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UCRL-51976

**CHARACTERISTICS OF GEOTHERMAL WELLS
LOCATED IN THE SALTON SEA GEOTHERMAL FIELD,
IMPERIAL COUNTY, CALIFORNIA**

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MS. date: December 15, 1975

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Frontispiece. Temperature gradient map of the Imperial Valley, California, showing Known Geothermal Resource Areas (KGRA) and the Salton Sea Geothermal Field (SSGF).

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Abstract

We have summarized the geophysical, geochemical, and geothermal characteristics of wells located in the Salton Sea Geothermal Field. Based on the geothermal characteristics of

the wells, we have developed a subsurface heat profile for the entire geothermal field. We have also drawn maps of temperature contours for specified depths throughout the field.

Introduction

The Lawrence Livermore Laboratory (LLL) is currently conducting research projects to assess the geothermal energy present in high-temperature/high-salinity (HT/HS) brines and to develop power conversion technology for these brines. As a part of these projects we have compiled geothermal well data on the Salton Sea Geothermal Field (SSGF), Imperial County, California (Fig. 1). The Energy Research and Development Administration (ERDA) has requested this data in support of their geological and environmental studies of the Imperial Valley.

The nature of Salton Sea geothermal brines and various methods of harnessing their energy potential are described by Palmer et al.¹ Towse, reporting on one such method--

extracting heat from high-temperature brines-- suggests that the SSGF contains enough hot water (150° to 300°C) to produce 400 MW of electrical power for 20 years.² Another method of recovering and converting the energy in HT/HS brines - total flow recovery - has been described by Austin et al.³ This method involves the development of an experimental field site located within the SSGF, an area of known HT/HS geothermal resources. LLL is planning such a site to accommodate turbine prototype tests in which brine from an active geothermal well will be a test fluid. Our effort to compile geothermal data is part of the process to acquire and develop an LLL geothermal site.

Fig. 1. Geothermal wells, Salton Sea Geothermal Field, Imperial County, California.

Description of Geothermal Wells

This section describes all geothermal wells located in and immediately adjacent to the SSGF. Official jurisdiction over these and all other geothermal wells in California is a function of the California Division of Oil and Gas (DOG).^{*} For each well, this agency officially designates: the owner of record, the owner's designated agent, location, status,

and name of well (Table 1). The SSGF is located within the Division area known as District One, administered from the DOG office in Long Beach, California by a regional geothermal engineer. The data in the following tables are, for the most part, from files maintained in this office.

Table 2 lists the following operational conditions of each well: total depth, location of perforations, plug location, casing size and location, and existing logs of the borehole. The terms in this table are from the DOG.

^{*}DOG has had regulatory authority over geothermal wells since 1965; geothermal wells located and operated before that time are not necessarily documented by official state files.

Table 1. Geothermal well description.

Well Name	Owner/Agent	Township/ Range-Section	American Petroleum Institute
Sinclair #1	<u>Geothermal Energy & Mineral Corp.</u>	12S/13E-10	02590015
Sinclair #2		12S/13E-4	02590016
Sinclair #3	Alice Denman P.O. Box 234 Calipatria, Ca 92233	12S/13E-10	02590017
Sinclair #4		12S/13E-4	02590018
Magmamax #1	<u>Magma Power Co.</u>	11S/13E-33	02590014
Magmamax #2		11S/13E-33	02590010
Magmamax #3	B. C. McCabe President, MPC 631 S. Witmer Los Angeles, Ca. 90017	11S/13E-33	02590011
Magmamax #4		11S/13E-33	02590012
Woolsey #1		11S/13E-33	02590013
Elmore #3		11S/13E-27	02590036

Table 1. (Continued)

Well name	Owner/Agent	Township/ Range-Section	American Petroleum Institute
Elmore #1	<u>Union Oil Co.</u>	11S/13E-27	02590027
River Ranch #1		11S/13E-24	02590029
Hudson #1	Dr. Carl Otte P.O. Box 7600 Los Angeles, Ca. 90054	11S/13E-13	02590028
IID #1	<u>Imperial Thermal</u>	11S/13E-23	02590019
IID #2	<u>Products, Inc.</u>	11S/13E-22	02590020
IID #3		11S/13E-23	02590021
State of Calif. #1	ITP, Inc. 110 N. Walker Dr. Chicago, Ill. 60606 L. H. Kreisel 7380 Central Ave. Newark, Ca. 94560	11S/13E-23	02590022
Sportsman #1	<u>Joseph I. O'Neill, Jr.</u> Jos. I. O'Neill 410 W. Ohio Midland, Texas	11S/13E-23	02590023
PDC #1	<u>Pioneer Dev. Co.</u>	11S/13E-10	02590024
PDC #2		11S/13E-10	02590025
PDC #3	No information	11S/13E-10	02590026
Well #1	<u>Salton Sea Chemical</u>	11S/13E-28	02590033
Well #5	<u>Products Corp.</u> No information	11S/13E-25	Not Assigned
Well #1	<u>J. P. Chandler & Lee Staton</u> No information	11S/14E-19	02590012

Table 2. Geothermal well status.

<u>Well name</u>	Sinclair #1	Sinclair #2	Sinclair #3
<u>Status</u>	Completed ^a 1958 Operated ^b 1958 Shut-in ^d 1958	Completed 1961 Abandoned ^c 1965	Completed 1963 Produced 1963 Operated 1975
<u>Depth^e (ft)</u>			
Total height of Kelly Bushing above surface-ft.	4725	2363	6922
Perforations ^f	5 3370 to 3445	5 None	12 3788-5179 5313-6868
Plugs ^g	None	0-2363	None
<u>Casing^h</u>			
Outside diameter (in.)	10-3/4 3-1/2 open ⁱ	12-3/4 9-7/8	13-3/8 8-5/8 6-5/8 5-1/2 open
Length (ft)	0-280 0-4692 4692-4725	0-304 0-2365	0-1365 0-5326 5272-6913 0-3730 6913-6922
<u>Logs^j</u>	SP, R, C	No information	SP, R, C, L
<u>Well name</u>	Sinclair #4	Magmamax #1	Magmamax #2
<u>Status</u>	Completed 1964 Operator 1975	Completed 1972 Produced 1972 Shut-in 1972	Completed 1972 Shut-in 1972 Operated 1974 Shut-in 1974
<u>Depth (ft)</u>			
Total height of Kelly Bushing above surface-ft.	5300	2805	4368
Perforations ^f	12 4287 to 5060	12 1797-2264	12 3784 to 4360
Plugs	None	2300-2805	None
<u>Casing</u>			
Outside diameter (in.)	13-3/8 9-5/8 7	20 13-3/8 8-5/8	20 13-3/8 9-5/8
Length (ft)	0-1765 0-5260 0-4006	0-110 0-1060 908-2264	0-100 0-1009 0-4360
<u>Logs</u>	SP, R, C, L	SP, R, C, P, T, L	SP, R, C, P, T
<u>Well name</u>	Magmamax #3	Magmamax #4	Woolsey #1
<u>Status</u>	Completed 1972 Shut-in 1972	Completed 1972 Shut-in 1973	Completed 1972 Shut-in 1972
<u>Depth (ft)</u>			
Total height of Kelly Bushing above surface-ft.	4000	2567	2400
Perforations	12 2618 to 3076	12 2376 to 2518	12 1866 to 2375
Plugs	3120 to 4000	None	None
<u>Casing</u>			
Outside diameter (in.)	20 13-3/8 9-5/8	12-3/4 8-5/8 2-7/8	20 13-3/8 8-5/8
Length (ft)	0-100 0-1032 0-3076	0-40 0-516 0-2566	0-105 0-1084 875-2375
<u>Logs</u>	SP, R, C, P, T	SP, R, C, P, L	SP, R, C, P, L

Table 2. (Continued)

<u>Well name</u>	Elmore #3			Elmore #1			
<u>Status</u>	Completed 1974 Shut-in 1974			Completed 1964 Produced 1964 Shut-in 1965			
<u>Depth (ft)</u>							
Total	2510			7117			
height of Kelly Bushing above surface-ft.	12			15			
Perforations	2007 to 2505			4766 to 7097			
Plugs	None			4307 to 7117			
<u>Casing</u>							
Outside diameter (in.)	16	10-3/4	7	20	13-3/8	8-5/8	6-5/8
Length (ft)	0-100	0-1068	0-2505	0-107	0-1510	0-4745	0-4307 4633 to 7087
<u>Logs</u>	SP, R, C, L			SP, R, C, L			

<u>Well name</u>	River Ranch #1			Hudson #1			
<u>Status</u>	Completed 1963 Produced 1963 Abandoned 1971			Completed 1964 Produced 1964 Abandoned 1971			
<u>Depth (ft)</u>							
Total	8100			6141			
height of Kelly Bushing above surface-ft.	15			15			
Perforations	3890 to 6570 6642 to 8093			5812 to 6112			
Plugs	0-8100			0 to 6141			
<u>Casing</u>							
Outside diameter (in.)	20	13-3/8	8-5/8	6-5/8	20	13-3/8	8-5/8
Length (ft)	0-108	0-1575	0 to 6632	2419-8093	0-97	0-1445	0-5884 5810-6112
<u>Logs</u>	SP, R, C			SP, R, C, L			

<u>Well name</u>	IID #1			IID #2			IID #3	
<u>Status</u>	Completed 1962 Produced 1965 Shut-in 1965			Completed 1963 Produced 1963 Shut-in 1964			Completed 1965 Shut-in 1965	
<u>Depth (ft)</u>								
Total	5230			5826			1700	
height of Kelly Bushing above surface-ft.	9			12			No information	
Perforations	4900-5212			3490-3702			No information	
Plugs	5215-5230			5811-5826			None	
<u>Casing</u>								
Outside diameter (in.)	20	16	11-3/4	7-5/8	18	11-3/4	9-5/8	No information
Length (ft)	0-67	0-303	0-1672	0-5215	0-90	0-1598	0-5811	No information
<u>Logs</u>	SP, R, C, L			SP, R, C, L			No information	

<u>Well name</u>	State of Calif. #1			Sportsman #1			
<u>Status</u>	Completed 1964 Produced 1964 Shut-in 1965			Completed 1961 Produced 1961 Shut-in 1961			
<u>Depth (ft)</u>							
Total	4848			4729			
height of Kelly Bushing above surface-ft.	11			12			
Perforations	4435-4806			3980-4720			
Plugs	4839-4848			4720-4729			
<u>Casing</u>							
Outside diameter (in.)	18	11-3/4	7-5/8	20	16	10-3/4	5-1/2
Length (ft)	0-102	0-1191	0-4848	0-65	0-283	0-1195	0-4729
<u>Logs</u>	SP, R, C, T, L			SP, R, L			

Table 2. (Continued)

<u>Well name</u>	Pioneer Dev. Co. #1	Pioneer Dev. Co. #2	Pioneer Dev. Co. #3
<u>Status</u>	Completed 1927 Abandoned 1928	Completed 1927 Abandoned 1928	Completed 1927 Abandoned 1928
<u>Depth (ft)</u>			
Total	727	1263	1473
height of Kelly Bushing above surface-ft.	No information	No information	No information
Perforations	No information	No information	No information
Plugs	No information	No information	No information
<u>Casing</u>			
Outside diameter (in.)	5" 2-7/8 2-1/4 open	No information	No information
Length (ft)	0-79 0-316 0-452 452-727	No information	No information
<u>Logs</u>	L	L	L
<u>Well name</u>	Salton Sea Chem. Prod. #1	Salton Sea Chem. Prod. #5	J. P. Chandler & Staton #1
<u>Status</u>	Completed 1932 Abandoned 1932	Completed 1933 Abandoned 1933	Completed 1935 Abandoned 1935
<u>Depth (ft)</u>			
Total	1054	960	590
height of Kelly Bushing above surface-ft.	No information	No information	No information
Perforations	No information	450-550	No information
Plugs	No information	550-960	No information
<u>Casing</u>			
Outside diameter (in.)	No information	9" 5"	8-1/4 6-5/8
Length (ft)	No information	0-420 0-550	0-151 0-400
<u>Logs</u>	L	L	L

^aThe drilling has been completed at the intended depth.

^bThe well is or has been flowed within the past year.

^cThe well is inoperative and the borehole is plugged.

^dThe wellhead is closed but the borehole is not plugged.

^eAll depths are reported in feet below Kelly Bushing (KB), a position 9 to 15 ft above local surface level. Height of KB above surface level is listed in the KB section of the table. Surface level in this area is below sea level. A topographic map of the SSGF area is included (Fig. 2).

^fListed by the depth of the perforated section and generally represent production zones for each well.

^gListed by the depth of the plugged section and represent closed sections of the borehole.

^hThe casing refers to the pipe that is lowered into the borehole. The o.d. for each length of casing in the borehole is given. Also the position of each length of casing in the borehole is supplied: 10-3/4", 0-280 ft means that the o.d. is 10-3/4 in. wide and the length of pipe with that diameter extends 280 ft below KB.

ⁱThe word "open" means that the borehole does not have any pipe.

^jLogs available for each borehole: SP - self potential, R - resistivity, C - conductance, L - lithology, P - pressure, T - temperature.

Fig. 2. Topography of the Salton Sea Geothermal Field.

Characteristics of Geothermal Wells

The following tables and graphs summarize the geothermal, geochemical, and geophysical characteristics of the wells listed in Table 1. We analyze these data on p. 38.

HEAT CHARACTERISTICS

Figures 3 to 19 illustrate the measured temperatures of each borehole. The figures are based on data taken from Refs. 4 through 8. When using the temperature data, note that the values represent the best available information, and are not necessarily accurate. Conditions affecting the accuracy include:

- Position - whether measurements are made at the wellhead, at the bottom of the well, at the drillstem, or at the flowline.
- Time - The borehole must reach temperature equilibrium before measurement. If it is measured beforehand, the result is inaccurate.
- Equipment - Type of temperature sensors used.
- Frequency - How often the temperature is measured.

Comments on the nature of these parameters were not always provided in the references. We believe that for some of the older wells, the

temperature reported is for flowline values, or for nonequilibrium conditions.

PRODUCTION CHARACTERISTICS

Table 3 lists production characteristics for the geothermal wells listed in Table 1. The data were compiled from available information bearing upon flow rates. Production rates are relative to wellhead pressure, orifice size, and duration of flow. Pressure and orifice size are given in the table; flow duration was available for only two wells. This information is drawn from a variety of records, some of which are over 15 years old. In most cases the values listed are those reported to the DOG and, therefore, should be reasonably accurate.

Geothermal wells in the SSGF area draw from naturally heated water reservoirs, which will not flow unless the borehole water column is stimulated. To do this, the entire column is lifted by means of nitrogen injection at the bottom of the well. Lifting the water column allows thermal expansion, reduction of water density, and initiation of flow. Once flowing, most wells usually continue unaided at relatively high production rates.

Production flow for SSGF wells is typically measured in several hundred thousand pounds per hour and consists of a liquid-steam mixture containing 10 to 20% steam. Two wells are listed with sustained flows of 4 and 90 days. Several others have produced for up to 18 months without decreasing appreciably.⁵ Sinclair well #4 has been observed on several occasions to flow for extended periods with a sustained production of over a hundred thousand pounds per hour.

GEOCHEMICAL CHARACTERISTICS

Most of the wells in the Salton Sea Geothermal Field produce substantial amounts of fluid from a water-dominated geothermal reservoir. All of these wells flow a mixture of steam and hypersaline brine at the wellhead. Brine analyses show surprisingly high mineral contents,

some of the brines having total dissolved-solid concentrations of more than 300,000 ppm. This salinity, accompanied by acidic properties, causes severe corrosion and scaling problems in the wells and support equipment. The potential for mineral recovery from these brines has been recognized and several attempts have been conducted to recover calcium chloride, potash, and several other mineral commodities.

Table 4 lists the chemical analysis of brines that are present in the geothermal wells. All samples are assumed to be collected at the wellhead. These data were compiled from the various companies involved in the SSGF activities and the source of each entry is referenced. The method of analysis and the condition of the geothermal fluid during analysis were not always given.

Fig. 3. Temperature of Sinclair #1.⁴

Fig. 4. Temperature of Sinclair #3.⁵

Fig. 5. Temperature of Sinclair #4.⁶

Fig. 6. Temperature of Magmamax #1.⁷

Fig. 7. Temperature of Magmamax #2.⁷

Fig. 8. Temperature of Magmamax #3.⁷

Fig. 9. Temperature of Woolsey #1.⁷

Fig. 10. Temperature of Elmore #1.⁵

Fig. 11. Temperature of River Ranch #1.⁵

Fig. 12. Temperature of Imperial Irrigation District #1.⁵

Fig. 13. Temperature of Imperial Irrigation District #2.⁵

Fig. 14. Temperature of Imperial Irrigation District #3.⁵

Fig. 15. Temperature of State of California #1.^{5,8}

Fig. 16. Temperature of Sportsman #1.⁵

Fig. 17. Temperature of Pioneer Development Company #1.⁴

Fig. 18. Temperature of Pioneer Development Company #2.⁴

Fig. 19. Temperature of Pioneer Development Company #3.⁴

Table 3. Production Characteristics

Well	Production Rate (lb/hr)	Wellhead Pressure (psi)	Date	Steam (%)	Orifice (in.)
Magma max #1	542,000	160	4-28-72	13	8
Magma max #1	405,000	96	4-29-72	14	8
Magma max #1	349,000	102	4-30-72	14	8
Magma max #1	339,000	122	5-1-72	15	8
Magma max #1	369,000	117	5-2-72	10	8
Magma max #1	399,000	103	5-3-72	13	8
Magma max #1	467,000	110	5-4-72	14	8
Sinclair #3	593,000	185	5-23-63	12	8
Sinclair #4	450,000	250	5-2-64	20	-
IID #1	625,500	200	6-62 90-day Test	25	7
IID #1	172,000	585	12-8-65	10	-
IID #1	375,000	485	12-9-65	11	-
IID #1	462,500	385	8-2-65	14	-
IID #1	500,000	285	-	17	-
IID #1	532,000	185	-	20	-
IID #2	377,000	212	3-64	18	8
IID #2	440,000	225	3-64	18	8
IID #2	349,700	263	3-64	16	8
IID #2	319,700	215	3-64	15	8
IID #2	395,400	225	3-64	14	8
Sportsman #1	327,000	248	4-61	15	5-1/2
Sportsman #1	293,000	205	4-61	16	5-1/2
Sportsman #1	324,000	200	-	17	5-1/2
State #1	305,000	465	6-64	15	8
State #1	364,000	400	6-64	18	8
State #1	405,000	347	6-64	20	8
Elmore #1	316,000	-	-	35	-
Hudson #1	432,333	-	8-64 4-day Test	22	7
River Ranch #1	244,700	-	10-65	20	7

Table 4. Chemical analysis of geothermal well brines.

Brine composition (ppm)		
Constituent	Pioneer Dev. Co. #3 ^{a,b} (Ref. 9)	State of Calif. #1 ^{a,c} (Ref. 5)
Aluminum	-- ^d	--
Ammonia (NH ₄)	--	--
Antimony	--	--
Arsenic	--	--
Barium	--	190
Boron	--	290
Bromine	--	--
Calcium	16,000	21,200
Cesium	--	17
Chlorine	68,000	127,000
CO ₂ as HCO ₃	300	6,900 ^e
Copper	--	2
Fluorine	--	--
Iodine	--	--
Iron	--	1,200
Lead	--	80
Lithium	--	180
Magnesium	--	27
Manganese	4,000	950
Nitrate (NO ₃)	1,050	--
Potassium	--	14,000
Rubidium	--	65
Silica	--	--
Silver	--	<1
Sodium	20,400 ^f	47,800
Strontium	--	--
Sulfate (SO ₄)	200	--
Sulfide Sulfur	--	30
Zinc	--	500
Summary Data		
Total of the above constituents ^g :	109,950	220,432
Total dissolved solids reported:	110,000 ^h	219,500
pH:	6.5	--
Specific gravity:	--	--
Bottom hole temperature:	>70°C	305°C

Table 4. (Continued)

Constituent	Sportsman #1 ^{a,b} (Ref. 10)	Magma Max #1 ^b (Ref. 7)	Magma Max #1 ^b (Ref. 7)
Aluminum	--	--	--
Ammonia (NH ₄)	--	--	--
Antimony	--	--	--
Arsenic	--	--	--
Barium	--	--	--
Boron	149 ^e	--	500
Bromine	--	--	--
Calcium	34,470	2,818	25,000
Cesium	--	--	--
Chlorine	201,757	20,548	--
CO ₂ as HCO ₃	--	--	--
Copper	--	--	--
Fluorine	--	--	--
Iodine	--	--	--
Iron	4,200	93	--
Lead	--	--	--
Lithium	150	28	--
Magnesium	18	46	--
Manganese	--	10	200
Nitrate (NO ₃)	--	--	--
Potassium	24,000	142	5,000
Rubidium	--	--	--
Silica	5	108	500
Silver	--	--	--
Sodium	70,000	8,562	52,500
Strontium	--	--	--
Sulfate (SO ₄)	34 ^e	--	--
Sulfide Sulfur	--	--	--
Zinc	--	--	--
Summary Data			
Total of the above constituents ^g :	334,783 ^g	32,355 ^g	83,700 ^g
Total dissolved solids reported:	334,987 ^h	38,072 ^h	--
pH:	4.82-6.10	6.65	--
Specific gravity:	1.207 ⁱ	1.022 ⁱ	--
Bottom hole temperature:	310°C	265°C	--

Table 4. (Continued)

Constituent	Woolsey #1 ^b (Ref. 7)	Woolsey #1 ^b (Ref. 7)	Woolsey #1 ^b (Ref. 7)
Aluminum	--	--	--
Ammonia (NH ₄)	--	--	--
Antimony	--	--	--
Arsenic	--	--	--
Barium	--	--	--
Boron	--	--	--
Bromine	--	--	--
Calcium	8,550	7,284	12,658
Cesium	--	--	--
Chlorine	59,015	49,342	83,183
CO ₂ as HCO ₃	--	--	--
Copper	--	--	--
Fluorine	--	--	--
Iodine	--	--	--
Iron	84	141	244
Lead	--	--	--
Lithium	65	63	90
Magnesium	651	113	136
Manganese	121	150	488
Nitrate (NO ₃)	--	--	--
Potassium	2,881	3,055	6,510
Rubidium	--	--	--
Silica	112	141	181
Silver	--	--	--
Sodium	49,257	28,195	49,729
Strontium	--	--	--
Sulfate (SO ₄)	--	--	--
Sulfide Sulfur	--	--	--
Zinc	--	--	--
Summary Data			
Total of the above constituents ^g :	120,735	88,484	153,219
Total dissolved solids reported:	131,732 ^h	98,624 ^h	151,237 ^h
pH:	6.2	6.45	6.25
Specific gravity:	1.076 ⁱ	1.064 ⁱ	1.106 ⁱ
Bottom hole temperature:	238°C	238°C	238°C

Table 4. (Continued)

Constituent	IID. #1 ^{a,c} (Ref. 11)	IID. #1 ^{a,j} (Ref. 9)	IID. #1 ^{a,b} (Ref. 12)	IID. #1 ^{a,b} (Ref. 12)
Aluminum	--	450	--	--
Ammonia (NH ₄)	409	482	--	--
Antimony	<1	<1	--	--
Arsenic	12	15	--	--
Barium	235	200	--	--
Boron	390	520	432	745 ^e
Bromine	120	146	--	--
Calcium	28,000	40,000	34,430	30,500
Cesium	16	22	--	--
Chlorine	155,000	185,000	200,000	168,000
CO ₂ as HCO ₃	>150	--	--	--
Copper	8	10	--	--
Fluorine	15	18	--	--
Iodine	18	22	--	--
Iron	2,090	3,200	3,416	2,000
Lead	84	104	--	--
Lithium	215	300	--	--
Magnesium	54	35	486	--
Manganese	1,560	2,000	30	1,300
Nitrate (NO ₃)	--	35	--	--
Potassium	17,500	24,000	29,900	18,200
Rubidium	137	168	--	--
Silica	400	>110	26	10
Silver	<1	1	--	--
Sodium	50,400	51,000	76,000	55,500
Strontium	609	740	--	--
Sulfate (SO ₄)	5	56	--	30
Sulfide Sulfur	16	--	--	--
Zinc	790	970	--	--
Summary Data				
Total of the above constituents ^g :	258,235 ^g	309,605 ^g	344,720 ^g	276,285 ^g
Total dissolved solids reported:	258,360 ^h	319,000 ^h	340,816 ^e	278,000 ^h
pH:	--	--	5.1	3.9
Specific gravity:	--	1.264 ^k	1.235 ^k	1.239 ^k
Bottom hole temperature:	316°C	316°C	316°C	316°C

Table 4. (Continued)

Constituent	IID. #2 ^{a,c} (Ref. 11)	IID. #3 ^{a,c} (Ref. 13)
Aluminum	--	2
Ammonia (NH ₄)	--	321
Antimony	--	--
Arsenic	--	<1
Barium	250	3
Boron	390	100
Bromine	--	15
Calcium	28,800	1,130
Cesium	20	--
Chlorine	155,000	19,700
CO ₂ as HCO ₃	690	1,880
Copper	3	--
Fluorine	--	1
Iodine	--	5
Iron	2,000	<1
Lead	80	--
Lithium	210	40
Magnesium	10	74
Manganese	1,370	6
Nitrate (NO ₃)	--	9
Potassium	16,500	1,250
Rubidium	70	--
Silica	400	120
Silver	<1	--
Sodium	53,000	10,600
Strontium	440	85
Sulfate (SO ₄)	--	621
Sulfide Sulfur	30	--
Zinc	500	--
Summary Data		
Total of the above constituents ^g :	259,764 ^g	35,964 ^g
Total dissolved solids reported:	258,765 ^h	35,600 ^h
pH:	--	7.5
Specific gravity:	--	1.023 ^k
Bottom hole temperature:	332°C	188°C

Table 4. (Continued)

Constituent	Sinclair #3 ^{a,b} (Ref. 14)	Sinclair #3 ^{a,b} (Ref. 14)
Aluminum	--	--
Ammonia (NH ₄)	340	570
Antimony	--	--
Arsenic	10	10
Barium	540	570
Boron	210	--
Bromine	--	--
Calcium	14,550	23,000
Cesium	--	--
Chlorine	93,650	141,500
CO ₂ as HCO ₃	60	--
Copper	--	1
Fluorine	2	5
Iodine	--	--
Iron	--	--
Lead	80	200
Lithium	49	80
Magnesium	780	1,940
Manganese	410	1,000
Nitrate (NO ₃)	--	--
Potassium	7,820	13,200
Rubidium	--	--
Silica	--	--
Silver	--	--
Sodium	36,340	50,600
Strontium	360	510
Sulfate (SO ₄)	58	--
Sulfide Sulfur	--	--
Zinc	--	--
Summary Data		
Total of the above constituents ^g :	155,259	233,186
Total dissolved solids reported:	183,700 ^h	276,100 ^h
pH:	5.3	4.3
Specific gravity:	1.114 ^k	1.180 ^k
Bottom hole temperature:	252°C	252°C

Table 4. Continued)

Constituent	Sinclair #4 ^{a,b} (Ref. 14)	Sinclair #4 ^{a,c} (Ref. 15)
Aluminum	<100	--
Ammonia (NH ₄)	--	--
Antimony	--	--
Arsenic	--	10
Barium	1,100	--
Boron	--	332
Bromine	--	25
Calcium	37,735	26,992
Cesium	--	--
Chlorine	210,700 ^e	154,590
CO ₂ as HCO ₃	--	--
Copper	3	--
Fluorine	--	14
Iodine	--	13
Iron	1,300	1,148
Lead	60	--
Lithium	400	287
Magnesium	2,225	736
Manganese	1,700	1,025
Nitrate (NO ₃)	--	5
Potassium	20,690	14,918
Rubidium	--	--
Silica	625	90
Silver	1	--
Sodium	78,000	58,443
Strontium	455	434
Sulfate (SO ₄)	75	19
Sulfide Sulfur	--	--
Zinc	600	--
Summary Data		
Total of the above constituents ^g :	355,769	259,523
Total dissolved solids :	387,500 ^h	266,560 ^h
pH:	5.0	5.3
Specific gravity:	--	1.22 ^k
Bottom hole temperature:	260°C	260°C

Table 4. (Continued)

Constituents	Sinclair #4 ^{a,b} (Ref. 16)	Sinclair #4 ^{a,b} (Ref. 16)	Sinclair #4 ^{a,b} (Ref. 16)	Sinclair #4 ^{a,b} (Ref. 16)
Aluminum	--	--	--	--
Ammonia (NH ₄)	--	--	--	--
Antimony	--	--	--	--
Arsenic	--	--	--	--
Barium	--	--	--	--
Boron	--	--	--	--
Bromine	--	--	--	--
Calcium	26,300	20,200	22,200	23,400
Cesium	--	--	--	--
Chlorine	--	--	--	--
CO ₂ as HCO ₃	--	--	--	--
Copper	--	--	--	--
Fluorine	--	--	--	--
Iodine	--	--	--	--
Iron	--	--	--	--
Lead	--	--	--	--
Lithium	--	--	--	--
Magnesium	--	--	--	--
Manganese	--	--	--	--
Nitrate (NO ₃)	--	--	--	--
Potassium	18,000	13,300	12,400	13,700
Rubidium	--	--	--	--
Silica	--	--	--	--
Silver	--	--	--	--
Sodium	53,800	52,000	46,600	52,500
Strontium	--	--	--	--
Sulfate (SO ₄)	--	--	--	--
Sulfide Sulfur	--	--	--	--
Zinc	--	--	--	--
Summary Data				
Total of the above constituents ^g :	98,100	85,500	81,200	89,600
Total dissolved solids reported:	--	--	--	--
pH:	--	--	--	--
Specific gravity:	--	--	--	--
Bottom hole temperature:	--	--	--	--

Table 4 Footnotes.

^aAverage analysis.

^bNot known if corrected for steam loss.

^cCorrected for steam loss.

^dSpaces marked with dashes indicate values not reported.

^eComputed.

^fSodium and potassium.

^gThe number is determined by summing all the constituents identified above - but it does not necessarily include all those present in the brine.

^hThe number is determined by analyzing all the dissolved solids present in the brine.

ⁱSpecific gravity at 20°C.

^jNot corrected for steam loss.

^kSpecific gravity at 25°C.

Geothermal Field Heat Characteristics

This section contains temperature profile maps of the Salton Sea Geothermal Field area (Figs. 20 through 31). The maps were compiled from temperature logs made available by owners of some fourteen of the nineteen geothermal wells in this area. Contours of equal temperature are plotted for depths ranging from 1000 to 6500 ft, in increments of 500 ft. The data points represent geothermal wells from which logs were obtained. The area outlined and the data points correspond to the SSGF boundary and geothermal well locations respectively, (Fig. 1). The maps are intended to serve as a base to which more detailed studies of the heat anomaly may be added.

Several interpretations of the temperature profile data have been made by adjusting contours to various fits of the data points, and then varying the fit both vertically and horizontally within reasonable geologic limits. The resulting maps exhibit a large thermal anomaly that appears to be circular and dome-like. Rex¹⁷ and Randall¹⁸ have also published maps

indicating the presence of a thermal anomaly in the Salton Sea area. The anomaly on their maps is generally circular, with the area of highest heat located at the south end of the Salton Sea. Our maps present a more detailed study of a smaller area within the anomaly defined by Rex, and present an interpretation that is generally consistent with the Rex and Randall maps.

A cross section of the heat anomaly (Fig. 32) shows a rather broad dome with sharply dipping limbs. Some minor irregularities, too small to appear on the cross section, are apparent on the 1000 and 1500 ft depth maps. These may be an expression of insufficient data in the central portion of the map area, or if real, a consequence of ground water circulation patterns different from those seen at greater depths. The patterns may be the result of faults thought to traverse this area,¹⁸ of ancient or present Alamo River drainage basin effects, or of a geothermally produced metamorphic zone that divides shallow water from deep water.

Fig. 20. Temperature at 305 m (1000 ft).

Fig. 21. Temperature at 457 m (1500 ft).

Fig. 22. Temperature at 610 m (2000 ft).

Fig. 23. Temperature at 762 m (2500 ft).

Fig. 24. Temperature at 914 m (3000 ft).

Fig. 25. Temperature at 1067 m (3500 ft).

Fig. 26. Temperature at 1219 m (4000 ft).

Fig. 27. Temperature at 1372 m (4500 ft).

Fig. 28. Temperature at 1524 m (5000 ft).

Fig. 29. Temperature at 1676 m (5500 ft).

Fig. 30. Temperature at 1829 m (6000 ft).

Fig. 31. Temperature at 1981 m (6500 ft).

Fig. 32. Block diagram of isothermal surfaces - Salton Sea Geothermal Field.

Conclusions

The information summarized in this report - geothermal well data and reservoir heat - has been compiled in support of LLL's projects in the Salton Sea Geothermal Field. The data indicate that a significant

portion of the Salton Sea anomaly is located immediately adjacent to the SSGF. Extending our data coverage to that adjacent area will provide a better understanding of the resource size and location.

Acknowledgments

Our data were obtained from various private and public sources who generously gave permission for access to their records. These sources include: Magma Power

Company, Union Oil Company, Imperial Thermal Products, Inc., Geothermal Energy and Mineral Corporation, and Joseph I. O'Neill Jr. Company.

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☆GPO 690-574-1976