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Hydrogen Energy Coordinating Committee Annual Report-Summary of DOE Hydrogen Programs For FY 1984

January 1985

U.S. Department of Energy
Assistant Secretary, Conservation and Renewable Energy
Office of Energy Systems Research

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U.S. Department of Energy
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Office of Energy Systems Research
Washington, D.C. 20585

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INTRODUCTION

An ideal fuel for use in meeting the Nation's energy needs would be one that is virtually inexhaustible, clean burning, convenient, versatile, and free from foreign control. Hydrogen could be such a fuel, but it has limitations in that it is practically nonexistent in its free state and must be produced, consuming a primary energy source such as gas, oil, or coal in the process. On the other hand, with existing technology for hydrogen utilization, hydrogen can serve as a fuel for all conventional energy uses, including industrial applications; electric power generation; and residential, commercial, and transportation purposes.

At present, nearly all of the hydrogen produced in the United States is derived from natural gas and petroleum. In future energy systems, which would include hydrogen as an element, hydrogen could be produced by water electrolysis and could be used as a fuel substitute or as an energy carrier similar to electricity. Water would be decomposed into its constituent elements of hydrogen (H_2) and oxygen (O_2) using a nondepletable energy source. The hydrogen produced would then be transported through various means, including pipelines, and burned to provide heat energy for the needs of the economy. Since the burning of hydrogen involves combining it with oxygen, the use of hydrogen as a fuel actually comprises a closed system in which (1) hydrogen and oxygen are separated from water, requiring the expenditure of energy, and (2) when needed, hydrogen is recombined with oxygen, forming water and in the process releasing useful energy. Hydrogen, like electricity, represents a medium for storing, distributing, and using energy generated from other sources. In the future, however, hydrogen could become a major fuel in the event that (1) fossil fuels become too valuable or scarce to burn and (2) hydrogen could be produced economically from renewable or long-term primary sources such as nuclear fission or fusion, solar, or coal.

The Hydrogen Energy Coordinating Committee (HECC) was organized in the Energy Research and Development Administration (ERDA), and was continued when ERDA programs were incorporated into the Department of Energy (DOE), to improve communications between various groups performing research related to hydrogen. The HECC holds meetings at which recent progress is reviewed, plans are exchanged, and a formal talk on a current topic of interest to hydrogen researchers may be presented. Minutes of these meetings are prepared and distributed to attendees and other interested persons. In addition, the HECC publishes an annual summary of DOE hydrogen programs. Last year's report was issued formally as "Hydrogen Energy Coordinating Committee-Summary of DOE Hydrogen Programs for FY 1983," U.S. Department of Energy Report No. DOE/CE/0034/2, January 1984.

The format used in reporting this year on the research projects and in tabulating the associated funding levels differs from that used in past years. The HECC agreed that the earlier format was misleading in reporting relatively high funding levels for hydrogen R&D. This format may have led to the appearance that DOE funding for development of hydrogen energy technology is much greater than is actually the case. Actually, much of the research is generic in nature, and may or may not be applicable to hydrogen technology development. In order to clarify the distinction between <u>mission-related</u> and <u>non-mission-related</u> activities, the research projects have been classified as being of two kinds:

(a) Research on projects or problems directly related to the development of hydrogen energy technology, including production, storage, transportation, and utilization of hydrogen. These are described as the mission-related hydrogen activities.

(b) Activities that are not mission-related but include programs of several kinds related to hydrogen. They include, for example, basic studies of chemical and physical phenomena in which hydrogen is a participant such as materials properties, studies of thermodynamics and kinetics and reaction mechanisms involving hydrogen and hydrogen containing species, and very long range, high risk approaches to hydrogen technology development that might be applicable to hydrogen production but where scientific feasibility is still in question or where systems and economic evaluations will be premature for the foreseeable future. These are categorized as non-mission-related activities.

The FY 1984 Summary is the seventh consecutive yearly report providing an overview of the hydrogen-related programs of the DOE offices represented on the HECC. A historical summary of the hydrogen budgets of these offices is given in Table 1. Table 2a provides the distribution by mission-related program element for FY 1984, while Table 2b pertains to the non-mission-related activities. Total DOE funding in FY 1984 for mission-related hydrogen research was \$3.5 million; DOE non-mission-related hydrogen research funding totalled \$19.3 million. The individual program elements are described in the body of this report, and more specific program information is given in the Technology Summary Forms in Appendix A.

Table 1. DOE Hydrogen Research Funding
(dollars in millions)

Research Area	FY 1976	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984 Mission-Related	FY 1984 Non-Mission-Related
DOE Hydrogen R&D Totals	**$24.6**	**$24.3**	**$21.5**	**$24.1**	**$29.9**	**$30.9**	**$28.9**	**$26.5**	**$3.5**	**$19.3**
Basic Energy Sciences (BES)	5.3	7.2	9.5	10.9	13.6	15.1	15.6	16.6	0.7	12.6
Energy Systems Research (ESR)	2.4	4.5	6.3	6.3	4.5	3.2	2.3	2.1	2.0	0.0
Fossil Energy (FE)	8.0	4.6	1.5	1.5	1.5	1.0	0.5	0.0	0.2	0.0
Fusion Energy (OFE)	0.2	0.0	0.7	0.9	1.0	1.0	1.0	0.6	0.0	0.0
Inertial Fusion (IF)	0.0	0.6	1.0	0.6	1.3	1.6	1.9	1.7	0.0	2.5
Military Application (OMA)	8.2	6.7	1.8	1.7	1.7	2.0	2.1	2.5	0.0	3.6
Solar Energy Programs (SEP)	0.2	0.4	0.4	1.1	1.4	6.6	5.0	2.8	0.5	0.6
Vehicle and Engine R&D (VERD)	0.0	0.2	0.2	0.3	0.3	0.2	0.4	0.2	0.1	0.0
Other Offices	0.3	0.1	0.1	0.8	4.6*	0.2	0.1	0.0	0.0	0.0

*Includes $4.2 million transferred to Advanced Technology Projects from Conservation and Renewable Energy.

Table 2a. FY 1984 Mission-Related Hydrogen Energy Research and Development by DOE Program Element (dollars in millions)

Division/Projects	Total	Production	Storage	Transport/ Materials	End Use
DOE Hydrogen R&D Totals	3.54	1.79	1.00	0.35	0.40
Basic Energy Sciences (BES)	0.70	0.20	0.50	0.0	0.0
Chemistry of Thermochemical Hydrogen Cycles	0.20	0.20	0.0	0.0	0.0
Hydride Research	0.50	0.0	0.50	0.0	0.0
Energy Systems Research (ESR)	2.00	0.90	0.50	0.20	0.40
Hydrogen Production	0.90	0.90	0.0	0.0	0.0
Hydrogen Storage	0.70	0.0	0.50	0.20	0.0
End-Use of Hydrogen	0.40	0.0	0.0	0.0	0.40
Fossil Energy (FE)	0.15	0.15	0.0	0.0	0.0
Low Cost Hydrogen Production from Coal					
Solar Energy Programs (SEP)	0.54	0.54	0.0	0.0	0.0
Solar Thermal Hydrogen					
Vehicle and Engine R&D (VERD)	0.15	0.0	0.0	0.15	0.0
Stirling Engine Materials Evaluations					

Table 2b. FY 1984 Non-Mission-Related Hydrogen Research and Development by DOE Program Element (dollars in millions)

Division/Projects	Total	Basic Studies	Long-Range Hydrogen Energy: Production	Storage	Transport/ Materials	End Use
DOE Hydrogen R&D Totals	**19.31**	**13.95**	**0.60**	**0.04**	**4.72**	**0.0**
Basic Energy Sciences (BES)	**12.60**	**12.60**	**0.0**	**0.0**	**0.0**	**0.0**
Photochemical Generation of Hydrogen	9.40	9.40	0.0	0.0	0.0	0.0
Materials and Hydride Research	1.90	1.90	0.0	0.0	0.0	0.0
Biological Mechanisms of Hydrogen Generation	1.30	1.30	0.0	0.0	0.0	0.0
Inertial Fusion (IF)	**2.55**	**1.35**	**0.0**	**0.0**	**1.20**	**0.0**
Hydrogen Related Studies in Support of Fusion Energy Devices						
Military Application (OMA)	**3.56**	**0.0**	**0.0**	**0.04**	**3.52**	**0.0**
Ultrahigh Pressure Studies of Hydrogen	0.22	0.0	0.0	0.0	0.22	0.0
Thermodynamics and Kinetics of Metal Hydrides	0.40	0.0	0.0	0.0	0.40	0.0
Hydrogen Compatibility of Materials*	2.50	0.0	0.0	0.0	2.50	0.0
Tritium Permeability of Low Permeability Metals	0.15	0.0	0.0	0.0	0.15	0.0
Plutonium Hydriding Kinetics	0.15	0.0	0.0	0.0	0.15	0.0
Intermetallic and Mixed Hydrides	0.10	0.0	0.0	0.0	0.10	0.0
Tritium Storage in Zeolites	0.04	0.0	0.0	0.04	0.0	0.0
Solar Energy Programs (SEP)	**0.60**	**0.0**	**0.60**	**0.0**	**0.0**	**0.0**
Biological Hydrogen Production						

*Includes $0.3 million project under Defense Programs/Nuclear Materials.

DOE PROGRAM DESCRIPTIONS

Basic Energy Sciences (BES)

The BES research relevant to the DOE hydrogen program is supported within three divisions: Chemical Sciences, Biological Energy Research, and Materials Sciences. The broad objectives of the research are to understand those chemical, physical, and biological problems that are related to such topics as thermochemical, photochemical, electrolytic, and biological hydrogen production; hydrogen storage in hydrides; and materials problems resulting from hydrogen embrittlement.

In the Division of Chemical Sciences, a variety of photochemical hydrogen research efforts are aimed at understanding the photosynthetic and biological processes which may lead to the utilization of solar energy. The photochemical research includes picosecond spectroscopy, prophyrin chemistry, photochemical mechanisms and kinetics, photoinduced electron transfer in mixed organic-inorganic systems, etc. Although very few of these projects are specifically and strictly aimed at hydrogen production, the photochemistry is relevant to hydrogen production as well as to the production of electricity or other fuels. Chemical research on hydrides related to the storage of hydrogen includes synthesis, characterization, and property studies of various hydride systems. The chemistry of hydrogen interactions and transport in pure metals, alloys, and metal/nonmetal compounds is studied to aid in the design of materials with specified thermal and kinetic properties and increased potential for hydrogen storage.

The Biological Energy Research program explores hydrogen production in a variety of organisms (algae, bacteria, etc.). In this program, emphasis is on defining the mechanisms by which hydrogen is evolved and quantitatively establishing the parameters governing hydrogen production.

Materials Sciences research efforts focus primarily on the effects of hydrogen on the properties of materials, the structure and behavior of hydrides, and hydrogen embrittlement studies. Topics include the structure of transition metals and rare earth hydrides for energy storage, thermodynamics, hydrogen solubility in solids and liquids, hydrogen occupancy sites within the crystal structure, diffusion, hydrogen trapping sites at lattice defects, internal reactions such as hydrogen or methane bubble formation, hydrogen-dislocation interactions, electrical conductivity of hydrides (superconductivity), surface-induced phenomena, use of ion accelerators for proton implantation or bombardment for simulation of irradiation creep, and development of neutron scattering/diffraction methods.

Energy Systems Research (ESR)

The Chemical/Hydrogen Energy Systems Program, sponsored by ESR, includes projects in hydrogen production, storage/transport, and end-use. During FY 1984, the C/HES Program continued to focus on far-term, high-risk/high-payoff research efforts with the aim of developing a technology base for hydrogen not tied to specific applications.

A key hydrogen production project is the work at Westinghouse on high temperature (1000°C) water vapor electrolysis (HTE). The advantage of this approach is that part of the energy for water decomposition is introduced as thermal input, reducing the less efficient and more expensive electrical input. During FY 1984, Westinghouse accumulated several thousand test-hours on cells based on solid oxide fuel cell technology, operating in the reverse or electrolysis mode. Several systems studies were completed to assist in defining process requirements, operating conditions, and associated economics. Westinghouse also completed a facility for the fabrication of HTE cells. Supporting research at the University of Illinois is establishing correlations between solid oxide electrode/electrolyte microstructure (e.g., porosity and surface state) and polarization behavior.

In a parallel effort aimed at reducing the operating cell voltage in water electrolysis, Brookhaven National Laboratory (BNL) continued investigations of anode depolarization processes. Subsequent to studies on the use of coal as a depolarizing agent which were terminated because of poor kinetics, several promising two step redox couple reaction systems were identified--a typical one involving the oxidation of toluene to benzoic acid.

Research efforts were initiated during FY 1984 on three advanced storage concepts: (1) hydrogen spill-over on palladium catalyzed carbon (Syracuse University), (2) electrochemically-enhanced storage in metal hydrides (Stanford University), and (3) vanadium-based hydrides (Allied Corporation). Ongoing hydrogen embrittlement studies at Battelle Columbus Laboratories and BNL have dealt with low-cycle fatigue cracks and the use of additives to inhibit embrittlement in pipeline steels. Since last year, Battelle has issued two comprehensive reports on this work and has initiated surface-science/fatigue-testing investigations aimed at defining the mechanism of inhibition.

In the final storage-related activity, SOCAL/Solar Turbines completed a design study aimed at optimizing heat/mass transfer in rapid cycling metal hydride devices such as compressors and heat pumps. The final phase of testing showed improved utilization of hydride but also underlined the importance of minimizing sensible heat losses.

The main end-use activity involved the achievement of operational status at BNL of a Hydrogen Technology Evaluation Center (HTEC) which incorporates a 5 kW photovoltaics array. During FY 1984, a 15 kW General Electric SPE electrolyzer was installed and was operated in conjunction with the array. The HTEC has the capability to serve as a test bed facility for projects involving organizations such as the International Energy Agency (IEA), as well as domestic and European manufacturers.

In addition to the major activities described above, BNL has conducted a substantial planning/technology assessment function, supporting research in most technical areas and assisting DOE in the IEA.

Fossil Energy (FE)

Hydrogen R&D, under coal conversion programs, is primarily concerned with obtaining hydrogen from coal for use in further processing of coal. It is mainly limited to the production of synthesis gas (CO and H_2) for reaction purposes. Although the processes under development are not intended for hydrogen manufacture in the usual sense, they can easily be modified to accomplish this, if required. A very limited effort is being expended on studies for low cost hydrogen production from coal.

Fuel processors are an integral part of fuel cell powerplant design and concern the generation of hydrogen-rich fuel streams. DOE-sponsored fuel cell programs have been reoriented to focus on the relatively high-risk cell and stack areas while the burden of continued fuel processor development has been left to the private sector. None of the current fuel processor development efforts is funded by DOE.

Fusion Energy (OFE)

The primary objective of the hydrogen-related projects within the OFE program has been the evaluation of the potential application of fusion energy for production of chemical synfuels. The program activities are focused on the preliminary conceptualization of fusion blanket systems and the assessment of high temperature electrolytic and/or chemical processes for the production of hydrogen. Preliminary cycle flow sheets and engineering analysis of blanket configurations have been developed for the thermochemical and high temperature electrolysis cycle. These hydrogen R&D projects were completed in FY 1983.

Inertial Fusion (IF)

In the inertial fusion process, energy is produced through the fusion of deuterium and tritium fuel contained in tiny glass or metal spheres referred to as pellets. The hydrogen-related research within the program consists of: (1) developing fabrication techniques for inertial confinement fusion pellets containing the hydrogen isotopes deuterium and tritium, (2) studying the physical and chemical properties of cryogenic deuterium and tritium, (3) determining the effects of deuterium and tritium on the strength of inertial confinement fusion pellet materials, (4) studying the permeation of deuterium and tritium through various fuel pellet shells at both elevated and room temperatures, and (5) determining the potential for using inertial confinement fusion to produce hydrogen.

Military Application (OMA)

Research on hydrogen for military applications is continuing and can be expected to remain important for the foreseeable future. Information developed in the unclassified research projects may be of interest to other users of hydrogen. Research areas include compatibility and interaction of hydrogen with various materials, electrical properties of solid deuterium and tritium, and ultrahigh pressure studies.

Solar Energy Programs (SEP)

Hydrogen research involving solar energy had been principally conducted by the Office of Solar Energy Programs, which was abolished at the beginning of FY 1982. The various projects are now conducted in two divisions: Solar Thermal Technology and Biomass Energy Technology.

The scope of hydrogen-related research in the Solar Thermal Technology program includes the development of thermochemical and photochemical cycles for the production of hydrogen from solar heat sources. Particular emphasis is given to high temperature reactions driven by central receiver power sources, such as occur in the water-splitting sulfuric acid cycle, to produce hydrogen fuel.

The Biomass Energy Technology activity is concerned with the production of hydrogen from renewable resources and emphasizes the photobiological approach, specifically biophotolysis, to produce hydrogen from water using sunlight. Photosynthetic bacteria, cyanobacteria, and algae, as well as in vitro experiments, are being conducted.

Vehicle and Engine R&D (VERD)

R&D projects related to hydrogen fuel for transportation have been phased out. The activity has been concentrated in the areas of engine adaptation and on-board fuel storage. A data base has been established that provides the effects of operating conditions, design adaptation, and operational adjustments on engine performance when using hydrogen fuel, so that designers can proceed with the first generation, optimized engine design. A broad range of on-board fuel storage techniques have been assessed, and the limitations thereof have been determined. The most favorable system with regard to size and weight, using liquid hydrogen (LH_2), requires more than twice the volume and four times the weight of an equivalent amount of gasoline.

Although hydrogen fuel projects are complete, investigations into hydrogen embrittlement and hydrogen permeability of high temperature alloys are being conducted as part of the Automotive Stirling Engine (ASE) program. The ASE uses hydrogen as a contained working fluid at high temperature (1500°F) and high pressure (2200 psi). Emphasis is placed on identifying existing and developing new alloys whose strategic element content is minimal. The effects of exposure to hydrogen on the mechanical properties of several casting and tubing alloys are being measured. Hydrogen permeability data are being obtained for both commercial alloys and new experimental alloys in high-purity hydrogen and in hydrogen doped with CO and CO_2.

Other Offices

Other DOE offices which have interest in hydrogen programs but do not presently fund research include the Energy Information Administration (EIA), Health and Environmental Research (HER), Nuclear Energy (NE), Operational Safety (OS), and Policy, Planning and Analysis (PE).

APPENDIX A

DOE HYDROGEN RESEARCH

TECHNOLOGY SUMMARY FORMS

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Basic Energy Sciences (BES)

TOPIC Photochemical Generation of Hydrogen

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X*

COGNIZANT DIVISION Chemical Sciences PRINCIPAL CONTACT M.E. Gress PHONE 301-353-5820

OTHER SPONSORING ORGANIZATION(S) ______ CONTRACTOR(S) ______

SUMMARY DATE October 1984 START DATE 1974 SCHEDULED COMPLETION ______ STATUS ______

FUNDING ($$10^6$) FY 1983 8.7 FY 1984 9.4 FY 1985 9.5 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To provide basic understanding of the chemistry of solar conversion processes.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Research in this area is aimed at the conversion of solar energy into a chemically usable form (as distinct from heat).

SUMMARY:

The research involves investigation of model systems and artificial photosynthesis, photoelectrochemical and photochemical cycles and reactions, photogalvanic phenomena, etc. Much of the work is at so fundamental a stage that we do not differentiate systems which might deliver hydrogen and those that might deliver electricity. The research projects in this program, which individually are relatively small, are located at ANL, BNL, LBL, SERI, The Notre Dame Radiation Laboratory, and approximately 20 universities.

*Clearly related to the energy conversion mission of DOE, while only tenuously related to the narrow area of hydrogen technology.

NEXT PHASE:

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Basic Energy Sciences (BES)

TOPIC Hydride Research

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Chemical Sciences PRINCIPAL CONTACT John L. Burnett PHONE 301-353-5802

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) Mound Laboratory, Brookhaven & Lawrence Livermore Nat'l. Labs.

SUMMARY DATE September 1984 START DATE 1966 SCHEDULED COMPLETION ____ STATUS Ongoing

FUNDING ($$10^6$) FY 1983 0.8 FY 1984 0.5 FY 1985 0.4 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To discover new hydrogen-storing compounds, to understand the chemistry of hydrogen interactions and transport in hydride systems.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The purpose is twofold: (1) enlarge our understanding of the chemical interactions of hydrogen with matter and (2) provide the understanding important to the economical and safe storage of hydrogen. Reversible hydrogen reactions with metallic and inorganic substances constitute a chemical approach to energy storage. Understanding the chemistry, thermodynamics, and transport of hydrogen as it interacts with storage materials strengthens our capability to improve such energy storage systems.

SUMMARY:

The research includes synthesis, characterization and property studies of hydride systems relevant to the storage of hydrogen. The hydrogen chemistry of pure metals, alloys, and metal-nonmetal compounds is studied to characterize important thermodynamic, structural, electronic and transport properties which aid in the design of materials with potential for hydrogen absorption.

NEXT PHASE:

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Basic Energy Sciences (BES)

TOPIC Chemistry of Thermochemical Hydrogen Cycles

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Chemical Sciences PRINCIPAL CONTACT John L. Burnett PHONE 301-353-5802

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) Los Alamos National Laboratory

SUMMARY DATE September 1984 START DATE 1974 SCHEDULED COMPLETION 1984 STATUS Terminating

FUNDING ($\$10^6$) FY 1983 0.3 FY 1984 0.2 FY 1985 0 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To provide the scientific base, principally inorganic chemistry, for identifying, evaluating and improving potential thermochemical cycles for hydrogen production. Research efforts include thermochemistry, characterization of reaction products, kinetics and mechanisms of reactions, mass and thermal transport, etc.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Understanding the chemistry of water-dissociating cycles provides insights for cycle modification and improvement. Thermochemistry research enables the evaluation of proposed schemes and is instrumental in leading to entirely new concepts of releasing hydrogen from water. The dissociation of water by thermochemical cycles has potential efficiency advantages over other concepts for water dissociation.

SUMMARY:

This research includes high temperature and inorganic chemistry to identify the reactions, thermodynamic properties of reactants and products, rates of reactions, etc. for water dissociation. Both exploratory and in-depth experimental research is carried out. The emphasis is on understanding the basic chemistry relevant to currently identified thermochemical cycles and is important to identifying new and improved approaches to thermochemically dissociating water.

NEXT PHASE:

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Basic Energy Sciences

TOPIC Hydrogen Effects on Solids and Properties of Hydrides

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Materials Sciences PRINCIPAL CONTACT L. Ianniello PHONE 301-353-3427

OTHER SPONSORING ORGANIZATION(S) ______ CONTRACTOR(S) Universities, DOE Labs.

SUMMARY DATE September 1984 START DATE ______ SCHEDULED COMPLETION ______ STATUS Continuing

FUNDING ($$10^6$) FY 1983 1.8 FY 1984 1.9 FY 1985 1.9 TO COMPLETION ______

OBJECTIVE (OR GOAL):

This is basic materials research aimed at increasing the understanding of hydrogen effects such as diffusion and embrittlement of solids and the properties of hydrides as a class of materials.

PURPOSE (BACKGROUND AND REASON FOR WORK):

To increase the understanding of hydrogen-related phenomena in solids--an important subject underlying many DOE technologies such as Fossil Energy, Fusion Energy, Defense Programs, Conservation Technologies and Solar Energy, as well as Hydrogen Production.

SUMMARY:

A wide spectrum of research is conducted covering both the interaction of hydrogen with materials and the formation, properties, and behavior of hydrides. Research is underway on hydrogen embrittlement, stress corrosion cracking, diffusion of hydrogen and hydrogen isotopes, hydrogen attack, structure of hydrides using neutron scattering, superconducting properties of hydrides, thermodynamics of metal hydrogen systems, hydrogen solubility and hydride precipitation, transmission electron microscopy of hydriding and de-hydriding, hydrogen trapping at defects, electrical and magnetic properties of hydrides, absorption and other surface-related phenomena. Additional information can be obtained from the publication DOE/ER-0143/2 "Materials Sciences Programs-Fiscal Year 1984."

NEXT PHASE:

*These funding levels represent a narrower, more focused definition of hydrogen-related research than was reported in previous years.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Basic Energy Sciences (BES)

TOPIC Biological Mechanisms of Hydrogen Generation

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Biological Energy Research PRINCIPAL CONTACT R. Rabson PHONE 301-353-2873

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) ______

SUMMARY DATE October 1984 START DATE ______ SCHEDULED COMPLETION ______ STATUS Ongoing

FUNDING ($$10^6$) FY 1983 1.5 FY 1984 1.3 FY 1985 1.3 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To generate an understanding of biological hydrogen generation and metabolism in a broad cross section of organisms.

PURPOSE (BACKGROUND AND REASON FOR WORK):

To explore biological systems as a means to develop a hydrogen generating technology based on biological principles using solar energy as the driving force. Furthermore, the utility of hydrogen as a driving force for biological synthetic reactions in microorganisms as a prospective biotechnology basis is studied.

SUMMARY:

The biological research is designed to explore the mechanisms by which hydrogen is evolved in various biological systems including algae and various heterotropic microorganisms. The aim is to understand the mechanisms of production, transfer, and utilization of hydrogen in these forms. Thus attention is given to the hydrogenase reactions as well as studies of the enzyme itself with a significant segment of this work relating to photosynthetic mechanisms. In addition, the way in which anaerobic microorganisms transfer hydrogen between species to drive bioconversion is also studied.

NEXT PHASE:

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Energy Systems Research (ESR)

TOPIC Hydrogen Production

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Energy Storage Technology PRINCIPAL CONTACT M. Gurevich PHONE 202-252-1507

OTHER SPONSORING ORGANIZATION(S) ____ CONTRACTOR(S) Westinghouse, U. of Virginia, U. of Illinois, Brookhaven National Laboratory

SUMMARY DATE September 1984 START DATE 1975 SCHEDULED COMPLETION ____ STATUS Ongoing

FUNDING ($$10^6$) FY 1983 1.0 FY 1984 .9 FY 1985 .65 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To develop methods for producing hydrogen based mainly on electrolysis which will provide a viable alternative to the direct use of fossil resources. The program emphasis is on longer-range research to significantly reduce the electrical energy input required to produce hydrogen.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The program in recent years has focused on the conversion of remote renewable resources to hydrogen for use as an energy carrier and fuel/chemical commodity. The primary aim is to increase the overall thermal efficiency of these systems through advanced materials, processes or the use of available thermal inputs. The program continues to seek new ideas and novel concepts for hydrogen production. During 1984, projects were selected for negotiations in the areas of photoelectrolysis and in solid electrolytes for medium temperature electrolysis. The contractors were selected based on a competitive procurement.

SUMMARY:

Westinghouse demonstrated operation of HTE cells at 1.2 Volts, 300 A/ft^2 and identified cross diffusion limitations for H_2/H_2O ratios above 50%. Westinghouse also completed construction of a dedicated cell processing facility and will begin to produce and optimize cells for electrolysis research. Anode depolarization studies at BNL and Texas A&M based on using coal/coal derivatives were terminated after verifying kinetics limitations. Additional efforts showed that a two-step redox couple approach for synthesizing organic substances shows some promise. A collaborative effort between BNL and a Politecnico di Milano researcher identified a class of hydrated phosphates of aluminum that show promise as proton conducting electrolytes for medium temperature electrolysis. A low level research effort with SUNY Stony Brook was continued looking at phthalocyanine thin film metal oxide electrodes for photoelectrolysis systems.

NEXT PHASE:

Westinghouse will focus on defining the polarization behavior of the cathode and cell interconnect materials. Studies of proton conducting materials will continue at BNL and Politecnico di Milano characterizing mixed protonic acids of phosphorus, arsenic, antimony in terms of stability, conductivity and related properties. The University of Pennsylvania will investigate alternate methods of making polycrystalline B" alumina and Battelle will initiate work on polymer-coated photoelectrodes for use in hydrogen production by photoelectrolysis.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Energy Systems Research (ESR)

TOPIC Hydrogen Storage

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED x NON MISSION-RELATED ____

COGNIZANT DIVISION Energy Storage Technology PRINCIPAL CONTACT M. Gurevich PHONE 202-252-1507

OTHER SPONSORING ORGANIZATION(S) ____ CONTRACTOR(S) Southern Calif. Gas Co., Battelle Memorial Institute, Allied Corp. Stanford Univ., Syracuse Univ.

SUMMARY DATE September 1984 START DATE 1976 SCHEDULED COMPLETION ____ STATUS ____

FUNDING ($$10^6$) FY 1983 0.6 FY 1984 0.7 FY 1985 0.5 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To identify, develop, and characterize various hydrogen storage options offering weight/volume/cost improvements over compressed gas and liquid storage systems as may apply to utility load leveling, stationary storage needs or mobile transport/storage requirements. During FY 1984 emphasis was placed on evaluating advanced concepts and longer range research in hydrogen storage.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Improved hydrogen storage systems are required to complement developments in advanced production technology. Metal hydrides, underground storage, microencapsulation, the use of cryoadsorbents and other novel concepts are among the options pursued. The use of the natural gas pipeline system is also being considered for both transport and storage. The need is for low-cost, high-capacity storage systems, especially for mobile storage options.

SUMMARY:

Syracuse University has conducted experiments that confirm the potential of a metal-assisted cold storage concept of storing hydrogen in catalyst coated activated carbon. Stanford has shown that the absorption of hydrogen in a metal hydride can be controlled using electrochemical methods and demonstrated this using a NaH electrolyte in a low melting organometallic salt solvent system. Battelle completed its H_2 embrittlement studies quantifying the effects of hydrogen and low-cycle fatigue on pipeline steels, and also identified inhibitors to minimize these effects. Allied Corporation initiated studies of vanadium-based metal hydrides for possible use in H_2 storage systems. SOCAL/Solar Turbines design study is aimed at optimizing mass/heat exchange in rapid-cycling metal hydride systems such as air conditioners and heat pumps.

NEXT PHASE:

The first year feasibility studies will be completed on the three advanced hydrogen storage concepts: Syracuse will investigate H_2 storage in catalyzed carbon in a scaled-up experiment; Stanford will explore alternate electrolyte/metal hydride combinations more suitable to practical hydrogen storage applications requirements; Allied Corporation will define the vanadium-based hydride system most compatible with storage applications and evaluate the suitability of ferro vanadium ore as the primary resource. Battelle will conduct surface science investigations coupled with materials testing to help define the mechanism of inhibition of H_2 embrittlement.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Energy Systems Research (ESR)

TOPIC End-Use of Hydrogen

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED x NON MISSION-RELATED ____

COGNIZANT DIVISION Energy Storage Technology PRINCIPAL CONTACT M. Gurevich PHONE 202-252-1507

OTHER SPONSORING ORGANIZATION(S) ____ CONTRACTOR(S) Brookhaven National Laboratory, General Electric, Solarex

SUMMARY DATE September 1984 START DATE 1979 SCHEDULED COMPLETION ____ STATUS Ongoing

FUNDING ($$10^6$) FY 1983 .5 FY 1984 .4 FY 1985 .1 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To illustrate the technical and interface aspects of hydrogen production/storage/transport systems in a user environment. The emphasis in FY 1984 was on longer-term base technology development and on exploring ties with future primary energy resources.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The ultimate ties of hydrogen technology to renewable resource conversion are clearly recognized. As various components and systems reach advanced stages of development, it is necessary to confirm their ability to interface with these resources. As one promising option, solar-photovoltaics represent a potentially cost-effective source of energy for producing hydrogen from water. Logically, illustration of advanced storage, transport and end-uses would follow.

SUMMARY:

The major project in this area is the work being conducted in BNL's Hydrogen Technology Evaluation Center (HTEC). This facility became operational in FY 1984 with the installation and checkout of the 15 kW General Electric SPE electrolyzer which was coupled with the existing 5 kW Solarex photovoltaics array. Steady state baseline tests were conducted and a computer/simulation model for evaluating system performance was developed and verified. Problems have developed with the electrolyzer, requiring repair at the manufacturer's facility, and testing has been dropped pending its return. In a separate test program, a performance mapping of a metal hydride hydrogen compressor provided by Ergenics was completed. The HTEC was also used by representatives from the University of Hawaii, Florida State Energy Center, and MIT for training/familiarization activities.

NEXT PHASE:

During the next phase, the PV/electrolyzer interface test program will be completed and a summary report will be issued describing cost/performance characteristics of such systems. Performance testing will also be conducted in association with PSE&G on a full-scale metal hydride compressor suitable for utility applications in generator cooling systems.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Fossil Energy (FE)

TOPIC Technical Evaluation and System Analysis of Hydrogen Production from Coal

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION METC: Coal Projects Management Div. PRINCIPAL CONTACT METC - Sophie Lai Eos - J. Bartis PHONE FTS 923-4105 703-522-6611

OTHER SPONSORING ORGANIZATION(S) ____ CONTRACTOR(S) Eos Technologies, Inc.

SUMMARY DATE October 1984 START DATE April 1984 SCHEDULED COMPLETION August 1984 STATUS ____

FUNDING ($$10^6$) FY 1983 0 FY 1984 0.01 FY 1985 0 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To conduct technical and systems evaluation of the most suitable coal gasification and gas separation technology to produce hydrogen at a minimum cost.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The abundant quantities of coal in the United States as well as the more favorable energy requirement and relative costs for producing hydrogen favors coal as the source for hydrogen production. The purpose of the project is to evaluate various suitable gasification, gas separation and gas upgrading technologies as a system to produce hydrogen from coal. In addition, the impact of a given unit operation or technology on the cost of hydrogen will be analyzed and further potential R&D needs will be identified to reduce costs of hydrogen.

SUMMARY:

The project consists of technical evaluation and system analyses of coal to hydrogen process via coal gasification; sensitivity analysis of the process selected and identification of potential areas of research and development to minimize the cost of hydrogen.

NEXT PHASE:

To investigate new approaches to enhance recovery of available hydrogen in coal by efficient gas separation techniques.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Fossil Energy (FE)

TOPIC Low Cost Hydrogen Production from Low-Rank Coals

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Surface Coal Gasification

PRINCIPAL CONTACT Leland E. Paulson PHONE FTS 783-0165

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) University of North Dakota Energy Research Center

SUMMARY DATE October 1984 START DATE FY 1983 SCHEDULED COMPLETION ____ STATUS ____

FUNDING ($\$10^6$) FY 1983 0.080 FY 1984 0.140 FY 1985 0 TO COMPLETION 0.140

OBJECTIVE (OR GOAL):

The objective of the project is to determine the feasibility of producing low cost hydrogen from low-rank coal. Fundamental mechanisms and reaction rates, including an understanding of autocatalytic activity of inherent coal alkalies, will be determined. Preferred method for PDU-scale production of hydrogen will be identified.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Significant research previously has been performed on catalytic high-rank coal gasification which culminated in the pilot-scale Exxon Catalytic Gasification Process. The Exxon Process, which was designed to produce SNG autothermally, used K_2CO_3 and featured cryogenic CH_4 separation with $CO + H_2$ recycle to the gasifier. Many of the same principles used to produce methane can be used to produce hydrogen. To maximize hydrogen production during gasification, thermodynamics dictate relatively low reaction temperatures for the shift reaction but not as low as required for CH_4 optimization. In contrast to higher rank coals, reasonable gasifier throughputs may be expected with highly reactive low-rank coals. Also, low-rank coals have high inherent alkali concentration, which might provide sufficient alkali catalyst for producing hydrogen.

SUMMARY:

A report giving theoretical calculations, equipment configuration, and process economics for low cost hydrogen production by single vessel catalytic gasification of low-rank coal is being prepared. Bench-scale tests of the steam-carbon and shift reactions are being performed at atmospheric pressure and 1300°F to compare hydrogen production from highly reactive low-rank coals [Indian Head (North Dakota) lignite, Wyodak (Wyoming) subbituminous coal, and Martin Lake (Texas) lignite]. Disposal catalysts (potassium/sodium carbonates and recycled ash) will be tested with the most reactive coal. Uncatalyzed North Dakota lignite is more reactive to steam than subbituminous, with product gas in both cases containing about 60% hydrogen, 30% carbon dioxide and traces of carbon monoxide and methane.

NEXT PHASE:

Tests will be performed adding catalysts with coal to increase gas production rate. Bench-scale testing data will be used to verify equation model predictions. The laboratory work combined with the modeling will be used to demonstrate the feasibility of low-rank coal hydrogen production. If results from bench-scale work indicate that low cost hydrogen from low-rank coal appears feasible, preferred process will be identified and PDU-scale work initiated.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Fusion Energy (OFE)

TOPIC Fusion High Temperature Electrolysis

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Development and Technology PRINCIPAL CONTACT A.L. Opdenaker PHONE 353-4954

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) Brookhaven National Laboratory

SUMMARY DATE October 1984 START DATE October 1979 SCHEDULED COMPLETION September 1983 STATUS Complete

FUNDING ($\$10^6$) FY 1983 0.22 FY 1984 0 FY 1985 0 TO COMPLETION 0

OBJECTIVE (OR GOAL):

Evaluate the potential for production of hydrogen from fusion via the high temperature electrolysis process.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Evaluate non-electric applications of fusion energy.

SUMMARY:

The HYFIRE II Fusion/High-Temperature Electrolysis Conceptual Design Study was brought to a conclusion in FY 1983. The study focused on coupling a commercial-sized tokamak fusion reactor with a high-temperature blanket to a state-of-the-art high-temperature electrolysis process for producing hydrogen and oxygen. The results of this study are reported in BNL-33701.

NEXT PHASE:

None; this project was completed in FY 1983.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Fusion Energy (OFE)

TOPIC Fusion Thermochemical Production of Hydrogen

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Development and Technology PRINCIPAL CONTACT A.L. Opdenaker PHONE 353-4954

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) Lawrence Livermore National Lab.

SUMMARY DATE October 1984 START DATE October 1974 SCHEDULED COMPLETION September 1983 STATUS Complete

FUNDING ($$10^6$) FY 1983 0.43 FY 1984 0 FY 1985 0 TO COMPLETION 0

OBJECTIVE (OR GOAL):

Evaluate the potential for production of hydrogen from fusion via the thermochemical process.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Evaluate non-electric applications for fusion.

SUMMARY:

In FY 1983, a study was completed for coupling the Mirror Advanced Reactor Study (MARS) high temperature blanket design concept with a sulfur-iodine thermochemical cycle to produce hydrogen. Also, the design of a fluidized bed decomposer, which is a key element in the high temperature step of a thermochemical plant, was completed.

NEXT PHASE:

None; this project was completed in FY 1983.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Inertial Fusion

TOPIC Hydrogen-Related Studies in Support of Fusion Energy Devices

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Fusion Research **PRINCIPAL CONTACT** M.A. Stroscio **PHONE** 301-353-3106

OTHER SPONSORING ORGANIZATION(S) None **CONTRACTOR(S)** Lawrence Livermore National Lab.

SUMMARY DATE October 1984 **START DATE** ______ **SCHEDULED COMPLETION** ______ **STATUS** Ongoing

FUNDING ($$10^6$) FY 1983 1.0 FY 1984 1.4 FY 1985 1.8 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To develop advanced fabrication techniques for Inertial Confinement Fusion (ICF) targets.

PURPOSE (BACKGROUND AND REASON FOR WORK):

This work is performed to support ICF research and development. In ICF, energy is produced through the fusion of deuterium and tritium fuel contained in small spheres (referred to as targets). The hydrogen-related research is concerned with the fabrication methods and processes for the production of these targets.

SUMMARY:

Techniques are developed for handling gaseous, liquid and solid D_2, HD, DT and pure molecular DT. As a result of fusion physics studies, it is possible to improve the energy output of targets if the fuel is condensed or solid. Therefore, fundamental studies of materials which lead to the formation of liquid and solid fuel layering are studied. These studies include phase separation effects during condensation and surface topography of the fully condensed fuels. The formation of low atomic number hydrogen compounds and their deterioration as a result of beta-decay are also studied. Hydrogen isotope diffusion rates, through low-Z materials at various temperatures, is also studied as it significantly affects filling of the low-Z targets. The synthesis of molecular DT and its atomic spin polarization (SP) has recently become of great interest because of significant target gains possible when implosions are performed with SP fuel.

NEXT PHASE:

It is anticipated that work of the same general nature will continue in support of ICF R&D, at least through 1987.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Inertial Fusion

TOPIC Hydrogen-Related Studies in Support of Fusion Energy Devices

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED x

COGNIZANT DIVISION Fusion Research PRINCIPAL CONTACT M.A. Stroscio PHONE 301-353-3106

OTHER SPONSORING ORGANIZATION(S) ______ CONTRACTOR(S) KMS Fusion, Inc.

SUMMARY DATE October 1984 START DATE ______ SCHEDULED COMPLETION ______ STATUS ______

FUNDING ($$10^6$) FY 1983 0.42 FY 1984 0.85 FY 1985 0.95 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To determine the physical properties of cryogenic mixtures of deuterium and tritium (DT). To study effects of the beta-decay of tritium on the properties of glasses and polymers and the temperature dependent permeability of the hydrogen isotopes through various polymers.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The work is performed to support inertial confinement fusion research and development. In inertial confinement fusion, energy is produced through the fusion of deuterium and tritium fuel contained in tiny spheres (referred to as pellets or targets) of glass or metal, some with polymer coatings. The fuel is "burned" by establishing high temperature and density conditions in the fuel through rapid compression or implosion of the pellet. The implosion process is the result of a very rapid heating and consequential ablation of the outer pellet surface by an intense, high energy beam of laser light or subatomic particles. The hydrogen-related research is concerned with fabrication methods and processes for the fuel pellets.

SUMMARY:

Techniques for forming and analyzing cryogenic (solid) films of deuterium and tritium are developed for inertial fusion applications. The effects of radiation-induced damage from the beta-decay of tritium on glass strength and surface smoothness and on polymer shells and coatings are investigated to determine the storage life of fuel containers for DT. The dependence of the permeation of hydrogen on glass compositon is studied.

NEXT PHASE:

It is anticipated that work of the same general nature will continue in support of inertial confinement fusion research and development at least through 1986.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Inertial Fusion (IF)

TOPIC Hydrogen-Related Studies in Support of Fusion Energy Devices

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED x

COGNIZANT DIVISION Fusion Research

PRINCIPAL CONTACT M.A. Stroscio

PHONE 301-353-3106

OTHER SPONSORING ORGANIZATION(S) None

CONTRACTOR(S) Los Alamos National Laboratory

SUMMARY DATE October 1984

START DATE ______

SCHEDULED COMPLETION ______

STATUS Ongoing

FUNDING ($$10^6$) FY 1983 0.25 FY 1984 0.30 FY 1985 0.30 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To examine interaction of hydrogen with inertial confinement fusion pellet materials.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The work is performed to support inertial confinement fusion research and development. In inertial confinement fusion, energy is produced through the fusion of deuterium and tritium fuel contained in tiny spheres (referred to as pellets or targets) of glass or metal. The fuel is "burned" by establishing high temperature and density conditions in the fuel through rapid compression or implosion of the pellet. The implosion process is the result of a very rapid heating and consequential ablation of the outer pellet surface by an intense, high energy beam of laser light or subatomic particles. The hydrogen-related research is concerned with fabrication methods and processes for the fuel pellets.

SUMMARY:

The effort involves development of techniques, equipment, and diagnostics for filling inertial fusion targets with deuterium-tritium gas at high pressure. Hydrogen effects on the strength of inertial confinement fusion target materials are determined. Permeation of hydrogen isotopes through various fuel pellet shells is studied at both elevated and room temperatures. During the FY 85 and FY 86 period, plans are underway to fabricate simulated glass targets aboard the orbiting space shuttle. These targets will be used to study permeation rates of hydrogen in different glasses. Glass formulations will be limited by the shuttle equipment available for fabrication.

NEXT PHASE:

Work will be expanded to include the fabrication of shuttle-sized pellets terrestrially at th[e] University of Missouri, Rolla. It is anticipated that work will continue in support of inertial confinement fusion research and development at least through 1987.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Metal Hydride Systems

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) ______ **CONTRACTOR(S)** Los Alamos National Laboratory

SUMMARY DATE September 1984 **START DATE** prior to FY84 **SCHEDULED COMPLETION** N/A **STATUS** ongoing

FUNDING ($$10^6$) FY 1983 0.3 FY 1984 0.4 FY 1985 0.4 TO COMPLETION N/A

OBJECTIVE (OR GOAL):

To develop solid metal hydride systems for handling hydrogen isotopes. This includes high pressure pumps, storage beds for transportation and in-process storage, and separation systems.

PURPOSE (BACKGROUND AND REASON FOR WORK):

To support tritium processing activities for weapons.

SUMMARY:

Started measurements of PCT curves for palladium hydrides and deuterides. This work was in support of a program to use palladium hydrides to isotopically separate hydrogen isotopes. Also started investigations of hydrogen embrittlement of steel using Rutherford backscattering of deuterons. Started preliminary work on a high pressure tritium pump.

NEXT PHASE:

Continue PCT measurements of Pd to higher pressures and to include tritium. Continue use of Rutherford backscattering to investigate hydrogen embrittlement. Complete initial design of a high pressure tritium pump and start fabrication.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Ultrahigh Pressure Studies of Hydrogen

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) DOE/OBES/DMS **CONTRACTOR(S)** Los Alamos National Laboratory

SUMMARY DATE September 1984 **START DATE** before FY84 **SCHEDULED COMPLETION** N/A **STATUS** ongoing

FUNDING ($$10^6$) FY 1983 0.20 FY 1984 0.22 FY 1985 0.24 TO COMPLETION N/A

OBJECTIVE (OR GOAL):

To measure the physical and chemical properties of the hydrogen isotopes and hydrogen-containing simple molecules to static pressures approching 1 Mbar (15 million psi) using diamond-anvil cells.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Hydrogen is a strategic fuel in nuclear fusion. At ultrahigh pressures, H_2 is also expected to transform into a metal that may prove useful as a high-energy fuel and as a high-temperature superconductor. Furthermore, a study of the high-pressure chemistry of H_2 is vital to metal-hydride programs. And, finally, H_2 is the simplest diatomic available for experimental and theoretical study of molecular interactions.

SUMMARY:

Basic to an understanding of H_2 is a determination of its phase diagram. We measured the melting curves of H_2 and D_2 from 20° to 373°K (0 to 80 kbar) and fitted the data to Simon-type equations suitable for extrapolation. Values of the compressibility and Debye temperature were computed at melting and the results compare favorably with those calculated from various theoretical models.

NEXT PHASE:

We are now in a position to determine the equation of state of solid H_2 and D_2 up to 200 kbar by single-crystal x-ray diffraction in diamond cells. The results will be used to resolve conflicting measurements made by Brillouin scattering and by photographic and interferometric methods.

DOE Hydrogen Research and Technology Summary

OFFICE Military Application (OMA)

TOPIC Hydrogen Transport and Trapping in Metals

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) DOE/OMA **CONTRACTOR(S)** Sandia National Laboratories, Livermore

SUMMARY DATE 24 October 1984 **START DATE** FY80 **SCHEDULED COMPLETION** -- **STATUS** in progress

FUNDING ($$10^6$) FY 1983 .1 FY 1984 .1 FY 1985 .2 TO COMPLETION --

OBJECTIVE (OR GOAL):

The main objective of this research is to develop a better understanding of hydrogen transport in metals and the influence of surface processes on permeation and diffusion.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Sandia is involved in a number of areas which require an understanding of hydrogen transport in a variety of materials over a wide range of temperatures and pressures. For reasons of safety and inventory control, transport properties are required for material selection and design.

SUMMARY:

Our work is primarily involved with the measurement of hydrogen isotope permeability and diffusivity in a variety of materials intended to contain hydrogen. Emphasis is placed on the study of surface films (such as oxides) on these materials and their effect on hydrogen transport. Although most applications would benefit from the development of permeation barriers, some require materials with very high permeabilities, such as palladium alloys for the purification of hydrogen isotopes.

NEXT PHASE:

We are currently constructing an ultra-high vacuum permeation system with in-situ surface analysis (Auger and ESCA) and surface modification (argon sputter-cleaning, sputter deposition of various materials, and chemical vapor deposition). It will have the capability to measure permeabilities and diffusivities of all three isotopes. We will continue to study bulk material properties, including trapping effects, using our existing deuterium and tritium permeation systems.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Isothermal Decomposition Kinetics of Uranium Hydride

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) DOE/OMA **CONTRACTOR(S)** Sandia National Laboratories, Livermore

SUMMARY DATE 25 October 1984 **START DATE** June 1984 **SCHEDULED COMPLETION** June 1985 **STATUS** in progress

FUNDING ($$10^6$) FY 1983 .2 FY 1984 .3 FY 1985 .3 TO COMPLETION --

OBJECTIVE (OR GOAL):

Determine kinetics and mechanisms of the isothermal decomposition of uranium hydride with particular attention to hydrogen overpressure effects.

PURPOSE (BACKGROUND AND REASON FOR WORK):

In use as hydrogen storage media, metal hydrides will be decomposed in the presence of hydrogen gas, yet most studies of hydride decomposition kinetics involve decomposition into vacuum. Uranium hydride is a "classic" system for which no satisfactory decomposition data exists.

SUMMARY:

We find the decomposition to follow pseudo first order kinetics, with a pressure dependence of the form $\ln(p/p^o)$ where p^o is a plateau pressure derived from dynamic pressure-composition-temperature curves.

NEXT PHASE:

We are now measuring dynamic PCT curves for UH_3. When this task is completed, we will complete kinetic measurements for the system.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Hydrogen-Assisted Crack Growth of Austenitic Stainless Steels

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) DOE/OMA **CONTRACTOR(S)** Sandia National Laboratories, Livermore

SUMMARY DATE 25 October 1984 **START DATE** ____ **SCHEDULED COMPLETION** ____ **STATUS** in progress

FUNDING ($$10^6$) FY 1983 .5 FY 1984 .7 FY 1985 .7 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To obtain quantitative data on the hydrogen-induced crack growth susceptibility of high strength metals. To gain a fundamental understanding of the mechanisms of hydrogen embrittlement. To develop and identify new alloys and processing techniques for achieving hydrogen-compatible service.

PURPOSE (BACKGROUND AND REASON FOR WORK):

High strength austenitic stainless steels were thought for many years to be resistant to hydrogen-assisted cracking. We now have direct experimental evidence that this is not the case. Avoiding the onset of this failure process is the critical concern, particularly in the design of advanced hydrogen containment and storage systems.

SUMMARY:

Sandia has developed a unique measurement capability for quantitatively determining the long-term resistance of high strength metals to crack propagation in gaseous hydrogen. The observed effects of high pressure hydrogen on crack growth kinetics and thresholds are being used to determine the effect of various material and environmental conditions on crack growth, define embrittlement mechanisms, and evaluate models of hydrogen embrittlement.

NEXT PHASE:

Complete studies on the effects of grain size and hydrogen pressure on crack growth kinetics. Study the crack growth properties of welded, of hot isostatically pressed, and of cold worked materials.

DOE Hydrogen Research and Technology Summary

OFFICE Military Application (OMA)

TOPIC Computer Modeling of Hydrogen in Metals

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) MFE **CONTRACTOR(S)** Sandia National Laboratories, Livermore

SUMMARY DATE 23 October 1984 **START DATE** FY80 **SCHEDULED COMPLETION** -- **STATUS** continuing

FUNDING ($$10^6$) FY 1983 .5 FY 1984 .5 FY 1985 .6 TO COMPLETION --

OBJECTIVE (OR GOAL):

Development of computer codes to model hydrogen diffusion, trapping, and recombination in metals.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Tritium inventory and permeation in fusion reactors is a prime area of concern.

SUMMARY:

A computer code DIFFUSE 83 has been written and has been distributed internationally to interested researchers.

NEXT PHASE:

Inclusion of additional experimental data as it becomes available.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Hydrogen-Related Research

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED x

COGNIZANT DIVISION Weapons Research, Development, and Testing

PRINCIPAL CONTACT Y.T. Song PHONE 301-353-5350

OTHER SPONSORING ORGANIZATION(S) N/A

CONTRACTOR(S) Sandia National Laboratories, Albuquerque, NM

SUMMARY DATE 25 October 1984 START DATE ______ SCHEDULED COMPLETION ongoing STATUS in progress

FUNDING ($$10^6$) FY 1983 0.5 FY 1984 0.6 FY 1985 0.6 TO COMPLETION --

OBJECTIVE (OR GOAL):

Develop fundamental and quantitative understanding of hydrogen materials interactions which relate to hydrides, hydrogen embrittlement and interfaces in semiconductor devices.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Hydrides (deuterides and tritides) are used in storage applications related to neutron tubes (weapons and medical). Pressure vessels are used to store isotopes so embrittlement is an important consideration. Hydrogen profoundly affects the behavior of various device interfaces.

SUMMARY:

New ion beam analysis techniques were developed to measure fundamental hydrogen transport including diffusion, solubility, trapping, and surface recombination in metals. Nuclear reaction analysis measurements of hydrogen in silicon-based microelectronics are correlated with optical/ir measurements of hydrogen bonding and electrical measurements. Nuclear magnetic resonance, electron spin resonance (esr) and density-of-states-related measurements such as superconducting properties are used to probe the electronic structure of rare earth and Pd hydrides, deuterides and tritides. Supporting theoretical modeling of band structures, diffusion and phase diagrams are coupled with the experimental programs.

NEXT PHASE:

New surface physics capabilities will be integrated with ion beam analysis techniques to measure the effect of impurities on H permeation in metals. The effect of H-passivation of defects on the electrical properties of Si-based MOS/MNOS devices will be examined. Statistical mechanics of diffusion processes and esr diagnostics of amorphous hydrides will be coupled to enhance understanding of these materials. Total energy calculations for Sc, V and Zr hydrides will be completed. Capabilities of Sandia's tritium research laboratory (TRL) will be utilized to study the superconducting properties of 2 kbar T_2 charged Pdt_x.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Nuclear Materials

TOPIC Waste Isolation Pilot Plant (WIPP) Program

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION R&D and Byproducts **PRINCIPAL CONTACT** John J. Jicha **PHONE** 301-353-3031

OTHER SPONSORING ORGANIZATION(S) ______ **CONTRACTOR(S)** Sandia National Laboratories, Albuquerque, NM

SUMMARY DATE October 1984 **START DATE** October 1982 **SCHEDULED COMPLETION** October 1985 **STATUS** ______

FUNDING ($$\$10^6$$) FY 1983 .4 FY 1984 .3 FY 1985 .2 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To understand the hydrogen embrittlement process in Ti-base alloys (Ti-0.3 Mo-0.8 Ni).

PURPOSE (BACKGROUND AND REASON FOR WORK):

TiCode-12 (Ti-0.3 Mo-0.8 Ni) is being considered as a primary canister material for the long-term isolation and storage of nuclear wastes. One possible failure mode for the canisters is cracking from hydrogen embrittlement. As such, the susceptibility of this material is being investigated, leading, ultimately, to a qualification of the alloy as a suitable material.

SUMMARY:

A slight change in mechanical properties has been observed at relatively high hydrogen concentrations and/or input fugacities. Time-to-failure decreases, the material becomes less ductile, and the fracture mode exhibits larger areas of brittle failure.

NEXT PHASE:

(1) Assess the effects of gamma radiation on the hydrogen uptake and brittlement processes.

(2) Determine the effect of smeared iron on hydrogen uptake/embrittlement.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Tritium Permeation Measurement of Low Permeability Materials

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) ______ **CONTRACTOR(S)** Lawrence Livermore National Laboratory

SUMMARY DATE October 1983 **START DATE** FY81 **SCHEDULED COMPLETION** ______ **STATUS** ongoing

FUNDING ($$10^6$) FY 1983 ______ FY 1984 0.15 FY 1985 0.15 TO COMPLETION ______

OBJECTIVE (OR GOAL):

To make the first "low temperature" (25° to 200°C) measurements of tritium permeability on materials of low permeability.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Containment of tritium with minimum leakage is desired whenever tritium is handled. Low permeability materials are thus of great interest. Many low permeability materials have been tested only at high temperatures because permeation is too slow to easily measure at low temperatures. With our sensitive technique, we will provide permeation data for materials at low temperature where no data now exists.

SUMMARY:

Tritium gas permeates through a sample membrane and is incorporated into an organic liquid on the other side; we measure tritium buildup by liquid scintillation count. We have taken preliminary measurements on several materials, but are still resolving a few uncertainties in our technique. In particular, preparation of the sample surface has a dominant effect on measured permeability and must be carefully controlled. We are currently verifying our entire method with a series of tests on copper, for which good data already exists.

NEXT PHASE:

Other metals will be tested. Surface-modified metals (ion implanted and oxidized) will also be tested. Some metals of very low permeability will be tested in thin layers on Pd foils.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Intermetallic Hydrides and Mixed Hydrides

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED x

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) Sandia (Albuquerque) **CONTRACTOR(S)** Lawrence Livermore National Laboratory

SUMMARY DATE October 1984 **START DATE** 1982 **SCHEDULED COMPLETION** 1984 **STATUS** ____

FUNDING ($$10^6$) FY 1983 ____ FY 1984 0.1 FY 1985 0.3 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To determine the behavior of the hydrides of AB_5 alloys by means of phase diagrams (P-T-C) and custom tailor alloys to provide specific P-T-Composition characteristics for various applications. Determine the physical behavior of metal hydride powders.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Provide hydrogen pressure from a small compact source at temperatures of ambient and at ambient plus or minus 100°C. Also prepare double hydrides which have capacities greater than those of single hydride compounds.

SUMMARY:

The intermetallic hydrides can be custom made, i.e., tailored by the addition of small amounts of foreign elements (Fe, Mn, Cr, Al, etc.) to provide high dissociation pressures at temperatures below and above ambient conditions and at the same time possess high H_2 capacity, e.g., H_2/alloy ratios of about six. The space occupied by H_2 in this type of system is less than in a conventional gas cylinder. The Van't Hoff plot, P vs $^1/T$, should have a small slope, ΔH, so that pressures over temperature range do not vary much. Mixing two different alloy hydrides allows us to reap the benefits of both. We can release hydrogen at one constant pressure and then can release H_2 at another constant pressure, i.e., we get a step function behavior. Cerium nickel-5 alloy is one suitable for the above work. The dissociation pressure at −22°C is 200 atm. Repeated hydriding and dehydriding reaches a lower limit of a particle size range of 2-20 microns size. A detailed report is contained in UCRL-53354. Another report deals with the dynamic behavior of hydride powders. It is UCRL-53554.

NEXT PHASE:

None.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Plutonium Hydriding Kinetics

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) ____ **CONTRACTOR(S)** Lawrence Livermore National Laboratory

SUMMARY DATE October 1984 **START DATE** FY83 **SCHEDULED COMPLETION** ____ **STATUS** ____

FUNDING ($$10^6$) FY 1983 ____ FY 1984 0.15 FY 1985 0.2 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To understand the plutonium-hydrogen reaction kinetics. To develop a numerical model which will incorporate both the heat and mass transport concepts to describe the process.

PURPOSE (BACKGROUND AND REASON FOR WORK):

A critical evaluation of the published results in the literature indicates that the measurement and control of the reaction temperature have been inadequate in many of the experiments. The range of the activation energy of the plutonium-hydride reaction (negative values to 8 Kcal/mole) reported by various investigators indicated that all the reaction parameters were not controlled. Thus, the quality of the available data is not adequate for the development of a numerical model which couples both heat and mass transport concept. The sample geometry must be well defined and optimized for heat transfer to obtain meaningful data. Special techniques must be developed to measure the reaction front temperature and record the reacting areas under isothermal and isobaric conditions.

SUMMARY:

The facility to conduct plutonium hydriding experiments has been completed and checked out using uranium. The sample size and geometry have also been defined.

NEXT PHASE:

The first experiments using plutonium will be performed shortly. A complete parametric study of hydriding will be carried out on both delta-stabilized 1 wt% of Ga and unalloyed plutonium.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Storage of Tritium in Zeolites (Molecular Sieves)

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ______ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) ______ **CONTRACTOR(S)** Lawrence Livermore National Laboratory

SUMMARY DATE October 1983 **START DATE** FY81 **SCHEDULED COMPLETION** ______ **STATUS** Dormant

FUNDING ($$10^6$) FY 1983 .04 FY 1984 .04 FY 1985 ______ TO COMPLETION ______

OBJECTIVE (OR GOAL):

Assessment of feasibility of tritium storage in zeolites.

PURPOSE (BACKGROUND AND REASON FOR WORK):

Current tritium storage methods require high-pressure equipment or pyrophoric metal hydride powders. A simpler means of storage is desirable. By physically trapping high-pressure tritium gas in the uniform pores of zeolites, we can store tritium in a chemically inert, low pressure form. With the proper zeolite, at high temperature tritium will diffuse into the zeolite, while at room temperature the tritium is trapped and retained. Helium-3 formed by radioactive decay of tritium may be released, since its kinetic diameter is less than that of tritium.

SUMMARY:

Linde 4A zeolite with 20-40 percent of the sodium replaced with cesium is the best of the 11 zeolites that we tested. With D_2 at 15,000 psia and 300°C, the storage capacity is about 67 cm^3 (STP)/g zeolite. In tests with D_2/He^4 and T_2/He^3, we found that the helium was released from this zeolite. After exposure to tritium for several weeks, no structural degradation of the zeolite by radioactive decay energy was found. However, long-term storage stability is only fair--up to 40 percent of the initially-stored gas was released over a two-month period.

NEXT PHASE:

No further experimental work is planned. Current results will be published.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Military Application (OMA)

TOPIC Hydrogen Getters

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Weapons Research, Development, and Testing **PRINCIPAL CONTACT** Y.T. Song **PHONE** 301-353-5350

OTHER SPONSORING ORGANIZATION(S) ____ **CONTRACTOR(S)** Lawrence Livermore National Laboratory

SUMMARY DATE October 1984 **START DATE** FY85 **SCHEDULED COMPLETION** FY85 **STATUS** new

FUNDING ($$10^6$) FY 1983 ____ **FY 1984** ____ **FY 1985** 0.080 **TO COMPLETION** ____

OBJECTIVE (OR GOAL):

To getter 1 ppm of tritium gas from moist room temperature air using a "direct" (i.e., no intermediate water catalysis) electrolytic getter. This getter is the yellow solid, hydrogen uranyl phosphate (HUP). HUP preferentially takes tritium out of air by electrical conduction of tritons.

PURPOSE (BACKGROUND AND REASON FOR WORK):

To find a cheaper getter than the present catalyst/zeolite system now used for removing tritium from air. The direct formation of tritiated water (HTO) is also undesirable because it is considered 25,000 times as toxic as tritium gas. This getter should be of interest at all tritium and fusion facilities.

SUMMARY:

Using Office of Fusion Energy funds, HUP was found to getter 97.5 percent of 1 ppm T_2-in-moist air in a 1 liter glass bulb. Also, 1.5 percent HTO was formed. We have since tried a first scale-up to a 5 m^3 clean-up box. A one square foot panel gettered 85 percent of the tritium over several days. The gettering occurs because the HUP electrically pulls the tritium in while leaving behind the air and water vapor. Further work will concentrate on making more surface area of getter, gettering faster, and fixing the gettered tritium in place.

NEXT PHASE:

To demonstrate the electrolytic getter as a possible alternative to be considered for the future. A summary of HUP's performance should be ready by the end of FY85.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Solar Heat Technologies (Solar Energy Programs)

TOPIC Solar Thermochemical Hydrogen--Ceramic Heat Exchanger

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Solar Thermal Technology PRINCIPAL CONTACT Frank Wilkins, Robert Hughey PHONE 202-252-1684, 415-273-6364

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) Garrett AiResearch

SUMMARY DATE October 1984 START DATE September 1983 SCHEDULED COMPLETION December 1984 STATUS Ongoing

FUNDING ($$10^6$) FY 1983 .29 FY 1984 .05 FY 1985 -- TO COMPLETION --

OBJECTIVE (OR GOAL):

The objective is to prove the technical feasibility of the solar production of hydrogen. Emphasis is being given to interfaces between solar central receivers and the chemical process, and to control of the process in a transient solar environment. This contract is for the design and test of a solar ceramic heat exchanger to be used in the acid vaporization step of the GA Technologies hydrogen production process.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The hydrogen production project was selected as a long-term, high-risk R&D project which would prove the feasibility of coupling solar energy to fuel and chemical processing. A successful experiment would require the development of solar core technologies, such as process control, storage, and high temperature materials.

SUMMARY:

The GA Technologies hydrogen production process is based on the thermochemical decomposition of sulfuric acid. A critical step in this process is the vaporization and superheating of the acid before it is introduced into the catalytic reactor. This contract is for the design and test of a single-tube solar-driven ceramic heat exchanger to perform this task. In FY 84, test hardware components were designed and fabricated, and a critical glass-metal seal was developed.

NEXT PHASE:

In FY 85, the test will be conducted and the result documented. The GA process will be compared with other fuels and chemicals processes for consideration in further development funding.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Solar Heat Technologies (Solar Energy Programs)

TOPIC Solar Thermochemical Hydrogen--Process Design

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Solar Thermal Technology **PRINCIPAL CONTACT** Frank Wilkins, Robert Hughey **PHONE** 202-252-1684, 415-273-6364

OTHER SPONSORING ORGANIZATION(S) None **CONTRACTOR(S)** Foster Wheeler Solar Development Corp.

SUMMARY DATE October 1984 **START DATE** September 1983 **SCHEDULED COMPLETION** December 1984 **STATUS** Ongoing

FUNDING ($$10^6$) FY 1983 .13 FY 1984 .09 FY 1985 -- TO COMPLETION --

OBJECTIVE (OR GOAL):

The objective is to prove the technical feasibility of the solar production of hydrogen. Emphasis is being given to interfaces between solar central receivers and the chemical process, and to control of the process in a transient solar environment. This contract is for the conceptual design of a commercial scale hydrogen production plant, along with preliminary cost estimates.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The hydrogen production project was selected as a long-term, high-risk R&D project which would prove the feasibility of coupling solar energy to fuel and chemical processing. A successful experiment would require the development of solar core technologies, such as process control, storage, and high temperature materials.

SUMMARY:

A conceptual design of a small commercial-scale hydrogen production plant using the GA Technologies process based on the thermochemical decomposition of sulfuric acid has been completed. This conceptual design is required to identify technology development needs and economical viability of the process using a solar thermal heat source.

NEXT PHASE:

In FY 85, cost estimates for the process conceptual design will be completed and documented. The GA process will be compared with other fuels and chemicals processes for consideration in further development funding.

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Solar Heat Technologies (Solar Energy Programs)

TOPIC Solar Thermochemical Hydrogen--Catalytic Reactor

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Solar Thermal Technology PRINCIPAL CONTACT Frank Wilkins, Robert Hughey PHONE 202-252-1684, 415-273-6364

OTHER SPONSORING ORGANIZATION(S) None CONTRACTOR(S) GA Technologies, Inc.

SUMMARY DATE October 1984 START DATE September 1982 SCHEDULED COMPLETION March 1985 STATUS Ongoing

FUNDING ($$10^6$) FY 1983 1.80 FY 1984 0.40 FY 1985 -- TO COMPLETION --

OBJECTIVE (OR GOAL):

The objective is to prove the technical feasibility of the solar production of hydrogen. Emphasis is being given to interfaces between solar central receivers and the chemical process, and to control of the process in a transient solar environment. This contract is for the desig and test of a solar catalytic reactor.

PURPOSE (BACKGROUND AND REASON FOR WORK):

The hydrogen production project was selected as a long-term, high-risk R&D project which would prove the feasibility of coupling solar energy to fuel and chemical processing. A successful experiment would require the development of solar core technologies, such as process control, storage, and high temperature materials.

SUMMARY:

The GA Technologies hydrogen production process is based on the thermochemical decomposition of sulfuric acid. A critical step in the process is the solar driven catalytic reactor in which t decomposition occurs. In FY 84, a high pressure, high flux test was designed and fabrication o hardware begun to characterize the performance and assess the structural design of a catalytic reactor.

NEXT PHASE:

In FY 85, the hardware will be tested, the data analyzed, and the results documented. The completion of this testing will help to verify the technical feasibility of a solar-driven catalytic reactor and will identify future areas of research. The GA process will be compared with other solar fuels and chemicals processes for consideration of further development funding

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Renewable Technology (Solar Energy Programs)

TOPIC Biological Hydrogen Production

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED ____ NON MISSION-RELATED X

COGNIZANT DIVISION Biomass Energy Technology PRINCIPAL CONTACT Beverly Berger PHONE 202-252-6750

OTHER SPONSORING ORGANIZATION(S) ____ CONTRACTOR(S) Solar Energy Research Institute (In-House & Subcontracted)

SUMMARY DATE October 1984 START DATE November 1978 SCHEDULED COMPLETION December 1984 STATUS ____

FUNDING ($$10^6$) FY 1983 1.0 FY 1984 0.60 FY 1985 0 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To conduct research to understand the photobiological process including photosynthetic water splitting in order to develop biological systems for hydrogen production from water and renewable resources.

PURPOSE (BACKGROUND AND REASON FOR WORK):

To develop processes for the production of high quality hydrogen for use as a fuel or chemical using bacteria, algae and in vitro biological systems.

SUMMARY:

Experiments at SERI and subcontractors include a variety of research areas. Photosynthetic bacteria, cyanobacteria, and algae are being studied for an understanding of their hydrogen producing systems. This includes studying genetics and biochemistry of the photosynthetic apparatus, electron transport and enzyme systems. In vitro systems are being developed which will incorporate components from biological and nonbiological systems for hydrogen production.

NEXT PHASE:

DOE HYDROGEN RESEARCH AND TECHNOLOGY SUMMARY

OFFICE Vehicle and Engine R & D (VERD)

TOPIC Stirling Engine Materials Evaluation

TYPE OF PROJECT (CHECK ONE): MISSION-RELATED X NON MISSION-RELATED ____

COGNIZANT DIVISION Technology Development and Analysis

PRINCIPAL CONTACT P.L. Sutton PHONE 202-252-8012

OTHER SPONSORING ORGANIZATION(S) ____

CONTRACTOR(S) NASA Lewis Research Center, IIT Research Institute (IITRI), AiResearch Casting Co., United Technologies Research Center (UTRC)

SUMMARY DATE October 1984 START DATE ____ SCHEDULED COMPLETION 1987 STATUS Ongoing

FUNDING ($$10^6$) FY 1983 .200 FY 1984 .145 FY 1985 .345 TO COMPLETION ____

OBJECTIVE (OR GOAL):

To identify existing and develop new experimental alloys suitable for the high temperature (1500°F), high hydrogen pressure (2200 psi) environment of the Automotive Stirling Engine (ASE).

PURPOSE (BACKGROUND AND REASON FOR WORK):

ASE viability requires replacement of the strategic metal alloys used for hot side components in current test engines with low-cost alloys containing minimal amounts of strategic elements. Hot side ASE components consist of both tubing and cast alloys.

SUMMARY:

Creep rupture testing in air of candidate heater head cast and wrought alloys has been completed at NASA Lewis and results summarized in report number DOE/NASA/51040-55. A similar test program conducted at IITRI in high pressure hydrogen is complete and results described in report number DOE/NASA-0303-1. Results showed that a hydrogen atmosphere had very little effect on creep rate and rupture life, but in some cases did reduce rupture ductility a slight amount. It was concluded that all candidate alloys investigated are compatible with the hydrogen working fluid used in the ASE. Cyclic oxidation testing at NASA Lewis of candidate heater head tube alloys has been completed and results described in report number DOE/NASA/51040-53. Composition and heat treatment optimization is nearing completion on the new experimental alloy being developed at UTRC. The alloy contains Fe-Cr-Mn(Mo)-Al-C(N). Creep rupture tests will be conducted in air and in hydrogen to determine the susceptibility of this carbide strengthened alloy to hydrogen environment embrittlement. A program has been initiated to explore the potential of near equiatomic iron aluminides for heater head applications in the ASE. Emphasis will focus on understanding the low temperature deformation behavior of this material.

NEXT PHASE:

Complete heat treat optimization and scale-up to complete castability and property characterization of UTRC alloy. Determine effect of processing history on intermetallic compound FeAl.

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