Flash Evaporator Studies at LaCygne Unit 2

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1.0 Introduction

A flash evaporator is an evaporative distillation process designed to produce high purity condensate make-up by distilling water which contains solids. This process was a common design for many years in steam power plants to purify make-up water. It still remains popular for applications which do not require the highest purity water. However, flash evaporators can be thermodynamically expensive depending on the location of the steam supply point to the evaporator. In recent years, advances in power plant water chemistry have made other water purifying processes such as the use of ion exchange demineralizers more popular for applications requiring very high purity water.

Kansas City Power and Light's LaCygne Unit 2 original design contains a flash evaporator which is used for purifying make-up water to the system. For several years, personnel at LaCygne have wanted to replace the Unit 2 flash evaporator with an ion exchange demineralizer system for two reasons: (1) they believed it was less costly than running the flash evaporator, and (2) they wanted a back-up make-up supply for Unit 1, a once-through supercritical unit. Because of its design, the make-up water purity requirements for Unit 1 are higher than those for Unit 2. The make-up water from the Unit 2 flash evaporator is not pure enough for Unit 1.

To justify the conversion to an ion exchange demineralizer system, LaCygne personnel wanted to determine the cost of running the flash evaporator. To study this, Kansas City Power and Light contracted with Performance Engineering, Inc. (PEI) to build a PEPSE model of the LaCygne Unit 2 turbine cycle and run sensitivity studies comparing the unit heat rate at various flash evaporator supply points.

The development of the PEPSE model and the results of the flash evaporator study are presented.

2.0 Unit Description

2.1 Overall Unit

LaCygne Unit 2 has a pulverized coal, single reheat, subcritical, drum-type boiler. Full load is approximately 700 MW at a main steam flow of 4.2 x 10^6 lb/hr. Design main steam and reheat temperatures are 1000 °F, and design main steam pressure is 2400 psig. The boiler was designed by Babcock and Wilcox and the turbine-generator was designed by General Electric. Figure 1 shows the turbine vendor heat balance schematic of Unit 2.

The unit is located approximately 40 miles south of Kansas City. It became operational in 1979.

2.2 Flash Evaporator

The flash evaporator is a Westinghouse single stage horizontal type with an integral deaerator, brine heater, and vapor condenser. It was designed to supply a maximum of 82,500 lb/hr of make-up water during normal operation. Figure 2 shows an operator's console diagram of the flash evaporator.

Hot steam to the evaporator is supplied through a variety of sources: (1) main steam, (2) hot reheat, (3) #6 extraction (#1 is the highest pressure), (4) Unit 2 auxiliary boiler, or (5) Unit 1 cold reheat. Main steam and the #6 extraction are the usual supply points. The steam is used to heat the "brine" entering the evaporator. When the supply is from main steam, it must be cooled by means of a desuperheating spray before entering the evaporator.

Hot brine is sprayed into the flash chamber, where, under vacuum, the high purity steam is formed as impurities are left behind in the brine. Demisters separate residual moisture from the steam, allowing the water droplets to fall back into the brine in the flash chamber. The steam is then condensed and is pumped away through the distillate pumps. The condensate is then cooled in the distillate heat exchanger, enters the cation and anion station ("C&A"), and then enters the distillate (condensate) storage tank.

Make-up to the evaporator passes through sodium zeolite softeners before entering the distillate heat exchanger. This preheats the make-up before entering the evaporator.

3.0 PEPSE Model

A detailed PEPSE model of both the LaCygne Unit 2 turbine cycle and the boiler were developed by PEI personnel. For the flash evaporator study, however, only the turbine cycle model was employed. The PEPSE turbine cycle model with the flash evaporator included appears in Figure 3. Figure 4 shows the flash evaporator detail of the PEPSE model which appears in the lower left corner of Figure 3.

4.0 Study

Performance of the turbine cycle with the evaporator in service and out of service was studied using two evaporator steam supply points, the #6 extraction and main steam.

Recall that the evaporator may be supplied by as many as five different steam locations, although these are the two most common supply points.

The base case represents the valves-wide-open (VWO) PEPSE results based on the turbine vendor heat balance without the flash evaporator in service. Case 1, also at VWO, has the evaporator in service with 95,000 lb/hr of steam supplied to the evaporator from the #6 extraction. Case 2, again at VWO, has the evaporator in service with 65,000 lb/hr of steam supplied to the evaporator from main steam and 30,000 lb/hr of desuperheating spray to cool the steam before entering the evaporator. Finally, Case 4 is the same as Case 3 except with a main steam evaporator supply flow of 95,000 lb/hr and a desuperheating spray flow of 60,000 lb/hr. Table 1 below presents the results of the four cases. All cases were performed at an evaporator efficiency of 100%, i.e., 100% heat transfer between the evaporator steam and the brine heater.

Table 1
PEPSE Flash Evaporator Results

CASE	DISTILLATE FLOW RATE (LB/HR)	GENERATION (MW)	HEAT RATE (BTU/KW-HR)
Base	0	707.7	7,978
Case 1 (95,000 lb/hr #6 ext)	70,000	707.3	7,983
Case 2 (65,000 lb/hr main stm)	38,000	699.1	8,107
Case 3 (95,000 lb/hr main stm)	60,000	694.5	8,188

Note: Final distillate conditions - 145 °F and 25 psia exiting distillate heat exchanger.

These three cases (plus the base case) were chosen because they represent typical operating conditions at the plant.

5.0 Conclusions

Under some conditions, such as supplying the evaporator with #6 extraction steam, operating the flash evaporator causes only small performance changes in the cycle. Under other conditions, however, such as supplying the evaporator with high quality main steam, system performance suffers greatly (see Table 1). This is because steam that could be used to produce power is now used for the evaporator to produce make-up. Also, this steam is cooled significantly and the pressure reduced significantly (through a pressure reducing valve) before reaching the evaporator - very costly from a thermodynamic standpoint.

Although the cost of running the flash evaporator can be low under certain operating conditions, it does not produce the higher purity make-up water needed to serve as back-up for the Unit 1 make-up water. This, coupled with the potential high cost of running the flash evaporator as determined from the PEPSE study, led engineers at La-Cygne to recommend that Unit 2 go to an ion exchange demineralizer for purifying make-up.

Flash evaporators may impact cycle performance and cycle thermodynamics significantly. Thermodynamic and heat balance tools such as PEPSE can be valuable in assessing these impacts.

PEPSE is a registered trademark of NUS Corporation.

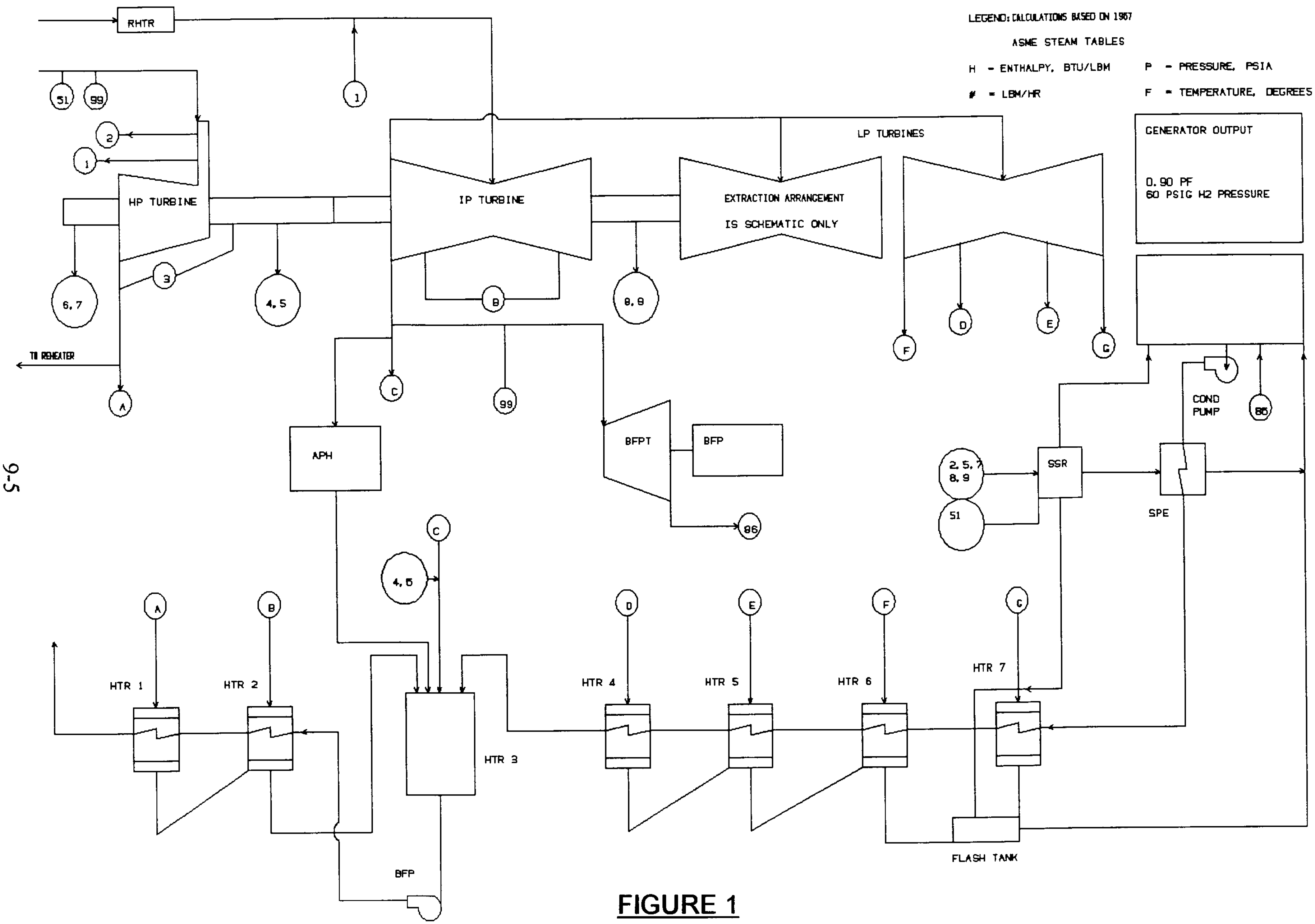

FIGURE 1

LaCygne Unit 2 Heat Balance Diagram

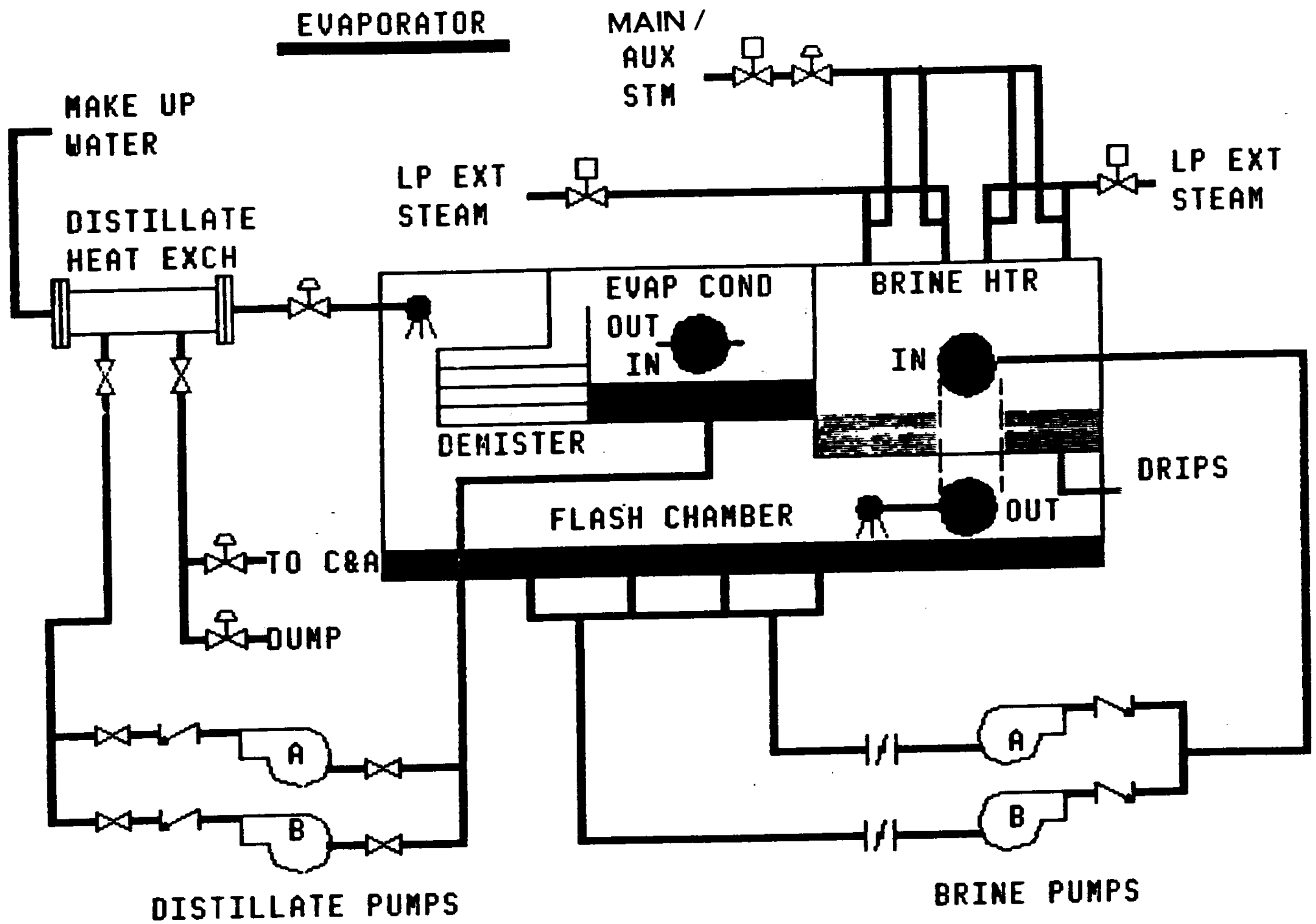

FIGURE 2

Flash Evaporator Diagram

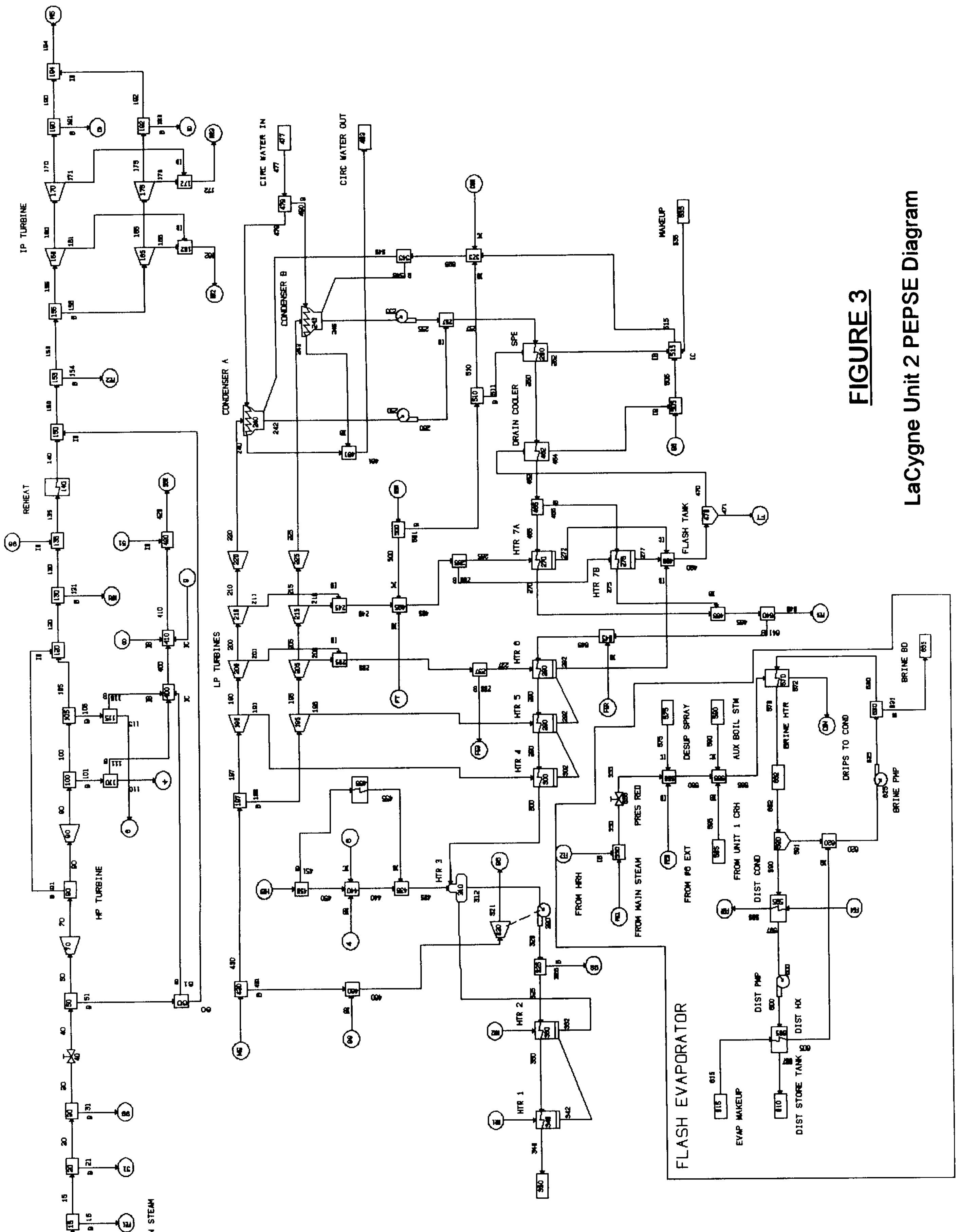

FIGURE 3

LaCygne Unit 2 PEPSE Diagram

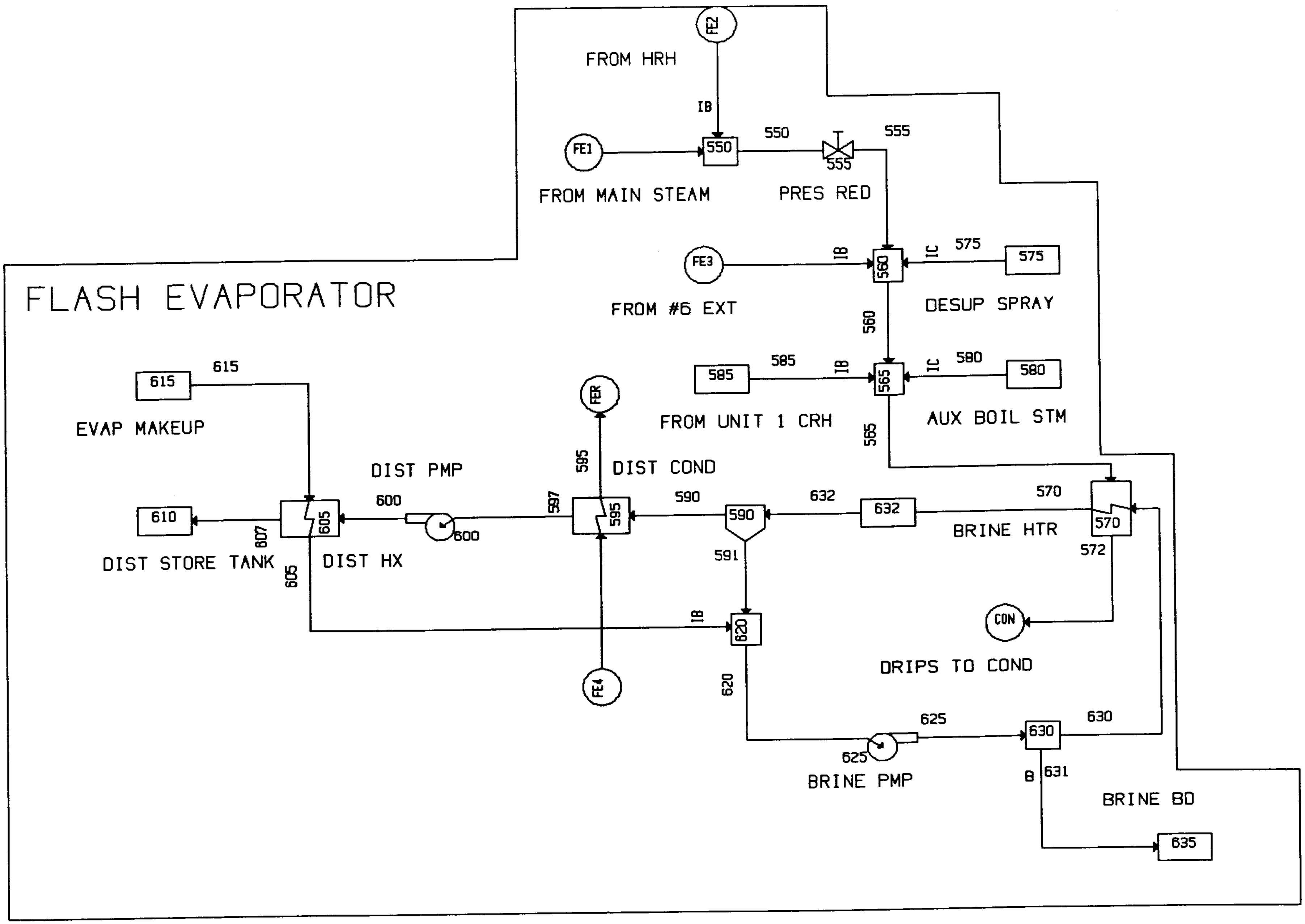

FIGURE 4

PEPSE Flash Evaporator Detail