# HEAT BALANCE AND OPTIMUM FLASHING PRESSURES FOR THE FIFTH UNIT OF CERRO PRIETO.

JORGE A. REZA.

INSTITUTO DE INVESTIGACIONES ELECTRICAS
Melchor Ocampo 403-4" Piso
Mexico 5, D. F.

## ABSTRACT

A computer program has been developed to calculate the heat balance and to optimize the electric generation both for one and two stages of flashing, for the fifth geothermal unit of Cerro Prieto, Mexico. The 3000 t/hr of separated brine from units 1 to 4, which at the present time are being rejected to waste, are to be utilized in a flash power cycle, in an optimum manner.

Two alternatives were presented: (a): A single-stage flash cycle with maximum generation of 24 MW net and flash pressure 30 psia and (b) Dual-stage flash cycle with maximum generation of 27.5 MW and corresponding pressures 30,62 psia.

Although the thermodynamic maximum is obtained for much lower pressures (25.4 MW at 19 psia and 31.5 MW at 14,46 psia respectively), scaling would cause serious damages to the surface equipment.

## INTRODUCTION

Since the starting of commercial operation of units 1 and 2 of Cerro Prieto (April 1973), approximately 1500 t/hr of separated brine are being rejected to an evaporating pond where the brine cools down and the suspended solids deposit. With the recent starting of units 3 and 4 (April, 1979), increasing the output to 150 MW, the amount of rejected brine is about 3000 t/hr. The estimated available thermal energy of the brine at 170°C is about 430 MW (t).

In early 1977, it was decided to build a fifth plant to use the rejected brine in a flash cycle to generate as much electric energy as permitted by the state-of-the art, making use exclusively of the separated brine from the 4, single flash, 37.5 MW(e) units.

The Instituto de Investigaciones Eléctricas (IIE) was awarded a contract to develop the conceptual engineering of the low-pressure power plant, and asked to present two alternatives; a) Single-stage flash cycle with single pressure turbine; and b) Dual-stage flash cycle with one dual-pressure turbine. In both cases the power output was to be optimized, taking into consideration all losses in the cycle.

In a separated project, but closely linked with the present work, the scaling effect on surface equipment upon lowering the brine pressure was to be determined so as to set a lower limit to the flashing pressures, for which scaling would be kept to acceptable levels. It was not until the results of the mentioned project were ready, to establish the actual operation conditions of the whole cycle.

As part of the heat-balance optimization, it was also required to optimize the cooling system and therefore reaching to an optimum condensing pressure. Obviously for this purpose, the heat balance of the plant was in turn required.

## TECHNICAL DISCUSSION

As it might be known, wells and separators are far apart from each other; therefore making difficult a convenient location of a common receiver where the saturated brine, from approximately 40 wells, gather. For technical reasons, it was decided to locate the collector and flashing plant near the evaporation pond and transmit the separated steam to the power house, which in turn was decided to be by the power house of the first 4 units. In that way, brine from the wells travels up to 2 km to complete flashing and from there, the separated steam travels about 1 km to the power house.

The diagram of the Cerro Prieto cycle is illustrated on Fig. 1 where the 5 units are represented in their simplest manner.

For the solution of the plant heat balance, each component of the cycle was thermodynamicaly analized; that is, the equations governing its performance were written according to its process. Energy and con-

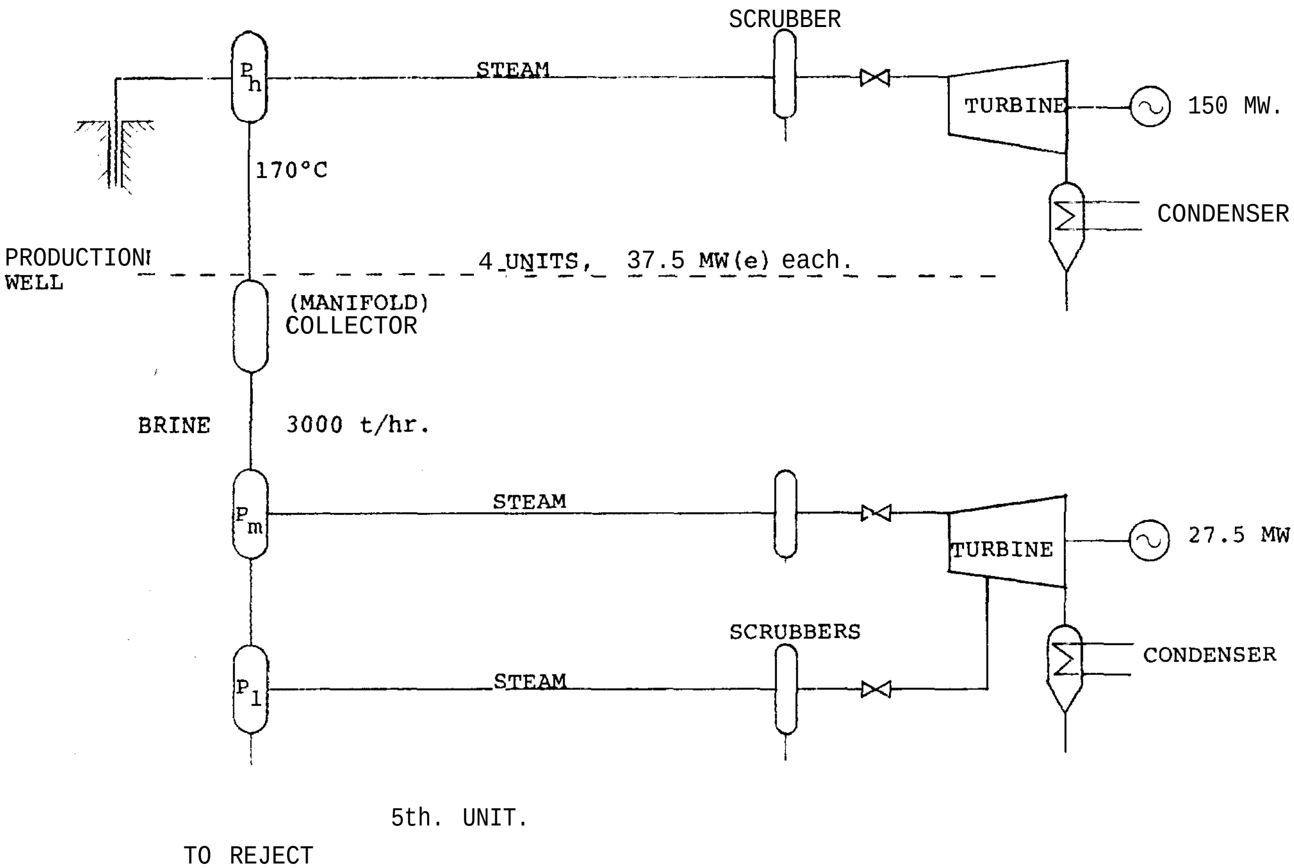


FIG. 1.- GENERAL DIAGRAM OF CERRO PRIETO THERMAL CYCLE.

tinuity equations were enough to describe each component, besides the need of reliable steam-water properties [2]. Single phase pressure and heat losses were calculated for pipes, fittings and separators when applicable and estimates of two phase pressure drops in the long line transporting saturated brine. Dukler's method [3] was used for that purpose.

It was clear from the beginning that a flashing pressure should exist for the generated power to be maximum. Fig. 2 shows the flashing process on a Mollier Chart. If the pressure is reduced from Pl to $P_2$ an amount of brine will flash and the separated steam (m) will expand down to condensing pressure. If on the other hand, the flash pressure is lowered to $P_2$, more steam will be obtained but less enthalpy change is available. What matters is the product of the amount of separated steam and the enthalpy change, in other words power generated. It follows that there should be a flashing pressure for which the power output is maximum.

Although it is obvious that more power would be obtained by having two flash stages, it was also necessary to do the single flash option so that an economic study could be made to compare both on the basis of cheaper installed Kwhr.

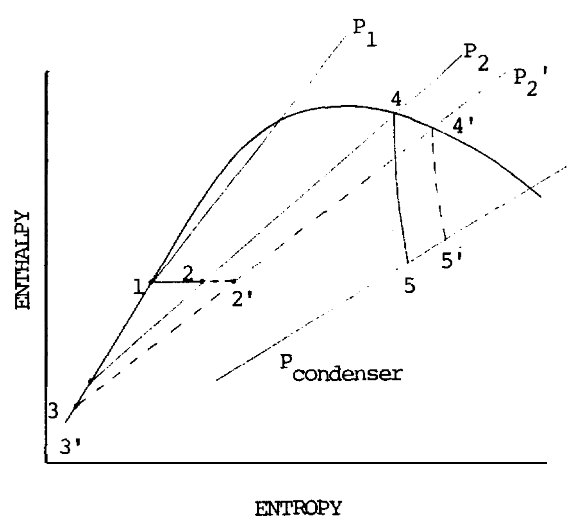


FIG. 2 FLASH AND SEPARATION PROCESS ON A MOLLIER CHART.

## COMPUTER PROGRAM

Once the energy and continuity equations as well as correlations for pressure and heat losses were established, for the entire cycle, and taking into consideration all mechanical and electrical ineficiencies, a computer program was written to solve the set of equations, making use of the steam-water properties [2] . The flow diagram of the program is shown on Fig. 3.

For the single flash cycle, the flashing pressure was varied from 10 to 40 psia and for each pressure the heat balance calculated. Similarly, for the dual stage cycle, the low pressure was varied from 10 to 35 psia and for each low pressure, the medium pressure was also varied from 35 to 70psia. For each low pressure and all medium pressure range the heat balance was calculated and results printed.

The program was written to calculate either single or dual flash cycle at user's will.

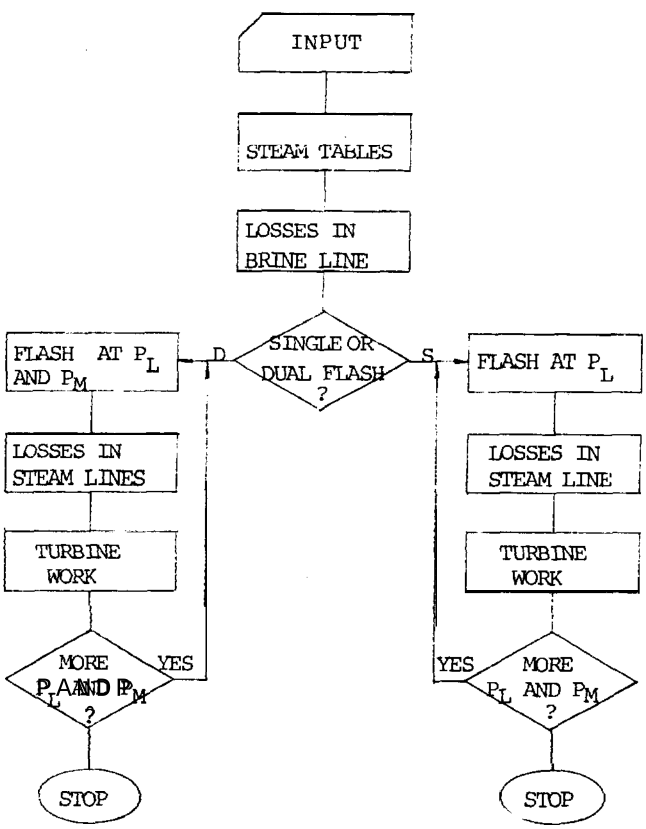


FIG. 3 FLOW DIAGRAM

## RESULTS

The computer results for both cases were plotted and are shown on Figs. 4 and 5. For the single flash cycle it is seen that there is clearly a unique flashing pressure for which the power output is maximum (25.4 MW at 19 psia). For the dual flash cycle it is seen that for each low flash pressure ($P_1$) there is a medium flash pressure ($P_m$) for which the output is maximum, but only for that particular $P_1$. There is however, a unique pair of $P_1$ and $P_m$ for which the power output is the absolute maximum. This is better illustrated by drawing a curve through all the relative maximums of each P curves. In the way, the absolute maxim3m output is 31.6 MW for the corresponding pressures $P_1$ = 14 psia and $P_m$ = 46 psia.

Mercado et el [1] have Eound that in order to assure a smooth operation and avoid serious damage to the surface equipment due to scaling, brine pressures lower than 30 psia must be avoided.

Considering the above restriction, it is clear that operation of the plant at its maximum generation cannot be possible. Therefore, the maximum output available corresponds to the lower pressure limit. The actual operating conditions will be: a) for single flash cycle $P_1$ = 30 psia Power output = 24 MW; b) for dual flash cycle $P_1$ = 30 psia, $P_m$ = 62 psia and Power output = 27.5 MW.

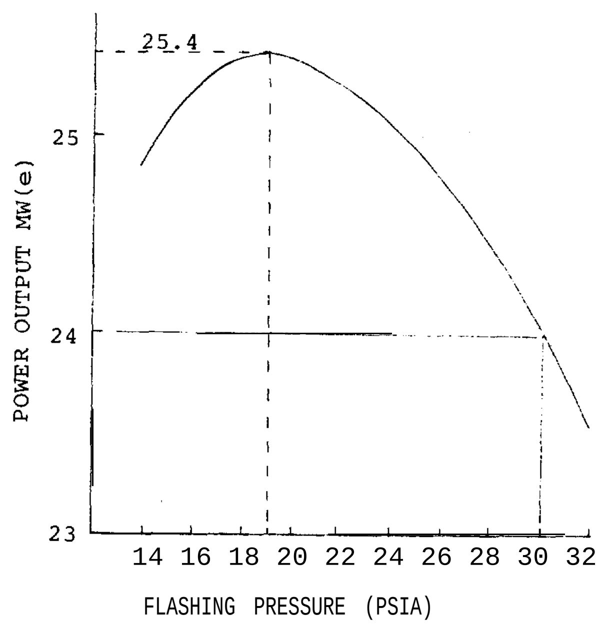


FIG.4 POWER OUTPUT AGAINST FLASHING PRESSURE FOR SINGLE FLASH CYCLE.

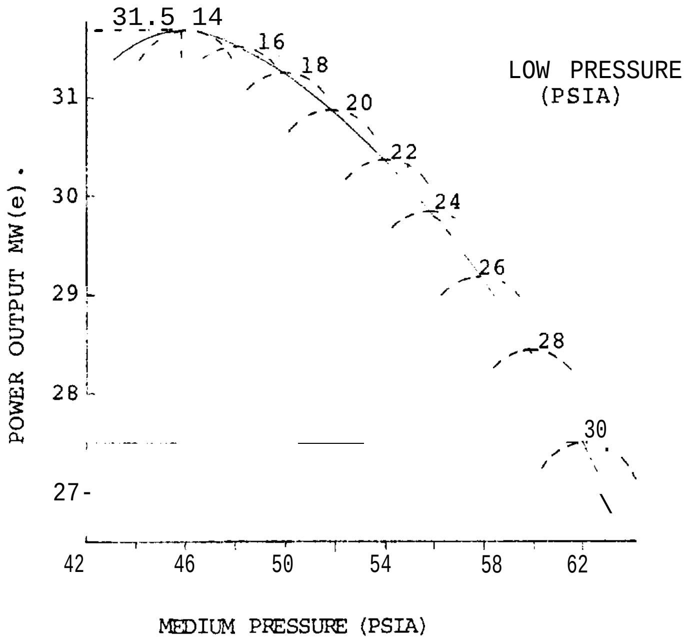


FIG. 5 POWER OUTPUT FOR DUAL FLASH CYCLE.

## REFERENCES


1. Mercado S., Hurtado R., et al. 1977 Selección de Separadores de Baja Presión. IIE Report No. FE-G2-2, México, D. F.
2. ASME Steam Tables, 1977.
3. Dukler A.E, et. al. 1964 Frictional - Pressure Drop in Two-Phase Flow. AICHE Journal Vol. 10 No. 1, P.44-51.
4. Milora S.L. and Tester I.W. 1976 Geothermal Energy as a Source of Electric Power. 1976, MIT Press.