Title
GEOTHERMAL RESOURCE INVESTIGATIONS AND DEVELOPMENT PLANS AT EAST MESA, CALIFORNIA

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GEOTHERMAL RESOURCE INVESTIGATIONS AND DEVELOPMENT PLANS AT EAST MESA, CALIFORNIA

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The American Association of Petroleum Geologists

Oklahoma City, Oklahoma
12 April 1978

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2. Republic Geothermal Inc., Santa Fe Springs, California
3. Imperial Magma Company, Escondido, California
4. U.S. Bureau of Reclamation, Boulder City, Nevada

Work performed under the auspices of the Department of Energy under Contract #W-7405-Eng-48.

INTRODUCTION

The title of this presentation is "Geothermal Resource Investigations and Development Plans at East Mesa, California" (see Figure 1). The outline we will follow is shown in Figure 2. We will discuss the geology of the resource including:

- Its location.
- Its recognition by means of geophysical surveys and its subsurface delineation by the construction of surfaces defining the distribution of points having in common the same temperature (i.e., "isothermal" surfaces), the same porosity, and the same permeability.

Subsequent to our discussion of the geology of this resource, we will discuss proposed uses of the resource. These include:

- Its possible use in the production of fresh water, and
- The generation of electricity by either the so-called binary cycle system or the flashed steam system.

A theme that should be pointed out - one of which many are aware - is that the definition of a specific geothermal resource at any geographic location and strategies for its exploitation depend on its specific intended use. A geothermal resource is not a reserve until it is united successfully both technically and economically at its site of occurrence with an energy user such as an electric generation plant.

Finally, we will comment on estimates of energy in place.

DESCRIPTION OF THE RESOURCE

Location of the resource is shown in Figure 3. The East Mesa Known Geothermal Resource Area (KGRA) is shaded in this figure. The KGRA lies about 125 miles east of San Diego. The resource lies within the Salton Trough, a topographic feature that is the surface expression of the East Pacific Rise northward from the Gulf of California. The resource occurs within a sequence of Tertiary clastics that are the accumulation of deltaic deposits associated with the ancient Colorado River system and lacustrine deposits associated with occasional isolation of the Trough from the Gulf of California.

Interest in the possible existence of a geothermal resource at East Mesa was generated by the recognition of a residual gravity anomaly mapped by Biehler in the late sixties and early seventies. The anomaly, which is of the order of a few μgal, is shown in Figure 4. The occurrence of the resource was further substantiated by heat flow studies conducted by the University of California at Riverside working under contract to the U.S. Bureau of Reclamation. These studies revealed the existence of an area marked by heat flows as large as 7 $\mu cal/cm^2$-sec. The results of heat flow studies are summarized in Figure 5.

Existence of a body of very hot water was confirmed with the drilling of deep wells by the U.S. Bureau of Reclamation, Republic Geothermal Inc., and Imperial Magma Company. The locations of these wells is shown in Figure 6, as is a line of section to which we will refer shortly. Information obtained from these wells has led to an interpretation of the resource that is sketched in Figure 7, a north-south cross-section through the zone of highest heat flow and, in fact, the area of highest temperature for any plane at depth through the resource. The resource is defined by the spatial distribution of temperature, porosity, and permeability.

In part, the geothermal resource is defined by an upper boundary surface which is the 300°F isothermal surface. All processes that would make use of the resource have minimum requirements for fluids at temperatures of about 300°F. Stratigraphic units do not appear to affect the distribution of temperature, and the structural geology of the resource is a very low-amplitude, faulted dome.

The lower boundary surface is characterized by permeabilities too low to allow for the very large mass flow rates expected of individual geothermal wells. This surface is still being mapped but seems to be convex up and to mimic the distribution of the 350°F surface.

Additionally, and obviously, the resource must contain sufficient porosity to provide an amount of movable energy in water adequate to supply the needs of any surface facility it will service over the life of that facility.

The north-south section shown in Figure 7 illustrates that the 300°F isothermal surface, for instance, is more shallow at the site of highest heat flow (left center of the figure) than elsewhere.

Understanding the distribution of the minimum acceptable permeability surface is still evolving. However, as noted, it appears to be shallowest near the zone of highest heat flow also. This conclusion is supported by the observation that at depths of about 5500 feet gross permeability appears to decrease toward the zone of highest heat flow, in particular from values around 30 md. to about one-third this value. The conclusion is further supported by the occurrence of quite low permeability, namely about 0.5 md., at depths below 6000 feet in the zone of highest heat flow. There is some reason for believing that the lower limit of acceptable permeability coincides with, or nearly coincides with, the loss of good reflectors as shown in reflection seismic profiles over the geothermal resource. This surface is presently being defined by review of these profiles, and it appears that this surface is also most shallow beneath the zone of highest heat flow.

Porosity decreases with depth, as indicated at the right side of the figure. Greatest loss-per-unit depth appears to be highest through the zone of highest heat flow. Inasmuch as porosity and permeability are directly related, this observation adds further support to the hypothesis that at any given depth minimum gross permeability tends to occur at the zone of highest heat flow. Integration of all these observations suggests that the best part of the geothermal resource may not be right above the heat source, but may be on the flanks. (Credit for suggesting this integrated concept should be given to Dr. J.L. Smith of Republic Geothermal, Inc.).

The nature of the primary source of heat is now known. However, as shown in the cross-section, fluids at temperature greater than 400°F are - based on geochemical thermometry - thought to occur at depths of 8000 feet or more.

Generally speaking, the fluids encountered in the shallower, extensively drilled portion of the East Mesa geothermal resource have a salinity in the range of 1800 to 5000 ppm. Total dissolved solids of five times this amount, namely 24,000 ppm, have been reported from the deepest well which was drilled to 8000 feet in the zone of highest heat flow.

Although totally dissolved solids are not large relative to resources such as the Salton Sea KGRA (where TDS are as high as 250,000 ppm), they are the cause of scale formation in production wells and equipment, and of plugging in some reinjection wells.

Reduction in porosity, reduction in permeability, and high gravity values all appear to be related to an increase in density of rock at the core of the resource. The cause of this change is not known. It may be the result of metamorphism due to stress under elevated temperature, or it may be the result of precipitation from geothermal brines containing dissolved solids. Petrographic studies should be useful to distinguish these mechanisms, and they are currently underway.

ANTICIPATED PRODUCTION FROM THE RESOURCE

A major problem for the exploiter of a geothermal resource is the mining of heat once its in-place distribution has been evaluated. Republic Geothermal, Inc. (Barkman et al., 1976) made preliminary reservoir estimates of parts of the East Mesa Geothermal Resource. Their study reveals (Figure 8) that there is on the order of 1300 megawatt-years of resource in Section 29 of the East Mesa site alone; and more than this, namely 1900 megawatt years in Section 30. On this basis - that there is on the order of 1000-2000 megawatt years per section - Republic concludes that there is more than an adequate supply of energy in the resource to service the anticipated needs of various energy production schemes. One is referred to their article for more details of the calculation.

The mining of heat, namely the production of fluid containing heat is controlled by the patterns of flow established by the producing and injection wells drilled into the reservoir. An ideal pattern is suggested in Figure 9. It is one that would neatly move fluid from the reservoir at prescribed rates with cooled, reinjected fluid moving from an injection well back to a production well in such a way as to remove still more heat from the rock matrix through which it passes. Although developers expect that wells will produce in the range of 40,000 bpd, experience thus far indicates that only flow rates less than this amount are attainable from wells drilled. As shown in Figure 10, maximum flow rates of the order of 15-20,000 bbl/day only are reported for acceptable wellhead conditions. Thus, for commercial production these natural flow rates must be increased with additional pressure drawdown provided by downhole pumps.

An equally important problem is the forecasting of long-term changes in temperature as a consequence of production of virgin fluid and reinjection of cooled fluid. Boundary conditions that affect long-term production such as bottom water influx are not well-known; and, consequently, predictions of long-term temperature behavior vary. Figure 11 displays temperature as a function of time for various assumptions regarding boundary conditions, namely with convection, slight convection, and no convection. The objectives of reservoir simulation studies are the prediction of temperature, pressure, and mass flow rate as a function of time throughout the field. A wide variety of results of analyses are reported by Republic Geothermal Inc., for instance (Barkman et al., 1976). A major conclusion of the study was that for some combinations of withdrawal rate, spacing of producers, permeability, and peripheral reinjection, adequate production rates, pressure, and temperature can be maintained for 20 to 30 years.

The geologist's and reservoir engineer's problem lies in understanding what combinations of reservoir properties, development drilling, and operating practices will result in successful exploitation of the energy in-place. This understanding can only be achieved by producing the resource, feeding back reservoir-related experience from that effort, and making whatever changes in the mining of heat that appear to be called for by the experience gained. Although in situ conditions of temperature, pressure, porosity, and permeability are now reasonably well understood, only by production of fluid can full understanding be achieved.

PROPOSED SCHEMES FOR EXPLOITATION

Various groups have proposed schemes for exploitation of the East Mesa Geothermal Resource. The U.S. Bureau of Reclamation (Figure 12) proposes to produce fresh water from the resource to augment the water supply of the Colorado River. The Bureau is investigating various processes for fresh-water production. These include the flash multiple distillation system, a schematic of which is shown in Figure 13. Also included is the vertical tube evaporator distillation system (Figure 14 shows the vertical tube evaporator unit now on-site at the Bureau's property at East Mesa). A third potential system calls for the use of high-temperature electrodialysis. These units have been operated extensively to determine which system could best produce fresh water on a large-scale basis.

The Magma Companies propose to produce 10 MW of electricity using the MAGMAMAX process, which is an experimental binary cycle. The process (Figure 13) includes: 1) downhole pumps to assure adequate flow rates per individual well, 2) very long nonbaffled, economically-priced heat exchangers, 3) special isobutane turbines that are thought to be unusually efficient, and 4) a secondary propane turbine that will produce a still additional increment of power. Magma anticipates that its system will be more efficient than any other for production of electricity from geothermal resources characterized by relatively low temperatures. Figure 16 is an artist's rendition of the completed power plant for East Mesa; and Figure 17 is a view of the turbine already installed at the turbine house at the Magma property at East Mesa.

Republic Geothermal, Inc. proposes to produce 50 MW of electricity using a conventional two-stage flash steam process. The reasons for selecting this process (Figure 18) were: 1) the technology for the process is proven; 2) the design for the plan is based entirely on standard practice; 3) from a practical point of view there are no delays expected in the delivery schedule of component parts; and 4) it is believed that the two-stage flash steam system is particularly well suited to the low-salinity, low noncondensable brines of the East Mesa resource. Figure 19 is an artist's rendition of the power plant that is to be built by Republic Geothermal, Inc. Figure 20 is a schematic of the two-stage flash steam system.

SUMMARY

Figure 21 is a summary of the highlights of this presentation. First, a concept of a type of geothermal resource is evolving. The type member is the East Mesa geothermal resource. Characteristics include a residual gravity anomaly, high-heat flow, and a core associated with highest heat flow, highest temperature, but relatively poor production. Second, experience in mining the heat of this resource via production history is not yet to be established. Third, several groups are about to evaluate, through major field operations, the technical and economic viability of exploitation of the resource. These activities include: 1) the U.S. Bureau of Reclamation, who are interested in water augmentation; 2) Republic Geothermal Inc., who are interested in electric power production using a two-stage flash system; and finally 3) Magma Power Company, who are interested in the production of electricity using the MAGMAMAX binary cycle system.

REFERENCE

Barkman, J.H., D.A. Campbell, J.L. Smith and R.W. Rex, 1976. East Mesa - Geology, reservoir properties and an approach to reserve determination. Summaries, Second Workshop Geothermal Reservoir Engineering, Stanford University, Stanford California, SGP-TR-20, 116-125.

GEOTHERMAL RESOURCE INVESTIGATIONS AND DEVELOPMENT PLANS AT EAST MESA, CALIFORNIA

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XBL 791-7795

Figure 1 Title and authorship of presentation.

OUTLINE

I. GEOLOGY OF THE RESOURCE

- A. Location
- B. Surface geophysical observations
- C. Subsurface interpretation

II. PROPOSED USES FOR THE RESOURCE

- A. For production of fresh water
- B. Binary cycle production of electricity
- C. Flash steam cycle production of electricity

III. ESTIMATES OF USEFUL ENERGY

XBL 783-473

Figure 2 Outline of talk.

EAST MESA GEOTHERMAL RESOURCE LOCATION

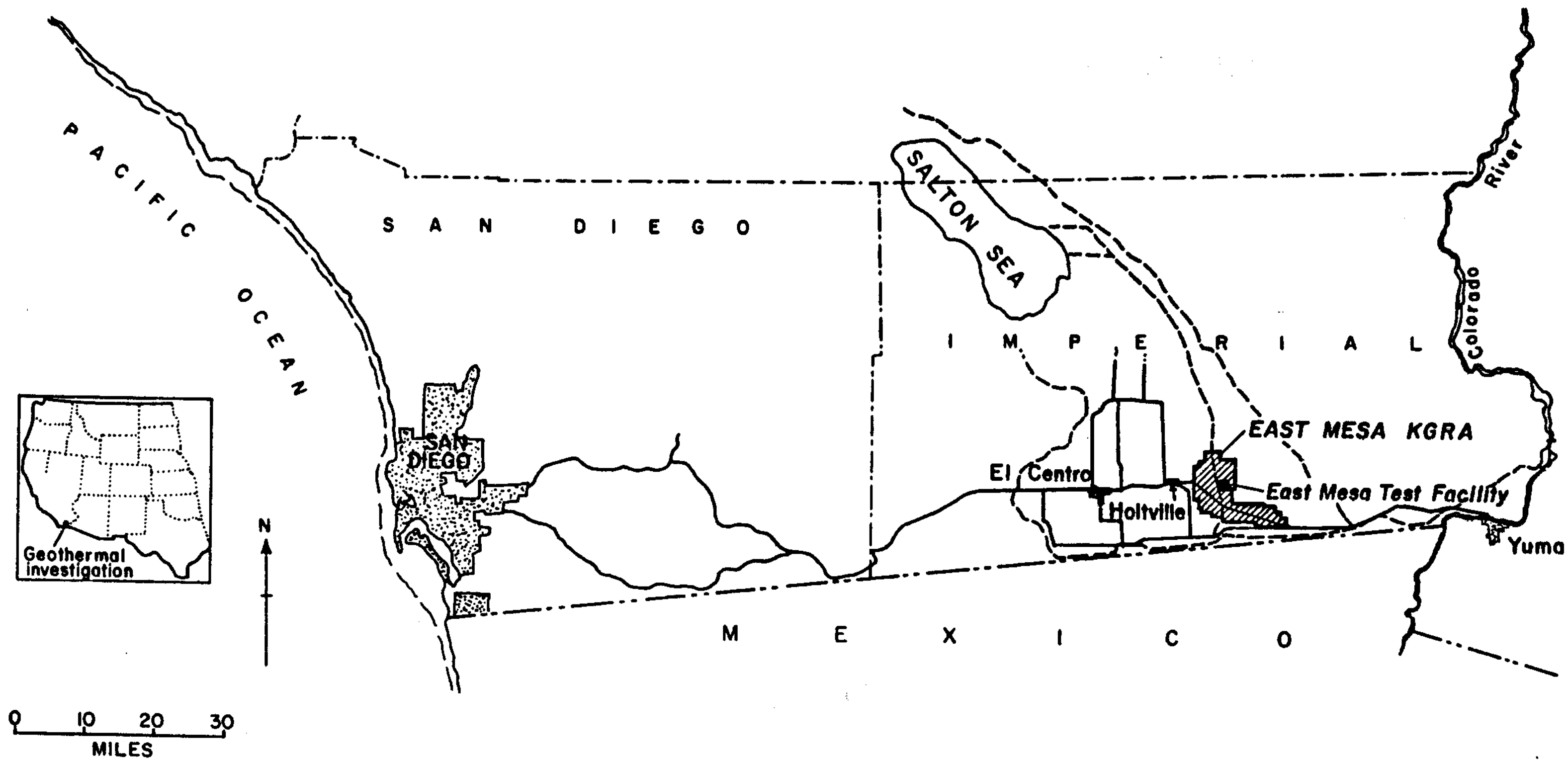

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Figure 3 Location of East Mesa KGRA.

EAST MESA GEOTHERMAL RESOURCE RESIDUAL GRAVITY MAP

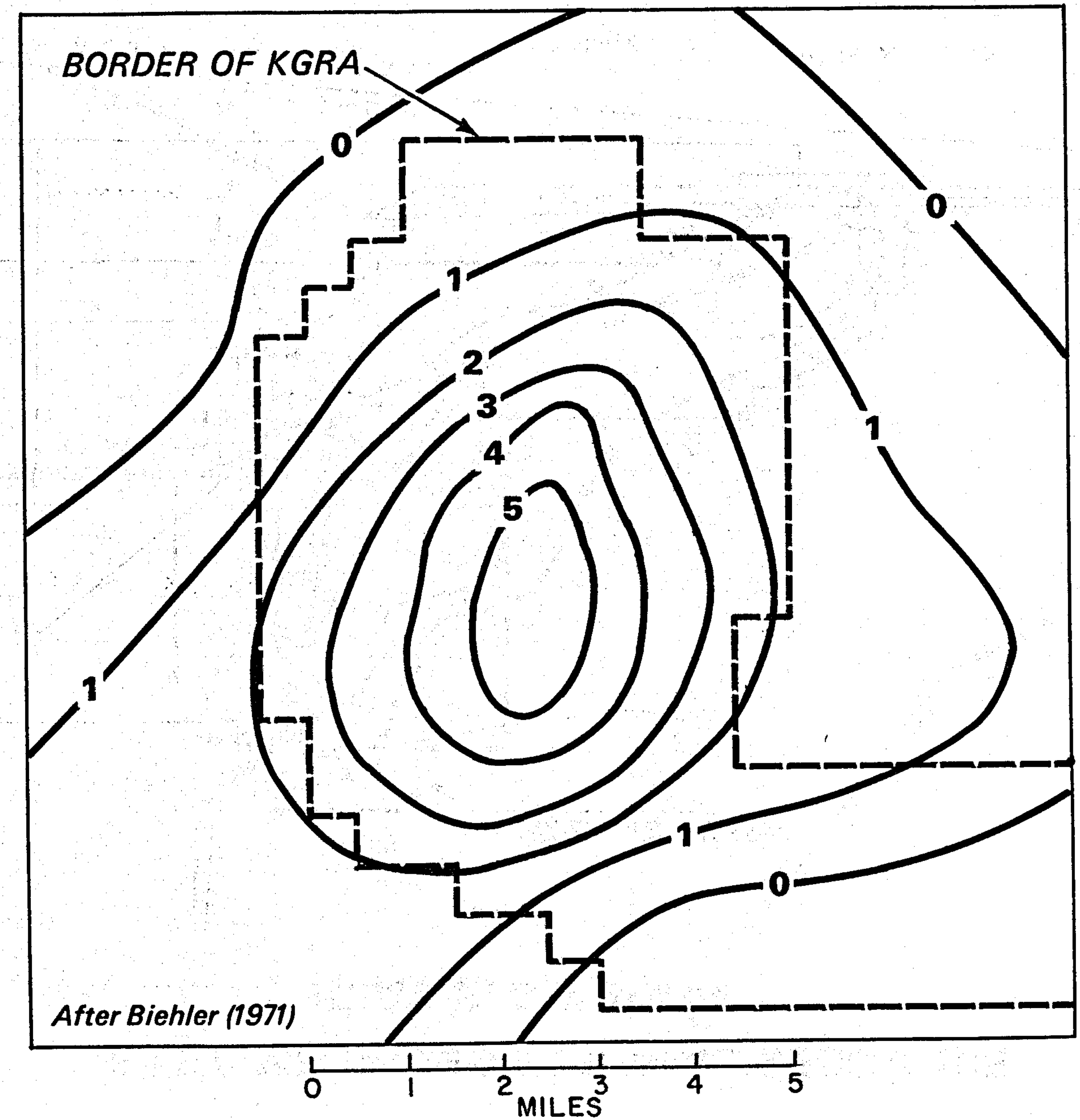

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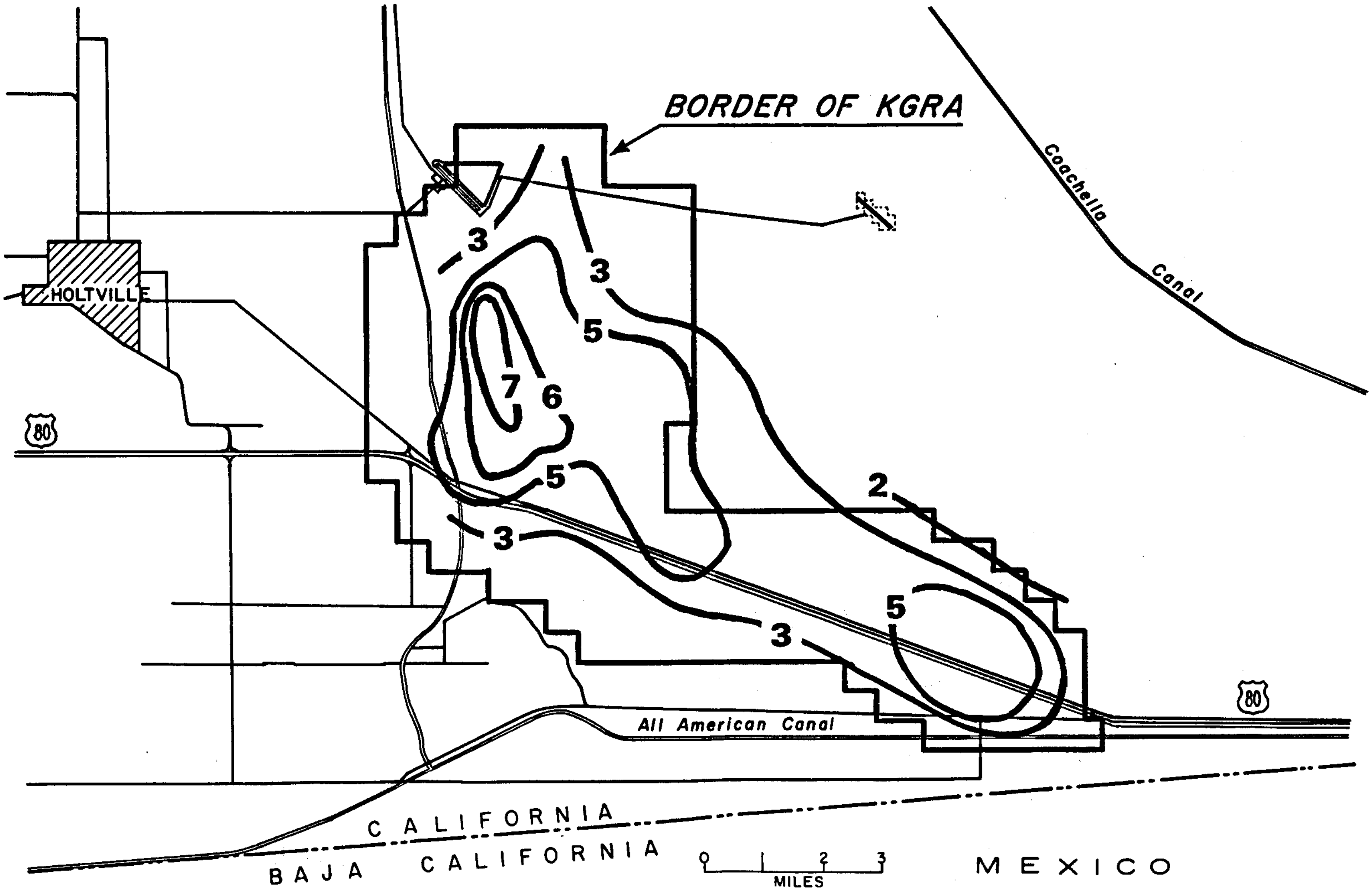
Figure 4 Residual gravity anomaly about the East Mesa geothermal resource.

EAST MESA GEOTHERMAL RESOURCE
HEAT FLOW DATA



After Swanberg (1974)

Figure 5 Heat-flow data.

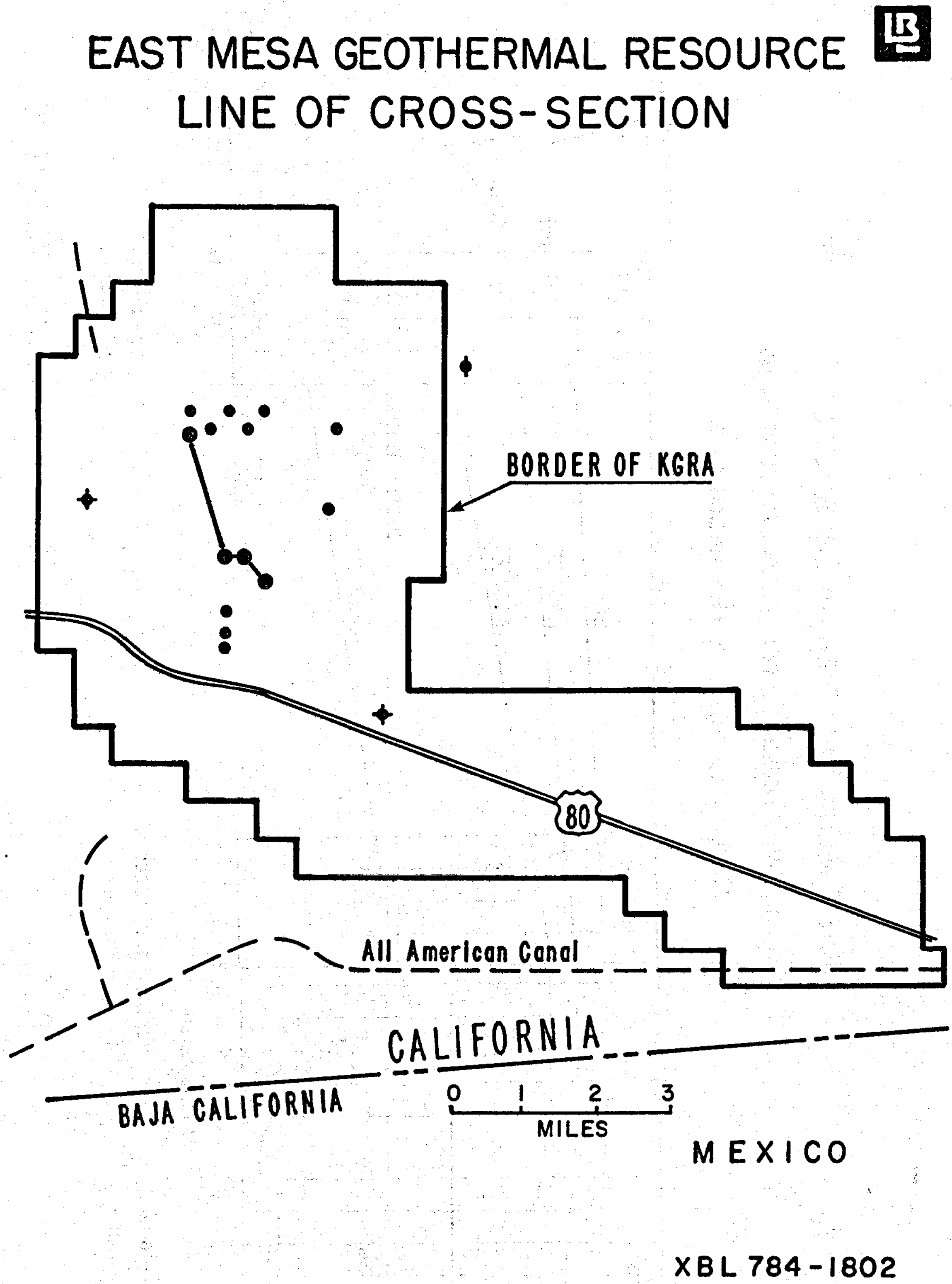


Figure 6 Well locations and line of reference cross-section.

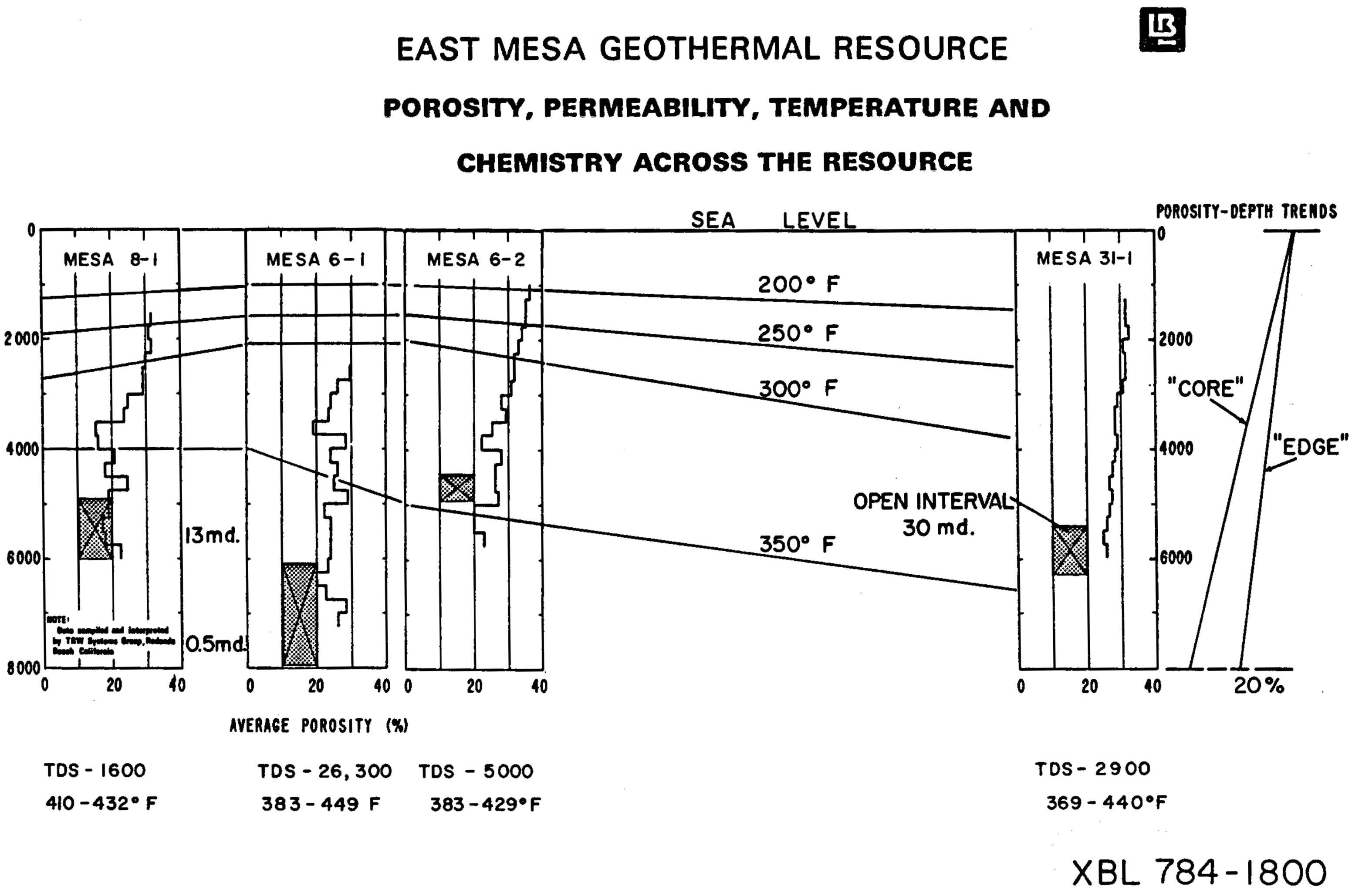


Figure 7 North-south cross-section through zone of highest heat flow.

EAST MESA GEOTHERMAL RESOURCE

ESTIMATES OF ENERGY

PRELIMINARY RESERVE ESTIMATE BY REPUBLIC GEOTHERMAL, INC.

Section	Average reservoir temperature (°F)	Average sand porosity (fraction)	Net sand (fraction)	Bulk volume ($ft^3 \times 10^{10}$)	Total initial heat content ($BTU \times 10^{14}$)	Reserve (MW-years)
29	334	0.17	0.60	8.4	8.7	**1315**
30	335	0.23	0.58	11.7	12.6	**1900**

$\rho_r = 165$ lbs/ft^3 , $\rho_w = 56.7$ lbs/ft^3 , $C_r = 0.19$ BTU/lb°F , $C_w = 1.12$ BTU/lb°F

XBL 784-627

Figure 8 Estimates of energy in place for two sections in the East Mesa KGRA (after Barkman et al., 1976).

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Figure 9 Republic Geothermal East Mesa project, proposed 48 MW geothermal power plant and associated wells. Drilled wells are shown in solid colors, blue are injectors, green are producers. Half-colored circles are proposed wells.

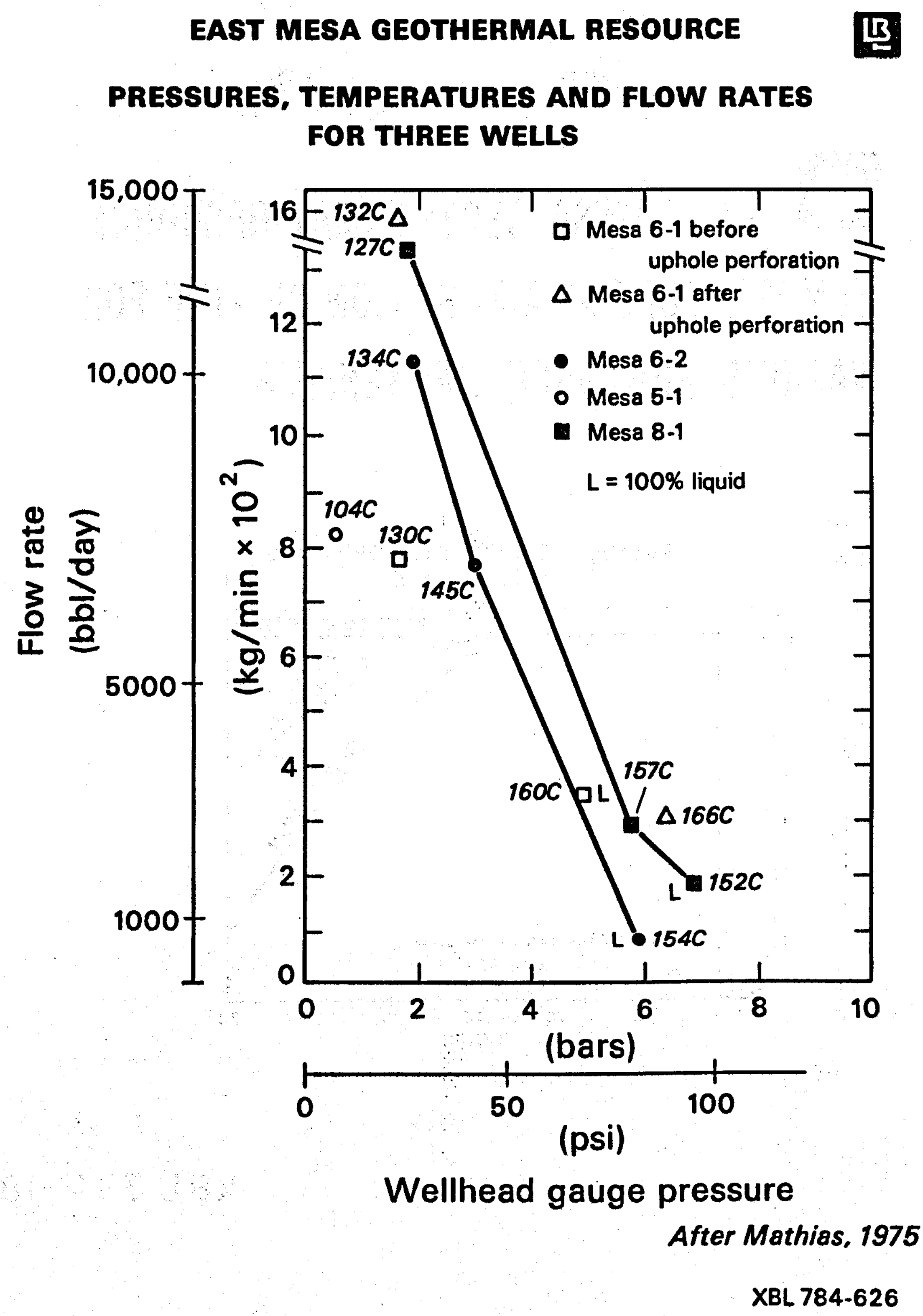

Figure 10 Pressure, temperature and flow rates for three wells.

EAST MESA GEOTHERMAL RESOURCE TEMPERATURE AS A FUNCTION OF TIME FOR VARIOUS RECHARGE MECHANISMS.

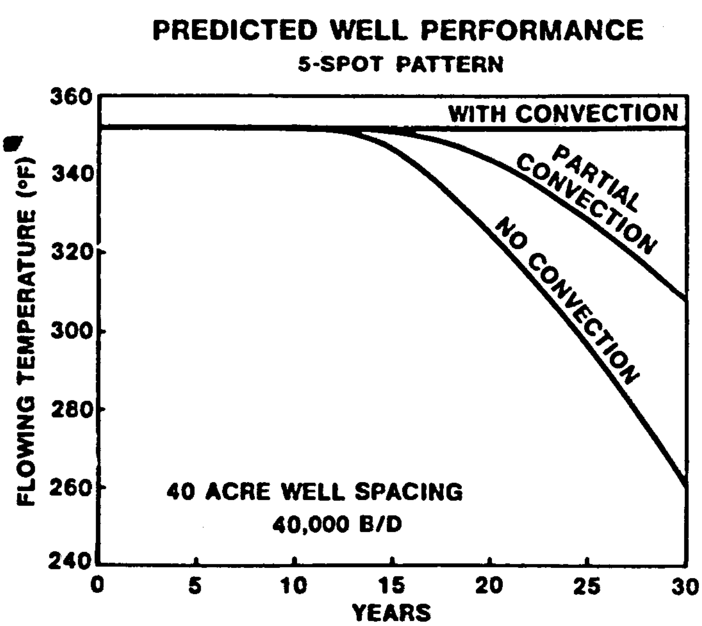

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Figure 11 Temperature of production wells as a function of time for three different recharge mechanisms.

EAST MESA GEOTHERMAL RESOURCE
PROPOSED USES OF THE RESOURCE

The *U.S . BUREAU OF RECLAMATION* proposes to produce fresh water from the resource to augment the quality of water of the Colorado River.

Processes for fresh water production include the following types of desalting units:

- MSF - Multistage Flash
- VTE - Vertical Tube Evaporators
- HTED - High Temperature Electro Dialysis

XBL 784-623

Figure 12   Proposed uses of the resource - U.S. Bureau of Reclamation.

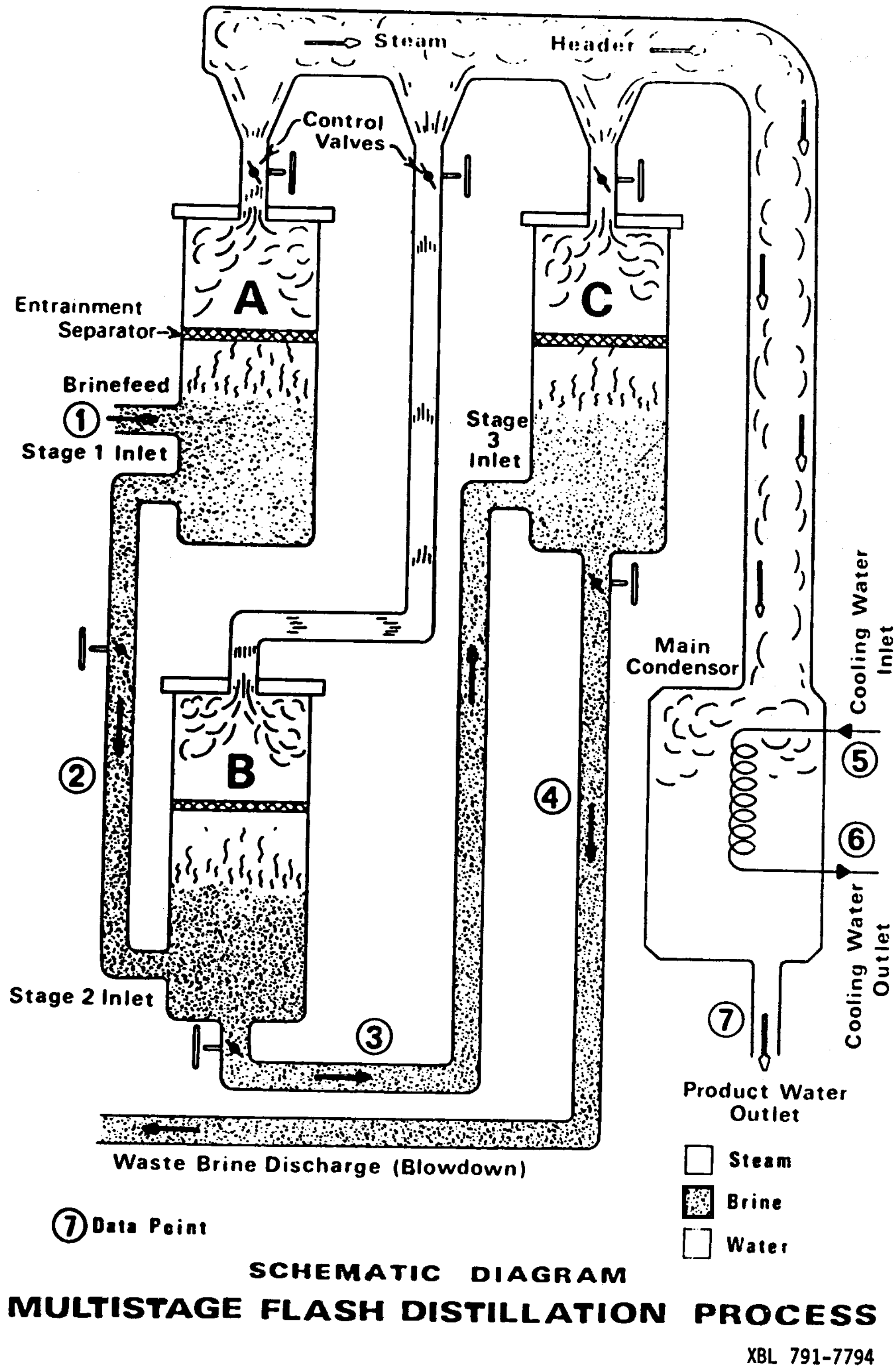

Figure 13 Schematic diagram of USBR multistage flash distillation process.

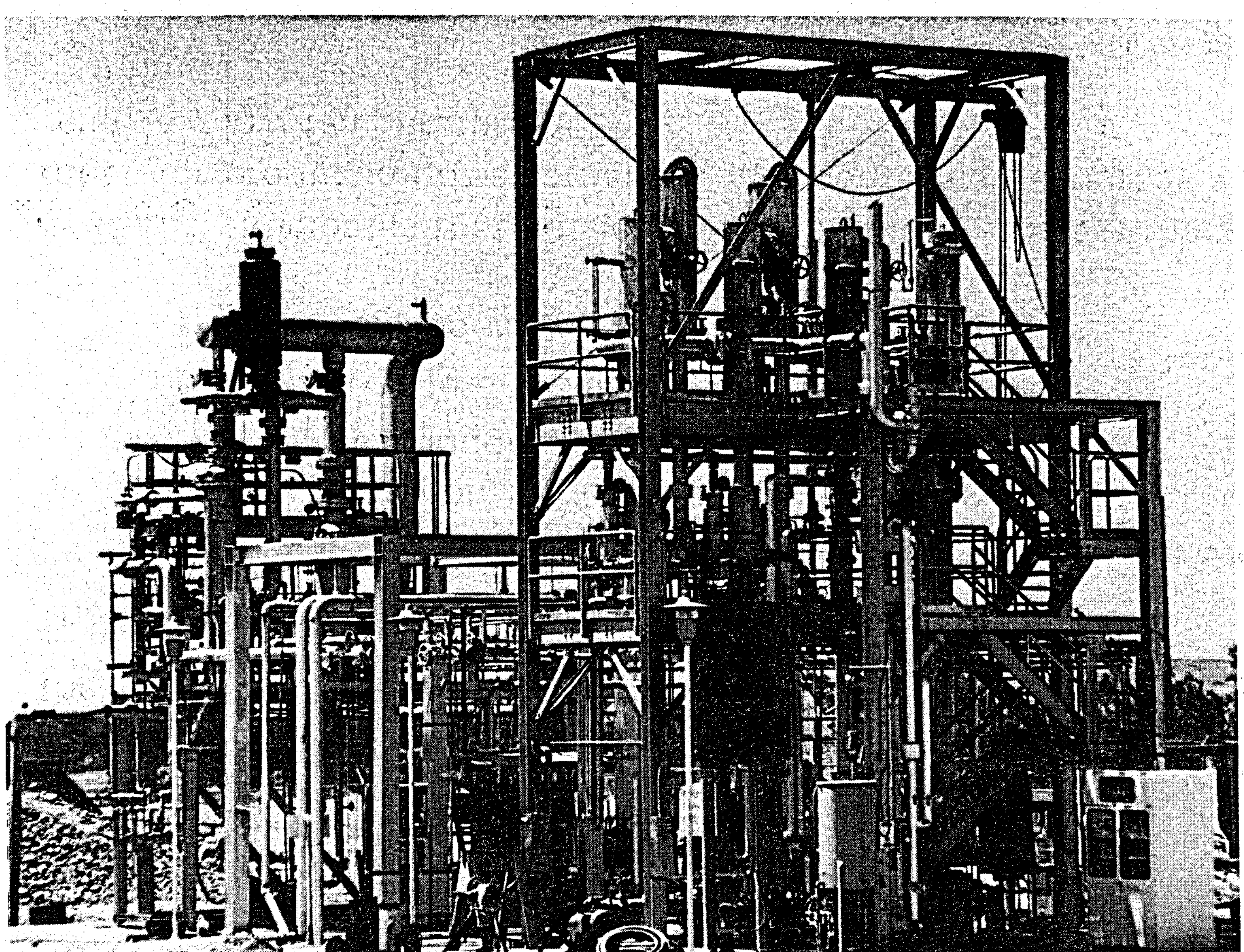

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Figure 14 Vertical tube evaporators (right half of photo), and multistage flash distillation unit (left half of photo) (USBR No. P1241-300-1153) at USBR site at East Mesa.

EAST MESA GEOTHERMAL RESOURCE
PROPOSED USES OF THE RESOURCE

MAGMA COMPANIES propose to produce electricity using the *"MAGMAMAX PROCESS"* at East Mesa.

The process includes:

- Downhole pumps to assure adequate flow rates per well
- Very long, non-baffled, economically priced heat exchangers
- Special isobutane turbine
- Secondary power generating propane turbine

MAGMA anticipates that its system will be more efficient than any other for production of electricity from geothermal resources with relatively low temperatures

XBL 784-624

Figure 15 Proposed uses of the resource - Magma Companies.

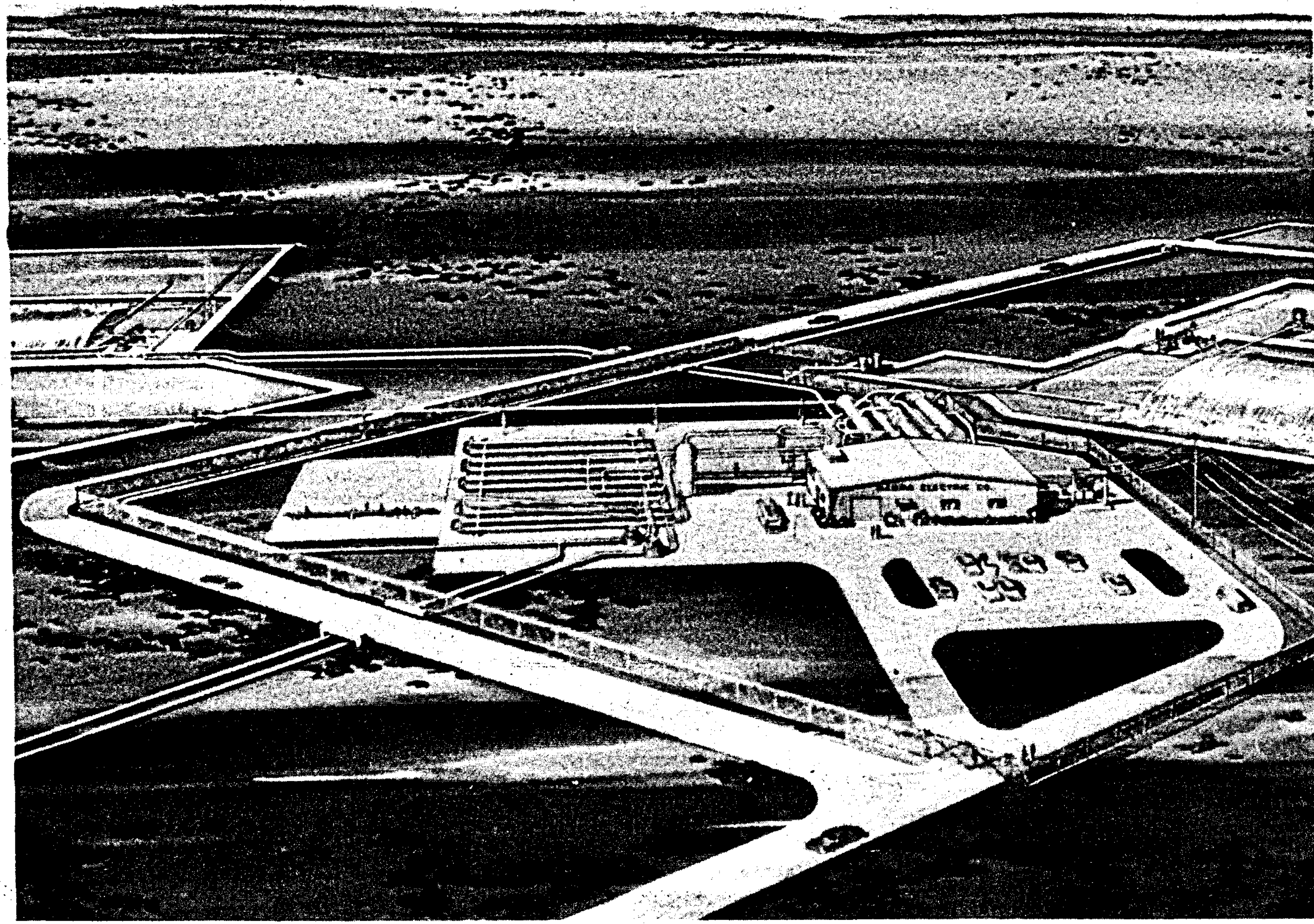

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Figure 16 Artist's rendition of the Magma Power Plant at East Mesa, California.

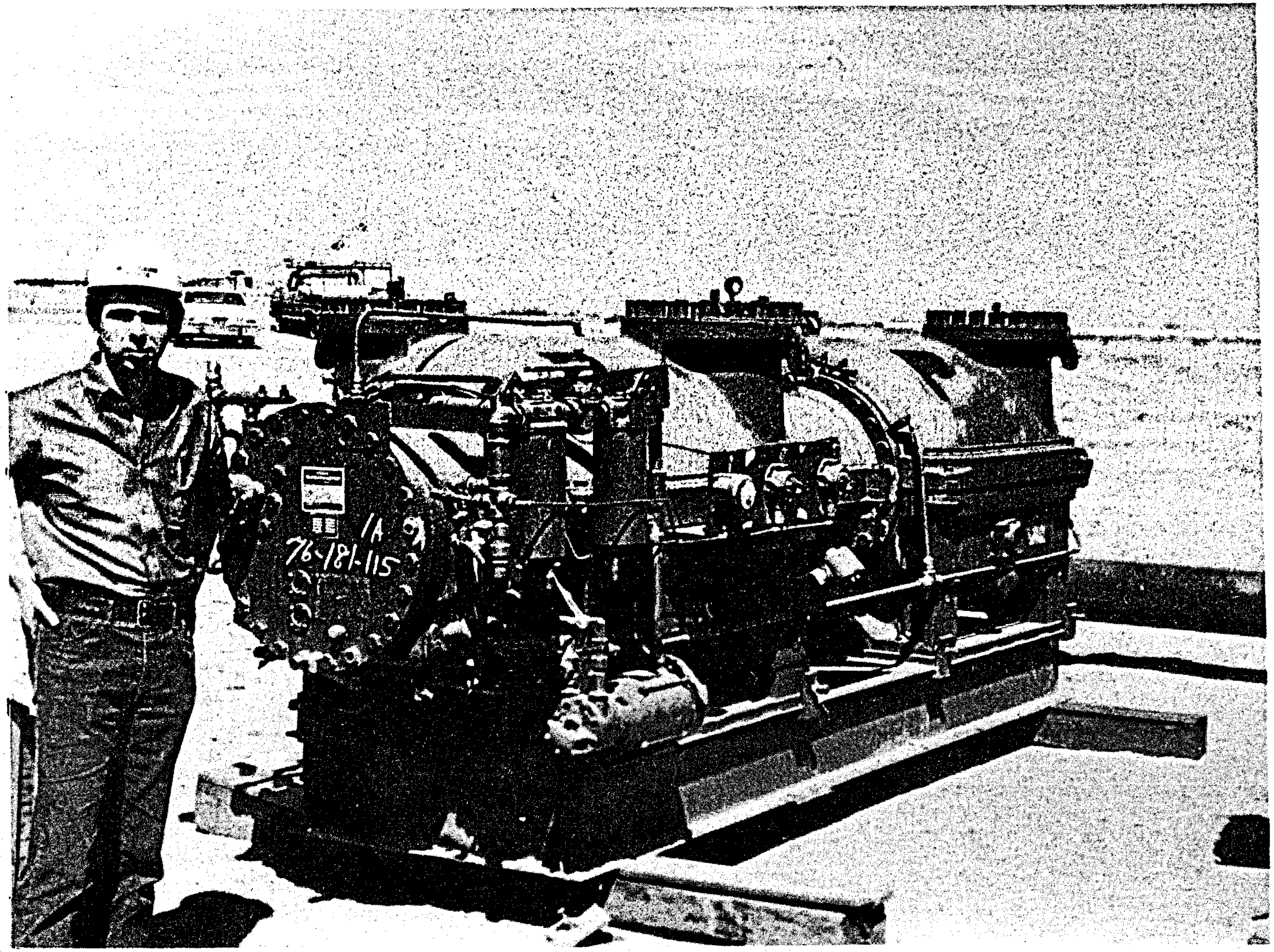

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Figure 17 Turbine for the Magma Power Plant at East Mesa, California.

EAST MESA GEOTHERMAL RESOURCE
PROPOSED USES OF THE RESOURCE

REPUBLIC GEOTHERMAL, INC. proposes to produce electricity using a two-stage flash process.

Reasons for selecting this process are:

- Proven technology
- Standard design features
- No delays expected in delivery schedule
- Well suited to chemistry of the resource

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Figure 18 Proposed uses of the resource - Republic Geothermal, Inc.

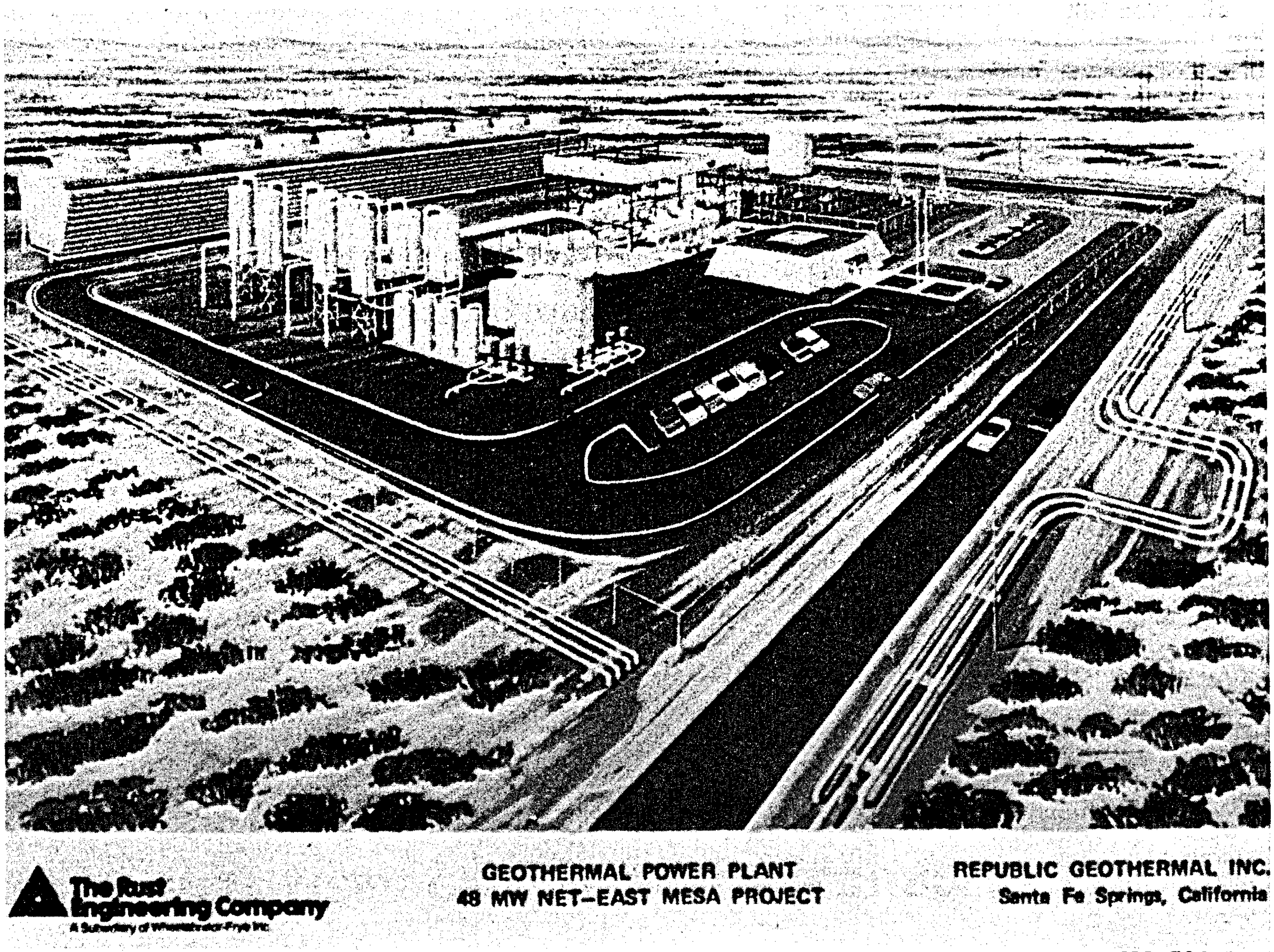

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Figure 19 Artist's rendition of the power plant by Republic Geothermal, Inc. at East Mesa, California.

TWO-STAGE FLASHED STEAM ENERGY CONVERSION PROCESS

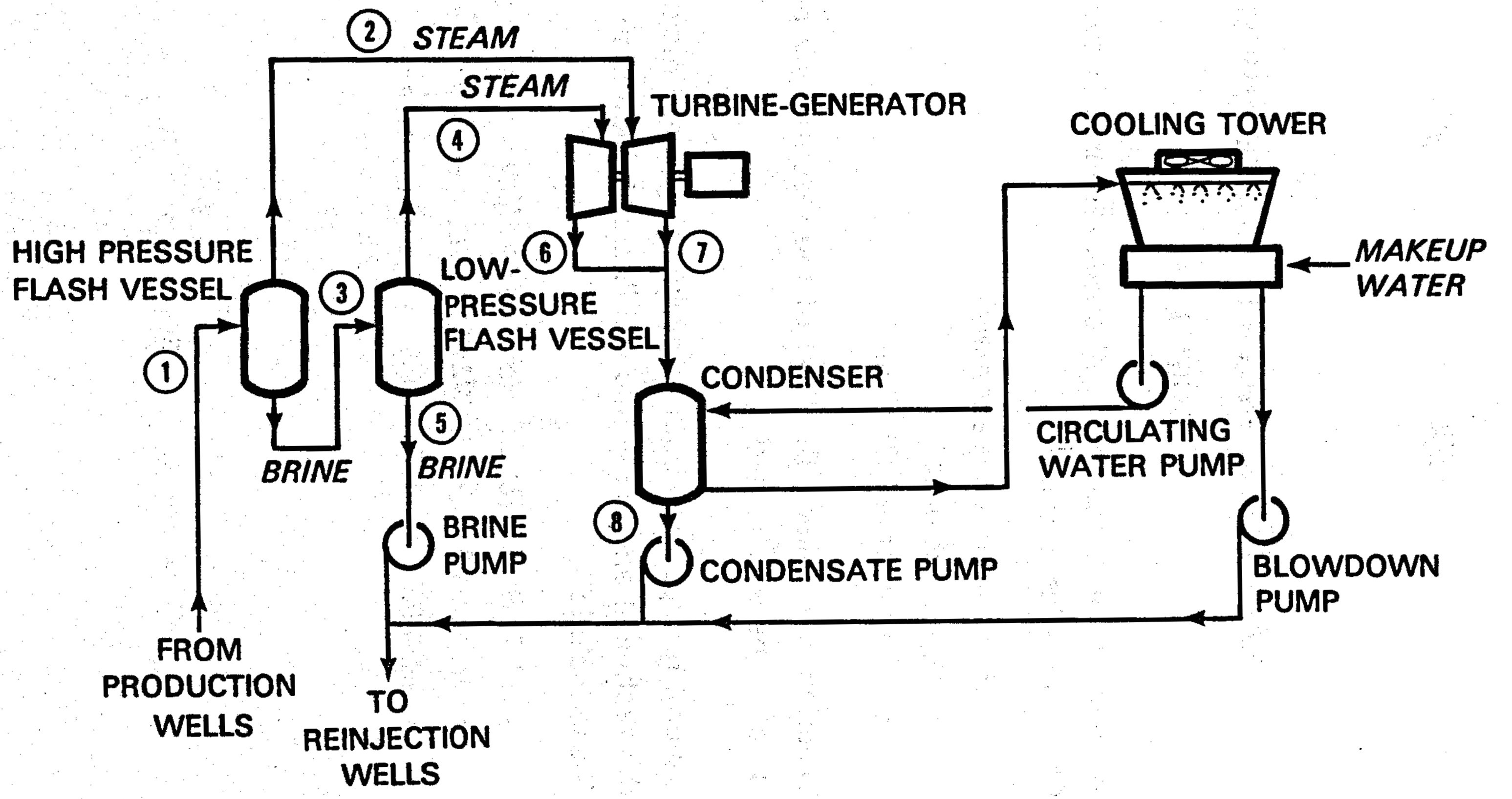

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Figure 20 Diagram for two-stage flashed steam energy conversion process.

EAST MESA GEOTHERMAL RESOURCE

SUMMARY

1. A concept for a type of geothermal resource is evolving. Characteristics include:
   - Residual gravity anomaly
   - High heat flow
   - "Degenerate" (?) core

2. Experience in mining the heat of the resource via production history is yet to be established

3. Several groups are about to evaluate, through major field experiments, the technical and economic viability of exploitation of the resource. These include:
   - *U.S. BUREAU OF RECLAMATION* - Water augmentation
   - *REPUBIC GEOTHERMAL, INC.* - Electric power
   - *MAGMA COMPANIES* - Electric power

XBL 784-622

Figure 21 Summary of talk.