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PRODUCTION TEST FACILITIES OF THE HOT BRINE
OF CESANO GEOTHERMAL FIELD

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1. - INTRODUCTION

Since 1968 ENEL has developed a prospecting program for geothermal fluid research in the Vulsini and Sabatini mountains regions. The data acquired from these investigations enabled ENEL to site the first exploratory well and discover the Cesano Geothermal Field (1).

This field is located approximately 15 Km north of Rome, (Fig. 1).

So far nine deep wells (1400 - 3000 m) have been drilled in this area. Bottom-hole temperatures range from a minimum of 145°C (C 5 well) at 1800 m of depth to a maximum of 300°C (C 4 well at 3080 m of depth).

Production characteristics of these wells are quite different : five are sterile or scarcely productive, four produce very high saline brines but with different physio-chemical characteristics. The pressures of productive wells at the same elevation above sea-level are also quite different. These facts prevent us from formulating hypotheses on the geothermal reservoir for the moment. This paper describes the results obtained with a small measuring plant in the first exploratory well C1, which began production in 1975.

C 1 well is located approximately 15 Km north of Rome, near the southern edge of the Baccano Valley (Fig. 2). Its characteristics (technical profile, depth, hydrogeology, thermal profile) are summarized in Fig. 3.

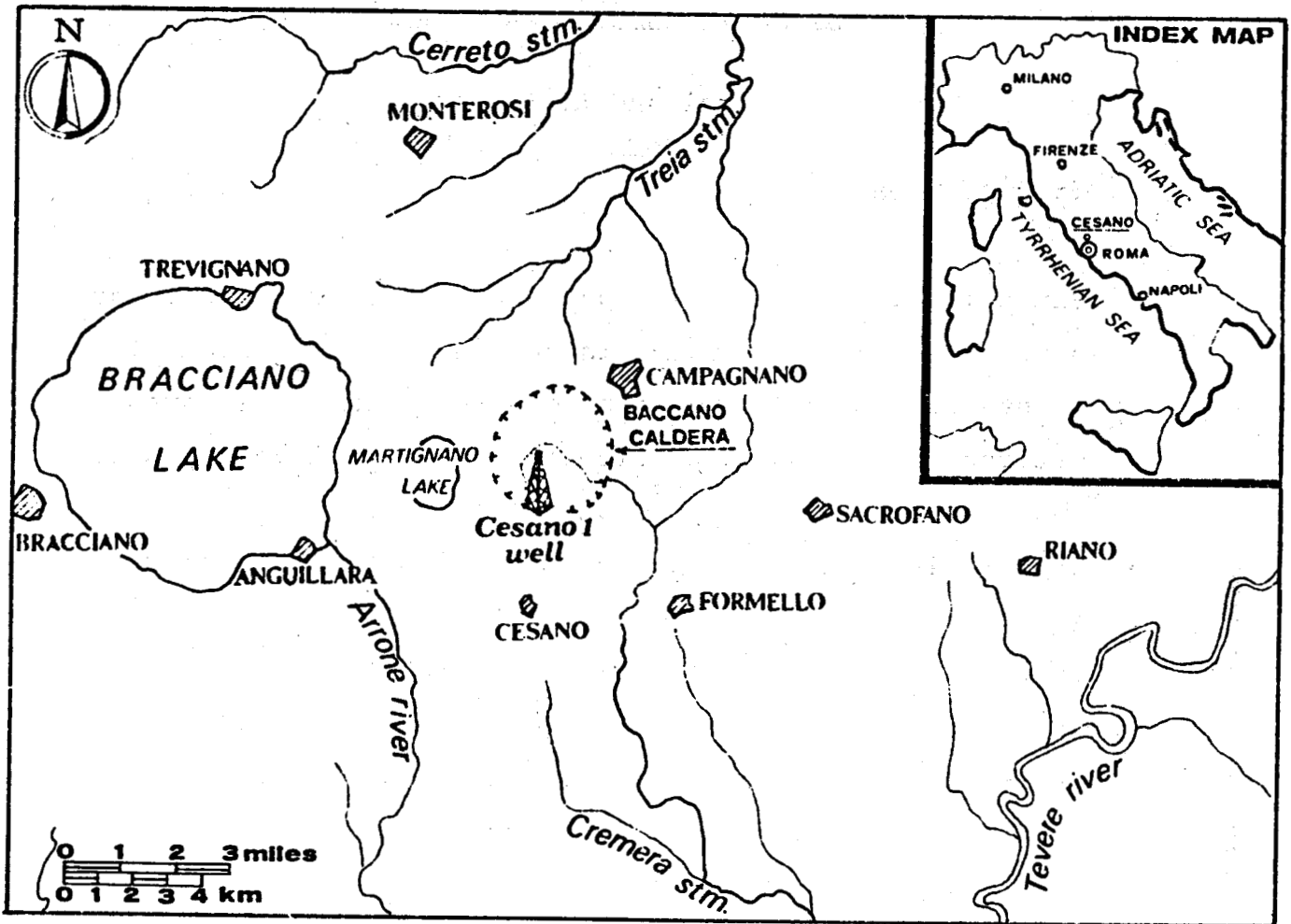
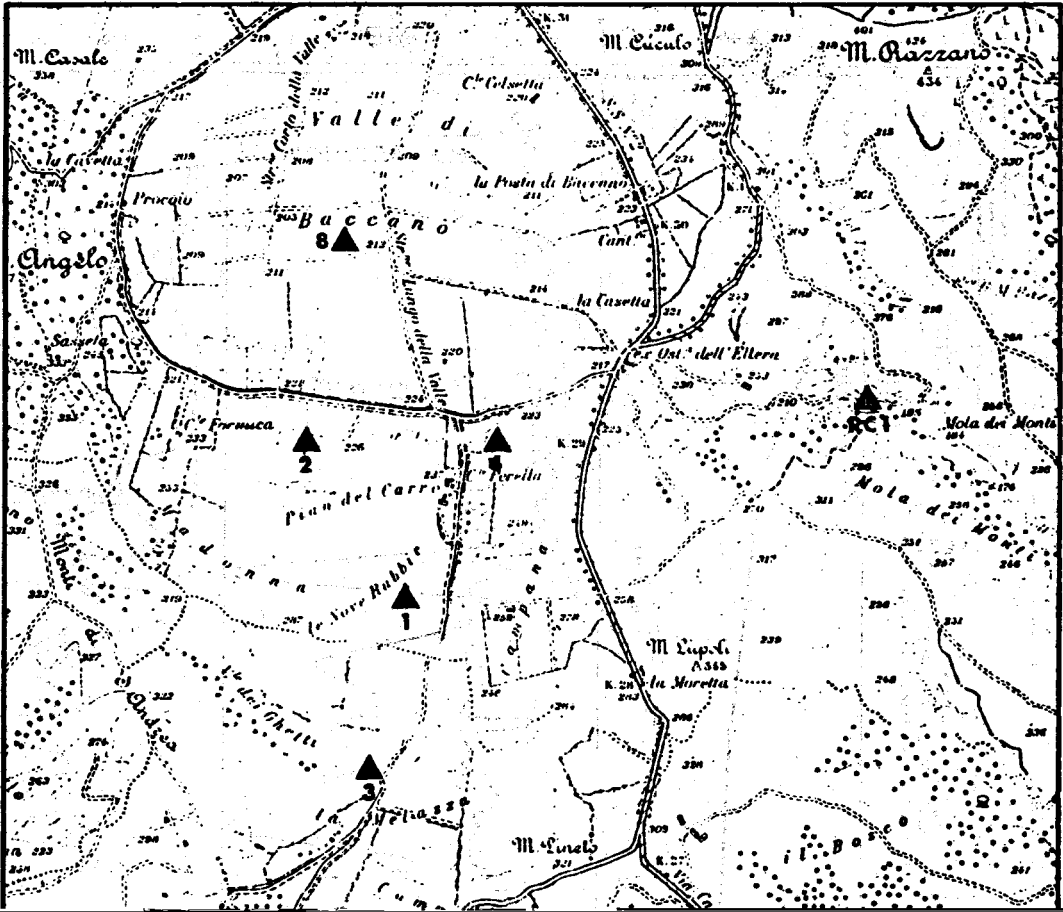


Fig. 1. Location of the Cesano area.



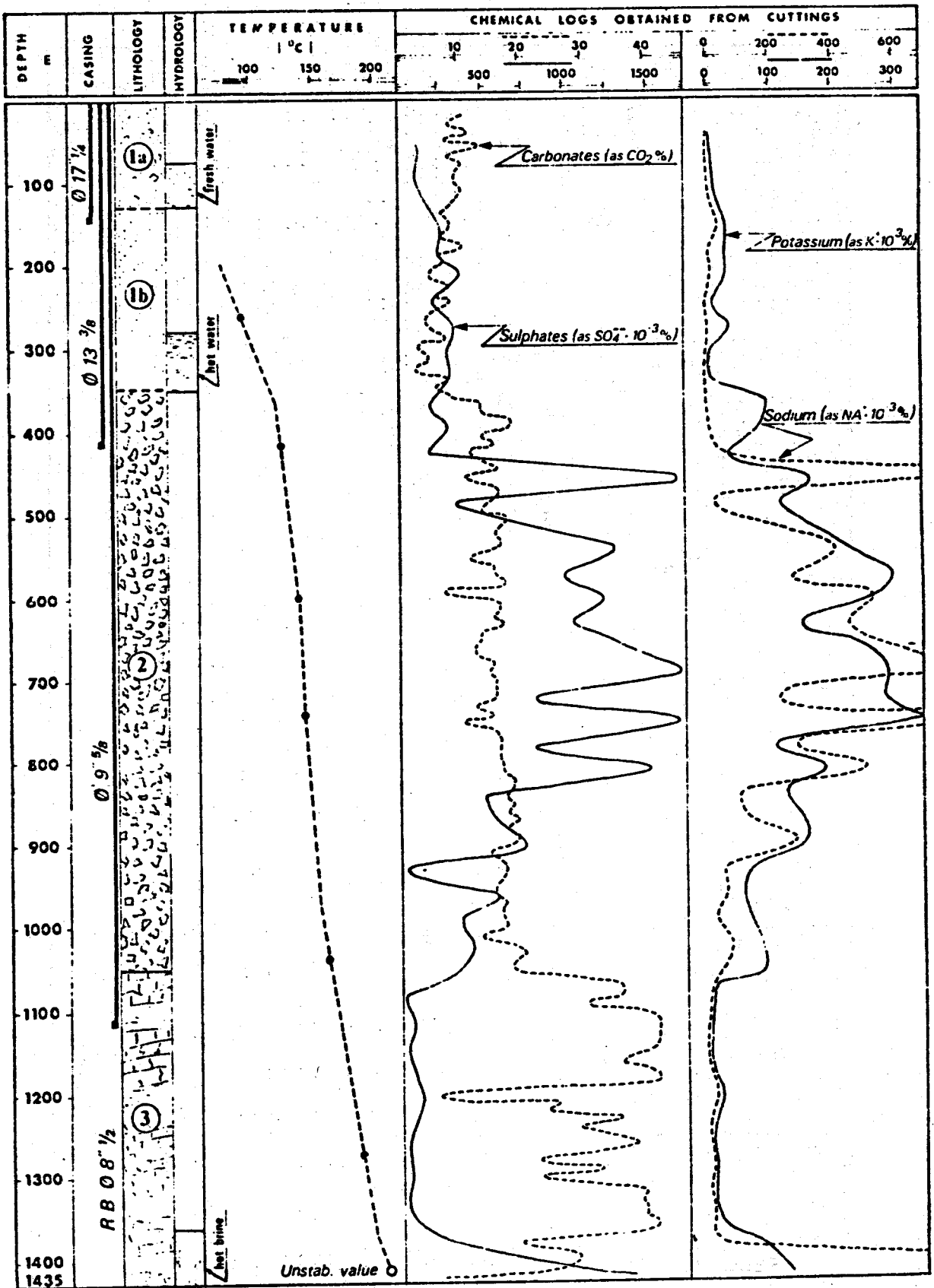


Fig. 3. Summary of geohydrological, thermal, and geochemical data.

2. - CESANO 1 TEST FACILITY

This well went into production for the first time in 1975 (1) when the drill-rig was still on the well.

As the water produced was a hot brine with an elevated salt concentration, the well-head equipment was rapidly affected by incrustation so that, after about 10 hours production, the well was shut-in. From this first production period, however, some data were gathered on the chemical composition of the brine (1).

Since no re-injection well was available for waste disposal, a steel-lined basin was built to collect the brine produced from the well, and a small separation plant assembled to measure flow conditions and the physio-chemical characteristics of the brine.

A sketch of this plant is shown in Figs. 4 , 5 and 6. The hydrostatic level being at a depth of ~ 105 m from the well-head gas lift stimulation is required to put the well into production.

A 230 m tubing was lowered into the well to perform this gas lift.

Flashing in the well causes the dissolved salts to precipitate and give rise to scaling phenomena in the well-head equipment (Fig. 7 and 8). A water pipeline was then inserted to flush water into the hot brine pipeline. The salt concentration thus dropped and it was possible to prevent sulphate incrustation on the pipes.

Three different types of materials and coatings were used down stream of the cyclon in an attempt at avoiding scaling.

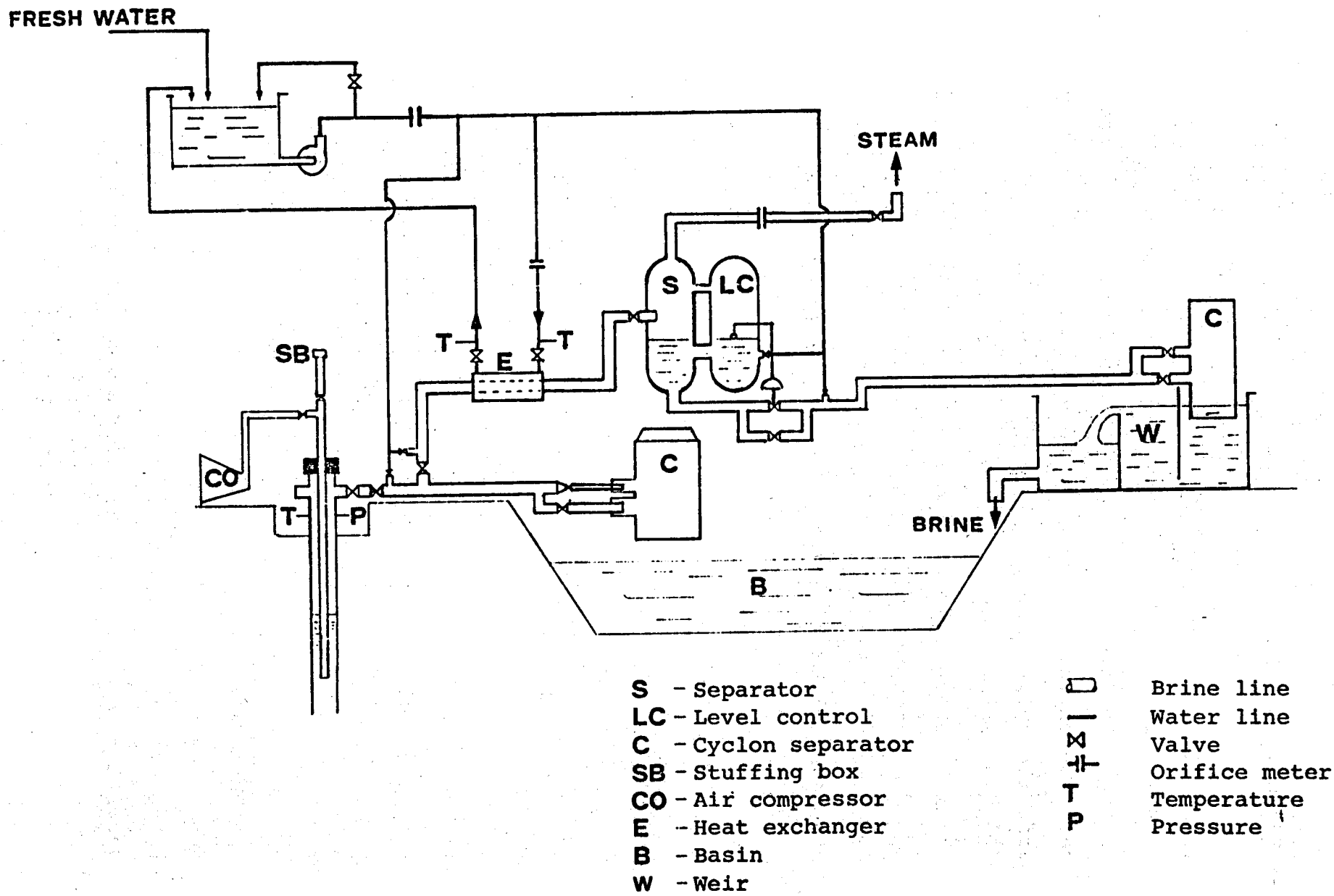


Fig. 4. Schematic diagram of separator assembly.

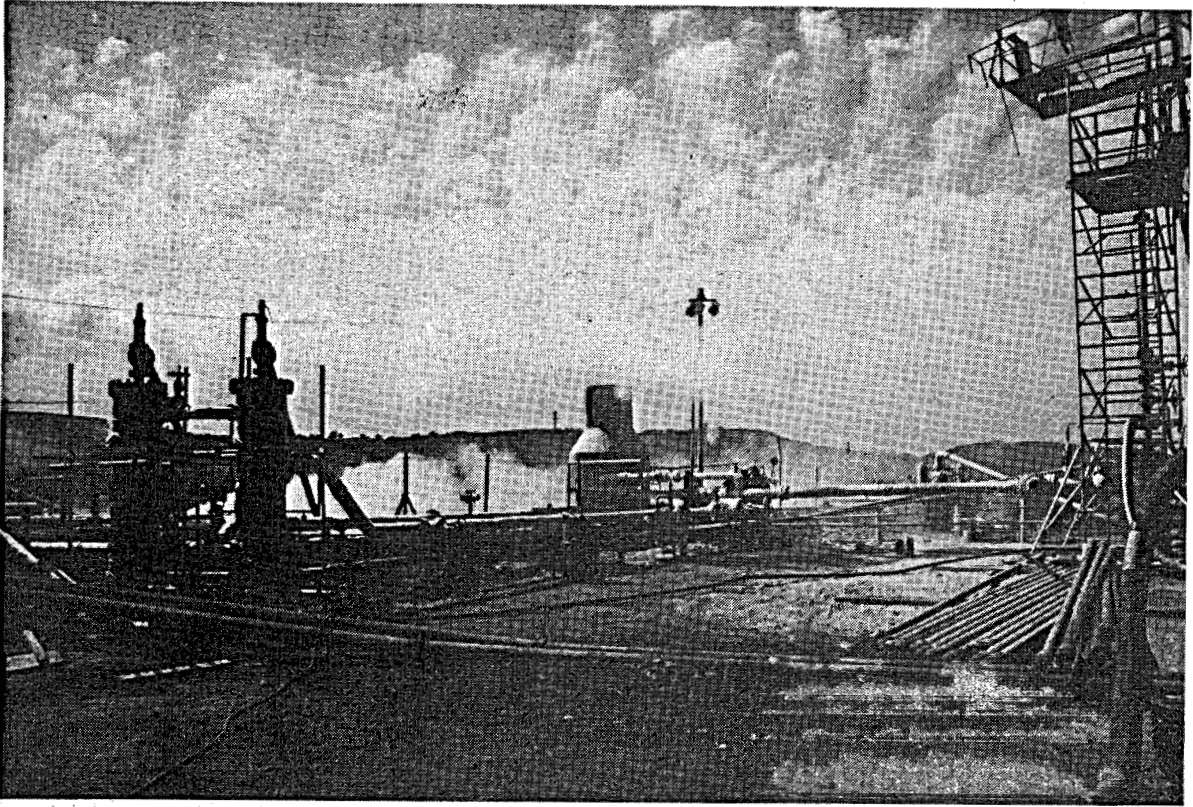


Fig. 5. View of separator.



Fig. 6. View of the basin for collecting the brine.

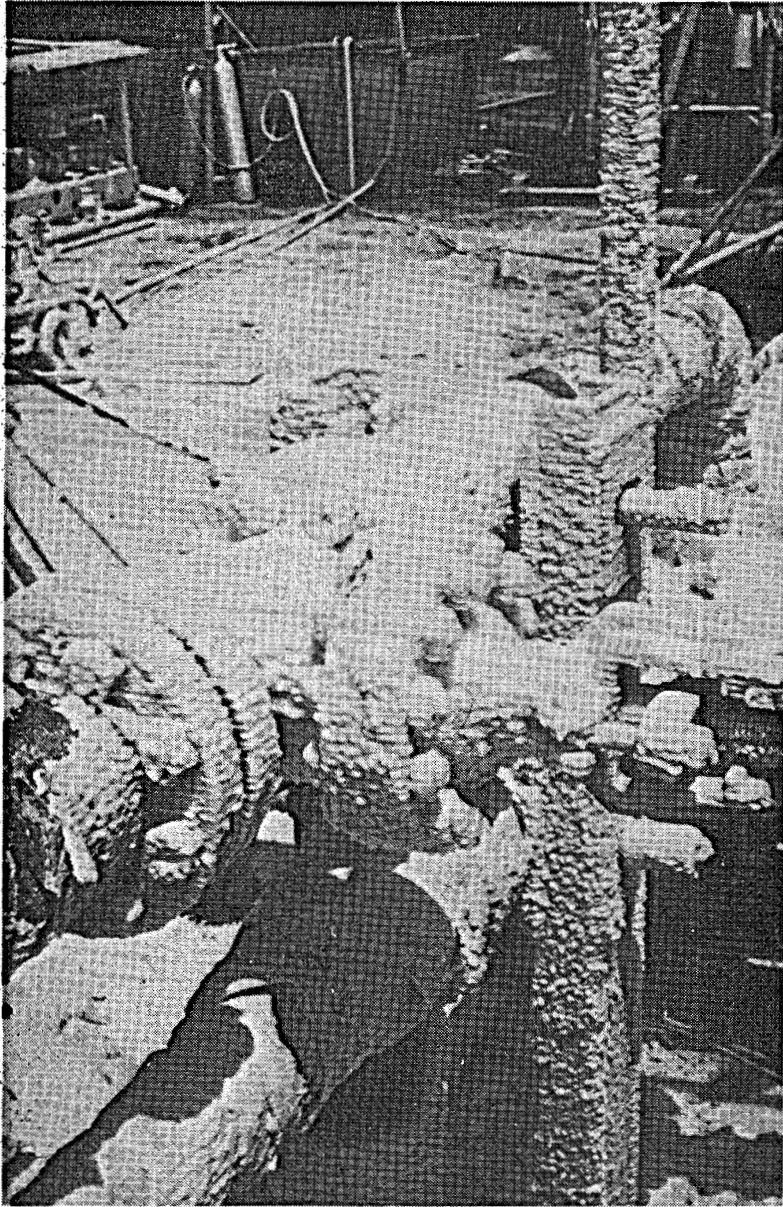


Fig. 7. View of scaling on outside of pipeline.

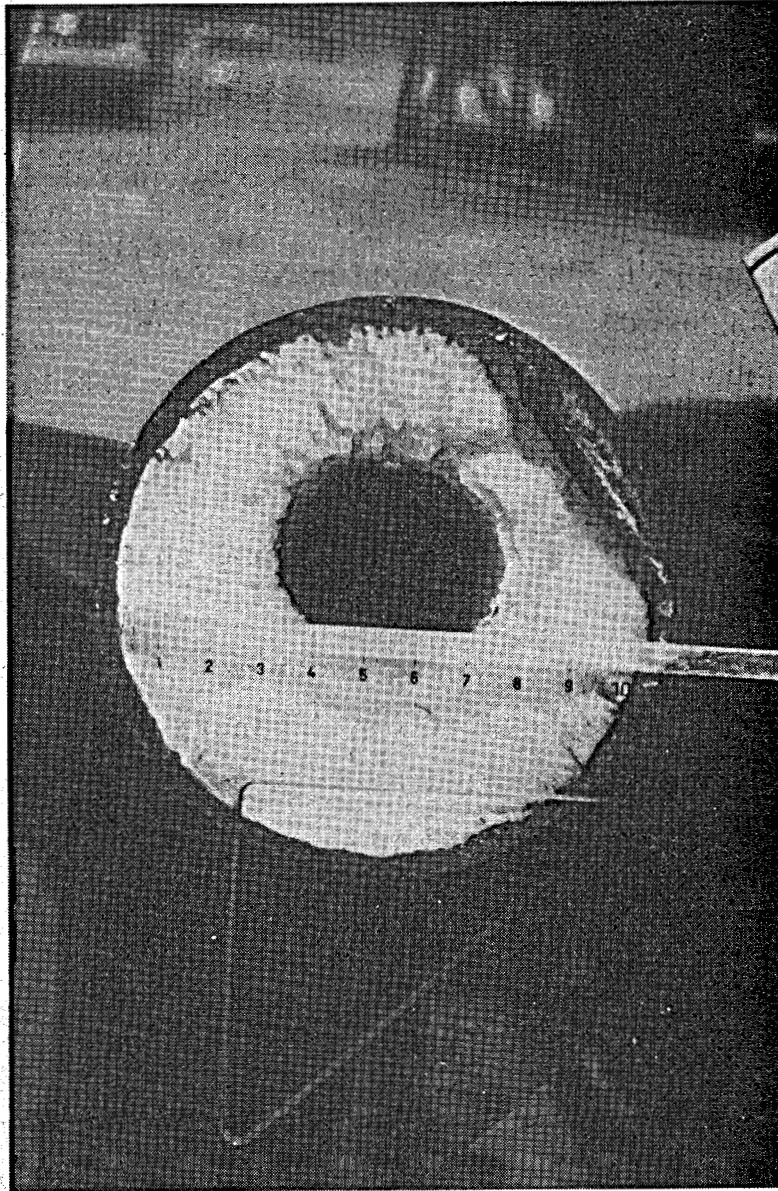


Fig. 8. View of scaling on inside of pipeline.

Figures 9 , 10 and 11 show the incrustations on these materials.

The first is stainless steel AISI 316, the second steel coated with zinc, the third steel coated with teflon. The thickness of scaling was respectively 6 mm, 6 mm and 4.2 mm after about 75 hours of production. The smaller thickness on steel coated with teflon is likely due to the fact that crystal formation takes longer on teflon. The materials examined did not show signs of corrosion after scaling was removed. We presume that scaling prevented a corrosion attack.

A small double-pipe heat exchanger was also installed to measure the brine-water heat transfer coefficient. A stuffing-box was mounted at well-head to lower measuring instruments during production. As shown in Fig. 4, the mixture was passed into a separator and the discrete phases measured with an orifice meter.

Although no difficulty was involved in measuring the steam phase, the water phase presented some problems on leaving the separator, as it contained a small percentage of steam carried over from the separator along with the water phase. Even a very small quantity of the order of 1/2% would cause a relatively large error in the estimated flow (2). Hence water was introduced in the level control tank both to reduce incrustation in the automatic valve and to condense part of the steam entrained in the liquid phase. A weir was mounted down stream of the separator to verify whether the orifice measurements were correct. Taps were left in different parts of the plant and at well head for sampling purposes.

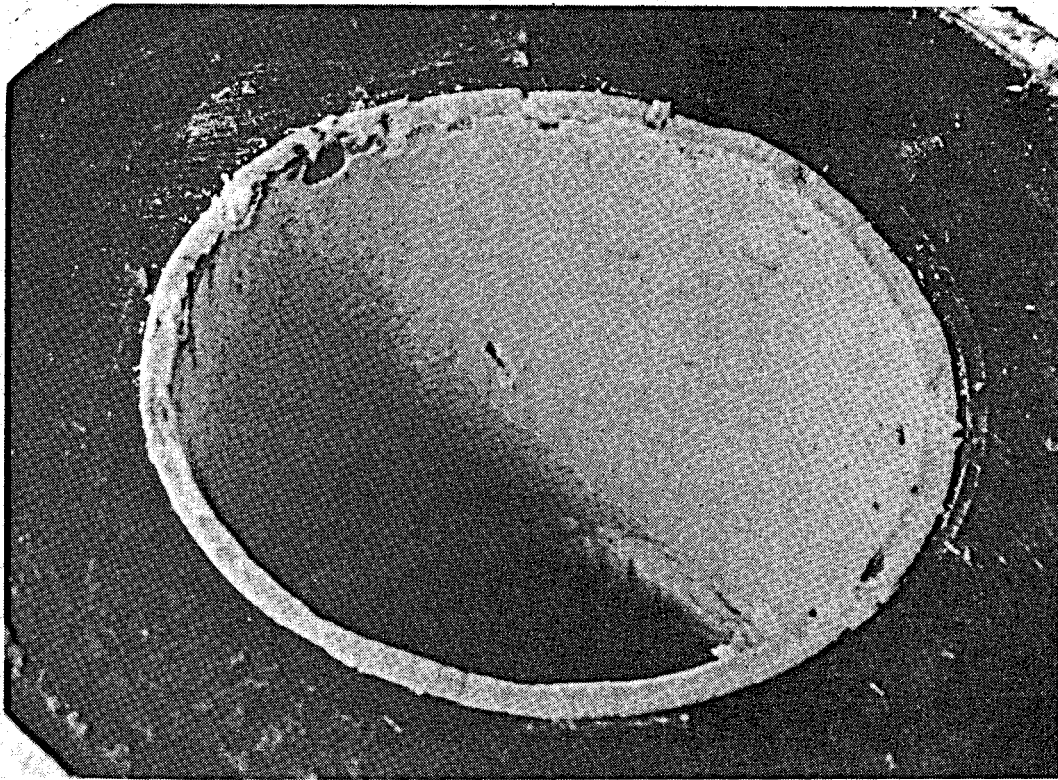


Fig. 9. Incrustation on stainless steel AISI 316.

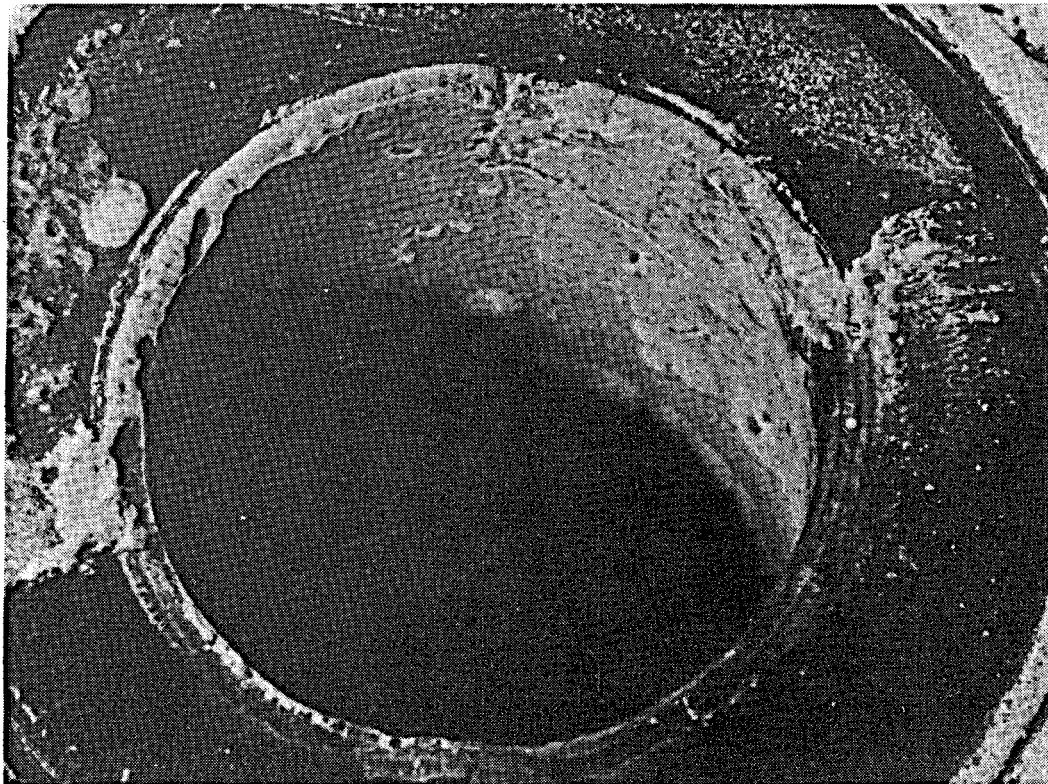


Fig. 10. Incrustation on steel coated with zinc.

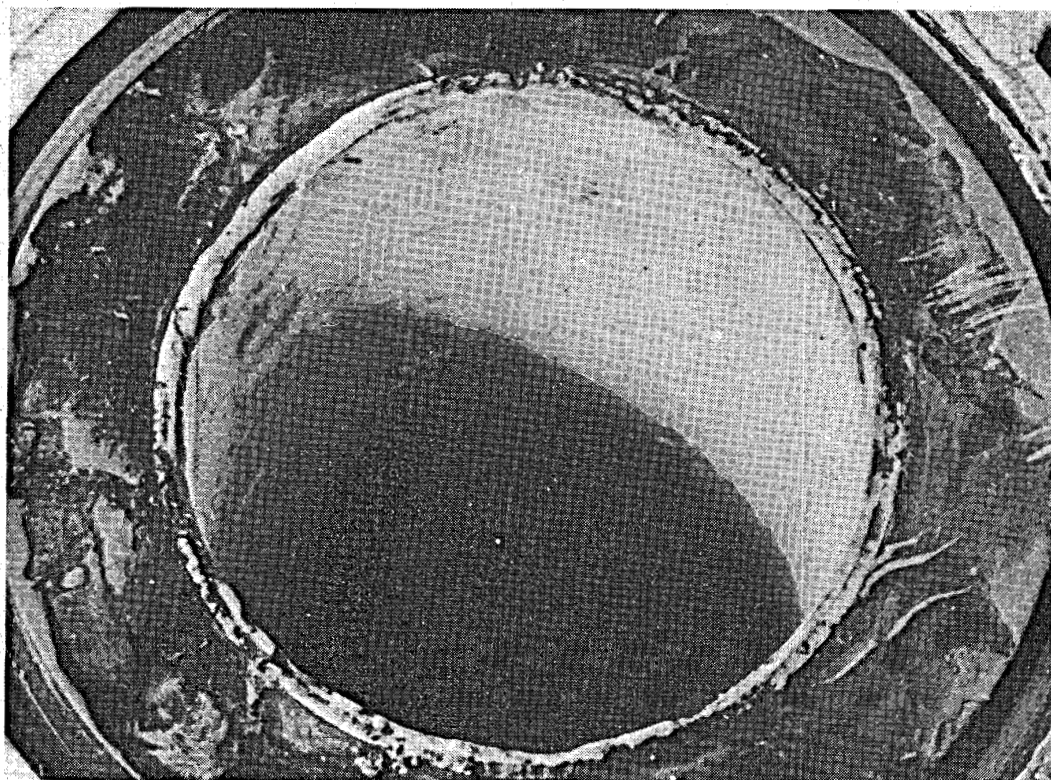


Fig. 11. Incrustation on steel coated with Teflon.

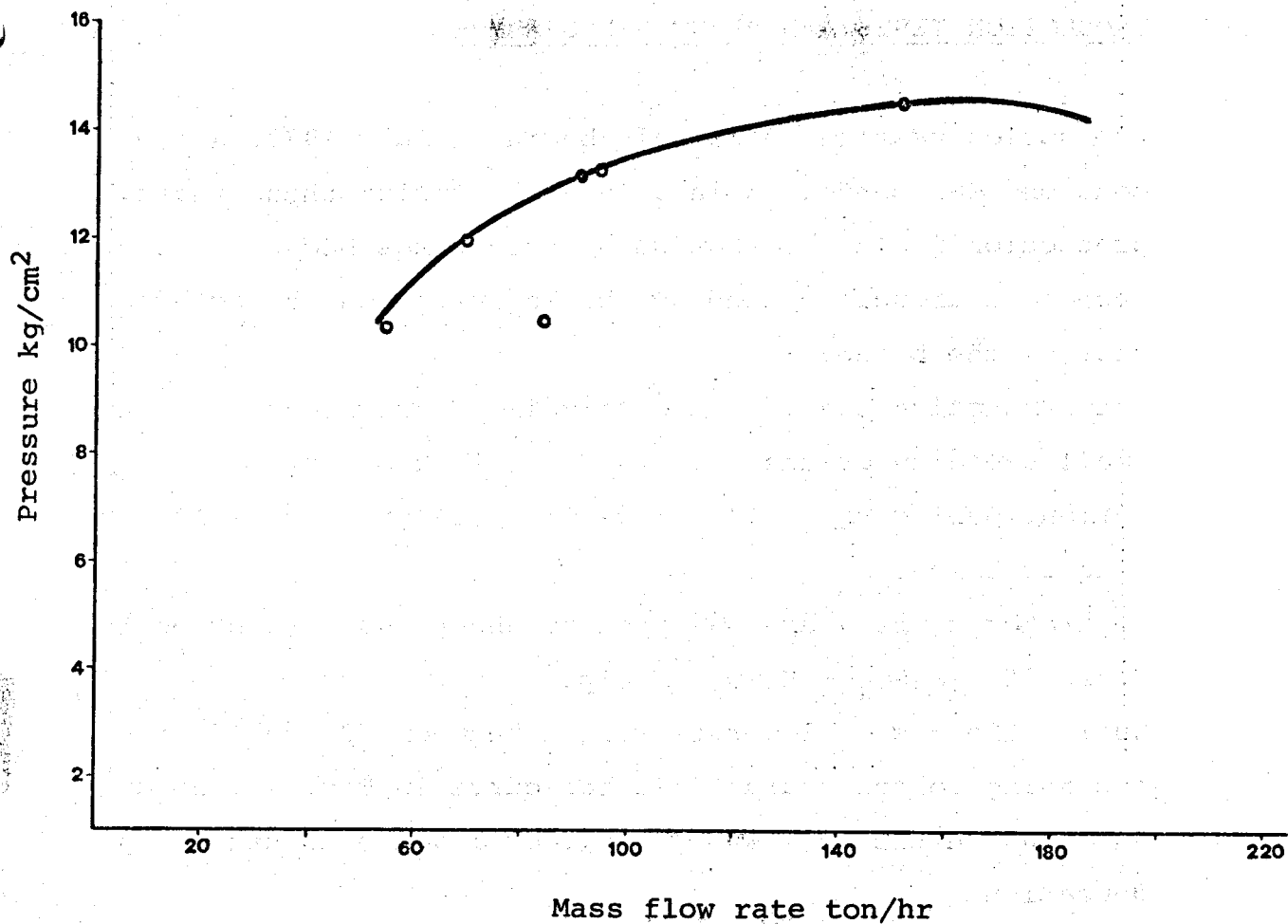


Fig. 12. Characteristic curve of C1 well.

3. - PRODUCTION TESTS AND PLANT PERFORMANCE

Production testing could only begin in July 1977. A second one was performed in July 1978. During these tests, production had to be shut-down three times because of technical trouble caused by the incrustation characteristics of the brine.

The production tests lasted only 135 hours because of the small capacity of the basin and the lack of water for dilution. During these 135 hours the well produced ~ 10.000 tons of brine.

Separator temperature was kept at about 140°C to prevent Glaserite $\text{Na}_2\text{SO}_4 \cdot \text{K}_2\text{SO}_4$ precipitation.

During the test, flow-rate ranged between 70 and 150 t/h, according to the characteristics curve in Fig. 12. Below 50 - 60 t/h the well stopped producing due to steam condensation.

The separator ran regularly during all the period of production but during the last hours, the bypass valve had to be opened because of partial obstruction of the automatic valve.

At the end of the production tests, the inner part of the cyclon was covered with a uniform CaCO_3 incrustation of about 20 mm of thickness, whereas the inner part of the steam pipe was quite clean. This is due to the fact that during the production a water valve was periodically opened to wash the steam pipe inside the cyclon.

The dilution of brine allowed us to maintain production for 75 hours continuously. Unfortunately scaling prevented us from obtaining accurate measurements.

The pressure top were regularly obstructed so that pressure, and flow rate measurements were discontinuous. Scaling on the thermometer well may have altered the temperature measurements.

The flow rate measurements in the weir was the most reliable as it was unaffected by scaling.

At the end of production water was flushed into the plant and well to avoid salt precipitation.

Recently a borehole geometry log was made to see if there were incrustations in the well. The results of this measure are shown in Figure 13.

It is clear from the figure that the thickness of the scaling increases with depth and then diminishes. At a depth of about 350 m (at flash level) the well was obstructed.

The discontinuities in the figure are probably due to the glaserite crystals that grew when the temperature of the brine dropped below about 120°C , as will be discussed later.

4. - CHEMICAL CHARACTERISTICS OF THE BRINE

Many samples were collected in order to estimate the physio-chemical characteristics of the brine.

Five types of sampling are used :

- 1) - in bottle set up at well-head to collect the brine under pressure conditions;
- 2) - collecting brine downstream of the weir, after dilution of the brine;

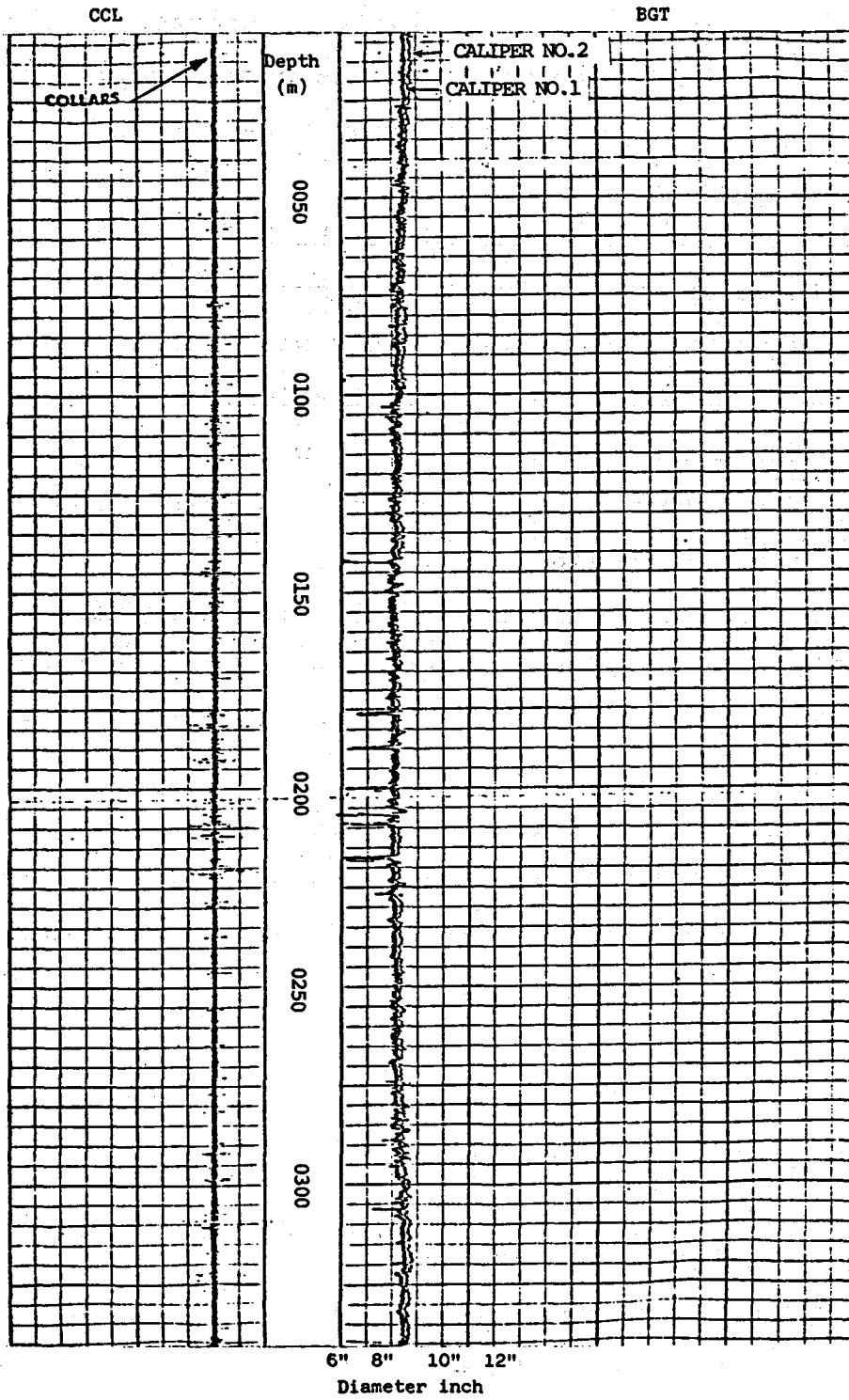


Fig. 13. Borehole geometry log.

- 3) - using an in-hole Küster sampler;
- 4) - collecting scaling samples inside and outside the pipes;
- 5) - deviating the two phase flow on a bypass and closing at the same time two valves.

The results of the chemical analyses are very different, depending on the type of sampling used. It must be remembered that the well produced a two-phase mixture of steam, brine and gas. For example, the samples collected with the bottle method of 1) did not always reflect the real conditions in the pipeline, as in some cases the gas phase was predominant in the sample and in others the liquid phases.

Downhole sampling, as in 3), was difficult because the high temperatures destroyed the o-ring seals of the sampler. Hence, the most reliable samples were those collected downstream of the weir, 2), although the total concentration were affected by evaporation and by inaccurate measurements of the flow-rate of the diluting water. The unreliable results of the fifth method may be due to the fact that the valves were not shut at the exact same time.

The results of the chemical analysis of the two productions tests are quite different, the main uncertainty lying in the Na/K ratio determination.

However the average composition of the brine can be represented as shown in table 1.

TABLE 1

CHEMICAL COMPOSITION OF BRINE IN mg/l

Ca ⁺⁺	~ 200	CS ⁺	~ 30
Mg ⁺⁺	~ 20	AS ⁺⁺⁺	~ 15
Na ⁺	~ 60000	Cl ⁻	~ 27500
K ⁺	~ 80000	SO ₄ ⁻⁻	~ 186000
Li ⁺	~ 220	HCO ₃ ⁻	~ 2500
Fe ^{+2/+3}	~ 1.5	H ₃ BO ₃	~ 7500
NH ₄ ⁺	~ 30	SiO ₂	~ 120
Rb ⁺	~ 400	TDS	~ 364000

The gas produced from the well was sampled downstream of the separator on steam line and was mainly carbon dioxide, whereas H₂S was absent (see Table 2).

TABLE 2

CHEMICAL COMPOSITION OF GAS (WEIGHT PERCENTAGE)

H ₂ S	—	N ₂	0.5
CO ₂	99.5	CH ₄	traces
H ₂	traces		

The scaling samples inside the pipes and separator were analyzed and revealed that the incrustations consist

mainly of CaCO_3 .

However sodium and potassium sulphate precipitation begins whenever the brine temperature drops below $\sim 110^\circ\text{C}$.

Scaling samples were collected inside the basin where temperature was $\sim 70^\circ\text{C}$. These were analyzed chemically and crystallographically. The results reveal that the in crustation consists mainly of glaserite $\text{Na}_2\text{SO}_4 \cdot 3\text{K}_2\text{SO}_4$. The figures given in Table 1 suggest that the hot brine discovered at Cesano has a particular composition, characterized by a prevalent sodium and potassium sulphate chemism and by its non-reducing property.

From these results it is clear that Cesano hot brine differs significantly from all the other thermal brines discovered to date in other parts of the world.

If we leave aside the constituents present in small quantities, the hot brine composition can be represented on a Jänecke diagram as shown in Fig. 14 (3). This diagram is drawn from published data. Using it we can easily explain the difference between the chemical analyses of the first production period, reported in (1), and the present results.

The composition of Table 1 could be represented by point A in the diagram of Fig. 14, whereas the results of the analyses reported in (2) could be represented by point B. The two point can be seen to lie on the same straight line as point G, which represents the composition of the glaserite. When a solid phase separates from a solution, the composition of the latter varies according to a straight line joining the point representing its initial composition and that of the solid phase. Hence, the solution of

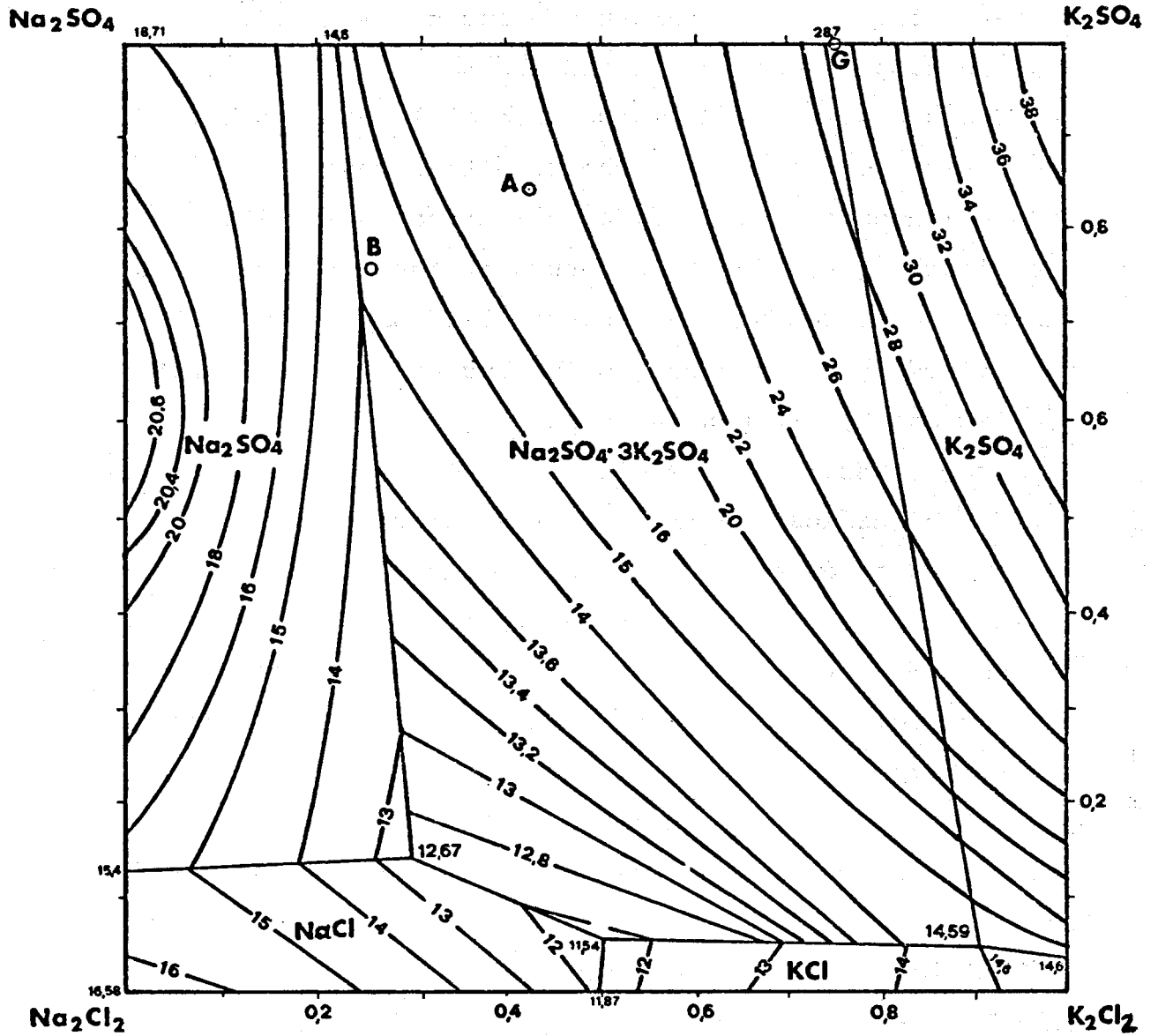


Fig. 14. Janecke's diagram at 100° C.

composition B can derive from a solution of composition A, after the glaserite has precipitated. The liquid samples of the 1975 production period were collected at atmospheric pressure when they obviously had lost most of their glaserite content. Their representative point on Jänecke's diagram thus shifted from a point A to point B. Solubility tests were also conducted on brine samples reconstructed in the laboratory. The boric acid was seen to increase the total solubility of the sodium and potassium salts (3) (4).

Finally, it should be noted that dissolved CO_2 forms about 2% of the total brine, as revealed by the gas/steam ratios measured in samples taken downstream of the separator.

5. - IN-HOLE PRESSURE AND TEMPERATURE MEASUREMENTS

In-hole pressure and temperature trends versus depth during production are given in Figs. 15 and 16.

These figures clearly show the level at which fluid evaporation begins for flow-rates of about 110 t/h.

Note that the pressure at the evaporating level is about 40 atm for a temperature of about 203°C . That is, this pressure is much higher than the steam vapour pressure as that temperature.

This phenomenon is due to the release of CO_2 from the solution and the gradual enrichment in steam of the gas phase.

Values of bottom hole static pressure were taken and plotted versus total mass produced from the well to investi-

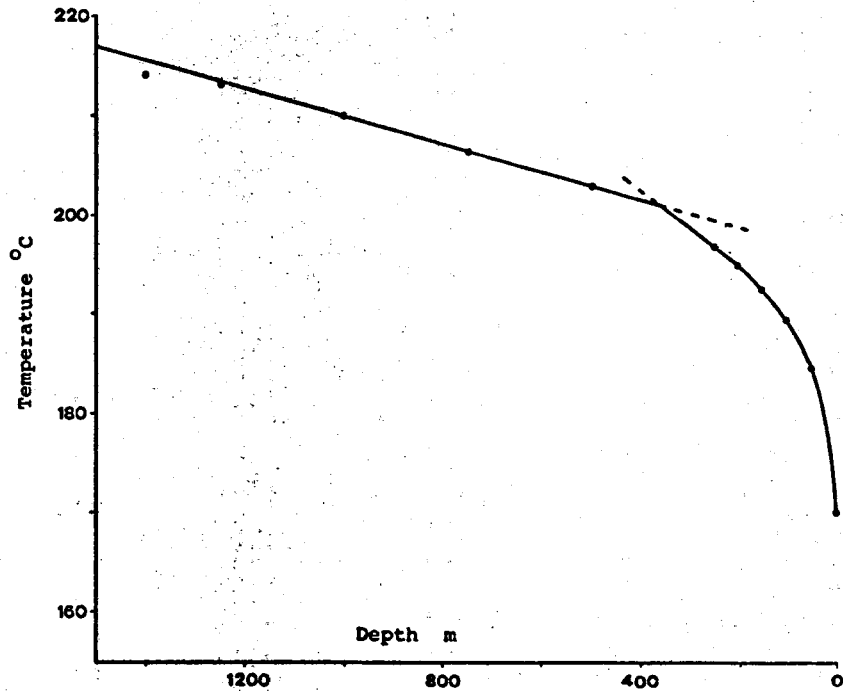


Fig. 15. In-hole temperature vs depth.

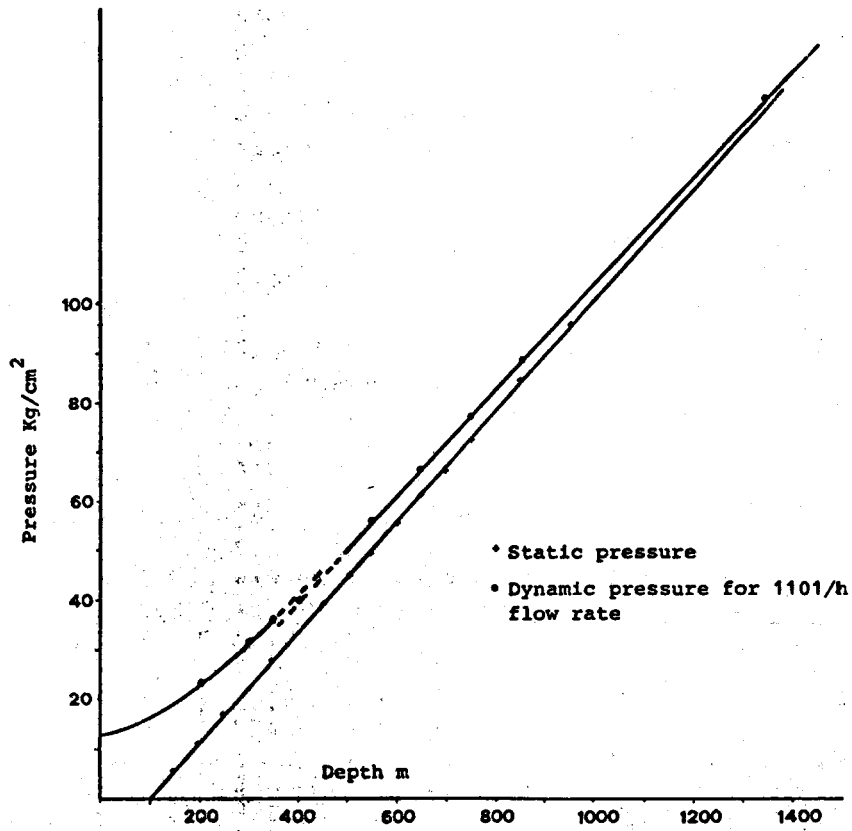


Fig. 16. In-hole pressure vs depth.

gate reservoir dimensions.

The results of the measurements indicate only that pressure drawdown is small, but, because of the inaccuracy of the instrumentation, no definitive conclusion can be drawn.

The interpretation of two pressure build-up tests after well shut-in did not add further information.

Maximum pressure build up was in fact smaller than 2 Kg/cm^2 for a mass flow-rate of $\sim 80 \text{ t/h}$ and then comparable with instrument accuracy; however, this pressure variation is not due to skin effect after shut-in as, bottom-hole pressure increases slowly.

In future these measurements are expected to improve.

At the moment no definitive conclusion can be drawn on geothermal reservoir geometry and dimension.

6. - CONCLUSION

The production tests, although short, did provide, at a low cost, an indication of the chemio-physical characteristics of the brine and production conditions.

Nevertheless the operations of this small pilot plant were made very difficult because of the incrustations and work will be required in future to improve the reliability of the measurements and to solve production problems (scaling inside the well and in the surface equipments).

However production and laboratory tests have shown that glaserite precipitation may be controlled by modifying

production conditions and diluting the brine with water. Finally, well Cesano 5 has provided a means of disposing of the waste from Cesano 1. Using the experience of past production tests, some studies have been made of the feasibility of exploiting the Cesano field for generating electricity or its potassic salts. Agronomic tests by the ANIC Company have shown that the glaserite could be used in fertilizers.

The plant, which will be described in detail in a separate report, will permit :

- long-term production from the well, by recurring to techniques for preventing scaling;
- flash steam production through special separators capable of operating in the presence of incrusting fluids;
- control of the Helical Screw Expander with concentrated brines;
- production of glaserite salt using a special crystallizer.

Meanwhile measurements and tests will also be carried out directed at acquiring further information on Cesano reservoir.

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