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ANNUAL REPORT

to

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DOE OFFICE OF PATENT
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Institutional Support

for the

Utah Consortium for Energy Research and Education

090 9000 Brigham Young University

663 3000 University of Utah 1484/2

662 9000 Utah State University

June 1979

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1. Introduction

A. General Background

The Utah Consortium for Energy Research and Education (UCERE) organized in April 1977, has been successful in demonstrating the viability of the founding concepts, i.e., a decision to work closely in the energy arena based on several factors: 1) a keen awareness by the faculty of the universities in Utah of the nations energy related problems and a sense of the role that Utah, as an energy exporting state, must play in the future; 2) many of the faculty of Utah's universities have a long history of working with federal and state agencies as well as the private sector on issues related to energy resource development in Utah and surrounding states; 3) a good working relationship with the executive and legislative branches of state government as well as strong ties to local major energy concerns in the private sector; 4) a sense of the need to pool intellectual resource where possible to provide a strong technical base of support for state and local policy making bodies.

This cooperative research spirit, however has not retarded the growth of energy related research activities by single investigators at their own respective institutions. Rather, the support provided to UCERE by DOE has had a marked impact on the nature of the energy research activities carried out at the member institutions.

B. Objectives and Organization

The objectives of the Consortium are stated as follows:

- 1) Avoid unnecessary duplication of effort in energy research and development among the Consortium members.
- 2) Identify areas of needed research and education that can be enhanced by cooperative efforts.
- 3) Prepare plans and proposals for funding and implementing such cooperative efforts.

- 4) Agree upon procedures for implementing cooperative efforts.

The Consortium is organized as follows:

- 1) The governing body of the Consortium shall consist of a Steering Committee, Composed of the presidents of the three universities, with the president of the University of Utah as chairman. The work of the Consortium will be overseen by a Coordinating Committee consisting of the vice presidents for research of the cooperating universities.
- 2) The Steering Committee will be advised by an Inter-institutional Advisory Committee, consisting of the three university vice presidents for research, the state of Utah's science advisor, a representative from industry, a representative from the executive branch, and a representative from the legislative branch of the government of the state of Utah. Each university shall organize its internal arrangements to facilitate the work of the Consortium, as the respective presidents choose to do.
- 3) No contractual obligations are specified or implied in this arrangement, nor will the Consortium enter into any contractual arrangements, obligations or disbursement of funds. These functions shall be reserved to the universities separately as set forth in paragraphs 5 and 6.
- 4) The Consortium's Steering Committee may invite other persons or organizations, including state and community governments and private firms, to participate in its activities.

- 5) It is agreed that the lead University for the Consortium shall be the University of Utah and that the contractual responsibilities of the other two universities and other interested parties shall be by separate subcontracts. The subcontracts shall in each instance be recommended by the Coordinating Committee and reviewed and approved by the Steering Committee.
- 6) Any discretionary funds that may be provided by any contract shall be assigned upon the recommendation of the Coordinating Committee, as reviewed and approved by the Steering Committee. The usual indirect cost allowances, as permitted by federal and state policy, are not discretionary funds and shall accrue under each contract and subcontract in accordance with each institution's indirect cost policy.

The Consortium Memorandum of Understanding is given in Appendix A. The Organization Table appears as Appendix B.

Since this Memorandum of Understanding was executed, some changes have emerged in the State government and associated mechanisms for interaction of the Consortium with the Governor's office and legislature. This connecting link is now provided by means of the Energy Conservation and Development Council and the State Science Advisor. The composition of the Energy Council and the enabling legislation are given in Appendices C and D. The executive secretary for the Council is the link between the Consortium, the Council, and the State agencies through whom policy coordination will flow. The State Science Advisor provides the link between the Office of Governor and the State Advisory Council on Science and Technology. A close working relationship has been established and mean-

ingful advisory input has been obtained from the Energy Council and the State Science Advisor's office on energy-policy issues associated with research in the socio-economics area. We will maintain this close coordinating posture with the Council and the Governor's office on those issues that impact Utah's interests in resources, environment, policy, etc.

II. Scope of Work

The scope of the Consortium plan is the marshalling of the academic research resources, as well as the appropriate non-academic resources within Utah to pursue, as appropriate, energy-related research activities. The heart of this effort has been the institutional contract between DOE and the University of Utah, acting as fiscal agent for the Consortium. This contract has been very useful in facilitating procurement procedures on several selected contracts but the majority of DOE projects for Consortium members are administered through regular procurement channels on an individual contract basis. The following project agreements are being administered under the Consortium's institutional contract:

1. Solving Social and Economic Problems Related to Energy Development.
2. Institutional Support for Research
3. Investigation of Labile Compounds from the Pyrolysis of Oil Shale in High Vacuum.
4. Manpower Requirement for Geothermal Energy Development.
5. Utah/Great Basin Energy Facility Siting Study.

Under item 2 above program development occurs. The details for the administration of this activity is covered in the next section.

III. Institutional Support for Research

A. Program Management

In 1978-79 funds were made available by DOE to provide support for exploratory research, program coordination and unique education

activities. The funds provided are administered by the Consortium Coordinating Committee under the direction of the Steering Committee. In the current support period the review procedure for exploratory research support was made more elaborate than in the preceeding year. In the 1978-79 period requests for exploratory research support were entertained from science, engineering, medical and social sciences in each of the three participating institutions. An ad hoc selection committee at each institution was empaneled to screen the various proposals and make recommendations regarding merit and relative priorities. The top eight proposals from each institution was then submitted to the Coordinating Committee for further review based on each institution's individual priorities. Each of the 24 proposals was sent out for peer review. A copy of the review request letter containing review criteria is attached as Appendix E. In each case, at least two reviewers were obtained. In some cases 3-5 reviewer's comments were solicited. As each reviewer provided a priority score of 1-5 (1 - poor, 5 - excellent), proposals were readily ranked as to relative scientific merit. As approximately \$150,000 was allocated for support of research projects, awards were then made on the basis of priority scores. Of twenty four proposals evaluated, sixteen were selected for funding (see Table 1). The average priority score was 3.98 with a range of 5.0 to 3.0. Awards were made in the following areas (see Table 2).

Program coordination expenses for Consortium activities were established at a level of \$5,000 for each university except that an additional \$1,000 was allocated to the University of Utah to cover honoraria for proposal review. These funds may be used only as direct costs. Indirect costs are not charged for any program activity, including exploratory research projects. Total allocation of institutional funds is given in Table 3.

TABLE 1
PROJECTS SELECTED FOR SUPPORT

INSTITUTION	INVESTIGATOR	PROJECT TITLE	GENERAL PROGRAM AREA	FUNDS AWARDED
BYU	L. V. Knight	The Development of Advanced X-ray Diagnostics for Laser Fusion Applications	Fusion	\$ 9,300
	R. M. Izatt	Production of Hydrogen by the Irradiation of Aqueous Uranium (IV) Complex	Basic Energy Sciences	\$10,000
	P. O. Hedman	Laser Doppler Anemometer Instrumentation for Coal Combustion and Gasification Diagnostic Measurements	Fossil Energy, Combustion & Liquefaction	\$10,000
	M. L. Lee	Mixed Charge Exchange Chemical Ionization Mass Spectrometry of Polycyclic Aromatic Hydrocarbons in Coal Conversion Products	Fossil Energy	\$10,000
	J. J. Christensen L. D. Hansen	Development of a Real-Time Ambient NH_3/HNO_3 Monitor	Environment & Safety	\$10,000
	R. N. Winget R. A. Heckmann	Evaluating Aquaculture Use of Thermal Effluents from Zero Discharge Power Generating Plants	Environment & Safety	\$ 7,424
Sub Total				\$56,724

TABLE 1 (cont'd)

INSTITUTION	INVESTIGATOR	PROJECT TITLE	GENERAL PROGRAM AREA	FUNDS AWARDED
USU	J. C. Batty D. R. Walker J. C. Anderson	Effective Utilization of Warm Water as an Energy Source	Conservation	\$10,000
	V. G. Lind R. E. McAdams O. H. Otteson	A Study of Nuclear Fission Induced by Fast Pions in Light Elements	Nuclear Fission	\$ 9,990
	W. F. Edwards R. Thompson	Electromagnetic Theory and Plasma Containment	Nuclear Fission	\$ 9,830
				Sub Total \$29,820
U of U	L. D. Spicer	Investigation of Photo-Assisted Catalysis	Basic Energy Sciences/Homogeneous Catalysis	\$ 9,830
	R. F. Boehm	Quantification of Performance Factors of Salt-Stratified Solar Ponds	Solar Energy	\$10,000
	F. V. Hanson	Catalytic Cracking of Synthetic Crudes Derived from Bituminous Tar Sands	Fossil Energy	\$10,000
	C. H. Pitt	Determination of Corrosion Rates of Selected Passive-Active Alloys in Utah Geothermal Waters	Geothermal	\$ 8,316

TABLE 1 (cont'd)

INSTITUTION	INVESTIGATOR	PROJECT TITLE	GENERAL PROGRAM AREA	FUNDS AWARDED
U of U	D. W. Pershing	Combustion of Shale-Derived Liquid Fuels	Fossil Energy	\$ 9,880
	J. N. Harris	Time Resolved Fluorescence Spectroscopy for Determination of Complex Mixtures	Basic Energy Sciences	\$ 9,956
	F. Brown	Study of Radionuclides in Reservoirs in Southern Utah	Environment and Safety	\$ 5,000
				Sub Total \$ 62,982
				Total \$149,526

TABLE 2

FUNDED PROJECTS BY AREA AND DOLLAR AMOUNT

	<u>AREA</u>	<u>NUMBER</u>	<u>DOLLAR AMOUNT</u>
1.	Fission/Fusion	3	29,120
2.	Environment & Safety	3	22,424
3.	Fossil Energy	4	39,880
4.	Basic Energy Sciences	3	29,786
5.	Conservation	1	10,000
6.	Geothermal	1	8,316
7.	Solar	<u>1</u>	<u>10,000</u>
	Total	16	149,526

Table 3

Summary of Allocation of Institutional Research Funds

I. Exploratory Research	\$149,526
II. Program Coordination	16,000
III. Educational Activities	15,000*
IV. Total Expenditures	<u>\$180,526</u>
V. Total Funds Available for 1978-79 and carry over of unexpended funds from 1977-78	\$199,886

* \$15,000 has been committed as matching funds for a series of workshops on the critical energy issues with state and local elected officials.

IV. Description of Selected Exploratory Research Projects

Since exploratory research projects funded in the current grant period (1978-79) are in relatively early stages of development (four months or less) it would be premature to provide project details in this report. Hence, an arbitrary selection of ten projects, in various stages of work have been selected. The reader should note that fifteen students are receiving support as they participate in the projects. The following represent a brief description of the work in progress on these projects:

1. Title: Determination of Corrosion Rates of Selected Passive-Active Alloys in Utah Geothermal Waters

Principial Investigator: Charles H. Pitt

Funds Awarded: \$8,316

Graduate Student(s): Mr. Yanki Hong

Institution: University of Utah

The need to develop geothermal resources for energy production is well established. It is generally recognized that severe corrosion problems can result from utilization of hot geothermal brines to produce electrical power.^{1,2} Critical metallic corrosion areas in geothermal systems are located wherever geothermal brines, steam or condensate make contact with equipment or piping. Included among these areas are turbine blades, rotors, piping and condensate systems. It has been found that the chemistry of brines is complex and that the concentration of minor cationic constituents such as Na and Ca play an important role in the corrosion rates and scale deposition from geothermal brines.³ It is also well known that the composition and temperature of geothermal brines varies from site to site and even from well to well at a given site. This work is aimed at determining the corrosion characteristics of commonly used commercial alloys in geothermal brines found in potential Utah geothermal resources. Particular attention is paid to hot brines below the boiling point in contact with alloys which exhibit passive film formation. These conditions are typical for systems handling steam condensate or piping hot geothermal brines. The economic benefits of such data are obvious in terms of efficient and economic operation of geothermal power systems.

Corrosion characteristics and corrosion rate measurements are being made using a Princeton 173D potentiostat with auxillary components, available in our laboratory. The equipment generates potential current curves which determine passivating current, passive current, and passive film breakdown potential. Corrosion rates are being determined utilizing methods described by Morris and Scarberry⁴ and Harrell.⁵ Stationary as well as rotating electrodes will be utilized to determine flow rate

effects. Samples of geothermal brines will be obtained from the various potential geothermal fields in the state such as the Roosevelt and Monroe area. Chemical analyses will be made of these samples before use. In some instances synthetic brines will be made in the laboratory to enable observation of the effect of varying impurity concentration such as Ca or Cl. Chemical analyses of many brines are available through the Department of Geology and Geophysics at the University of Utah and the University of Utah Research Institute. The effect of temperature variation in the ambient to 90°C range on the corrosion rates and parameters will also be investigated. The metal alloys to be studied will include the chrome-moly low alloy steels (1 Cr 1/2 Mo), (5 Cr 1 Mo), and 12% Cr and the stainless steels 304, 316 and 410.

References

1. Workshop on Materials Problems Associated with the Development of Geothermal Energy Systems. U.S.B.M. Open Report File. OFR 128-76 PB-261349 pg. 45-62; 87-99.
2. Proc. 2nd U.N. Symposium on the Development and Use of Geothermal Resources 1975, V3, pg. 1815-20, 1871-77, 1959-63. PB-262503
3. Ibid. Wahl, E. and Yen, I. p. 1855.
4. Predicting Corrosion Rates with the Potentiostat, Morris, P.E., and Scarberry, R. C. Corrosion, 28, No. 12, 1972 p. 444-52.
5. Modern Applications of Potentiodynamic Data in Research and Industry, Harrell, J. B. Petrolite Corp. Houston, Texas 1975.

2. Title: Combustion of Shale-Derived Liquid Fuels

Principal Investigators: David W. Pershing and Harold R. Jacobs

Funds Awarded: \$9,880

Graduate Student(s): Mr. Robb Winter and Ms. Jasmina Stanojevic

Department: Chemical Engineering, Mechanical and Industrial
Engineering

Institution: University of Utah

Because of the dwindling supplies of conventional liquid fuels, considerable emphasis is currently being placed on the development of both above-ground and in-situ technologies for the production of fuel from oil shale formations. Research at the University of Utah under the direction of Professor H. R. Jacobs has demonstrated the viability of both combustion and steam retorting (in-situ) of raw oil shale. The resulting oil, however, has significantly different physical properties and chemical composition than most crude oils. In particular, the non-Newtonian oils often contain as much as 2.0 percent nitrogen, chemically bound within the oil. (Convention crudes rarely exceed 0.8 percent nitrogen.) Further, the nitrogen speciation can be shifted by altering the degree of refluxing and/or the temperature of the retorting process. This "fuel nitrogen" can be a major source of nitrogen oxide emissions from fossil fuels (Martin and Berkau, 1972; Turner et al., 1972; Heap et al., 1973; Pershing et al., 1975). Although a large portion of the shale crude will probably be utilized as a gasoline and/or chemical feedstock, the heavier fractions will be burned in some form. Hence, there is currently considerable concern about increased air pollutant emissions (NO_x) from shale oil combustion.

Recent work elsewhere (Pershing, et al., 1979) has demonstrated that NO_x emissions increase approximately linearly with increasing fuel-nitrogen content for high-turbulence, fine atomization oil burners. Figure 1 shows the total and fuel NO_x emissions from 20 different liquid fuels fired in a small test furnace under identical combustion conditions. These data indicate

Figure 1. Importance of Fuel Nitrogen Content
(from Pershing et al., 1979)

that crude shale oil (obtained from the Parahoe project) resulted in NO_x emissions almost twice that of any other conventional oil tested. In addition, the distillate fuel (No. 2 oil) produced from the shale crude resulted in NO_x emissions substantially above the other distillate oils tested. Thus there can be little doubt of the potential of high NO_x emissions with shale oils. Further, removal of the fuel nitrogen by denitrofication during refining appears to be both difficult and expensive. This twelve-month study is, therefore, designed to demonstrate the potential of advanced burner-design technology for the control of NO_x emissions.

The overall objective of this study is to demonstrate that emission levels under 200 ppm NO_x can be achieved with shale oils containing as much as 2.0 percent nitrogen and thereby alleviate the need for denitrofication during refining. In particular, this study is designed to:

1. Demonstrate the potential of advanced burner-design concepts and two-stage combustion. The study will not attempt to optimize these technologies, but rather to define the critical parameters needing further in-depth research.
2. Establish the influence of the raw-shale composition (as a function of geographic origin), and of retorting parameters on the effectiveness of control technology. It appears likely that the minimum NO_x emissions will be a strong function of the fraction of the fuel nitrogen which is refractory (non-volatile).

It is hoped this study will provide support for the proponents of oil shale development. In addition, it will provide preliminary data required to

evaluate the need for a larger research effort in that area. The approach will be primarily experimental, utilizing existing retorting and combustion facilities within the Departments of Chemical and Mechanical Engineering. The primary fuel is shale oil provided from the modified in-situ process developed by H. R. Jacobs of the Mechanical Engineering Department. The sources will include both a moderately rich reserve (about 20 gal/ton) in the Utah, Green River formation and low-grade reserve (10 to 15 gal/ton) near Vernal, Utah. Tests will also be conducted on both a distillate and a crude shale oil from the Parahoe project. The focus of this study will be NO_x emissions, but SO_2 , CO, and unburned hydrocarbons will also be monitored.

Three types of experimental studies are planned for the proposed 12-month program. The first will define the emissions typical of current combustion conditions while the latter two experimental series will investigate two types of combustion modifications for NO_x control. Each study is described in detail below.

The purpose of the first set of experimental studies is to define the influence of raw-shale composition and retorting parameters on NO_x emissions under conditions typical of industrial practice (without NO_x control). The variable-swirl, high-turbulence burner will be used, since it is typical of current industrial oil burners. Two conventional heavy fuel oils (Indonesian @ 0.24%N, Alaskan @ 0.51%N) will be burned in addition to the various shale oils for comparison purposes. Pyridine doping will be used in conjunction with the distillate and heavy oil tests to quantify the influence of volatile nitrogen content. The experimental parameters will include:

- . Excess air (1 to 5% excess O_2);
- . Mean Droplet Size (20 to 100 micron);
- . Atomizer (ultrasonic vs. conventional).

It is now well established that the most effective means of controlling the rate of fuel nitrogen oxidation to NO is to reduce the rate of secondary-air mixing. This can be accomplished by either aerodynamically reducing the secondary air entrainment rate or by physically displacing the location of the second-stage air injection some distance downstream from the burner (two-stage combustion). Researchers at the Energy and Environmental Research Corporation (Gershman, et al., 1977) are currently developing a triple-concentric low NO_x pulverized coal burner which is based on the aerodynamic staging concept. Early formulations of this concept have been used by Babcock and Wilcox (a large American boiler manufacturer), and by Steinmuller (a German boiler manufacturer) to produce low NO_x pulverized coal burners.

The purpose of this second series of experimental studies is to show that the aerodynamic staging concept can be applied to the combustion of shale oil liquids. The work will not attempt to produce detailed, hardware-design specifications; rather, it will demonstrate that low emissions are possible and identify the critical parameters. Studies will include the effect of:

- . Primary-zone stoichiometry;
- . Tertiary-air displacement distance;
- . Secondary-air swirl;
- . Oil-nozzle design;
- . Liquid-fuel composition.

In addition, the experimental work will investigate the importance of shale origin and of retorting conditions.

The purpose of the final experimental test series is to investigate external staging both alone and in conjunction with advanced burner design concepts (as recommended by Johnson, et al., 1978). Again the focus will be on demonstrating concept viability, not on design specification development. The parameters of interest include:

- . Residence-time distribution
- . Stoichiometric ratios
- . Drop size and size distribution
- . Oil composition

The exact details of this last experimental test series will depend heavily on the results of the preceeding work.

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3. Title: Catalytic Cracking of Synthetic Crudes Derived from Bituminous Tar Sands

Principal Investigator: Francis V. Hansen

Funds Awarded: \$10,000

Graduate Student(s): Mr. J. Dorius

Department: Mining and Fuels Engineering

Institution: University of Utah

Integration of tar sand-derived liquids (TSDL) and products produced from these liquids into a petroleum based economy requires that the TSDL and products be compatible with petroleum crudes and petroleum-derived products. However, there is evidence in the literature (1-3) that the chemical constituents (in a given boiling range) of coal-derived liquids and products are not compatible with the chemical constituents of petroleum-derived gas oils and products of the same boiling ranges. This research activity will focus on assessing the extent to which TSDL and petroleum-derived gas oils are compatible, on devising a processing scheme that will permit the direct conversion of TSDL to home heating or diesel fuel, kerosine and/or gasoline in existing, refinery processing equipment and on the characterization of TSDL, TSDL-petroleum gas oil blends and products produced from these feedstocks.

The initial phase of the experimental program involves the catalytic cracking of a series of petroleum-derived gas oil feedstocks. These feedstocks include a light vacuum gas oil, a heavy vacuum gas oil and a short resid derived from the Rangely and Altamont petroleum crude oils. These six feedstocks cover a broad range of feedstock properties since the Rangely crude is a normal crude and the Altamont crude is a highly paraffinic crude. The entire process variable space, including conversion, temperature, catalyst-to-oil ratio, contact time, and catalyst recirculation rate, is being explored with each feedstock. In addition to process variable studies, the deposition of coke on the catalysts and coke burning rates is being investigated. These experiments will lay the foundation for evaluating the subsequent studies with synthetic, tar sand-derived liquids. The initial catalysts studied are a

pair of non-zeolite silica-alumina cracking catalysts (i.e., W. R. Grace, Davison Division, high pore volume, high alumina silica-alumina (HVHA $\text{SiO}_2\text{-Al}_2\text{O}_3$); and high pore volume, low alumina silica-alumina (HVLA $\text{SiO}_2\text{-Al}_2\text{O}_3$)) and a commercially available zeolite-based cracking catalyst (i.e. W. R. Grace, Davison Division, CBZ-1).

Feedstock Characterization

A TSDL produced from the bituminous tar sand of the Sunnyside deposit will be blended with the light vacuum gas oils derived from the Rangely and Altamont crudes (5%, 10%, 25%, 50%, 75% and 100% TSDL) to prepare a series of feedstocks for the investigation. The TSDL, the petroleum gas oils and selected blended feedstocks will be characterized as to chemical constituents. The feedstocks will undergo fractional distillation on a spinning band distillation column to obtain narrow boiling range fractions with minimal temperature overlap. The individual fractions will then be subjected to gradient elution chromatographic (GEC) separation (4). The seven basic compound types from GEC are saturates, mononuclear and dinuclear aromatics, polynuclear aromatics, polynuclear aromatic soft resin, hard resin, eluted asphaltenes and "polar" asphaltenes. The eluted fractions will be subjected to spectroscopic analysis (ultra-violet and visible, infrared, NMR and high molecular weight, high resolution mass spectrometry) to provide a basis for ascertaining the nature of the reaction pathways for specific critical species (i.e., benz (a) pyrene, benz (a) anthracene, dibenzothiophene, etc.) in the catalytic cracking process. In addition to the GEC-spectroscopic characterization the blended feedstocks characterization will involve simulated distillation, elemental analysis for H, C, O, S and N, metals analysis, carbon residue and the traditional physical properties. The information obtained in the characterization and

blending studies will be correlated with product quality data and catalyst performance data in order to define an optimum blend of TSDL and petroleum gas oil for the catalytic cracking process.

Catalytic Cracking Studies

The initial catalytic cracking studies with the blended feedstocks will be carried out with the silica-alumina cracking catalysts in order to clearly define the effects of the presence of the molecular species indigenous to TSDL in the synthetic feedstock. The onset of product quality degradation (i.e., octane number reduction in the case of gasoline selectivity; diesel index in the case of diesel fuel selectivity; etc.), or significant loss of catalyst activity and/or selectivity, will be used to define the proportions of TSDL and petroleum gas oil that can be blended to produce a viable synthetic feedstock for catalytic cracking. Process variable space will then be mapped for the "optimum" synthetic feedstock using the silica-alumina catalysts. The process conditions that maximize the product yield for a specified selectivity (i.e., gasoline production, fuel oil or kerosine production, etc.) and product quality will then be defined as the standard condition for the evaluation of zeolitic cracking catalysts, both commercially available and synthesized in the laboratory.

The coking tendency of each catalyst with the various feedstocks and catalyst regenerability will be ascertained. These studies will be carried out in-situ by following the conversion and product quality as function of the process parameters. The actual coke make, the coke burning rate and the heat of combustion of the coke will be determined by thermal analysis (duPont 990 Thermal Analyzer) external to the cracking unit. The coking data will be correlated with the feedstock characterization data to evaluate catalyst performance and to refine the definition of an "optimum" TSDL-petroleum

gas oil blend. The heat of combustion data will be used to heat balance a hypothetical catalytic cracking unit processing the "optimum" synthetic crude over the most promising zeolitic catalyst.

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4. Title: Investigation of Photo-Assisted Catalysis

Principal Investigator: Leonard D. Spicer

Funds Awarded: \$9,830

Graduate Student(s): John Peterson and Dennis Bennett

Department: Chemistry

Institution: University of Utah

We propose to explore the concept of photo-assisting catalytic reactions using new technology associated with currently available tunable laser sources of light. The principle objectives are twofold. 1) We will attempt to increase the efficiency of selected catalytic reactions by photostimulating the system along the reaction coordinate. This may involve exciting either the reactant or intermediates associated with the catalyst and should prove to be a valuable tool for studying mechanisms of important catalytic reactions. 2) We will explore the possibility of beneficially modifying catalytic reaction paths by selective photostimulation. The latter includes both specifically stimulating desired mechanistic paths and/or inhibiting competing routes of a less desirable nature.

The concept used is quite general and should be applicable to a variety of important catalytic processes. The exploratory ground work which we plan to set for the specific studies outlined here will undoubtedly be transferrable to other important commercial areas such as catalytic cracking and reforming processes and hydrogenation-dehydrogenation reactions.

To date the use of laser sources to study the potential of light assisted catalysis has been largely neglected despite the fact that there has been extensive activity in both the areas of photochemistry and catalysis. The marriage of these two well-developed fields is ripe, and we propose to explore this important chemical technique from a fundamental point of view using state of the art laser light sources. The only report of which we are aware dealing with the effect of laser light on conventional catalyst performance showed a dramatic effect on the product distribution from the decomposition of formic acid using a platinum catalyst at 250°C.¹ The light source was a CO₂ laser producing infrared light and presumably stimulating vibrational modes in the molecule.

The two areas selected for initial studies are hydrodesulfurization reactions on alumina supported cobalt molybdenum catalysts and hydrogenation of hydrocarbons on metal cluster catalysts. The former reactions are important in desulfurization of fossil fuels in attempts to minimize emission of sulfur compounds into the lower atmosphere where photochemical and thermal, homogeneous and heterogeneous reactions of sulfur containing species all play a role in air chemistry.²⁻⁷ Of particular interest and difficulty in desulfurization procedures are the aromatic sulfur containing cyclic compounds found naturally in fuels, and we plan to use these as model systems in our initial studies.

The area of homogeneous catalysis using metal clusters has received considerable attention as a model for heterogeneous surface catalysis.⁸ The mechanisms involved in hydrogenation with these metal complexes are relatively complex and are only now beginning to be understood on the molecular level.^{8,9} One recently reported group of these catalysts, the rhodium-phosphite cluster family appears to dissociate readily in the hydrogenation process¹⁰ and we are particularly interested in attempting to photo-assist this dissociation step. In general, homogeneous catalysts can provide important selectivity, and because of this they have recently been employed in new commercial processes.¹¹

The area of catalytic science is of critical importance to contemporary technology because of the need for both high efficiency and high selectivity in industrial processes. The rational design of catalytic systems depends on understanding and controlling reactions at the molecular level. Such design is essential if we are to conserve energy and resources while maintaining industrial productivity. In this regard, well characterized light is a valuable probe and stimulant for molecular studies.

Both heterogeneous¹² and homogeneous catalysts¹¹ are currently used extensively for commercial chemical processes. Each has specific characteristics which determine to a large extent the suitability for the specific process of interest. Heterogeneous systems have the advantage of being stable, easy to handle, and conveniently separable from reaction components. Homogeneous catalysts are preferred in cases where increased selectivity is desirable. In some respects this differentiation is currently being bridged by studies of metal cluster catalysts. These catalysts are homogeneous and yet have characteristics analogous to metal surfaces.

Here we outline our approach in examining two specific problems which were selected as part of our initial survey of systems suitable for photo-assistance. In each case we are interested in probing the catalytic process at the molecular level to elucidate and eventually direct the detailed mechanism of the catalytic reaction. We are also interested in selectively stimulating the reacting molecules and/or catalyst in the reaction coordinate for the rate determining step and thus increasing the turnover number for the process. It is anticipated that parallel work both in the heterogeneous, hydrodesulfurization reactions and in the homogeneous, hydrogenation reactions will be carried out initially.

The importance of the hydrodesulfurization process for removal of sulfur compounds from fuels and inorganic sulfides has been reviewed extensively.¹³⁻¹⁸ The traditional catalyst used for hydrodesulfurization is sulfided CoMo/Al₂O₃. Whereas the detailed mechanism for the reaction at this catalyst is not well understood, it currently represents the clear choice for most commercial applications. Indeed in this work we hope to clarify the role of Co in promoting the reaction as well as the contribution of molybdenum disulfide in the sulfided alumina supported catalyst.^{19,20}

The initial work will be carried out using the CoMo/Al catalyst supported on Al₂O₃ since it is the one most commonly used industrially. To avoid impurities found in most commercial catalysts, in house preparation will be employed using standard impregnation procedures with pure γ -Al₂O₃. The incipient-wetted material will be oven-dried for several hours followed by overnight calcination in air at 500°C.

Using this catalyst we plan to study desulfurization of thiophene and benzothiophene as model compounds. Benzothiophene is a good representative of sulfur compounds encountered in many commercial fuels and appears to be well suited for this fundamental investigation. Additionally thiophenes and condensed thiophenes are the most difficult sulfur compounds to desulfurize and often remain unchanged in commercial processes.^{17,18} The catalytic hydrodesulfurization of thiophene produces H₂S in the initial reaction and the resulting 1,3 butadiene is reduced sequentially giving both butene and butane as end products. The mechanism is thought to involve direct hydrogenolysis of the carbon sulfur bonds with extrusion of the sulfide.²¹⁻²³

The mechanism for hydrodesulfurization of benzothiophene, however, is more controversial. H₂S and ethylbenzene are major products^{24,25} but small amounts of dihydrobenzothiophene^{26,27} and styrene have also been identified.²⁸⁻³⁰ It appears that competitive pathways exist involving hydrogenation of the thiophene ring as the first step in one case and hydrogenolysis with carbon-sulfur bond cleavage in the other case. In the several possible reaction routes, each presumably is rate limited by a different step.

A reaction scheme has recently been proposed²⁹ in which the initial step involves a competition between carbon sulfur bond scission to yield 2-vinylthiophenol as an intermediate and saturation of the thiophene ring to form dihydrobenzothiophene. If this initial step is rate determining, it should be possible to photo assist each path. Vibrational excitation of the C-S bond might assist cleavage directly in the aromatic system while electronic excitation of the aromatic system is likely to assist hydrogenation and may even promote C-S bond cleavage as well.

If on the other hand subsequent steps are rate determining, it should be feasible to selectively assist carbon sulfur bond cleavage from the thiol and in the saturated ring. This then represents an example where it may be possible to direct which detailed mechanism is most efficient and thus enhance or eliminate one of the biproducts of the reaction, styrene, depending on the nature of the photolysis used. Thus in addition to increasing the rate of the overall hydrodesulfurization process we expect also to provide data which will aid in distinguishing which mechanism is favored for the catalytic reaction in the absence of light using the technique of selective photostimulation. It is clear that the catalytic process is rich in chemistry and the major products detectable are easily analyzed as an indicator of catalyst activity.

The most realistic method of using the catalyst is in a flow system. Therefore we will spectroscopically monitor the products in the effluent flow from the reaction center. This method has the advantage of allowing us to scan the wavelength of the irradiating light while making the analysis in order to optimize the efficiency of the light in promoting the reaction. Alternately we will also employ a static method of reaction and accumulate products following irradiation for a known time period. In either case a complete product analysis will be carried out gas chromatographically either by diverting a fraction of the flowing gas or injection of a measured aliquot.

Studies of hydrogenation using transition metal cluster catalysts and transition metal complex catalysts are proposed as a concurrent investigation of photo-assisted catalysis. These reductions occur readily in homogeneous solution and in certain cases appear to be accompanied by either a ligand dissociation step⁸ or a cluster dissociation¹⁰ in the molecular mechanism at the point where the hydrogen is accommodated by the transition metal. In rhodium based systems, for example, as the reaction proceeds, the unsaturated reactant, e.g., olefin, binds to the metal dihydride after which a series of two hydrogen shifts saturates the alkyl ligand which leaves the complex. Several of these steps, particularly the dissociative ones, should be subject to photo-stimulation and in addition any initial process which may require fragmentation of the metal cluster in advance of the active participation of the transition metal atoms can presumably be accelerated.

Alternate, less well defined, mechanisms of metal cluster catalysts including those representing simulations of metal surface-catalyzed olefin hydrogenation reactions may also be subject to photo-assistance since the energetics of multiple center binding can be probed, and such interactions should be subject to excitation. In both cases the advantage of studying homogeneous catalysts lies in the uniform nature of the reaction medium. Thus a favorable geometry for photolysis can readily be achieved and the individual molecular entities present can be probed independently.

There are a relatively large number of organometallic and metal cluster systems now known to exhibit catalytic activity.^{8,9} One initial investigation will be centered on rhodium and cobalt systems. In this group $\text{ClRh}[\text{P}(\text{C}_6\text{H}_5)_3]_3$ ³¹⁻³³ and the recently reported clusters $\{\text{HRh}[\text{P}(\text{OR})_3]_2\}_x$ ^{10,34} are good hydrogenation catalysts for olefins and $n^3\text{-C}_3\text{H}_5\text{Co}[\text{P}(\text{OR})_3]_3$ ^{35,36} complexes are good catalysts for arene hydrogenations. The synthesis of these systems will be carried out from literature preparations due in large part to the beautiful work of Muetterties and co-workers.³⁴

The catalytic hydrogenation reactions reported are usually carried out under mild conditions with temperatures in the range of 0-100°C and hydrogen pressures of 1-3 atmospheres. We will initially follow literature procedures for establishing catalytic activity using quartz or pyrex glass reaction vessels with teflon stopcocks. The experimental method will involve parallel reactions using the same catalyst preparations with and without laser excitation. Analysis of products to establish the turnover rate will be by gas chromatography.

One of the first sets of experiments we hope to investigate involves the potential photostimulation of olefin reduction with the active new catalysts^{10,34} $\{\text{HRh}[\text{P}(\text{OCH}_3)_3]_2\}_3$ and $\{\text{HRh}[\text{P}(\text{O-}i\text{-C}_3\text{H}_7)_3]_2\}_2$ by aiding in the cluster dissociation step. This should produce the reactive $\text{HRh}[\text{P}(\text{OR})_3]_2$ group even more readily than it is formed thermally and may increase the efficiency of this catalyst to levels even higher than reported previously. Other studies on the single transition metal complexes indicated previously will be directed toward either exciting the metal ligand groups to facilitate attack by olefin or electronically exciting the complex to increase the reactivity both with hydrogen and olefin and possible even aid in hydrogen transfer to the olefin.

It is apparent that the possibilities for photostimulation in homogeneous systems are almost limitless and we have only suggested a few initial investigations from this group here. As the research progresses we hope to gain a reasonable amount of insight which will aid in being carefully selective both in choosing reactions suitable for photostimulation and in concentrating on the appropriate ranges of radiation energy which will be most effective in increasing catalytic activity and alternately in probing and controlling the detailed mechanisms by which the catalytic processes occur.

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5. Title: The Development of Advanced X-ray Diagnostics for
Laser Fusion Applications

Principal Investigator: Larry V. Knight

Funds Awarded: \$9,300

Graduate Student(s): David Gaines, Ray Perkins, Robert Gardner, Rulon Nye

Department: Physics

Institution: Brigham Young University

Laser fusion power appears to be an attractive solution to the energy crisis. However, after massive expenditures world wide, achievement of this goal still appears somewhat remote. The problems are complex and highly technical; the solutions have followed only after careful, usually costly, analysis of the relevant parameter space. This analysis takes place in an environment similar to that found in a hydrogen bomb explosion. Obviously, the diagnostic effort required for a careful analysis is also complex and technical. New techniques are required which are within the range of expertise at BYU.

The principal reason for an interest in the development of x-ray optics for laser fusion is the need for short wavelength radiation to probe high density plasmas. This need is evident with the emergence of high power lasers such as SHIVA and SHIVA NOVA which are capable of producing ultrahigh densities ($n_e \sim 10^{23} - 10^{26} \text{ cm}^{-3}$) such high densities would reflect long wavelength radiation limiting its usefulness as a diagnostic tool.

As the laser fusion program moves into high density ablatively driven implosions, x-ray probing of dense plasmas will become a very important diagnostic technique.¹ Several approaches for using probing x-ray radiation to measure high electron densities with absorption, Schlieren, and interferometric techniques have been made.^{2,3} Figure 1 illustrates the density regimes for which these three x-ray techniques would be useful. Attwood and Ceglio have suggested x-ray probing experiments capable of detecting the pusher-ablator interface both in a flash mode giving two dimensional spatial information and in a streak mode giving space-time information.⁴ In all of these approaches a high intensity, subnanosecond, monochromatic x-ray source is a critical element and means of manipulating the x-ray beam is a requirement for most of these techniques.

X-Ray Optics⁵

The term x-ray crystal optics refers to the use of crystalline like components to manipulate beams of x-ray photons by diffraction much as beams of visible photons are directed by glass components because of refraction. The principal difference between diffraction optics and refraction optics is the much stronger wavelength dependence of diffraction. Because of this difference x-ray optics is capable of giving high resolution spectral information as well as spatial information.

Crystals

There is a large number of combinations of geometry and structure that can enhance the utility of x-ray crystals as optical components both as imaging devices and as sensitive dispersive elements in spectrometers. A flat crystal is commonly used in x-ray spectrometers. These spectrometers are not very sensitive, because the crystal does not focus in any direction and the radiation coming from a point source will diverge out in the shape of a fan, the thickness of the fan being determined by the Bragg condition. In many laser fusion diagnostic problems sensitivity is not important because of the high x-ray flux. Flat crystals may also image a monochromatic source in one dimension.⁶ The Bragg condition determines the path of each x-ray for a pure monochrome. Thus, the edges of the target, as defined by x-ray emission, are uniquely determined. The resolution is dependent on the rocking curve of the crystal and the line width of the radiation.

If the crystal is bent into a cylindrical shape, there is focusing in one dimension with an increase in sensitivity. If the axis of the cylinder is along the plane of dispersion, two dimensional imaging occurs--the Bragg condition defining one dimension and the geometry of the crystal the other dimension. This configuration is called vertical focusing.⁷ If the cylinder axis is perpendicular to the plane of dispersion, the geometry can be made to conform to the configuration required for a Rowland concave grating.⁸ This geometry has the effect of placing a virtual pinhole for a different wavelength at each point on the Rowland circle. Thus, we are offered the interesting prospect of imaging the target at several different wavelengths simultaneously. Using a crystal bent in this fashion to focus x-rays is known as horizontal focusing.⁹

If the crystal is bent in such a way that both horizontal and vertical focusing are accomplished, the crystal will act much like a point focusing lens. However, now the surface becomes more complicated. This is because reflection is occurring over the entire face of the crystal. In this situation the ideal shape for perfect focusing of a single wavelength is for the crystal planes to form a set of confocal ellipsoids of revolution. If the spacing between ellipsoids for a ray originating from a focus is $\lambda/2$ there will be point focusing between foci. Exact focusing is limited to one wavelength of x-ray radiation and the required geometry is very complicated since, in general, it demands that the separation of crystal planes vary with position.¹⁰

An example of a point focusing crystal is the spherically shaped quartz crystal developed by Hewlett-Packard as a key component in an instrument for surface analysis called ESCA (Electron Spectroscopy for Chemical Analysis).^{11, 12} The crystal was used to focus an intense beam of monochromatic x-rays on a surface producing photo electrons which were analyzed by an electron spectrometer to determine the chemical properties of the surface. Hewlett-Packard has discontinued to sell and manufacture the ESCA instrument and consequently no longer makes the crystals. However, crystals of this type can be obtained from Surface Science Laboratories of Palo Alto, California. This company employs former Hewlett-Packard employees who were the technical leadership of the ESCA program.

The ESCA crystal as it presently exists would be useful in x-ray spectroscopy, x-ray imaging, and as a monochromator-condensor. The crystal is presently being evaluated as an imaging element. Its value as a high sensitivity spectrometer and a monochromator-condensor is well established by its ESCA application. Preliminary measurements indicate that the spatial resolution of the ESCA crystal is better than 50 μm .¹³ No lower limit to the resolution has been established because the resolution was limited by external optics. In this respect it is interesting to note that the Russians have reported a resolution of 16 μm with a similar crystal.¹⁴ A spectrometer using an ESCA crystal as a dispersive element would be orders of magnitude more than a flat crystal. This may not appear to be an important consideration because high sensitivity has not been a requirement of laser fusion diagnostics in the past, however, inevitably a need for more sensitivity will arise as the analysis of plasma experiments becomes more sophisticated. The use of such crystals as monochromator-condensors for x-ray probing of high density plasmas could be very important.

A promising approach to the production of crystals and complicated crystal geometries has recently been reported by Barbee of the Center for Materials Research at Stanford University.^{15,16} Thin film methods have been used to produce stable layered structures that exhibit high diffraction efficiency for x-rays. Several different metals have been used to produce "crystals" with 2nd spacings that range from less than 20Å to several thousand Å with uniform layer thickness of less than 1Å and from 25 to 2000 layered pairs in a single device. This technology suggests the strong possibility of designing and building crystals with a desired Bragg angle, bandwidth, and geometry. Devices made by this technique could provide x-ray mirrors and filters immediately and a variety of more sophisticated x-ray optical imaging and filtering devices in the future.

A 1J mode locked Nd-YAG laser will be used to irradiate various thin metal targets. A spherically bent x-ray diffraction crystal will select single (monochromatic) x-ray lines from the emitted x-ray spectra. This monochromatic radiation will be used to backlight various targets, producing an x-ray shadow-graph.

The study will generate spectral information from 100eV to 7KeV, spatial information for several different x-ray bands, and temporal information. The research will be done using a mode locked neodymium laser capable of producing single pulses with energy from between one to two joules and with pulse widths of between 50 and 200 psec. The program will be to shoot disk targets about 100 to 300 μm in diameter and 1 μm to a few μm thick. The target material will be chosen from Aluminum, Silver, Titanium, Scandium, Vanadium and Copper, using some low Z, some medium Z, and some moderately high Z metal. The diagnostics will include the standard diagnostics necessary to characterize each laser pulse, and to measure the x-ray emissions from the target.

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Figure 1

6. Title: Mixed Charge Exchange Chemical Ionization Mass Spectrometry
of Polycyclic Aromatic Hydrocarbons in Coal Conversion
Products

Principal Investigator: Milton L. Lee

Funds Awarded: \$10,000

Graduate Student(s): Mr. Dan Vassilarios

Department: Chemistry

Institution: Brigham Young University

Products and by-products from coal conversion processes often contain large concentrations of polycyclic aromatic hydrocarbons. These aromatic fractions are usually very complex mixtures, containing several hundred easily detected compounds. The most powerful approach to the detailed identification of polycyclic aromatic hydrocarbons in complex mixtures is combined capillary column gas chromatographic mass spectrometry. The mass spectra of isomers, however, are indistinguishable by conventional electron impact or chemical ionization techniques. A mixed charge-exchange chemical ionization technique has recently been proposed by us to distinguish between isomers, and it appears that the resultant mass spectra can be related to the ionization potentials of the compounds studied.

In this study, mixed charge-exchange chemical ionization mass spectra will be obtained for over 100 standard polycyclic aromatic hydrocarbons. Correlations will be made with ionization potentials of these compounds. Since most of these ionization potentials are unknown, they will be calculated by computer from sophisticated molecular orbital theory calculations. This information will be used to predict compound structure from mass spectral data alone.

The development of this analytical technique could prove to be extremely useful for the detailed analysis of complex organic mixtures as found in coal fluids.

will be transmitted. Other reactions will be run using filters such as Vycor, Pyrex, etc. to filter out the higher energy radiation in order to simulate the kind of radiation in sunlight. Finally, the photolytic reactions will be carried out in the presence of sunlight itself.

Gases evolved from photolytic reactions will be collected and the volume measured in gas-type burets. The composition of the gases will be determined by gas chromatography, infrared spectroscopy and mass spectrometry. Our preliminary determinations have shown that carbon monoxide and methane are produced when certain carbon sources such as 18-crown-6 are present. All of the instruments necessary for the collection and analysis of the gases are available at Brigham Young University.

The effect of several system variables on the quantity and composition of evolved gas will be studied. These variables are pH, temperature, metal and ligand concentrations, and region of the electromagnetic spectrum (i.e., ultraviolet vs. visible).

The ligands used to study the effect on gas production of the formation of metal complexes will be of three types: 1) organic species that do not complex strongly, 2) ligands that form extremely stable water soluble metal complexes and 3) ligands of type 2 anchored to polymers. Ligands of type 1 include 18-crown-6, 15-crown-5, sugars, and amino acids. (Ligands of type 2 include porphyrins and similar macrocyclic compounds as well as Schiff bases).

The copper-uranium system discovered in our laboratory and described above has a photolytic reaction color very different from that of either metal ion alone. This fact suggests a novel interaction among the reaction intermediates. The increased hydrogen production in this system

over that found in the absence of copper(I) suggests that it would be interesting to identify the species involved and the reactions which are occurring. This reaction will be studied by electron excitation spectroscopy, mass spectrometry, nuclear magnetic spectroscopy, and electron spin spectroscopy. These instruments are available at Brigham Young University.

The procedures and instrumentation to be used in this investigation have been used by Dr. Perry Maxfield to perfect catalysts for use in petrochemical research. The same methods used to perfect these catalysts can be applied to the development of catalysts for hydrogen production. Briefly, these methods include: (1) define the basic catalytic reaction to be studied (in this case the photooxidation of water to produce hydrogen), (2) determine the metal ion(s) that would be the most effective (in this proposal uranium (IV) alone or with copper(I)). (3) use ligands and system parameters to obtain the maximum productivity of the catalyst system (in this proposal ligands will be used to give the optimum redox potential, absorbance of radiant energy and electron density for the reaction).

Significance:

The production of hydrogen from water is rapidly becoming a very important area of energy research. Currently, hydrogen is being produced by electrolysis and from fossil fuels. The thermodecomposition of water is also becoming important. All three of these processes require terrestrial energy input. The production of hydrogen by solar energy has the great advantage that the energy source is extra-terrestrial and virtually limitless. This proposal is, therefore, significant because of the dependable amount of sunlight found here.

Another area of increasing interest in catalysis is the use of multimetal systems.^{8,9} The introduction of another metal as a co-catalyst can give very interesting and rewarding results. For instance, the catalytic intermediates may contain metal pairs, metal clusters or even metal-metal bonds.

We have photolyzed uranium tetrachloride by a combination of ultraviolet and/or visible light in water and find that the yield of hydrogen is a little better than that expected for a 2 electron photooxidation. Specifically, 1 meq. of UCl_4 under some conditions can give 0.8 to 1.1 meq. of H_2 . These results point to the possibility of a catalytic effect in the reaction process. If 18-crown-6 (I) is added to the solution,

I

there is a sharp increase both in rate of evolution and quantity of gas. Some methane and carbon monoxide are formed in addition to H_2 . If a little CuCl is added to the reaction mixture, a large increase in the rate of gas evolution is observed. These interesting observations are now being investigated in detail. It is significant that photolysis using only visible light of a uranium(IV)-copper(I) system also produces hydrogen.

Rationale:

Uranium(IV) was chosen in this work for several reasons. First, it is known that uranium(VI) photoreduces with oxalate ion¹⁰ while

uranium(IV) has been reported to photoreduce at very low temperatures.¹¹ Second, oxidation states and redox potentials for uranium are varied. The following potentials (electron volts) are known for acid solutions.

The uranium(IV) state was chosen for this work because it can be either oxidized or reduced. Third, uranium(IV) has a wide absorption spectrum in the visible region making for favorable absorption of radiant energy. Fourth, the uranium(IV) ion can complex with a number of interesting ligands such as porphyrin-type macrocycles.

The importance of ligands in catalysis has been mentioned above. The ligand, 18-crown-6, has potential to help increase the stability of U(III) over U(IV) because of the expected¹² higher stability of the known complex with the former species over that of the latter. This complex stability is expected to decrease the redox potential between the two states. This decrease in redox potential will allow conversion from one state to the other to take place using radiation of low energy. The use of porphyrins and Schiff-base compounds as ligands is also proposed to increase the absorption of radiant energy.

Methods and Procedure:

The experimental procedure to be followed will be to photolyze aqueous uranium(IV) solutions containing ligands and/or a copper(I) halide with a high pressure ultraviolet lamp (250 watt). Some of the reactions will be carried out in quartz ware so that the total radiation

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7. Title: Production of Hydrogen by the Irradiation of Aqueous Uranium (IV) Complexes

Principal Investigator: Reed M. Izatt

Funds Awarded: \$10,000

Graduate Student(s): Mr. Marvin Tedjamer

Department: Chemistry

Institution: Brigham Young University

The ultimate goal of our research is to find an effective catalyst for the photochemical production of hydrogen from water. A study is now underway in this laboratory to better understand the photochemistry of aqueous UCl_4 solutions. The proposed study will involve (1) measuring the quantity of gas evolved, (2) determining the percent composition of the gas, and (3) identifying the metallic species present in the solution before, during, and after the reaction.

In the accelerated race to obtain new energy sources to replace fossil fuels, a number of researchers have recently turned their attention to the production of hydrogen from water by solar energy in the presence of inorganic photochemical receptors or catalysts. The overall goal of these previous investigations has been to find an inorganic catalyst that will economically produce hydrogen from water using solar energy. Since this field of research is very new, little is understood concerning the chemical reactions involved in this process and to date, only poor hydrogen productivity has been reported. During the past several years, a number of workers have reported that photolysis of aqueous solutions containing metal ions such as Cr^{2+} , V^{2+} , and Eu^{2+} (see footnotes in references 1 and 2) increases hydrogen production over that found in the absence of photolysis. More recently Eu(II)^1 , Cu(I)^2 ,

Mo(II)³, Fe(II)⁴, and Rh(I)⁵ have been studied in detail. In all cases the photooxidation reaction was found to be

The problems encountered in these studies which inhibit practical application of the chemical systems used are numerous: (1) the reactions are non-catalytic, 2) the quantum yields are generally low, 0.01 to 0.6. 3) the best production of hydrogen occurs in the ultraviolet region, although sunlight reaching the earth's surface contains very little ultraviolet radiation, 4) the reaction products often unproductively absorb the radiation, 5) the reactants are often poor absorbers of radiant energy, and 6) some metals used such as Rh and Eu are prohibitively expensive.

Only in the reactions of rhodium and iron have organic ligands (more complex than the anion or solvent) been used in reaction mixtures for hydrogen production. In one study, rhodium was coordinated to a complex isocyanide ligand.⁵ In another study, addition of glucose to the iron reaction slightly increased the yield of hydrogen.⁴ Addition of ligands to the reaction mixture is common in all areas of homogeneous catalysis and correct use of ligands can be as important as the correct choice of metal in this field.⁶ The ligands affect many important reaction variables among which are the electronic densities, redox potentials, absorption spectra, and reaction rates of the metal catalysts. All of these variables are significant in the catalytic production of hydrogen. Ligands used to adjust these parameters can be anchored to polymers such as polystyrene and cellulose⁷ so that the coordinated metal can be maintained in the solid phase for easy recovery.

8. Title: Slurry Pipeline Transport of Large Particle Coal

Principal Investigator: Richard W. Hanks

Funds Awarded: \$9,440

Graduate Student(s): Mr. Van Cosby

Department: Chemical Engineering

Institution: Brigham Young University

The national energy situation dictates substantial increases in the use of coal and other fossil fuel energy resources as oil and natural gas reserves become depleted. Large resources of these fossil fuels as well as many important minerals are found within the state of Utah. As major increases in the use of these natural resources occur, existing conventional rail and truck transportation systems may be inadequate to handle the volume of materials to be shipped to processing areas. Rugged mountainous terrain often renders access to new and undeveloped sites difficult by conventional means. All of these features lend attractiveness to the increased use of long distance slurry pipeline transportation as a means of handling part of this increased load. As evidence of the real interest in slurry pipelines, one need only consider House Bill No. HR1609 and Senate Bill No. S707 which were recently under debate and modifications of which are now being prepared. These Bills concern the granting of eminent domain rights for long distance coal slurry pipelines, several of which would exceed 1,000 miles in length. Numerous other smaller lines are also being proposed and considered, at least two of which are in Utah.

At the present time, two long distance coal slurry pipelines exist in the U.S. These are: 1) the 108 mile, 12 inch Consolidation Coal pipeline from Cadiz, Ohio to a power generating site near Cleveland; and 2) the 273 mile, 18 inch Black Mesa coal pipeline from Kayenta, Arizona to the Mohave power station in southern Nevada. The Cadiz line has been mothballed, but the Black Mesa line is operative.

Proposed long distance lines are envisioned to be 3-4 feet in diameter, a size much larger than any built to date. The design of such large pipelines requires extrapolation of design methods far beyond the ranges covered by presently available data and correlations. Current industry practice is to design both the slurry and the pipeline so that significant heterogeneous flow behavior is avoided because reliable hydraulic resistance correlations or theories are not available for predicting friction losses for heterogeneous non-Newtonian slurries; or for dealing with problems of restarting a line which has been shut down if a bed of deposited solids forms. Considerable economic incentive exists to increase the top-size of the solids being transported because it significantly reduces pipe-end dewatering costs (1). This, however, would necessitate pipeline designs within the poorly understood mixed-heterogeneous flow regime. The development of fundamentally based design models for mixed-heterogeneous flows would be highly desirable and could have significant economic impact on the energy transportation industry in general as well as in the state of Utah.

The urgent need for increased utilization of coal, fossil fuels and minerals indicates a potentially great increase in the use of long distance slurry pipelines for transporting these raw materials from western mine sites to coastal or otherwise conveniently located power and processing plants where more plentiful supplies of process water exist. Another application of slurry transport of potential interest to Utah energy industries is the transport of high-wax base Utah crude oils. These high-wax base crudes can be distilled to recover the lighter overhead which can then be used as a transport vehicle for the heavy wax bottoms when the latter are converted to prilled form (2). Thus, the difficult-to-pump crude could be converted to an easily pumped slurry and put through existing crude pipe lines (2). Such slurries exhibit pronounced non-Newtonian rheological properties (2). A reliable method for predicting hydraulic frictional resistance and, hence, pipe size and pumping power requirements, for heterogeneous (mixed size fractions) slurries is urgently needed and should be developed. Slurries of this type containing high proportions of fines generally exhibit non-Newtonian rheological properties. The availability and adoption of such a method could have an important economic impact on the transportation of coal and other energy raw materials of the state.

The major objective of the overall research program of which this is the initial phase will be to develop a reliable hydraulic resistance model for heterogeneous flow of non-Newtonian slurries of mixed size fractions in large diameter pipelines which could be used to design pipelines capable of transporting coal, minerals and other energy raw materials in slurry form with larger top-size particles and fewer fines than current industry practice allows.

Because of time and budget limitations imposed by the nature of Utah Energy Consortium initiation grants, the above major objective cannot be met in this study. With it as the goal, however, the following supporting objectives are envisioned in initiating work leading to a larger follow-on effort.

1. Initiate development of realistic concentration profile models for heterogeneously suspended solids in turbulent flow of homogeneous non-Newtonian fluids.
2. Initiate development of reliable theoretically based models for the deposition or suspension velocities of larger particles in heterogeneous non-Newtonian slurries. Such models must be consistent with the concentration profile models of supporting objective 1.
3. Prepare research proposals to funding agencies such as DOE, DOT and NSF for support of the larger project required to achieve the major objective.

The proposed project will be conducted as a pilot study in preparation for a larger effort.

The following approach steps have been identified:

1. Identify mathematical models for turbulent flow of homogeneous non-Newtonian fluids in pipes. Existing successful models for two simple and commonly used rheological forms (power-law (3) and Bingham plastic (4)) will be examined, as well as more complex but realistic rheological models. As part of the evaluation, these models will be programmed on the computer and compared with available data. Modifications as needed will be made to render these models as accurate and realistic as possible. The effect of slurry rheology on hydraulic resistance has been shown (5) to be crucial in slurry pipeline design.
2. Initiate rheological measurements to determine the relation of rheological parameters to concentrations and particle size distributions. Special attention will be given to finding the lower limit of particle size required to create a homogeneous carrier medium that will support large particles.
3. Initiate theoretical modeling work to incorporate more realistic concentration profiles into turbulent flow analyses of slurries.
4. Initiate theoretical modeling work to develop a theory for critical deposition velocity prediction in heterogeneous slurries.
5. Initiate literature searches to obtain pertinent data for heterogeneous flow of coal and mineral ore slurries for comparison with theoretical models.
6. Prepare proposals to DOE, DOT and NSF to address the larger questions of concentration distribution and velocity profile predictions as outlined in the objectives above.

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9. Title: Effective Utilization of Warm Water as an Energy Source

Principal Investigator: J. Clair Batty, David R. Walker,
and Jay C. Andersen

Funds Awarded: \$10,000

Graduate Student(s): Mr. Ronald Israelson

Departments of: Mechanical Engineering, Plant Science and Economics

Institution: Utah State University

Food, produced in more favorable climates and transported to various parts of the country, has often been less costly than if produced locally. Thus, the Intermountain West with its harsh winter climate has become heavily dependent upon the Southwest for much of its food. However, increased fossil fuel costs are leading to increased transportation costs. Furthermore, producers in the Southwest depend upon ground water supplies which are declining at alarming rates in some areas. Urban use of water is replacing agriculture. Higher energy costs have tremendously increased the costs of pumping irrigation water.

A major economic incentive thus seems to be shaping up for greater local food production, particularly greenhouse production of winter vegetables, provided one major barrier can be overcome. That barrier is the large quantities of a low cost form of energy for greenhouse heating. Fossil fuels are rapidly becoming too expensive for this purpose, hence we must look elsewhere.

The Intermountain area has rather large amount of warm water which seeps up along fault lines (see attached material). Also, the extensive coal deposits in the area will continue to be developed at least partially by conversion processes requiring cooling which will result in additional large quantities of warm water.

At first glance these geothermal waters or the warm effluent from electrical power generating plants constitute a tantalizingly attractive source of energy. However, efforts to utilize such energy sources have usually met with frustration. The temperatures of the water available are usually less than 130°F (55°C). To obtain practical heat transfer rates through the relatively small temperature differences involved require large heat exchanger areas. Some past studies have shown efforts to use warm water as an energy source for space heating to be uneconomical unless the water temperature is at least 160°F if conventional heat exchangers were used. The difficulties are often further compounded by exchanger fouling and corrosion when highly mineralized geothermal waters are used. After a few weeks or months of operating under such conditions, the exchanger tubes and pipes are choked with precipitated solids.

Geothermal waters are also often accompanied by gases which are toxic to plants. Hence if used as a source of energy for greenhouse heating such waters must not be exposed directly to the interior of the greenhouse. Another problem to be considered in heating greenhouses is the tendency for wide variations between daytime and nighttime temperatures because of the low thermal inertia inherent in this type of structure.

The technical challenge then is to devise a high capacity heating system which can utilize relatively low temperature water as an energy source, overcome corrosion and precipitation problems and provide high thermal inertia and all at a price the greenhouse operator can afford. Once such a system is devised it must be tested and demonstrated so that it will find wide application.

The United States Department of Energy recognizes the need for further work in this important area as indicated by numerous Program Research and Development Announcements (PRDA's) on Engineering and Economic Studies for Direct Applications of Geothermal Energy. DOE is interested in site specific studies and thus far have tended to fund research groups with demonstrated experience. Utah needs some experience and expertise in using geothermal waters for agricultural purposes in order to be viable in attracting funds allocated for this purpose.

PROJECT OBJECTIVES

1. Study the economic and technical feasibility of establishing a greenhouse and/or agriculture industry in Utah which utilizes warm geothermal waters or industrial effluents as a source of energy.
2. Prepare proposals for funding of demonstration units and further research.

PROCEDURES

1. Construct and test a small scale experimental greenhouse heating system. The system would be based largely on the design described in the appendix pages 11- 18. This could be accomplished within the limited budget by:

(a) Constructing the unit within an existing greenhouse located at Utah Hot Springs (warm water is available at the site and the co-operation of the greenhouse owner has been secured).

(b) Utilizing graduate research assistants to assist with the fabrication, instrumentation and testing of the heat exchanger unit under the direction of the principal investigators.

2. Simultaneously prepare proposals to construct and test larger commercial scale demonstration units for greenhouse and/or agriculture operations utilizing available warm waters. Utah Power and Light Company has expressed a strong interest in exploring ways of using some of the immense quantities of low grade heat available in cooling water at their various power plants. This energy source would be considered along with the relatively abundant warm geothermal springs of the intermountain area.

It is anticipated that the initial small scale experimental unit and subsequent report would strengthen the proposals for additional studies.

3. Thoroughly explore both the technical and economic feasibility of commercial greenhouse and agriculture operations upon obtaining necessary funding.

THERMAL SPRINGS OF THE UNITED STATES AND OTHER COUNTRIES OF THE WORLD

FIGURE 2.—Western part of the conterminous United States showing location of thermal springs. Chiefly from ref. 148.

DESCRIPTION OF THERMAL SPRINGS

FIGURE 7.—Utah showing location of thermal springs. From ref. 14S.

THERMAL SPRINGS OF THE UNITED STATES AND OTHER COUNTRIES OF THE WORLD

Thermal springs and wells in the United States (excluding Alaska and Hawaii)—Continued

No. on figure	Name or location	Temperature of water (°F)	Flow (gallons per minute)	Associated rocks	References on chemical quality	Remarks and additional references
Utah (See fig. 7.)						
1	Warm Springs in sec. 20, T. 12 N., R. 15 W., 17 miles north-northwest of Terrace railroad station.	Warm	900	Alluvium		Water used for irrigation. Ref. 508.
2	Blue (Honeyville) Springs, in T. 13 N., R. 5 W., 18 miles southeast of Snowville.	86		do.	508	6 springs. Refs. 144, 521.
3	Udy's Hot Springs, near the Malad River 2 miles southwest of Plymouth.	90-122	3,500	Carboniferous strata near Wasatch fault.		8 main springs. Water is saline. Used for bathing. Resort. Refs. 144, 508.
4	Crystal Springs, in T. 11 N., R. 2 W., 12 miles north of Brigham City.	121-134		do.	508	About 30 springs. Water used locally. Refs. 124, 133, 144, 508, 521.
4A	Near south end of Little Mountain, 7 miles west-northwest of Corianna.	Warm	Small	Paleozoic strata	508	
5	T. 6 N., R. 5 W., on east side of Promontory Point.	84		Faulted (?) schist and gneiss (Precambrian).		Ref. 144.
6	Utah (Bear River) Hot Springs, in T. 7 N., R. 2 W., 8 miles northwest of Ogden.	131-144	110	Faulted quartzite (Cambrian).	20, 133, 137, 144, 409, 522	12 springs. Water is saline and ferruginous. Ref. 133.
6A	Clay's Hot Springs, 10 miles north of Ogden.	140	50	Quartzite on Wasatch fault.		2 springs. Water is saline and ferruginous. Used for bathing. Ref. 512.
7	Patio Spring, 12 miles northeast of Ogden.	68	200	Lake beds (Quaternary).		Water used for bathing.
8	Ogden Hot Springs, in T. 6 N., R. 1 W., at mouth of Ogden Canyon.	121; 150	Small	Syenite on Wasatch fault.	522	2 springs. Water used for bathing. Refs. 133, 144, 413, 505.
9	Big Springs, in T. 2 S., R. 8 W., on the west side of Stansbury Range.	74		Carboniferous strata near fault.		2 springs. Water is brackish. Ref. 144.
10	Grantsville Warm Springs, 5 miles northwest of Grantsville.	74-91	50	Wasatch Formation (Eocene).		6 springs. Water is brackish; used for bathing. Deposit of calcareous tufa. Refs. 133, 144, 508.
10A	Morgan's Warm Springs, 4 miles southwest of Stockton.	80	500	do.		Water is ponded. Used for bathing and irrigation.
10B	Russell's Warm Springs, 4.5 miles southwest of Stockton.	90	200	do.		Water is ponded. Used for irrigation.
11	Beck's Hot Springs, 4 miles north of Salt Lake City.	123		Paleozoic strata on Wasatch fault.	123, 133, 137, 413	Several springs. Water smells of H ₂ S. Resort. Refs. 124, 144, 511, 512, 521, 526.
11A	Warm Springs, 2 miles north of Salt Lake City.	118	350	do.	525	Water used for bathing. Refs. 137, 511-513, 523.
12	Wasatch Springs, in the northwestern part of Salt Lake City.	120	350	Limestone (Carboniferous) near Wasatch fault.	525	Water used for bathing. Sanitarium. Refs. 133, 137, 144, 513, 523.
13	Crystal Springs, in T. 4 S., R. 1 W., 4 miles southwest of Draper.	70		Alluvium		Several springs. Water used for bathing. Refs. 133, 144, 523.
14	Schneitter's Hot Pots, 4.5 miles northwest of Heber.	85-115	20	Wasatch Formation (Eocene) near Carboniferous limestone.	133, 137	20 main springs. Water used for bathing. Extensive deposit of tufa. Refs. 133, 144, 413, 514, 523.
14A	Luke's Hot Pots, 4 miles northwest of Heber.	73-110	30	do.		Several springs. Water used for bathing. Ref. 514.
14B	Buhler's Springs, 3.5 miles northwest of Heber.	80-108	10	do.		Several springs. Water used for bathing. Extensive deposit of tufa. Refs. 137, 510, 514.
15	Saratoga Springs, on northwest shore of Utah Lake.	111	211	Wasatch Formation (Eocene).		Several springs. Water used for bathing. Resort. Ref. 523.
16	T. 8 S., R. 1 E., on south shore of Utah Lake 5 miles northwest of Payson.	83	200	Alluvium		Water used locally. Ref. 523.
17	T. 10 S., R. 1 E., near the north end of Lone Ridge 2 miles east of Goshen.	70	2,000	Faulted Carboniferous strata.		Several springs. Water used locally. Ref. 523.
18	Castilla Mineral Springs, in T. 9 S., R. 3 E., in Spanish Fork Canyon 15 miles south of Provo.	111; 145		Carboniferous strata near Wasatch fault.		3 springs. Resort. Refs. 138, 144, 526.
19	Sec. 14, T. 5 S., R. 5 E., on Diamond Creek 15 miles east of Springville.	Warm	700	Wasatch Formation (Eocene).		2 springs. Water smells of sulfur.
19A	12 miles northeast of Jensen, in canyon of Green River.	90	10	Paleozoic or Mesozoic strata.		2 springs issuing at river edge.
20	Hot Springs, in T. 11 S., R. 14 W., at north end of Fish Springs Mountains and 3 miles north-northeast of Fish Springs (town).	74-78		Alluvium near faulted Paleozoic strata.		Several springs. Water used locally. Refs. 133, 144, 506, 515, 520.
21	Big Spring, in T. 11 S., R. 14 W., 1 mile southeast of Hot Springs (No. 20).	85		do.		3 springs. Refs. 144, 506, 520.
22	Fish Springs, in T. 11 S., R. 14 W., 4 miles southeast of Hot Springs (No. 20) and 3 miles east of Fish Springs (town).	80-140		do.	406	7 springs. Water smells strongly of H ₂ S. Large deposit of tufa. Refs. 144, 406, 506, 515, 520.
23	Sec. 33, T. 11 S., R. 15 W., on Miller's Ranch 8 miles south of Trout Creek.	64	500	Alluvium		Several springs rising in pools. Water used for irrigation. Refs. 506, 520.
24	Abraham Springs, in T. 14 S., R. 8 W., on Fumarole Butte, 19 miles north-northwest of Delta.	100-205	1,200	Fractured lava (Tertiary).	507	20 springs. Deposit of manganese. Refs. 109, 144, 502, 512, 516, 520.
25	Sec. 31, T. 15 S., R. 19 W., in Snake Valley 1 mile west of Gandy.	82	Large	Limestone (lower Paleozoic).		Several springs. Water used for irrigation. Deposit of tufa. Ref. 520.
26	Sec. 9, T. 16 S., R. 18 W., in Snake Valley 2 miles south of Foote's Ranch.	68	1,050	Alluvium		Several springs rising in pools. Water used for irrigation. Refs. 144, 520.
27	Knoll Springs, in sec. 11, T. 15 S., R. 18 W., in Snake Valley 12 miles southeast of Smithville.	68-71		Alluvium near Carboniferous strata.		Several springs. Water smells of H ₂ S. Used locally. Refs. 144, 520.
28	Sec. 24, T. 22 S., R. 6 W., 3 miles north-west of Hutton.	94	Large	Interbedded tuff and lava (Tertiary).		Water used for irrigation. Ref. 520.
29	Brewer's Springs, in secs. 13 and 24, T. 18 S., R. 2 E., 1 mile northwest of Wales.	57-62	400	Alluvium near faulted Wasatch Formation (Eocene).		3 springs. Water used for domestic purposes and irrigation. Ref. 521.
30	Lowry's Spring and Squires' Spring, in sec. 23, T. 18 S., R. 2 E., 3 miles south of Manti.	59; 62	40	Faulted Wasatch Formation (Eocene).		Water used for irrigation. Ref. 524.
31	Livingston Warm Springs, in sec. 13, T. 18 S., R. 2 E., 1 mile south of Manti.	62; 73	283	do.		2 main springs. Water used for domestic purposes and irrigation. Ref. 524.
32	Manti Springs, in sec. 17, T. 18 S., R. 3 E., 2 miles southeast of Manti.	59; 65	30	do.		Do.
33	Morrison Spring, in sec. 35, T. 18 S., R. 2 E., 2 miles northeast of Sterling.	61	2,500			Water used for irrigation. Ref. 524.
34	Gunnison Spring, in sec. 18, T. 19 S., R. 1 E.	61	8	Alluvium		Water supply for cattle. Ref. 521.

DESCRIPTION OF THERMAL SPRINGS

Thermal springs and wells in the United States (excluding Alaska and Hawaii)—Continued

No. on figure	Name or location	Temperature of water (°F)	Flow (gallons per minute)	Associated rocks	References on chemical quality	Remarks and additional references
Utah—Continued						
	Ninemile Warm Spring, in sec. 4, T. 19 S., R. 2 E.	72	900	Alluvium near faulted Wasatch Formation (Eocene).		Water used for domestic purposes and irrigation. Ref. 524.
	Sec. 32, T. 20 S., R. 2 E., 8 miles northeast of Redmond.	58	15	Faulted Wasatch Formation.		Water used for irrigation. Ref. 524.
	Redmond Springs, in secs. 11 and 12, T. 21 S., R. 1 W., near Redmond.	70	6,000	do.		Several springs. Water used for domestic purposes and irrigation. Ref. 524.
	Salt Spring, in sec. 17, T. 21 S., R. 1 E., 2 miles northeast of Salina.	72	2	Faulted Jurassic strata.		Ref. 524.
	Oak Spring and Christianson Spring, in sec. 1, T. 22 S., R. 2 W., 2 miles west of Aurora.	60	20	Faulted lava (Eocene).		Water supply for cattle. Ref. 524.
	Herrin's Hole Spring, in sec. 23, T. 23 S., R. 2 W., 1 mile north of Glenwood.	63	450	do.		Water used for irrigation. Ref. 524.
	Cove Springs, in sec. 27, T. 23 S., R. 2 W., 1 mile west of Glenwood.	60	4,000	do.		Several springs. Water used for irrigation. Ref. 524.
	Richfield Hot Springs, in sec. 28, T. 23 S., R. 3 W.	74	1,500	Faulted limestone (Eocene).		Several springs. Water supply for town; also used for irrigation. Ref. 524.
	Indian Spring and Parcel Creek Spring, in sec. 25, T. 23 S., R. 2 W., near Glenwood.	60	130	Faulted lava (Eocene).		Water used for domestic purposes and irrigation. Ref. 524.
	Sec. 5, T. 24 S., R. 2 W., 2 miles southeast of Richfield.	52-61	4,500	Lava (Tertiary).		Several springs. Water used for irrigation. Ref. 524.
	Sec. 25, T. 24 S., R. 3 W., 6 miles south of Richfield.	59	25	Alluvium overlying Wasatch Formation (Eocene).		Water used for domestic purposes and irrigation. Ref. 524.
	Parcho Spring, in sec. 6, T. 25 S., R. 3 W., 2 miles northeast of Joseph.	65	700	Alluvium.		Water used for irrigation. Ref. 524.
	Johnson Spring, in sec. 27, T. 25 S., R. 3 W., 2 miles southeast of Monroe.	80	200	Faulted lava and tuff (Eocene).		Do.
	Cooper Hot Springs, in sec. 15, T. 25 S., R. 3 W., 0.5 mile east of Monroe.	144-156	100	Faulted tuff (Tertiary).	524.	Several springs. Water used for irrigation.
	Joseph Hot Springs, in sec. 23, T. 25 S., R. 4 W., 1 mile southeast of Joseph.	135-146	30	Lava (Tertiary).		Several springs. Water used for irrigation. Deposit of tufa. Ref. 524.
	Sevier Spring, in sec. 32, T. 25 S., R. 4 W.	59	100	Alluvium.		Water used for domestic purposes; also water supply for cattle. Ref. 524.
	Roosevelt (McKean's) Hot Spring, in T. 27 S., R. 9 W., on west slope of Mineral Mountains 15 miles northeast of Milford.	192	10	Granite.	518.	Water smells strongly of H ₂ S. Water supply for cattle. Deposits of tufa and sinter.
	Warm Springs, secs. 21 and 28, T. 30 S., R. 12 W., 2 miles south-southwest of Thermo railroad siding.	60-175	20	Alluvium near faulted (?) lava (Tertiary).	518.	About 16 springs issuing from a low ridge. Deposits of dense calcareous tufa. Water supply for cattle.
	Radium (Dotson's) Warm Springs, in sec. 7, T. 30 S., R. 9 W., 1 mile east of Minersville.	97	67	Quartzite.	518.	3 springs. Water used for bathing and irrigation.
	La Verkin Hot Springs, on Rio Virgin 2 miles north of Hurricane.	103-132	1,000	Faulted Triassic strata.		Several springs. Refs. 133, 144.
	T. 37 S., R. 7 W., 25 miles southwest of Panguitch.	Warm		Lava (Tertiary) overlying Wasatch Formation (Eocene).		Ref. 133.
	Undine Springs, in T. 25 S., R. 17 E., in Labyrinth Canyon of the Green River.	Warm		Sandstone (Triassic).		Many small springs. Deposit of tufa. Ref. 133.
	Warm Spring Canyon near its junction with "Narrow Canyon" or "Dark Canyon" of the Colorado River.	91		do.		Ref. 133.

10. Title: A Study of Nuclear Fission Induced by Fast Pions
in Light Elements

Principal Investigator: V. Gordon Lind, Robert E. McAdams,
and O. Harry Otteson

Funds Awarded: \$9,990

Graduate Student(s): Mr. Cameron Vaziri

Department: Physics

Institution: Utah State University

Like many other processes in nature the fission process is only partially understood. We are investigating the fission (and consequently fusion) mechanism by inducing fission in light nuclei with fast pions. Since the pion is the "glue" which holds the nucleus together it is an ideal probe to investigate processes in which the nucleus is split into two or more fragments. Although energy is not available from the fission of light nuclei, their relative simplicity should yield more information about the fission process. The goal of this research is to obtain a better understanding of the fission mechanism so that better and safer fission and/or fusion reactors can be built and that the expected timetable for developing a workable fusion reactor can be shortened.

MEMORANDUM OF UNDERSTANDINGUTAH CONSORTIUM
FOR
ENERGY RESEARCH AND EDUCATION1. Formation of the Consortium

The United States, including both the public and private sectors, has recognized the importance of further developing the nation's energy resources and has initiated programs to stimulate that development and facilitate it in the fashion responsive to the economic, mineral, and energy needs of the country and to the environmental, social, and political requirements as well. Likewise, the state of Utah has taken initiatives with similar objectives in mind. To accomplish these purposes, substantial programs of research in the sciences, energy technology, environment, health, legal, and socio-economic areas will be required, together with a major educational program designed to afford increased opportunities for our young people and improved public understanding of the major public issues involved in such a development.

Significant resources of energy lie within the state of Utah. The three universities in the state have in the aggregate major research and educational capability in all of the areas related to the development of the state's energy resources, as noted above. Many of the needed research and educational activities can be implemented more efficiently and with greater effect through a cooperative effort among these three institutions rather than by each acting wholly independently of the other two.

In consideration of the above, the below-named universities, resident in the state of Utah, hereby form the Utah Consortium for Energy Research and Education. The Consortium will facilitate the formulation and implementation of those activities referred to in the title which lend themselves to a cooperative effort which promises to produce greater overall benefits in research and education than if such were separately undertaken by each institution acting alone. It is recognized, however, that there are other research and education activities in this broad area that can be carried out more effectively by one institution working alone rather than as a part of the Consortium. Thus, each university will remain free to pursue its own research and education efforts in these general areas either as a part of the Consortium, when

cooperative efforts promise to yield greater benefits, or independently of the Consortium if such an arrangement similarly promises greater results than under the Consortium's auspices.

2. Objectives of the Consortium

The objectives of the Consortium are to:

- (a) Avoid unnecessary duplication of effort in energy research and development among the Consortium members.
- (b) Identify areas of needed research and education that can be enhanced by cooperative efforts.
- (c) Prepare plans and proposals for funding and implementing such cooperative efforts.
- (d) Agree upon procedures for implementing cooperative efforts.

3. Organization of the Consortium

- (a) The governing body of the Consortium shall consist of a Steering Committee, composed of the presidents of the three universities, with the president of the University of Utah as chairman. The work of the Consortium will be overseen by a Coordinating Committee consisting of the vice presidents for research of the cooperating universities who will appoint inter-university advisory committees to develop research and educational activities in specific areas of mutual interests, as determined by the Coordinating Committee.
- (b) The Steering Committee will be advised by 1) an Inter-institutional Advisory Committee, consisting of the three university vice presidents for research, the state of Utah's science advisor, a representative from industry, a representative from the executive branch, a representative from the legislative branch of the government of the state of Utah, and 2) a National Advisory Council. All members of both councils will be invited to serve by the Steering Committee on an annual basis. Each university shall organize its internal arrangements to facilitate the work of the Consortium, as the respective presidents choose to do.
- (c) No contractual obligations are specified or implied in this arrangement, nor will the Consortium enter into any contractual arrangements, obligations or disbursement of funds. These functions shall be reserved to the universities separately as set forth in paragraphs 3e and 3f.

- (d) The Consortium's Steering Committee may invite other persons or organizations, including state and community governments and private firms, to participate in its activities.
- (e) It is agreed that the lead University for the Consortium shall be the University of Utah and that the contractual responsibilities of the other two universities and other interested parties shall be by separate subcontracts. The subcontracts shall in each instance be recommended by the Coordinating Committee and reviewed and approved by the Steering Committee.
- (f) Any discretionary funds that may be provided by any contract shall be assigned upon the recommendation of the Coordinating Committee, as reviewed and approved by the Steering Committee. The usual indirect cost allowances, as permitted by federal and state policy, are not discretionary funds and shall accrue under each contract and subcontract in accordance with each institution's indirect cost policy.

4. Termination

This agreement may be terminated by each or all of the parties thereto upon written notification to others involved.

5. Ratification

The provisions of this Memorandum of Understanding will be in effect when signed by the Presidents of the University of Utah, Utah State University, and Brigham Young University.

1 April 1977

Date

David Pierpont Gardner, President
University of Utah

April 5, 1977

Date

Glen L. Taggart, President
Utah State University

Apr. 4, 1977

Date

Dallin H. Oaks, President
Brigham Young University

Organizational Structure for the Utah Consortium
for Energy Research and Education

Voting members of Energy Conservation and Development Council

Dr. Joan Coles
1357 Third Avenue
Salt Lake City, Utah

Phone: 581-7525 (Business)
364-9921 (Home)

Dr. Val A. Finlayson
Vice President for Research
Utah Power & Light Co.
Adjunct Professor
College of Engineering
University of Utah

Phone: 350-3772 (Business)
942-6564 (Home)

Cyrus M. McKell
Professor of Brain Science
College of Natural Resources
Director for the Institute for
Land Rehabilitation
Utah State University

Phone: 752-4100 (Business)
753-1556 (Home)

Marjorie A. Billings (Mrs. Peter W.)
1600 Arlington Drive
Salt Lake City, Utah 84103

Phone: 364-8670 (Home)

Roger A. Markle
President, Valley Camp Coal Company
Scofield Route
Helper, Utah 84526

Phone: 355-8888 (Business)
355-8516 (Home)

Lee Kopoloski
567 Fifth Avenue
Salt Lake City, Utah 84103

Phone: 533-8791 (Business)
533-8791 (Home)

Dr. George R. Hill, III
Presently, Director of Fossil Energy Research
ETRI
Professor of Chemical Engineering
College of Engineering
University of Utah
Effective September 1, 1977

Phone: (414) 493-4800,
Ext. 472

Commissioner Calvin Black
San Juan County
88 East Center
Blanding, Utah 84511

Phone: 678-2021 (Business)
678-2698 (Home)

Mayor Ted Wilson
Mayor of Salt Lake City
200 City and County Building
Salt Lake City, Utah 84111

Phone: 328-7704 (Business)

Representative Glade M. Sowards
Speaker of Utah
State of Utah
380 West First South
Vernal, Utah 84073

Phone: 789-0657 (Office, Vernal)
789-0149 (Home, Vernal)
532-1668 (S.L.C)

Representative Mike Dmitrich
Utah State Representative
566 No. Dover Circle, P. O. Box "M"
Price, Utah 84501

Phone: 637-0426 (Home)
637-1272 (Office)

Senator Ivan Matheson
Senator, State of Utah
R.F.D. #1, Box 75
Cedar City, Utah 84720

Phone: 586-9239

Senator Edward T. Beck
Senator, State of Utah
557 South 4270 West
Kearns, Utah 84118

Phone: 298-4604

ENERGY CONSERVATION AND DEVELOPMENT COUNCIL

Ex-officio Members

Michael Gallivan, Executive Director
Development Services
Room 104 State Capitol Building
Salt Lake City, Utah 84114
Phone: 533-5961

Dr. Lyman Olsen, Director
Division of Health
Department of Social Services
72 East Fourth South
Salt Lake City, Utah 84111
Phone: 533-6111

James Edwin Kee, State Planning Coordinator
Office of the State Planning Coordinator
Room 118, State Capitol Building
Salt Lake City, Utah 84114
Phone: 533-5246

Beth Jarman, Executive Director - Effective June 1, 1977
Department of Community Affairs
Room 101, State Capitol Building
Salt Lake City, Utah 84114
Phone: 533-5231 (temporarily)
533-5248

Gordon Harmston, Executive Director
Department of Natural Resources
438 State Capitol Building
Salt Lake City, Utah 84114
Phone: 533-5357

HAROLD NEWMAN
GARTH JONESJAMES HANSEN
GENEVIEVE ATWOOD

LEGISLATIVE GENERAL COUNSEL

Approved [Signature]
Proofread [Signature]
Indexed CRD 124 77

(ENERGY CONSERVATION AND DEVELOPMENT COUNCIL)

1977

GENERAL SESSION

HB. 272

BY GLADE SOWARDS

DOUGLAS SONNTAG

JOHN GARR

MIKE DMITRICH

AN ACT RELATING TO THE CONSERVATION AND DEVELOPMENT OF ENERGY IN
UTAH; ESTABLISHING AN ENERGY CONSERVATION AND DEVELOPMENT
COUNCIL; PROVIDING FOR ITS COMPOSITION, ORGANIZATION,
POWERS, FUNCTIONS, AND DUTIES; PROVIDING FOR ITS
RELATIONSHIP WITHIN THE EXECUTIVE DEPARTMENT, FOR
COMPENSATION OF MEMBERS, AND FOR ITS STAFF; APPROPRIATING
\$175,000 TO THE COUNCIL FROM THE GENERAL FUND FOR FISCAL
YEAR 1978; AND PROVIDING AN EFFECTIVE DATE.

Be it enacted by the Legislature of the State of Utah:

Section 1. (1) The legislature finds and declares that:

(a) Energy resources are essential to the health, safety,
and welfare of the people of Utah and to the economy of the
state, and it is the responsibility of state government to
conserve such resources and to insure that a supply of energy
adequate to meet basic needs is maintained for protection of
public health and safety and for promotion of the general
welfare.

(b) The state and the nation face serious and impending
shortages of energy which require that immediate action be taken
to promote conservation and development of the nation's energy
resources and the wise use of existing energy in order to meet
this challenge.

(c) State and national energy resources require effective
management, including both conservation and development; and the
development of the state's resources should be based on a
recognition of the finite nature of human, financial, and natural

resources and of the land's limited ability to absorb the impacts of large-scale developments.

(d) Maximum and timely public participation and coordinated government involvement at every significant stage of the decision-making process involving energy use and development will help avoid unnecessary delays and is essential to the protection and representation of the public interest.

(e) Present practices relating to the location of major energy facilities should be improved so that the costs of development may be fully and equitably weighed against the benefits resulting from them.

(2) The legislature declares that it is the policy of this state:

(a) To employ a range of measure to promote the development of the energy resources within the state, inasmuch as substantial undeveloped energy resources lie within the boundaries of the state;

(b) To promote conservation and reduce wasteful, uneconomical, and unnecessary uses of energy; and

(c) To establish and consolidate the state's administrative responsibility with respect to energy resources to most effectively accomplish the state's energy goals.

Section 2. (1) There is created the Utah energy conservation and development council comprised of 13 members as follows:

(a) The director of the department of community affairs, or his designated representative;

(b) The director of the department of natural resources, or his designated representative;

(c) The director of the division of health, or his designated representative;

(d) The state planning co-ordinator, or his designated representative; and

1
2 Section 3. (1) The council shall maintain offices within
3 the office of the state planning co-ordinator and shall be a
4 section within that office.

5 (2) The council shall hold regular meetings at its offices
6 on dates fixed and formally announced by it at least once every
7 two months and may hold other meetings at such times and places
8 as it may by order provide. Meetings may also be held upon call
9 by the governor, the chairman, or a majority of the council; and
10 for these meetings the notice of the time, place, and purpose of
11 meeting shall be given by mail, telephone, or telegraph to each
12 member at least seven days prior to the date of the meeting.

13 (3) The council shall keep complete minutes of its
14 meetings.

15 Section 4. (1) The council shall have the following
16 powers, functions, and duties:

17 (a) To provide for the coordination of energy resource data
18 collection throughout Utah state government;

19 (b) To develop projections of future state energy
20 requirements;

21 (c) To determine and analyze the feasibility and effects of
22 proposed energy development projects in the state;

23 (d) To develop criteria to be followed by state agencies in
24 the formulation of rules and regulations and standards and in the
25 granting or disallowing of permits for energy resource
26 development projects;

27 (e) To represent the state at interstate and federal energy
28 meetings;

29 (f) Examine the feasibility and desirability of
30 establishing energy corridors and energy transmission corridors
31 and, if such corridors are feasible, to make recommendations and
32 assist state agencies and local governments in the establishment
33 of these corridors;

(e) The director of the department of development services, or his designated representative; and

(f) Eight citizens of the state appointed by the governor. The members of the council appointed by the governor shall be selected from the fields of natural resources development, education, the sciences, or fields of private endeavor relating to environmental protection or consumer interests; and each citizen member shall be a person who, as a result of education and training, experience, and interests, is well qualified to analyze and interpret economic and environmental issues, natural resource data, and related information.

(2) Of those members appointed by the governor under subsection (1) no more than four shall be from the same political party. Three of the members first appointed to the council by the governor shall be appointed for terms of office of one year, three for two years, and the remaining two for three years, each to commence their respective initial terms of office on April 1, 1977, but their successors shall be appointed for terms of office of three years each. Any vacancy occurring in the membership to the council appointed by the governor other than by expiration of the term shall be filled for the unexpired term. Each shall serve until a successor has been duly appointed and qualified.

(3) The council shall elect a chairman from its membership at the first meeting of the council held after April 1st of each year to serve for a term of office ending on the next April 1st and until a successor has been elected and qualified. Seven members of the council shall constitute a quorum, and actions of the council shall require a vote of a majority of those present.

(4) Each member of the council appointed by the governor shall receive a per diem allowance as approved by the board of examiners and travel expenses as provided in the rules and regulations promulgated under section 63-2-15.

HB No. 272

(g) To provide leadership in state energy conservation planning and implementation;

(h) To recommend to the governor and to the state legislature changes in federal and state laws or rules and regulations;

(i) To monitor federal legislation on energy development and conservation and recommend policy positions with regard to it;

(j) To develop and recommend energy policy to the governor and to the legislature; and

(k) To promote and coordinate the implementation of the state's energy policy.

(2) The council is also authorized to promulgate and enforce such rules and regulations as may be necessary to effectuate the purposes of this act.

Section 5. The council shall make reports at least annually to the governor and to all members of the legislature on all matters which may come before it and be accountable to the legislature for all funds expended by it.

Section 6. (1) The state planning co-ordinator shall appoint an executive secretary to the council, subject to the approval of the council. The executive secretary shall be a qualified executive with technical and administrative experience and training. In addition to such other functions, powers, duties, rights, and responsibilities provided for in this act, the executive secretary shall have general administrative supervision of all operations and actions of the council. The executive secretary shall receive a salary to be fixed by the legislature and shall be entitled to travel expenses as provided for in the rules and regulations promulgated under section 63-2-15.

(2) The executive secretary annually shall prepare and submit to the governor, to be included in his budget to be

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- 1 HB. No. 272
2 submitted to the legislature, a budget for the requirements of
3 the council for the following fiscal year.
4 Section 7. There is appropriated to the energy conservation
5 and development council from the general fund, from funds not
6 otherwise appropriated, the sum of \$175,000 for the purposes of
7 this act for the fiscal year ending June 30, 1978.
8 Section 8. This act shall take effect upon approval.

MANAGEMENT AND FISCAL ANALYSIS

H.B. No. 272

This bill carries an appropriation of \$175,000 to provide for the purposes of the Act.

OFFICE OF THE LEGISLATIVE FISCAL ANALYST

H.B. No. 272 (ENERGY CONSERVATION AND DEVELOPMENT COUNCIL)--
This bill was recommended by the Economic Development,
Business and Labor Study Committee as a result of its
study during the 1975-76 interim.

OFFICE OF LEGISLATIVE RESEARCH

LEGISLATIVE GENERAL COUNSEL

Approved [Signature]
Proofread [Signature]
Indexed

SUMMARY OF PROPOSED LEGISLATION

H.B. NO. 272

BY: Glade Sowards; Douglas Sonntag; John Garr;
Mike Dmitrich; Harold Newman; Garth Jones;
James Hansen

(ENERGY CONSERVATION AND DEVELOPMENT COUNCIL)

The following is a brief summary of
Establishes an energy conservation and development council in the

executive department of state government, provides for its composition,

organization, powers, functions, and duties and for compensation of

its members and for its staff, and appropriates the initial funding for
this council.

23 January 1979

Refer to: 79-076

Dear Dr.

As we discussed in our recent telephone conversation, my office administers funds to provide support for started grants and/or exploratory research in energy-related areas. The general guidelines used for identifying eligible projects are contained in the attached memorandum. I would greatly appreciate your assessment of the attached proposal.

In your evaluation of this project please consider the following factors:

1. Is the idea presented basically sound?
2. Is sufficient evidence presented to provide a reasonable expectation that the project can make adequate progress?
3. Does the investigator possess the requisite skills and/or facilities to carry out the proposed research?
4. Given the \$10,000 budget limit, and the proposed budget, can the project, as described, be expected to achieve the stated results with the resources requested within one year's time limit?
5. The potential for the proposed exploratory research effort to produce sufficient new data or ideas to warrant additional funding from federal or private sector sources.

In your evaluation of the proposal employing the above criteria, please use the following numerical ranking for each criteria:

1 = poor; 2 = fair; 3 = average; 4 = very good; 5 = excellent.

The sum of these numerical ratings will then provide an overall rating of the proposal.

23 January 1979
Page Two

The reviewers comments and ranking will be provided to each investigator, on request, but the reviewer's name will be kept confidential as is the case with the federal peer review system.

I appreciate your assistance in this matter. If you have any questions please call me.

Sincerely yours,

A handwritten signature in dark ink, appearing to read "Ronald J. Pugmire", written over the typed name.

Ronald J. Pugmire
Associate Vice President
for Research
(801) 581-7236

RJP:bm

Enclosure

14 November 1978

Refer to: 78-499

MEMO TO: David M. Grant
Larry Lattman
G. Richard Lee
Walter Oberer
William F. Prokasy

FROM: Ronald J. Pugmire

SUBJECT: Availability of Department of Energy Funds for
Exploratory Energy Research

The Department of Energy has made a limited amount of financial support available to the Utah Consortium for Energy Research and Education for conducting exploratory research in energy related areas. These funds are to be awarded by the participating institutions (University of Utah, Utah State University, and Brigham Young University) on a competitive basis following a peer review of proposed research activities. The general guidelines are attached for proposals considered.

The mechanism for proposal selection is as follows:

1. Deans should solicit innovative ideas from their respective faculty. The deans are to screen 1-page letter proposals initially to select those that fit the general guidelines and to assure that high quality research is considered for funding.
2. Following submission of letter proposals from the deans involved, an ad-hoc faculty review committee will be constituted to rank the preliminary proposals as to general appropriateness, merit, energy relevance, capabilities of the faculty members, etc.
3. Those letter proposals ranked in the top 10-12 of proposals received will be selected for consideration of a more detailed (not more than 4-5 page) proposal that will be reviewed by a peer group (to be selected).

As DOE has entrusted us the responsibility to review and fund exploratory research proposals that, hopefully, will uncover new knowledge that can be used to solicit longer term research support, your assistance in assuring the quality of preliminary proposals submitted for consideration will be greatly appreciated. The preliminary proposals should have an attached budget. Preliminary (1-page letter) proposals should be forwarded from your office so as to reach my office not later than December 1, 1978. Joint proposals from two or more faculty (or colleges) will also be considered.

If you have any questions please call me.

Ronald J. Pugmire
Associate Vice President
for Research

RJP:bm

Attachment

27 October 1978

Refer to: 78-480

MEMO TO: Coordinating Committee
Utah Energy Consortium

FROM: Ronald J. Pugmire
Executive Secretary

SUBJECT: Guidelines for Allocating DOE
Institutional Support

As a result of the last meeting of the Coordinating Committee and the follow-up conference call, I will reiterate the guidelines that were agreed upon at that time for allocating institutional support under our DOE consortium arrangement.

- 1) Institutional support will not be allowed to provide support for on-going projects.
- 2) Institutional support will be used as seed money for exploratory research.
- 3) Research projects supported must be clearly identified energy research areas. Priorities will be given to projects which support the Department of Energy National Energy Plan.
- 4) For a project to be funded it must be innovative, novel, and demonstrate that it can lead eventually to independent support. Proposals and principle investigators must be of high quality.
- 5) Funding for projects are not intended to run longer than one year.
- 6) It is anticipated that awards will be made for no more than ten thousand dollars unless unusual circumstances obtain. It is anticipated that awards will go to projects deemed most worthy of support without consideration of institutional affiliation.
- 7) In order to facilitate an appropriate peer review of proposals submitted, the proposals will be grouped by disciplinary areas. Three recognized specialists in each of these disciplinary areas will be selected from among the various faculties of the Consortium and asked to review each proposal in their area of specialty.

- 8) Each institution may submit as many as 8 proposals to be considered for funding.
- 9) When an award for institutional support is made, a written letter progress report submitted quarterly is required. These progress reports will be reviewed by the committee. In addition, a detailed final report and financial statement will be required at the end of the project.
- 10) Awards will be made by subcontract from the University of Utah.

It is anticipated that 15-16 proposals will be supported as a result of this review. We should do our best to insure that we consider proposals from our top people so that the quality of work supported will withstand close external scrutiny.

I trust that the above items reflect the consensus that we reached in our meeting. If you want to make any changes in them please get in touch with me.

Ronald J. Pugmire
Associate Vice President
for Research

RJP:bm

Distribution: Leo Vernon
Bartell Jensen
Don Nielson