WELLHEAD UNITS AND GEOTHERMAL DEVELOPMENT IN EL SALVADOR

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Abstract. Backpressure and condensing units have been strategically positioned in the generating expansion plan of El Salvador (ES) to make it more efficient bath technically and economically. Four 5 Mu each backpressure units were acquired, each pair with different technical features according to the tield conditions for which they were planned. A special locally designed arrangement of 2x5 Mu units was put in operation at Berlin, joining two producers to a single separation plant which feeds in parallel the two turbines located in the lower elevation wellpad. The units have operated satisfactorily for 3 years, showing high efficiency over the operating range of steam flows and pressures, and helping to discover problems related to corrosion, damage in the wells, temperature effects and silica depositions.

The production of @otherma-electricity with respect the total generated, was 14% in average for the last two ycars, *but* has remained well above such value since 1975, and greater than 25% for half of that period. A mall part of this generation has come from wellhead units yielding remarkable benefits which encourage further utilization.

INTRODUCTION

The exploration of the ES geothermal **resources** began in the mid 60's thanks to the support of the United Nations (PNUD). Some 18 areas were found attractive, five of them receiving greater investigation (which included a first deep exploratory well) Ahuachapan (AH1, 1200m), Chipilapa (CH1, 900m), Parras Lempa (PL1, 940m), Berlín (TR1, 1450m) and Sta.Rosa de Lima in the eastern-most region of ES. Fig.1 shows these zones and other hydrothermal sites in the country, differentiating those that have evolved to projects; in conjunction with the hydroelectric and thernal facilities covering the national electricity demand. The national potential, in respect to the resource that could serve for the production of electricity, has been preliminary evaluated at some 4 W Mwe (1), assigned to the areas located along the young volcanic chain that runs E-W near the pacific coast.

By starting the works in 1970, the first condensing unit, a separated steam or so-called "single flash" plant, was commissioned in June 1975; fallowed one year later by an identical unit. It should be noted that the construction of the 2nd. unit (1973-July 1976), took only half the time of the first one mostly due to the impetus originated in the petroleum price crisis of 1973. By march 1901 a 3rd. unit of 35 MW "double flash" was commissioned, although lacking the additional wells originally planned for the project, due to different constraints that made the drilling activity halt since 1978. The lack of extensive drilling caused the problems of a centralized depletion of the reservoir conditions, affecting the functioning of the wells, which lead CEL to impose a limitation an the mass extraction from the field. This reduced the annual generation by abut 200 Gwh/yr, which became more sensible by 1987 when, induced by a dry year crisis, the Generation system began to retake a significant annual thermal contribution.

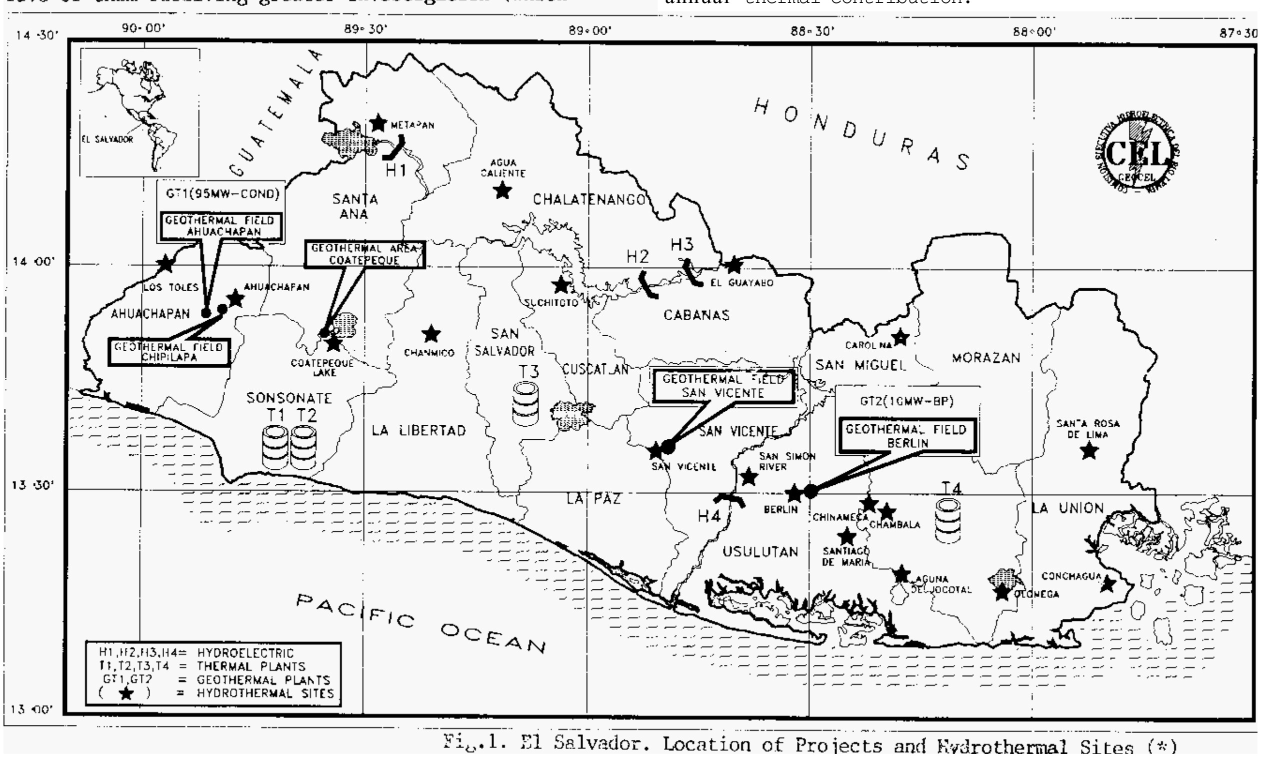

Fig.1. El Salvador. Location of Projects and Hydrothermal Sites (*)

From 1976 to 1980, with a great deal of its own resources, CEL also pursued the exploration of Chipilapa to the east of Ahuachapan and of the eastern-central areas of San Vicente, Berlin and Chinameca. The most profitable prospect was that of Berlin (see fig.1) where a 3 0 º C liquid dominated reservoir was discovered, with 4 of the 5 deep exploratory wells resulting producers for a total capacity of about 28 Mwe (condensing). Production testing of the wells was finalized only by 1987 because of the field work limitations imposed by the already existing civil war. A first evaluation of the feasibility of installing a condensing power station was also available by 1982, but the cited limitations prevented the commissioning of a 1x55 chi unit by 1985-86, which rnuld have delivered another 4CC Gwh/yr to the System.

In spite of the war, by 1985 a new effort was undertaken by CEL with the support of bilateral cooperations from friendly governments like Italy, Belgium and France, which were oriented to the exploration of the central western zone of the country and to the acquisition of small (5Mw) backpresure wellhead units to generate electricity from the available stem. This has been possible at Berlin giving an opportune reinforcement with local resources to the generation, under the above cited crisis.

Frm 1990 onwards, having regained the peace and financial institutions, a renovated impulse has been undertaken to develop large projects such as the 1st. condensin,; geothermoelectric development at Berlin (modular 2x25Mw), the stabilization of Ahuachapan (additional drilling and reinjection), and the final exploration of San Vicente (*see* location in fig.1).

PRODUCTION OF GEOTHERMO-ELECTRICITY

The generation system of El Salvador is composed of hydroelectric (47.5%) geothermal (12.8%) and thermal **powers plants** (39.7%), having a total installed capacity of 817.5 Mu in 1994. That of geotheml is *105* Mw, composed of 95 Mu condensing at Ahuachapan and 10 Mu backpressure at Berlin.

Another 5 Mu backpressure are expected to be commissioned at Berlin by the end of this year.

Only 75-85% of the actual capacity can be operated due to limitations in the three types of plants, the deficits from hydro and geo being very similiar at around 6% of the total.

Fig.2 shows the recent evolution of supply (installed capacity) and maximum demand in tern of power. In the last two years, this demand reached an equivalent of *470* Mu, which in view of a total capacity of 817 Mw seems to indicate no problems to satisfy the demand of the next years. However, it is the lack of energy that has been found to be *a* critical situation, making any contribution of geothermal energy important.

Table 1 shows the historical contribution of electrical energy since 1975 from the three main sources in the country. it can be noted that a Geothermal participation of more than 14% extended along the whole 19 years period of operation, or a value greater than **25%** for half of that period. After **a** long period of reduced percentages of around 4%, the thermal (fossil fired) generation increased again by 1987, *a* year in which **some** 1 0 Gwh from Berlin **and** Ahuachapan could virtually be added to the system.

The price of energy in El Salvador increases **as** thermal participation increases, because of the cost impact of imported fuels. This means that the importance of geotheml generation is not only to exploit the local resources to reduce dependency from petroleum but also to reduce the cost of base energy.

The magnitude of the contribution from backpressure units since 1992, **has** produced benefits in therms of energy and economics **as** shown in table 2, in which the theoretical **cases** of 1, 2 and 3 units operating at rated capacity has also been calculated to observe the benefits under normal conditions. An average generation

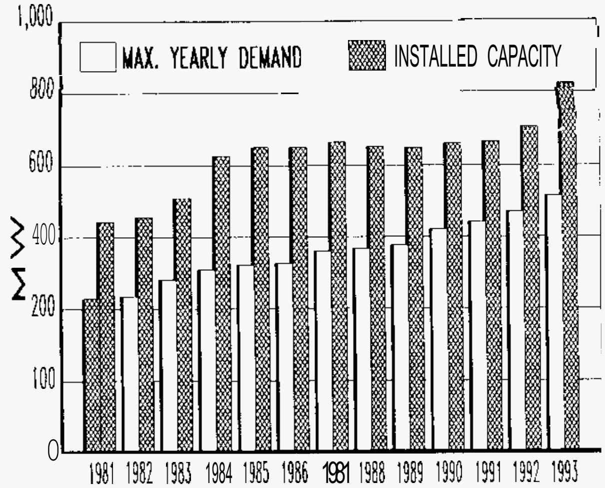

Fig. 2 Supply and Demand of Power 1981-1993

EAR	HYDRAULIC		GEOTHERMAL		THERMIC		TOTAL	
	GWH	%	GWH	%	GWH	%	GWH	%
975	355.3	36.8	72.3	7.5	430.1	55.7		
976	389.7	35.5	279.8	25.4	538.3	39.1		
977	482.2	38.9	400.1	32.3	429.8	28.8	1238.4	10C
978	829.3	60.3	391.0	28.4	358.1	11.3	1375.9	10C
979	1079.1	73.0	392.2	26.5	155.6	0.5	1479.1	10C
980	047.3	71.7	390.5	26.7	7.8	1.5		
1981	730.3	52.1	612.3	43.6	22.6	4.3	1403.0	100
1982	830.3	58.3	513.4	36.0	60.0	5.7	1424.9	100
1983	951.3	61.8	523.0	34.0	81.2	4.3	1539.8	100
1984	017.4	63.0	531 6	33.0	64.8	4.0	1613.8	100
1985	1171.1	686	421.9,	24.7	113.0	6.6	1706.0	100
1986							1671.3	100
1987	1133.3	59.9	434.5	23.0	324.3	17.1	1892.1	100
1988	1302.3,	65.7	430.0	21.7	249.1	12.6		
1989	1425.5	70.2	440.9	21.7	164.1	8.1	2030.5	100
1990	1647.8	74.3	418.7	16.9	150.7	6.8	2217.2	100
1991	1268.5	55.2	424.5	18.5	504.1	26.3	2297.1	100
1992	1415.7	59.4	350.9	16.4	575.3	24.2	2381.9	10C
1993								

Table 1. Gross Energy Generation by Sources 1975-1993

of 20 Gwh/year from one of the wellhead units, equivalent to 5.5% of the total geothermal generation in 1992-1993, would yield an income of the order of 1 million US$ and so contribute to a recovery of past expenses in exploration. The lower part of the table presents the expected situation for one to three backpressure units at some 0.9 usual plant factor, in which **case** revenues would *range* from 2 to 6 million US$, with energy contributions of more than 10% of the total.

BACKPRESSURE UNITS IN THE ES DEVELOPMENT

The general philosophy to decide an the acquisition of backpressure units was to procure a rapid utilization of the available steam from existing producers, generating low cost electricity and obtaining revenues for the many years that the successfully exploratory wells have to wait for a condensing power plant. In fact, Berlin is an example case of a very long wait of 15 years to present. Two real situations were considered: (a) that at Berlin, in which at least 10 Mw could be installed on existing producers in a very favorable economic scheme, even though requiring drilling for reinjection; (b) that of new areas under deep exploratory drilling, like Chipilapa, for which an straight forward process can not be assured because the wells are still to be drilled, but existing other areas with similar drilling programs, like Coatepeque or San Vicente, that could also be a possibility to accomodate such installations.

Quantity of Units. A maxim of 3 units of 5 Mw each for every possible area was established, considering also that 3 x 5 Mu wellhead units utilize more or less the same stem as a 1x20 or 1x25 Mw condensing plant, and on the other hand, below 20-25 Mw the economics of condensing becomes poor. The individual size of 5 Mu comes from the local experience as normal average of productivity. Accordingly, 2x5 Mw wellhead units were the first group requested for Berlin (valid for the eastern zone of the country) and the same number for Chipilapa (for the western zone).

Allocation of wellhead units in the expansion plan. As can be seen in fig. 3, the use of wellhead units has always been conceived for early exploitation of each area under exploration or development; thus, the pair of units originally operating at Berlin could be moved to San Vicente once this area reaches the drilling stage, which in turn is expected to happen in correspondence with the arrival of a condensing solution for Berlin. This of course, does not mean that those wellhead units could not remain at Berlin if convenient at a given ment. Similarly, the two units requested for Chipilapa, could be moved to Coatepeque or, in principle, to any of the other areas. By now, the real situation is not so different than originally though, and a 3rd unit (one of those acquired for the western zone) has been moved to Berlin, to be commissioned by the end of this year. The fourth unit is by now in atand-by as the production wells drilled in Chipilapa did not meet the minimum technical requirements.

Arrangement of the 2x5 Mw facility at Berlin. The application of wellhead units at Berlin was designed with many optimizing features. The layout takes into consideration the 100 m difference in elevation between production wells far a separation distance of about 500 m, favoring a two phase transport pipeline. The specific analysis was also in accordance with the fact that the production capacity of the well at higher elevation is greater than 5 Mw, even when considering a high Steam consumption, while that of the other is almost below such capacity. A single location of both units at the lower elevation producer, was then convenient to join bath mixtures in a single separator from which a flexible and complementary use of the Steam can be made, thus ensuring a 10 Mw operation *(see* scheme and general flow diagram in figs 4 and 5).

Technical Characteristics of the Turbines. For the Berlin field, a 6 to 10 bar range of inlet pressures was specified to give attention to the high ranee of wellhead pressures. A five stages turbine was finally adapted by the manufacturer to achieve steam consumptions in the range of 12.6 to 14 t/h/Mw, in relation to an atmospheric backpressure of 0.94-0.95 bar.

Only for the purpose of identification we name this turbine as type 1. On the other hand, a 3 stages turbine with a single inlet pressure of 5.5 bar was selected for other applications, thinking on a conservative range for the new areas. This is here differentiated as type 2 turbo-generator group. Table 3, summarizes all major technical data and characteristics of these two ypes of backpressure turbogroupes, together with those of the condensing units of Ahuachapan.

Operating Experience. The most critical factor delaying the planned star-up of the project, was the construction of the hot reinjection well. In spite of CEL's efforts, there were many outside constraints. Starting with a sabotage to the drillin rig, then a shallow blow-out of stem at depth of 144m lead to abandon the site TR6, each of these events implying relevant administrative complications, for a total delay of about 3 years. To have the project in

Year	Back Pressure Units (Berlin)			Condensing (Ah)		Total Geoth		Incomes from BP energy in thousand U$ Dolares (Calculated For a Reference Value of 50$/Mwh)
	Units	Gwh/yr	%	Gwh/yr	%	Gwh/yr	%	
1992	1 x 5 MW	23.1	6.0	367.80	94.0	390.9	100	1155
1993	1 x 5 MW	17.6	5.0	362.00	95.4	379.6	10C	880
1994	1 x 5 MW	35.9	8.4	370.56	91.6	406.5	10C	1795
	1 x 5 MW	39.0	9.65	365	90.35	404.0	100	1950
	2 x 5 MW	78.0	17.60	365	82.40	443 0	100	3900
	3 x 5 MW	117.0	24.30	365	7570	482.0	100	5850

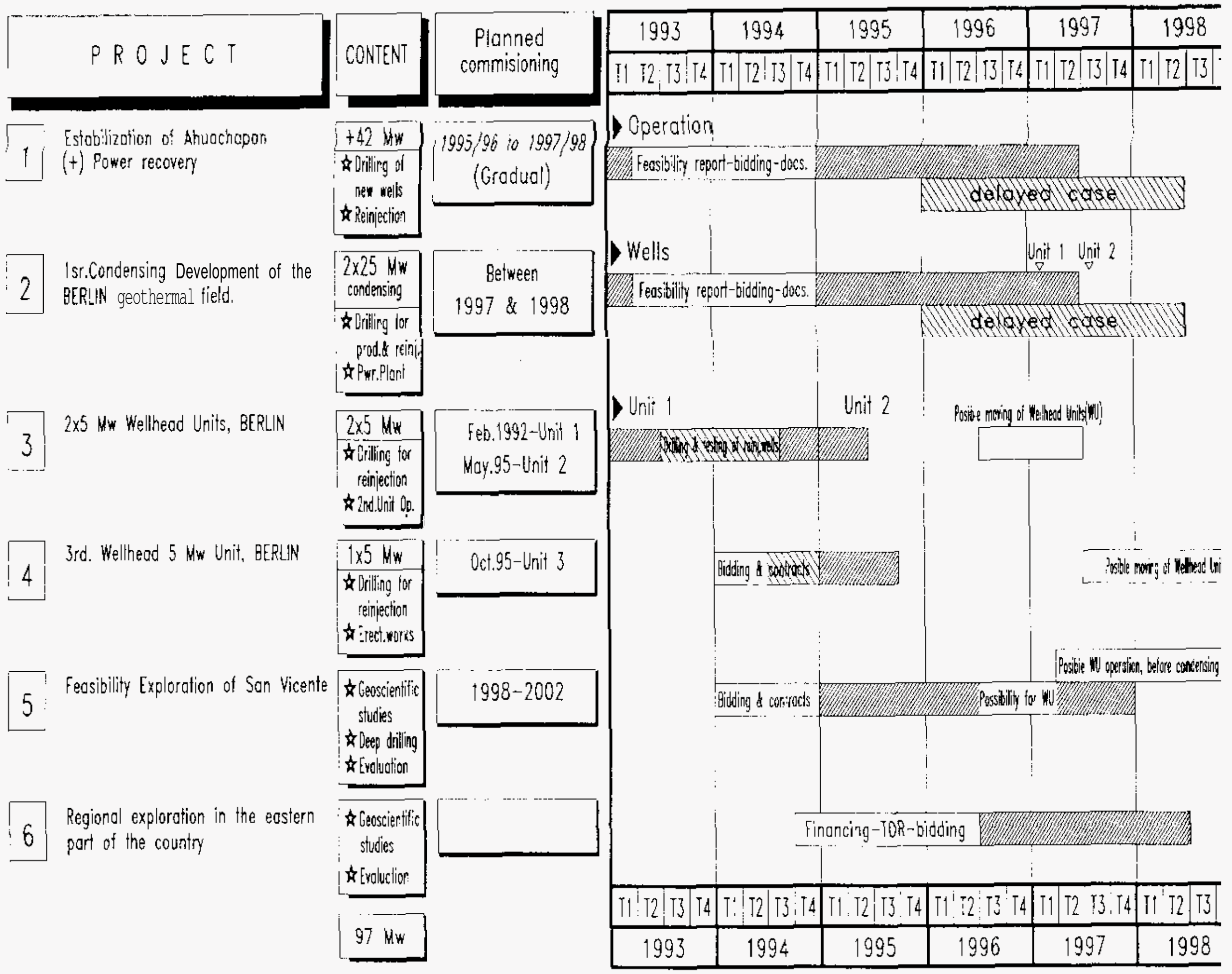

Fig. 3. The Wellhead Units in the Generating Expansion Plan.

operation, a temporary scheme of hot reinjection in the second producer TR9 was implemented; enabled by the versatility of the original layout, although this resulted in cooling of the well.

The generation of electricity began in February 1992, using both units in a alternate way and disposing the waste water with hot reinjection in TR9 and cold reinjection in the old poor producer TR1. It was only until April 1994, when a reinjection well TR14 was completed and succesfuly tested, that a 5 Mw operation was initiated in a normal way; alternating the units to prevent other possible problems due to inactivity after the field test. Attempts to recover the temperature and productivity conditions of the well TR9, were restricted by the lack of waste disposal means. By mid 1994 a second well (TR8) was drilled north of the field and resulted in good permeability, therefore increasing the reinjection capacity. Berlin is intended to be in any case a totally reinjected field as indicated in the scheme of fig.6.

After a few months of operation, it was found that the producer TR2 was sending ferrous and rocky materials probably coming from the inside of the well, caused by corrosion phenomena or damage. This finding has been one of the most practical benefits of the wellhead units operation, because it would otherwise have remained hidden an probably increased the damage during the many years of shut-in conditions of the well before a condensing utilization.

Similarly, the cold reinjection in TR1 resulted in a reduction of the absorption capacity of the well due to silica deposition, which was almost re-established by discharging the well (after recovery and stimulation). On the other hand, the attempts to recover the conditions of TR9 as producer may include steam or mixture injection from TR2 or another method, a key action to start the production of electricity with a 10 Mw capacity.

Economics of wellhead units The experienced capital investments referred to thn complete installation of 2x5 Mw units at Berlin, including reinjection well and piping and not including the costs of the production wells, was 1200 US$/kw. However, the current additional investments related to reinjection drillin; and piping, probably lead to a final estimate of 1400 US$/kw.

Although the operation has not been possible with the two units at full capacity, the energy cost has resulted in about 30 US$ /Mwh, an attractive low cost for the generation of electricity, specially in relation to the higher cost of 70-100 US$/Mwh for thermo-electricity.

CONCLUSIONS

The wellhead units at Berlin have operated very satisfactorily. Although reinjection activities imposed more delays than expected, the benefits obtained from their operation are both technical and economical. The production of electricity, even if limited by many factors, has been important. In the meanwhile, due to the fact that the waiting time for the condensing plants has increased, more reasons exist to pursue a continued use of wellhead units.

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DATA	CONDENSING (AHUACHAPAN)		BACKPRESSURE (BERLIN)	
	Units 1 & 2 (Single Flash)	Unit 3 (Double Flash)	Units 1 & 2 (Type 1)	Units 3 & 4 (Type 2)
Year of start-up	1975, 1976	1981	1992	1995
Type turbine	Single cylender double flow impulse, 5 x 2	Doble admission impulse-reaction (3, 4) x 2	Action double flow 6 blade stages	Action single flow 3 blade stage:
Rated capacity (Mw)	30, each	35	5 each	5, each
Max.capacity (Mw)	35, each	40	5 each	5 each
Velocity, RPM	3600	3600	6160-1800 w/red	6060-1800
Primary steam pressure Kg/cm2a	5.7	5.6	6 a 10	5.5
Secondary steam pressure Kg/cm2a	-	1.53		
Exhaust pressure/Kg/cm2a	0.085	0.085	0.95(atmosph)	0.95 (atm)
Primary steam temperature C	156 (saturated)	155.3(Saturated)	158 c 179 (sat)	159 (sat)
Primary steam flow rate t/h	230 c/u	170.0(Combinable)	63 a 72 each	76
Net specific steam consumtion, primary, t/h/MW	8	9.5(Average)	12.6 to 16	16
Condenser				
Type	Direct contact	Direct Contact		
Cooling water temp. C	27	27		
Outlet water temp. C	40.3	40.3		
Cooling waterflow rate t/h	8.65	12.26		
Cooling tower				
Type	Cross flow, induced draft w/vertical axis fans	5		
Number of cells	5 each	5		
Design wet bulb temp. C	22	22		
Fan motor power	80 Kw/fan	80 Kw/fan		

Table 3. Technical Data of ES Geothermal Units

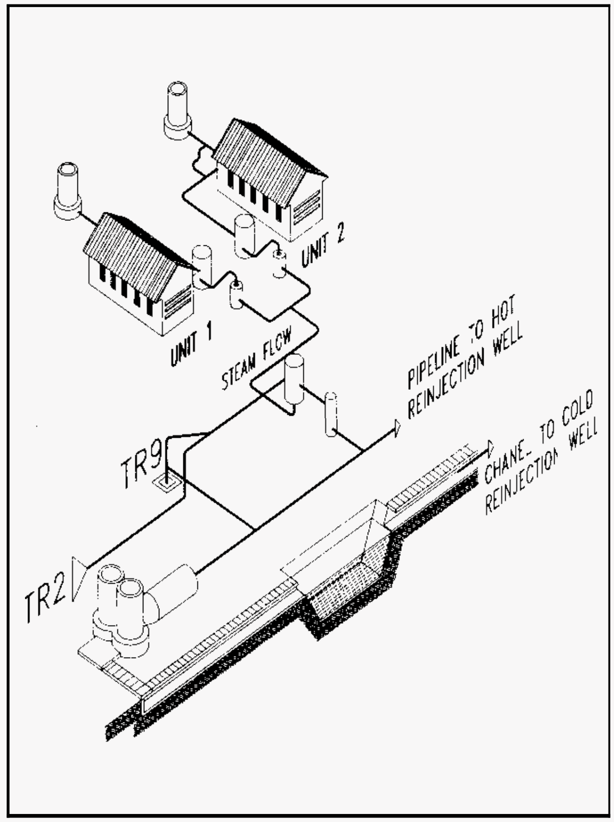

Fig. 4. Arrangement of 2x5 Mw facility at Berlin.

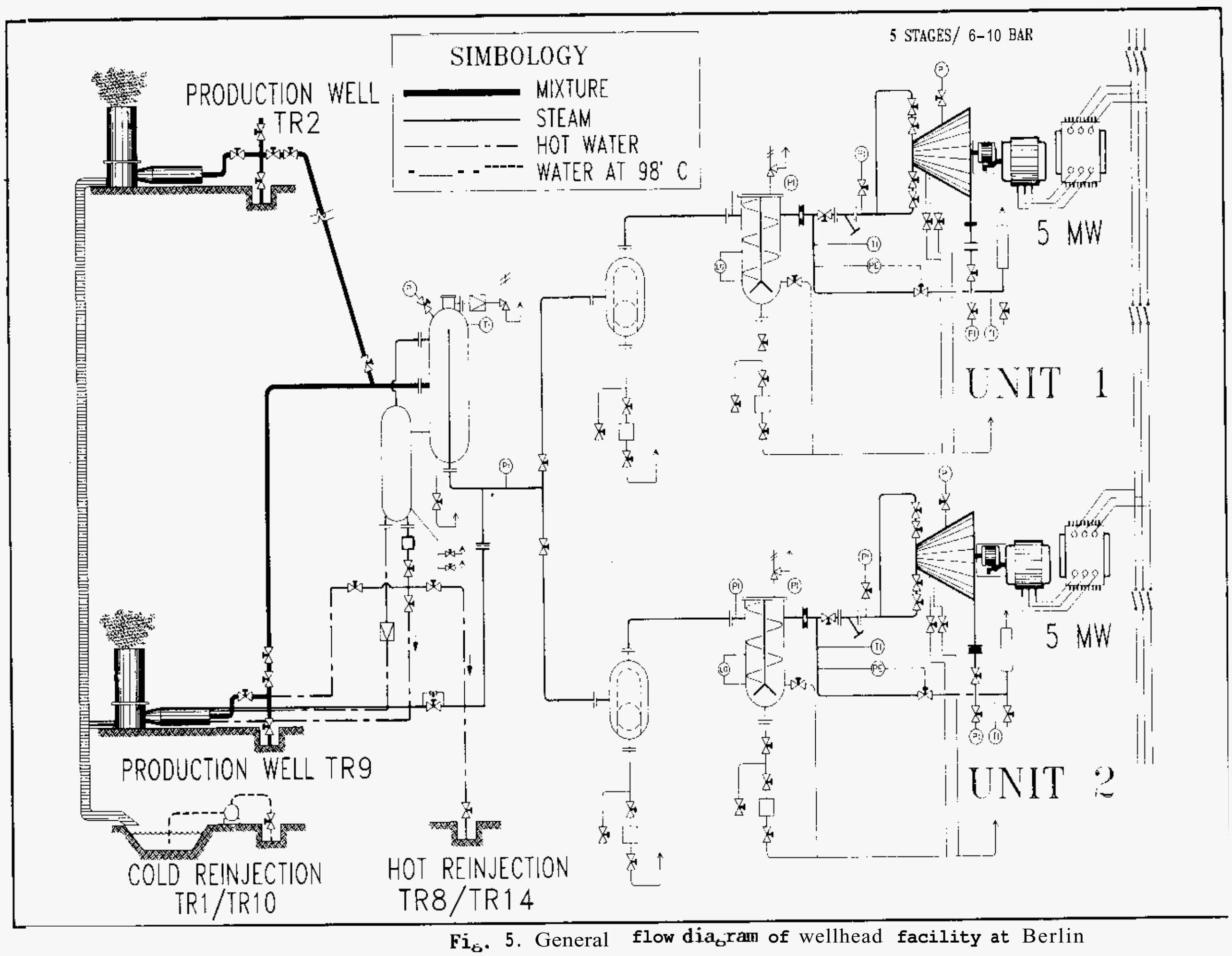

Fig. 5. General flow diagram of wellhead facility at Berlin

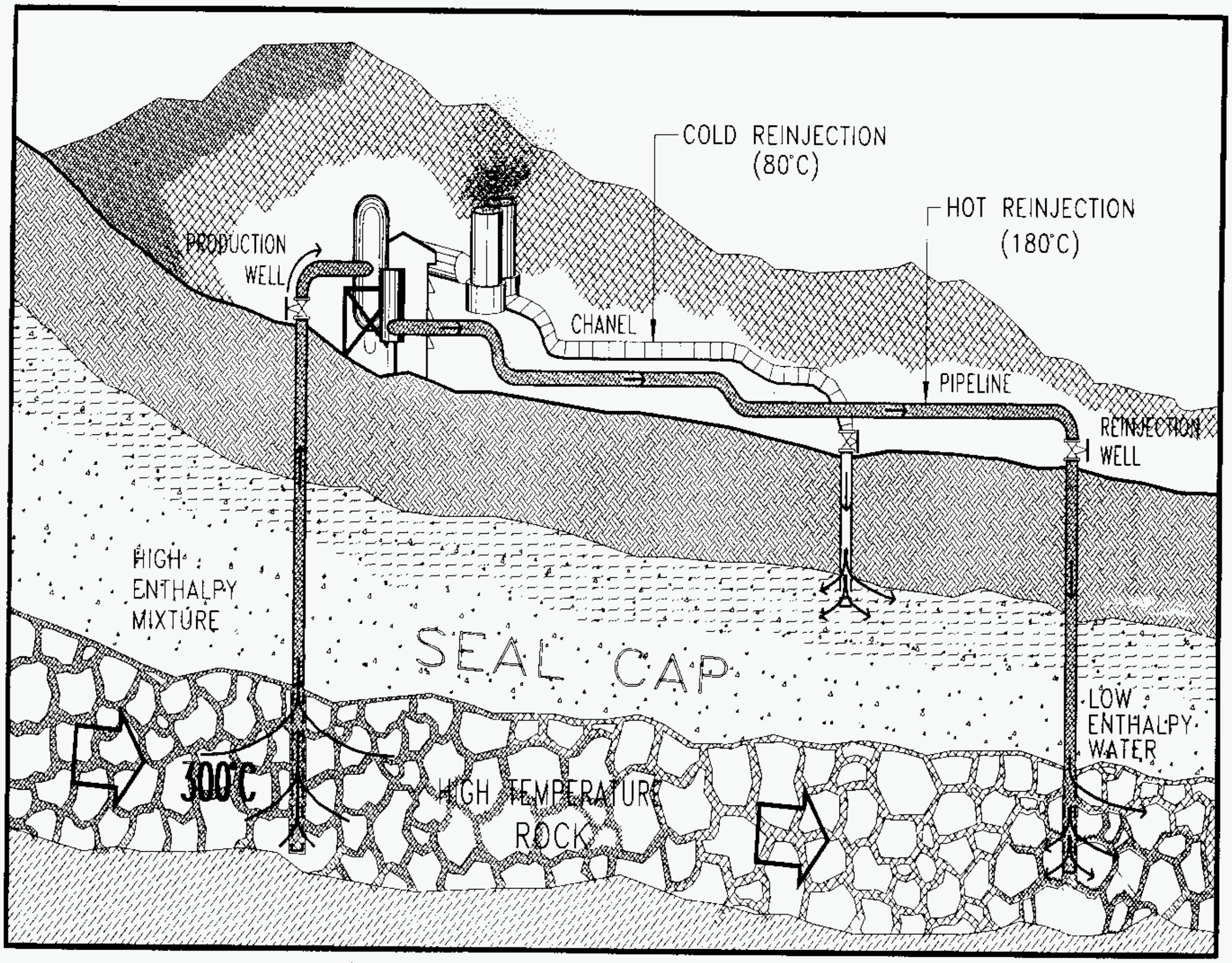

Fig. 6. Total Reinjection Scheme at Berlin Field.

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