WRIGHT

GL03966

ENERGY TECHNOLOGY PROGRAM PLAN

FOR

CONVERSION TECHNOLOGY

FIELD SYSTEM TECHNOLOGY

WELL STIMULATION

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for

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SUMMARY

This document forms the basis of the ET development programs in hydrothermal energy conversion and field system technology.

The approach taken in planning the programs was to first study the current hydrothermal power industry growth, and the projected availability of hydrothermal resources as estimated by the U.S.G.S. in circular 790. With this information an assessment was then made to determine if existing technology would permit DOE goals for hydrothermal energy power-on-line to be met.

It was found that current industry growth using flash system technology would not permit DOE 2020 goals to be met. This conclusion is based on the assumption that industry would not develop a resource if the cost of the resulting power were 50 mills/kW hr. or greater. Flash steam technology meets this criteria with good flowing wells at temperatures of 350 - 400°F or higher. The U.S.G.S. has not projected sufficient resource of this quality to meet power-on-line goals and only a small part, about 1/4 of the resource base can be utilized with steam technology.

The use of binary plants to generate power is calculated to produce 50 mill power at temperatures as low as 280°F if adequate well flows are obtained. Industry is not acting on the calculated advantages for binary technology, because the advantages have not been demonstrated. An analysis of the utility industry planning cycle indicates that the acceptance of binary technology must be obtained by the mid to late 1980's if DOE 2020 power-on-line goals are to be met. These goals, as well as maximum utilization of the resource base require advanced technology compared with the current steam technology.

With this need identified, technology programs were planned to provide utilities with the necessary information on binary technology and to obtain additional design data in areas of potential problems. Major programs were identified in each of the following areas:

- Technical data dissemination
- Direct contact heat exchanger development
- Small plant development
- Minimum ground water usage
- Plant performance improvement
- Downhole pump development
- Well stimulation

Successful completion of these programs with resulting industry acceptance and implementation of the resulting technology is projected to increase

power-on-line using hydrothermal resources by a total of 126,000 MW(e) This is equivalent to 40 billion barrels of imported oil over the planned 30 year lifetime of the plants. Successful completion of these programs have the potential of allowing economic utilization of 85 percent of the resource identified by the U.S.G.S.

Management of the programs is delegated to lead laboratories, Idaho National Engineering Laboratory for Conversion Technology and the Los Alamos Scientific Laboratory for Field System Technology via the respective DOE field offices. The lead laboratories will provide general direction and coordination of the various program elements. Management plans will be required for all major program elements.

The following is the estimated budget requirement for the Conversion Technology program.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
BA										
BO	To Be Supplied Later									

CONTENTS

FIGURES

TABLES

DGE/ET PROGRAM PLAN FOR CONVERSION SYSTEM TECHNOLOGY AND FIELD SYSTEM TECHNOLOGY

1.0 INTRODUCTION

This plan describes technical programs that the Department of Energy, Division of Energy Technology will conduct to accelerate the commercialization of electric power generation from geothermal energy. The plan is limited to conversion technology and Field System Technology programs. Consideration has been given to the current state-of-the-art in geothermal power generation technology, current growth of hydrothermal power in the U. S., and the identified and undiscovered resource base in the U. S. delineated by the USGS[(1)]. DOE/DGE goals which have been established are discussed with respect to the technology necessary to achieve these goals and more importantly, maximize the utilization of this energy resource base.

Two types of power/conversion systems are discussed, flash steam systems (dual or single) and binary systems. A flash steam plant utilizes geothermal energy by dropping geothermal fluid pressure to produce steam for driving a turbine. A dual flash plant drops the pressure in two stages to improve the geothermal fluid utilization. Binary plants utilize geothermal energy by transferring heat to an organic fluid which in turn drives a turbine. A binary system is more thermodynamically efficient than either type of flash steam system, but it is a new technology in this country. It is considered an advanced technology in this plan.

In planning programs to accelerate the commercialization of geothermal electric power generation it has been assumed industry would respond to a demonstration of favorable economics. The basic approach developed in the plan is to define the distribution of the predicted U. S. geothermal resource in terms of well flow and temperature. Programs are then assessed against their ability to improve the economics and to resolve problems associated with the generation of power from the resource so that maximum utiliation of the resource is obtained.

Section 2 briefly summarizes the current status of geothermal power development in the U. S. , including current economics and the rate of industry growth.

(1) USGS Circular 790 Assessment of Geothermal Resources of the United States - 1978

Section 3 gives the basis for the technical programs. The total geothermal resource is analized in terms of its rate of discovery and technical needs for economic utilization. Section 4 defines the programs in Conversion Technology and section 5 defines programs in Field System Technology. Section 6 defines the management system which DOE will use to accomplish the program.

2.0 CURRENT STATUS OF GEOTHERMAL POWER GENERATION

Electrical production from geothermal energy is currently competitive with conventional power generation methods for a limited range of geothermal resources. Figure 1 shows the cost of geothermal electrical power from binary and flash steam plants as a function of resource temperature and average well flow rate, and compares it to a survey of power costs from new conventional plants in the south-western United States. This figure shows that:

(1) Geothermal power costs are influenced by resource temperature and well flow rate, with both effects becoming more influential at lower temperatures.

(2) For the higher resource temperatures, geothermal power is competitive with new conventional power sources.

(3) Binary plants extend the temperature range of competitive power generation costs significantly below that for which dual-flash steam plants are competitive.

Figure 2 supports the contention of competitive geothermal power costs by illustrating the historical growth of geothermal power in both the U. S. and the world. Both are growing rapidly, with the U. S. growth rate at approximately 19% per year. Table 1 provides a listing of current U. S. geothermal projects. Three conclusions are apparent from this tabulation:

(1) The overwhelming majority of U. S. geothermal development is in Geysers.

(2) Almost all of the other resources being developed, or planned for development, are the high-temperature resources which Figure 1 shows to be economical with dual-flash steam plants, providing reasonable well productivity is achieved.

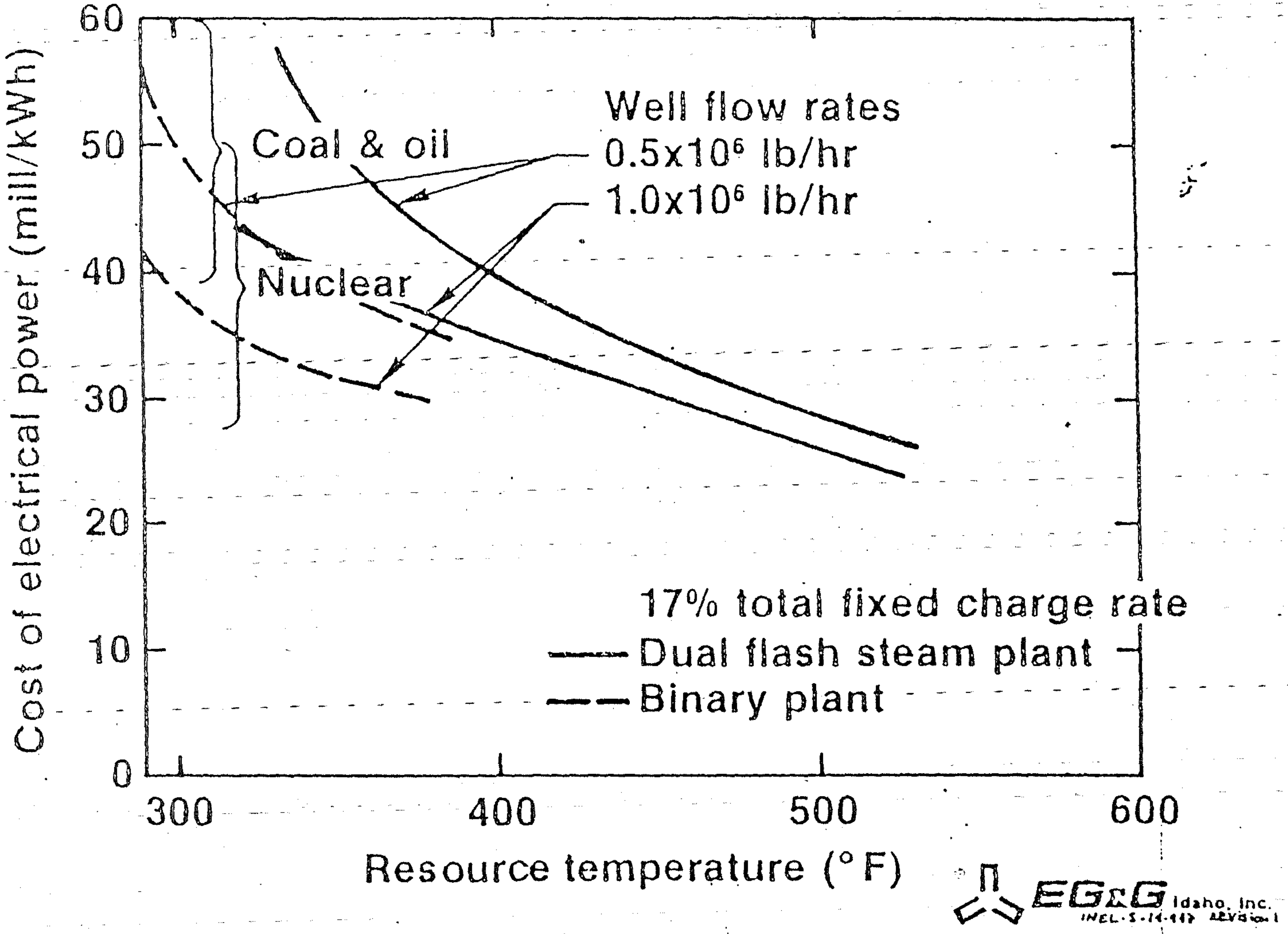

Figure 1 Cost of Geothermal Power

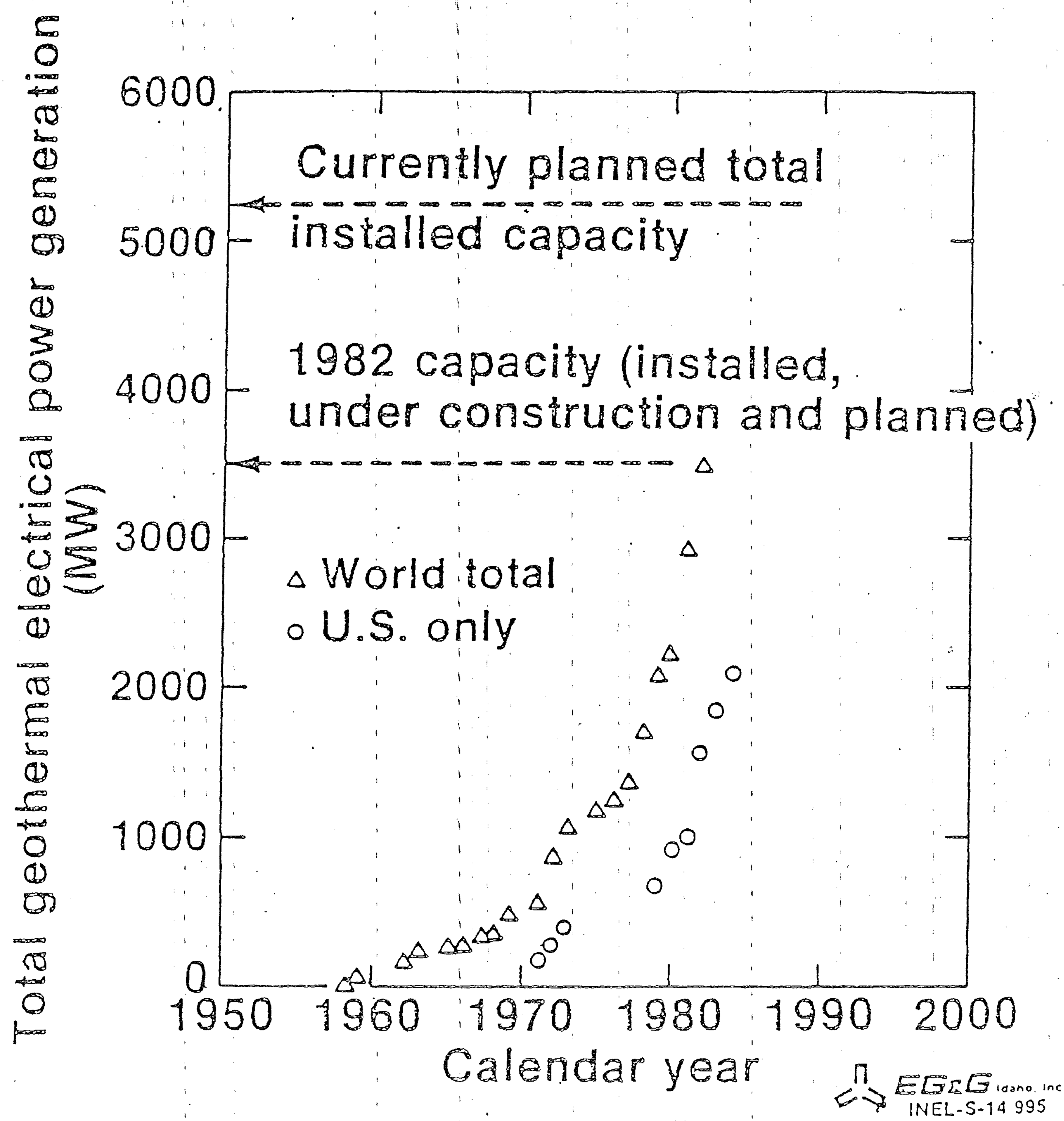

Figure 2 Growth of Geothermal Electrical Capacity

Project (location)	Resource Temperature (°F)	Operating	Under design or construction	Projected	Total
PG&E (Geysers)	460 (dry steam)	608	608	705	1921
NCPA (Geysers)	460 (dry steam)		110		110
San Diego G&E (Salton Sea)	640			10	10
Valles Caldera (New Mexico)	500		50		50
Union/Chevron Oil (Brawley)	500		10		10
MAPCO/Republic (Westmorland)	500			50	50
Phillips/Rogers (Roosevelt)	460		50		50
O'Brien/VTN (Roosevelt)	460		50		50
Sierra Pacific Power (Nevada)	>400			50	50
Chevron/SCE (Heber)	360		50		50
Magmamax Binary (East Mesa)	360		10		10
Republic (East Mesa)	335		64		64
INEL Binary (Raft River)	290		5		5
		608	1007	815	2430

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Table 1 Geothermal Power Plants in the United States

(3) Industry is not expanding using the binary cycle even though a significant economic advantage is calculated to exist. (Figure 1)

3.0 PROGRAM BASES

To establish the technical program requirements it is necessary to evaluate where geothermal commercialization is presently headed and how well or likely the current path is to meet DOE power on-line goals.

The DOE hydrothermal goals are 3-4000 MW(e) by 1985, 20-40,000 MW(e) by the year 2000, and 70-140,000 MW(e) of installed capacity by the year 2020. Figure 3, which is a semilog replot of Figure 2, shows the historical and projected near-term growth of U. S. geothermal power in relation to the goals for geothermal power on-line. If the geothermal power industry continues its present growth rate as shown on Figure 3, the DOE 1985 goal would be missed slightly (2500 MW on-line versus a 3000-4000 MW target); and the year 2020 target would be greatly exceeded. These data indicate that current industry growth is sufficient to meet DOE power-on-line targets, if there is sufficient economic resource and/or technical barriers are not encountered.

In this section the total U. S. hydrothermal resource is analized, the rate of availability is projected and the economic worth of the available resources is assessed. From this information an assessment is made which shows that there is not sufficient economic resource to meet DOE power on-line goals with current technology. Technical programs are defined which improve the economics of generating power from the hydrothermal resource. An increase of 126,000 MW(e) production is projected based on the improved economics.

3.1 Resource Base

The USGS has projections of the total recoverable hydrothermal resource base, in the U. S. in USGS Circular 790. The recoverable hydrothermal resource above 90°C is projected to be approximately 2400 x 10^{18}J, of which approximately 400 x 10^{18}J have been located, and 2000 x 10^{18}J are presently undiscovered. Figure 4 sums identified and undiscovered resources above 90°C by temperature category. (See Appendix A for the

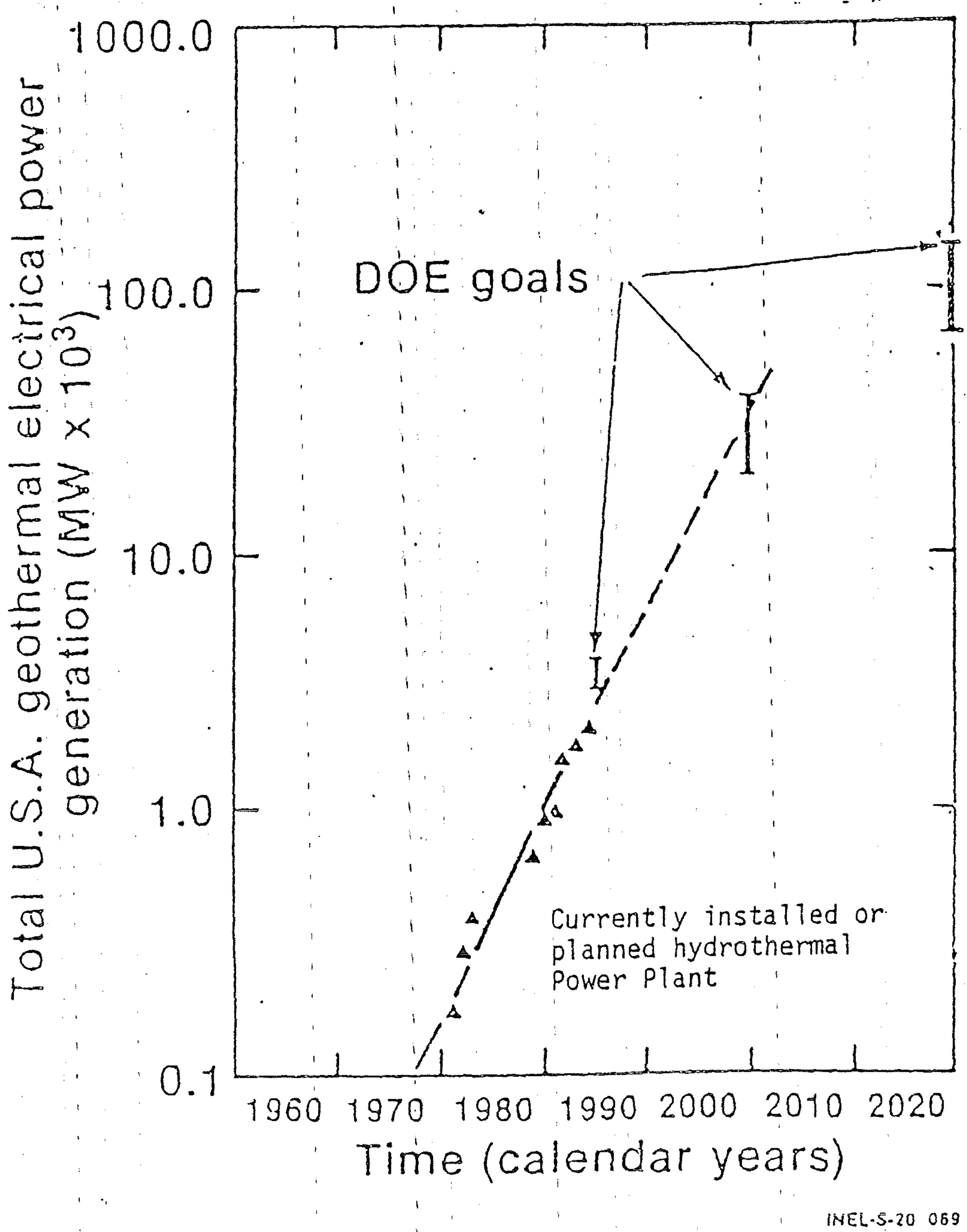


Figure 3 Historical Growth of Geothermal Power vs. DOE Goals

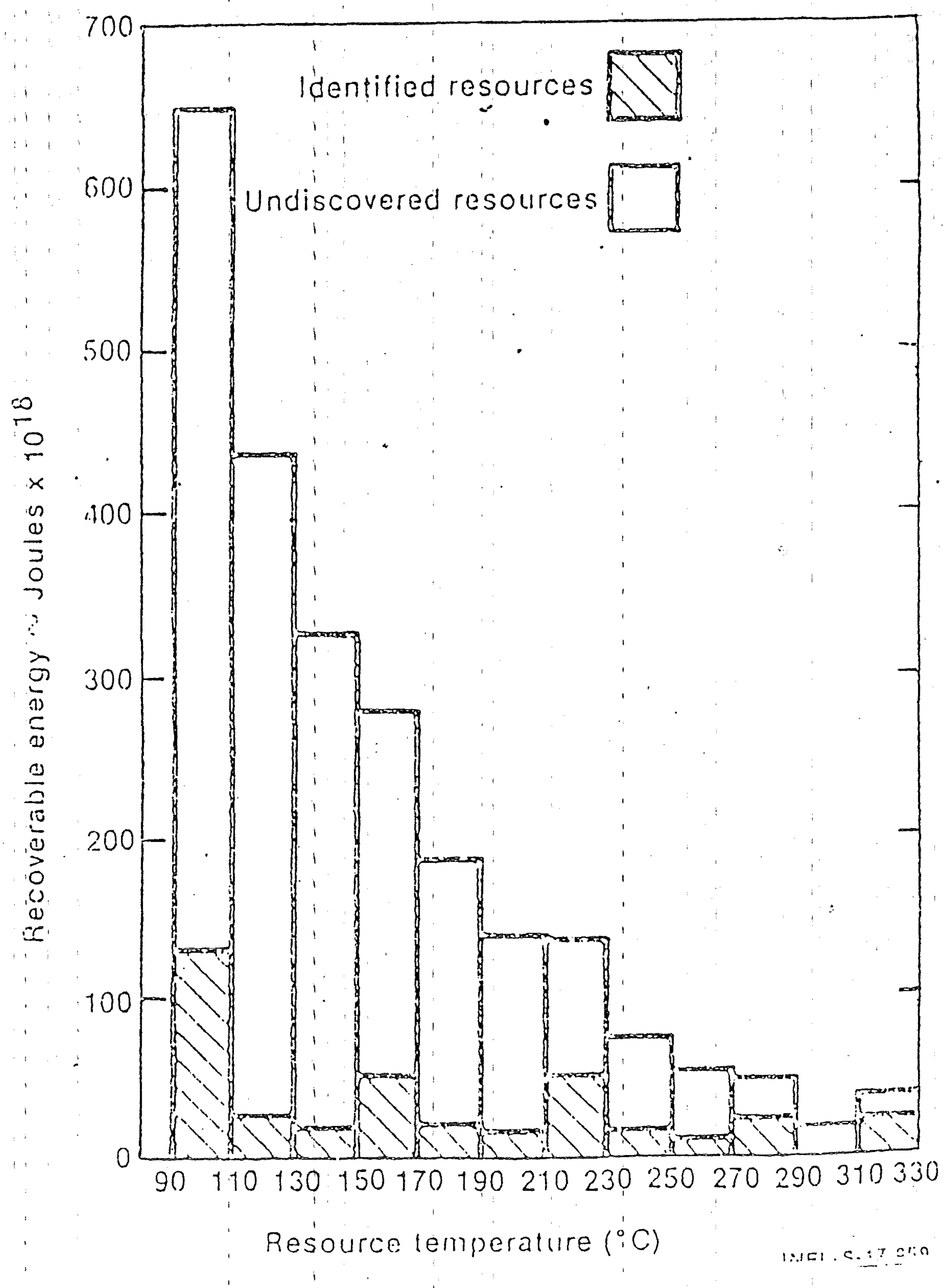


Figure 4 Temperature Distribution of Recoverable Hydrothermal Energy

basis upon which Figure 4 and related figures were determined.) Its evident that a very substantial portion of the resource base exists below the temperatures currently being exploited (see Table I) by flash-steam technology (resource >200°C).

Figure 5 shows the total electrical power potential of the hydrothermal resource base presented in Figure 4. It does not consider whether the power could be economically produced or the time frame in which it would be available. Two curves are shown, one for binary cycles and the other for flashed-steam cycles. The flashed-steam cycle represents the current dual flash technology which is generally considered to represent the practical limit of performance for flashed-steam systems. The binary system curve shows a greater power potential because of a higher utilization efficiency (more power per pound of geothermal water, see Appendix B) and represents current binary system technology. Further improvements to binary cycle performance, to be discussed later in this document, are not included in the binary cycle curve but would further increase the utilization of the resource base over that provided by flashed steam system for any temperature. Both the flashed-steam and the binary curves approach a maximum value as a result of the power output dropping (per pound of geothermal fluid) as geothermal supply temperatures decrease.

Three conclusions are apparent from Figure 5.

(1) With exclusive use of flashed-steam systems DOE power on-line goals would barely be met, 90,000 MW versus 70,-140,000 MW(e) goal in 2020, even if all resources were economical. (An unrealistic condition)

(2) Exclusive use of the flash-steam systems greatly reduces the overall contribution of geothermal energy to the nations power needs.

(3) At all temperatures greater power is extracted from the geothermal fluid when binary systems are used.

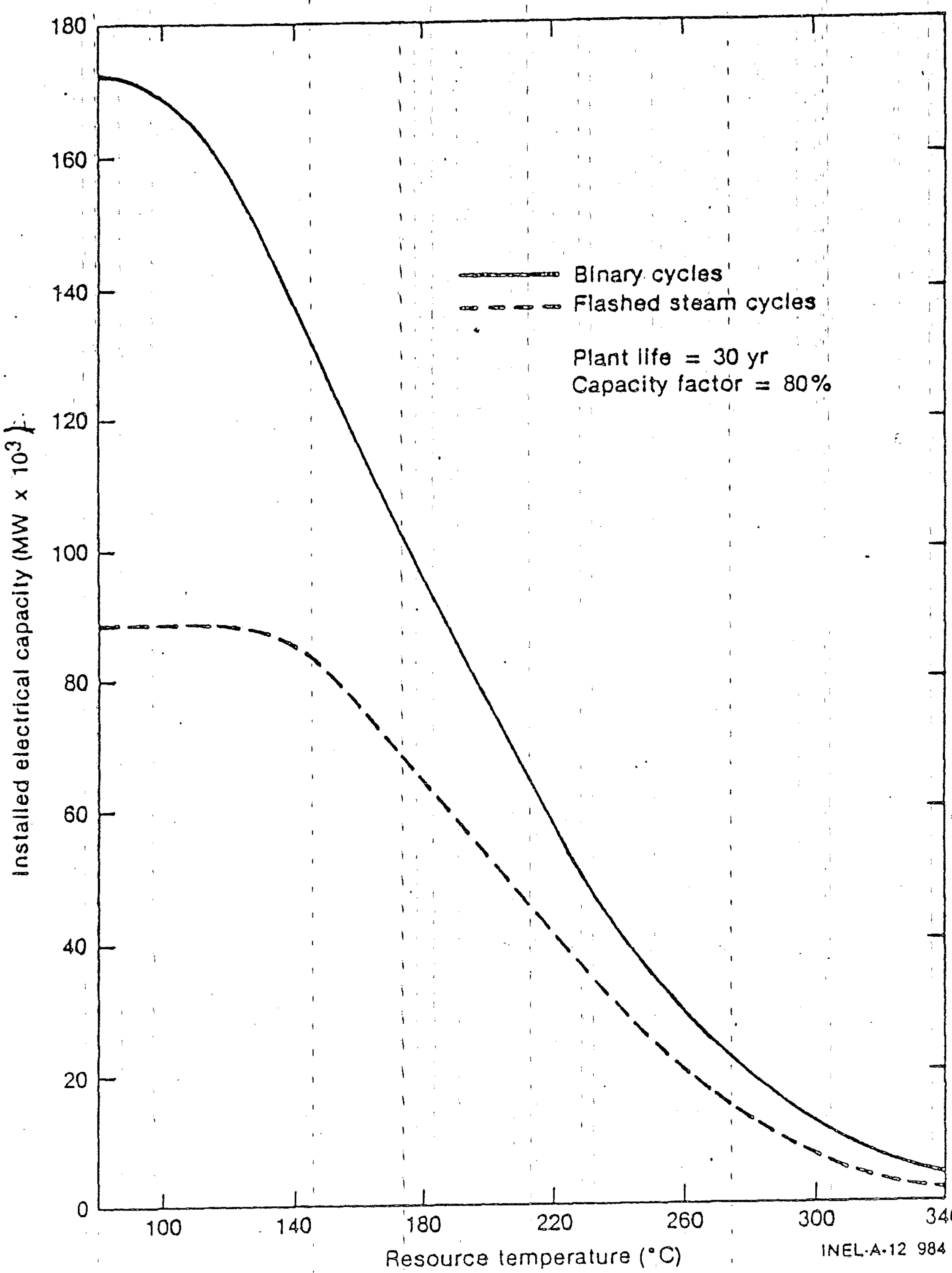


Figure 5 Power Generation Limits for Estimated U. S. Hydrothermal Resource Base-Current Technology

3.2 Industry Growth Trends and Limits

As shown previously, industry is expanding using the more economic vapor-dominated resources and the higher temperature liquid resources. The Geysers is the only commercial vapor-dominated system in the U.S. today. There have been reports of a vapor-dominated system in Northern Nevada, but it is not anticipated major growth will occur using vapor-dominated systems because of limited supply. The most likely area of continued growth in the immediate future is the high-temperature liquid systems using flashed-steam conversion technology. Numerous plants of this type are currently in the planning stages in the U. S. as shown on Table 1.

Current identified resources have the potential to support ~10,000 MW(e) of installed capacity for 30 years at a power cost of 50 mills/kWh or less using high temperature dual-flash steam technology (see Appendix A for calculations). These resources could sustain the geothermal power growth shown on Figure 3 until around 1990-1995. Growth beyond this point would depend upon the rate at which the unidentified resource base is located, the fraction of the resource which is economical and local considerations, whether technical, institutional or environmental which may delay or prevent their development.

Primary geothermal exploration is being conducted by oil companies, and the past successes of these companies provide a reasonable means for projecting the rate at which geothermal resources will be located. In the U. S. oil and gas industry, discovery has taken place at an exponentially decaying rate, and approximately 90% of the resources have been discovered within 30 years of the initiation of significant exploration. Based on these assumptions, and adding five years for project development, a projected maximum availability of resources for economical electric generation using today's flash-steam technology is shown as the limiting curve of Figure 6. (See Appendix A for the calculational basis of these projections.)

This limiting curve shows there is ample resource to support the current growth of the geothermal power industry until after the year 2000. At

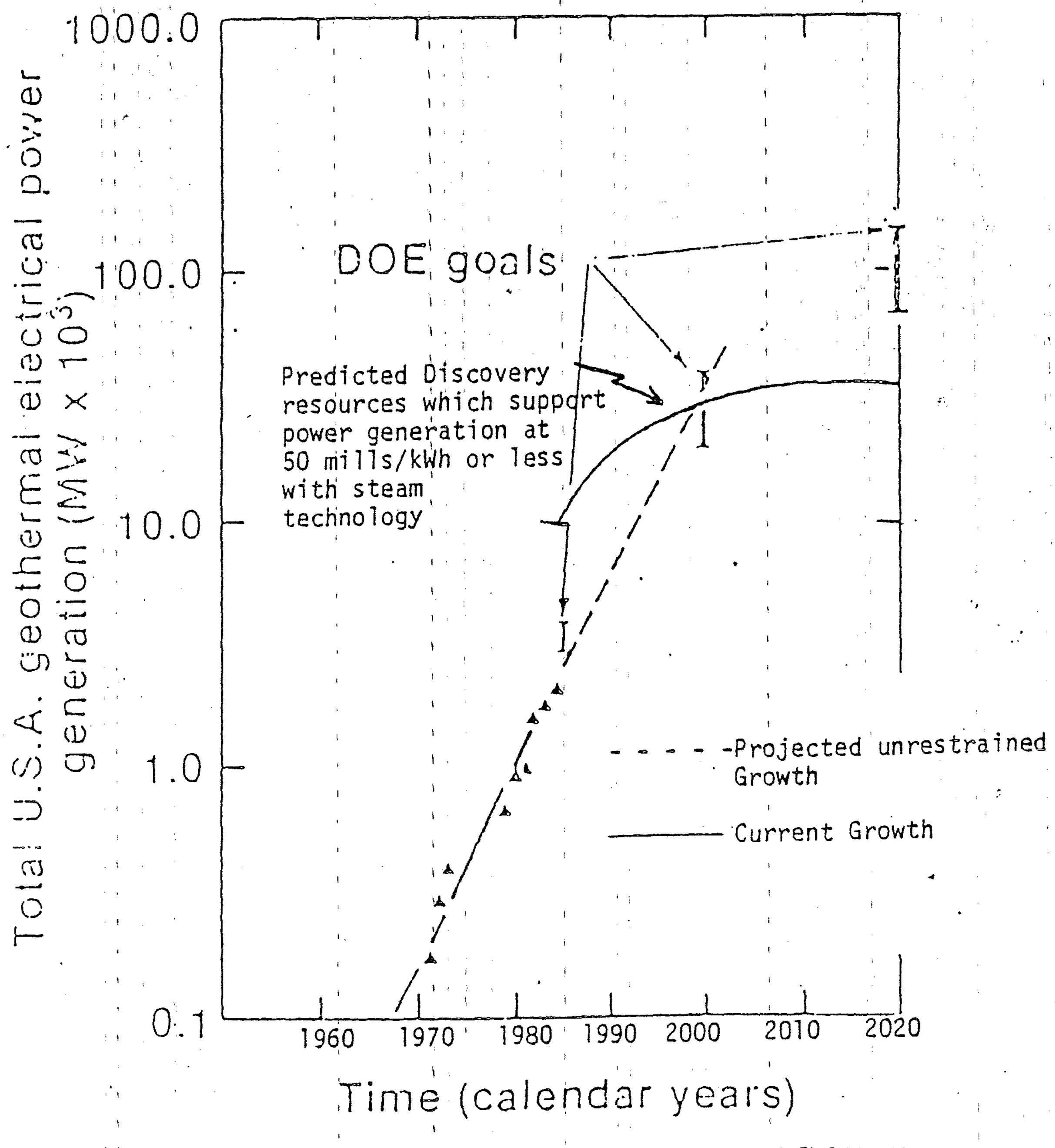


Figure 6 Effect of Resource Discovery Rate on The Hydrothermal Power Industry Using Flash Steam Technology

that time, resources will begin to limit growth and around 2020, growth will terminate at an installed capacity of around 45,000 MW(e). This is well below the DOE target of 70-140,000 MW on-line in the year 2020. To meet the 2020 goal, it is necessary that industry begin building binary plants which increase the percentage of the resources which are economically competitive, and which increase the power obtained from the resources. To practically sustain growth after the year 2,000 industry must begin a major program building binary plants shortly after 1995. A ten year planning cycle is common in the utility industry and planning for binary plants must initiate shortly after 1985. Magma Imperial is presently constructing a binary plant in California (See Table I) but there is little other apparent active interest in binary plants at the present time. To get binary plants into the utility planning cycle, a vigorous technology program is required immediately which stimulates industry interest, assures that the economics projected on Figure 1 are correct, and in particular resolves technical barriers associated with binary technology.

In summary the following conclusions can be derived from the preceeding material:

(1) An active geothermal industry is currently developing economic resources. If the growth of this industry can be maintained, long-range DOE goals will be met.

(2) In the short-term (i.e., in the 1985 time frame) there will likely be a need to quickly resolve engineering problems associated with the transition from the use of vapor-dominated systems to the use of high-temperature, liquid-dominated systems.

(3) High-temperature resources are limited and industry growth will slow in the 1990-2000 year time period without the use of moderate-temperature resources.

(4) Stimulation is needed to get industry acceptance of advanced conversion technologies, which permit economical utilization of moderate-temperature resources (130-200°C range).

(5) This industry acceptance must be obtained by the mid 1980's for incorporation into the utility planning cycle to allow continued

industry growth past the mid 1990's.

3.3 Advanced Technology Programs

This section defines major areas in which programs will be conducted by the Department of Energy to help resolve technical barriers and stimulate industry conversion to binary technology. The gain in potential economical power on-line for each of the major program elements is assessed.

The definition and scope of the major program elements are as follows:

(1) Conversion System Technology - all technology programs related selection, design, construction, operation and maintenance of electrical power plants.

(2) Field System Technology - All technology related to the selection design, construction, operation and maintenance of the system that provides geothermal water to the power plant and disposes of the plant effluent (includes wells, piping, pumps, controls, etc.)

3.3.1 Conversion Technology

The conversion technology program has two principal end objectives:

(a) Provide a technical climate that will encourage industry to switch from dual-flash systems to binary systems.

(b) To improve the efficiency of binary systems so that a greater percentage of the geothermal resource is economical.

The conversion to basic binary technology is projected to result in an incremental 41,000 MW(e) of economically competitive geothermal power on-line. This is based on calculations summarized in Appendix A which shows that dual-flash steam plants will support 45,000 MW(e) for 30 years at an 80% capacity factor, with power costs of 50 mills kWh or less. The same resource base will support 86,000 MW(e) under the same conditions using current binary technology, a difference of 41,000 MW(e), worth 15.4 x 10^9 barrels of oil over the 30-year plant lifetime.

Better conversion-plant performance improves power generation costs by reducing the investment required for the well field, and also increases the potential output from individual resources and the total resource base. Appendix B shows the potential for a 20% or more improvement in plant performance, over the current basic binary technology. These improvements result principally from increased use of staging, use of hydrocarbon mixtures and reduced condensing temperature. The increment which is economical at 50 mills/kWh or lower increases from 86,000 to 111,000 MW(e) for 30 years. This increase is worth 9.4 x 10^9 barrels of oil over the projected plant lifetime.

The conversion of industry to binary technology basically requires a demonstration that the calculated economic advantages summarized on Figure 1 are real and that there are a minimum of unforeseen engineering and operational problems. Programs are described in this plan to obtain necessary operating experience using 5MW, 500kW and 60kW systems. These systems will be used to demonstrate basic binary technology and investigate advanced systems. In addition programs are planned to provide solutions to the known operating problems such as, limited availability of cooling tower makeup water and corrosion and/or scaling due to geothermal fluids.

3.3.2 Field System Technology

Field System Technology programs which provide the greatest payoff are those which increase well flow rates since the flow directly determines the number of wells required. Although several sub-programs makeup the Field System Technology work the most significant benefits are expected to occur from well pumping and well stimulation. These two items are evaluated below:

Pumping: A target has been established for the pumping program to make an additional 35,000 MW(e) available at 50 mills/kWhr from the geothermal resource. The principal program in this area is the development of high temperature deep well pumps. Study of a few specific geothermal wells for which data were available shows that geothermal well flow can easily be doubled by pumping (Appendix A). This in itself will permit meeting target increase in power on-line. However, well production and distribution with liquid or two phase geothermal resources is a new engineering area with little prior experience. It is anticipated there will be a substantial number of unforeseen problems which will require engineering R & D to permit economic utilization of the geothermal resource.

Stimulation: Well stimulation is a standard technology in oil reservoir development. This technology cannot be directly transferred to geothermal reservoir development and a testing program is required to ascertain proper techniques for geothermal fields. Hydrologists generally agreed that well stimulation will greatly enhance the flow of poor producing wells, but will do little for the exceptionally high producing wells. On this basis, a well flow distribution curve was developed with a goal of 60% improvement in the flow rates which are less than 555,000 lb/hr. Meeting this goal will bring an additional 25,000 MW(e) into the economic range of 50 mills/kWh, which is worth 9.4 x 10^9 barrels of displaced oil.

A summary of the potential impact of all advanced technology programs is shown graphically in Figure 7.

3.4 Hydrothermal Industry Growth Limits

On Figure 6 it was shown that the availability of economically developable resources would limit the growth of the geothermal power industry using flash-steam technology. In the preceeding section programs are described which are intended to stimulate industry conversion to binary technology and to improve binary technology. These are projected to make an additional 126,000 MW of power from the hydrothermal resource economical for industry development.

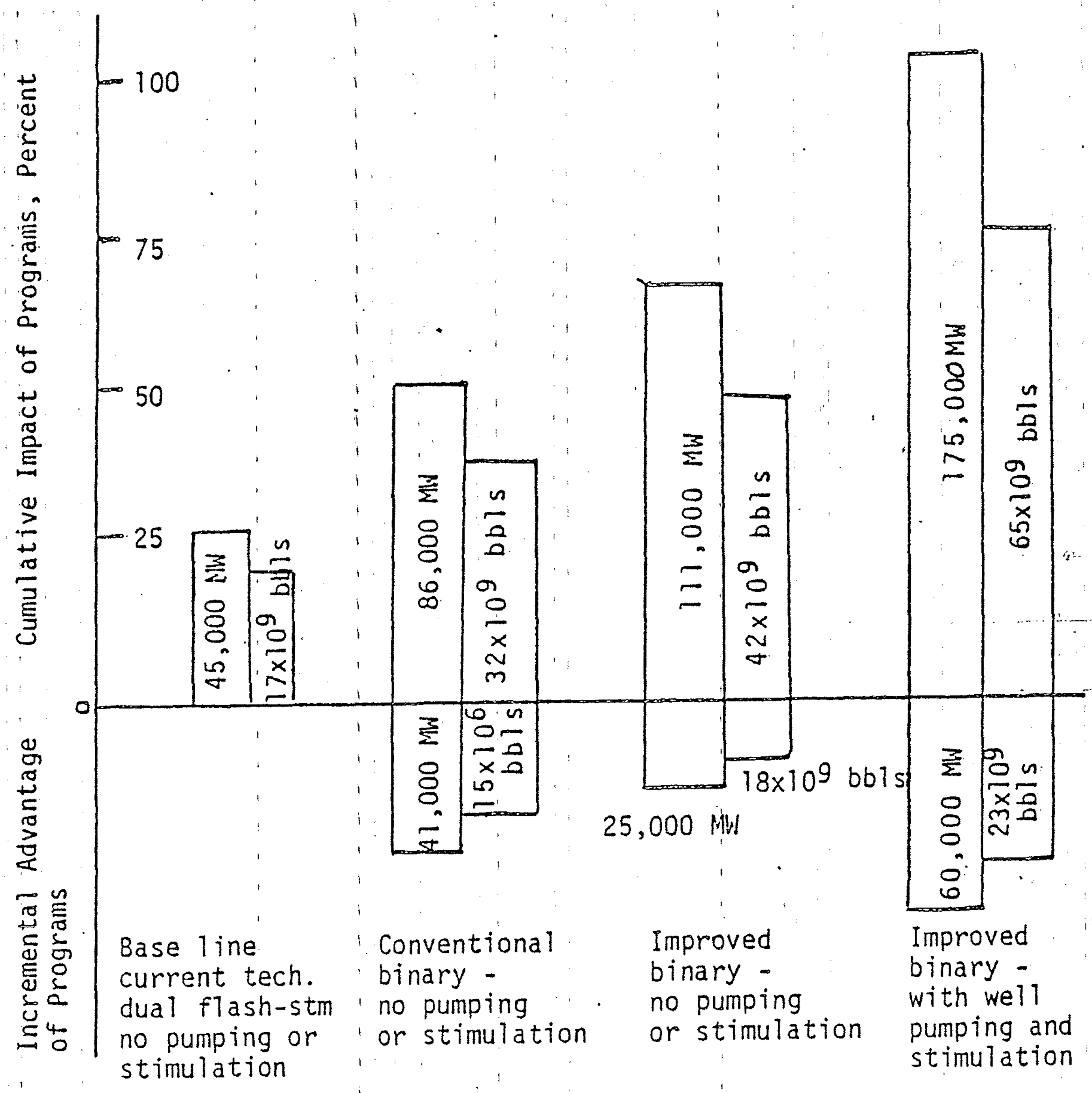


Figure 7 Impact of Advanced Technology Programs on Econcomically Recoverable Hydrothermal Resourses

On Figure 8 the anticipated availability of this additional resource is plotted versus the extrapolated growth of the U. S. Hydrothermal industry. This figure shows that successful completion of the advanced programs will permit meeting the DOE 2020 hydrothermal goals, but it will not permit continued industry growth at the current rate beyond 2020. Continued growth at this point will require discovery of major unpredicted hydrothermal resources in the continental U. S., development of undersea hydrothermal resources, development of geopressured resources, or the development of a hot dry rock power industry.

The advanced programs described in this plan involve technology which can be used on either geopressured or hot dry rock resources. This technology should improve the economics of using these resources and the potential payoff for the advanced programs could greatly exceed the benefits defined in this plan if it helps speed the commercialization of these additional geothermal resources.

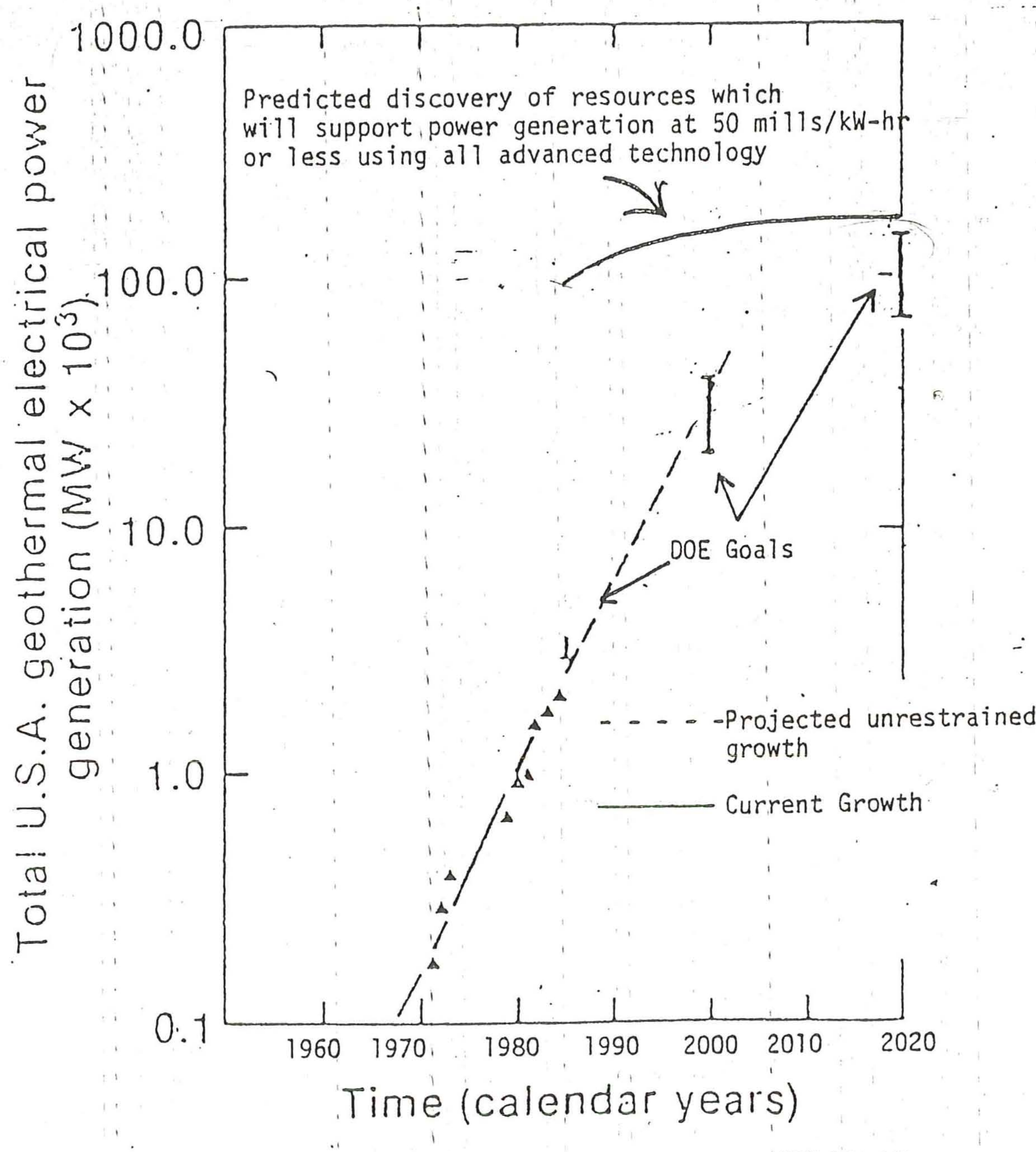


Figure 8 Effect of Resource Discovery Rate on The Hydrothermal Power Industry Unsing All Advanced Technology

4.0 CONVERSION TECHNOLOGY PROGRAM

The previous sections have shown that the use of binary cycle conversion systems is essential for the full utilization of the hydrothermal resources. Moreover, this technology must be in place by the late 1980's if the DOE estimates of geothermal energy contribution to the national energy picture is to remain valid. It has been shown that binary technology, while capable of increasing the utilization of the higher temperature reservoirs, primarily permits those reservoirs which are at lower temperatures to be used. The programs outlined in this section are aimed at the technical demonstration of the binary cycles, particularly those designed for the lower temperature reservoirs and the removal of significant barriers that would limit the application of the binary system and hence limit the utilization of the hydrothermal resource.

Much of the required technology is essentially state-of-the-art applications similar to that used in the process industry, but generally unfamiliar to the utility industry. There are however, significant differences, such as the closed cycle nature of the power cycle and the greater emphasis on the importance of guaranteed efficiency and component performance. In addition, geothermal power plants, unlike conventional power plants must be designed for a variety of energy source conditions including: temperature, relative productivity, corrosive fluids, limited cooling water, dissolved gas and possibly a resource temperature which changes with time. The geography of the area, resource size and its shape all influence the size of the plant and plant size strongly effects economics. Such items represent barriers to the development of the geothermal potential if design alternatives cannot be found to overcome them either technically or economically.

Finer points involve such items as a lack of accurate knowledge of working fluid properties. Much work has been done over the years, nationally and internationally, to obtain precise measurements of the thermodynamic properties of water (steam) used as the working fluid inessentially all major power plants. In contrast, geothermal plants may use a variety of working fluids, none of which has a data base comparable to that available to designers of steam power systems.

4.1 Program Descriptions

The Conversion Technology programs are listed below with a brief description of each program. Background material is provided for some of the newer programs in the Appendices. Detailed program descriptions will be contained in management plans for each of the following program elements. The management plans will be maintained as appendixes to this plan when they are completed.

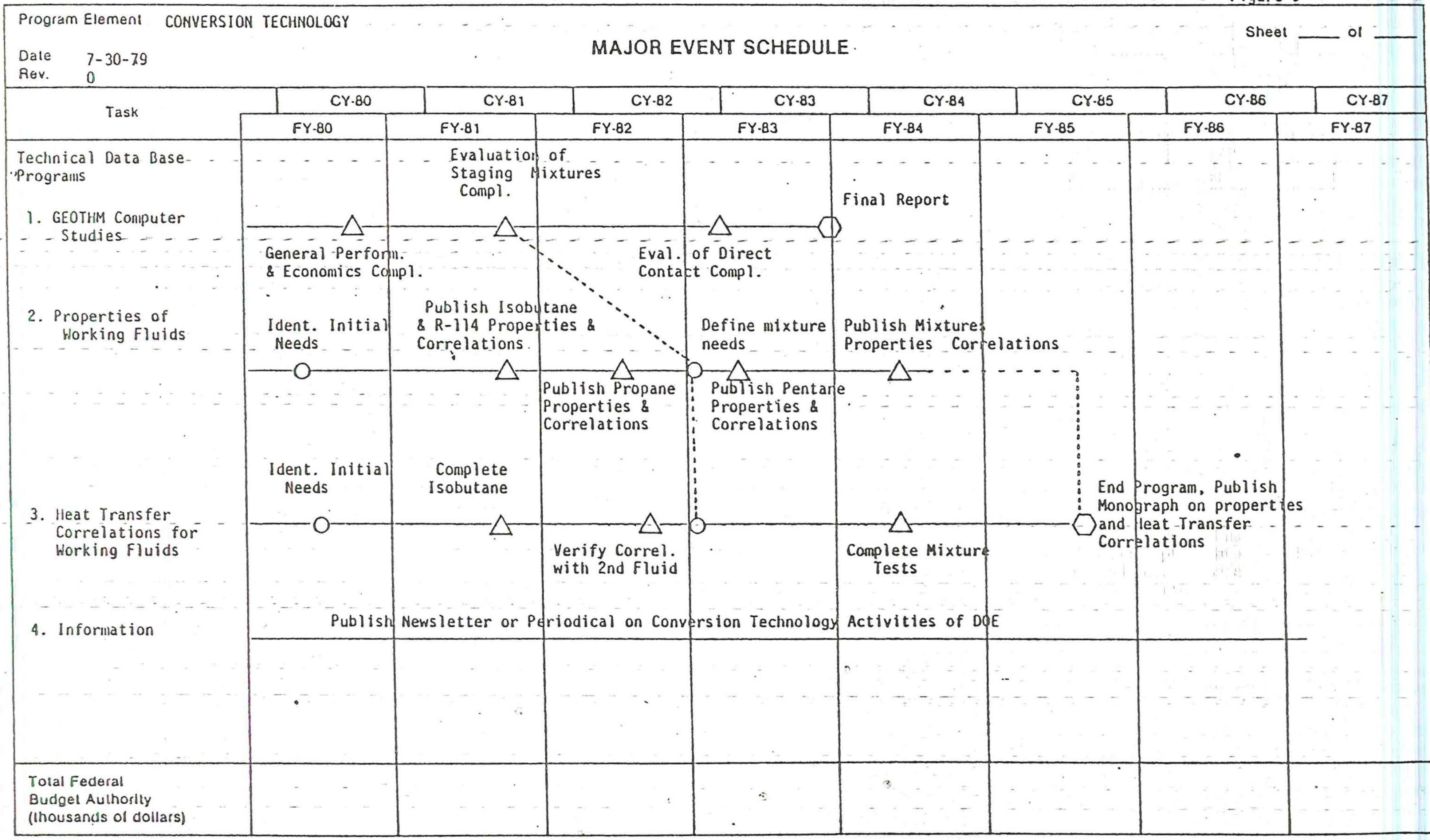
4.1.1 Technical Data Base Programs

These programs are intended to accelerate the development and dissemination of information regarding geothermal conversion systems. The primary thrust is to provide conversion system performance and cost estimates, working fluid property and heat transfer data. Figure 9 provides a schedule of the major activities, milestones and cost of the program.

4.1.2 Direct Contact Heat Exchanger Program

The purpose of this program is to provide a design alternative to very high cost heat exchangers when corrosive and/or fouling geothermal waters are encountered. The program consists of both small scale tests and an integrated system test with a 500kW pilot plant. If necessary, a large, full scale direct contact heat exchanger will be tested using the 5MW pilot plant at Raft River. Major concerns are actual direct contact heat exchanger performance, environmental restrictions on the loss of working fluid and overall plant performance. These concerns will be evaluated by this program. Figure 10 provides a schedule of the major activities, milestones and cost estimates of this program.

Figure 9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Date 7-30-79
Rev. 0
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CY-85
CY-86
CY-87
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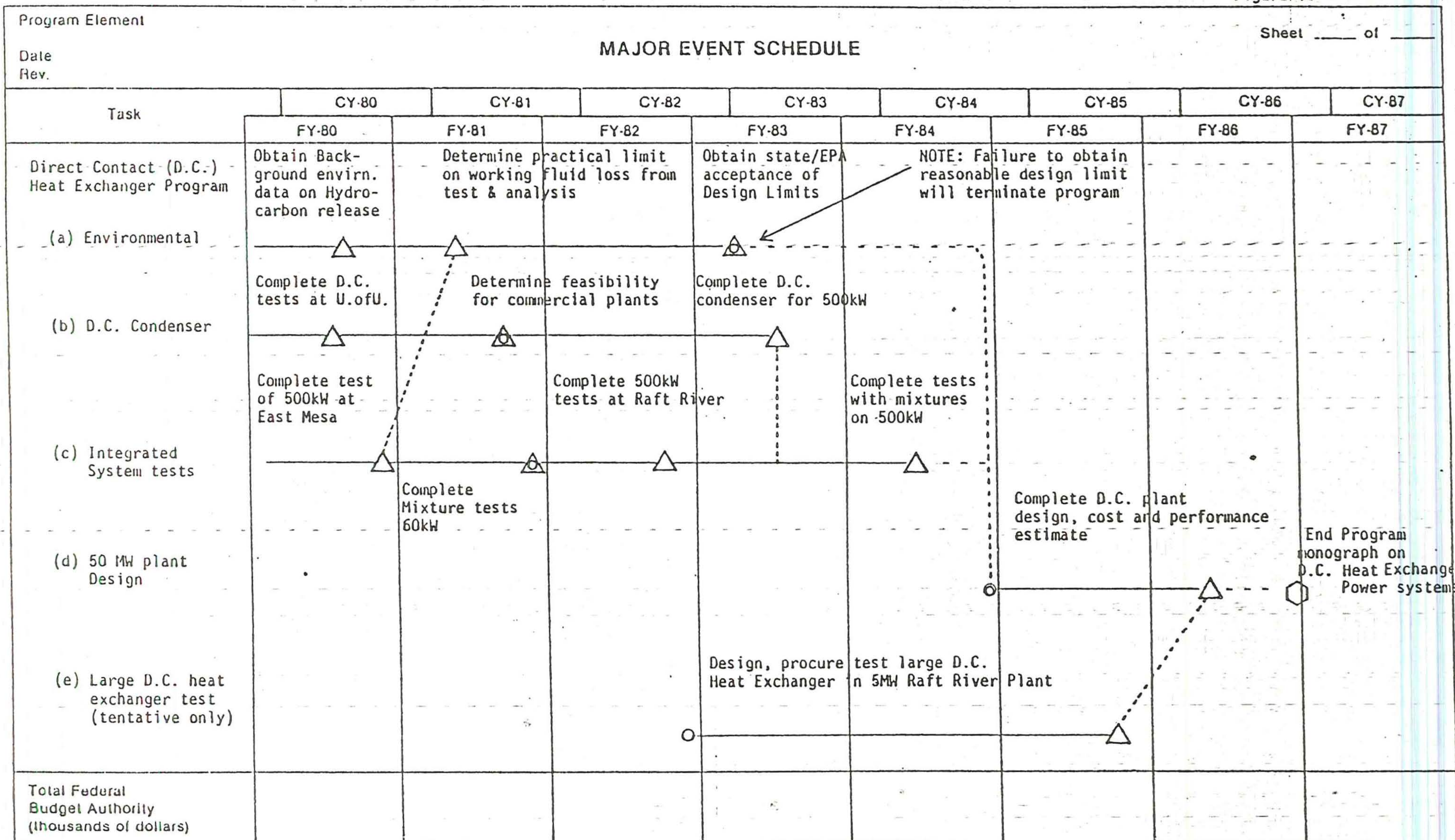
FY-87
Technical Data Base Programs
1. GEOTHM Computer Studies
Evaluation of Staging Mixtures Compl.
Final Report
General Perform. & Economics Compl.
Eval. of Direct Contact Compl.
2. Properties of Working Fluids
Ident. Initial Needs
Publish Isobutane & R-114 Properties & Correlations
Define mixture needs
Publish Mixtures Properties Correlations
Publish Propane Properties & Correlations
Publish Pentane Properties & Correlations
3. Heat Transfer Correlations for Working Fluids
Ident. Initial Needs
Complete Isobutane
End Program, Publish Monograph on properties and Heat Transfer Correlations
Verify Correl. with 2nd Fluid
Complete Mixture Tests
4. Information
Publish Newsletter or Periodical on Conversion Technology Activities of DOE
Total Federal Budget Authority (thousands of dollars)

Figure 10



Program Element
Date
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MAJOR EVENT SCHEDULE
Sheet ____ of ____
Task
CY-80 CY-81 CY-82 CY-83 CY-84 CY-85 CY-86 CY-87
FY-80 FY-81 FY-82 FY-83 FY-84 FY-85 FY-86 FY-87
Direct Contact (D.C.) Heat Exchanger Program
(a) Environmental
Obtain Background envirn. data on Hydrocarbon release
Determine practical limit on working fluid loss from test & analysis
Obtain state/EPA acceptance of Design Limits
NOTE: Failure to obtain reasonable design limit will terminate program
(b) D.C. Condenser
Complete D.C. tests at U.ofU.
Determine feasibility for commercial plants
Complete D.C. condenser for 500kW
(c) Integrated System tests
Complete test of 500kW at East Mesa
Complete 500kW tests at Raft River
Complete tests with mixtures on 500kW
Complete Mixture tests 60kW
(d) 50 MW plant Design
Complete D.C. plant design, cost and performance estimate
End Program monograph on D.C. Heat Exchanger Power systems
(e) Large D.C. heat exchanger test (tentative only)
Design, procure test large D.C. Heat Exchanger in 5MW Raft River Plant
Total Federal Budget Authority (thousands of dollars)

4.1.3 Small Plant Programs

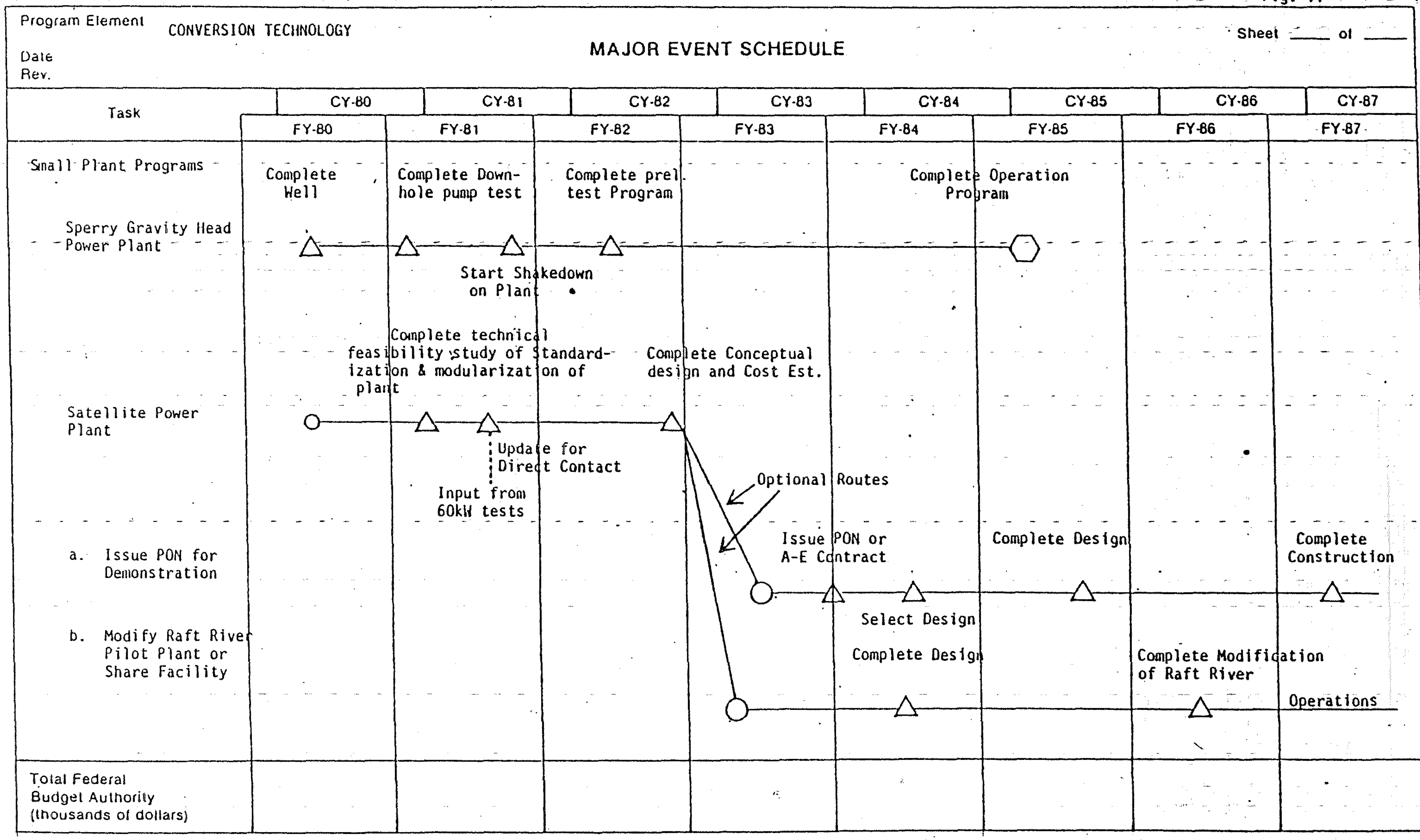
The purpose of this program is to provide small economical power plants. Such plants may be essential to the timely and full development of the geothermal resource (See Appendix C for further discussion). Two approaches are included: A well head unit incorporating an advanced power cycle and down hole heat exchanger and a Satellite System consisting of a centralized control and maintenance area with small satellite process areas distributed along the resource. This type plant design may be required in linear faulted systems where the well field may extend over a considerable distance.

The wellhead system is currently in design and a demonstration is planned within a few years. The satellite plant is a new project which will attempt to provide a modular-standarized approach by utilizing the flexibility provided by the dual boiling cycle and use of mixtures as the working fluid to cover a large temperature and power range. This program involves design PRDA's and an system for a demo plant or a pilot system at Raft River depending on design results. Figure 11 provides a schedule of the major activities, milestones and cost of the small plants program.

4.1.4 Minimum Ground Water Use/Heat Rejection Programs

A large portion of the geothermal resources that can be used for electrical power production are located in regions where a shortage of ground water either limits the amount available for use as cooling water or substantially increases the plant cost through purchase of water rights. The purpose of this program is to develop methods to reduce or eliminate dependence on ground water for cooling. Approaches are to utilize geothermal water and/or hybrid cooling systems. Chemical treatment of the geothermal water, the use of fluidized bed cooling towers, the use of hybrid towers and cycle design that produces a high quality condensate are approaches included in this program. Because of the concentrating of the chemicals in the geothermal water when used for cooling, material selection for corrosion resistance is an important part of the program.

Fig. 11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FY-82
FY-83
FY-84
FY-85
FY-86
FY-87
Small Plant Programs
Sperry Gravity Head Power Plant
Complete Well
Complete Down-hole pump test
Complete prel. test Program
Complete Operation Program
Start Shakedown on Plant
Satellite Power Plant
Complete technical feasibility study of Standardization & modularization of plant
Complete Conceptual design and Cost Est.
Update for Direct Contact
Input from 60kW tests
Optional Routes
a. Issue PON for Demonstration
Issue PON or A-E Contract
Select Design
Complete Design
Complete Construction
b. Modify Raft River Pilot Plant or Share Facility
Complete Design
Complete Modification of Raft River
Operations
Total Federal Budget Authority (thousands of dollars)

High performance condensers will be studied and tested as means of improving heat rejection costs. Figure 12 provides a schedule of the major activities, milestones and cost of this program.

4.1.5 Improved Performance and Cost Programs

The economics of geothermal power production and hence resource utilization is significantly influenced by conversion system performance. Studies and experiments in this portion of the program are designed to find means of increasing performance. Methods presently identified use staging, working fluid mixtures or high performance equipment to minimize thermodynamic losses. Performance increases and the economic tradeoff involved with staging concepts are investigated by use of the GEOTHM computer code. The use of mixtures as a working fluid requires experimental verification of the benefits projected analytically. The lowering of condenser temperature (and/or reduction in heat exchanger size of cooling losses) by use of a high performance condenser also requires tests. All means of increasing performance require testing with direct contact heat exchangers as well as with shell and tube exchangers since direct contact systems may impose unique constraints. Investigation of new concepts which promise to improve either performance or plant cost are included in this program. Figure 13 provides a schedule of the major activities, milestones and cost of this program.

4.2 Major Technical Milestones

The need for the binary cycle was demonstrated in section 2 and the potential further increase in the resource base by use of advanced binary cycles was shown in section 3. It was further pointed out in section 2 that utility acceptance of the binary cycle must be obtained by the mid 1980's. The Conversion Technology programs were then outlined in 4.1 with the major emphasis on removing barriers to binary cycle use and improved performance. These programs are designed to meet two major

Figure 12

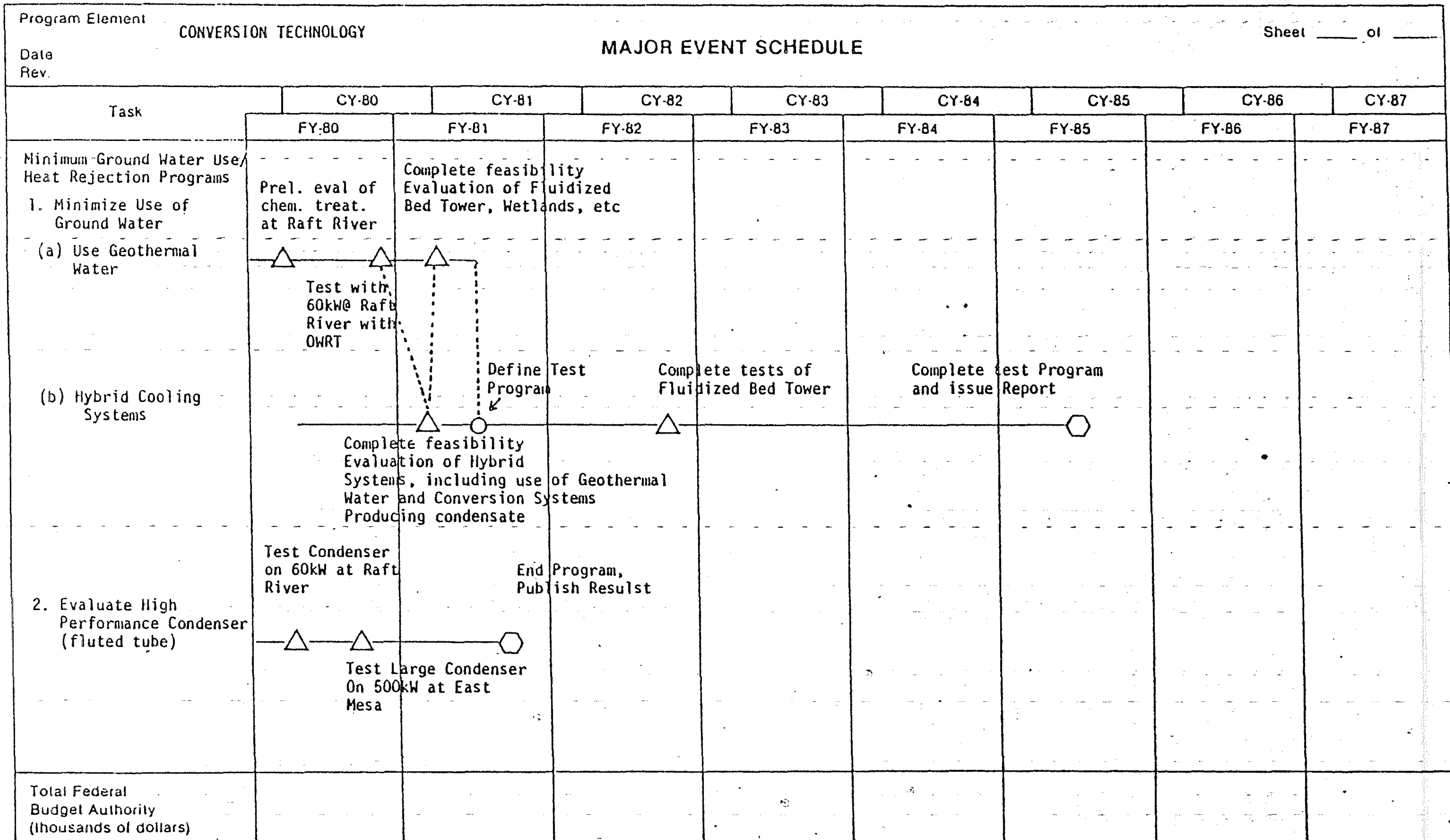
Program Element
CONVERSION TECHNOLOGY
Date
Rev.
MAJOR EVENT SCHEDULE
Sheet ____ of ____
Task
CY-80 CY-81 CY-82 CY-83 CY-84 CY-85 CY-86 CY-87
FY-80 FY-81 FY-82 FY-83 FY-84 FY-85 FY-86 FY-87
Minimum Ground Water Use/ Heat Rejection Programs
1. Minimize Use of Ground Water
(a) Use Geothermal Water
Prel. eval of chem. treat. at Raft River
Complete feasibility Evaluation of Fluidized Bed Tower, Wetlands, etc
Test with 60kW@ Raft River with OWRT
(b) Hybrid Cooling Systems
Define Test Program
Complete tests of Fluidized Bed Tower
Complete test Program and issue Report
Complete feasibility Evaluation of Hybrid Systems, including use of Geothermal Water and Conversion Systems Producing condensate
2. Evaluate High Performance Condenser (fluted tube)
Test Condenser on 60kW at Raft River
End Program, Publish Resulst
Test Large Condenser On 500kW at East Mesa
Total Federal Budget Authority (thousands of dollars)

Fig. 13.

Program Element CONVERSION TECHNOLOGY

Sheet ____ of ____

MAJOR EVENT SCHEDULE

Date

Rev.

Task	FY-80 (CY-80)	FY-81 (CY-81)	FY-82 (CY-82)	FY-83 (CY-83)	FY-84 (CY-84)	FY-85 (CY-85)	FY-86 (CY-86)	FY-87 (CY-87)
Performance Increase Programs								
Mixtures for working fluids		Complete prel. tests on feasibility of mixtures with direct contact heat exchanger		Complete experimental evaluation of mixture in shell & tube heat exchanger and air cooled Condenser			Complete mixture demonstration on modified 5MW Plant	
Reduced Condensing temperature		Complete evaluation of potential methods	Verify methods experimentally	Report Results				
Total Federal Budget Authority (thousands of dollars)								

milestones, demonstration of basic binary technology by 1983 and advanced technology by 1986. These targets were picked to give utility planners necessary information to begin the planning processes which will cause DOE 2000 and 2020 hydrothermal goals to be met.

The programs utilize three major facilities for testing of binary concepts: The 60kW, the 500kW and the 5MW pilot plants. The 5MW plant uses shell and tube heat exchangers, the 500kW direct contact heat exchangers and either may be tested with the 60kW system. The interrelationship between these three pilot plants and there roles relative program goals is shown on Figure 14. The experimental programs lead to the two major requirements established for conversion technology: A technical demonstration of the conventional binary cycle (Milestone 5 in 1983) and technical demonstration of advanced binary concepts (Milestone 9 in 1986).

Other important milestones are a technical demonstration of direct contact heat exchanger systems and experimental evaluation of mixtures of hydrocarbons as a binary system working fluid. In addition to these facilities , testing and evaluation of a first generation advanced binary wellhead generator utilizing down-hole heat exchanger and gravity head pumping will be completed in 1984. The technical feasibility for the satellite plant concept will be established by 1982 and testing of a demonstration unit completed by 1985 if this is found necessary. By 1985 the pilot plants will have accrued several years of performance and operation and maintenance data. This binary plant experience will be available to the utility industries in ample time for them to include geothermal binary cycles in their forward planning for 1995 and later.

CONVERSION TECHNOLOGY - MAJOR EXPERIMENTAL/PILOT PLANT PROJECTS INTERFACE

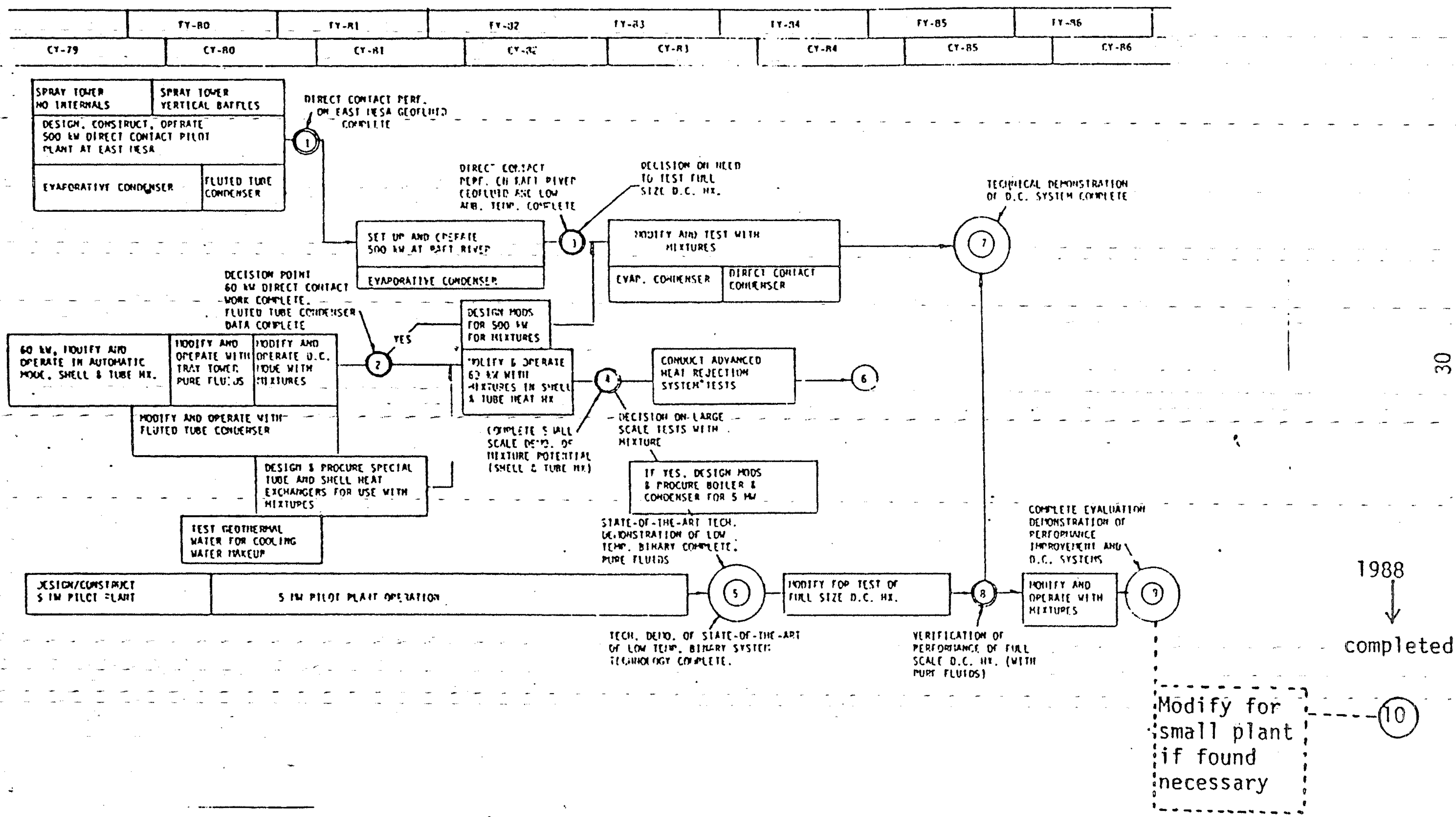

Figure 14

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4.3 Program Interfaces

The purpose of this section is to define major interfaces that may exist between the conversion technology programs and other components of DGE, DOE, other government agencies or co-operative arrangements with private industry.

1. Direct Contact Heat Exchanger Program - Injection of hydrocarbon working fluid disolved in the geothermal water and release of small amounts of hydrocarbon vapor from the condenser vent may require approval of state and federal environmental protection agencies and/or agencies concerned with water resources. The ultimate application of direct contact systems depends upon satisfactorily working this interface to the benefit of the program.

   The Lawerence Berkeley Laboratory (LBL) has responsibility for the direct contact programs (see section 6) and therefore is responsible for obtaining resolution of environmental problems. LBL will interface directly with DOE environmental personnel and Environmental Protection Agency personnel as necessary. Interfacing with state agencies may be delegated to organizations currently interfacing with State personnel.

   Proposed hydrocarbon release limits will be established based upon (a) analysis and experiments using the 60kW and 500kW pilot plants (b) estimates of practical limits on recovery and (c) background data on hydrocarbon releases and hydrocarbons found in water system.

2. Limit Ground Water Use - The portion of this program which treats geothermal water for cooling tower makeup has the interest of OWRT and several private companies in the water treatment business. Interfacing arrangements between DOE and those parties interested in participating in the work must

be concluded. DGE will implement the cooperative program with OWRT based upon programs defined by INEL. PON's will be issued by the Idaho Operations Office.

3. Working Fluid Properties - The National Bureau of Standards conducts programs to measure fluid properties and has performed some tests for DGE. It is anticipated that further work will be performed by USBS for DGE. The participation of NBS will be defined by the program perpared by LBL. Funding arrangements will be between DGE and NBS.

4.4 Program Cost Summary

(To be supplied when programs have been approved and program costs estimated)

5.0 Field System Technology

(To be supplied by LASL)