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THE MEXICAN EXPERIENCE WITH MODULAR POWER PLANTS: GENERATION AND BRINE DISPOSAL

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ABSTRACT

Several years of operating well head power plants at Los Azufres have shown that this plants are a very practical and reliable tool to find the best design of the reinjection system. The article describes the arrangement for hot and cold reinjection used for three of those plants in northern Los Azufres. Several recommendations extracted from the mexican experience are presented with special emphasis on the practical aspects for handling the separated brine avoiding precipitation and silica scaling.

The peculiarities of Los Azufres regarding the disposal of the brine are presented, warning about the danger of extrapolating this solution to other geothermal fields. Finaly, some statistics related with the operation of the well head power plants are indicated in tables, showing the amount of water reinjected every year.

INTRODUCTION

In several places (Hiriart, 1983, 1985; Alonso 1987) it has been discussed the advantages and disadvantages of small, back pressure power plants in geothermics.

In Mexico since 1982 we have 5 units of 5 MW each whose technical characteristics have been presented in other publications (Plauchú and Manzur, 1987). Up today the result has been quite good, in table 1 we present some statistics of the energy production accumulated since August 1982.

In Danuary 1987 a sixth unit was commisioned at well AZ-18. Meanwhile ten more 5 MW power plants where ordered. The idea is to install some of them, perhaps *k* in Los Azufres and the others in Los Humeros and La Primavera.

The result in Mexico from using this plants, other than the economical has been quite important in the following aspects.

a) We have been able to detect at a proper time the variations in production of she wells we planned to connect to a more efficient central power plant. In some cases like wells AZ-19, AZ-28 and AZ-9 the changes show to be quite big. Other than decay in the production of steam of the wells like the ones already mentioned, the changes in production of water, gas contents in the steam, chemical composition of the brine, etc... are of extreme importance before investing in a central power plant. It is quite different the reliability of the results obtained from short term well tests than those obtained having one or more years a well under production.

b) We have been able to detect the real capacity of the inyection wells keeping the injection flow for years. To detect the problems in the well such as changes in permeability, corrosion of the liner pipes, etc...

c) Perhaps the most important experience gained with small well head power plants regarding the disposal of the separated water is how to handle it to avoid scaling with the silica and corrosion.

The method we use now is different than what we thought at the beginning. The experience was gained dealing with only 5 MW. It is not too much of a problem to stop a unit for a test or to change a piece of equipment in the injection system. In what follows in this article we present the results of this experience in handling the brine for reinjection.

Taking back the statistics of the 5 units installed at Los Azufres the following is important. In Fig. 1 it is shown the location of every unit and the injection wells.

In table 2 we present an average steam consumption and water production of every unit, for year. This has been taken from Table 1 reducing these values to steam and water extraction based on the typical curves of the turbines and of every well.

From the same table 1 one can construct table 3 of Plant Factor as done in Ortega (1987), that is a comparisson of the energy realy produced per unit with the maximum energy that would have been generated, 5 MW during 8760 hours (l.year).

It is important to notice from this table 3 that in some wells this factor is low because the production of the well is not enough, to produce the 5 MW.

ORIGINAL DESIGN OF THE REINJECTION SYSTEM

In figure 1 are shown the three production wells (AZ-5,13 and 19) that will produce separated water and well AZ-15, the one to be used as injection well. The problem was to design a system for hot reinjection, that is, keeping under pressure the whole system and avoiding loosing heat (Mora, 1983). We call "hot" injection a temperature 15 or 20^C less than the 175°C that corresponds to the water inside the separator, and cold injection to the one when the brine is firstly flashed to atmospheric pressure and then allowed to cool down to something less than *60^C.*

The three production wells and the one for injection are shown schematicaly in figure 2 to see the difference in hight and in Fig. 3 it is presented their relative horizontal position, the distance from the production wells to the AZ-15 is of five kilometers. As noticed there, well AZ-13 is 165 m higher than the injection well. AZ-5 is 135 m and AZ-19 only 75 m. That is, one has enough pressure head to keep the pipes under pressure on there way to the injection well.

To procede with the design of the system, several points must be taken into account to avoid problems during operation. Some of them are:

a) The posibility to control the water level in every separator. It should be noticed that if one puts a valve right after the separator, flashing will occur inmediatly down steam of the valve and consequently scale will form there. To avoid that, the valve must be put in a place where enough head is available to avoid flashing.

b) Since in some places the three injection lines must be integrated into only one, before arriving to the injection well, care must be taken to avoid problems of water level control when one or more wells are opened or closed.

c) Since the injection well AZ-15 has never been tested in the long run, one must be carefull in providing some sort of indication if the '.veil is not accepting all the disposed brine without changing the water level at every separator and without enforcing the operator to stop one or more generating units.

d) Provision must be consider to allow in every well a certain change in the production of separated water.

e) Because of the way the separators are operated, some steam leaves through the water pipe. Its effect is very important in the friction losses and also in maintaining the pH low because of the gases associated with the steam.

f) Finally, the system must be simple, avoiding automatic sensors that can be spoiled by the scale.

The main characteristics of the wells are presented in table 4-. Wells 5, 13, 19 have a well head power plant of 5 MW nominal capacity. Only wells 5 and 13 are able to produce 5 MW using approximately 62 t/h each. Well 19 will not be able to produce more than 45 t/h expecting a generation of the order of 3 MW. Even though the production of this well is low, the plant was installed to expand the knowledge of the reservoir in that area. It is important to see that the acceptance of the injection well AZ-15 is more than the total needed for disposal of the brine of the three production wells.

The topography of the site is caracterized by a rough terrain, with a creek that runs almost along the injection line drawn in Fig. 3. Since the rain in the site is abundant, it is frequent to see some landslides. Alteration of the soil because of the geothermal manifestations is often found.

The design selected for the reinjection system is the one shown in Fig. *h* and was take from ______ Mora (1983). First note that a collector was installed in the lowest point between the production wells. The pressure in the collector was maintained by means of a returning pipe that runs up to a hill 87 m high, that permits to keep in approximately 8 bar the pressure. In case that the injection well starts lossing acceptance, the excess will be flushed up through this return pipe to a pond. The location of this pond permits to drain it to a bigger reservoir constructed specially for that purpose with a small earth dam.

The separated water comming from the three production wells enters to the collector separately. At the entrance is located the valve that serves to control the water level in every separator. Remember that this is the lowest point of the system, upstream of the collector. This permit to open or close the valves with a good pressure upstream, staying always far away from the flashing point. Any way, to prevent problems due to scaling, every valve was installed with a by pass circuit that has two purposes. One is to permit to remove the valve for cleaning and maintenance, the other, to replace the valve by an Orifice plate for permanent use when having a precise estimate of the water mass flow rate.

A big argument arouse during the design regarding the need of thermal insulation of the thtee pipes. The heat loss is small and any decrease in temperature is helpfull to avoid flashing at all the points. Of course the other advantage is economics. On the other hand if one is seeking a hot injection it sounds reasonable to insulate it. Also the safety of the personnel is also in favor of this second choice.

The final decision was to leave the pipes without instalation. In Fig. 5 it's presented the effect of including thermal insulation of the pipes. Figure 6 and 7 compares the behavior of the system when the injection well is closed and all the brine is flowing back to the returning pond.

The most difficult problem to solve was to avoid flashing at the arrival of the hot brine to the injection well. The solution was to insert a tube, deep enough to ensure to have at least 8 bar at the exhaust of the pipe but of a diameter small enough to produce a back pressure due to friction, of at least 8 bars in this injection pipe at the well head. It is fare to confess that even though this is perhaps the only solution technically good it was impractical. To hang 500 m of pipe inside the well is something very difficult and dangerous.

This describes in general terms the arrengement for hot reinjection that was constructed in the northern part of Los Azufres.

COLD REINFECTION SYSTEM

Two important things were found during the time when the hot injection was used. First, it was impossible to keep a high pressure at the entrance of the well AZ-15. The fluid started flashing in the pipe at least 20 or 30 meters before arriving to the well head producing vibrations and knocks. Second, simultaneously with this period some experiments where done trying to understand the mechanism of deposition and scaling of the silica in the formation of the reservoir and it was concluded that it is more dangerous to inject at 1502C than 30 or 209C. The reason is the big amount of monomeric silica still present in the water that doesnot polimerizates because of the low pH of the hot brine. One of the reasons of this low pH is the amount of gas carried along with the steam that comes out with the water from the separator.

An external problem that helped to make the decision to change from hot to cold injection was the monthly high rain during the summer of 1983 that practically destroyed the four pipes that arrive to the collector. Then a new system was designed to solve in a few days the disposal of the brine.

The Laguna Verde dam, specially constructed for the geothermal project, (see Fig. 3) was used as a collector of separated brine. The water from wells AZ5 and AZ-13 was sent by gravity to the dam. From a special intake valve the brine collected at the dam was sent by means of a poliurethane flexible pipe to well AZ-40 for cold injection. To reduce the amount of rain water captured at the dam, a "belt" channel was constructed around the dam to intercept the runoff and send it to the creek right after the dam. The water from well AZ-19 was sent by gravity to well AZ-15 using the old pipe that runned from the collector to the well.

In the last <\ or 5 years the system has been working with no problems. The following aspects in favor and against this method must be pointed out.

- The big size of the Laguna Verde pond permits to stop the injection even for 1 or 2 months when repairing is needed, storing the disposed water.

- The use of flexible pipe was the best solution in a terrain so difficult as the one of Los Azufres.

- The Laguna Verde dam was constructed in a place with a lot of thermal manifestation, specially gas escapes. When the dam is full, all the gases bubbles in that water making the pH to descend to values lower than ^.0. The result has been a great amount corrosion in the liner of well AZ-4-0.

SMALL POWER PLANTS AND REINFECTION

It is important to examine the experience of reinjection in northern Los Azufres thinking in what would have happened. The big central power plant of the northern Azufres would have been constructed using several wells, producing big amount of brine, without this previous experience at a small scale.

The initiation with portable plants of 5 MV7 served to understand first that the problem of the behaviour of the injection well is nore important from the point of view of corrosion of the liner rather than the decrease of the acceptance. Also to give its proper place to the short run injectability test and to understand that in the long run the aceptance can increase specially nhen the cold water produces fracturing of the rock matrix or when it arrives at steam caps reducing its pressure at the moment of the condensation. In Los Azufres we found that the best for the central power plant will be to dispose the water in a pond at the same platform of the well leaving it a certain amount of time for polinerization of the monomeric silica and then to conduct it by gravity or by pumping to the injection well. It was also found that flexible pipes for reinjection eventhough its higher price, are the safeness solution in a difficult terrain.

Perhaps the main problem in reinfection is one that looks naive but realy damage the wells. It is the arrival of dust and debris in the pipes. Specially in places like Los Azufres with a lot of pines, the leaves that falls into the pond must be retained and screened very carefully before conducting it to the well. Leaves and dust are excelent sealing elements for the fractures inside the well (Hernández, 1988).

ACTUAL ARRANGEMENT

In general we can sa that the procedure we have chosen for the disposal of the water at every well head power plant is as follows.

At the platform, the separated water is sent to a pond (usualy the same that was used for the mud when drilling). The purpose of that is to allow the brine to cool down and to release the gases disolved, so polimerization can be achived.

If the brine is immediately piped without the previous step for polimerization the pipe begins to plug with scaling. The size of the pond should be as big as posible, on the order of L\-0 m^2 per each t/h of brine taking care that the inlet and oulet are properly separated to avoid short circuiting.

The intake structure of the pipe that will conduct the brine to the injection well is perhaps the most critical part of the whole system, (Hernández, 1988). It must have some sort of screen or other device to avoid the entrance of leaves, branches and debris. Also it must avoid the entrance of dust and sand. (Our experience in Azufres has shown that this has been the main source of troubles in reinjection).

The pipe we use, as told before, is poliurethane welded with heat at the site. It is very easy to change it to another site when the portable well head power plant is changed. Since those pipes run following the topography of the terrain it is important to install vents a little before the highest point of a loop. Failure on doing that (as it has happened to us several times) reduces significantly the hydraulic gradient available.

Arrival to the injection well is also important. Our injection wells usually accept more fluid than the amount injected. That produces some kind of free fall in the upper part of the well producing two effects.

a) If the pipe is "introduced" into the well allowing a proper venting, air will be sucked by the fluid. The flow will be quite stable but the fluid injected will be a mixture of air and water.

b) If the pipe is tightly connexted to the head of the well without allowing air to enter, the free fall inside the well will produce a pressure fluctuation asociated to the evaporation of the fluid. Other than the mechanical problems caused by the pressure oscillation care must be taken with the supeirsaturation of the brine when it evaporates (flashes) part of its water. At the injection well we generally construct a pond to deviate the brine • in the case of any maneuver or logging in the well.

The interconection of two injection pipes comming from different wells forming a "Y" to continue to the injection well must be handled with care since the mixing of two brine streams with different degree of polimerization can cause precipitation and scaling with the silica. This happened to us in the Tejamaniles zone in southern Los Azufres.

The polimerization pond that is rear by the wellhead power plant is actually used in Los Azufres also for receive the condensates of the exhaust of the plats (15 96 of the consumed steam, approximately 9 t/h) because this fluid contains Boron in amounts higher than those required by the envirotnental regularions.

PECULIARITIES FOR REIN3ECTI0N IN LOS AZUFRES

Every geothermal field has its own peculiarities that should be taken into account when discussing the heat reinjection system. There are some of Los Azufres that might not be extrapolated to other cases.

a) Static level. Most of the wells that are used for reinjection have their static water level around 500 m depth. That is one has some 50 bar of "free pumping" using only this difference. In other cases like Cerro Prieto in northern Mexico, the water level is only 10 m depth, there, the acceptance is very low and the brine must be pumped.

b) Location. The wells that were selected for injection are wells originally drilled for exploration purposes in the periphery of what is know now as the geothermal field. That is they are far enough from the heat of the reservoir, being quite remote the posibility of cooling down the reservoir because of short circuiting of the cold water.

c) Scaling. In some fields like Cerro Prieto, as soon as the séparated water is discharged to the silencer, the supersaturated brine begins to precipitate the silica being it in the form of amorphous silicates or as a scale on the walls of the channels. At Los Azufres this doesn't happen. The difference is in the amount of clorine ion dissolved. In Cero Prieto the silica content is in the order 1100 ppm and the total disolved solids are in the range of 25000 ppm, meanwhile at Los Azufres for a little less silica, 1000 ppm, the total disolved solids are less than 8000 ppm.

d) Topography. Fortunately the reinjection wells of Los Azufres are in the lower part of the field In some cases the topographic diferrence between a production well and those for reinjection is more than 100 m. This permits to have the whole injection system by gravity.

e) Terrain. An important peculiarity of Los Azufres is the instability of the soil, originated by the geothermal alteration and by the excess of rain at the site. This has obligated us to use only flexible (and expensive) pipes for injection.

CONCLUSIONS

The experience in México with portable, back pressure, well head, 5 MV capacity power plants has been quite satisfactory. Actually we have 6 units at Los Azufres and 10 more are under construction. The first one of this group will arrive to the field by the end of this year. Plans are being studied to order an other set of 10 units more.

The advantages of these units are its low cost per installed KW, the utilization of the wells right after its completion, the posibility of evaluation of the reservoir y a continuous extraction of fluid and finally one that has been stressed in this article is the posibility of testing the whole injection system, including injection well, conduction, polimerization, ponds etc. to find the real problems of the reinjection before constructing the central power plant.

The mexican experience discussed in this article for a field like Los Azufres was presented pointing out the peculiarities of this field and warning with flat extrapolations from one field to another.

The experience is, that cold (ambient temperature) reinjection is preferable than hot because the scaling problem is reduced if properly handled the fluid allowing it to cool and to release the gases for prompt polimerization before piping it to the injection well.

Two systems were presented in the article, one for hot, pressurized, system for injection gathering the fluid of three wells at different hights. Other a cold system that uses a storage pond to regulate the fructuarions in brine production and injectability of the receiving well.

Some recommendations were presented for those involved in this kind of problems pointing out the importance of keeping away from the pipe entrance all debries such as leaves, branches, plastic bags, dust and sand because they finaly are the most important and frequent source of problems in an injection system.

All the information transmitted in the article is the result of the experimentation done with the use of portable, well head, power plants that we consider is of great importance before entering in the design of a fixed central power plant. We realize that the importance of having a safe and reliable system for reinjection of the separated water is as valuable as having a reliable system os steam supply.

REFERENCES

ALONSO E., H. (1987): Current perspectives on the development of geothermics in Mexico. Proc. 9 th Annual Geothermal and Second IIE-EPRI Geotermal Conference and Workshop. EPRI AP-4259-SR2. Special Report. Palo Alto California, 2-1-10.

HERNANDEZ, C. (1988): Estudio para el control de incrustaciones y azolves en el sistema de inyección del PAZ-7. Departamento de Factibilidad de Proyectos. Oficina de Ingenieria Quimica y Ambiental. Gerencia de Proyectos Geotermoeléctricos. Comisión Federal de Electricidad. México. IT-AZ-0488, 32 pp.

HIRIART L., G. (1983): One year experience with portable back-pressure turbines in Los Azufres. Proc. 9 th Workshop on Geothermal Reservoir Engineering. Stanford University. Stanford, California, 275-278.

HIRIART L., G. (1985): Los Azufres geothermal development México. Geothermal Resources Council Bulletin 14 (1), 3-9.

MORA P., J.L. (1983): CompOrtamiento del sistema de reinyección en un campo geotérmico. Departamento de Factibilidad de Proyectos. Gerencia de Proyectos Geotermoeléctricos. Comisión Federal de Electricidad. México. ET-AZ-0483, 35 pp.

ORTEGA P., L. (1987): Operation of the movile units of Los Azufres. Proc. 9 th Annual Geothermal and second IIE-EPRI Geothermal Conference and Workshop EPRI AP-4259-SR-2. Special Report. Palo Alto, California. 12-1-7.

PLAUCHU L., A. and MANZUR L., S. (1987): 5 MW geothermal turbogenerators specifications. Proc. 9 th Annual Geothermal and Second IIE-EPRI AP 4259-SR-2. Special Report. Palo Alto California. 14-1-7.

Year	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
1982	6 544	7 024	4 381	10 900	834
1983	23 437	29 013	36 755	38 009	5 252
1984	37 147	36 456	37 127	40 675	8 133
1985	32 747	34 431	38 529	37 148	18 069
1986	37 498	36 567	35 908	32 862	12 990
1987	29 505	32 400	41 902	38 550	1 719

Tabla 1 Accumulated generation (MWh) of every well head unit.

Year	Unit 1	Unit 2	Unit 3	
	steen	stean	steam	water
1982	78.5	84.2	52.5	52.5
1983	281.2	348.1	441.1	441.1
1984	445.7	437.4	445.5	445.5
1985	392.9	413.1	462.3	462.3
1986	449.9	438.8	430.8	430.8
1987	354.1	388.8	502.8	502.8

	Unit 4		Unit 5	
Year	stean	water	steam	water
1982	130.8	43.6	10.0	6.6
1983	456.1	152.0	63.0	42.0
1984	488.1	162.7	97.5	65.1
1985	445.7	148.5	216.8	144.5
1986	394.3	131.4	155.8	103.9
1987	462.6	154.2	20.6	13.7

Tabla 2 Steam and water extracted from the reservoir per each unit (thouthands of tons per year).

Year	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
1982	55	96	91	98	15
1983	66	95	96	98	12
1984	98	88	95	91	38
1985	99	88	100	96	24
1986	86	83	82	75	30
1987	67	74	96	88	--

Tabla 3 Average power factor of every unit.

AZ-5	Production steam = 62 water = 57	
AZ-13	Production steam = 62 water = 20	
AZ-19	Production steam = 42 water = 40	
AZ-15	Acceptance	= 300 (t/h).

Tabla 4 Main characteristics of the wells (t/h).

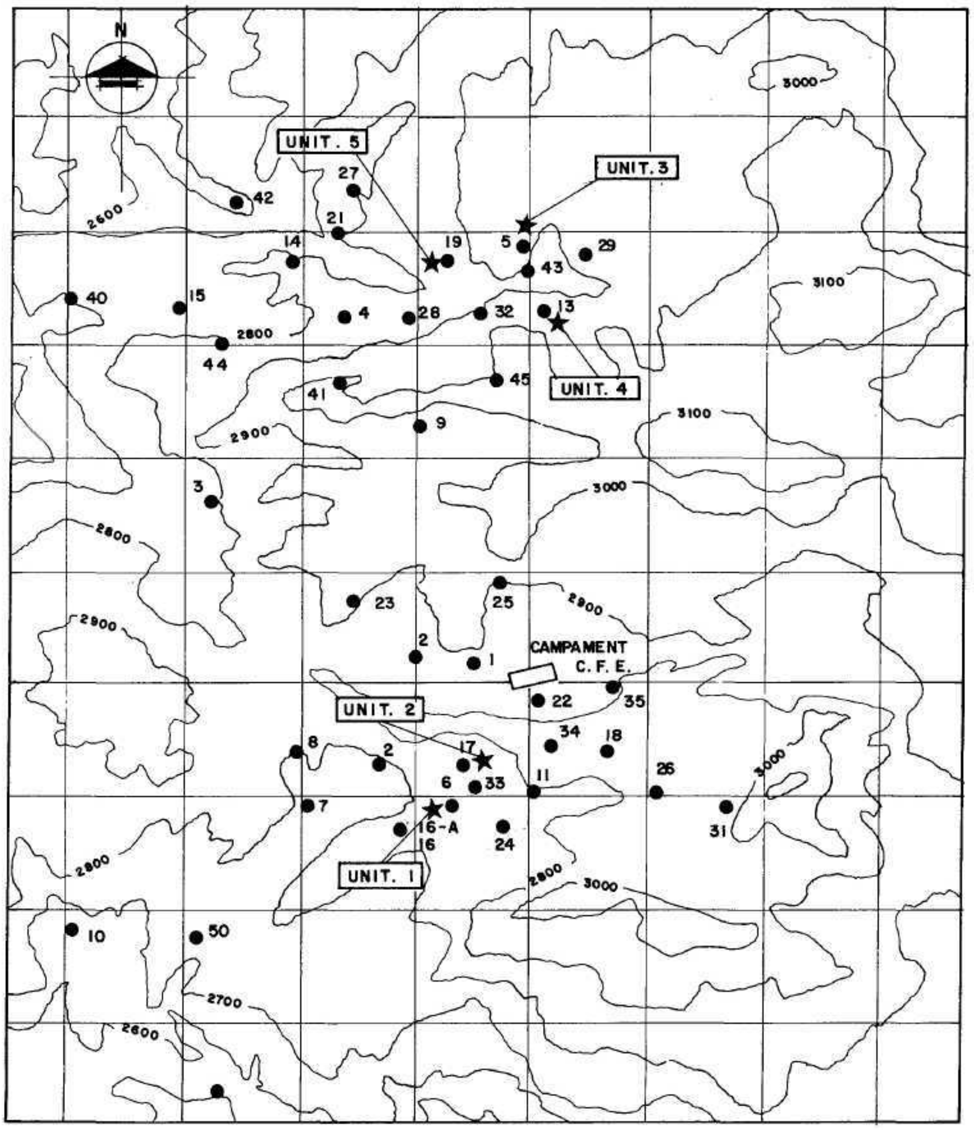

Figure. I. Wells and 5 MW plant location at Los Azufres. (Not all wells are shown on this map).

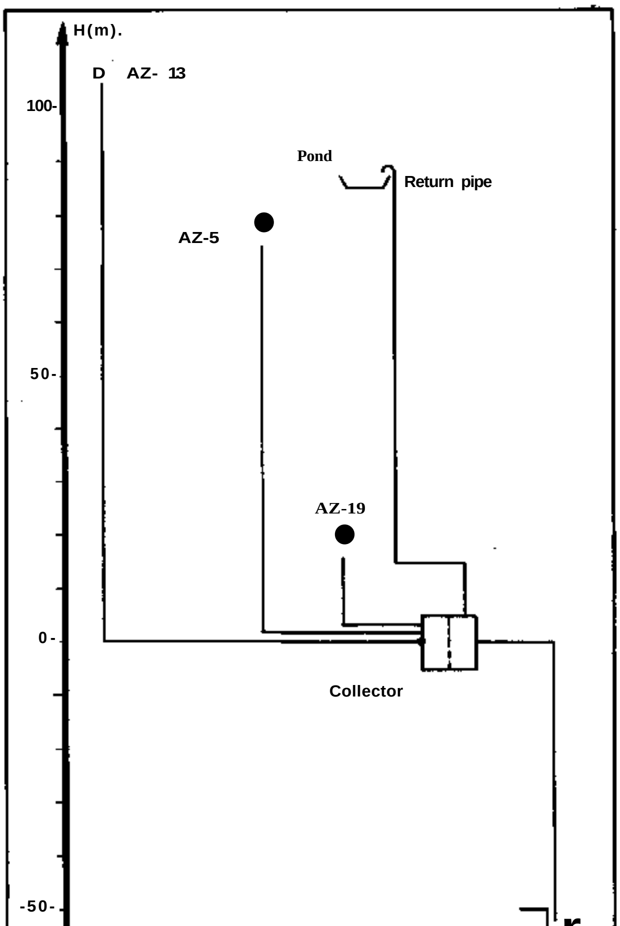

Figure 2. Relative high of the wells.

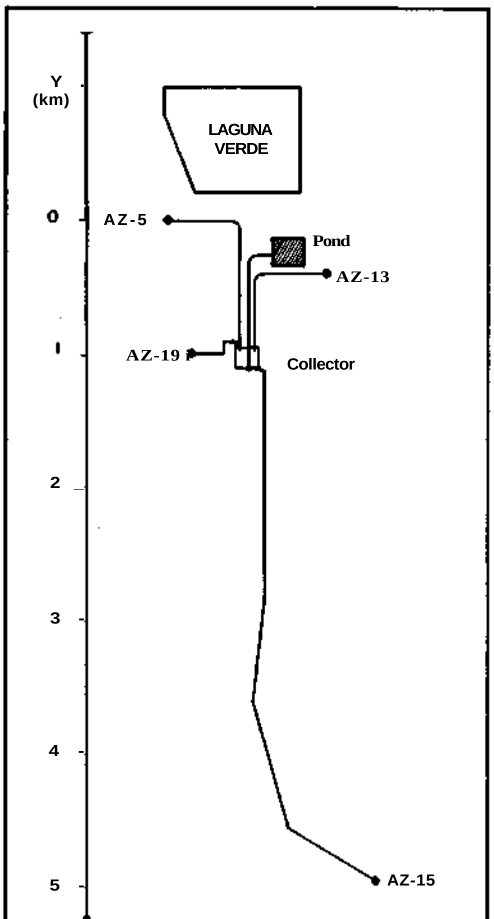

Figure 3. Relative location of the wells.

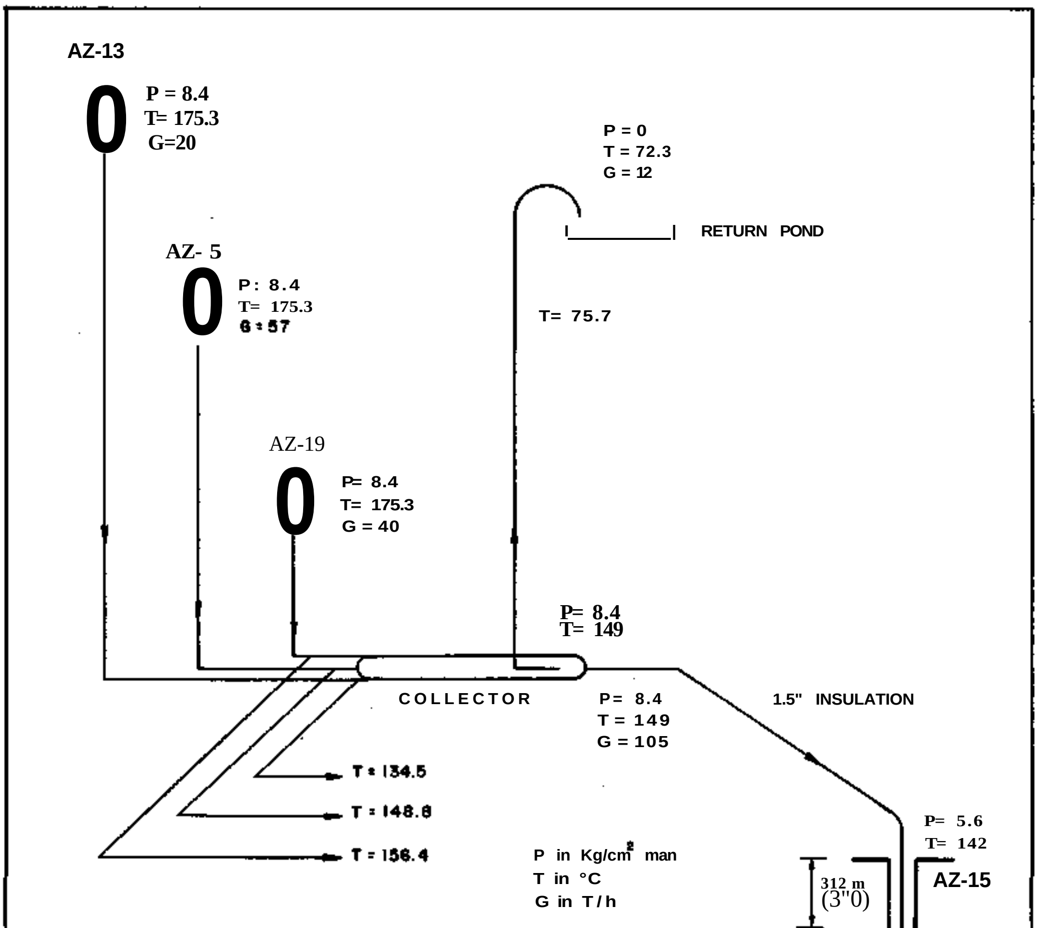

Figure 4. Reinjection arrengement. Design parameters without thermol insulation.

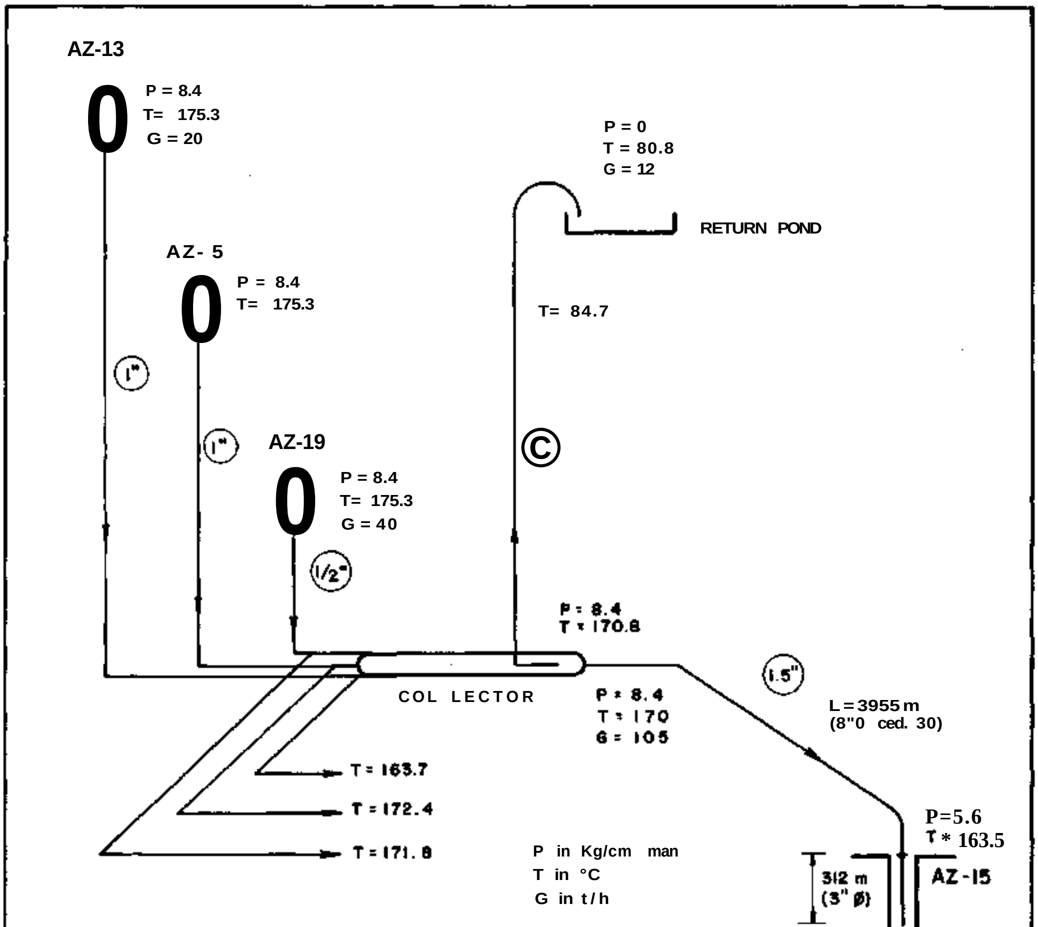

Figure 5. Behaviour of the system with thermal insulation.

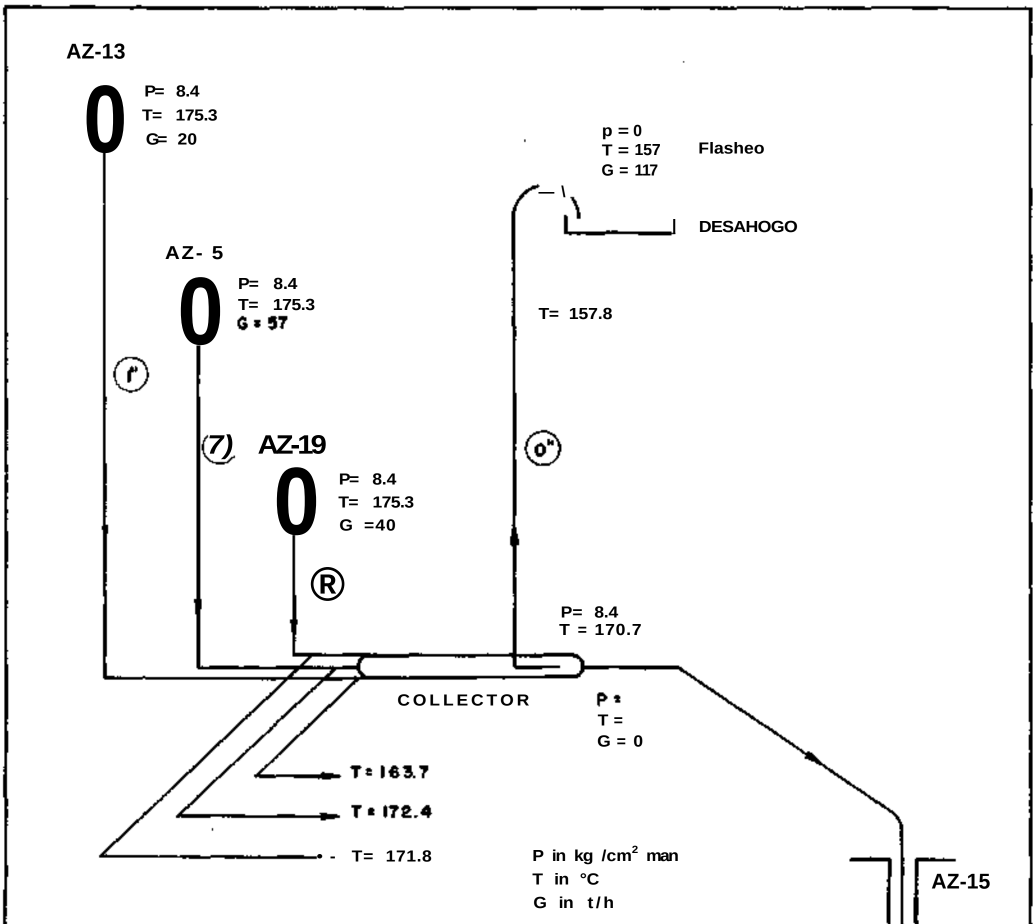

Figure 6. Heat and mass balance with thermal insulation and Az-15 closed.

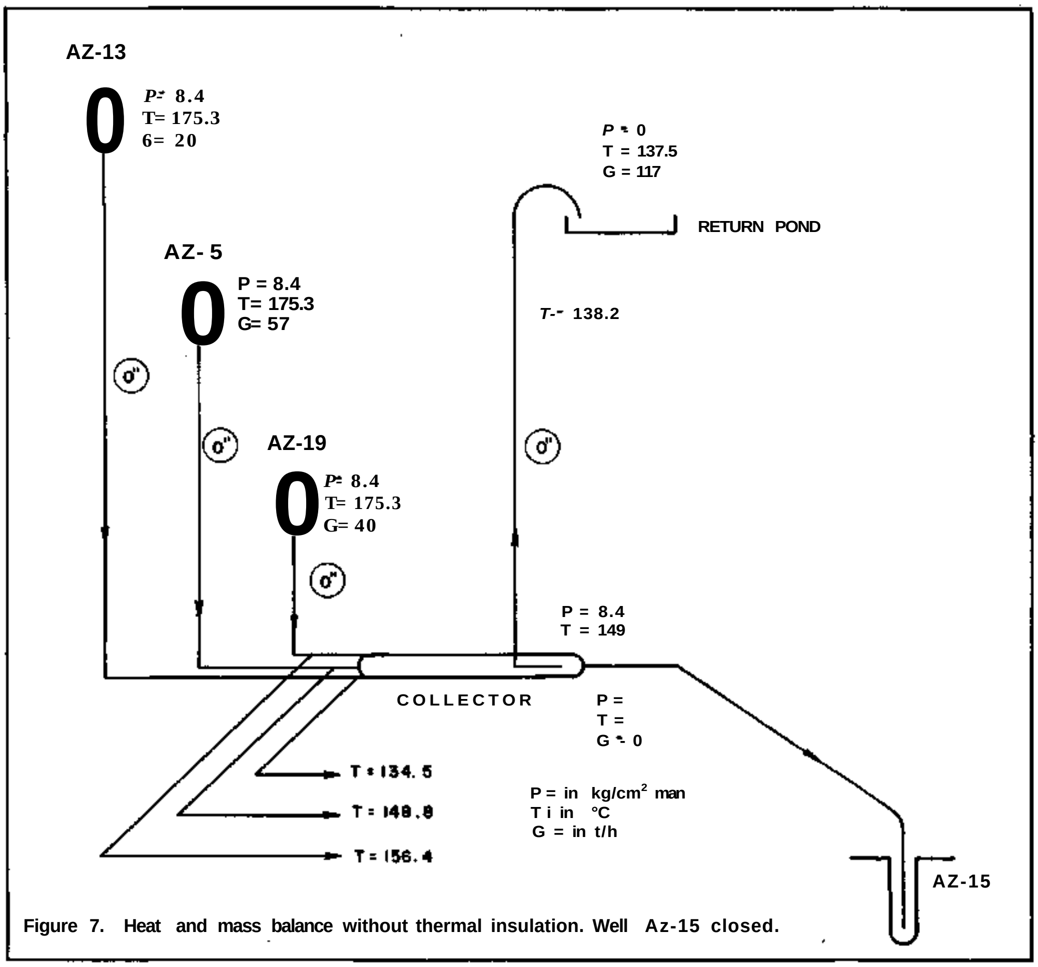

Figure 7. Heat and mass balance without thermal insulation. Well Az-15 closed.