Dup

UPDATE OF RESERVOIR ENGINEERING ACTIVITIES AT CERRO PRIETO

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INTRODUCTION

During 1979 a number of important developments occurred at the Cerro Prieto Geothermal Field, Mexico. In April, the total generating capacity at the field reached 150MWe as the third and fourth 37.5 MW units went on line. Last August, after careful analyses and planning, high temperature brine reinjection was initiated in one of the wells. Also a pilot brine treatment plant for future reinjection tests at low temperature began operation. The new wells in the eastern and southeastern parts of the field confirmed the existence of very hot (>320°C) reservoirs below 2000 m depth.

NEW WELLS (Figure 1 and Table 1)

In addition to two work-over rigs, four EMSCO drilling rigs (one GB-500, one J-750 and two GB-800) were active in the field. Between December 1978 and November 1979, fifteen wells were drilled at Cerro Prieto; two of which were for exploration (NL-1 and O-473). At the present time (December 1979) four wells are being drilled, two for production (M-147 and T-328) and two for exploration (E-1 and M-189). Next in the drilling program are M-109, M-117, M-125, and T-364.

WELL COMPLETION AND DEVELOPMENT

The evolution of the procedures for completing and developing the wells at Cerro Prieto has been described in detail recently by Domínguez[1]. Casing completions presently being used are illustrated in Table 2.

The intermediate casings have A.P.I. Buttress threads, the production casings have S.E.U. Hydrill threads to obtain a better seal under high-temperature conditions and to avoid erosion problems caused by cavitation or abrasion usually encountered in Buttress collars.

The lower part of the 9 5/8 in. production casing is run through a 12 1/4 in. hole, and is cemented in a shale interval. Care is taken so that the cement does not penetrate the geothermal reservoir. The depth to which casing is cemented is decided based on: 1) lithology and mineralogy (correlating with neighboring wells), 2) geophysical well logs, 3) drilling mud temperature (the change of temperature during circulation should be between 10 and 15°C) and 4) major circulation losses. Once the production casing is cemented, the drilling continues (8 1/2 in. hole). After adequate permeable and hot aquifers have been intersected, a 7 in. N-80, 29 lb/ft. liner with Hydrill Super EU thread is installed in the open hole. The upper part of the liner, on the average 300 m, is cemented in. The total length of the installed liners averages about 550 m.

DRILLING PROBLEMS

As reported last year, the main drilling problems encountered are the loss of circulation during drilling and cementing operations.[2] To reduce these losses low density muds and cements are used.

Presently, ligno-sulphanate muds with 4 to 8% diesel oil and low specific gravity, varying between 1.11 and 1.20 (about 9.5 lb/gal) are utilized. In high temperature wells (>320°C) an inorganic polymer is added to the mud so that its viscosity remains adequate for long enough periods (about 40 hours) to allow well logging or lowering the casings into the hole. Otherwise the mud tends to flocculate after about 10 to 15 hours.

The conductor casings are cemented using sulfate-resistant API class B cements. For the intermediate and production casings, API class G cements with 40% silica flour and activated pozzolan or perlite are used. This type of cement will give the casing more freedom to expand and provide enough insulation to avoid thermal shocks because of temperature differences between the inside and outside of the casings. In addition, the slurry has low density (about 14 lb/gal) which might reduce possible losses of circulation.

In early 1980, tests will be carried out at the field with a new ceramic based cement; its slurry is of rather low density (11-12 lb/gal). Before cementing the production casings, the hole is filled with a mud column whose weight is similar to the maximum which the formation will have to withstand during the cementing operation. Experience has indicated that the column height should not exceed 2000 m. If no significant losses are observed, the specific gravity of the mud is reduced and the cementing operation is completed in two or three stages.

PROBLEMS WITH EXISTING WELLS

There are evidences of cement degradation and casing corrosion in some of the existing wells. The disintegration of the cement has permitted fluid movement behind the casings, accelerating their external corrosion and the scaling of the slotted liners[3]. In some wells (e.g. M-3, M-7, M-45) parts of the production casing are missing or its thickness has been significantly reduced. This occurrence can result in troublesome complications.

In well M-3, completed in 1964, the deteriorated casing and cement permitted hot water (>200°C) to invade the sediments and create a hot-water zone at about 125 m depth, above a cement plug at 622 m. Recently, when trying to repair the casing the driller almost lost control of the well because of this anomalously hot zone. The well was finally controlled by drilling through the plug and squeezing cement into the hot aquifer, between 630 and 895 m. Presently CFE is closely monitoring the water level in M-3 in case the hot water may still be flowing upwards around the cement plug and behind the casings. If this happens, further cement will be squeezed into the aquifer. In the long run plugging only the casing will not solve the problem.

Even where the repairs are feasible, they are very expensive and reduce appreciably the original production capacity of the wells.[3]

FLUID PRODUCTION (Table 3)

With the generating capacity at Cerro Prieto doubled, the total fluid extraction has correspondingly increased. For example, in September 1979, 26 wells were producing a total of 1370.7 metric tons of steam per hour to generate an average of 134.2 MWe. That is, 10.2 tonnes/hr of steam are needed per megawatt. Presently, these 26 wells send the steam through seven main steam lines which are interconnected at the power plant.

TWO-PHASE FLUID TRANSMISSION LINE

Since July 1978, the steam-brine mixture produced by M-53 has been sent through a pipeline to well M-39 where the steam is separated from the brine. The 1738.5 m long, 16 in. diameter, schedule 40, carbon steel, seamless pipeline is covered by a 2 in. thick fiberglass insulation layer. Its performance is monitored by 29 Bourdon manometers and 8 thermocouples. Originally, the pipeline carried 49.2 tonnes/hr of steam and 56.2 tonnes/hr of brine, for a wellhead pressure at M-53 of 170 psig, and a separation pressure at M-39 of 97 psig. In November 1979, these values dropped to 32.3 tonnes/hr, 56.1 tonnes/hr, 142 psig and 93 psig, respectively.

After 18 months of almost continuous operation, no major problems have been detected. Significant and continuous scaling has occurred at M-39 in the valves and pipes carrying the separated water. In September 1978, because of a water hammer, three of the seven omega expansion loops jumped from their support. The pipeline was not ruptured and was back in operation after a few days.

REINJECTION

Beginning in August 1979, untreated separated brines from well M-29 were reinjected into well M-9. Using the M-29 separation pressure (130 psig) about 40 tonnes/hr of approximately 165°C fluid are injected via well M-9 into an aquifer located between 721 and 864 m depth. The injection rate had decreased by December 1979 to about 25 tonnes/hr.

The test is being carefully monitored. Temperature, pressure and spinner surveys have been conducted in well M-9. The pressure and temperature of neighboring producing wells are also being observed to detect any changes which might result from injecting brines into the shallower aquifer. (The depth to the geothermal reservoir around M-29 is more than 1100 m.)

In the future, because of a 30 MW low pressure turbine which will be on line in 1981, large amounts of 100°C brines supersaturated with silica will be available for reinjection. To avoid major problems in the pipes and reservoir, the excess silica will have to be eliminated before reinjection. Pilot plant-scale tests at rates varying between 3 and 15 tonnes/hr have begun to determine the isothermal (∿100°C) rate of polymerization of silica for different pH values. Also, sedimentation tests with and without flocculants are being conducted.[4]

WELL TESTS

In 1979 CFE conducted two long-term interference tests. The first one between M-102 and M-103 indicated that the reservoir permeability was about 90 md. The other test, between wells M-93 and T-366, has just been completed and no results are yet available.

A two-rate flow test was carried out in well M-93 using Kuster tools with high temperature clocks developed by Sandia. The tests demonstrated that the modified clocks could operate at temperatures of up to 340°C for 12 hour periods. The maximum downhole time seemed to be determined by the failure of the Viton O-rings, and not of the clocks.

The LBL pressure-temperature-flow tool was tested with the improved surface equipment during an injection test of well M-9. The pressure and temperature transducers, and surface equipment, functioned well up to the hottest temperature encountered in the well (∿220°C). However, the LBL-modified Kuster flow-tool indicated no-flow below the perforated interval and did not recover when it was pulled up the well. It was observed during the tests that the turbine bearings were failing during each survey of the hot well section. Bearings were brought from the Kuster plant near Los Angeles to allow new bearing installation for each well profile. This helped, but did not solve the problem.

The exploratory well NL-1 (Fig. 1) has cooled considerably since it was completed (Table 1). CFE ran a number of geophysical well logs, and LBL completed temperature and flowmeter surveys of the well to try to find any possible casing failure. The resolution of the tools was not sufficient to detect cracks in the casings or flow within the well.

FUTURE DRILLING ACTIVITIES

Over the last two years CFE carried out an extensive exploration program in the Mexicali Valley, especially at Cerro Prieto, Tule Check and Mesa de Andrade. (See Figure 2.) Self potential, seismic reflection, resistivity, thermal gradient, mercury-sniffing, gravimetry and magnetometry surveys have been completed at the last two sites. Only deep confirmation drilling is needed to assess the potential of the new areas.

In 1980 the Comisión Federal de Electricidad plans to drill between 21 and 30 new deep wells in the Mexicali Valley. The actual number will depend on the arrival date of two additional drilling rigs, bringing to six the number available for new wells. Eight of the new wells planned will be exploratory, four at Cerro Prieto, two at Tule Check and two at Mesa de Andrade.

REFERENCES

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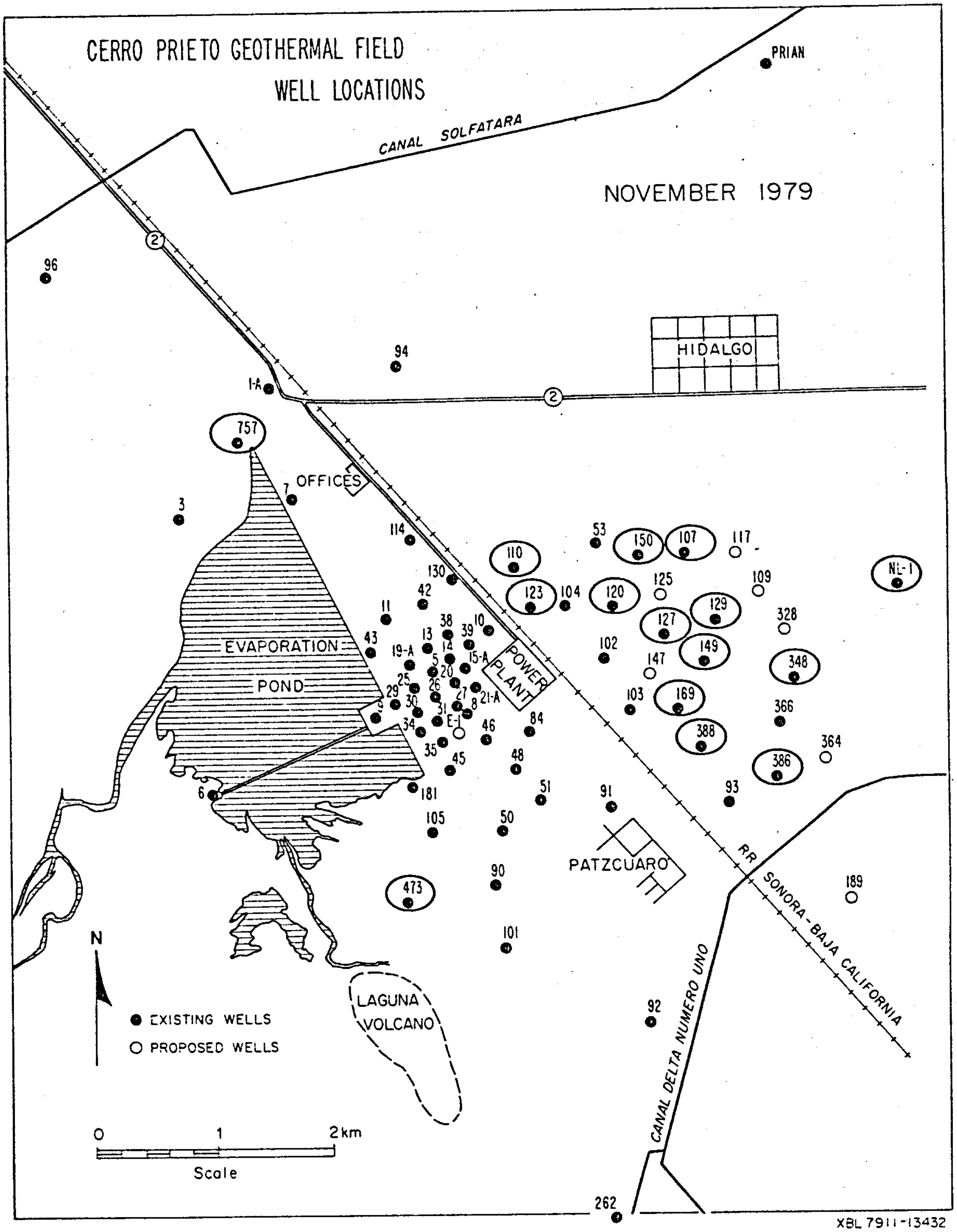

FIGURE 1. Location of wells drilled between December 1978 and November 1979 (Well numbers are circled.)

MEXICALI VALLEY
LOCATION OF GEOTHERMAL AREAS

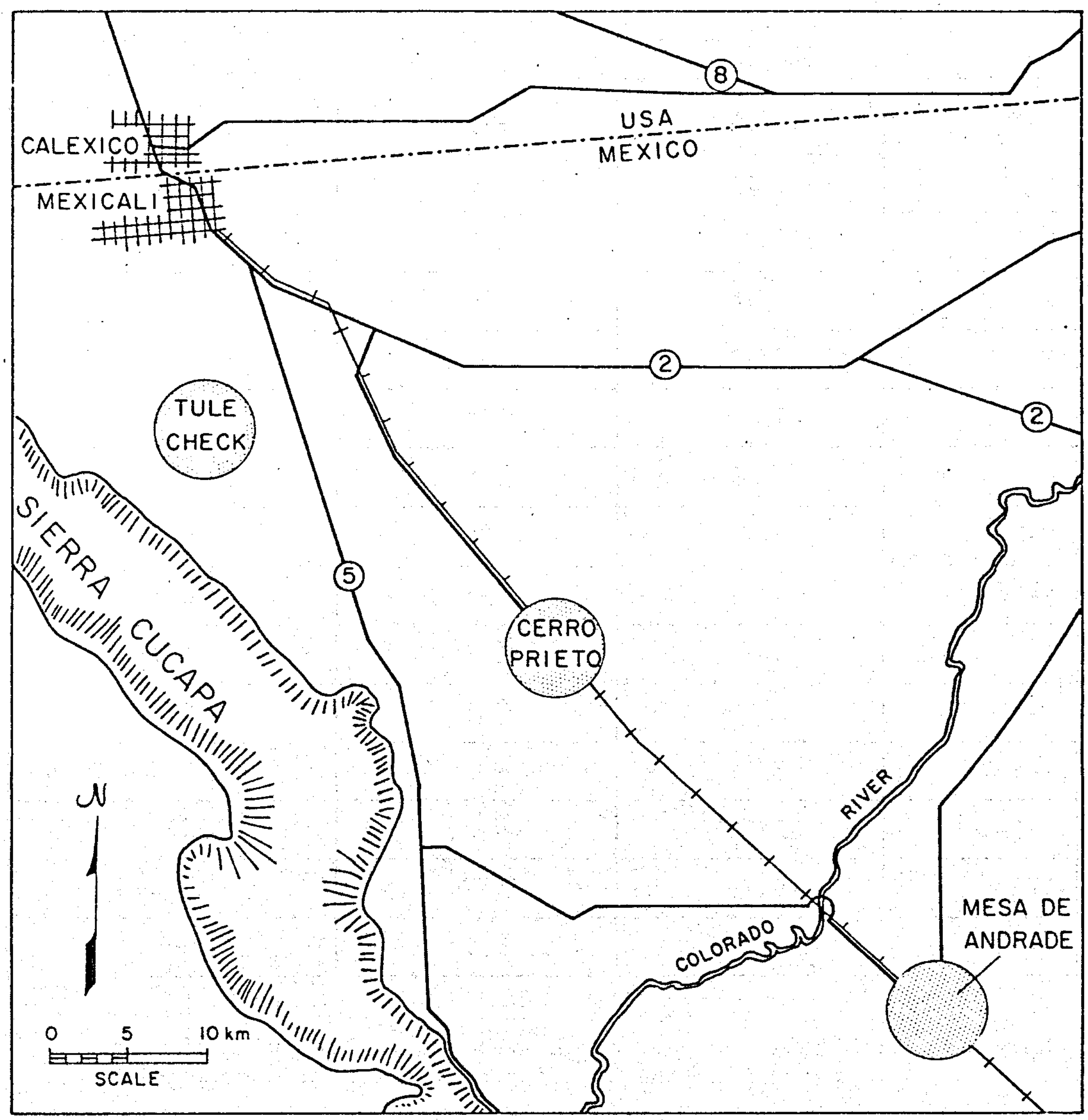

FIGURE 2. Location of Geothermal Areas in the Mexicali Valley.

TABLE 1

CERRO PRIETO FIELD

WELLS DRILLED AFTER NOVEMBER 1978

Well	Date Drilling Completed	Depth (m)	Maximum Measured Temperature (°C)
M-107	1/79	2225	(1)
M-110	5/79	1996	310
M-120	8/79	2101	>327 (2)
M-123	12/78	1905	(1)
M-127	5/79	2504	(1)
M-129	7/79	2198	344
M-149	3/79	2395	338
M-150	12/78	2104	353
M-169	7/79	2393	331
NL-1	9/79	3347	(3)
O-473	4/79	2267	278
Q-757	3/79	935	218
T-348	11/79	2895	(1)
T-386	9/79	2657	>302 (2)
T-388	10/79	2570	(1)

Notes: (1): The lower part of the well was filled with mud, preventing the lowering of the temperature probe.

(2): Temperature still increasing, wellbore not yet in thermal equilibrium.

(3): Temperature dropping due to unknown causes (e.g. 9/7/79 ~252°C, 10/1/79 ~151°C, at 2900m depth).

TABLE 2

Cerro Prieto - Present casing completions

Casing	Production wells			Exploration wells		
	Diam. (in)	API Grade	Depth (m)	Diam. (in)	API Grade	Depth (m)
Conductor	20	H-40	0-60	20	H-40	0-60
Surface	--	---	---	13 3/8	K-55	0-300
Intermediate	13 3/8	K-55	0-1000	9 5/8	N-80	0-2000
Production or Lower	9 5/8	N-80	0-1800	7	N-80	2000 - 3000
Liner	7	N-80	1800 - 2300	4 1/2	N-80	3000 - 3500

TABLE 3

CERRO PRIETO FIELD (SEPTEMBER 1979)

WELL PRODUCTION CHARACTERISTICS

Well	Aperture (1) diam. (in.)	Pressure (in psig)		Production (metric tons/hr)		Enthalpy(2) (cal/g)
		Wellhead	Separator	Steam	Brine	
M-5	7 7/8	105	90	33.3	89.3	301
M-8	6	100	92	36.2	92.4	307
M-11	6	98	97	16.1	32.0	334
M-14	3 7/8	260	91	32.0	115.2	275
M-19A	7 7/8	102	93	54.1	127.0	316
M-21A	2 3/4	550	90	29.3	71.5	311
M-25	4	228	97	36.9	85.0	318
M-26	3 1/2	397	95	43.0	142.0	284
M-27	7 7/8	93	92	27.0	62.3	317
M-29	7 7/8	127	125	18.0	86.5	263
M-30	7 7/8	110	96	48.6	132.7	302
M-31	7 7/8	98	97	39.3	129.2	285
M-35	7 1/2	129	97	64.2	129.4	333
M-42	8	199	97	49.7	157.2	288
M-45	7 7/8	98	94	22.5	12.0	490
M-48	8	128	109	72.1	79.3	407
M-50	8	126	109	82.6	184.3	326
M-51	8	120	112	96.6	135.4	378
M-53	8	142	93	32.3	56.1	348
M-84	8	110	100	69.2	58.5	437
M-90	8	110	109	51.8	128.9	315
M-91	8	127	117	83.7	178.4	333
M-103	4	780	140	138.4	185.2	390
M-105	8	131	118	72.9	125.2	356
M-114	8	102	98.5	51.5	171.2	284
M-130	8	100	98.5	69.4	155.5	322
			TOTALS:	1370.7 tonne/hr	2921.7 tonne/hr	

Note:

(1) Minimum aperture between wellhead and separator.

(2) The enthalpy of the steam/brine mixture is obtained from standard steam tables based on the separator pressure and the fractions of steam and brine produced.