



Troubleshooting Heat-Transfer Fluid Systems

A version of this article appeared in the
December 2011 Issue of:



Anatomy of a Heat Transfer Fluid Analysis

by Jim Oetinger, Paratherm Director of Technology

Articles on thermal fluid generally start with a variation of the statement that “Thermal fluid systems typically require little ongoing maintenance for the first few years of operation” and then go on to extol the various advantages of indirect thermal-fluid process heating over competitive heating methods such as direct heat, steam, etc. The unsaid corollary to that statement is that by the time there is a problem, the operating personnel that were trained on the system have moved on, been excused or promoted.



As a result when things go wrong the guessing begins. And unless there is an obvious issue like a geyser from the expansion tank vent or a pump that sounds like it’s moving ball bearings, someone eventually will say “the fluid did it”.

Several “crimes” seem to occur with some frequency. This article will review these “crimes” and how the evidence can be misinterpreted. The suspect fluid properties will be discussed and the testing procedures necessary to determine which one (if any) is responsible will be examined. Finally the recommended corrective action will be proposed.

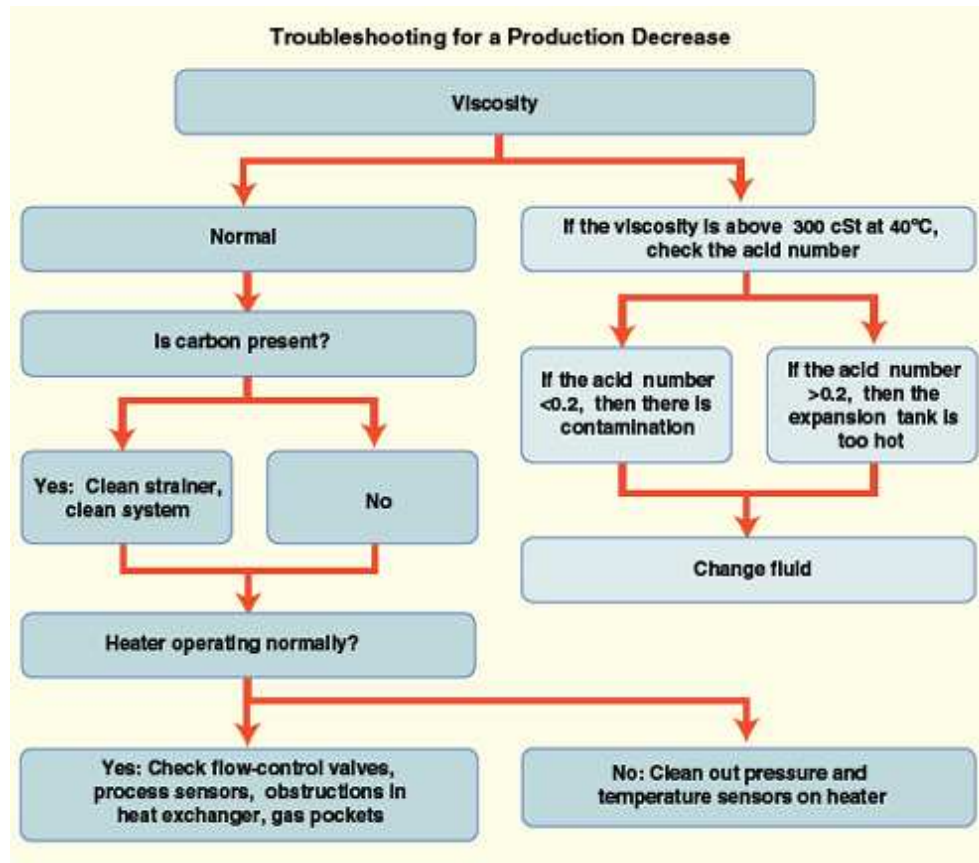
1. Decrease in production rates Part 1 — a large laundry complained about reduced productivity from

their thermal fluid system that was operating at 450°F. They had increased the heater outlet temperature to maintain throughput on the ironers and steam and hot water generators but were still losing ground. (Note: this is an excellent reason to log the heater outlet temperature so that you know when the changes started). Previous test results had shown carbon formation so plans were made to activate a side stream filter to remove the carbon. Before the plan was implemented a sample was pulled that immediately identified the problem.

The fluid property that has the most effect on heat transfer rates is viscosity. Because the *fluid* heat transfer coefficient (which controls the rate of heat transfer between the heat exchange surface and the fluid) is only one element of the *overall* heat transfer coefficient, changes in the viscosity at elevated temperature (350°F+) have to be significant (on the order of 200%) to cause a noticeable change in system performance. In this case, the problem was obvious and required no testing — a sample that was extracted at operating temperature went almost solid when it cooled. This puts the fluid well above the 200% threshold.

2. Decrease in production rates Part 2 — A chemical plant requests sample kit because one of its vacuum reactors is taking too long to heat. Even though the fluid had been in the system for many years and had recently been tested, it was assumed that it had gone “bad”. This situation is probably one of the more common “whodunits” of heat transfer systems. It all comes to light when someone realizes that the heater temperature has to be increased to keep production on schedule. In this case the evidence against the fluid was further strengthened by the relatively “normal” heater pressure and temperature readings. This prompted the request for the sample kit *and* a quotation for a complete fluid changeout. While the latter course of action is appealing to the fluid supplier, it is unlikely to solve the problem since the problem isn’t the fluid.

The overriding evidence in this specific situation was that there had been no maintenance required on the system since the fluid had been tested. Fluid had not been removed or added (which eliminates contamination as a suspect) nor had any of the operating conditions changed. It turned out that there was a leak in the vacuum system, undetected by a faulty sensor, which together resulted in an increased heat load for distilling the product.

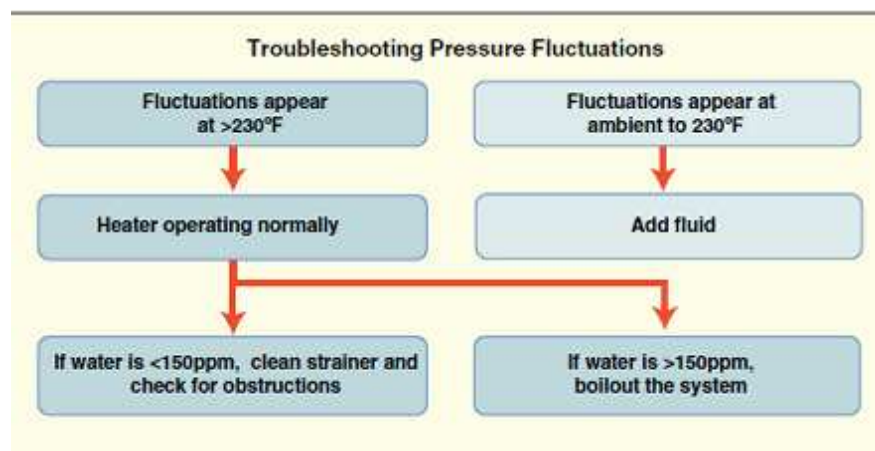


3. Decrease in production rates Part 3 — A poultry processor was experiencing reduced throughput in a continuous convection oven. The heater and pumps were checked for problems and all temperature and pressure sensors replaced. Someone suggested cleaning the heat transfer fluid system. The fluid had been in service for a number of years and so it was just assumed to have degraded and formed blockages in the coils— as the temperature drop across the heat exchanger was much lower than when the unit was new. That the fluid had been tested routinely and was in good condition was totally ignored in the evaluation. Management wanted to clean the system and then change the heat transfer fluid. A lube-oil additive type cleaner was added to the system with the expectation that the problem would be solved. When there was no progress, another sample kit was requested along with a request to quote replacement fluid. Once again the viscosity of the sample was well within the normal range. The plant manager was very disappointed when the results came back once again that the fluid was not the problem—and that he'd have to send the maintenance staff back in to keep looking for the real culprit. Eventually it was discovered that an air damper inside the oven had a broken weld that allowed it to flip up into the air stream effectively blocking the coils. Throughput was reduced because insufficient heat was getting to that section of the oven.
4. Pressure fluctuations — A chemical plant noticed that the pump pressure would begin to fluctuate as the fluid temperature approached 350°F after an extended shutdown. Fluid was added to the system through the expansion tank which made the situation worse for a period of time. Since the system had been kept under a nitrogen blanket during the downtime, water absorption through the expansion tank vent was ruled out. Convinced that the fluid had degraded during the shutdown, plans were made to take another outage and replace the fluid. To pacify management, a sample was taken and tested. Pressure fluctuations are the result of entrained gas. Aeration of the fluid is often blamed particularly if fluid is added through the expansion tank. However, entrained air doesn't abruptly become gaseous — it causes problems from the start. While it is true that overheating a fluid can produce more volatile molecules that will theoretically vaporize, in practice the relatively low liquid-to-vapor expansion rate (about 20) pretty much rules this out as the source of gas. The real culprit is most often water, which has an expansion rate

of 1000. Until water is either drained from the system or flashed off through the vent, it remains in the bottom of the thermal buffer tank or the expansion tank. Tanks have been known to rust through at the bottom because the water has been in the same place for many years. When the heat-transfer fluid flows out of the tank as the system cools, the water is carried into the system piping, and then is dispersed into the circulating fluid when the pump starts. As the system temperature reaches 220°F or so the water droplets become steam bubbles and the pressure fluctuations begin. What causes confusion is that the pressure problems don't appear at the expected 212°F. Depending on the system pressure and design and the amount of water present, symptoms may not begin until the heater temperature reaches 280°-300°F. If the pump is operating at a slightly negative suction head, even lower water concentrations can result in pressure fluctuations.

5. Pump seals — a hot-roll calendaring operation was experiencing repeated rotating joint-seal failures. The seal faces were being scored severely enough from the inside out to create fluid leakage. Two of the oldest seals were experiencing the greatest number of failures. While the fluid tests showed no significant change in the fluid condition, there was visible residue of a previous brand of insoluble fluid, and yet the most compelling evidence was that particles were collecting on the side-stream filter elements. To prevent further problems from what was suspected to be carbon (from degraded heat-transfer fluid), the user began to evaluate a system flush and fluid change.

The majority of carbon particles produced by fluid degradation are the result of fluid oxidation (as determined in fluid analysis by the Total Acid Number). These acids are formed when hot fluid is exposed to air in the expansion tank. They are thermally unstable (compared to the fluid itself) and so degrade into carbon at relatively low temperatures (375 to 400°F) once the concentration has reached an acid number of 0.3 or so. If the expansion tank continues to run hot, the acid number will either stabilize or continue to increase. If the cause of the oxidation has been corrected the acid number will decrease as the acids are consumed. The carbon that is formed is similar to "soot" in appearance and will remain suspended in the fluid which causes the fluid to appear to be black. The particles will drop out of suspension in stagnant fluid and form sediment (sludge). However, individually these particles are extremely fine (<0.5micron) and as such are incapable of damaging rotating seals because they pass between the rotating faces. However they will clump on 25 micron filter elements which can be misleading. In this case, the solution required analysis of the filter. The particles were analyzed and found to contain 90+% iron. This information was transmitted to the customer who shelved the plan to flush the system and replace the fluid. Instead he concentrated on improving his filtration system to eliminate the metallic particles.



6. Erratic Production — A food processor began experiencing sporadic production problems with a multiple-user heat-transfer system used to heat tanks. Once again, the pump pressures and temperatures were all within the expected ranges. Because the fluid had been in service for a number of years, the

likely solution was deemed to be fluid replacement. The shutdown was planned and quotes were obtained. After the costs of the fluid and lost production were totaled, cooler heads prevailed and it was decreed that the fluid should be tested by the current fluid suppliers to be sure it really did need to be replaced. Although the fluid had not been tested for a number of years and actually was a blend of several fluids, the supplier was able to determine that the fluid was in acceptable condition. Now that the easy non-solution was not applicable the real investigation started. Particularly confusing but overlooked when the fluid was the prime suspect was the fact that the most significant decline in production occurred when there was the least demand on the heater. Fluid velocity has even more effect on heat transfer performance than viscosity so whenever there is a drop in heat transfer, it's time to look at the flow rate.

Liquid-phase heaters require continuous flow to prevent fluid degradation. Hence these systems need some way to bypass the heat users when heat is not required. There are two ways to accomplish this:

1. A back-pressure control valve that maintains flow when the 2-way control valves are closed.
2. One or more 3-way control valves (depending on the number of users) with a manual pressure-equalization valve on the bypass port.

Theoretically 3-way valves are superior to a backpressure valve arrangement because they provide a constant flow through the heater — a concept that is favored by the purists — if the balancing is done rigorously. This exact balance is difficult to maintain over time due to changes in equipment and the ever-present potential for 3rd shift adjustment. In this particular case, it was discovered that the bypass valves on the least-used leg of the system had been fully opened so that when that system was not operating, a substantial amount of fluid was bypassing. When unit was operating, the bypass volume was reduced which increased the pressure/flow to the other units and brought production rates back up. Instead of attempting to balance all of the bypass valves (which would have required the installation of multiple pressure gauges) the solution was to install a back pressure valve between the feed and return header and then close all of the bypass valves effectively turning them into 2 way valves. While this control scheme did allow the heater flow to vary, it made system much easier to control since each user was independent of the others.

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Jim Oetinger, Paratherm Corporation's Director of Technology, has over 30 years experience in the chemical and plastics industries. He has been involved with a wide range of products and processes including pigments, refrigerants, consumer plastic recycling, polymer compounding, process instrumentation and spray dried polymers as well as having 18+ years experience in sales and marketing of thermal fluids. Jim has authored articles on system troubleshooting for Process Heating, Chemical Engineering Progress, Plastics Technology and Die Cast Management. A member of the Delaware Valley Chapter of the American Institute of Chemical Engineers, he holds a Chemical Engineering degree from Clarkson University and a Masters of Management degree from Northwestern University. Jim and his family reside in a suburb of Philadelphia PA.



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