PURIFICATION OF CE-CEBU GEOTHERMAL POWER COMPANY STEAM SUPPLY USING VERTICAL RECYCLING SEPARATORS

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ABSTRACT

Of the three geothermal power plants operated by CalEnergy in Leyte, only CE-Cebu did not include in its configuration any steam purifying system upstream of each turbine, As a consequence, the plant experienced major steam related disruptions and equipment failures during the reliability test operation. This eventually led to the premature repair of its four back-pressure turbines. To address this problem, vertical two-stage recycling separators were installed, and these have been in service since December 1997.

Actual performance of the separator in the removal of moisture and other impurities in steam, and the method used in the determination of its efficiency will be presented in this paper. Also, results of the recently conducted inspections of the turbines will be compared to that of last year's when the plant was operating without the separators.

1.0 HISTORICAL BACKGROUND

Located in Upper Mahiao, Kananga, Leyte, Philippines is a 127.26 MW power plant operating with four Geothermal Combined Cycle Units (GCCU). Each GCCU consists of a 20.31-MW back-pressure steam turbine, and three bottoming units utilizing pentane as the motive fluid, each producing 3.835 MW power. Pentane is evaporated in the vaporizer by the steam leaving steam turbine, and prior to that, preheated by either the condensate or the non-condensable gases coming fiom the vaporizer. Geothermal steam at 150.84 psia is supplied to the plant via two pipelines each more than a kilometer long. In the original configuration, steam was supplied directly to the turbine inlet since the plant had no secondary separators.

Steam fiom any geothermal source contains high degree of dissolved solids, corrosive gases, and when saturated, liquid. These can have detrimental effect on the piping system, instruments, and most importantly the turbine. Primary separators located within the gathering system cannot guarantee the removal of all of these. Besides, no matter how dry, steam condenses as it travels a long distance fiom the source and may form into a water slug which could damage the turbine and other prime equipment on impact. That is why most geothermal power plants included in their design the installation of secondary separators for added protection.

The ill-effects of operating without any separator was felt after the 744-hr reliability test conducted in 1996. Three turbine inlet strainers failed, sending debris to the turbines. This was caused by the overwhelming amount of moisture and carryover solids in steam. Inspection of the turbines showed excessive scale deposition on the inlet nozzles and blades; corrosion and erosion on blades, nozzles, shroud bands, inter-stage sealing fins, rotor, and casing. Vaporizer and pre-heater tubes also got clogged up decreasing their efficiency. This eventually led to the early repair of the turbines and exhaustive cleaning of heat exchanger tubes internals.

The installation of the separators was conceptualized even before the plant was completed. However, it was only after the incident that two units were installed. The centrifugal vertical recycling type was selected fiom among the many types available as this was already tested, besides, there are identical vessels already installed in the Visayas Geothermal Power Company in Malitbog.

2.0 SEPARATOR FEATURES

The installed vertical recycling separators can process large amounts of steam and can handle large amounts of condensate carried in steam (20% by weight). The separator has two stages of separation (Fig. 1). Steam enters the vessel and flows through stationary guide vanes where it comes out into the vortex chamber spinning. Initial separation happens at the vortex chamber where liquid and other impurities are thrown out to the wall by centrifugal force and trickle down to the stilled liquid chamber.

In the second stage, the spinning vapor with some entrained liquid droplets converges towards the center of the vortex chamber, increasing in velocity as it enters the vortex finder tube. The entrained liquid collects on the tube wall and together with some vapor is sucked through a gap in the wall, down the recycling line, and through the central hole in the baffle plate and back into the vortex chamber. The clean vapor comes out of the vessel through the vortex finder tube and past the gap.

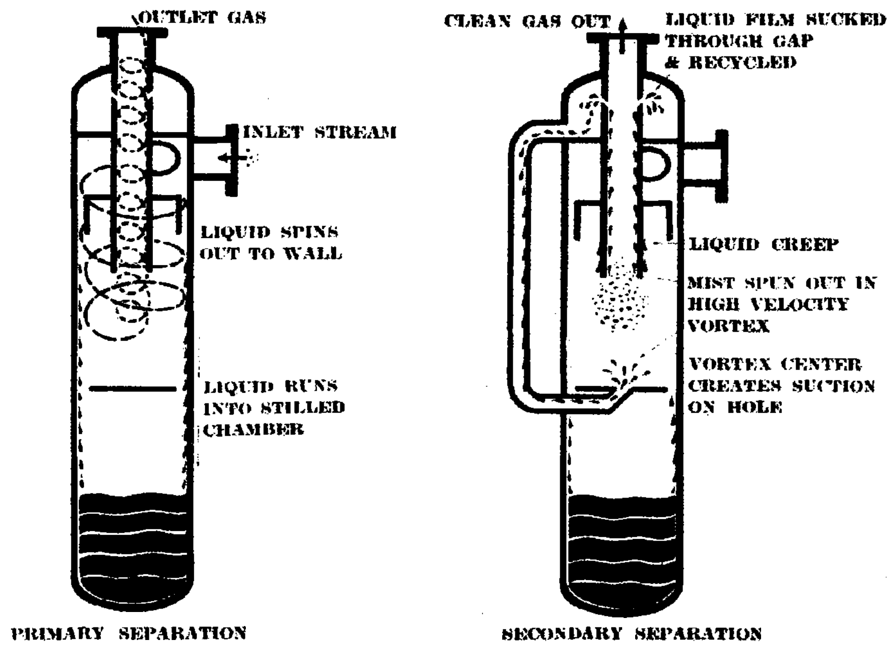

Figure 1. Two stages of separation in a vertical recycling separator.

3.0 PURIFYING SYSTEM

Shown below (Fig. 2) is the steam purifying system setup. Steam enters the separator at 150.84 psia and is processed, separating all the free liquid and most of the entrained liquid from the vapor. Brine collected at the separator liquid chamber is delivered into the flash tank through the 3-inch or 6-inch condensate line. The level control valve maintains the normal liquid level in the separator. The dump valve, on the other hand, only opens during upset conditions or when the high level switch (not shown) is activated.

For measurement purposes, a multi-port isokinetic sampler for steam was installed on a vertical downflow pipe upstream of the separator. A liquid sampling port is also located on the condensate line after the separator, before the level control valve.

4.0 SEPARATOR EFFICIENCY

Outlined below are the procedures used in determining the efficiency of the separators in removing solid impurities and moisture. These procedures were based on the efficiency test conducted on identical vessels installed in VGPC.

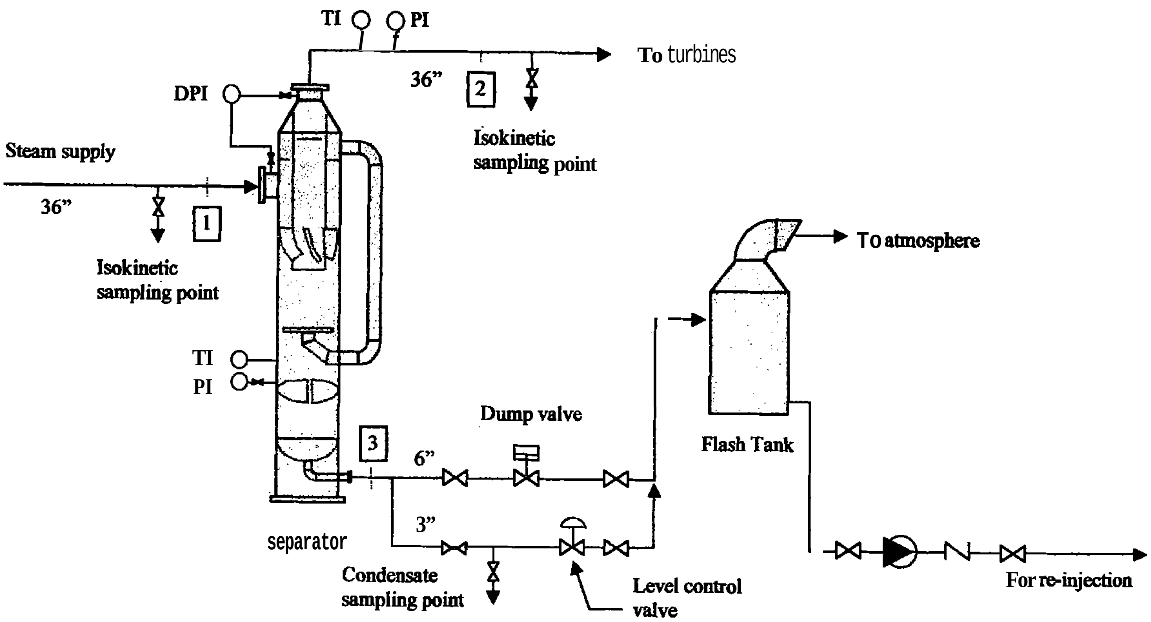

Figure 2. CE-Cebu steam purifying system.

Determining Solid Impurities Removal Efficiency:

- Samples were taken from the isokinetic sampler located before and after the separator, and the sampling point on the condensate line after the separator.
- Steam supply flow rate, $\dot{m}_1$, was also taken.
- Samples were analyzed in the laboratory using the Atomic Absorption Spectrophotometer (AAS). So that, the concentrations of Sodium (c_1 for the entering steam, c_2 for the leaving *steam,* and c_3 for the brine) were known.
- Flow rate for brine, and steam leaving the separator, $\dot{m}_3$ and $\dot{m}_2$, respectively, were calculated by solving the following equations simultaneously:

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_3 \qquad (1)$$

$$\dot{m}_1 c_1 = \dot{m}_2 c_2 + \dot{m}_3 c_3 \qquad (2)$$

- Efficiency of the separator in removing impurities was then determined using the following equation:

$$\eta = \dot{m}_3 c_3 / (\dot{m}_1 c_1) \qquad (3)$$

As of this writing, the data required in calculating the efficiencies of the separators following the procedures above were not available. However, with these units being identical to those in VGPC, their efficiency could be assumed to be somewhat the same. Tabulated below (Fig. 3), are the results of the efficiency test conducted on the VGPC separators.

Unit	Flow Rate (tons/hr)			Concentration of Na (ppm)			Efficiency
	Steam		Brine	In steam		In Brine	
	Inlet	Outlet		Inlet	Outlet		
1	482.5241	481.2651	1.2591	0.3201	0.0251	113.1861	92.36%
2	460.796	459.201	1.595	0.388	0.012	108.845	97.02%
3	467.667	465.462	2.204	0.499	0.015	102.783	97.07%

Figure 3. Efficiency of the separators determined using Sodium as analyte.

Above table showed a very efficient scrubbing of the impurities from steam. Sodium ion and most of its compounds are highly soluble and go with the liquid in steam, and thus, is also indicative of the efficiency of the separators in the removal of moisture.

5.0 PRESSURE DROP

Pressure drop across the vertical separator *can* be estimated using the following quation used by Porta-Test:

$$\Delta P = (0.1872\, \dot{m} / C)^2\, v \quad (4)$$

where: $\dot{m}$ = mass flow rate of steam, lb/hr
v = specific volume of entering vapor, ft^3/lb
C = flow coefficient, equal to **287,600** for this vessel

Given a mass flow rate of steam equal to **1,123,447.5** lb/hr and the specific volume of entering vapor at **3.07028** ft3/lb, the computed pressure drop is only minimal at **1.48** psi.

6.0 INSPECTION RESULTS

Pictures taken of the turbines during the recently conducted inspection (after more than a year of operation with the separators online) showed blades, nozzles, and other internals to be of much better condition than before the installation of the separators. Scale deposition, corrosion, and erosion were very much less that only minor repairs were performed on the turbines. Also, clogging of the heat exchanger tubes were not as severe as before so that only minimal cleaning was required.

Shown below (Fig. 4a - 11) are pictures of some turbine parts in the as-found condition:

A) Before the separators were installed

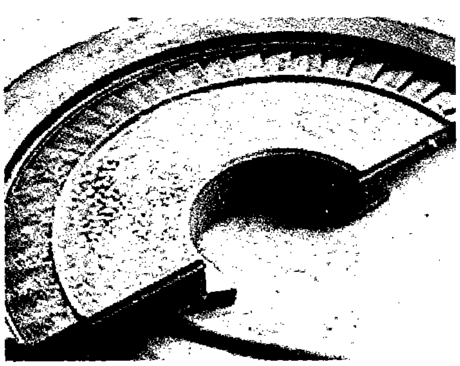

Figure 4a First stage diaphragm (lower half).

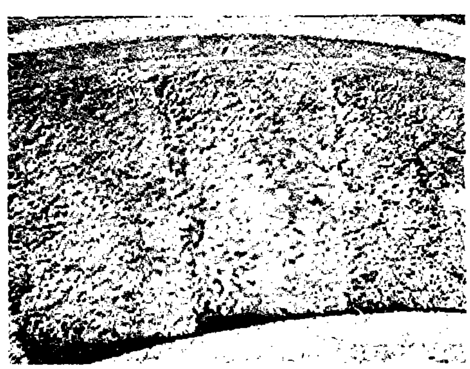

Figure 4b. Close-up of the nodes.

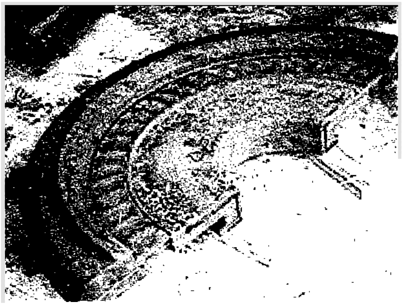

Figure 5a. First stage diaphragm (upper half).

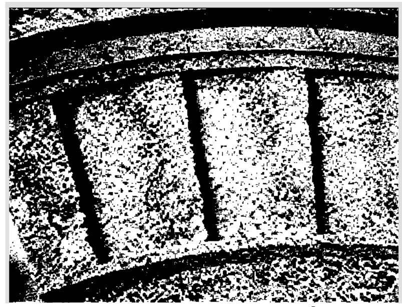

Figure 5b. Close-up of the nodes.

Figure 6. First stage rotating blades.

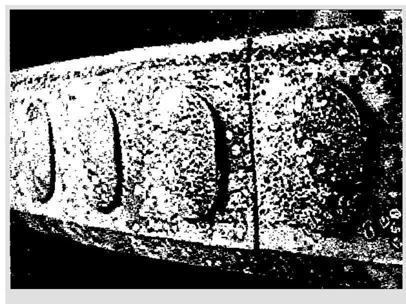

Figure 7. First stage shroud

B) After the separators were installed

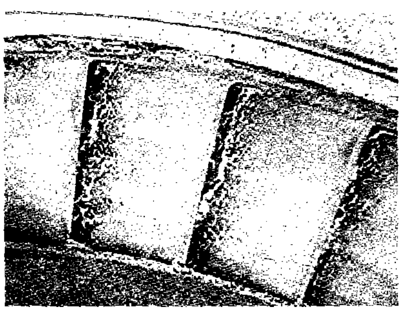

Figure 8. First stage diaphragm nozzles (upper half).

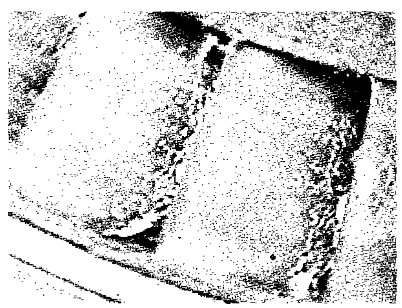

Figure 9. First stage diaphragm nozzles (lower half).

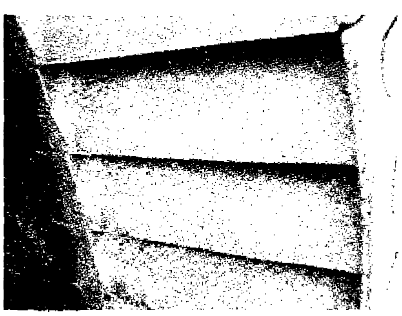

Figure 10. First stage rotating blades

Figure 11. First stage shroud.

7.0 CONCLUSION

The installation of the separators proved to be beneficial in that they served as checkpoints for solid particles as well as excessive moisture (water slug) carryover in steam which could have otherwise caused catastrophic damage to the turbines and other prime equipment. Such installation could help minimize the routine turbine overhaul maintenance costs, increase life cycle efficiency and maintain the operating availability of the steam turbines, and avoid steam-related emergency shutdowns.

Initial costs in the installation of the purifying system may be high. However, with the savings on maintenance costs, the capital can be recovered in such a short time - about two to three years of operation in our case.

For economic reasons, it is considered proper and prudent engineering practice for geothermal power plants to be designed with secondary separators.

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Porta-Test Recycling Separators Catalog