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Mr. Megawatt
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Obvious Problems Just Need Some Perspective

by Frank Todd, Manager, Thermal Performance

Years ago, my brother and I were working on his VW Squareback (and if you recognize that, join the grey hair club). We discharged the battery 4 times and the car still would not produce self-sustaining combustion. We were sure the problem was the carburetor. After about 36 hours of work, we stood there dumbfounded, staring at the silent engine. Then out walked our Dad, who took one look and said, "Is this wire important?"

It was the wire from the coil to the distributer. Moisture separator reheaters (MSR) are particular to nuclear power plants, but the things we can learn apply to fossil plants as well. Most nuclear power plant steam generators (boilers or HRSGS to our exclusively fossil or combined-cycle types) produce saturated steam. By the time it goes through the HP turbine, there is a significant amount of moisture in the steam.

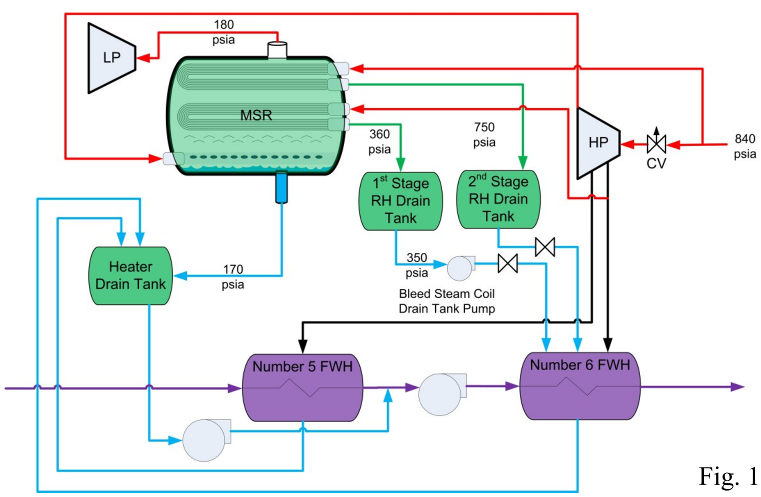

Fig. 1

In a nuclear plant, there are no IP turbines. Not wanting to turn the LP turbine into a water wheel, this moisture is removed by a moisture separator and heated in a reheater. Sometimes the reheater has two stages, using extraction steam (also called bleed steam) from the HP turbine for the first stage, and main steam from upstream of HP turbine for the second stage. In this case, it's a two-stage reheater. The main steam exits the steam generators at about 840 psia with about 0.25 percent moisture. I know this seems a little wimpy to you supercritical folks, but it can still make electricity. HP exhaust pressure is about 180 psia with about 12 percent moisture. The HP exhaust steam passes through a moisture separator and a two-stage reheater, where it is heated to about 500°F. See Figure 1 for a visual.

Gregory Gigawatt and I had just gotten off the plane from BTU city when I noticed I'd missed a call. The message: "Hey, Mr. Megawatt, this is the shift supervisor at Metropolis Nuclear Power Station. We have a problem with our moisture separator, Superman is still trying to figure out entropy so we need you to come and take a look. Oh, and bring your tie."

The last part of that message gave me pause; it was a clear indication of management frenzy.

After going through the security check points, we sat down with Steve the Salty Shift Supervisor, or S4, to discuss the situation. Steve informed us that second-stage reheater steam supply flow was way up, LP inlet temperature had been decreasing, and they were down a few megawatts. They had put together action plans, Kepner-Tregoe analysis, and root cause analyses, and then proceeded to implement multiple troubleshooting procedures with peer checks, all to no avail. Their plant indicator now had a sad face and management wanted the smile back again. We had worked with S4 before and knew that if he was stumped, we were in big trouble. He was one of those rare shift supervisors who had been around long enough to know the turbine side of the plant better than most. My first question was, "When are you going to be on mid-shift so we can come

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in and talk about this without extra help?”
So we had three days to look over some data and evaluate some hypotheses before we could do a plant walkdown.

We looked at some plant data and came up with the following facts:

- The A-side LP inlet temperature had decreased about 20°F
- The turbine first-stage pressure had decreased about 0.5 percent
- The steam flow to the second stage reheater had increased about 150 klbm/hr
- The final feedwater heater extraction pressure was down about 1.5 percent
- Final feedwater temperature had decreased about 2°F
- Feedwater flow had decreased about 40 klbm/hr
- First stage reheater drain flow also decreased to almost nothing

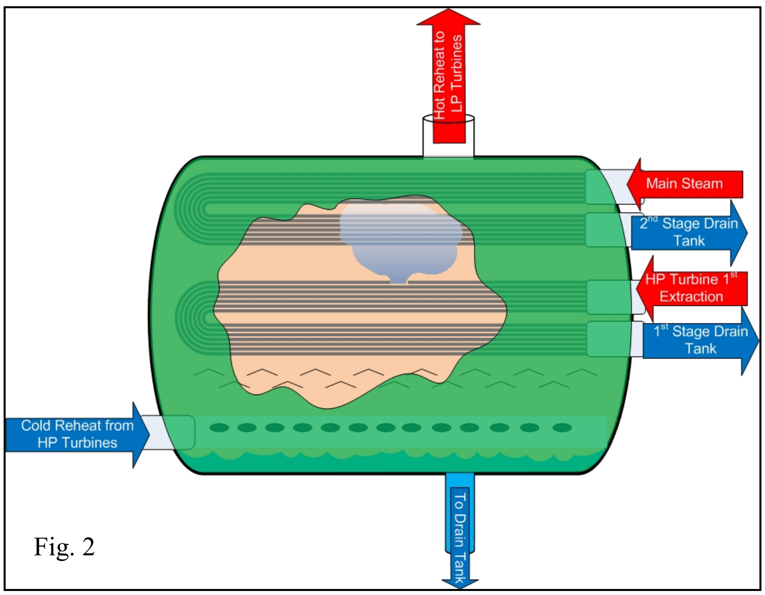

Fig. 2

The system engineer said we should not trust the first-stage reheater drain tank flow because it had been jumping all over the place and was not indicating correctly. I glanced at Double G and he gave me the look that said, “Where have we heard that before?”

I asked S4 what their best theory was, and he said that from Day 1, management thought it was a tube leak on the second-stage reheater because of the high steam flow and the low turbine first-stage pressure. I could tell by the look in his eyes that he did not buy it, even if they did have a 64? stack of paper as proof.

I asked him if we could take a walk around and he got an auxiliary equipment operator, Jersey Jeff, to crawl out of the waterbox and show us the plant. Jeff was more than happy to lead us around, but he smelled a little fishy (really). S4 knew his operators. Jeff took us right to where we needed to be, although I did make an utter fool of myself trying to put on the safety harness. As we approached one of the bleed steam coil drain tank pumps, I asked Jeff to wait, because I noticed that the control valve was almost closed. Upon my query, Jeff informed me that they were having a lot of problems with the pump this cycle, apparently excessive vibration and problems with the seals. Out came my little black book and we moved on to the MSRs. Next we took a look at the second stage reheater drain valve, which was nearly wide open; the line was shaking like a ´67 Mustang with a cylinder missing. At this point, I pulled out my stethoscope and got up close and personal with the MSR. Finding a seam in the insulation, I placed the business end of the stethoscope on the side of the MSR at a couple of locations and heard what I expected to hear.

After Jeff stopped laughing, I suggested he listen too. We heard a distinct “clang-clang” inside the vessel and I said, “OK, let’s go back and talk to Steve.” Jeff walked into the control room and told Steve that the “Doc” wanted to speak with him.
“What’s the prognosis?” S4 said with a smile.
“Well,” I said, “bet you a 6-pack that if you isolate the first stage reheater, the LP inlet temperature will increase and you will pick up a couple of megawatts.”

Steve looked at me, a little astonished. He asked the system engineer to put together an action plan; once it passed the weight test and got all the necessary approvals he would take me up on my bet.

The couple of weeks turned into a couple of months, but there I was, back with Jeff and Steve on midshift. Jeff had the enviable task of closing the rather large and long-winded isolation valve, but I brought enough doughnuts to make sure he had the requisite energy. While we were out, Greg put together a model so we could compare what we thought was wrong with the plant data. During the briefing for the test, we indicated that the TTD (Terminal Temperature Difference, equal to the saturated tube-side temperature, minus the shell outlet temperature) would decrease about 10°F when the valve was shut, and the MWe should increase about 1.5 MWe. Since I was asking them to do something abnormal to the plant, we had to give a good explanation of why we were doing it. So I presented the following line of reasoning.
I pointed to Figures 1 and 2 as I explained. First, I did not believe that the second-stage reheat had a leak because the drain valve was wide open. If the second-stage tubes were leaking, the steam would all

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go into the shell and the drain valve would be closed farther than normal. The same line of reasoning, but in the opposite direction, led me to believe that the first-stage coil was leaking; the drain valve was almost closed and the pump was beating itself to death. Pumps do not like low flow (especially with saturated liquid). I believed the flow indication was correct; the sharp drops in flow were when the tube leak got lonely and asked some of its neighbors to join in the fun (the clanging sound in the MSR). Much of the bleed steam was dumping into the shell of the MSR, causing the moisture to increase going into the second -stage reheater, which caused a greater demand, and thus higher steam flow. The final feedwater heater shell pressure and tube outlet temperature were decreasing for two reasons.

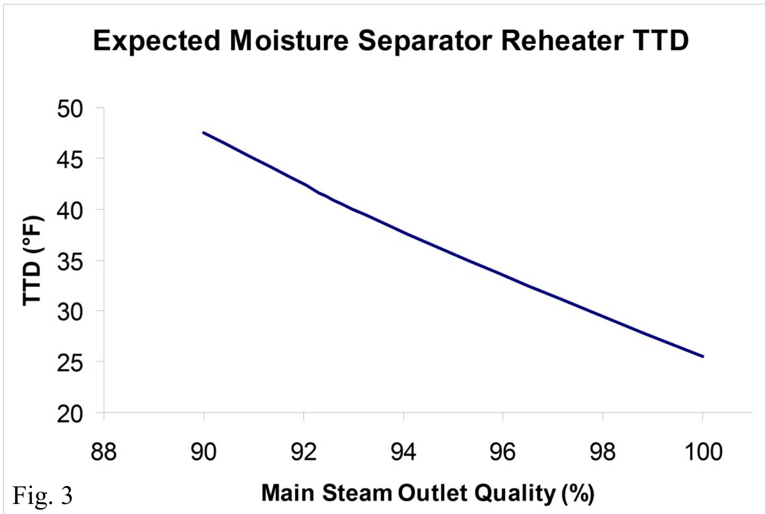

Fig. 3

- First, the final heater and the first-stage heating supply steam come off the same extraction point on the high-pressure turbine. The tube leak caused a higher flow, which resulted in an increased pressure drop in the extraction line, reducing the heater shell pressure.
- Second, since the first-stage pressure decreased about 1 percent, whereas the heater pressure decreased 1.5 percent, the problem was higher flow downstream of the turbine inlet at the first extraction. Remember the second-stage reheat steam supply comes off upstream of the throttle valves. If the second-stage had a tube leak the percent change in turbine first-stage pressure would be close to the percent change in the heater shell pressure.

Based on the plant values, I surmised that the leak was so bad that the reheater was hurting the cycle more than it was helping. We used the actual changes in bleed steam drain flow rate and the design information on the tubes to determine how much of a leak to create in the computer model.

From Figure 3, you can see the effect increasing moisture has on the MSR TTD. Not only does the first-stage heating steam start out at high moisture, but also after it expands into the MSR shell the moisture content increases significantly.

When we isolated the first-stage reheater the TTD improved by 19°F, and generation increased about 2.5 MWe. I was wrong again! (I always try to be wrong in the right direction). I asked Jeff if he could open and shut the valve another 10 times so we could get some good statistics, but in spite of the doughnuts he did not see the humor so I hi-tailed it out of the control room before I ended up impaled on the traveling screens with all the fish. As a bonus, we did the analysis to tell them if they should fix it now or wait till the next outage.

Since the outage was only a couple of months away, it made sense to operate with the first-stage reheater isolated until the outage.

Just like that distributer coil wire my brother and I missed, sometimes the answer to our problems is staring us right in the face. In this case it was the bleed steam coil drain pump that led us to the problem. Objectivity is often difficult, especially when we are caught up in the middle of an issue and those in charge think they already know what the answer is. Sometimes it helps to call a buddy from far away in order to get a fresh look at the problem. After escaping from Jeff and a waterbox cleaning, I took my 6-pack of Wrigley's (it is a nuclear power plant after all) and headed back to my clock that would definitely need a good wind.

Mr. Megawatt is Frank Todd, manager of Thermal Performance for True North Consulting. True North serves the power industry in the areas of testing, training and plant analysis. Todd's career, spanning more than 30 years in the power generation industry, has been centered on optimization, efficiency and overall Thermal Performance of power generation facilities.

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