HITTING A HOME RUN!! --- A CONDENSER SUCCESS STORY

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Abstract:

The largest single factor that can affect turbine cycle efficiency within a generation station is the heat transfer of the condenser. Depending on turbine design, poor condenser performance can cost as much as 7% in extra fuel being consumed. Thus, maintaining condenser performance can be of benefit not only economically to the plant but also to the environment. The factors affecting condenser heat transfer are; tube-sheet macro fouling, tube deposits, air in-leakage and air removal pump condition. This paper is a comprehensive look at Chalk Point's Unit #2 condenser performance during the year 2000 and the corrective actions taken in 2001 to improve unit backpressure by 2.5 in.Hg.

This condenser began the year 2000 with the actual backpressure at design conditions. This paper details how, over the next twelve months, condenser performance deteriorated to the point where the actual backpressure had risen to 2.5 in.Hg. above design. Because the unit was forced to run on one circulating water pump for a period of eight weeks, factors such as tube-sheet macro fouling, tube fouling deposits and silting was accelerated. The demand for MWs during the summer, meant that the unit had to operate during the entire bio-fouling season without cleaning the condenser water boxes. In addition to the fouling problems, air in-leakage began to increase in September 2000 and its effect soon became as significant as the performance loss due to fouling. The air in-leakage was caused by a failure of the cross over expansion joint in the Low Pressure turbine combined with the rupture of the steam seal supply line to the gland seals. These sources of air in-leakage were discovered only one month prior to the overhaul through leak tests conducted with helium injection. Compounding the effect of the air in-leakage was the fact that one air removal pump was due for a complete overhaul and the other pump was in need of repair.

Introduction:

The Chalk Point Generating Station is owned and operated by MIRANT. It is located on Eagle Harbor Road in Aquasco, Maryland at the confluence of the Patuxent River and Swanson Creek in the southeastern corner of Prince George's County. The ambient air temperature varies from -15"F to 107'F. The site is approximately 15 ft above sea level.

Chalk Point Units 1 and 2 are identical B&W supercritical, once-through, double reheat, regenerative cycle boilers and were converted to balanced draft design. Each unit is rated for 355 MWs. The furnace is of the open, water-cooled, dry bottom type. These units are designed to burn pulverized coal through the front and rear wall burners. The boilers are designed for a maximum rating of 2,500,000 LB/hr main steam flow at superheated outlet conditions of 1000 F and 3,575 pig. At this rating, the reheat outlet conditions are 1050 F at 1020 pig and 1000 F at 315 pig for the first and second reheat stages, respectively. The condensers were built by Worthington and are designed to condense 1,450,000 Lbs./Hr. of steam with a heat rejection of 1,435,000 BTU/Hr. At circulating water inlet temperatures of 59 degrees F the design Back-pressure with a cleanliness factor of 85% is 1.11 " Hg. The circulating water system consists of two half capacity Worthington pumps rated at 125,000 GPM driven by GE motors rated at 600 HP. The circulating water system is counter-flow to the river with the discharge canal extending over one mile upstream of the inlet structure to the condenser. The intake structure is downstream of the discharge canal and brackish water from the Patuxent River is directed by the inlet canal to the intake structure, which houses the pumps and inlet screens. The river water temperatures vary from 32 degrees in the winter to 90 degrees F in the summer. The condenser tubes were originally made of Aluminum Bronze material and were replaced with Titanium tubes in 1987-88. There are four waterboxes to each condenser and each box is once through. These units are also equipped with an Amertap online cleaning system.

Units 1 and 2 are each equipped with two Worthington reciprocating piston vacuum pumps which are connected together by a common header leading to each of the air removal sections of the condenser. The discharges from each of the air removal pumps are tied together and exit through a common silencer before exiting the building into the atmosphere. The unit is designed to run with only one vacuum pump in service. However, due to the air leakage caused by two Low Pressure turbines and their gland seals, (even when the seals are in good condition), both air removal pumps remain in service for efficient operation of the condenser.

Condenser performance monitoring on these units is accomplished using data obtained from the Process Information system and additional testing conducted by vendors and plant personnel.

INITIAL CONDITIONS JUNE 2000:

Unit #2 was on an extended outage during the spring of 2000. It was in March that all of the condenser maintenance activities were performed such as bullet cleaning of the condenser tubes and any air leakage repairs. This unit did not return to service until June and due to low circulating water flow while the unit was off-line, much of the tube cleaning benefit was not realized due to silt build up in the tubes. The importance of maintaining the proper circulating water velocities through the condenser will be discussed later in this paper. The following were the initial conditions of the condenser when the unit returned to service:

	ACTUAL	DESIGN
LOAD	355 MWS	355 MWS
CW INLET TEMP.	77.5 F	59 F
CW TEMP. RISE	14.9 F	14.0 F
BACKPRESSURE	2.6" HG	2.2" HG @ 77.5 F
HOTWELL O2 PPB *	2.8 PPB	<5 PPB

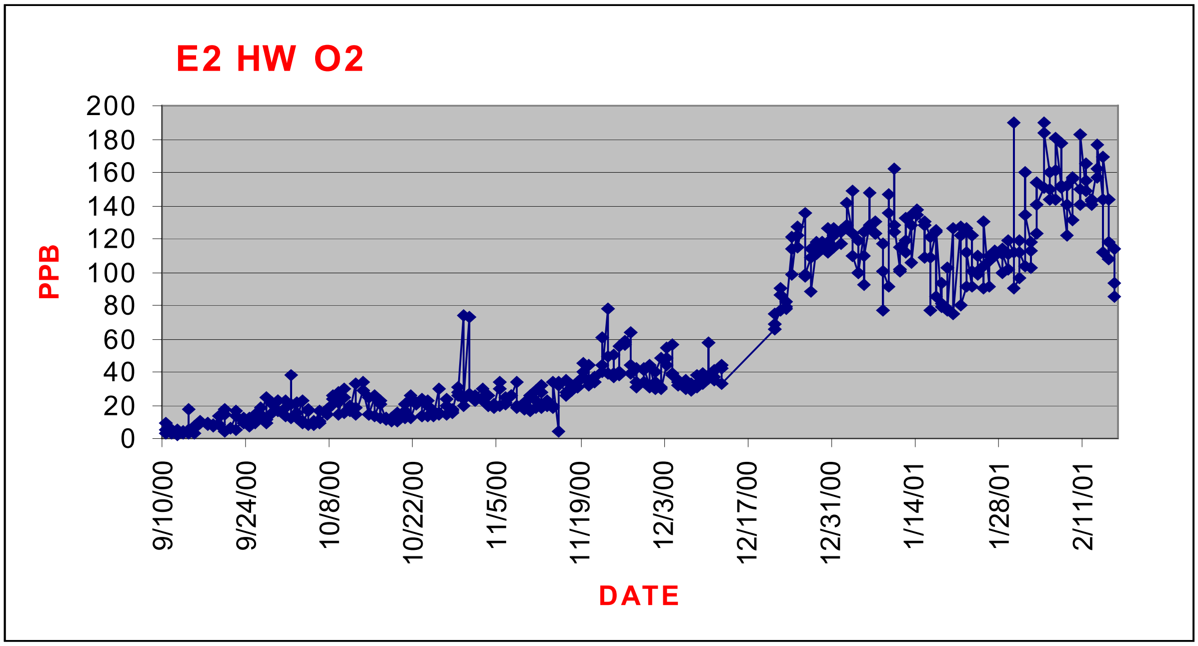
***Notice that condenser air in-leakage was not a problem in June 2000.**

CONDENSER AIR LEAKAGE:

HOTWELL DISSOLVED OXYGEN:

A very important part of condenser monitoring is the ability to determine the effectiveness of the air removal capabilities of the condenser and the amount of air leakage that the condenser may be experiencing. A necessary part of this monitoring is the dissolved oxygen analyzer that determines the oxygen content of the condensate leaving the Hotwell. Chalk Point is fortunate enough to have an on-line analyzer that is connected to the Plant Information system.

Below is a graph of the gradual increase in Hotwell dissolved oxygen beginning in Sept. 2000:

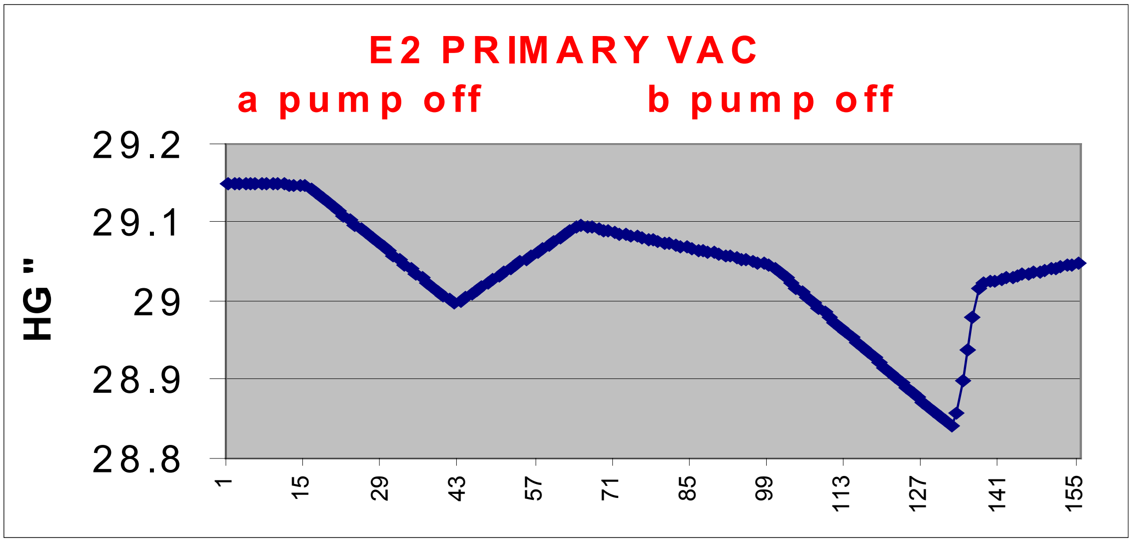


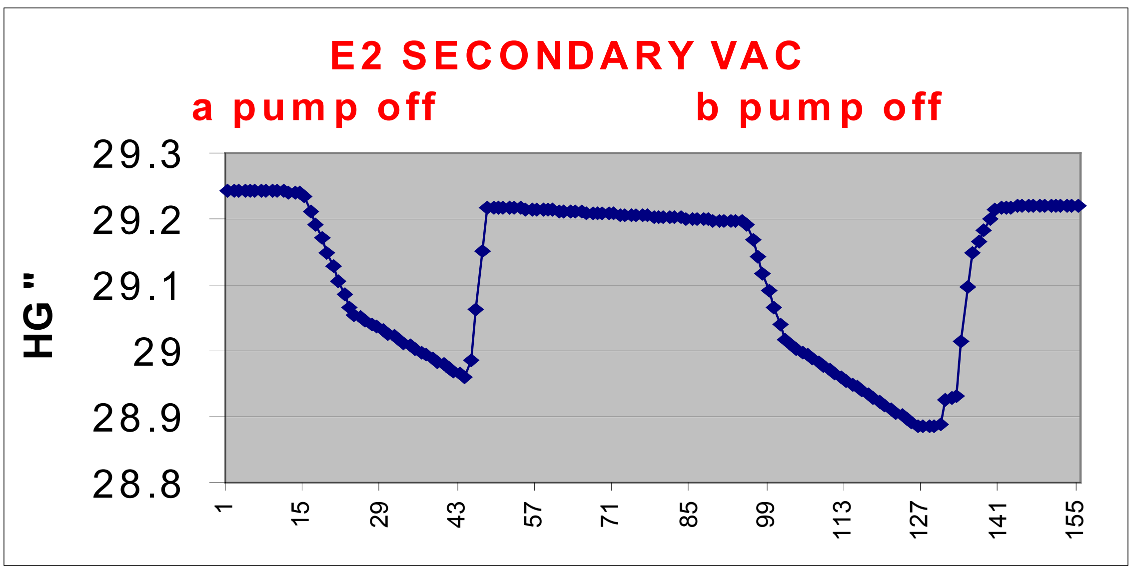
AIR REMOVAL PUMP TESTING:

It was noticed that the level of Oxygen was increasing in the condensate from the hotwell. As a result, tests were performed on the air removal pumps in order to determine their condition. The test of the air removal pump involves shutting each pump off while the load remains constant and recording the following:
Unit Backpressure
Circulating Water Inlet Temperature
Hotwell Temperature
Hotwell Oxygen Content
Air Removal Pump Motor Amps (Taken while both pumps are in service)

Fortunately, because of the many tests that have been conducted a baseline has been established for this unit during these tests. With a tight condenser and when air removal pumps are in good condition, when a pump is removed from service, the average increase in Hotwell O2 is 5 PPB with a negligible increase in back-pressure and a one degree increase in hotwell temperature.

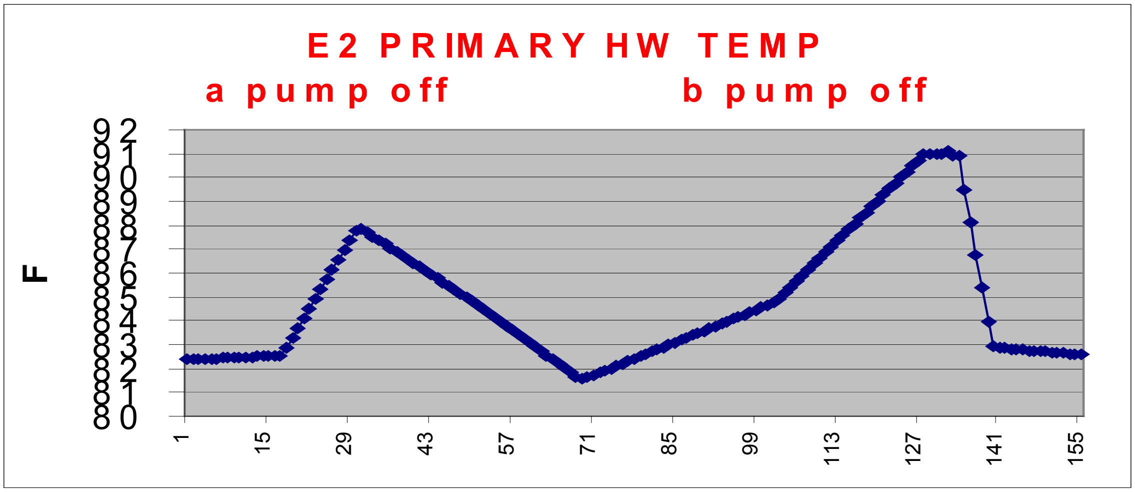
The following graphs indicate the vacuum response from a typical air removal pump test :

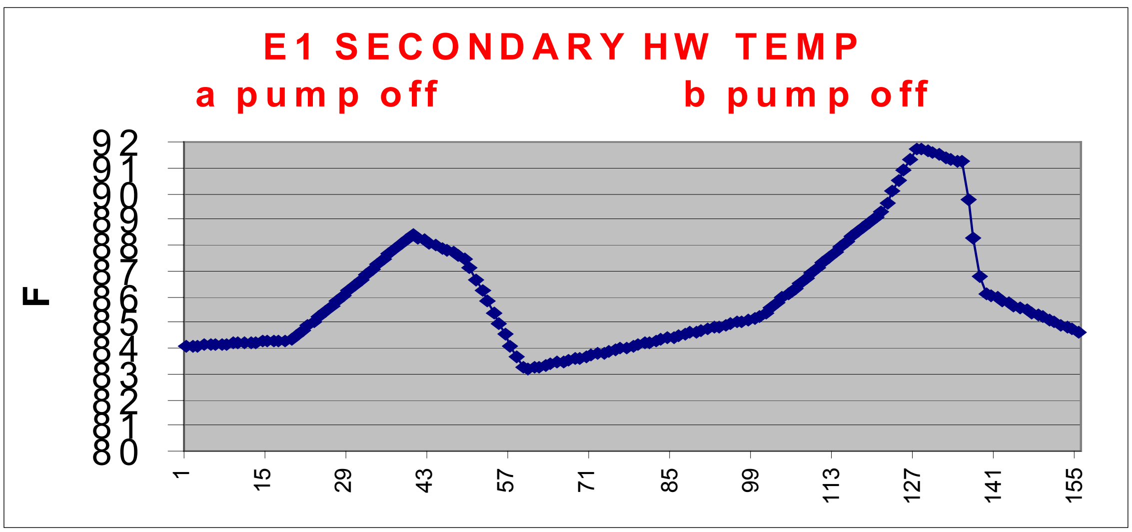


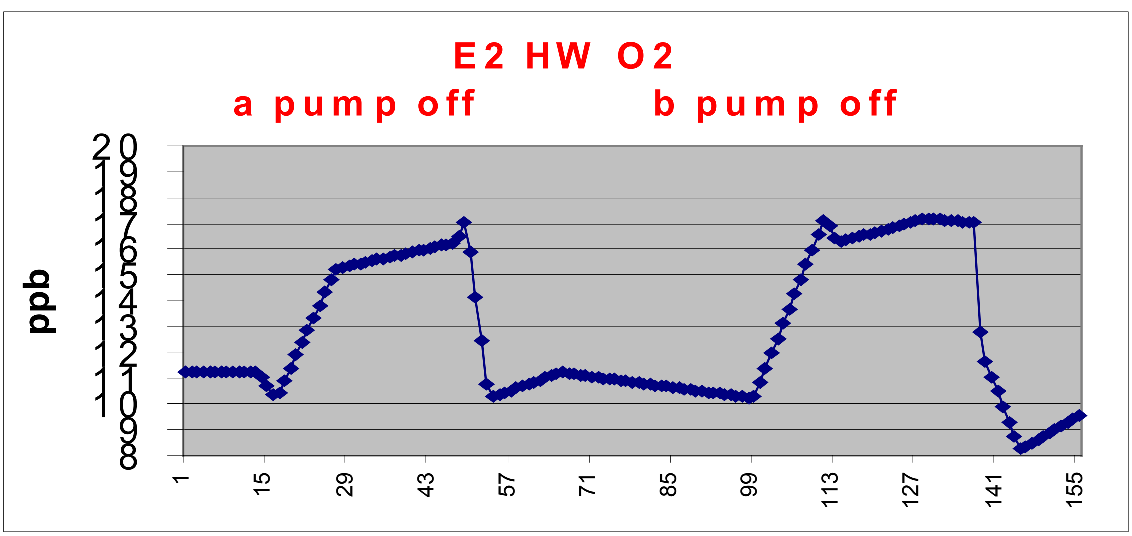


From the graphs above and the graphs on the following page, one would begin to make the conclusion that the B pump is removing more non-condensable gas than the A pump. Another tool that can be used to determine air removal pump condition is the trending of the motor amps of the pumps. It has been our experience that as a one pump begins to deteriorate, the amps on the motor decrease while the amps on the motor of the good pump increase. Trending of the air removal pump motor amps, along with the air removal pump testing, has been an accurate method of determining air removal pump condition.

The graphs below indicate typical hotwell temperature and dissolved oxygen response when air removal pumps are taken off:







HELIUM LEAK TESTING:

These units are periodically tested for air leakage using the conventional method of filling the hotwell to the expansion joint with water. Filling the condenser with water to the expansion joint is a very quick and easy method of finding air leakage below the expansion joint. During these tests it is common to locate approximately a dozen small areas of air leakage. This supercritical cycling unit runs approximately 100 days between boiler leaks, so that the opportunity to perform this test occurs approximately four times a year when the unit is brought off-line. Unfortunately however, this type of test does not identify any leaks that may exist on the turbine deck. The best method of identifying leaks on the turbine deck is by use of helium injection. The air leakage check during a short outage in the Fall failed to indicate any major leaks below the expansion joints, therefore it was decided to contact Conco to perform a helium leak check to help us locate and eliminate any air leakage on the turbine deck. Helium leak testing was performed by Conco services in February of 2001. The following list indicates the location and severity of leaks identified by the Helium leak test: (This test was conducted just prior to the Spring overhaul.)

Turbine Deck:

Secondary Low Pressure Cross-Over expansion Joint --- 60,000 divisions

Secondary Low Pressure West Gland Seal Packing --- 36,000 divisions

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Mezzanine Level:

Secondary Condenser South Expansion Joint --- 18,000 divisions
(Helium may be carrying over to Cross-Over expansion joint)

Secondary Condenser North Expansion Joint --- 1,800 divisions

Basement:

No leaks

Note: The term “divisions” refers to the level of response as indicated by the Helium leak detector.

The helium testing confirmed the theory that the air leakage had to be coming from above the expansion joints and located the leaks on the turbine deck. The major leaks of the cross-over expansion joint and the steam seals on the low pressure turbine were definitely large enough to cause problems with the heat transfer to the condenser tubes due to air leakage. The response times of these leaks was almost instantaneous, it took less than 20 seconds for the helium to arrive at the sample point just downstream of the silencer, which is located approximately 150 feet away from the air removal pumps.

LOW PRESSURE CROSSOVER JOINTS:

Upon disassembly of the low pressure cross-over, significant damage to the bellows expansion joint was found. The pictures below indicate the actual damage that produced an over-range during the helium leak test of over 60,000 divisions.

STEAM SEAL PIPING:

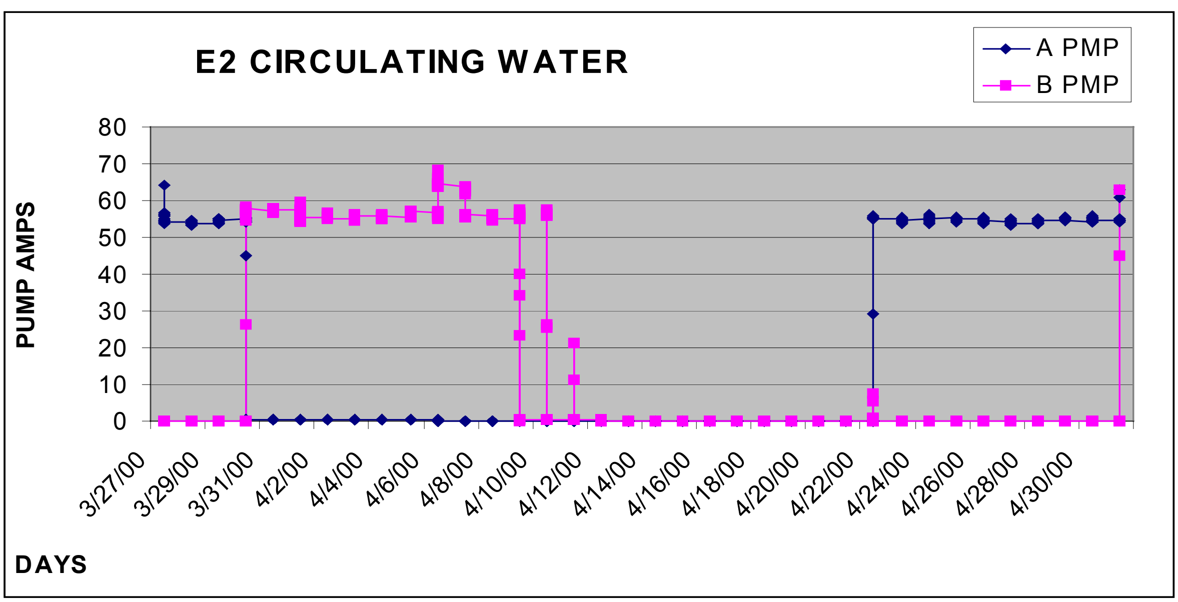
As the dissolved oxygen began to increase in the hotwell, it was determined to be a serious problem when the concentration exceeded 20 PPB, (parts per billion). The first assumption that was made was that the steam seals on the low pressure turbine were beginning to deteriorate. As a result of this assumption the pressure on the steam seal header was increased to compensate for any additional clearance in the steam seals. However, when the pressure to the steam seals was increased, there was no decrease in the dissolved oxygen in the hotwell. Since increasing the steam seal pressure had no effect, it was theorized that the steam seal piping inside the LP turbine may be leaking. This condition had occurred in cycling units #3 and #4, but had never occurred in our base loaded units.

It was suggested at this time to increase the suction created by the steam packing exhauster in order to determine any response in the dissolved oxygen. During this test as the steam packing exhauster vacuum was being increased, the additional load on the exhauster motor caused it to trip. Much to everyone's surprise, the back-pressure on the condenser decreased along with the dissolved oxygen content of the hotwell. This led us to believe that there was a serious problem with the steam seal lines, causing us to place a high priority on the inspection of this piping during the overhaul. The leakage rate of 16,000 divisions obtained during the helium testing confirmed a significant problem in the steam seal area. Upon inspection, the steam seal piping was found to be ruptured in several places; this not only allowed air to leak into the condenser, but the steam leak also added to the heat load of the condenser. Unfortunately, no pictures taken of the damaged area of the steam seal piping.

BIOFOULING:

LOW CIRCULATING WATER FLOW CAUSES SILT BUILD-UP:

Although the condenser was cleaned using metal cleaners, the unit was not immediately returned to service due to the extended work performed during the overhaul. During this time, the circulating water system needed to be placed into service to support the auxiliary equipment in the plant. It was decided that in order to save on plant station service, that only one circulating water pump would be run on the condenser being placed into service. As a consequence, the tube water velocity fell to just 3.4 ft/sec, which is only half of its designed value. This condition led to accelerated silt build-up within the tubes. The following graphs indicate the length of time that each condenser was being operated with only one pump in service.



CONTINUOS SUMMER OPERATION:

After returning to service from the overhaul, the condenser remained in service until October with no opportunity to clean the waterboxes of macro-fouling. The pictures below are an indication of the amount of debris and accumulation of growth that units 1 and 2 see every summer. Since being forced to reduce and replace the chlorine injection with non-chlorinated circulating water treatment, the amount of macro-fouling due to garvia has increased dramatically. The injection rates of the sodium hypochlorite are currently being increased and under study in order to reduce the amount of garvia growth. As illustrated in the picture, when we are not fighting garvia, leaves become a serious concern in the fall.

BULLET CLEANING:

Each year unit 1 and 2 condensers are cleaned using mechanical scrappers that are specifically designed for the unit's tube ID and wall thickness. This activity is performed by Conco services and is usually completed on a straight time basis in four to five days. There have been occasions, however, when the cleanings needed to be completed in a single weekend and during those times all 25,000 tubes were shot in less than 24 hours. Conco is our service provider of choice due to their familiarity of our plant and their excellent track record.

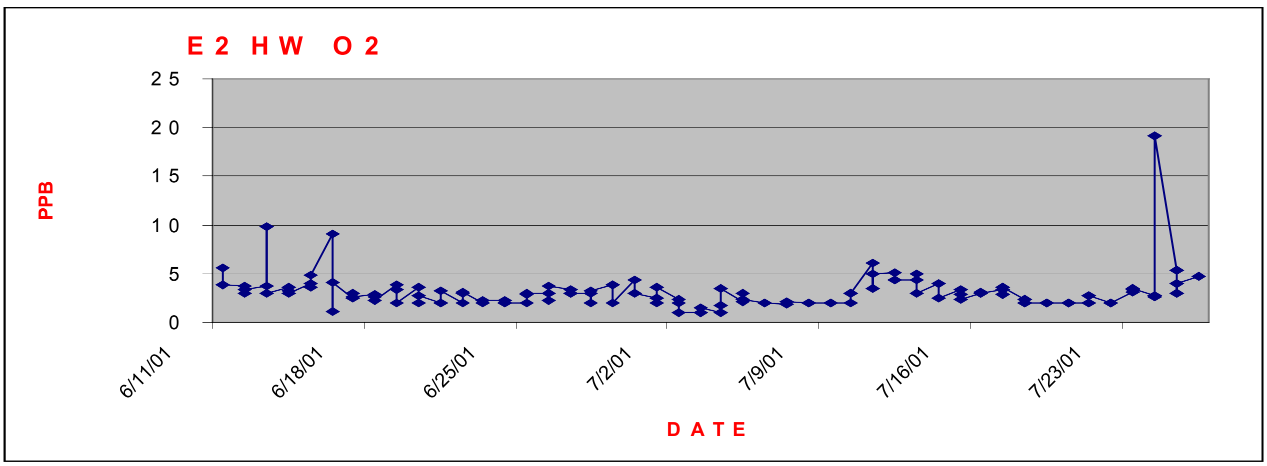
The selection of tube cleaner design depends on the mineral analysis of the deposit. During the cleaning process, tube deposit samples are taken and an ultimate analysis of the sample is performed. Also, the total deposit weight is tracked and is used as a basis to determine if more frequent cleanings of the condenser are required. When chlorine was used to control biological growth, manganese was a large component of the tube deposit and due to the hardness of the deposit, a stiff cleaner had to be used. However, a majority of our deposit is now silicon and iron and as a result of this relatively soft deposit, we now use a cleaner with flexible blades.

During this last cleaning of unit #2 a video of the cleaning process was taken from inside the tube with a specially designed camera. One of the surprising findings of the video was that the garvia attached to the inside surface of the tube was not removed by a 300 psig water flush. (A small portion of this video will be shown during the presentation of this paper)

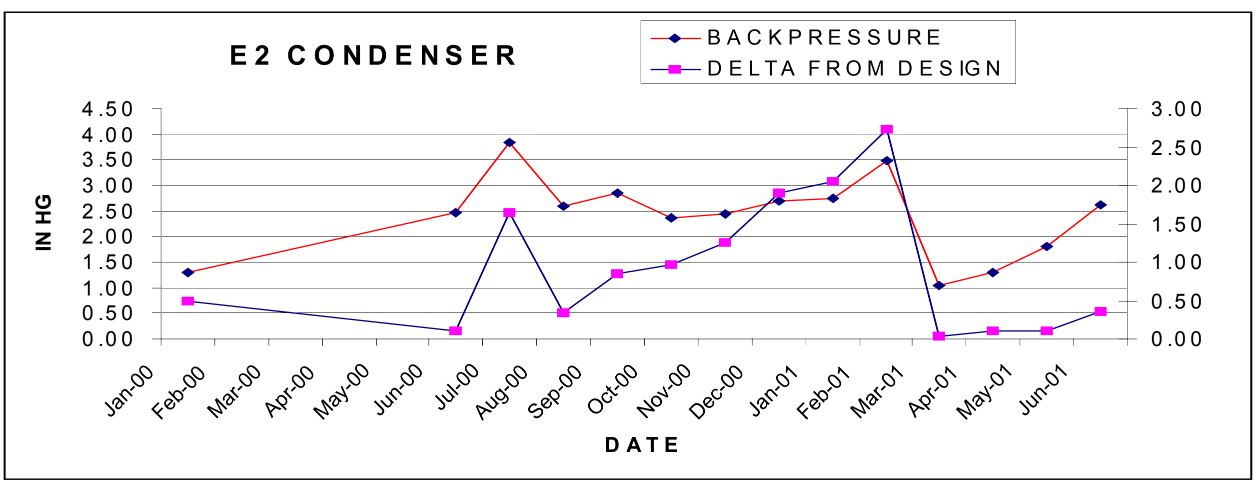
FINAL RESULTS:

CONDENSER AIR LEAKAGE:

The air leakage rate on Unit #2 continues to be under control and the air removal pumps appear to be sufficient for removing non-condensable as evidenced by the following graph:



The chart below indicates the condenser performance before and after the overhaul. It should be noted that in February prior to the overhaul that the performance delta from design was +2.7 " Hg.



The following table summarizes the results comparing June of 2000 to June of 2001:

	DESIGN	JUNE 2000	JUNE 2001	UNITS
LOAD	**355**	**355**	**355**	**MWS**
CW INLET TEMP	**59**	**77.5**	**81.0**	**DEG F**
CW OUTLET TEMP	**14**	**14.9**	**14.0**	**DEG F**
BACKPRESSURE	**1.25**	**2.6**	**2.6**	**IN HG**
BP DELTA FROM DESIGN		**.6 @ 77.5 F**	**.2 @ 81.0 F ***	**IN HG**
HOTWELL O2	**<5**	**2.8**	**3.4**	**ppb**

*** Notice that the backpressure benefit from the cleaning is being maintained in 2001 because both circulating water pumps remained on when the unit returned to service !**

The result of this 2.7" Hg back-pressure improvement, according to the back-pressure curves on the turbine, is a reduction of unit heat rate by approximately 7%. This efficiency improvement has already realized a fuel savings this year of $840,000 and a NOx emission savings of $125,000. In fact, even though the circulating water temperatures are 30 degrees higher now in July than what they were in February, the unit's heat rate remains 5% better.

Conclusions:

The condition of the condenser is a major factor in determining unit heat rate and often generation capacity. As a result, condenser performance has a tremendous impact on unit operation economics. The performance monitoring of the condenser and routine removal of tube fouling can significantly improve condenser heat transfer and greatly improve the efficiency of the low pressure turbine. However, a decline in condenser performance may not be due to fouling alone but also to either air ingress and/or the inability of the air removal system to maintain the concentration of non-condensibles in the shell side of the condenser at an acceptable level. Air ingress can occur in unexpected places while reduced performance of the vacuum pumps can also be a factor. It has been shown that the condition of the latter can often be determined from the results of quite simple tests.

Acknowledgements:

We wish to thank the management of the Chalk Point Generating station for permission to present this paper and would like to acknowledge the thoughtful suggestions contributed by members of the staff of Conco Systems, Inc.