

Gaining a Clear Picture of Pump Operation

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When a piping system problem is found, the first response often is to add a pump. Using a piping system analysis tool can be a better solution. In this paper we discuss what a clear picture of piping system operation can provide for the pump system trouble-shooter.

Gaining a Clear Picture of Pump Operation

Often things are not as they first seem, especially when one is trying to determine how a pump system is operating. That's why it is often difficult to troubleshoot a fluid piping system that is experiencing problems and to arrive at a plan to correct the trouble. The best way to identify problems within a system and to make the corrections is first to have a clear picture of how the system operates.

Developing an educated guess is one option to solving system problems, but that ability comes only with years of experience. Simple trial and error may be another option. Either way one thing is certain when a piping system is required for continued operation in a power plant: system failure is not an option.

Fluid piping analysis software makes it possible to simulate the operation of the total piping system. Once the computer simulation reflects the piping system's actual operation, plant personnel can try various options on the piping system model without fear of failure.

Personnel at a cogeneration plant discovered just how helpful such software can be. They used

commercially available fluid piping software to gain a clear picture of the plant's auxiliary cooling water system operation. The auxiliary cooling water system supplies cooling water to lube oil coolers, fan cooling coils, air compressors and generator coolers, along with a variety of other equipment needed for plant operation.

Auxiliary cooling water systems are found in virtually every commercial power plant, as well as in other types of process plants. This particular cogeneration plant's experience is common in auxiliary cooling water systems at many power plants. The system requirements changed over time as the plants' cooling requirements changed and as the piping system components wore and corroded. Such changes sometimes require a system rebalance, modifications to existing pumps or possibly even addition of new pumps to meet the cooling water system's new conditions.

When this power plant was initially designed, the auxiliary cooling water requirements for the various loads were determined and the cooling water system was designed to meet the system's cooling loads. Each pipeline in the system was sized to achieve the desired flow rate. The auxiliary cooling water pumps and motors were selected and sized to meet the total system flow requirement. Balancing valves were inserted into each circuit to limit each individual load's flow to the set value for that load. At the time the system was initially started, the auxiliary cooling water system provided sufficient cooling water load for full plant operation with only two auxiliary cooling pumps operating. A third, 100 percent capacity pump was installed as a backup for the two operating pumps.

New Cooling Requirements

Over time, new equipment was added as the plant's power generating capacity was increased. With the new components came new cooling load requirements, adding to the auxiliary cooling water system loads. Plant operating personnel often incorrectly consider auxiliary cooling water systems as infinite resources. As a result of this incorrect assumption, the new cooling loads are added to the auxiliary cooling water system with no regard for the effects the new loads have on the existing loads. Such was the case at this power plant.

After years of operation, the equipment experienced wear and heat exchangers became fouled and partially plugged, causing a flow reduction through the system. This flow reduction in the circuits caused the equipment being served to overheat. To correct the problem, plant operators opened balancing valves on the individual circuits to increase the flow rate to the components being cooled.

After still more continuous operation, one of the two operating auxiliary cooling pumps tripped due to an overloaded motor. Plant operators immediately started the standby auxiliary cooling water pump to return the system to normal. After investigating the problem, plant personnel determined that the motor tripped due to excess current. They further determined that the two running pumps were operating off the end of their pump curves, indicating that the motors were, in fact, overloaded. When the third auxiliary cooling water pump was started, all three pumps were running, meaning a standby pump was no longer available. The flow rate through the three cooling water pumps, however, was within the manufacturer's recommended flow range and the motors were no longer overloaded.

Plant operators believed the solution was to operate three auxiliary cooling water pumps at all times to meet the increased needs of the cooling water system. The plant's operating procedure, however, required a stand-by pump for all critical piping systems. The auxiliary cooling water system is a critical system, so a design change was immediately initiated to install a fourth auxiliary cooling water pump to ensure that a stand-by pump was available. The utility's project engineering group was tasked with implementing this change.

Adding a New Pump

Because the auxiliary cooling water system modification was required to increase plant reliability, the project was put on a fast track. The scope of work included specifying the fourth auxiliary cooling water pump, motor and switchgear. In addition, engineers planned design changes to connect the new pump to the existing suction and discharge manifolds; to design the pump foundation; and to add the instrumentation, pipe supports, electrical conduit and cabling.

Their first step was to specify the new pump because it had the longest delivery lead time. They originally planned to install a fourth auxiliary cooling water pump identical to the existing three pumps. Because additional cooling loads were added to the cooling water system over the years, engineering wanted to ensure that the existing three pumps could still meet the current plant cooling loads. Therefore, a system audit was conducted on the loads being fed by the auxiliary cooling water system. Plant engineering discovered that even with the added system loads, the two existing pumps should have had sufficient capacity to meet the auxiliary cooling water system's flow needs.

The system audit determined that a full auxiliary water system hydraulic analysis should be carried out to determine why the existing pumps were unable to meet the current cooling water system needs.

Problem Discovered

The engineering team modeled the auxiliary cooling water system using commercially available fluid piping software. The goal was to see how the system was really operating. The software they chose simulates the piping system's operation by calculating the balanced flow rates and pressures in every system pipeline. The simulation software results included a clear picture of how the pipelines, pumps, components and control valves operate together as a total system.

Most commercially available fluid piping software programs use a drawing interface showing how the items in the piping system are connected. Figure 1 is an example of the output of a piping system model created using the PIPE-FLO program by Engineered Software.

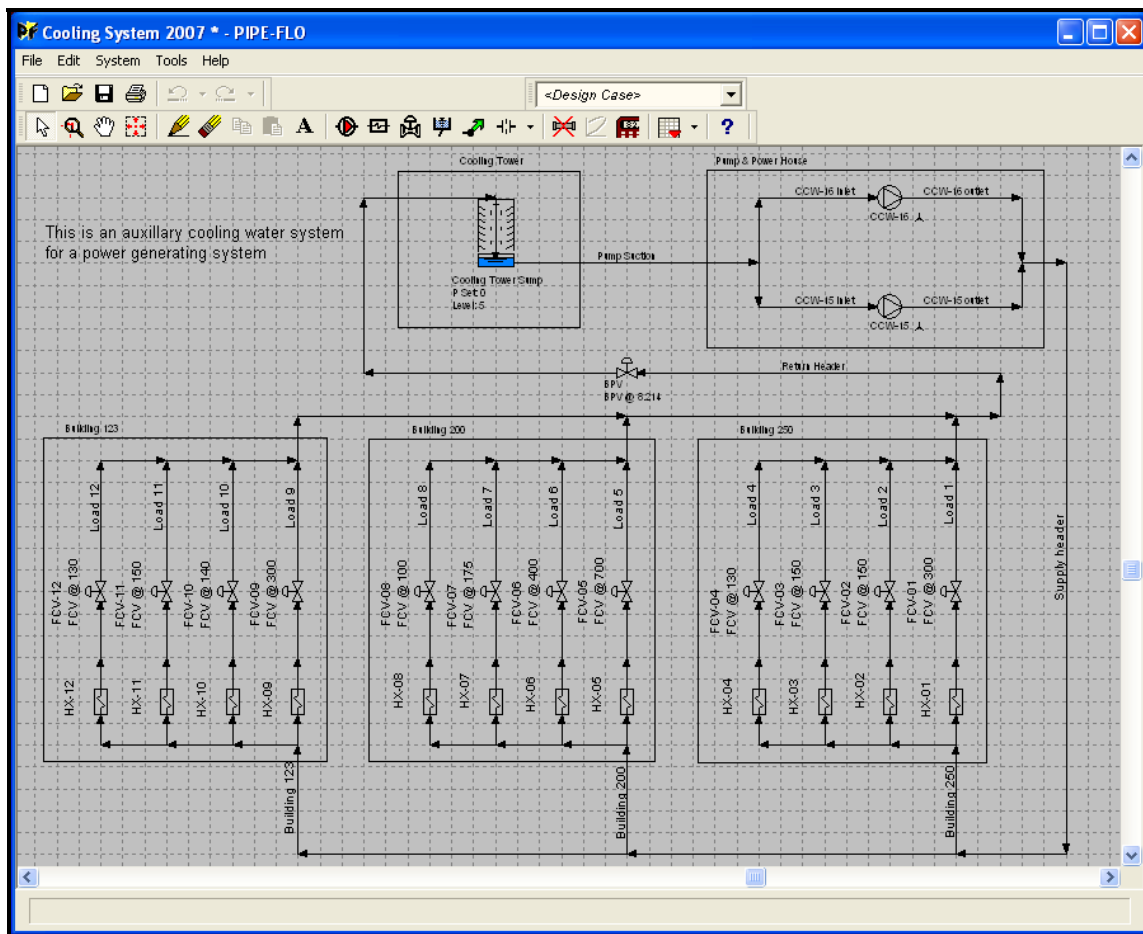


Figure 1. Piping Schematic

Piping schematic of the auxiliary cooling water system using piping simulation software. Note how the piping schematic looks like a CAD drawing. Photo courtesy of Engineered Software, Inc.

Although different piping analysis programs have different features, most programs' piping system models are created through the following steps:

- The piping system is drawn in schematic form using the program's built-in drawing tools
- Operating data for the various tanks, pumps, components and controls is entered into the model
- Individual pipeline details are entered, including pipe inside diameters, pipe lengths and roughness, along with fluid properties, valves and fittings
- The simulation software uses this information to calculate how each item in the piping system operates.

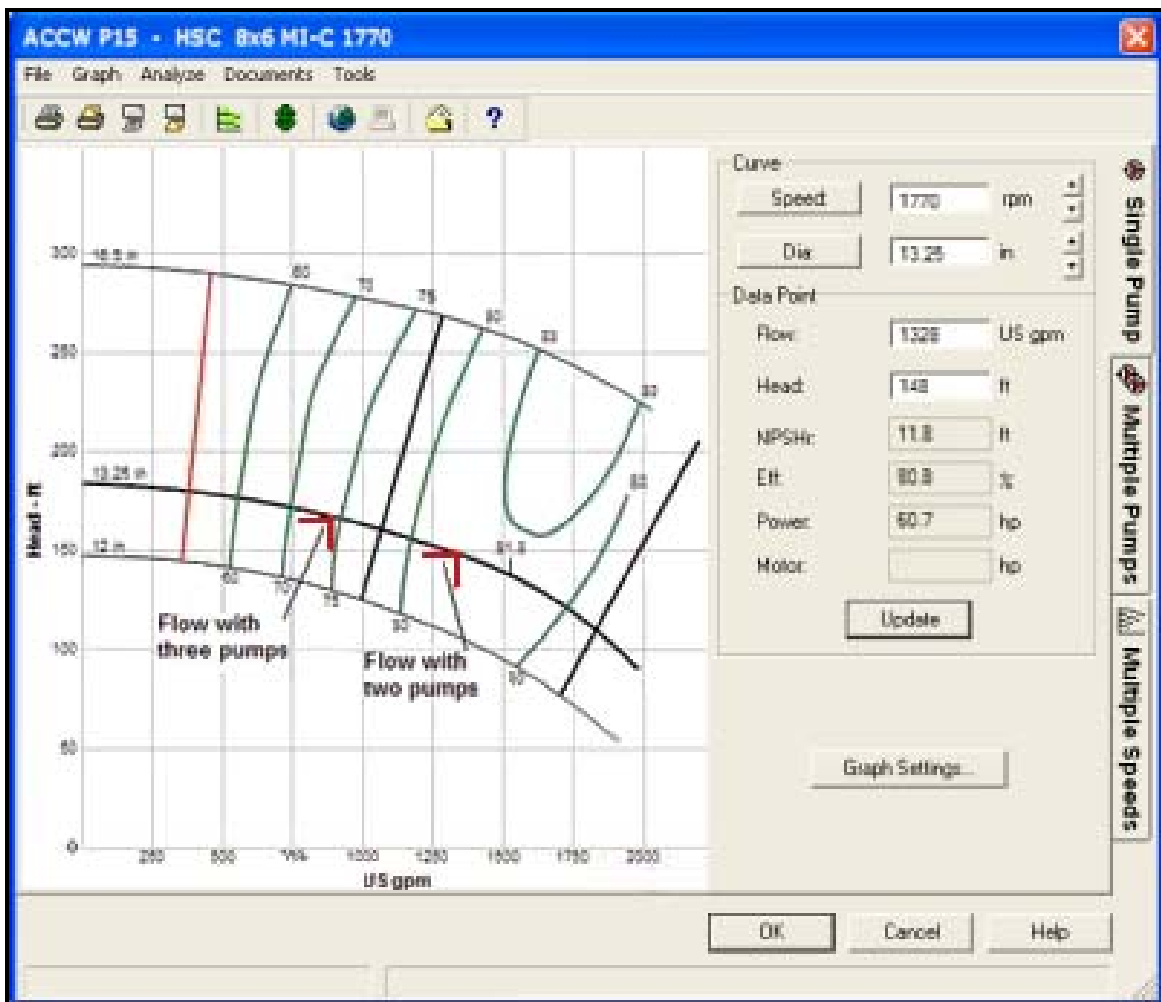


Figure 2. Pump Curve showing normal flow
Optimal operating location on the pump curve with two and three auxiliary cooling water pumps operating. Photo courtesy of Engineered Software, Inc.

Many available piping analysis programs include engineering data tables to allow the software to look up physical properties for the fluids, pipe material, valves and fittings. This streamlines creating the piping system model.

After personnel created the cogeneration plant's piping system model, their next step was to set all the loads for the heat exchangers to their design flow rates. They then performed a full hydraulic network simulation. While reviewing the results, personnel confirmed that the two auxiliary cooling water pumps were well within the normal operating area and should have been able to provide sufficient flow for the system (Figure 3).

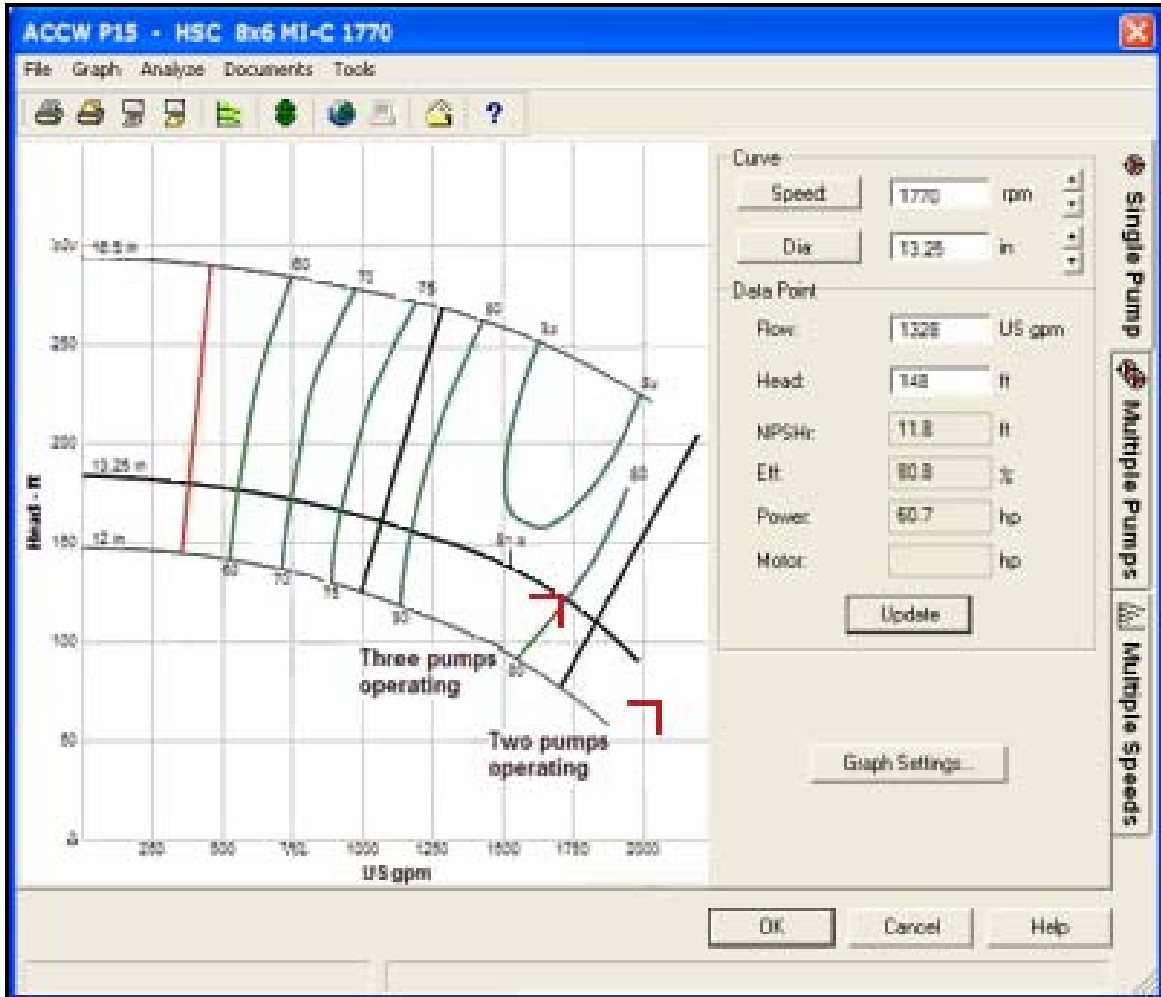


Figure 3. Pump curve showing excess flow
With two pumps operating and all balancing valves open, the flow rate through the auxiliary cooling water pump ran off the end of the pump curve causing motor overload. Photo courtesy of Engineered Software, Inc.

Personnel performed an additional auxiliary cooling system hydraulic analysis with all three pumps running (the way the system was operating). The flow rates through these pumps were well to the left of each pumps' best efficiency point (also Figure 3). When engineering reviewed these calculated results, they also discovered that large differential pressures across the balancing valves existed with the three pumps operating.

The next step was to compare the piping system model results to the auxiliary cooling water system's actual operating data. With all three pumps running in the actual system, the discharge pressures for the pumps were lower than the calculated discharge pressure as predicted by the hydraulic simulation. This

indicated that the actual pumps might have been running farther out on their pump curves than the hydraulic model had predicted, indicating greater flow through the pumps and system.

In looking at the throttle valve positions serving the auxiliary cooling loads, plant personnel discovered that most valves in the actual system were in their fully open position. As a result, the system was not balanced and the flows were much greater than their design values. Further investigation revealed that after each new load was added to the auxiliary cooling water system, the system had not been rebalanced. When this was discussed with the plant operators, they said that over time the various heat exchangers required additional flow from the auxiliary cooling water system to keep the outlet temperatures at their required values, so they opened the balance valves to increase the flow.

By not rebalancing the system after adding each new load, the flow rates going to the new loads caused a reduction in the original loads' flow rates. This caused the increase in the loads' outlet temperatures that the operators saw. The operators responded by opening the balancing valves to these loads to return the operating temperature to the required value. This went on for many months until, it seemed, all of the balancing valves in the auxiliary cooling water system were at their fully opened position.

After determining this fact, personnel performed a system hydraulic analysis with all balancing valves in their fully opened position. This reflected the auxiliary cooling water system's current operating configuration. Personnel discovered that with all balancing valves fully opened and two auxiliary cooling water pumps in operation, the pumps were running off the end of their pump curve (Figure 3). This caused a large current draw on the motors that drive the auxiliary cooling water pumps. This caused the pump to trip on high current, requiring the third pump to be placed in operation.

Personnel performed another auxiliary cooling water system analysis, this time with three pumps in operation. The calculated discharge pressure for the auxiliary cooling water pumps closely matched the observed discharge pressure in the actual plant. In addition, the pressures through the remainder of the system closely matched the hydraulic analysis' calculated values. This indicated that the auxiliary cooling water system's hydraulic model closely matched the actual system's operation.

Balancing the System

In looking at the calculated results with all throttle valves in their 100 percent open position, the analysis showed that flow rates to all the loads in the auxiliary cooling water system greatly exceeded the required flows determined in the audit. As a result, personnel decided that the first step in correcting the auxiliary cooling water system's problem was to balance the system by adjusting the balancing valves to limit all system loads to their design values.

Personnel then used the piping analysis software to determine the positions for each balancing valve in the system. This was accomplished by entering the manufacturer's Cv values for the balancing valves into the piping system model. With this information, the program was able to calculate the position of each of the balancing valves.

Plant personnel conducted the system's hydraulic analysis with two pumps in operation (the original normal system operating condition). The program calculated the position of each of the system's balancing valves. Once this was accomplished, personnel had a starting point for balancing the system with two pumps in operation.

So that the system could be balanced while the plant was operating, personnel placed each balancing valve in the position corresponding to the normal operating condition of two pumps in service. Because the system was currently running with all three auxiliary cooling water pumps, each of the loads was assured of getting more than its required flow during the changing of the system.

To ensure that the piping system model and the actual piping system were still in agreement, personnel performed a hydraulic analysis using three auxiliary cooling pumps with the balancing valves set up for two pump operation. They used an ultrasonic flow meter to compare the actual system values to the calculated values in the piping system model. The flow rates in each of the circuits closely matched the values calculated by the piping system model.

The final step was to shut down the third auxiliary cooling water pump and return the system to its normal operation. After the stand-by pump was shut down, personnel again checked the flow rate feeding each of the loads with the ultra sonic flow meter. After reviewing all the flow rate measurement results, they determined that all but two of the auxiliary cooling water system loads were receiving their design flow rates.

Cleaning the Heat Exchangers

Next, personnel conducted an investigation of the two heat exchangers. They placed pressure gauges across the heat exchangers in question and discovered that the observed differential pressure was higher than the piping system model indicated. They contacted the heat exchanger manufacturer, which supplied a curve showing the differential pressure across the heat exchangers for a range of flow rates. The piping system model for the two heat exchangers in question was compared with the manufacturer supplied data. Personnel updated the model with the manufacturer's information and determined that the two heat exchangers in question still had a high differential pressure for the observed flow rate.

The higher differential pressure observed across each heat exchange suggested that the water sides of the heat exchangers were fouled or partially blocked. The manufacturer suggested performing a heat balance for each heat exchanger to confirm the assumption.

The inlet and outlet temperatures for both the load side and the auxiliary cooling water system side were recorded, along with the observed flow rates. The results confirmed that the heat transfer rates in the exchangers were below their design values. This information, along with the abnormally high differential pressure across the auxiliary cooling water tube sheets, was a clear indication of fouling in the heat exchangers in question.

As a result of this information, plant personnel cleaned the heat exchanger tube sheets during the next plant shutdown.

Avoided Capital Cost

Often when a problem is encountered in piping systems (in this case, the auxiliary cooling water pump motor tripping on high current), the first response is to "power through the problem" by adding a pump. This results in masking the problem instead of correcting it. In this example, plant staff was able to use a piping system analysis tool to gain a clear picture of what was really happening in the piping system. With a clearer picture, the staff was able to isolate the true problem, try a variety of options and correct the problem without purchasing and installing additional equipment.

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Once it was shown that the hydraulic analysis software produced an accurate auxiliary cooling water system model, the plant staff was able to use the model to check the testing and recommendations. This eliminated the need to take the auxiliary cooling water system offline (along with the entire plant) to verify that the proposed changes would work. As it turned out, plant staff was able to perform the entire system balancing without affecting the generating station's operation. The only time operational changes were required was when the two fouled heat exchangers were removed from service for cleaning and this was accomplished during a scheduled plant outage.

Finally, by balancing the system, the cost was minimal, consisting only of the time needed to analyze and rebalance the system (something that should have been done after every system modification).

Adding a fourth auxiliary cooling water pump would have resulted in a major capital cost for the pump, motor, switchgear and interconnecting piping. This change would also have required a construction outage to tie in the new auxiliary cooling water pump. Finally there would have been the added cost of continually running and maintaining the third auxiliary cooling water pump.

As a result of using a software tool to gain a clear picture of the auxiliary cooling water system's operation, the plant staff was able to correct the problem without the large expenditure of capital and operating costs, saving time, money and additional manpower.

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