Biphase Energy Systems

Research-Cottrell

UCRL- 13806

FINAL REPORT

MASTER

INVESTIGATION OF CLEAN WATER TEST
SITES FOR PROTOTYPE TURBOMACHINERY

CONTRACT NO. 7695203

Prepared for the

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

January 5, 1978

Prepared by:

Donald J. Cerini

Donald J. Cerini
Project Manager

Approved by:

Lance Hays

Lance Hays
President

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TABLE OF CONTENTS

Text

- I. Introduction
- II. Test Requirements
- III. Survey
 - A. Firms Contacted
 - B. Responses
 - C. Facility Descriptions
- IV. Certification of Labor Expended
- V. Conclusions

Appendices

- A. Negative Responses to Test Support Survey
- B. Affirmative Responses to Test Support Survey with Completed Questionnaire
- C. Facility Information

Page 1, Figs. C-1 & C-2. Edward's Test Station Steam Test Facility

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INTRODUCTION

The national need to develop alternate energy sources has established the importance of geothermal energy conversion. ERDA has recognized the importance of developing efficient conversion systems by undertaking the development of total-flow expanders. Since the majority of the nation's geothermal reserves are water-dominated, the utilization of conventional steam turbo-machinery represents a means of near-term but low-efficiency resource utilization. The total flow expander development thus represents the logical step in technology advancement to obtain efficient energy extraction from the liquid flow component of the well flow in addition to the steam enthalpy conversion.

One such total-flow expander development is being undertaken by the University of California, Lawrence Livermore Laboratory (LLL). The development program utilizing a two-phase impulse-type expander has successfully demonstrated conversion performance which agrees well with predicted performance. The performance prediction shows operation at operating conditions with elevated pressures and flowrates can effect a significant performance increase. This includes performance evaluations at operating conditions comparable to a geothermal well conditions. The flow conditions necessary for this type of complete system performance characterization are beyond the capabilities of the test facility utilized in the preliminary tests at the LLL hot-water test facility. As an alternative to increasing the existing facility to meet the expanded test requirements, test facilities in the industrial California community are being surveyed to assess their capability in supporting future tests of the LLL expander. Biphase Engines, Inc. of Santa Monica, California has been contracted by LLL to perform this survey. The goal of the Biphase Engines survey will be to identify organizations with, first, an interest in supporting the LLL turbine test program and, second, to review their test capabilities with respect to the turbine test requirements. The results of the survey will be described in the following sections, which will include a listing of all organizations contacted. The responses to all inquiries will be given. The affirmative responses to the test-support requirement will be detailed with 1) a description of the test facility, 2) range of operating conditions, 3) facility modifications and auxiliary equipment required and costs thereof, and 4) testing schedule costs.

II. TEST REQUIREMENTS

The engineering test requirements were presented with two options to maximize the number of industry responses. The first option being the type of flow to be provided as either a single-phase hot-water or hot water and steam flow. The second option being a flow capability which is either continuous or periodic with a 30-minute flow duration. The necessary instrumentation and controls for the operation of the turbine would be provided by LLL. The test facility would be responsible for facility modifications and installation of piping and controls required to provide steam and/or hot water to the test system interface. The test facility requirements would also include a steam and hot-water discharge handling system to provide a subatmospheric (2 psia) exit pressure at the turbine discharge. The specifics of flowrate, pressures, and temperatures are summarized in Table I. This was the form in which tests requirements were presented to the organizations expressing an interest in supporting the test program. An indication was given that the testing could be performed during off-hour periods to provide a minimum interference with other tests or peak-load periods.

III. SURVEY RESULTS

A. Organizations Contacted & Preliminary Survey

A total of 22 organizations were contacted to discuss the program requirements with respect to their test capabilities. Of these contacts, six indicated they had neither steam nor hot-water test facilities available. The remaining 16 organizations expressed an interest in reviewing the detailed test requirements. This response to the preliminary survey is indicated in Table II, along with the names of the organizations, persons contacted, and phone numbers. Of the organizations contacted, eight are classified as public utilities, eight as industrial, and six as in the aerospace field.

B. Secondary Survey

Letters transmitting the data in Table I were sent to the 16 organizations that indicated an affirmative response to the preliminary survey and an interest in reviewing the specific test requirements. The responses to the secondary survey are summarized in Table III. Shown are the four companies that responded negatively in writing. Copies of these letter responses are contained in Appendix A. A fifth responded by telephone indicating the Solar Division of International Harvester Co. could not consider supporting the test program. Two organizations indicated, by letter, their interest in supporting the program. The written responses and completed questionnaires are contained in Appendix B. Four additional affirmative responses and the information requested in the questionnaire were conveyed by telephone. The total of six affirmative responses received to date are summarized in Table II and described in the following sections. Prior to final report submission a response will be obtained for all Table III entries.

C. Facility Descriptions

1. Wiley Laboratories. This is a private company located in Norco, California, an area east of Los Angeles. This company provides general flow test and calibration services. The company is currently supporting large-scale pressurized water flow tests to simulate nuclear reactor cooling-failure studies. They are very interested in performing the type of tests outlined. They currently have a capability of supplying hot water at the condition specified for 15 minutes in a blow-down system. They have plans to increase the storage capacity of the system, which would

increase the flow duration to one hour. The schedule for this is uncertain. The associated facility modification cost would be \$30,000. They have no current steam flow capabilities, but with a 90-day lead time and at a cost of \$20,000 they would install a boiler to provide the steam-water flow conditions as specified for 30 minutes, with a one-hour recovery time.

2. Edwards Test Station, Jet Propulsion Laboratory. The test station located at the Edwards Air Force Base currently has steam flow capability used previously to operate ejectors for high-altitude simulation rocket tests. The steam flow is provided by four steam generators (Clayton Mfg. Co.) with a total capacity of 40 lbm/s at 275 psia. There is no current hot-water flow capability, but they would modify a 900 ft.³ - 900 psi accumulator with the addition of a nitrogen pressurization system. This would provide a blow-down flow system with the desired 30 lbm/sec flowrate. The size and pressure rating of the tank limit the flow duration from the desired 30 minutes to 20 minutes and the maximum output pressure from the desired 1133 psia to 900 psia for the hot-water flow option. For the steam-water flow option, the output pressure of the steam generators limits the two-phase mixture pressure to 275 psia at 409F in lieu of the test requirements of 360 psia at 434F. There is no current capability for a subatmospheric discharge capability since there is no condenser available. They indicated they would meet the subatmospheric discharge requirement but have not, at this time, identified the method they would use in implementing such a capability or what the cost would be. The cost to modify the facility would be \$12,600, as required to provide steam and water mixing to provide either the hot water or hot water-steam flow capabilities. At an additional cost, they would provide test system controls or instrumentation. Two photographs showing the spherical tank to be used as the water accumulator are shown in Appendix C, Figs. C-1 and C-2. A concrete pad approximately 15 x 20 ft. is indicated as a possible location for the test turbine which is adjacent to the steam generators located in the building shown on the left side of Fig. C-1. They indicated the additional testing costs would be \$1,700 per test day for operating personnel and \$50 per test day for steam/water costs.

3. Aerojet Liquid Rocket Co. This division of the Aerojet General Corporation located in Sacramento has a demonstrated capability in large-scale tests with steam and water. This capability has been developed primarily to support rocket motor tests requiring subatmospheric test environments. Preliminary discussions indicate the test requirements of Table I are well within their capabilities and interests. Some facility modifications would be required to provide a water storage capability. The modification will be described in the response to the questionnaire which is being prepared.
4. McDonnell Douglas Corporation. The McDonnell Douglas Astronautics Company of Huntington Beach, CA has a pumped continuous-water-flow system which they would propose as a test support system. It contains gas-fired heaters that would provide a water flowrate of 25 lbm/sec. at 800 psia and 520F. A system modification to increase the flowrate to 30 lbm/sec would cost \$15,000. To increase the pressure and temperature to 1130 psia and 560F would cost an additional \$30,000. To increase the steam-generating capacity to meet the Option B steam-water requirements would require a \$45,000 facility modification.
5. Southern California Edison Company. This electric power-producing utility has indicated an interest in supporting the LLL test program. One potential test facility identified is the Ormond Beach Power Plant of Ventura County. This facility has two auxiliary steam-generating systems, one of which would be considered for use on the turbine test program. The associated boiler has a 200,000 lbm/hr, 530 psi steam output. A water storage system is available. The addition of a second boiler feed pump would provide the capability of either hot water or hot water-steam flows at the conditions of interest. The means of providing the subatmospheric turbine discharge conditions is being reviewed since the only available condensers at their facility are integral to their turbo-generators. They will arrive at a solution to this problem and have expressed an interest in discussing it and the other facility and cost details in a meeting of their, and possibly LLL's, operating personnel if further discussions are warranted.

6. Burbank Public Service Department. The City of Burbank has demonstrated a sincere interest in the advancement of geothermal technology over the past several years by taking part in a joint venture of utility and private companies aimed at geothermal resource development. They reviewed the request for the LLL test support and responded with similar enthusiasm. They would propose to meet the test requirements by modifying an auxiliary steam-generating system quite similar to the Southern California Edison response. They have indicated a significantly higher steam pressure of 1400 psi is available from a boiler with a 440,000 lbm/hr. capacity. An additional feed water pump and water reservoir would be added to provide the water flowrate at the desired 1133 psia. To achieve the specified water temperature of 560F, they propose to install a tank for mixing steam and water to provide a saturated water flow at 1133 psia or a steam-water mixture at 360 psia. The test support system would also include the necessary steam and water control valves, condenser for subatmospheric (2 psia) discharge and quick-acting shut-off valves for the inlet steam and water lines. The price of these various items is included in the \$25,000 facility modification cost item as indicated on the questionnaire, Appendix B. Also indicated is a test personnel cost of \$50/hr. and a steam-water cost of \$500/hr. (most of which is for fuel). In consideration of water costs and water conservation requirements, they pointed out a need to operate a closed-loop water flow system. This is commensurate with the steam condenser flow being returned to the boiler but only if the water purity is maintained. They have identified a covered test area of approximately 400 sq. ft. which is available as a suitable test site.
7. Pacific Gas & Electric Company. This public utility has also indicated a general interest in supporting geothermal technology advancement. At this time, they could not be as specific as, for example, the Burbank Utility Co. with regard to identifying a particular facility to be used. This is primarily a result of the greatly increased load on a steam-generating power plants with the reduction in hydro-electric power in turn resulting from the California drought. They indicated they would forward the information requested at the first indicated availability of a suitable facility. They welcome the opportunity to review the program requirements in general before a facility is identified, or in detail afterward.

IV. CERTIFICATION OF LABOR EXPENDED

The following is a summary and certification of costs incurred in completing the survey described herein:

<u>Direct Engineering</u>	<u>Hours</u>	<u>Costs</u>
Lance Hays	84	\$1,627.50
Donald Cerini	107	1,658.50
Emil Ritzi	16	224.04
General Office	33	<u>1,437.74</u>
Labor Total		\$4,947.78
Labor Overhead		3,463.44
Fee		<u>588.78</u>
TOTAL:		\$9,000.00

V. CONCLUSIONS

Based on the response from the organizations contacted in the utility, aerospace and industrial community there is a growing awareness and interest in supporting geothermal technology. Several of the firms contacted indicated a desire and intent to prepare the material requested. On the occasion of this final summary preparation these firms again indicated they had been unable to prepare the facility and test cost estimates but wished to remain in consideration for test-support if the program were to proceed.

Considering the responses received the Burbank Public Service Department appears the most ready to support the program as outlined. The Edwards Test Station of the Jet Propulsion Laboratory can provide similar high quality test-support upon completion of their steam and water flow system. Both firms, with their demonstrated interest in geothermal energy, could be depended upon to provide the desired test support services.

TABLE I

TEST FACILITY REQUIREMENTS FOR
PROTOTYPE GEOTHERMAL TURBINE TESTING

1. FLOW CONDITIONS* - (a) or (b)

a. Hot Water Only:

Flowrate	- 30 lb/s
Inlet Temperature	- 560°F
Inlet Pressure	- 1133 psia
Exhaust Pressure	- 2 psia
Exhaust Vapor Quality	- 0.35

b. Hot Water and Steam:

Flowrate	- 30 lb/s
Inlet Temperature	- 434°F
Inlet Pressure	- 360 psia
Inlet Vapor Quality	- 0.189
Exhaust Pressure	- 2 psia
Exhaust Vapor Quality	- 0.35

2. TEST DURATION

- a. Total Test Period - 6 weeks
- b. Individual Test Duration - 30 minutes at full flow
- c. Start Date - approximately March 1978

3. TEST PACKAGE CHARACTERISTICS

- a. Height - 8 ft.
- b. Diameter - 6.5 ft.
- c. Weight - 2,000 lbs.
- d. Auxiliary Requirements - 5 kVa of 115 volt A.C., 20 gpm cooling water

4. GENERAL

The turbine test package is self-contained. Controls, instrumentation and dynamometer will be included by LLL. All rigging and installation will be provided by LLL. The major facility requirements are inlet liquid and vapor lines and an exit line and condenser to accept the 30 lb/s flowrate of 2 psia.

*Any combination of hot water and steam between these limits is acceptable so long as the total enthalpy is about 448.7 BTU/lbm.

TABLE II

ORGANIZATIONS CONTACTED FOR PRELIMINARY TEST-SUPPORT-PROGRAM REVIEW

Organization	Address	Addressee	Telephone	Preliminary Survey Response		Written Survey Sent	Response	
				YES*	NO		YES	NO
<u>Industrial</u>								
1. Wylie Laboratories	128 Maryland St. El Segundo, Ca. 90245	Mr. Paul Turkhimer	(213) 322-1763	X		X	XT**	
2. General Electric Co.	9350 Flare Dr. El Monte, Ca. 91734	Mr. Oscar Stubberud	(213) 572-5136	X		X		X
3. Marine Steam Div. of the Westinghouse Corp.	P.O. Box 1920 San Pedro, Ca. 90731	Mr. Quent Jervis	(213) 833-5227	X		X	XT	
4. Clayton Mfg. Co.	P.O. Box 5530 El Monte, Ca. 91734	Mr. William Hecox	(213) 443-9381	X		X		X
5. Solar Div. of the International Harvestor Corp.	P.O. Box 80966 San Diego, Ca. 92138	Mr. B.P. Davidovac Manager of Market Development Dept.	(714) 238-5500	X		X		XT
6. Atomics International Div. of North American Rockwell Corp.	8900 De Soto Ave. Canoga Park, Ca. 91304	Mr. Karl Kozak	(213) 341-1000	X		X		X
7. Babcock & Wilcox	Los Angeles, Ca.	Mr. Paul Benson	(213) 483-4820		X			XT
8. Porter Boiler Co.	Los Angeles, Ca.	Mr. John Clarkson	(213) 774-7806		X			XT

*YES/NO indicates decision as to interest in Test-Support Program

*XT - Telephone response received, to be followed with completed questionnaire in the case of affirmative response

TABLE II - Cont.

Organization	Address	Addressee	Telephone	Preliminary Survey Response		Written Survey Sent	Response	
				YES	NO		YES	NO
<u>Public Utilities</u>								
9. San Diego Gas & Electric Co.	P.O. Box 1831 San Diego, Ca. 92112	Mr. Victor Dillowary	(714) 232-4252	X		X		XT
10. Los Angeles Dept. of Water & Power	111 N. Hope St. Los Angeles, Ca. 90012	Mr. Margin Grayman	(213) 481-5555	X		X		X
11. Southern California Edison Co.		Mr. George Crane	(213) 572-2775	X		X	XT	
12. Burbank Public Service Department	P.O. Box 631 Burbank, Ca. 91503	Mr. J.D. Woodburn	(213) 847-9650	X		X	X	
13. Pasadena Dept. of Water & Power	100 N. Garfield Pasadena, Ca. 91109	Mr. Karl Johnson	(213) 577-4425	X		X		XT
14. Pacific Gas & Electric Co.	77 Beal St. San Francisco, Ca. 91406	Mr. William Barr Manager of Steam Generation	(415) 781-4211 x2188	X		X	XT	
15. Long Beach Dept. of Water & Power	Long Beach, Ca.		(714) 426-5951		X			
16. Southern California Gas Co.	Los Angeles, Ca.	Mr. S. Kahn	(213) 689-3216		X			

TABLE II - Cont.

Organization	Address	Addressee	Telephone	Preliminary Survey Response		Written Survey		
				YES	NO	Sent	Response	
Aerospace								
17. McDonnell Douglas Astronautics Co.	5301 Bolsa Ave. Huntington Beach, Ca. 92647	Mr. Red Moore	(714) 896-2172	X		X		
18. Rocketdyne Div. of North American Rockwell Corp.	5633 Canoga Ave. Canoga Park, Ca. 91304	Mr. Richard Johnson	(213) 884-4000	X		X		X
19. Edwards Test Station Jet Propulsion Laboratory	4800 Oak Grove Dr. Pasadena, Ca. 91103	Mr. Harry Cotrell	(213) 354-2681	X		X	X	
20. Aerojet Liquid Rocket Corporation	P.O. Box 13222 Sacramento, Ca. 95813	Mr. Richard Simonsen Mr. R. Belford	(916) 355-2681 (916) 355-3299	X		X	XT	
21. Lockheed Aircraft Corp.	Burbank, Ca.	Mr. R.Winston	(213) 847-1944		X			
22. Aerojet General Corp.	Azuza, Ca.	Mr. M. Karpal	(213) 334-6211		X			

TABLE III

ORGANIZATIONS SUBMITTING AFFIRMATIVE RESPONSES TO WRITTEN SURVEY

Organization	Facility Description	Water (Option A)				Water/Steam (Option B)				Facility Preparation Cost	Operating Personnel	Materials	Optional Items Available (Cost not included in Cost Summary)	Remarks
		Flow-rate lbm/ sec	Press. psia	Temp. °F	Duration min	Flow-rate lbm/ sec	Press. psia	Temp. °F	Duration min					
1. Wylie Laboratories	General purpose flow-test system	30 50	1133 1133	560 560	10 30	0 30	360	434	30	20,000 70,000	----- -----	\$1000/day \$1500/day	instrumentation	Availability date - 120 days ARO
2. General Electric Co.														①
3. Marine Steam Div. of the Westinghouse Corp.														②
11. Southern California Edison Co.	Auxiliary steam generating plant													②
12. Burbank Public Service Dept.	Auxiliary steam generating plant	50	1133	560	30 or (cont)	30	360	434	30	25,000	\$50/hr	\$500/hr	instrumentation	1. Test Area Size 20'x20' 2. City Council approval required 3. No oil carryover into stream
14. Pacific Gas & Electric Co.	Auxiliary steam generating plant													
17. McDonnell Douglas Astronautics Co.	General purpose flow-test system	25	800	520	30 or (cont)	0								②
19. Edwards Test Station Jet Propulsion Laboratory	Steam/water rocket type support system	30	900	532	20	30	275	409	30	12,600	\$1700/day	\$50/test	1. instrumentation 2. condenser	
20. Aerojet Liquid Rocket Company	Steam/water rocket type support system													②

① can support tests at Schenectady, N.Y. or Lynn, Mass. facilities but cannot estimate earliest test opportunity at this time.

② can support test program, but have been unable to complete questionnaire as requested, desire to remain in consideration for program support

APPENDIX A

NEGATIVE RESPONSES (WRITTEN) TO TEST SUPPORT SURVEY

1. Clayton Manufacturing Company
2. Los Angeles Department of Water and Power
3. Atomics International Division of Rockwell International
4. Rocketdyne Division of Rockwell International

Clayton Manufacturing Company

August 29, 1977

WORLD HEADQUARTERS
P. O. Box 5530
El Monte, CA 91734
(213) 443-9381 • (213) 283-4131
Cable: Clayco, El Monte • Telex: 6-74404

Mr. Donald J. Cerini
Biphase Engines, Inc.
2907 Ocean Park Boulevard
Santa Monica, California 90406

Reference: BE77:208

Dear Mr. Cerini:

This is in reply to your letter dated August 17, 1977 addressed to our Mr. William Hecox requesting the availability of high pressure steam testing facilities for your current turbine test program.

We have no facility or equipment available that would be sufficient to supply your requirements for volume, pressure or temperature.

Therefore, we are unable to offer you any proposal. Neither are we able to refer you to any local source that might be able to supply your test facility needs for this project.

We appreciate your request and are sorry we are not able to offer any assistance for this specific requirement.

Yours very truly,

CLAYTON MANUFACTURING COMPANY

Richard L. Cook
Sales Representative
Steam Generator Division

RLC:jj

MA/13

cc: W. Porter
W. Hecox
J. H. Brown
E. Brown

Department of Water and Power

the City of Los Angeles

TOM BRADLEY
Mayor

Commission
JOHN L. MALONEY, President
SARA C. STIVELMAN, Vice President
FREDERIC A. HEIM
PATRICIA C. NAGLE
HERBERT C. WARD
JUDITH K. DAVISON, Secretary

LOUIS H. WINNARD, General Manager and Chief Engineer
CARL M. TAMAKI, Assistant General Manager and Chief Engineer
PAUL H. LANE, Chief Engineer of Water Works and Assistant Manager
JAMES L. MULLOY, Chief Electrical Engineer and Assistant Manager
WILLIAM D. SACHAU, Chief Financial Officer

August 31, 1977

Mr. Donald J. Cerini
Geothermal Program Manager
Biphase Engines, Inc.
2907 Ocean Park Boulevard
Santa Monica, California 90406

Dear Mr. Cerini:

This is in answer to your letter dated August 16, 1977, in which you asked if the Los Angeles Department of Water and Power would be interested in taking part in a test program by supplying high-pressure water and steam from one of our power generating stations. The water and steam would be used intermittently to drive your total flow turbine.

As our Mr. M. Grayman indicated when he spoke to you by telephone, supplying the quantity of hot water and steam that your test facility requires would reduce our electric generating capability by more than 15MW. In addition, operating service, construction cost, and liability contracts would have to be made. The legal work involved in the preparation of such documents and the cost of our loss of electric generation capacity at a time when capacity is short makes it very difficult for us to provide the facilities necessary for your turbine testing.

We are sorry to inform you that we have decided not to participate in your turbine testing program at this time.

Very truly yours,

H. L. HOLLAND
Engineer of
Design and Construction

MG/REB:sr

cc: 1 Attached

Atomics International Division
8900 De Soto Avenue
Canoga Park, California 91304
(213) 341-1000

Rockwell
International

September 2, 1977

In reply refer to 77AT-7781

Mr. Donald J. Cerini
Geothermal Program Manager
Biphase Engines, Inc.
2907 Oceanpark Boulevard
Santa Monica, California 90406

Reference: Your Letter BE77:210 dated August 17, 1977

Dear Don:

I have reviewed the in-house and field laboratory capabilities at Atomics International for providing steam to conduct the test of the Lawrence Livermore Laboratory geothermal total-flow turbine. I regret that we do not have the steam capacity to perform these tests.

The Atomics International Division is extremely interested in the geothermal energy programs and the success of the subject test.

Thank you for your request. I look forward to serving you in the future. If you have any additional questions, please contact me at (213) 341-1000.

Very truly yours,

K. M. Kozak
Marketing Representative

hgw:5/2

Rocketdyne Division
6633 Canoga Avenue
Canoga Park, California 91304
Telex: 698478

Rockwell
International

September 8, 1977

In reply refer to: 77RC6749

Mr. Donald J. Cerini
Biphase Engines, Inc.
2907 Ocean Park Blvd.
Santa Monica, Calif. 90406

Dear Mr. Cerini:

Thank you for your inquiry of August 16, 1977 (BE77:201).

We have reviewed our test capabilities for evaluating your Geothermal Total Flow Turbine and find that we are unable to meet your desired test parameters. The Rocketdyne flow facilities primarily use water and gas (GN_2 or Helium) at ambient temperatures, or LN_2 or GH_2 at cryogenic temperatures as a test fluid.

Thank you for your interest in our organization. Please do not hesitate to call if we may be of further assistance.

Sincerely,

ROCKWELL INTERNATIONAL
Rocketdyne Division

R. L. McMillion
Manager
Engineering Laboratories

RLM:JJS:mg

cc: R. R. Johnson

APPENDIX B

AFFIRMATIVE RESPONSES (WRITTEN) TO TEST SUPPORT SURVEY

1. Edward's Test Station, Jet Propulsion Laboratory
2. City of Burbank Public Service Department

INTEROFFICE

344E-77-1306-1123/CS

DATE 8-10-77

TO Harry Cotrell

SEC. 340

FROM M. Guenther/C. Worthen *EW* EXT. 165-561/540

SEC. 344

SUBJECT Geothermal Total Flow Turbine Testing (Lawrence-Livermore)

ETS is interested in participating in the testing of the Geothermal Total Flow Turbine built by the Lawrence Livermore Laboratory. Our Edwards AFB Test Facility has 4 ea. Clayton steam generators capable of delivering a total of 10 lb/sec. of saturated steam at 275 psi and 409°F, and we have a 900 ft.³, 900 psi accumulator. By adding a GN₂ pressurization source to the top of the accumulator and a high pressure outlet system to the bottom of the accumulator, we can deliver 30 lb/sec. of saturated hot water at 900 psia and 532°F for a duration of 20 minutes. We can also provide a 30 lb/sec. 2-phase mixture at 275 psi and 409°F.

Please contact us if we can be of further service.

cc: D. EVANS

Please Return By August 10, 1977 To:

EIPHASE ENGINES, INC.
2907 OCEAN PARK BLVD.
SANTA MONICA, CA. 90405

1. Would you be interested in making your facility available for testing of the Geothermal Total Flow Turbine developed by Lawrence Livermore Laboratory? X YES NO

2. Approximate cost for facility modifications. \$ 12,600.

3. Hourly personnel cost ^{per} ~~starting~~ test operations. \$ 1,700.

4. Steam/Hot Water cost per test. \$ 50.

5. Desired changes to test date, flow conditions, etc., COMMENTS:

a. Hot water only: can deliver 30 lb/sec., saturated steam, 900 psia and 532°F, for 20 minute duration.

b. Hot water/steam: can deliver 30 lb/sec., .189 Quality two phase mixture, 275 psi and 409°F, for > 30 minute duration.

Note: (1) Assume local readout of turbine test package data parameters.

(2) Mixture flow by orifice calculation if not part of turbine test package.

August 25, 1977

Mr. Donald J. Cerini
Geothermal Program Manager
Biphase Engines, Inc.
2907 Ocean Park Boulevard
Santa Monica, California 90406

Dear Mr. Cerini:

BE77: 200, Total Flow Turbine Test Facilities

We are returning herewith our response to your questionnaire transmitted to us on August 16, 1977.

We would be very pleased to be able to participate in this program.

Should you require any further information, please contact Mr. Russ Shattuck, Mechanical Engineer, at (213) 847-9653.

Very truly yours,

J. D. Woodburn
Chief Engineer

JDWcmb

Enclosure

cc: R. W. Caldwell
R. D. Shattuck

PUBLIC SERVICE DEPARTMENT

164 W. MAGNOLIA BLVD. • P.O. BOX 631 • BURBANK, CALIFORNIA 91503

Please Return By September 5, 1977 To:

BIPHASE ENGINES, INC.
2907 OCEAN PARK BLVD.
SANTA MONICA, CA. 90406

1. Would you be interested in making your facility available for testing of the Geothermal Total Flow Turbine developed by Lawrence Livermore Laboratory? ☒ YES ☐ NO

2. Approximate cost for facility modifications.

\$ 25000

3. Hourly personnel cost during test operations.

\$ 50

4. Steam/Hot Water cost.

\$ 500/HOUR

5. Desired changes to test date, flow conditions, etc., COMMENTS:

WOULD NEED 6 MOS LEAD TIME

6. Test Facility Description:

STEAM ELEC GENERATING PLANT. WOULD
USE STEAM AT 1400 PSI, 1000°F TO MIX WITH
HEATED BOILER FEEDWATER. EXHAUST WOULD
GO TO TURBINE CONDENSER.

7. Name of Your Facility: CITY OF BURBANK

PUBLIC SERVICE DEPT
164 W MAGNOLIA
PO BOX 631
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APPENDIX C

FACILITY INFORMATION

Page

1	Figs. C-1 & C-2	Photograph of Edward's Test Station Steam Test Facility
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Fig. C-1

Fig. C-2