC

The intermetallic compound Mg_2Cu reacts with H_2 at approximately 300° to form MgH_2 and $MgCu_2$. Excess Mg in

the alloy also reacts to form MgH_2. In the latter case a pressure-composition isotherm exhibits two plateaus. The equilibrium dissociation pressure of H_2 was measured as a function of temperature for both systems from which thermodynamic functions for the reactions concerned were calculated.
(EQUILIBRIUM, DISSOCIATION, PRESSURE, THERMODYNAMIC, TEMPERATURE)

H73 43005 THE EFFECT OF MINOR CONSTITUENTS ON THE PROPERTIES OF VANADIUM AND NIOBIUM HYDRIDES
Reilly, J.J., and R.H. Wiswall, Jr., (Brookhaven National Lab., Upton, N.Y.), International Meeting on Hydrogen in Metals, Julich, Germany, Mar 72, Report No. BNL-16546

The stability of vanadium dihydride was found to be remarkably sensitive to small amounts of impurities. For example, at 40°C the dissociation pressure of $VH_{\sim 2}$ made from zone-refined, vanadium is 4.0 atm while $VH_{\sim 2}$ made from zone-refined, high-purity, vanadium containing 1.66 atomic percent Si is 18.0 atm. Other metal contaminants, normally found in commercial-grade vanadium have similar effects. Results are given which permit the comparison of the potency of various metal additives after correcting for the effect of an arc melting step, which alone has a slight effect on the subsequent dissociation pressure of $VH_{\sim 2}$. In some cases the effect of varying the concentration of a single additive by tenfold or more was studied. It was also found that, upon substitution of deuterium for hydrogen, the resulting $VD_{\sim 2}$ was very much more stable than $VH_{\sim 2}$.
(HYDRIDE, VANADIUM, NIOBIUM, DISSOCIATION, PRESSURE, IMPURITY)

H73 43006 PURE AND SIMPLE: STORING HYDROGEN IN HYDRIDES
Anon, Scientific American, V 227:46, Aug 72

Workers at the Phillips Research Laboratories in the Netherlands may have found another way: they have successfully synthesized intermetallic compounds in which the hydrogen is held in the form of hydrides. The hydrogen can be released and reabsorbed at room temperature and at pressures of a few atmospheres.
(HYDRIDE, INTERMETALLIC)

H73 43007* METAL HYDRIDES FOR ENERGY STORAGE
Wiswall, R.H., Jr., and J.J. Reilly, (Brookhaven National Lab., Upton, N.Y.), Report No. BNL-16889, 7th Intersociety Energy Conversion Engineering Conference, San Diego, Calif., Sept 25 '72

The use of metal hydrides as hydrogen reservoirs facil-

itates the storage and subdivision of central-station power for automotive and other purposes. Hydrides with a wide range of properties have been synthesized and studied, and several appear to have promise for specific storage applications. Results are reported on the effect of alloy constituents on hydride stability; on the formation of hydrides by metals reacting with gas mixtures such as those produced by the steam reforming of hydrocarbons; and on the feasibility of integrated systems of hydride reservoir plus engine or fuel cell.
(HYDRIDE, ENERGY, STORAGE, STABILITY)

H73 43008* METAL HYDRIDE ENERGY STORAGE SYSTEMS
Hoffman, K.C., (Brookhaven National Lab., Upton, N.Y.), J.J. Reilly, R.H. Wiswall, T.V. Sheehan, and W.E. Winsche, Intersociety Energy Conversion Engineering Conference, Boulder, Colo., 68, V1:981-5

It has been founded that Mg-Ni and Mg-Cu alloys will react reversibly with hydrogen to form metal hydrides. These metal hydrides provide the basis of a hydrogen storage technique with many advantages over both liquid and compressed gas hydrogen storage. The possibility of applying this storage concept to a variety of energy conversion systems has been studied and several attractive applications have evolved. Of special interest is a fuel cell power system utilizing a metal hydride as its fuel source.
(HYDRIDE, METAL, ENERGY, STORAGE, FUEL)

H73 43009 REVERSIBLE ROOM TEMPERATURE ABSORPTION OF LARGE QUANTITIES OF HYDROGEN BY INTERMETALLIC COMPOUNDS
Vanvucht, J.H., Philips Research Reports-25, p 133-40, 70

Some hexagonal intermetallic compounds of the composition AB_5, where A represents a rare-earth metal and B nickel or cobalt, are reported to absorb and desorb easily large quantities of hydrogen gas under relatively small pressures at room temperature. For some selected compounds, viz., $LaNi_5$ and $SmCo_5$, absorption isotherms and X-ray data are given. The compound $LaNi_5$ forms the hydride $LaNi_5H_{6.7}$ at room temperature under 2·5 atmosphere of hydrogen pressure. Its unit cell expands 25 vol.% and seems to retain its hexagonal symmetry. $SmCo_5$ forms the hydride $SmCo_5H_3$ at room temperature under 4·5 atmosphere of hydrogen pressure, while its unit cell expands 10 vol.% and becomes orthorhombic. For both hydrides the heat of reaction is found to be about 7 kcal/mol H_2.
(HYDRIDE, TEMPERATURE, ABSORPTION, INTERMETALLIC)

H73 43010* IRON TITANIUM HYDRIDE: ITS FORMATION, PROPERTIES, AND APPLICATION
Reilly, J.J., and R.H. Wiswall, Jr., (Brookhaven National Lab., Upton, N.Y.), Division of Fuel Chemistry, American Chemical Society, Chicago, Ill., Aug 73, Avail:TAC

The intermetallic compound FeTi reacts with hydrogen to form, in succession, hydrides of the approximate composition FeTiH and $FeTiH_2$. The composition limits have been determined and are diagrammed. Both hydrides have dissociation pressures of over one atmosphere at 0^oC, unlike the very stable TiH_2. The relative partial molar enthalpies of hydrogen have the rather low values of -3.36 Kcal/gm atoms of hydrogen in the lower hydride and -3.70 to -4.03 in the higher; the properties of the latter vary with the hydrogen content. Pronounced hysteresis effects are observed, the absorption isotherms of pressure vs. composition frequently being several atmospheres higher, at a given composition, than the desorption isotherms. The lower hydride, FeTiH, has tetragonal symmetry and a density of 5.88. The hydriding behavior is quite sensitive to the composition of the Fe-Ti phase. If Ti is in slight excess over the equiatomic proportion, the hydrogen sorption isotherm no longer shows the plateaus and inflections characteristic of the appearance of new phases. The properties of iron-titanium hydride make it useful for hydrogen storage. A working hydride reservoir has actually been made and used as the source of fuel for a hydrogen-burning Wankel engine.
(IRON, TITANIUM, HYDRIDE, STORAGE, ENGINE)

H73 43011* METAL HYDRIDES AS A SOURCE OF FUEL FOR VEHICULAR PROPULSION
Hoffman, K.C., W.E. Winsche, R.H. Wiswall, J.J. Reilly, T.V. Sheehan, and C.H. Waide, (Brookhaven National Lab., Upton, N.Y.), SAE-International Automotive Engineering Congress, Ja 13 '69, Paper 690232

Studies of the equilibrium relationships and kinetics of the reversible reaction of hydrogen with magnesium-nickel and magnesium-copper alloys indicate that such systems have properties that may form the basis of a convenient and inexpensive method of storing hydrogen. This unique hydrogen storage technique offers the possibility of utilizing this clean and potentially economical fuel for motor vehicle propulsion. A vehicle propelled by a hydrogen-fueled internal-combustion engine would produce an exhaust that is inherently free of the hydrocarbon, carbon monoxide, and

carbon dioxide pollutants that are major contributors to the atmospheric pollution problem in urban areas. The characteristics of this vehicular propulsion concept have been estimated and indicate that the hydrogen engine is potentially superior in performance to other inherently hydrocarbon-free propulsion concepts such as battery and fuel cell powered electric drives.
(HYDRIDE, METAL, FUEL, ENGINE, STORAGE)

H73 43012 MAGNETS THAT ATTRACT HYDROGEN
Zijlstra, H., Chemical Technology, V 2:280-4 N5, May 72

Properties of rare-earth elements and compounds are useful in a number of roles: as petrochemical catalysts, grain refiners in steel, getters in vacuum tubes, fluorescent powders, etc. Now there are two newer properties that might acquire economic importance in the near future.

We are considering here a family of compounds of lanthanides, R, and 3d-transition metals, T, of composition RT_5. Some of these compounds are ferro-magnetic and show high magnetocrystalline anisotropy. This makes them potentially suitable for the manufacture of permanent magnets. But they also have a remarkable affinity for hydrogen.
(LANTHANIDE, AFFINITY, MAGNET, RARE EARTH)

V. SAFETY

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H73 50000* LIQUEFIED HYDROGEN SAFETY
Edeskuty, F.J., and R. Reider, (Los Alamos Scientific Lab., Los Alamos, N.M.), U.S. Atomic Energy Commission, LA-DC-9569, 68, Avail:TAC

The accident experience and accident potential in the use of liquefied H is examined with respect to cold damage to tissue, asphyxiation, H/air (O) mixtures, material properties, air and moisture condensation and pressure buildup. The control of liquefied H safety problems is reviewed in: facility design which includes site selection, materials of construction, disposal, pressure relief (storage, insulation space, and explt. volumes) and control of spills; safe procedures which include standard operating procedures, safety training and education, emergency procedures, control of ignition sources; and operating principles such as H monitoring, storage above atmospheric pressure, purging (before and after operations), inerting, leak control, chilldown procedures, venting procedures.
(LIQUID, SAFETY, CONTROL, DAMAGE)

H73 50001 LIQUEFIED HYDROGEN SAFETY. REVIEW
Anon, American Society of Safety Engineers Journal, V 14: 18-23 N5, May 69

Accident problems from use of liquefied hydrogen are discussed with respect to tissue damage, asphyxiation, fires and explosions, material properties and pressure buildup; advice on safety controls is provided in facility and equipment design, and safe procedures including those for emergencies and training and operating principles.
(SAFETY, LIQUID, FIRE, ASPHYXIATION)

H73 50002 SAFETY REQUIREMENTS FOR HIGH-TEMPERATURE DESIGN
Gernhardt, P., N69-37674, DEW Technology Report, V 9:353 N2, 69, (In German), Avail:TAC

In tube furnaces used in hydrogen production plant tubing is subjected to extremely high stresses. As it is difficult to obtain creep rupture values for a service life of 10,000 hours, design for a 50,000 hour life is more appropriate in such plant, the design safety factor is a time variable, so that it is recommended to use initial safety factors in a way that after the planned lifetime the safety factors become unity. Up to that moment, creep

ruptures are unlikely to occur. Afterwards, creep rupture occurrences are ascribed to actual stress increases due to interfacial effects.
(SAFETY, FURNACE, TEMPERATURE, DESIGN)

H73 50003 DESIGN OF FAIL-SAFE CONTROL SYSTEMS FOR STEAM REFORMING PLANTS
Axelrod, L.C., and J.A. Finneran, (M.W. Kellogg Co., New York, N.Y.), Safety Air Ammonia Plants, V 7:1-6, 65

The major safety considerations inherent in the design and operation of current steam-CH_4 reforming plants for the production of NH_3-synthesis gas are cited as safety of design in reformer tubes, transfer line, compressed air systems, and the secondary reformer.
(STEAM, REFORMING, CONTROL, SAFETY)

H73 50004 THE INTENSITY OF THE NARCOTIC ACTION OF HYDROGEN AT HIGH PRESSURE
Lazarev, N.V., Farmakol. i Toksikol., V 6:29-32, 43, (In Russian), Avail:TAC

The biological narcotic action of hydrogen under pressure was tested in a preliminary experiment on a white mouse in a pressure chamber containing a mixture of 95 percent nitrogen and 5 percent oxygen; a hydrogen feed up to 55 atmospheric pressure of the nitrogen-hydrogen mixture did not produce narcosis.
(PRESSURE, SAFETY, NARCOTIC)

H73 50005 A PRACTICAL SAFETY STANDARD FOR COMMERCIAL HANDLING OF LIQUEFIED HYDROGEN
Connolly, W.W., (Air Reduction Co., Inc., New York, N.Y.), Advances in Cryogenic Engineering, V 12:192-7, 67

The title subject is discussed. Safety factors include non-confinement, welded piping, proper ventilation, flame propagation control, and insulation.
(SAFETY, STANDARD, COMMERCIAL, LIQUID, HANDLING)

H73 50006* HANDLING HAZARDOUS MATERIALS
Cloyd, D.R., (Clyde Williams & Co., Columbus, O.), and W.J. Murphy, (Research Institute of Temple University, Philadelphia, Pa.), NASA-SP-5032, Washington, D.C., Sept 65, Avail:TAC

This publication deals with highly reactive materials that have been studied in the search for fuels and oxidizers

for space work: Liquid hydrogen, pentaborane, fluorine, chlorine trifluoride, ozone, nitrogen tetroxide, and hydrazine and its derivatives. It describes both the hazards that have restricted the use of these materials and the procedures by which they have been handled and stored safely. References are given to work done by NASA and other investigators.
(SPACECRAFT, FUEL, LIQUID, HANDLING, SAFETY)

H73 50007 HYDROGEN VENT FLARE STACK PERFORMANCE
Lapin. A., (Air Products and Chemicals, Inc., Allentown, Pa.), Advances in Cryogenic Engineering, V 12, 67, Avail:TAC

This paper describes the tests that were performed to establish practical limits for a hydrogen vent flare stack operating under adverse weather conditions. The basic components of the vent stack are a flare, molecular seal, flame front generator ignition system, pilots, support skirt, associated piping, valves, and gauges; all assembled and mounted on a concrete pad.
(FLARE, VENT, SAFETY)

H73 50008 PILOT CURRICULUM AND INSTRUCTORS GUIDE EMPHASIZING SAFETY IN COMPRESSED GASES AND CRYOGENIC LIQUIDS
Logan, E.M., and W.T. Kitts, (NASA, Manned Spacecraft Center, Houston, Tex.), N69-27573, NASA-TM-X-61563, Aug 25 '67, Avail:TAC

Emphasis in this guide is on the various safety aspects in the handling of industrial compressed gases and cryogenic liquids at the Manned Spacecraft Center, Houston. Specifically, the guide covers: (1) the atmosphere and the role of quality control in compressed gases; (2) handling and related aspects of compressed gases; (3) an introduction to cryogenics and liquid oxygen; (4) related aspects on liquid nitrogen, liquid hydrogen, and liquid helium.
(SAFETY, CRYOGENIC, COMPRESSED, GAS, LIQUID)

H73 50009 SAFETY IN THE USE OF LIQUEFIED GASES AT VERY LOW TEMPERATURES. PARTICULAR CASE OF LIQUID HYDROGEN.
Thurel, G., Chim. Ind., Genie Chim., V 102:17-25 N1, 69, (In French)

The physiological and physical risks involved in the use of liquefied H and the U.S. safety regulations applicable are reviewed in relation to the properties of H and in com-

parison with those of hydrocarbons. Recommendations are derived for avoidance of condensation of liquid O in liquid H, of formation of flammable concentrations of H in the atmosphere, and for minimizing the effects of any combustion which occurs.
(LIQUID, SAFETY, FIRE)

H73 50010* STORAGE AND HANDLING OF CRYOGENS
Edeskuty, F.J., and K.D. Williamson, Jr., (Los Alamos Scientific Lab., Los Alamos, N.M.), Advances in Cryogenic Engineering, V 17:56-68, Plenum Press, New York, 72, Avail:TAC

Review of the safety requirements and implementation techniques of cryogen storage and transfer operations. The more demanding requirements of the lower boiling temperature and smaller latent heat of vaporization of liquid hydrogen and liquid helium are shown to have led during the last two decades to a more sophisticated technology and to better handling procedures applicable to all cryogens. Safe operation with any cryogen calls for adequate instrumentation and a thorough knowledge of that cryogen and of the system using it.
(SAFETY, STORAGE, TRANSFER, INSTRUMENTATION)

H73 50011* SAFETY IN THE USE OF LIQUID HYDROGEN
Chelton, D.B., (National Bureau of Standards, Cryogenic Engineering Lab., Boulder, Colo.), Technology and Uses of Liquid Hydrogen, edited by R.B. Scott, W.H. Denton, and C.M. Nicholls, Macmillan Co., New York; Pergamon Press, Ltd., Oxford, 64, p 359-78, Avail:TAC

Determination of criteria for safe handling of liquid hydrogen. The physical and chemical properties of hydrogen are reviewed briefly, and considerations entering into the choice of the structural materials used in equipment for handling liquid hydrogen are outlined. Several potentially hazardous conditions existing in connection with large-scale liquid-hydrogen systems are discussed. Certain additional hazards arising in laboratory usage of liquid hydrogen are considered.
(SAFETY, LIQUID, LABORATORY)

H73 50012 HYDROGEN PLANT SHUTDOWNS REDUCED
Ciuffreda, A.R., (Esso Research and Engineering Co., Florham Park, N.J.), B.N. Greene, Hydrocarbon Process, V 51:113-17 N5, May 72, Avail:TAC

This is a report of the American Petroleum Institute Committee which contains survey of 34 steam-reformer hydrogen plants throughout the world. Results show shutdown causing failurer reduced but persistent problem remain. These problems include - premature stress-rupture failures of HK-40 alloy-steel reformer-furnace tubes caused by localized over-heating; failure of pigtails, headers and transfer lines because of excessive creep, design and fabrication factors, or internal insulation failures; and corrosion failures of carbon and alloy steels in the carbon-dioxide removal facilities. (STEAM, REFORMING, DESIGN, CORROSION)

H73 50013* SAFETY PROBLEMS AND SAFETY CODES CONCERNING LIQUID HYDROGEN AND LIQUID HELIUM
Edeskuty, F.J., (Los Alamos Scientific Lab., Los Alamos, N.M.), LA-DC-8463, 67, Avail:TAC

Safety problems which occur in the storage and handling of liquid H and liquid He include material selection, contamination, pressure relief, and stress anal. Proper material selection, requires optimization of a number of factors, only one of which is the metal ductility at the use temperature. Careful control must be exercised over contaminants since they can accumulate over a period of time which could result in line plugging or the formation of explosive or detonable mixtures.
(SAFETY, STORAGE, PRESSURE, TEMPERATURE, CONTAMINANT)

H73 50014* HYDROGEN SAFETY MANUAL
Anon, (NASA, Lewis Research Center, Cleveland, O.), N68-25704, NASA-TM-X-52454, Washington, 68, Avail:TAC

A manual containing safety guidelines and standards for personnel handling and using hydrogen is presented. Prescribed precautions have general applicability as acceptable standards for meeting minimum safety requirements, and are designed to ensure that the life and health of personnel are not jeopardized and that the risk of damage to property is minimized. The nature of hazards of gaseous and liquid hydrogen, hydrogen-air mixtures, and hazards induced by diffusion and leakage of hydrogen are discussed. Design

principles for test facilities, equipment, storage facilities, and related hardware are described. Included are discussions of procedures for eliminating ignition sources; protection of personnel and equipment; storage and test locations and blast effects; operating procedures; and emergency procedures.
(SAFETY, MANUAL, LEAKAGE, DESIGN)

H73 50015 CONSIDERATIONS WHEN DESIGNING, ASSEMBLING, AND OPERATING A GASEOUS HYDROGEN PRESSURE SYSTEM
Northrup, C.J.M., Jr., R.P. Wemple, and L.P. Baudoin, (Sandia Labs., Albuquerque, N.M.), N73-21257, SC-DR-72-0593, Nov 72, Avail:TAC

Much of the information required to design, assemble, and operate a gaseous hydrogen system safely is scattered throughout the literature in a number of diverse reports and articles. This report draws on many of these technical papers and the authors' experiences to present some of the more common problems and solutions encountered when dealing with gaseous hydrogen.
(GAS, SYSTEM, DESIGN, REVIEW)

H73 50016 PROJECT ROVER LIQUID HYDROGEN SAFETY: FIVE YEAR LOOK
Ehrenkranz, T.E., (Los Alamos Scientific Lab., Los Alamos, N.M.) LA-DC-7689, 65, Avail:TAC

Large scale use of liquid H has been associated with Project Rover at Jackass Flats, Nevada, since 1959. Main components of the liquid H system are described.
(LIQUID, SYSTEM, SAFETY)

H73 50017 SAFETY OF HYDROGEN PRESSURE GAUGES
Voth, R.O., (National Bureau of Standards, Washington, D.C.) Advances in Cryogenic Engineering, V 17:182-7, 72, Avail:TAC

To determine the relative safety of various gauge case designs, thirty-five pressure gauges were purchased and intentionally ruptured using high pressure hydrogen gas. Fire was emitted from nearly all gauges; however, gauges with solid fronts and plastic crystals emitted the fire and debris out the rear of the case making them safer for use in a hydrogen system.
(SAFETY, PRESSURE, RUPTURE, FIRE)

H73 51000 EFFECT OF WATER VAPOR ON H_2-O_2 DETONATIONS
Kerkam, B.F., and E.K. Dabora, (Michigan University, Ann Arbor, Mich.), AIAA Journal, V 4:1101-2, Ja 18 '66, Avail:TAC

The note describes the effects of water vapor addition on the reaction length in detonations of two mixtures of H_2-O_2 and on the quenching conditions of such detonations. It was found that water addition to H_2-O_2 mixtures shortens their reaction lengths, and its effects on the quenching limit can be accounted for by Belles' explosion limit criterion.
(DETONATION, QUENCHING, REACTION)

H73 51001 UPPER LIMIT OF FLAMMABILITY OF HYDROGEN IN AIR, OXYGEN, AND OXYGEN-INERT MIXTURES AT ELEVATED PRESSURES
Holmstedt, G.S., (Lund Institute of Technology, Sweden), Combustion & Flame, V 17:295-301 N3, Dec 71

The upper limit of flammability of hydrogen in air, oxygen, oxygen-helium, oxygen-neon, oxygen-argon, and oxygen-carbon dioxide mixtures was measured at room temperature and pressures between 0.97 and 29 atmospheres. The maximum safe percentage of oxygen in a hydrogen-oxygen-helium mixture was calculated for pressures between 0.97 and 29 atmospheres.
(FLAMMABILITY, LIMIT, AIR, OXYGEN, PRESSURE)

H73 51002 STORAGE AND HANDLING OF HYDROGEN WITH SAFETY
Stoll, A.P., Chemical Engineering, N185:CE11-16, Ja-Fe 65

Safety precautions during handling of hydrogen, liquid or gaseous, indicate that formation of explosive mixtures of hydrogen with air both inside and outside equipment should be prevented; storage and handling of liquid hydrogen at -253 C and its handling in laboratory.
(SAFETY, STORAGE, HANDLING, LIQUID, GAS, EXPLOSION)

H73 51003 THE DANGER OF EXPLOSION OF MIXTURES OF FLAMMABLE VAPORS AND GASES WITH AIR. XI. THEORY OF EXPLOSIVE COMBUSTION AND METHODS OF COMPUTATION OF TECHNICAL EXPLOSIVITY PARAMETERS
Pilc, A., (Institute Chem. Igolnej, Warsaw, Poland), Przemysl Chem., V 45:544-6 N10, 66, (In Polish)

A simple equation for calculating the theoretical and real lower explosion limits regarding the diffusion coefficient of the flammable component is derived. The real limit concentrations of upward propagation of flame for

CH_4, H, C_2H_2, and CS_2, are in satisfactory agreement with those obtained exptl.
(EXPLOSION, LIMIT, CALCULATION, DIFFUSION)

H73 51004 THE DEPENDENCE OF THE LOWER LIMIT OF HYDROGEN EXPLOSIVITY ON THE INITIAL TEMPERATURE OF THE HYDROGEN MIXTURE WITH AIR
Pilc, A., J. Strzelecki, (Institute Chem. Igolnej, Warsaw, Poland), Przem. Chem., V 47:151-4 N3, 68, (In Polish)

The lower limit of H explosivity was determined at the downward propagation of the flame at various initial temperatures. The higher the initial temperature of the mixture, the lower the flame temperature.
(EXPLOSION, LIMIT, TEMPERATURE)

H73 51005 HYDROGEN FLARE STACK DIFFUSION FLAMES: LOW AND HIGH FLOW INSTABILITIES, BURNING RATES, DILUTION LIMITS, TEMPERATURES, AND WIND EFFECTS
Grumer, J., A. Strasser, J.M. Singer, P.M. Gussey, and V.R. Rowe, (Bureau of Mines, Pittsburgh, Pa., Safety Research Center), N71-12103, NASA-CR-111419, Dec 70, Avail:TAC

A laboratory-scale hydrogen safety study was conducted which determined several combustion characteristics of hydrogen diffusion flames. Experiments show that ambient air may enter the top of a hydrogen flare stack when the hydrogen flow is low. A new concept, supported by photographic evidence, predicts that diffusion flames burning in air on a wide, upright pipe (stack) and fed with slow, upward flows of buoyant gas will induce a downward flow of air along the walls of the pipe that can support combustion within the pipe.
(FLARE, FLOW, INSTABILITY, SAFETY)

H73 51006 THE OXIDATION OF HYDROGEN
Richtering, H., (Gottingen University, West Germany), Low Temperature Oxidation, edited by W. Jost, Gordon and Breach, Science Publishers, Inc., New York, 65, p 37-82, Avail:TAC

Study of the reactions of mixtures of hydrogen and oxygen under various conditions. These mixtures react explosively at temperatures above 500 to 600°C. Investigators have found that a slow reaction occurs below these temperatures, and that explosion levels are dependent on several parameters

such as temperature, pressure, composition, and additives. The low pressure reaction is discussed, and the great importance of the walls is shown.
(EXPLOSION, TEMPERATURE, PRESSURE, REACTION)

H73 51007 HAZARDS DUE TO HYDROGEN ABOARD A SPACE VEHICLE
Caras, G.J., (Redstone Arsenal, Ala.), Report No. 291, Sept 64, Avail:TAC

This bibliography consists of twenty-three annotated references on the subject of hazards to space vehicles as a result of hydrogen leaks.
(SPACECRAFT, HAZARD, LEAK, DETECTION)

H73 51008 FLASH AND FIRE TEST: EVALUATION OF THE BEHAVIOR OF NONMETALLIC MATERIALS IN HYDROGEN
Anon, (MSC White Sands Test Facility, N.M.), N72-30496, NASA-TM-X-68739, Mar 30 '72, Avail:TAC

Tests conducted to evaluate the behavior of nonmetallic materials in hydrogen are described. The results of the flash and fire test are presented. The flash and fire test is used to evaluate the tendency of heated materials to ignite in a hydrogen atmosphere when subjected to an ignition source.
(FLASH, FIRE, IGNITION, NONMETALLIC)

H73 51009* HYDROGEN LEAK AND FIRE DETECTION: A SURVEY
Rosen, B., V.H. Dayan, and R.L. Proffit, (Technology Utilization Division, NASA, Washington, D.C.), NASA-SP-5092, 70, Avail:TAC

The effort described in this report was performed during the period March 1, 1963 to August 31, 1968. This report on the detection of hydrogen fires and leaks contains a critical review of the applicable literature, a discussion of the experiences and needs of typical producers and users of hydrogen, an evaluation of the present state-of-the-art of detecting hydrogen fires and leaks, and recommendations for further development of equipment and basic research.
(SAFETY, LEAK, FIRE, DETECTION, REVIEW)

H73 51010 PREVENTION, DETECTION, AND SUPPRESSION OF HYDROGEN EXPLOSIONS IN AEROSPACE VEHICLES
Caras, G.J., (Army Missile Command, Huntsville, Ala.), N66-37281, NASA-CR-78268, Mar 31 '66, Avail:TAC

This report reviews and summarizes the hazards to aero-

space vehicles caused by hydrogen. Topics such as flammability limits of hydrogen in hydrogen-oxygen and hydrogen-air mixtures, methods of detecting hazardous conditions, and means of inhibiting fires and explosions are discussed.
(EXPLOSION, SPACECRAFT, DETECTION, SUPPRESSION)

H73 51011 HYDROGEN HANDLING SUIT PROTECTS NASA TECHNICIANS
Anon, Safety Maintenance, V 136:23-4 N4, Oct 68

Hydrogen handlers suit described is made of glass, wool, and with special lining designed to protect wearer against extremely high temperatures for approximately two and one-half minutes; suit features built-in airconditioning unit utilizing liquid air and providing positive pressure inside suit to prevent gaseous hydrogen from entering suit.
(SAFETY, FIRE, PROTECTION)

H73 51012 H_2-O_2- NO_x FLAMMABILITY AND EXPLOSIBILITY: A LITERATURE SURVEY
Johnson, J.E., Jr., (Allied Chemical Corp., Idaho Falls, Idaho), Report No. ICP-1002, Oct 71

Results of a literature survey are presented concerning hydrogen flammability and explosibility. Combustion and explosion limits are given and effects of nitrogen oxides and other substances on these limits are discussed. Reaction mechanisms are included to help explain these effects. It was concluded that although nitrogen oxides do sensitize near-stoichiometric H_2-O_2 mixtures toward thermal ignition, they do not increase the flammability of hydrogen near its composition limits for combustion.
(FLAMMABILITY, EXPLOSION, SURVEY, IGNITION, REACTION)

H73 51013 HIGH-ALTITUDE EXPLOSION PROPERTIES OF THE HYDROGEN-OXYGEN SYSTEM IN VENTED TANKS
Kaye, S., R.T. Murray, (General Dynamics/Convair, San Diego, Calif.), Advances in Cryogenic Engineering, V 13:545-54, 67, Avail:TAC

The explosion or detonation hazard arising in the interstage of a Saturn rocket from the presence of liquid and (or) solid H or O was evaluated. Fires generally result when the vent is large, although a few explosions also occur; however, fires and explosions always occurred when the vent was small.
(EXPLOSION, TANK, VENT)

H73 51014* EXPLOSION CRITERIA FOR LIQUID HYDROGEN TEST FACILITIES

Hord, J., (Cryogenics Division, National Bureau of Standards, Boulder, Colo.), Unpublished NBS Report 10734, Fe 72

Current practices for assessing personnel safety hazards at open-air and enclosed liquid hydrogen test facilities are reviewed. A maximum credible accident for an open-air test facility is specified, and available H - air explosion data are reviewed with due consideration to these specifications. A method of assessing fireball and overpressure hazards at open-air test facilities is deduced; also, references for the evaluation of shrapnel hazard are given. Overpressures in enclosed test facilities are discussed and recommendations given for the minimization of blast hazards; potential blast hazards, in this case, are well defined. Additional experimental work is needed to provide better blast criteria for open and enclosed liquid hydrogen test facilities. Directions for future work are indicated.

(SAFETY, EXPLOSION, LIQUID, CRITERIA)

350

H73 52000* THE INTERGRANULAR EMBRITTLEMENT OF NICKEL BY HYDROGEN
Latanision, R.M., and H. Opperhauser, Jr., (Martin Marietta Labs., Baltimore, Md.), Report No. MML-TR-73-03c, Mar 73, Avail:TAC

The mechanical behavior of polycrystalline nickel specimens that were deformed in tension and cathodically charged with hydrogen simultaneously was investigated with particular emphasis on the fracture of such electrodes. This procedure leads to very definite if, however, weak serrated yielding and also markedly reduces the elongation at fracture compared to polycrystals unexposed to hydrogen.
(EMBRITTLEMENT, INTERGRANULAR, NICKEL, BEHAVIOR, MECHANICAL)

H73 52001 THE EFFECT OF COMPOSITION AND TENSILE STRENGTH ON THE SUSCEPTIBILITY OF ALLOY STEELS TO CADMIUM PLATING (HYDROGEN) EMBRITTLEMENT
Langstone, P.F., (Ministry of Technology, London, England), Report No. D.Mat. 159, Oct 68, Avail:TAC

Sustained load, fracture toughness and bend tests were made to determine the susceptibility to cadmium plating (hydrogen) embrittlement of a range of 3% chromium-molybdenum-vanadium steels of different carbon contents, impurity contents, and tensile strengths. Sustained load life and critical crack size fell sharply with increase of tensile strength from 110 to 120 tonf/sq in.
(STEEL, EMBRITTLEMENT, STRENGTH)

H73 52002* HYDROGEN ENVIRONMENT EMBRITTLEMENT OF METALS
Jewett, R.P., R.J. Walter, W.T. Chandler, and R.P. Frohmberg, (Rocketdyne, Canoga Park, Calif.), N73-21444, NASA-CR-2163, Mar 73, Avail:TAC

Hydrogen environment embrittlement refers to metals stressed while exposed to a hydrogen atmosphere. Tested in air, even after exposure to hydrogen under pressure, this effect is not observed on similar specimens. Much high purity hydrogen is prepared by evaporation of liquid hydrogen, and thus has low levels for potential impurities which could otherwise inhibit or poison the absorbent reactions that are involved. High strength steels and nickel-base alloys are rated as showing extreme embrittlement; aluminum alloys and the austenitic stainless steels, as well as copper, have negligible susceptibility to this phenomenon. The cracking

that occurs appears to be a surface phenomenon, is unlike that of internal hydrogen embrittlement.
(EMBRITTLEMENT, METAL, CRACK, AIR, PURITY)

H73 52003 PETCH ANALYSIS OF HYDROGENATED TANTALUM SHEET
Gazza, G.E., (Army Materials Research Agency, Watertown, Mass.), AMRA-TR-66-10, May 66, Avail:TAC

The anomalous behavior in ductility exhibited by tantalum, at low temperature, with hydrogen as an impurity was investigated utilizing a Petch-type analysis. The change in lattice friction stress and dislocation locking stress parameters were determined through a temperature range from room temperature to -196 C. The results of the investigation show the locking stress remained essentially unchanged by small hydrogen additions while the lattice friction stress increased significantly at temperatures below -78 C.
(TANTALUM, DUCTILITY, STRESS)

H73 52004 HYDROGEN EMBRITTLEMENT OF STEEL
Tkachev, V.I., A.K. Litvin, V.A. Teterskii, and A.I. Soshko, Problemy Prochnosti, V 4:69-73, Dec 72, (In Russian), Avail:TAC

A correlation is established between the changes in the strength and ductility of steel, resulting from the hydrogen content and from the type of interaction between iron and hydrogen. It is shown that the influence of hydrogen on the strength properties is most pronounced within the temperature range that is characteristic of chemisorption of hydrogen by iron. An analysis of experimental data shows that hydrogen embrittlement is caused by mechanicochemical processes occurring at tips of developing cracks.
(STEEL, EMBRITTLEMENT, STRENGTH, DUCTILITY, CHEMISORPTION)

H73 52005 THERMODYNAMICS OF THE SOLUBILITY AND PERMEATION OF HYDROGEN IN METALS AT HIGH TEMPERATURE AND LOW PRESSURE
Shupe, D.S., and R.E. Stickney, (M.I.T., Cambridge Research Lab., Cambridge, Mass.), Journal of Chemical Physics, V 51: 1620-25 N4, Aug 15 '69, Avail:TAC

The solubility and permeation of hydrogen in metals is analyzed on the basis of classical thermodynamics plus a minimum of kinetic theory. Expressions are derived from x, the number of H atoms absorbed per solid atom, and J, the permeation rate, in the limiting cases of continuum and free-molecule flow. The analysis provides a simple explanation of

existing experimental data on the solubility and permeation of hydrogen in tungsten and in molybdenum at high temperature and low pressure.
(METAL, PERMEATION, SOLUBILITY, THERMODYNAMICS)

H73 52006 INTERNAL FRICTION MEASUREMENTS FOR THE ANALYSIS OF HYDROGEN IN STEEL PARTS
Begemann, S.H.A., (Boeing Co., Renton, Wash.), Report No. D6-23401, 68, Avail:TAC

Damping versus temperature curves were determined, by means of a torsion pendulum internal friction apparatus, for hydrogen charged cold drawn 4340 steel wire. A relaxation peak, identified as the Hydrogen Cold-Work Peak, was found in the curves between -90 C and -70C. A plot of this relaxation peak height versus charging time shows a linear relationship over only a limited range. The low hydrogen concentration levels that can cause hydrogen embrittlement were found to be below the limits of accurate detection by internal friction methods.
(STEEL, FRICTION, INTERNAL, DAMPING, TEMPERATURE)

H73 52007 INFLUENCE OF SURFACE TREATMENTS AND COATINGS ON THE EMBRITTLEMENT OF HIGH-STRENGTH STEELS BY HYDROGEN UNDER PRESSURE: CASE OF 35 NiCrMo 16 STEEL
Fidelle, J.P., J.M. Deloron, C. Roux, and M. Rapin, (Oak Ridge National Lab., Tenn.), Report No. ORNL-tr-2058, 69, Avail:TAC

A rough surface accentuates gaseous hydrogen embrittlement. An improvement of the microgeometrical profile or a superficial compression by blasting improves the life of steel, on the other hand. Electroplated zinc causes an irreversible embrittlement of the investigated steels. The hydrogen-susceptibility of nickel makes its presence undesirable either as a primary deposit or as a bonding coat. Chromizing of a steel which is to be deformed under hydrogen is not desirable if it cannot favor an austenitic barrier coating there.
(EMBRITTLEMENT, STEEL, HIGH STRENGTH, COATING, SURFACE)

H73 52008 HYDROGEN STRESS CRACKING OF HIGH STRENGTH STEELS
Beck, W., E.J. Jankowsky, and P. Fischer, (Naval Air Development Center, Warminster, Pa.), Report No. NADC-MA-7140, Dec 23 '71, Avail:TAC

The report deals with hydrogen induced embrittlement

and stress cracking of high strength steel parts. Selected mechanical methods involving the different types of test specimens for the measurement of hydrogen embrittlement or delayed failure, and relevant methods for the quantitative determination of hydrogen extracted from embrittlement susceptible specimens are presented. Different techniques for restoring ductility or preventing delayed failure are also included. A new thermodynamic approach to the interpretation of the hydrogen embrittlement phenomenon is offered and a number of variables which control the generation or minimization of hydrogen embrittlement is analyzed and discussed in the light of electrochemical kinetics.
(STEEL, STRENGTH, CRACK, STRESS, EMBRITTLEMENT)

H73 52009 HYDROGEN PERMEATION AND EMBRITTLEMENT IN FERROUS MATERIALS
Namboodhiri, T.K.G., and L. Nanis, (Pennsylvania University, Philadelphia, Pa), Report No. UPH2-TR-004, Nov 72, Avail:TAC
The sensitive electrochemical permeation technique was used in conjunction with scanning electron microscopy and tensile loading to determine (i) hydrogen diffusivity and solubility, (ii) effect of plastic deformation on the above parameters, and (iii) structural features and kinetics of hydrogen embrittlement, in Armco iron and 4340-steel.
(PERMEATION, EMBRITTLEMENT, METAL, SOLUBILITY)

H73 52010 HYDROGEN-INDUCED PHASE TRANSFORMATIONS IN TYPE 304L STAINLESS STEELS
Holzworth, M.L., and M.R. Louthan, (E.I. du Pont de Nemours Co., Savannah River Lab., Aiken, S.C.), Report No. DP-MS-67-107, Je 21 '68, Avail:TAC
Electrolytic charging of hydrogen into Type 304L stainless steel at room temperature and 100C induced partial transformation of the austenite to the same martensitic phases (alpha (bcc) and epsilon (hcp) as are formed by cold-working hydrogen-free austenite at low temperatures (-196C).
(STAINLESS STEEL, DISLOCATION, PHASE, TRANSFORMATION)

H73 52011 HYDROGEN BRITTLENESS IN NONFERROUS METALS
Kolachev, B.A., (Foreign Technology Div., Wright-Patterson AFB, O.), Report No. FTD-HT-23-95-68, Jl 18 '68, Avail:TAC
The book is devoted to problems concerning the interaction of hydrogen with metals, and the harmful effects this

has on the properties of the metal. Considerable attention is given to processes that take place during the hydrogen-metal interaction, the state of hydrogen in liquid and solid solution, and the interaction of hydrogen with dislocations and other structural imperfections of metals. The effect of hydrogen on the structure and properties of the following metals are discussed: Be, Mg, Al, U, Ti, Zr, V, Nb, Ta, Cr, Mo. W. Pt, Cu, Ag, Au. Special attention is devoted to the hydrogen brittleness of Ti alloys.
(EMBRITTLEMENT, METAL, NONFERROUS, STRUCTURE)

H73 52012 HYDROGEN BEHAVIOR IN METALS USING NUCLEAR MAGNETIC RESONANCE
Zamir, D., and C. Korn, (Israel Atomic Energy Commission), AD-729-690, Nov 70, Avail:TAC

Parameters considered important for the explanation of hydrogen embrittlement of titanium and its alloys have been measured using NMR techniques. The diffusional activation energy was found to be constant with respect to the hydrogen concentration. Hydrogen in titanium aluminum alloys was found to exist in two different crystallographic environments, one diffusing faster than the other. X-ray measurements on hydrogen free Ti_3Al and Ti_3Al containing hydrogen giving an H/Ti ration of 1.3, showed extreme distortion to the lattice upon hydrogen absorption.
(EMBRITTLEMENT, TITANIUM, ALLOY, DIFFUSION)

H73 52013 EVALUATION OF HYDROGEN EMBRITTLEMENT MECHANISMS
Barth, C.F., and E.A. Steigerwald, (TRW Equipment Labs, Cleveland, O.), Report No. ER-7477, Jl 1 '70, Avail:TAC

The incubation time which precedes the initiation of slow crack growth in the delayed failure of high-strength steel containing hydrogen was reversible with respect to the applied stress. The kinetics of the reversibility process indicated that it was controlled by the diffusion of hydrogen. Reversible hydrogen embrittlement studies were also conducted at liquid nitrogen temperatures where diffusional processes should not occur. The previously reported low temperature embrittlement behavior was confirmed indicating a basic interaction between hydrogen and the lattice. The experimental results could be satisfactorily explained by the lattice embrittlement theory proposed by Troiano.
(EMBRITTLEMENT, MECHANISM, STEELS, STRENGTH, DIFFUSION)

H73 52014 EMBRITTLEMENT. VOLUME 1
Anon, (Defense Documentation Center, Alexandria, Va.) Report bibliography Mar 63-Dec 69, Report No. DDC-TAS-70-51-1, Je 70, Avail:TAC

The annotated bibliography is a compilation of unclassified and unlimited reports on embrittlement. Corporate author-monitoring agency, subject, and contract number indexes are provided.
(EMBRITTLEMENT, BIBLIOGRAPHY, INDEX)

H73 52015 A NEW APPROACH TO BEND TESTING FOR THE DETERMINATION OF HYDROGEN EMBRITTLEMENT SUSCEPTIBILITY OF SHEET MATERIALS
Jones, R.L., (General Dynamics/Astronautics, San Diego, Calif.), Report No. GDA-MRG-235, Je 15 '61, Avail:TAC

A series of experimental programs were carried out to determine the suitability and sensitivity of a new test technique for the determination of hydrogen embrittlement susceptibility of materials.
(EMBRITTLEMENT, SHEET, BENDING)

H73 52016 A COMPARISON OF HYDROGEN EMBRITTLEMENT AND STRESS CORROSION CRACKING IN HIGH STRENGTH STEELS
Kortovich, C.S., and E.A. Steigerwald, (TRW Equipment Labs., Cleveland, O.), Report No. ER-7530, Je 15 '71, Avail:TAC

The purpose of the study was to compare the known behavior of hydrogen embrittled high-strength steel to the characteristics of environmentally-induced stress corrosion failure where hydrogen is continuously generated at the specimen surface.
(EMBRITTLEMENT, CRACK, STEEL, STRENGTH, STRESS, CORROSION)

H73 52017 A COMPARISON OF VARIOUS TEST METHODS FOR DETECTING HYDROGEN EMBRITTLEMENT
Jankowsky, E.J., (Naval Air Development Center, Warminster, Pa.), Report No. NADC-MA-7066, Je 8 '71, Avail:TAC

Four hydrogen embrittlement test methods were evaluated using three paint strippers as the embrittling media. Results were compared with those obtained with notched C-rings, the method now prescribed in paint stripper specifications. In general, all the methods give good results and good correlation.
(EMBRITTLEMENT, DETECTION, TEST)

H73 52018 THE REACTION OF A TITANIUM ALLOY WITH HYDROGEN GAS AT LOW TEMPERATURES
Williams, D.N., and R.A. Wood, (Battelle Columbus Labs., Columbus, O.), Journal of the Less-Common Metals, V 31:239-247, May 73, Avail:TAC

An investigation of the effect of temperature on the surface hydriding reaction of Ti-5Al-2.5Sn alloy exposed to hydrogen at 250 psig was made. Reaction conditions were controlled so as to expose a vacuum-cleaned, oxide-free alloy surface to an ultra-pure hydrogen atmosphere. Reaction times up to 1458 hr were studied. The hydriding reaction was extremely sensitive to experimental variables and the reproducibility of reaction was poor.
(GAS, REACTION, TITANIUM, ALLOY, TEMPERATURE)

H73 52019* TESTS FOR HYDROGEN EMBRITTLEMENT OF STEELS USED IN THE TANK FARM CYLINDERS
Mills, R.L., and F.J. Edeskuty, (Los Alamos Scientific Lab., Los Alamos, N.M.), U.S. Atomic Energy Center, LA-3602, 66, Avail:TAC

Specimens of alloy steels used in H_2 storage tanks were exposed to gaseous H_2 under pressure for 24 hrs. In separate tests, specimens were exposed to cathodic H_2 for 30 minutes at a c.d. of 1 amp./in.^{2} Immediately following exposure, samples were deformed through successive 180^o bends until broken. None of the steels was measurably affected by exposure to H_2 gas under the test conditions, but all steels were embrittled by cathodically liberated H_2. Cathodic embrittlement increased with time and stress of the samples.
(EMBRITTLEMENT, STEEL, CYLINDER, GAS, PRESSURE)

H73 52020* TESTING FOR HYDROGEN EMBRITTLEMENT: PRIMARY AND SECONDARY INFLUENCES
Nelson, H.G., (NASA, Ames Research Center, Moffett Field, Calif.), N72-31548, NASA-TM-X-62173, Aug 72, Avail:TAC

An overview is presented of the hydrogen embrittlement process, both internal as well as external, to make more clear the type of parameters which must be considered in the selection of a test method and test procedure, so that the resulting data may be meaningfully applied to real engineering structures. Three primary influences on the embrittlement process are considered: (1) the original location and form of

the hydrogen, (2) the transport reactions involved in the transport of hydrogen from its origin to some point where it can interact with the metal to cause embrittlement, and (3) the embrittlement interaction itself.
(EMBRITTLEMENT, TEST, PROCEDURE)

H73 52021 HYDROGEN MOVEMENT IN STEEL-ENTRY, DIFFUSION, AND ELIMINATION
Fletcher, E.E., and A.R. Elsea, (Battelle Memorial Inst., Columbus, O.), Report No DMIC-219, Je 30 '65, Avail:TAC

The report discusses the ways in which H_2 enters steels, how it moves through steel, and methods whereby it may be removed from steel. The solubility of H_2 is important in understanding other aspects of the behavior of H_2 in steel and such aspects of solubility as preferred lattice sties, lattice expansion, measurements of solubility, and estimates of equilibrium H_2 pressure in steel are discussed. The permeation of H_2 through steel consisting of interactions at both the entry and exit surfaces of the metal as well as diffusion through the bulk metal is discussed. The various possibilities of H_2 entry by corrosion processes, electrochemical processes, and other means are considered as well as factors which influence the rate of H_2 removal from iron and steel.
(STEEL, DIFFUSION, SOLUBILITY, PERMEATION)

H73 52022 AN X-RAY STUDY OF HYDROGEN INDUCED PHENOMENA AFFECTING MECHANICAL BEHAVIORS OF AUSTENITIC STAINLESS STEELS
Kamachi, K., and S. Miyata, (Yamaguchi University, Japan), Mechanical Behavior of Materials, V 3, Aug 15-20 '71, (In Japanese)

Hydrogen induced phenomena on austenitic stainless steels were studied by the X-ray diffraction method. By hydrogenation of various sorts of austenitic stainless steels, structural changes, i.e., phase transformation of austenite into alpha phase and epsilon phase, development of lattice defects such as dislocations and stacking faults, and surface cracks, occurred.

The results by the examinations of X-ray were verified by direct observation by transmission electron microscopy.
(STEEL, STAINLESS, AUSTENITE)

H73 52023   HYDROGEN EMBRITTLEMENT STUDIES OF A TRIP STEEL
McCoy, R.A., (U.S. Navy, Washington, D.C.), and W.W. Gerberich, Metallurgical Transactions, V 4:539-547, Fe 73, Avail:TAC

The conditions of cathodic charging, gaseous hydrogen environment, and loading for which a TRIP steel may or may not be susceptible to hydrogen embrittlement were investigated. In the austenitic state, the TRIP steel appeared to be relatively immune to hydrogen embrittlement. It was shown that it is the strain-induced martensitic phase, alpha prime, which is embrittled.
(STEEL, EMBRITTLEMENT, SUSCEPTIBILITY)

H73 52024   EMBRITTLEMENT OF TRIP STEEL IN HIGH-PRESSURE HYDROGEN GAS
Vandervoort, R.R., A.W. Ruotola, and E.L. Raymond, (California University, Livermore, Calif.), Metallurgical Transactions, V 4:1175-1178, Apr 73, Avail:TAC

Experimental study of the effects of high-pressure hydrogen gas on the mechanical properties of TRIP steel. The results obtained include the findings that TRIP steel is very notch-sensitive and highly susceptible to embrittlement in a high-pressure hydrogen environment, and that its losses in strength and ductility are caused by the interaction between hydrogen and stress-assisted martensite during deformation.
(EMBRITTLEMENT, PRESSURE, STEEL, MECHANICAL)

H73 52025*   EFFECTS OF HIGH PRESSURE HYDROGEN ON METALS AT AMBIENT TEMPERATURE
Walter, R.J., and W.T. Chandler, (Rocketdyne, Canoga Park, Calif.), N70-18637, NASA-CR-102425, Fe 28 '69, Avail:TAC

Thirty five alloys were investigated for their susceptibility to high pressure hydrogen environment embrittlement at ambient temperature; subsequently they were ranked according to their reduction of notch strength in 10,000 psi hydrogen. The ranking in order of decreasing embrittlement was as follows: (1) high strength steels and nickel-base alloys; (2) moderate and low strength iron-base alloys, pure nickel, and titanium alloys; (3) nonstable AlSl type 300 stainless steels, berylium-copper, and commercially pure titanium; and (4) aluminum alloys, pure copper, and the stable AlSl type 300 stainless steels. The degree of hydrogen environment em-

brittlement was found to increase with increasing hydrogen pressure and to be a complex function of notch severity.
(EMBRITTLEMENT, PRESSURE, GAS, METAL, ALLOY)

H73 52026* GAS-PHASE HYDROGEN PERMEATION THROUGH ALPHA IRON, 4130 STEEL, AND 304 STAINLESS STEEL FROM LESS THAN 100 C TO NEAR 600 C
Nelson, H.G., and J.E. Stein, (NASA, Ames Research Center, Moffett Field, Calif.), N73-21442, NASA-TN-D-7265, A-4749, Ap 73, Avail:TAC

Gas phase hydrogen permeation studies were conducted on hollow, cylindrical membranes of triply zone-refined alpha iron, AlSl 304 austenitic stainless steel, and AlSl-SAE 4130 steel in both the normalized (ferrite and carbide) and quenched and tempered (martensite) conditions. For all membrane materials, expressions for the coefficients for hydrogen permeation were determined by analysis of steady state transport; the coefficients for diffusion were determined by the lag time technique applied to nonsteady state transport; and through a knowledge of the Sievert's constants, the subsurface equilibrium lattice hydrogen concentrations were determined.
(PERMEATION, IRON, STEEL, MEMBRANE, DIFFUSION)

H73 52027 HYDROGEN EMBRITTLEMENT IN IRRADIATED STEELS
Rossin, A.D., (Argonne National Lab., Ill.), Report No. ANL-7266, Fe 67, Avail:TAC

H_2-charging conditions that completely embrittle type 4340 high-strength steel have a negligible effect on 212-B pressure-vessel steel in tensile and delayed-failure tests. Much higher H_2 charges reduce the notch-tensile strength slightly. Delayed failure is observed only at stresses above 90% of the notch-tensile strength of the hydrogenated 212-B.
(EMBRITTLEMENT, STEEL, STRENGTH, TENSILE)

H73 52028 FORMATION AND DEVELOPMENT OF CRACKS DURING THE FRACTURE OF HYDROGEN-ADSORBED IRON
Grigor'eva, G.M., K.V. Popov, and E.S. Nosyreva, Fiz. Metal. Metalloved., V 30:637-9 N3, 70, (in Russian)

Technical iron in the annealed state was studied. The 10-fold fractured samples were hydrogenated electrolytically to a content of 3 ml/100 g. Fracture surfaces of samples tested at temperatures of maximum development of reverse H

embrittlement (-60° to -80°) have a very uneven surface with deep depressions and high hillocks. The present study of the structure and the arrangement of cracks in hydrogenated iron makes it possible to assume that under temperature-rate conditions for the development of reversible H brittleness the formation of the main crack is brought about by way of the emergence of a large number of crack nuclei, their development, and the subsequent impoverishment of the connectors between them.
(IRON, CRACK, FRACTURE)

H73 52029 EFFECT OF PRESSURIZED HYDROGEN UPON INCONEL 718 AND 2219 ALUMINUM
Lorenz, P.M., (Boeing Co., Seattle, Wash.), N69-19152, NASA-CR-100208, Fe 14 '69, Avail:TAC

Inconel 718 and 2219-T6E46 aluminum were tested in the environment of pressurized high purity hydrogen gas using surface flawed fracture toughness specimens and preflawed Inconel 718 pressure vessels. Presence of pressurized hydrogen gas severely affected flaw growth characteristics of Inconel 718, but had no detectable effect upon 2219-T6E46 aluminum.
(INCONEL 718, ALUMINUM 2219, EMBRITTLEMENT, HIGH PRESSURE, GAS)

H73 52030* HYDROGEN ENVIRONMENT EMBRITTLEMENT
Gray, H.R., (NASA, Lewis Research Center, Cleveland, O.), N72-27574, NASA-TM-X-68088, 72, Avail:TAC

Hydrogen embrittlement is classified into three types: internal reversible hydrogen embrittlement, hydrogen reaction embrittlement, and hydrogen environment embrittlement. Characteristics of and materials embrittled by these types of hydrogen embrittlement are discussed. Hydrogen environment embrittlement is reviewed in detail. Factors involved in standardizing test methods for detecting the occurence of and evaluating the severity of hydrogen environment embrittlement are considered. The effect of test technique, hydrogen pressure, purity, strain rate, stress concentration factor, and test temperature are discussed.
(EMBRITTLEMENT, ENVIRONMENT, REACTION, REVERSIBLE)

H73 52031 EFFECT OF HYDROGEN ON TENSILE PROPERTIES OF PALLADIUM-HYDROGEN SYSTEM
Smith, R.J., and D.A. Otterson, (NASA, Lewis Research Center, Cleveland, O.), N71-19011, NASA-TN-D-6211, Mar 71, Avail:TAC

Tensile properties of both annealed and as-received palladium wire were measured as functions of hydrogen content. The yield stress, ultimate tensile stress, and elongation at maximum stress were determined and showed abrupt changes with respect to hydrogen content near the boundaries of the phase diagram. The dependence of the tensile properties on hydrogen content within a single phase region was interpreted in terms of electronic structure and work hardening.
(PALLADIUM, PROPERTY, TENSILE)

H73 52032 DIFFUSION OF GASES THROUGH METALS
Lombard, V., N70-19137, Rev. Met. (Paris), V 26:343-50 N7, Jl 29, NASA-TT-F-12806, (In French), Avail:TAC

The diffusion of hydrogen through metals, under various temperatures and pressures, chiefly with nickel, was investigated. Other elements involved to some extent are iron, platinum, nitrogen, argon and helium. It was found that when hydrogen is mixed with other gases there is no difference in the rate of diffusion. The tests concerning nitrogen, argon and helium do not provide any definitive results because of poor apparatus. It was found in addition that metal sheets placed close to one another have an additive value as far as hydrogen diffusion is concerned, i.e., hydrogen diffuses through 2 mm of nickel just as rapidly whether the nickel is a solid piece or two pieces in close conjunction.
(DIFFUSION, METAL, RATE, TEMPERATURE, PRESSURE)

H73 52033 COMPATIBILITY OF METALS WITH HYDROGEN
Cataldo, C.E., (NASA, Marshall Space Flight Center, Huntsville, Ala.), N69-19002, NASA-TM-X-53807, Dec 26 '68, Avail:TAC

This report summarizes three different but related categories of hydrogen embrittlement problems encountered in various components of Saturn launch vehicle hardware. The status of research programs, established to investigate these failure mechanisms and solutions to prevent failures, is presented. Corrective actions taken to minimize failures from high pressure hydrogen effects, the formation of hydrides in titanium, and hydrogen absorption through various metals

processing techniques are described.
(EMBRITTLEMENT, SPACECRAFT, FAILURE, PREVENTION, METAL)

H73 52034 A STUDY OF HYDROGEN EMBRITTLEMENT OF VARIOUS ALLOYS
Groeneveld, T.P., E.E. Fletcher, and A.R. Elsea, (Battelle Memorial Institute, Columbus, O.), N69-28526, NASA-CR-98448, Ja 23 '69, Avail:TAC

The susceptibilities of 14 selected high-strength alloys to hydrogen-stress cracking were evaluated. The susceptible alloys were used to evaluate the hydrogen-embrittling tendencies of selected cleaning, inhibited acid pickling, and electroplating processes, and to evaluate the effectiveness of selected baking treatments for relieving hydrogen embrittlement.
(EMBRITTLEMENT, ALLOYS, HIGH STRENGTH, SUSCEPTIBILITY)

H73 52035 ABSORPTION OF CATHODIC HYDROGEN BY IRON AND STEEL
Radhakrishnan, T.P., (Bhabha Atomic Research Centre, Bombay, India), Report No. BARC-585, 72, Avail:TAC

Delayed failure and embrittlement due to hydrogen absorption pose intricate problems and limit the application of many high-strength steels in industry and technology. Hydrogen pickup occurs concomitantly during various chemical and electrochemical metal finishing processes and also during galvanic corrosion of the plated steel components. The behavior of cathodic hydrogen in iron and steel and, in particular, the various factors which influence absorption were examined. The mechanism of entry and release of hydrogen was considered on the basis of electrochemical kinetics with due emphasis on the location and state of hydrogen in steel.
(IRON, STEEL, ABSORPTION, CATHODIC, DIFFUSION)

H73 52036 THE LOW-TEMPERATURE EMBRITTLEMENT OF NIOBIUM AND VANADIUM BY BOTH DISSOLVED AND PRECIPITATED HYDROGEN
Hardie, D., and P. McIntyre, Metallurgical Transactions, V 4, May 73

Like other exothermic occluders of hydrogen, niobium (columbium) and vanadium may be embrittled by the presence of a precipitated hydride. However, alloys containing hydrogen

concentrations well below the solubility limits at room temperature show very interesting features when tested in tension at subambient temperatures. Niobium containing 25 ppm H, from which little hydride precipitates above 77K, shows a ductility minimum on cooling which is strain-rate-dependent and may be attributed to diffusion of hydrogen to microcrack nucleation sites. When the hydrogen content is increased a further reduction in ductility occurs at lower temperatures due to the martensitic precipitation of niobium hydride. The behavior displayed by V-H alloys is broadly similar, except that here the influence of hydrogen diffusion overshadows the embrittling effect of the hydride precipitation is less easily distinguished from that involving hydrogen in solution in vanadium than in niobium.
(EMBRITTLEMENT, TEMPERATURE, NIOBIUM, VANADIUM)

H73 52037 EFFECT OF HIGH DISLOCATION DENSITY ON STRESS CORROSION CRACKING AND HYDROGEN EMBRITTLEMENT OF TYPE 304L STAINLESS STEEL
Louthan, M.R., Jr., J.A. Donovan, and D.E. Rawl, Jr., (Savannah River Lab., du Pont, Aiken, S.C.), Corrosion, V 29 N3, Mar 73

A thermochanical treatment of Type 304L stainless steel, which retards both the martensitic transformation and coplanar dislocation motion, appears to increase the resistance to SCC and hydrogen embrittlement. However, the importance of the transformation to martensite in reduction resistance needs to be further resolved, because Tenelon and Armco 21Cr-6Ni-9Mn stainless steels, which exhibit coplanar dislocation motion but do not transform to martensite, are susceptible to both stress corrosion and hydrogen embrittlement.
(STEEL, STAINLESS, EMBRITTLEMENT, DISLOCATION, MARTENSITE)

H73 52038 ENHANCED FLAW GROWTH IN SSE MAIN ENGINE ALLOYS IN HIGH PRESSURE GASEOUS HYDROGEN
Frick, V., G.R. Janser, and J.A. Brown, (Aerojet Liquid Rocket Co., Sacramento, Calif.), Space Shuttle Materials, V 3:567-604, 71

The effects of high pressure gaseous hydrogen upon candidate alloys for the Space Shuttle Main Engine components were evaluated for static load conditions using surface flawed flat plate PTC specimens. Tests were performed in high purity, gaseous hydrogen at a pressure of 7500 psig and temperatures in the range of $-320^{\circ}F$ to $+1000^{\circ}F$. (GAS, PRESSURE, ENGINE, EMBRITTLEMENT)

H73 52039 HYDROGEN EMBRITTLEMENT OF METALS
Rogers, H.C., Science, V 159:1057-64, N3819, Mar 8 '68

Hydrogen interacts with many metals to reduce their ductility and frequently their strength also. It enters metals in the atomic form, diffusing very rapidly even at normal temperatures. During melting and fabrication, as well as during use, there are various ways in which metals come in contact with hydrogen and absorb it. The absorbed hydrogen may react irreversibly with oxides or carbides in some metals to produce a permanently degraded structure. (EMBRITTLEMENT, METAL, MECHANISM)

H73 52040 A METHOD FOR DETERMINATION OF THE PERMEATION RATE OF HYDROGEN THROUGH METAL MEMBRANES
McBreen, J., L. Nanis, and W. Beck, (University of Pennsylvania, Philadelphia, Pa.), Journal of the Electrochemical Society, V 113:1218 N11, Nov 66, Avail:TAC

A sensitive electrochemical method for the precise measurement of diffusion coefficients and permeation rates of hydrogen through metal membranes is described. A mathematical analysis of the pertinent diffusion equations is given. Suggestions are made regarding uses of the method. (PERMEATION, RATE, MEMBRANE, METAL, DIFFUSION)

H73 52041 HYDROGEN EMBRITTLEMENT AND HYDROGEN TRAPS
Bockris, J. O'M., and P.K. Subramanyan, (University of Pennsylvania, Philadelphia, Pa.), Journal of the Electrochemical Society, V 118:1114 N7, Jl 71, Avail:TAC

The permeation of H through iron and an iron-nickel alloy as a function of time is reported. Below a certain critical H overpotential, the H permeation occurs as a function of time in a simple way; and can be repeated indefinitely on the same specimen.
(EMBRITTLEMENT, IRON, PERMEATION)

H73 52042 MATHEMATICS OF THE ELECTROCHEMICAL EXTRACTION OF HYDROGEN FROM IRON
Nanis, L., and T.K. Namboodhiri, (University of Pennsylvania, Philadelphia, Pa.), Journal of the Electrochemical Society, V 119:691 N6, Je 72, Avail:TAC

The transient current of hydrogen removal from iron following steady-state permeation is analyzed theoretically for two limiting conditions at the input side.
(IRON, EXTRACTION, MODEL, MATHEMATICAL)

H73 52043 ON THE ROLE OF IRON DISSOLUTION IN CRACK PROPAGATION DURING HYDROGEN CHARGING OF AN Fe-Pt ALLOY
Pickering, H.W., and P.J. Byrne, (U.S. Steel Research Center, Monroeville, Pa.), Journal of the Electrochemical Society, V 120:607 N5, May 73, Avail:TAC

Iron dissolution during cathodic charging of iron and its alloys is generally negligible, in agreement with thermodynamic conditions at the surface. This is not true, however, of iron alloys for which hydrogen discharge is easy, and also may not in general be true within cracks or cavities. Crack propagation occurs for specimens loaded in tension which (i) is independent of the level of hydrogen charging and (ii) has anodic dissolution of iron associated with it. Internal (hydrogen-produced) cracking does not occur. The role of ohmic drops in promoting anodic dissolution at the base of the cracks during hydrogen charging is discussed.
(IRON, CRACKING, DISSOLUTION)

H73 52044 PROTECTION OF STEEL FROM HYDROGEN CRACKING BY THIN METALLIC COATINGS
Matsushima, I., and H.H. Uhlig, (M.I.T., Cambridge, Mass.), Journal of the Electrochemical Society, V 113:555 N6, Je 66, Avail:TAC

Cold rolled and stress relieved 0.5% carbon steel specimens electroplated with Ni, 0.50-2.5μ thick and bent to the test span after plating are especially resistant to hydrogen cracking when polarized cathodically in dilute sulfuric acid saturated with As_2O_3. Arsenic or an As compound deposits cathodically on the Ni coating which supplements protection by Ni alone. The mechanism of protection is apparently one of altering the kinetics of H+ discharge, resulting in less occlusion of hydrogen by steel. Accordingly, such coatings

to be protective need not be continuous.
(STEEL, CRACKING, PROTECTION, COATING, NICKEL)

H73 52045 PERMEATION OF ELECTROLYTIC HYDROGEN THROUGH PLATINUM
Gileadi, E., M.A. Fullenwider, and J. O'M. Bockris, (University of Pennsylvania, Philadelphia, Pa.), Journal of the Electrochemical Society, V 113:926 N9, Sept 66, Avail:TAC

The absorption and permeation of electrolytically generated hydrogen through thin platinum foils have been observed directly by an electrochemical method. The diffusion coefficient and the associated apparent energy of activation were determined. The concentration of absorbed hydrogen was obtained, and it was shown that atomic hydrogen tends to concentrate in areas of high strain in the metal where it can be in a lower energy state.
(PERMEATION, PLATINUM, DIFFUSION)

H73 52046 THE ROLE OF ADSORBED CN GROUPS IN THE HYDROGEN EMBRITTLEMENT OF STEEL
Beck, W., A.L. Glass, and E. Taylor, (Aeronautical Materials Lab., Philadelphia, Pa.), Journal of the Electrochemical Society, V 112:53 N1, Ja 65, Avail:TAC

Specimens of ultra high strength steel were charged cathodically with hydrogen or immersed without charging in a NaOH solution of $NaC^{14}N$ and the adsorption of $C^{14}N$ groups determined by means of radioactivity measurements. In addition, the desorption of adsorbed $C^{14}N$ groups was also studied. Heats, designated heats of adsorption, energies of activation, and the surface coverage with $C^{14}N$ were calculated. It is concluded that $C^{14}N$ groups are strongly and preferentially adsorbed on highly active centers and the hydrogen recombination reaction retarded accordingly.
(EMBRITTLEMENT, STEEL)

H73 52047 ESTIMATES OF THE POSSIBILITY OF HYDROGEN EMBRITTLEMENT OF TANTALUM IN THE FRCTF
Wohlberg, C., (Los Alamos Scientific Lab., Los Alamos, N.M.), Report No. LA-3508, Aug 18 '65, Avail:TAC

An evaluation was made of the possibility of destructive hydriding of Ta in the FRCTF. The assumption was made that even if the Na used in the reactor is well gettered in advance, undetermined amounts of H_2 will get into the system during

installation of fuel elements and subsequent operations.
(EMBRITTLEMENT, TANTALUM, CONTAMINATION)

H73 52048 THE EFFECT OF LOADING MODE ON HYDROGEN EMBRITTLEMENT
Saint John, C., and W.W. Gerberich, (Minnesota University, Minneapolis, Minn.), Metallurgical Transactions, V 4:589-94, Fe 73, Avail:TAC

Hydrogen embrittlement is shown to occur very easily in notched-round bars under opening mode I (tension) but not under antiplane shear mode 111 (torsion). The stress tensor invariants under mode 1, 11, 111 loadings and how these affect interstitial diffusion are discussed. It is suggested that long range diffusion of hydrogen down orthogonal trajectories to the vicinity of the crack tip, which can occur under mode 1 but not mode 111, is a key part of any hydrogen embrittlement mechanism.
(LOAD, EMBRITTLEMENT, DIFFUSION)

H73 52049 THE EFFECT OF SURFACE AND COATING TREATMENTS ON THE EMBRITTLEMENT OF STEEL AT HIGH RESISTANCE BY HYDROGEN UNDER PRESSURE: THE CASE OF 35 NiCrMo 16 STEEL
Fidelle, J.P., N69-20923, NASA-TT-F-12099, Fe 69, Avail:TAC

It is shown that gold, aluminum, and cadmium can protect disks for several months, which would be broken after a few minutes under hydrogen pressure if there were no coating. The authors analyze the cause and nature of the rupture of 35 NiCrMo 16 steel under various pressures.
(EMBRITTLEMENT, STEEL, COATING, SURFACE, RUPTURE)

H73 52050 THE EFFECT OF HYDROGEN AND TEMPERATURE ON MECHANICAL PROPERTIES OF THE Ti-5Al-2.5Sn ELI ALLOY
Nadler, R.A., (Westinghouse Electric Corp., Pittsburgh, Pa., Astronuclear Lab.), N66-35874, NASA-CR-77890, Sept 65, Avail:TAC

The effects of hydrogen content on the mechanical properties of the Ti-5Al-2.5Sn ELI alloy were investigated in the temperature range -320 to +200°F. In addition, the absorption of hydrogen by the alloy was studied to determine safe operating limits for the 0.020-inch thick core band. The data show that Ti-5Al-2.5Sn ELI can tolerate 300 ppM hydrogen at all temperatures investigated.
(PROPERTY, MECHANICAL, ALLOY)

H73 52051 THE MECHANISM OF HYDROGEN EMBRITTLEMENT IN STEEL
Tetelman, A.S., (Stanford University, Dept. of Materials Science, Calif.), N67-30934, NASA-CR-85771, Jl 67, Avail:TAC

The process of brittle fracture in structural materials can be separated into three stages: (1) crack nucleation, (2) slow crack growth, and (3) rapid, unstable fracture. Hydrogen embrittles steel by affecting the first two of these stages. In corroded, electrolytically charged, or thermally charged specimens, excess hydrogen precipitates at inclusions or carbides in molecular form, causing the initiation of voids or microcracks. The hydrogen pressure in these defects causes them to grow either by plastic deformation or by cleavage, depending on the intrinsic toughness of the particular steel and the shape of the nucleating particle.
(EMBRITTLEMENT, STEEL, FRACTURE, MECHANISM)

H73 52052 STRESS CORROSION CRACKING AND HYDROGEN EMBRITTLEMENT IN 410 STAINLESS STEEL
McGuire, M.F., (Case Western Reserve University, Cleveland, O.), N73-22471, Ph.D. Thesis, 72, Avail:TAC

The stress corrosion cracking behavior of two bcc stainless steels was investigated as a function of yield strength, applied potential, and temperature in several dilute salt solutions. Hydrogen permeation rates for the same environmental and material conditions were obtained. Under all conditions, the occurrence of stress corrosion cracking could be accounted for by a hydrogen embrittlement mechanism rather than either an adsorption of anodic dissolution process.
(STAINLESS, EMBRITTLEMENT, CORROSION, CRACK, STRESS)

H73 52053 REVIEW OF LITERATURE ON HYDROGEN EMBRITTLEMENT
Groeneveld, T.P., E.E. Fletcher, and A.R. Elsea, (Battelle Institute, Columbus, O.), N66-23505, NASA-CR-74034, Ja 12 '66, Avail:TAC

This report deals primarily with the loss in mechanical properties experienced by high strength iron-base and nickel-base alloys and by titanium as a result of hydrogen introduced into the material during manufacturing and processing of the alloy, or in service.
(EMBRITTLEMENT, REVIEW, STRENGTH, SUSCEPTIBILITY)

H73 52054* ROLE OF HYDROGEN IN HOT-SALT STRESS-CORROSION OF A TITANIUM ALLOY
Gray, H.R., (NASA, Lewis Research Center, Cleveland, O.), N71-10008, NASA-TM-X-52899, 70, Avail:TAC

The role of hydrogen was studied in promoting embrittlement at elevated temperatures, where the process of hot-salt stress-corrosion occurs. Salt-coated specimens of the Ti-8Al-1Mo-1V alloy were subjected to low-strain-rate tensile tests, creep exposure tests, and stress-rupture tests to demonstrate the effects of hot-salt stress-corrosion. Severe embrittlement and/or cracking was observed in all types of tests. Significant increases in hydrogen concentrations in stress-corroded specimens were measured by standard vacuum-fusion chemical techniques.
(EMBRITTLEMENT, TITANIUM, CORROSION)

H73 52055 PROPERTIES OF MATERIALS IN HIGH PRESSURE HYDROGEN AT CRYOGENIC, ROOM, AND ELEVATED TEMPERATURES
Harris, J.A., Jr. and M.C. Van Wanderham, (Pratt and Whitney Aircraft, West Palm Beach, Fla.), N71-33728, NASA-CR-119884, Je 30 '71, Avail:TAC

Results of mechanical property tests of nickel, titanium, and iron alloys in 5000 psig gaseous helium and hydrogen at various temperatures, and the comparison of test results to determine degradation of preperties due to the hydrogen environment are presented.
(MECHANICAL, PROPERTY, METAL, PRESSURE, TEMPERATURE)

H73 52056* INFLUENCE OF GASEOUS HYDROGEN ON METALS
Walter, R.J., H.G. Hayes, and W.T. Chandler, (Rocketdyne, Canoga Park, Calif.), N71-32489, NASA-CR-119917, May 24 '71, Avail:TAC

The gaseous hydrogen environment embrittlement was investigated in Inconel 718, Inconel 625, AlSl 321 stainless steel, Ti-5Al-25Sn ELl, and OFHC copper. The program was divided into the following phases: (1) Tensile tests on notched specimens were used to determine the effect of as-received material condition, heat treatment, and welding on the hydrogen environment embrittlement of Inconel 718 in 5000 psi hydrogen at room temperature. (2) The effect of 5000 psi hydrogen on the tensile properties of the alloys was determined at room termperature and -200 F. (3) Threshold stress intensities for the alloys listed above and in addition

2219-T87 aluminum alloy were determined with modified WOL specimens for a hydrogen pressure of 5000 psi and room temperature.
(GAS, EMBRITTLEMENT, TENSILE, PRESSURE, TEST)

H73 52057 PERMEABILITY DATA FOR AEROSPACE APPLICATIONS
Anon, (I.I.T. Research Institute, Chicago, Ill.), N69-14111, NASA-CR-95993, Mar 68, Avail:TAC

A compilation of data is presented on the permeation of propellants and pressurant gases through metals, nonmetals, and composite materials. The form is suitable for use by the designers of spacecraft liquid propulsion systems. The following information is given for each permeant type or trade name, temperature, permeability rate, permeability rate as reported, units reported, reference, solubility, diffusivity, and relevant comments.
(SPACECRAFT, PERMEATION, PROPELLANT, METAL)

H73 52058 LATTICE DILATATION AND HYDROGEN EMBRITTLEMENT CRACKING
Syrett, B.C., (International Nickel Co., Inc., Suffern, N.Y.), Corrosion, V 29:23-7, Ja 73

Stress corrosion cracking in a precracked high strength material, occurring by a hydrogen embrittlement mechanism, is investigated. The direction of slow crack growth is shown to be dependent partly on the angular variation in hydrogen concentration and partly on the angular variation of the extensional stress. The maximum dilatation occurs in the crack plane where an increased hydrogen solubility is to be expected.
(EMBRITTLEMENT, CRACK, STRENGTH)

H73 52059 INVESTIGATION OF THE REACTION OF TITANIUM WITH HYDROGEN
Koehl, B.G., D.N. Williams, and E.S. Bartlett, (Battelle Institute, Columbus, O.), N69-19949, NASA-CR-99576, Mar 18 '69, Avail:TAC

An investigation of the reaction between titanium and hydrogen gas was made to determine the factors which promote surface hydriding and methods of preventing it. High-purity hydrogen was essential for a reaction to occur between titanium and hydrogen gas.
(REACTION, TITANIUM, SURFACE, PRESSURE)

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