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DOE/ET/27103 - TI

SUPPORT SERVICES RELATING TO GEOOTHERMAL PROGRAMS

FINAL REPORT

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FOR THE DEPARTMENT OF ENERGY

Division of Geothermal Energy

Contract No. DE-AC01 79ET103.001

79ET27103

① LEWIN and ASSOCIATES, INC.

② TERRA TEK

③ ENGINEERING and ECONOMICS RESEARCH, INC.

AUGUST, 1981

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FINAL REPORT

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Introduction

This report summarizes the efforts undertaken under the Geo-pressure Support Contract, DE-AC01-79ET27103. Attached are copies of the deliverables submitted under this Support Contract.

Lewin and Associates, together with Terra Tek and the Engineering and Economics Research, Inc., have provided support for 21 months for a total cost of \$309,837, and a total of 7,324 direct productive man-hours. This is within the contractual agreement which called for 7740 person hours plus or minus 10 percent. The expenditure of time and effort has been documented in the monthly cost management reports and contract management summary reports.

The Statement of Work for this support contract is shown on Attachment 1. Eight Task Orders were issued under this contract, as shown on Table 1. The performance under these Task Orders is discussed in the monthly reports and is summarized below by Task Order.

Task Order 1

The purpose of Task Order 1 was to assist the Division of Geothermal Energy, DGE, in its assessment of processes through which geopressured methane production and geopressure-geothermal power can be increased. Further, to evaluate alternative approaches for implementing proposed Federal activities to ensure maximum possible leverage from use of available public resources in Federal geopressure-geothermal R&D programs. Deliverables submitted under this Task Order are:

- An analysis of geopressure-geothermal resources by Lewin and Associates, which evaluates the technical and economic

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TABLE 1

SUMMARY OF GEOPRESSURE CONTRACT TASK ORDERS

<u>Task Order</u>	<u>Period</u>	<u>Dollars</u>			<u>Hours</u>
		<u>Budget</u>	<u>Actual</u>	<u>Difference</u>	
1. Shallow Well Analysis	11/79-1/80	35,000	34,979	(21)*	609
2. General Support	10/79-2/80	25,000	16,220	(8,780)	410
3. HDR Review	11/79-12/79	5,000	4,998	(2)	123
4. General Support	8/80-11/80	86,092	78,884	(7,208)	1,770
5. General Support	3/80-4/80	25,000	21,408	(3,592)	692
6. R&D Plan	5/80-7/80	42,000	41,135	(865)	1,234
7. General Support	12/80-6/81	91,000	90,614	8,614	2,097
8. Edna Delcambre	4/80-6/80	22,628	<u>21,599</u>	(1,029)	<u>389</u>
Total			309,837		7,324

*() Indicates task performed under budget.

potential as well as outlines the major areas of uncertainty.

- Preliminary evaluation of conventional production from eight geopressured reservoirs by Terra Tek, and
- Technical and economic feasibility of significant advances in gas separation, hydraulic and thermal energy equipment for use in conjunction with shallow wells and geopressured zones by The Engineering and Economics Research, Inc., (EER).

These reports address two questions:

Question 1: Should the geopressure-geothermal program evaluate hydropressure and shallow geopressure resources, as well as the deeper geopressure resources?

In response to this question, the economics of producing hydropressured and geopressured aquifers were developed and the resources which have the potentially most favorable economics determined. Furthermore, the power available from kinetic and thermal energy was analyzed under current and advanced technology and the economics of these total energy systems were discussed.

Question 2: What should the duration and structure of a generic well testing program be?

This analysis was conducted by varying the reservoir parameters to determine the economically most critical ones. The second part of answering this question consisted of a paper discussing, in generic terms, the type and duration of well tests designed to obtain the maximum information.

The responses to these two questions and the recommendation submitted to DOE on geopressured aquifer drilling programs and R&D strategy are summarized below.

The analysis of the design well drilling program concluded that shallow, deep, and ultradeep geopressured aquifers can produce methane at approximately the same cost. However, hydropressure aquifers are uneconomic under natural flow conditions. The reservoirs in Louisiana appear to be a more attractive resource target than the ones in Texas, both in terms of cumulative gas production and economics.

The total energy system analysis concluded that electrical power prices from thermal and hydraulic energy is comparable to those of conventionally generated electricity. There is sufficient energy for shallow reinjection and a surplus that could be sold commercially.

The sensitivity analysis concluded that no single parameter will probably increase the economics significantly. As one parameter improves, another becomes constraining and limits production. Methane content was found to have the greatest impact on the economics, while net pay had the greatest effect on production.

If free gas can be produced, gas production can be doubled and the cost halved. Deep reinjection into the producing aquifer can increase the total recoverable gas twenty-fold and could allow sustained production from smaller reservoirs.

Finally, a well testing program was devised that includes two short term pressure build-up and drawdown tests to measure permeability and porosity, and a long term (1-2 years) test for defining reservoir limits.

Task Order 2: General Support

The purpose of this Task Order was to allow Lewin and Associates, Terra Tek, and EER to provide immediate and informed support when requested by the Division of Geothermal Energy. To enable us to perform this support, we attended the Fourth United States Gulf Coast Geopressure-Geothermal Energy Conference in Austin, a Hot-Dry Rock Program Review in Washington, D.C., and a Geothermal Drilling and Completions Conference in Washington, D.C. Further, a presentation and supporting graphics concerning geopressure prospects and well locations in Texas and Louisiana were prepared.

Task Order 3: Hot-Dry Rock Review

The purpose of this Task Order was to comment on a draft Program Plan for development of updated plans with the goals, objectives, strategy, program elements, and schedules for the Hot Dry Rock program.

Our comments to this program plan are presented in the attached report, "Comments to Hot Dry Rock Program Plan," which is a page by page review of the draft plan together with an overall assessment, by Lewin and Associates in association with Terra Tek and Engineering and Economic Research, Inc.

Task Order 4: General Support

The purpose of this Task Order was to:

- develop updated plans including goals, objectives, strategy, program elements, and schedules for the geopressure-geothermal program,

- assess novel techniques by which amounts of geopressured methane production and geopressure-geothermal power "on-line" can be increased, and
- evaluate alternative approaches for ensuring maximum possible leverage from the Design Well program.

Four supporting efforts were initiated under Task Order 4:

- The Research and Development Plan for geopressure-geothermal resources initiated under Task Order 6 was completed.
- By special invitation, Lewin and Associates presented a paper at the Geothermal Resources Council meeting in Salt Lake City in September of 1980, titled "Economics of Total Energy Systems for Geopressured Aquifers." This paper is attached.
- The above paper generated interest in the reinjection of produced fluids into geopressured aquifers and Lewin and Associates and Terra Tek were asked for a more detailed analysis evaluating the pressure characteristics of the production and injection wells, as well as the net energy available from methane, thermal, and kinetic sources. These studies are attached and are summarized later.
- The fourth item was a study requested by DGE to determine the equipment items most likely to inhibit the drilling of Design Wells and to suggest ways of overcoming any problems.

In addition to an initial report, (attached) this entailed monitoring the equipment markets and reporting on developments as described in the monthly reports.

In addition to the above four studies, other supporting activities were conducted for DGE, including the preparation of background papers that illustrated various aspects of the geopressure-geothermal Wells of Opportunity and Design Well programs.

Task Order 5: General Support

The purpose of this Task Order was to provide a series of analytic evaluations and assessments in the following areas:

- economic analyses
- institutional assessments
- policy studies
- technology transfer activities, and
- research and development program evaluation

Under this Task Order, DGE was assisted with general support, including papers and working notes in several areas; resource requirements and other plans were prepared; background information on the unconventional gas resources in the U.S. was provided, and the R&D programs to commercialize these resources, in particular the Department of Energy's Geopressure-Geothermal Program, were described and assessed. Also, work started on an outline of the Geopressure-Geothermal R&D Program Plan.

In addition, the National Petroleum Council Report (Draft) on "Unconventional Gas Sources - Volume IV, Geopressure Brine" was reviewed and written critiques prepared.

The major comments are:

1. The report essentially concludes that the geopressured gas resource will not be a major contributor to the nation's energy supplies before the year 2000, based on existing

preliminary data from the drilling of oil and gas wells into and through the geopressured zones, unless the DOE's ongoing R&D work proves to be unexpectedly successful (better than the best case). However, the report does not address the major uncertainties that exist about the resource nor the possibility that DOE's program could achieve significant results within the next decade (in time for an industry to develop before 2000).

2. The report only briefly analyzes reinjection into the producing aquifer and concludes that the amount of energy required to reinject would make this technique uneconomic. However, energy might be available from other sources, for example total power systems or conventional coal or nuclear electricity plants, that would serve to, in effect, generate gas from other energy sources.
3. The role of total energy systems has been down-played. Our analysis shows that a substantial portion of the deep reinjection energy requirements can be met from hydraulic and thermal energy, whereas the NPC report briefly analyzes the energy available and concludes it will probably not be sufficient for technical development.
4. The report in general assumes that no R&D developments are possible that will make this unconventional gas resource more attractive. Potential technology advances are briefly addressed, but not thoroughly assessed and analyzed.
5. The draft report does not address the total resource in place and it, consequently, does not include an estimate

of the total recoverable resource that could be produced after the year 2000 or before, if the DOE's efforts are successful.

Task Order 6: R&D Plan

The purpose of this Task Order was the development of detailed plans for the goals, objectives, strategy, program elements, and schedules for the geopressure-geothermal program.

The largest effort under this support contract was preparation of the "Research and Development Program Plan for Geopressure-Geothermal Resources." Work on outlining this plan started under Task Order 5, General Support; the main effort was provided in Task Order 6, R&D Plan; and preparation of the final plan for publication was done under Task Order 4, General Support.

This document presents the Department of Energy's Research and Development Program Plan for Geopressure-Geothermal Resources for FY81 through FY86. The Plan provides an overall perspective for these energy sources and describes the R&D program directed toward resolving the geologic, technical, and economic barriers that currently impede their development. The topics covered in the Program Plan include:

- (1) The program goals, objectives, and strategy;
- (2) The status of resource definition, research and technology development, including the program milestones;
- (3) The supporting environmental activities;
- (4) The management plan for the program;
- (5) The financial requirements.

Task Order 7: General Support

The purpose of this Task Order was to assist DGE through:

- economic analyses
- environmental analyses
- overcoming institutional constraints
- policy studies
- technology transfer activities
- research and development program evaluating, and
- systems analysis

Five major supporting efforts were conducted under this Task Order:

- The first was completion of a study by Terra Tek, titled "Evaluation of Rejection into Geopressured Reservoirs." This report analyzes well pressures and production in injection wells, and the thermal and hydraulic energy availabilities of produced brines (attached).
- The second effort was an analysis by Lewin and Associates, based on the above report by Terra Tek. This analysis evaluated the technical potential, the energy balance, and the economics of reinjecting produced brines into geopressure-geothermal aquifers (attached). It concluded that the thermal and mechanical energy could provide a major portion of the energy required to reinject into the producing aquifer, thus extending the recoverable resource base significantly. Even though uneconomic at current gas prices, this disposal method would be relatively independent of real price increases in energy costs and the economics could therefore improve over time.

- The third effort was following up on the geopressured well equipment paper, titled "Availability of Geopressured Well Equipment." This paper discusses the primary types of equipment and services used in drilling wells to test geopressured aquifers and discusses the supply situation as of the end of April, 1981. As a follow-up to this paper, monthly surveys were conducted of the current supply situation, as documented in the monthly reports.
- The fourth effort under this Task Order was a study by the Engineering and Economics Research, Inc., on "Environmental Controls With Related Issues Applicable to Hydrothermal and Geopressured Resource Development." This report identified and evaluated environmental control type issues that may be common to both the hydrothermal and geopressure-geothermal technologies (attached).
- The fifth effort consisted of preparing background, educational materials on the Geopressured-Geothermal Program in the form of a brochure and thus assisting DGE in technology transfer activities and overcoming institutional constraints.

Task Order 8: The Edna Delcambre Final Report

The purpose of this Task Order was to assist DGE in its technology transfer activities. It consisted of Terra Tek preparing a final report on the Edna Delcambre Well of Opportunity (attached), the purpose of which was to document the results of production testing a geopressured reservoir. At the start of this task, a meeting was held in Chicago between representatives of Lewin and Associates, Terra Tek, and IGT to gather data and discuss previous analyses of the well test.

ATTACHMENT 1
STATEMENT OF WORK

GENERAL

The contractor's effort will be up to 7740 person hours to perform a series of analytical evaluations and assessments that will encompass the following areas:

1. Economic, environmental and energy impact analyses,
2. Institutional and social constraints assessments,
3. Policy studies,
4. Financial and capital market evaluations,
5. Decision analyses,
6. Legislative assessments,
7. Technology transfer activities,
8. Cost-effectiveness and cost/benefit studies,
9. Research and development program evaluation, and
10. Systems analyses.

The contractor will provide these services in response to any written or telecommunications media task order that is transmitted within the terms and provisions of the general overall contract. While DOE is not and will not be obligated to assign any specific new, continuing or stated level of work, the contractor will begin work as soon as the cost estimates have been approved by the contracting officer and definitive tasks have been issued by him.

The contractor should have in-house capabilities in the following 11 and related skill areas: economic research and base studies, planning and planning research, environmental analysis, operations research, geology, systems engineering, geophysics, marketing, applied mathematics business law, water and land-use rights, utilities operations, and management. The contractor should demonstrate broad, specific and relevant training and experience, as well as educational background on the part of the in-house staff appropriate to the expertise required to perform each task order as it is assigned.

SPECIFIC

The contractor will furnish such necessary qualified personnel, facilities, materials, and services as are needed to fulfill the requirements of specific research and development analyses, evaluations and other assessment activities within the scope of a general overall contract. The specific task orders issued will call for performance of such functions as:

1. Development of updated plans including, but not limited to, goals, objectives, strategy, program elements and schedules for the geopressured-geothermal and hot dry rock programs;

2. Analysis of Government options related to development and utilization of geopressured-geothermal and hot dry rock energy resources;
3. Assessment of processes through which amounts of geopressured methane production and geopressured-geothermal power "on-line" and non-electric applications can be increased;
4. Evaluation of alternative approaches for implementing proposed Federal actions and for ensuring maximum possible leverage from use of available public resources in Federal geopressured-geothermal and hot dry rock research and development programs.

In addition, the task will call for:

- Recommendations for collecting data needed in evaluating the effectiveness of specific policy options;
- Consideration of the degree to which technology gaps or risks tend to increase capital or operating costs and can be reduced;
- Preparation of background papers on policy proposals meant to enhance technology development opportunities, if adopted;
- Evaluation of financial and capital markets in context of specific Geothermal Loan Guaranty questions relating to geopressured and Hot Dry Rock beyond those performed to date;
- Reports and analyses of actions taken by Government and industry relative to geopressured-geothermal and hot dry rock energy resource development and utilization.