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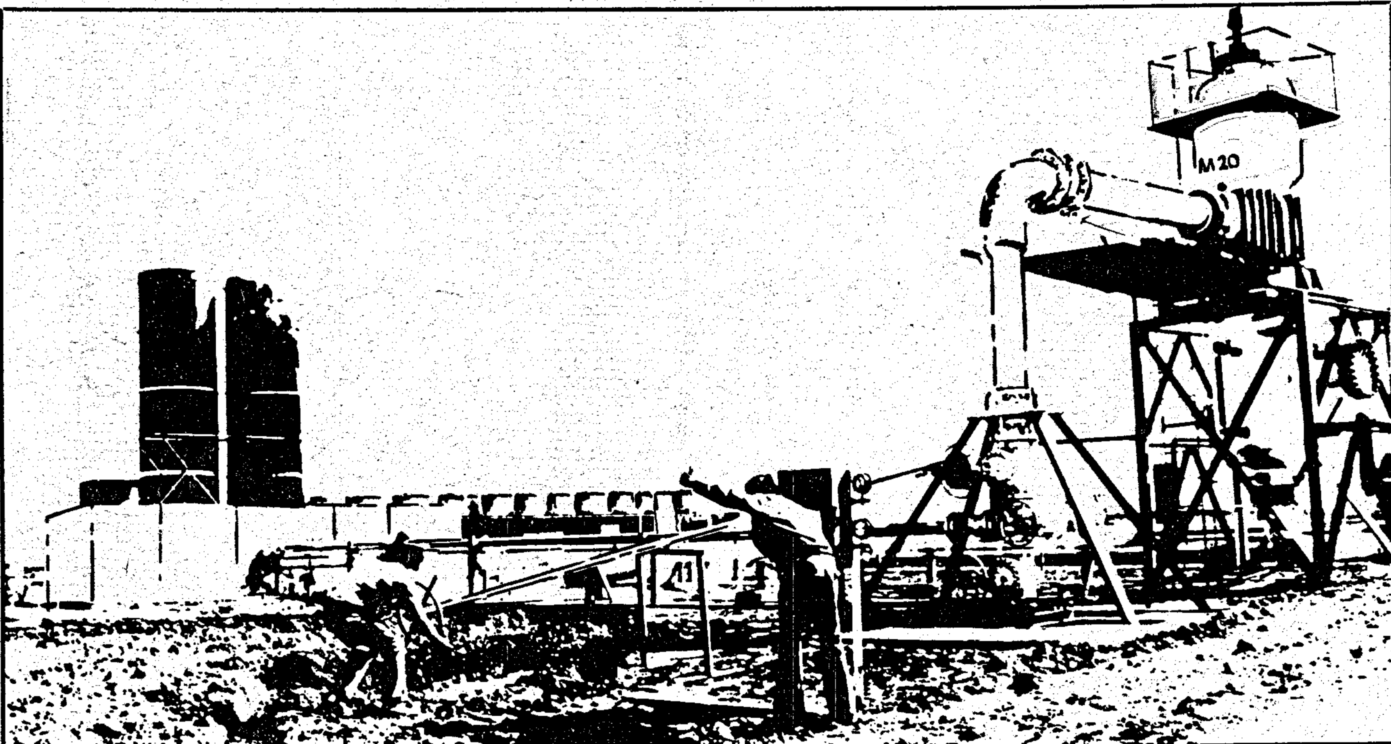

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RECENT ACTIVITIES AT THE CERRO PRIETO FIELD

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INTRODUCTION

The purpose of this paper is to describe some of the latest activities of interest to reservoir engineers at the Cerro Prieto geothermal field. Special emphasis is given to the wells drilled in 1978 for exploration purposes and to provide steam to the existing and future power plants. The present power output is 75MW. Two additional 37.5MW units are scheduled to go on line in March and May 1979, while the total generating capacity at Cerro Prieto will reach about 400MW in 1985. Additional information is available in a number of papers in References 1 and 2.

NEW WELLS (Figure 1)

At the present time (December 1978), there are six drilling rigs active, four for new wells and two to repair old ones. Because of generally different reservoir conditions and depths, the Cerro Prieto field can be divided into three blocks: Block I, presently the main producing area, centered around M-5; Block II, south of a line which approximately passes through wells M-35 and M-46; and Block III, NE of the railroad track which roughly coincides with the trace of the Cerro Prieto fault.

In 1978 twelve wells have been completed and three are presently being drilled.

Production Wells: M-43, M-102, M-103, M-104, M-114, M-130, M-181, T-366
Exploration Wells: M-93, M-94, M-96, S-262
Wells Being Drilled: M-107, M-123, M-150

Depth: The average depth of these wells is 2000m; the deepest are T-366 (2980m) and M-96 (2728m). The new production wells have reached the hot water reservoir(s) between: 1500 and 1700m (Block I, Wells M-43, M-114, M-130), 1453 and 1610m (Block II, Well M-181), and 1800 and 2000m (Block III, Wells M-102, M-103, M-104).

Lithologic and Temperature Characteristics: In Block I the downhole temperatures measured were: 294°C (M-130), 271°C (M-114), 265°C (M-43), which are only moderate for this block. While in Block II, 287°C was measured at the bottom of M-181.

In Block III, the downhole temperatures in M-102 and M-104 are about 345°C, similar to M-53. To the NW, in M-94, it only reached 208°C. The lithologic column and structural conditions found in M-53, drilled in 1974, are generally repeated in wells M-102, M-103 and M-104. Nevertheless, towards the SE the permeable hot zone deepens quite appreciably. It was found between 2400 and 2560m in M-93, and between 2427 and 2922m in T-366. In these two wells the characteristic of the productive intervals is quite different. In M-93 high permeability zones were indicated by large lost circulations. On the other hand, in T-366 these losses were minimal, and visual inspection of the recovered cores indicate low permeabilities. (A relatively long perforated interval was installed in this well.) The temperatures measured in the drilling muds at rest in the well were 221°C (M-93) and 230°C (T-366). These values suggest that after cleaning the wells and a heating up period, the temperatures will reach at least 340°C. This seems to indicate that Block III may have production potential, independent of an apparent decrease in permeability and increase of depth towards the SE. This area, which already has seven completed wells, will supply steam to the Cerro Prieto II plant (additional 110MW by 1983 and 220MW by 1985)

Exploration well M-96, NW of the main production area, reached basement at about 2713m. The maximum temperature (108°C) was reached at 1977m; 97°C was measured at 300m indicating a shallow hot aquifer. South of the field another exploratory well, S-262, penetrated basement at 1470m. There, the highest temperature was measured at the bottom of the hole (100°C).

Casings (Figures 2 and 3): In most of the wells built in 1978 a 7-5/8" Ø, K-55, 45.3 lb/ft. casing with Hydrill Super EU thread was used. When required, as in M-102 and M-94, a 5" Ø, K-55, 23 lb/ft. liner with Super EU thread was installed. Recently it was decided to change the diameter of the production casing to 9-5/8" Ø to increase steam production and because it is easier to obtain commercially. In M-103 and T-366 a 9-5/8" Ø, N-80, 47 lb/ft. production casing with Buttress thread and 7" Ø, N-80, 29 lb/ft. hanging and cemented liner with Hydrill Super EU thread were installed. With the new grade of casing larger mechanical capacity has been sought to better withstand the tension and compression stresses which have created many problems at Cerro Prieto. Nevertheless, one will have to wait to find out the corrosive effect of the geothermal fluids on this type of casing.

DRILLING PROBLEMS

Three main problems during the drilling of these wells have been encountered: a) lost circulation during drilling and cementing operations, b) fishing problems, and c) cave-ins and stuck tools.

Lost Circulation: During drilling and cementing, this is the most important problem. In some cases, circulation losses could be controlled. In other cases, like in M-93, almost 100m were drilled with complete loss of circulation in order to clearly penetrate into the producing layer and get good production. This may result in stuck pipes and in cementing problems. With this procedure, the probability of losing cement slurry into the formation is increased. This is a severe problem because the production casing could fail when the well is heated up. In some cases, like in M-93, M-123 and M-150, in addition to losses near the production zones, lost circulation has occurred in the upper 1000m, while cementing the 11-3/4" Ø or 13-3/8" Ø surface casing. This situation is very serious because the safety of the anchor and seals which prevent upward flows depend heavily on a good cement job. This problem was only encountered in Block III, and is related to the high permeability of its sandy layers.

Fishing Problems: These problems are closely related to circulation losses since they create conditions which may end with tools getting stuck in the borehole. Then, if the tools fail mechanically a fishing problem results. Some fishing operations were successful, but in M-94 and M-103 they failed.

In M-94 it was decided to hang a 5" ∅ production casing in the upper part of the producing zone which remained open. Pipes which could not be fished out were left in the hole from 2328 to 2601m. This lower part of the well showed high temperatures but low permeability. Another interval of high temperature, presently covered by the casing, was detected at 1600m, it showed a maximum of 214°C.

In M-103 because of the good thermal characteristics of the well, it was decided to slant-drill above the fish. The drilling was successful but there exists uncertainty about the behavior of the 9-5/8" ∅ production casing when the well heats up. The thermal expansion in the area of deviation, may produce collapse or fracture of the casing. This is being watched as the well begins to heat up.

Cave-Ins and Stuck Tools: Another problem is the caving of shales near the high temperature zones. This occurs when the drilling operation takes too long, because of lost circulation or other causes. This is well known in the oil industry when the drilling lasts more than 60 days. In Cerro Prieto it is complicated by the presence of fractures or possibly faults which increase the probability of cavings. This results in stuck or caught tools.

When this situation develops, special mud conditions are used in the hole. But if this does not stop the caving, temporary plugs of cement bridging the zones affected are used to stablize the formations. This will allow the installation and cementing of casing which will definitely solve the problem.

In Blocks I and II these types of problems have not occurred or have been easily solved following the procedure described, but in Block III they have been more severe.

DEVELOPMENT OF NEW WELLS

A number of wells drilled before 1978 were developed this year. The chemical characteristics of the separated brine produced are given in Table 1.

From the 1978 wells M-102, M-114 and M-130 have been developed. Figure 4 shows the evolution of the characteristics of M-102 during the later part of its development. With time and orifice-diameter changes there is a marked variation in the wellhead pressures. However, chemical indices and the "Na-K-Ca" geothermometer remain essentially constant. At Cerro Prieto when orifices (or purges) are changed, these parameters are used to detect any possible variation in the downhole source of the produced steam-brine mixture.

Total production of M-102 was 120 tonnes/hr. of steam and 180 tonnes/hr. of brine at 13.8 bars (200 psig). This is a good well, and even better characteristics are expected to be found in the rest of the wells in Block III, especially in T-366 and M-93 which are only beginning to heat up.

TABLE 1

CHARACTERISTICS OF CERRO PRIETO WELLS DEVELOPED DURING 1978

WELL	DATE	PERFORATED INTERVAL (depth m)	FLOW CONDITIONS	WELLHEAD PRESSURE bars (g)	Na mg/l	K mg/l	Ca mg/l	Cl mg/l	TEMP. (°C)	ENTHALPY kJ/kg
M-50	11/24/78	1144-1249	6" ø cone	14.0	7009	1859	337	12958	306	1379
M-51	2/8/78	1245-1567	6" ø orif.	23.1	10600	3342	551	20534	335	1561
M-53	6/20/78	1845-1996	5-1/2"ø orif.	12.1	10396	3454	429	19692	345	1632
M-84	8/4/78	1536-1691	5" ø cone	22.1	10341	3118	486	19694	325	1494
M-90	2/20/78	1221-1379	5" ø orif.	15.1	6221	1773	242	12242	320	1460
M-91	2/2/78	2133-2294	6" ø orif.	17.9	9281	2476	405	16757	318	1448
M-101	5/19/78	1193-1394	6" ø orif.	6.4	2703	423	3	4310	241	1042
M-102	10/20/78	1793-1990	6" ø orif.	19.3	11266	3342	481	21019	329	1519
M-105	10/18/78	1480-1673	6" ø cone	15.7	9793	2851	529	18794	320	1462

WELL TESTING

Measurements of temperatures, pressures, flow-rates, and enthalpies have been made for several years at Cerro Prieto. During 1978 several well tests have been performed, and data from long-term measurements in M-6 and M-10 have been collected. Preliminary analyses of data have been made for the measurements listed in Table 2. The water-level data from M-6 is quite satisfactory, but are not considered to be reliable due to the different depths of penetration, and large differences in temperature at M-6 and within the producing field. When reservoir simulation is used this data will be very valuable. The well test involving M-101 has been analyzed, but the values for kh/μ and ϕch cannot be considered to be satisfactory, since recent reservoir models suggest that two or more separate aquifers are penetrated at different depths by the five wells involved in the test. The measurements made when M-53 was brought on-line would have made a contribution to our knowledge of that portion of the field, but anomalous increases in water level (downhole pressure) completely obscured the M-53 production effect for several weeks. The anomalous behavior has been ascribed to a medium-scale earthquake (5.3 Richter) whose epicenter was about 20km south of the production field. The water levels rose before the earthquake (in spite of the drawdown), and began to decrease slowly soon after the major shock.

Several productivity tests have been made using two or more rate changes as a means of determining near-well parameters. The data for three such tests carried out during the long interference test with M-101 has been studied, but the multiple aquifer effects have made the parameter values difficult to determine.

Presently, there are additional analyses, simulation of well tests, and new measurements in the planning stage for 1979. Efforts will be made to determine the hydrological characteristics of the stratigraphic discontinuity between Blocks II and III.

TABLE 2

SUMMARY OF WELL TEST RESULTS

OBSERVATION WELL	PRODUCING WELLS	kh/μ md-ft/cp	ϕch ft/psi
M-6	Entire Wellfield	4.7×10^{6}	
M-101	M-50,51,90, 91	1.5×10^{6}	2.3×10^{-2}
M-104 M-10	M-53 Entire Wellfield	Earthquake	
Two-rate Tests	M-51 M-90 M-91	Inhomogenieties	

FINAL REMARKS

The drilling activity at Cerro Prieto will continue at least at the present pace: six rigs will be operating in the field, about 20 new wells are scheduled to be completed in 1979.

As new wells become available two-rate flow tests and long-term interference tests have been planned to establish the characteristics of different blocks of the Cerro Prieto reservoir(s).

REFERENCES

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2. "Proceedings First Symposium on the Cerro Prieto Geothermal Field, Baja California, Mexico," San Diego, Calif., September 20-22, 1978, Lawrence Berkeley Laboratory, Rept. LBL-7098 (in preparation).

ACKNOWLEDGMENTS

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GLOSSARY OF TERMS USED IN FIGURES 2 AND 3

C.C.R.B. (Cople corto, rosca Buttress): Short connector, Buttress thread
C.C.R.R. (Cople corto, rosca redonda): Short connector, round thread
Cementada: Cemented
Colg. (Colgador): Hanger
Cond. (Conductor): Conductor casing
Cople Especial: Special connector
Cople Flotador: Floating collar
Cople Retén: Baffle connector
Cuñas Sencillas: Simple wedges
Lastrabarrenas: Drill collars
Pérdida de Ciculación: Lost Circulation
Perf. (Perforación): Wellbore
Pescado: Fish
Plano: Flat
Pozo: Well
Ranurada: Slotted
R.B. (Rosca Buttress): Buttress thread
R.H.S.E.U. (Rosca Hydrill Super EU): Super EU Hydrill thread
S.L.: Slotted liner
Tapón Cemento: Cement plug
Tapón de Fondo: Downhole plug
T.R. (Tubería): Casing
Tubo: Pipe

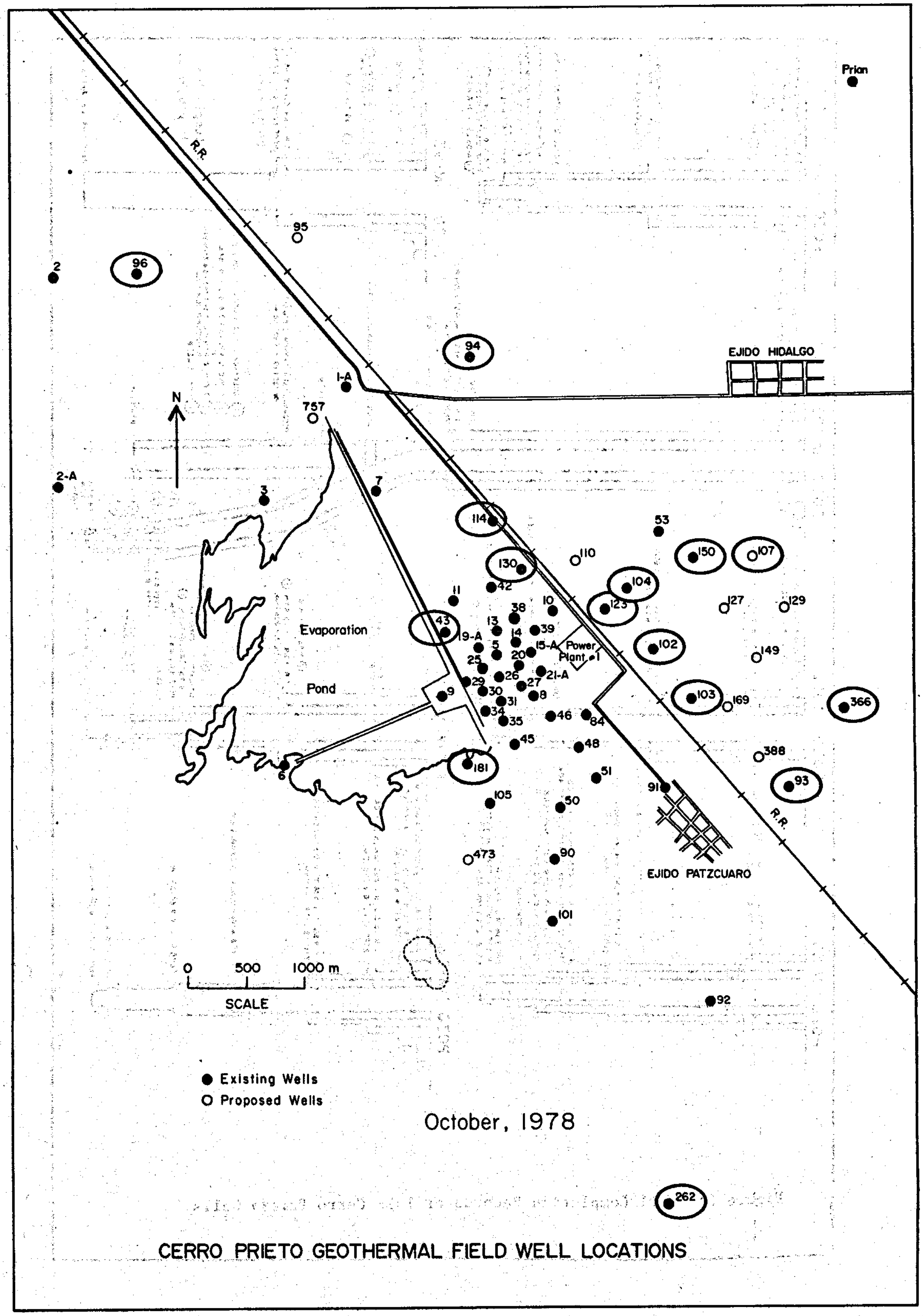

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Figure 1: Location of 1978 Wells (Well numbers are circled).

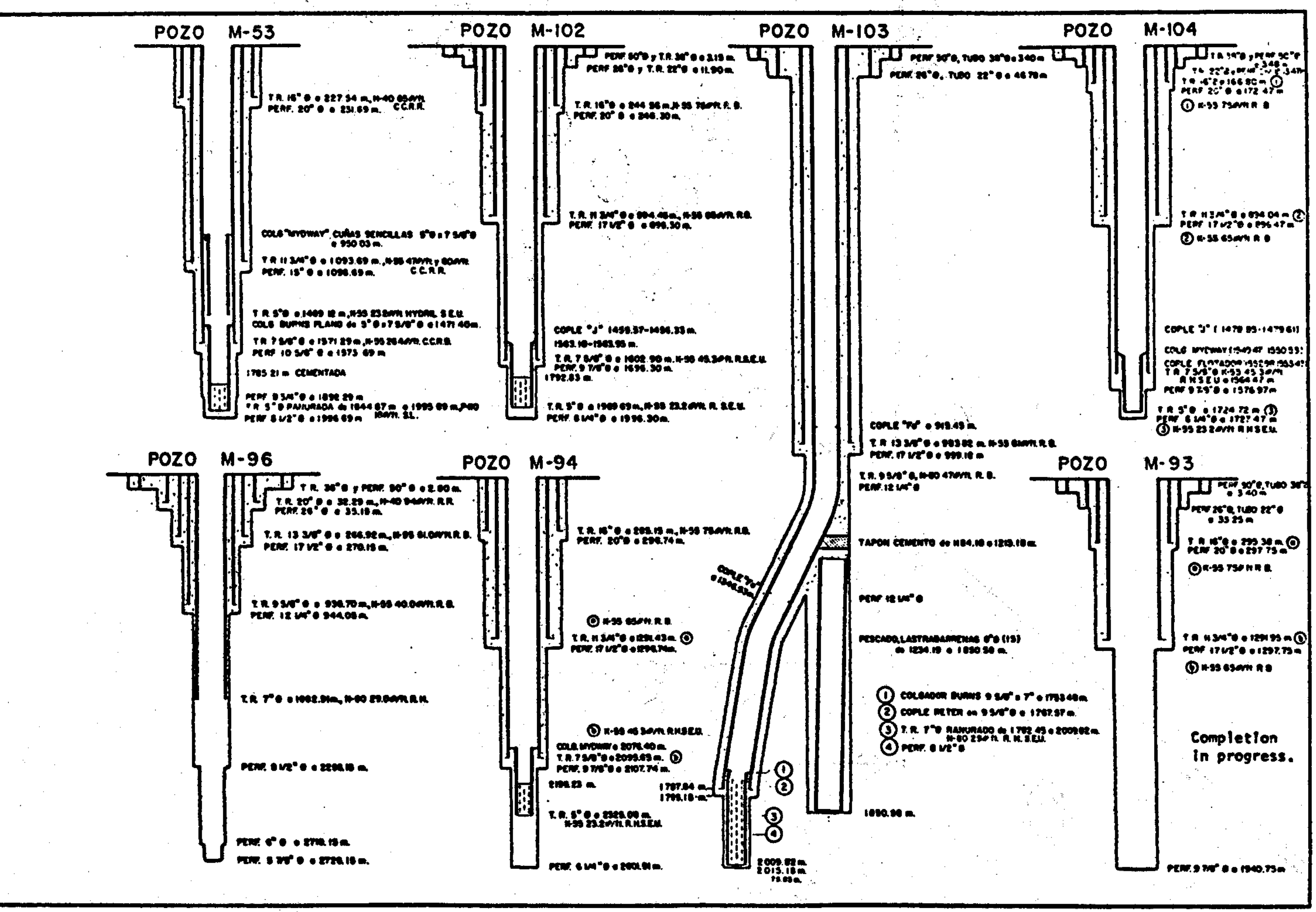

Figure 2: Well Completion Records of 1978 Cerro Prieto Wells

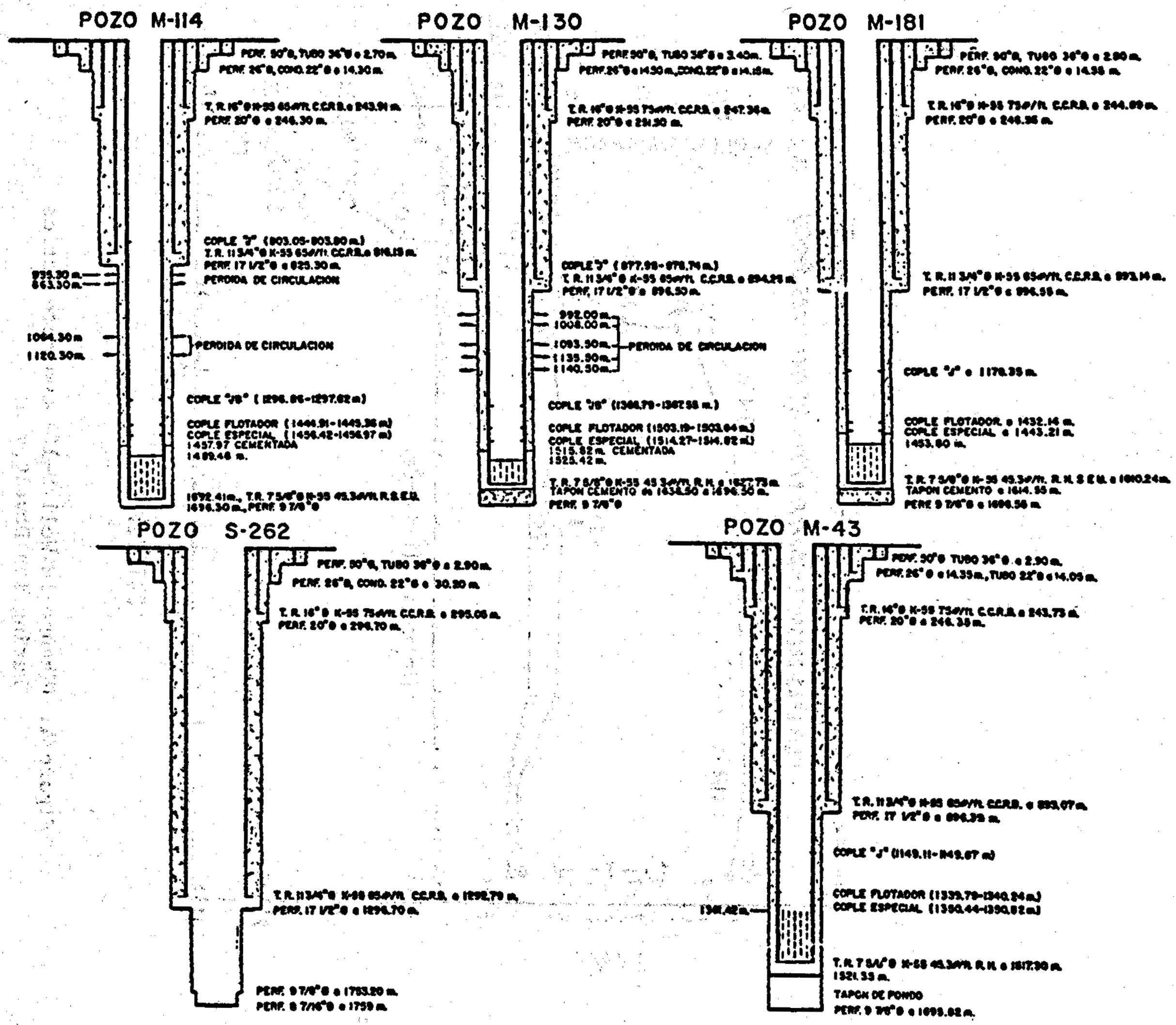

Figure 3: Well Completion Records of 1978 Cerro Prieto Wells

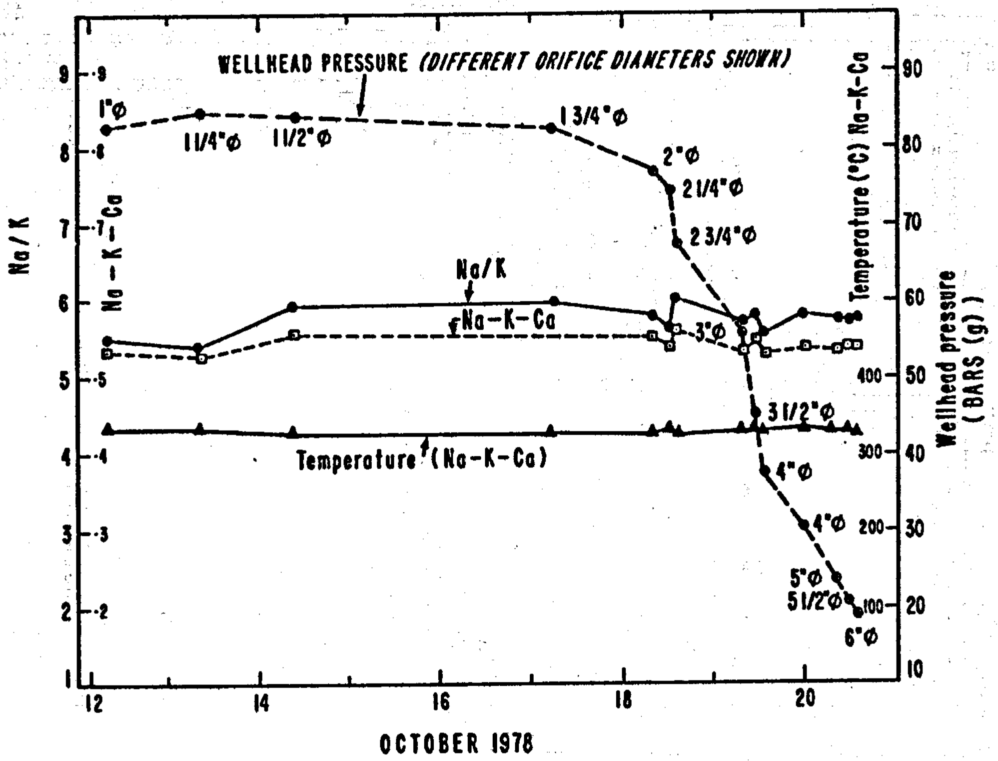

Figure 4: Change in Well M-102 Characteristics During its Development