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Keep Your Cool About Thermal Fluids

Don't fall for common myths about hot oil systems

By Jim Oetinger, Paratherm

EVEN THOUGH thermal-fluid heating systems have been widely used for over 80 years, they still provoke a certain amount of fear and trepidation in users. This anxiety is reinforced by any number of horror stories that usually involve systems that suddenly develop a “problem” after years of trouble-free operation. Maybe it’s a fire around a pump or another piece of equipment. Or maybe the heater room fills up with smoke. What makes these incidents into oft-repeated horror stories is the lack of a readily apparent explanation for the event. Accident investigators might want to know why the pump seal was leaking, when the flash/fire/autoignition of the fluid was last tested, or whether a higher-temperature thermal fluid should have been specified. Then, whoever has the most experience with these systems will recite some myths and old wives’ tales about thermal fluids and systems, and blame the incident on one of them.

Because thermal fluid systems do involve a combustible liquid under moderate pressure at an elevated temperature, they should inspire some degree of caution. However, few plants have people who’ve had time to develop a real understanding of how such systems work; thus, the myths and old wives’ tales get accepted. So here, to help you reduce the potential for safety incidents, let’s dispel five of the more common myths.

Myth 1 — New thermal fluid always contains water. It’s easy to see how this myth keeps going. After new fluid is added to the system, suddenly hot fluid “geysers” out of the expansion tank vent into the catch tank and possibly onto the

heater room floor. Or the pump begins to cavitate at every startup. Typically these incidents result in calls to the supplier, berating it for sloppy quality control and requesting an immediate shipment of “good” fluid. Ignoring the plant’s own role in this problem (e.g., storing drums of fluid unprotected outside), the truth is all new fluid does contain trace amounts of water, typically less than 150 ppm. This is why new system startup instructions include a boil-out (“seasoning” or “conditioning the fluid”) step. A proper boil-out not only removes any water in the new fluid but also eliminates water remaining in components from hydrotesting and in piping left exposed to weather prior to installation.

Unfortunately, often the boil-out is terminated prematurely, as soon as the pump cavitation stops or the scheduled time is up. Any water left in the system will collect in the bottom of the expansion tank and in other cold (less than 212°F) low points such as the thermal buffer tanks. The fluid samples shown in Figure 1 come from the main loop and thermal buffer tank of a system that had been operating steadily at 550°F. Covered by the thermal fluid (because it’s heavier and insoluble in water), water can’t evaporate and, as a result, can remain hidden for years. Documented incidents testify to water remaining in place long enough to corrode through the metal, causing a thermal fluid leak (which creates its own excitement because these tanks are usually installed above the heater) even though the system has been run continuously. Normal operating-temperature swings might not generate



enough flow past the hidden water to pull it into the main loop. However, a large drop in temperature at shutdown or adding new “good” fluid through the expansion tank may cause enough flow to dislodge the water. Problems might begin at the expected temperatures during startup (when the heater outlet temperature reaches 220–250°F) or might not occur until the outlet temperature exceeds 350°F in a large multiple-loop system. The most effective way to prevent geysers is to take the time to do a thorough boil-out after every cold shutdown. Circulate fluid through all branches and all heat exchangers. Leave the boil-out valve open until the expansion tank temperature is above 230°F and no more steam is visible from the vent. Justification for this extra time is simple — water will keep a system from operating.

Myth 2 — The thermal fluid must be bad because my pump seal is leaking. Leaking pump seals should be a concern because they are involved in a majority of thermal fluid fires. Seals are the only components of a thermal fluid system where there isn’t a solid piece of metal between the hot combustibile fluid and air. So while the ignition source isn’t always identifiable, the fuel source is always the leak from the pump seal. What perpetuates this myth is that leaking seals often will have carbon buildups on the outer surface. While this carbon can force the seal faces apart and cause a leak, it doesn’t necessarily indicate the fluid needs replacing.

Mechanical seals are lubricated by a thin film of fluid that seeps through the gap between the faces. Once this fluid hits the air on the outside surface it acts just like the fluid around a leaking flange, producing some smoke and lots of carbon. Worn or poorly installed replacement seals will allow more fluid to seep out between the faces, producing more carbon. While it’s true that carbon is formed in the fluid as it degrades, these particles typically are soft, soot-like and small enough to

pass between the faces (think graphite). Even larger pieces of “coke” that flake off heater tubes can’t cause seal leaks because they’re still soft enough to be ground up between the tungsten carbide and silicon carbide faces typically specified for thermal fluids. Only metal particles are hard enough to score a seal face; this is why a 60+ mesh screen should be installed in the pump suction Y-strainer on a new system or on any system that has had the piping opened up or new components added.

Myth 3 — An open-top drum makes a great catch tank. This seems like a good idea until the heater room suddenly fills with smoke or worse. Every thermal-fluid heater installed inside a building requires a catch tank to collect the discharges of the expansion tank vent and system relief valves. Whether the expansion tank is open to atmosphere or blanketed with nitrogen, these collectibles typically will include water and volatile byproducts of fluid degradation (“low boilers”), along with the occasional fluid geyser from entrained water. This is why it’s not a good idea to re-use any fluid from the catch tank; re-use can allow collected water and other volatiles to vaporize again and end up back in the tank (or on the floor around the tank when it bubbles over).

Where the open catch tank myth really falls apart is when the same catch tank also serves as the collection point for the heater relief-valve discharge. A heater relief valve doesn’t lift very often but when it does it discharges the hottest fluid in the system into the catch tank. The hot fluid shooting into the tank can explosively vaporize any water lying in the bottom — this, in turn, will vaporize the rest of the tank contents and fill the heater room with a potentially ignitable cloud. Preventing this requires containing these types of discharges and draining the tank frequently. Both requirements can be met if the catch tank is a closed-head dish-bottom steel tank with a drain valve, pressure-rated sight glass and a minimum 4-in.-dia. vent



THERMAL FLUID SAMPLES

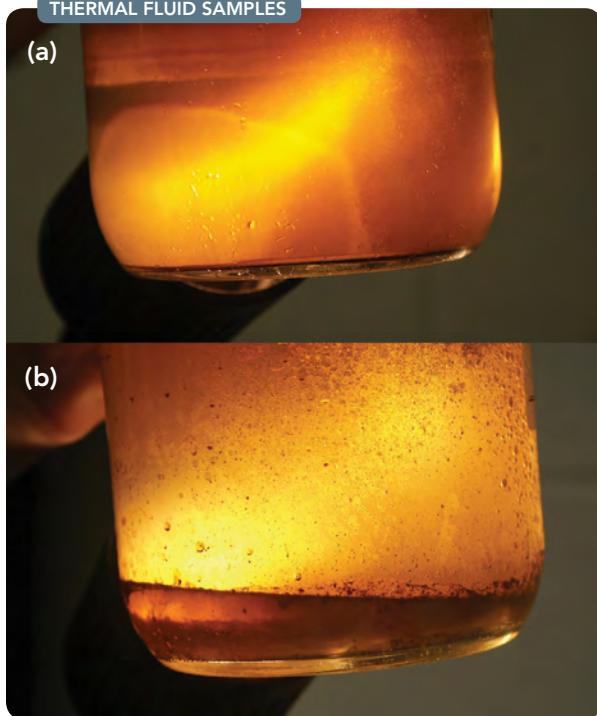


Figure 1. Fluid from the main loop (a) is fine but fluid from thermal buffer tank (b) has layer of water.

to a safe location (preferably outside of the building). If the tank must be vented inside the heater room, locate the vent as far away as possible from the doorway, control panel and fresh air inlet.

Myth 4 — Never operate a thermal fluid above its autoignition temperature (AIT). Autoignition (spontaneous ignition) is the most frightening potential source of fire because all you theoretically need is temperature and a leak to turn the heater room into a furnace. As long as the fluid temperature stays below the stated AIT, so the myth goes, the risk of fire is minimal. The truth actually is pretty simple. With the excep-

tion of most vapor-phase products, a few high-temperature aromatic-based liquids and many low-temperature non-aqueous fluids, most thermal fluids don't have a true AIT. The current standard test method, "Autoignition Temperature of Liquid Chemicals" (ASTM E 659-78), involves injecting 100 microliters of liquid into a heated 500-ml flask. If no ignition of the sample is observed within 10 minutes, the temperature of the flask is raised and another sample is injected. The critical piece of information regarding this test appears in the "Significance and Use" section (5.5): "This test method is not designed to measure the autoignition temperature of materials which are solids or liquids at the test temperature (for example, wood, paper, cotton, plastics, and high-boiling-point chemicals). Such materials will thermally degrade in the flask and the accumulated degradation products may ignite." Because most liquid-phase thermal fluids have boiling points (i.e., vapor pressure exceeds 14.7 psia) above 690°F, any reported AIT less than the boiling point is by definition not a true AIT.

Fluids can and do spontaneously ignite, though. Insulation fires can result from spontaneous ignition, as can some pump fires. However, the material that ignites isn't the original thermal fluid but fluid that's been exposed to air for an extended time. In porous insulation such as fiberglass, rock wool or perlite, the fluid wicks away from the leak point, leaving a thin film through the insulation. The limited supply of air and constant high temperature from the pipe cause the fluid to decompose. Eventually the decomposition products reach their AITs and ignite. Use of nonporous insulation or judicious use of porous insulation can prevent these fires. Leaked fluid that pools under a pump or some other uninsulated piece of equipment can undergo a similar decomposition. The most effective



way of preventing these pool fires is to ensure any leaked fluid drains away from the hot equipment.

Myth 5 — My flash point has fallen so I can't start up. This myth is widely repeated by corporate safety departments and rogue insurance representatives. It assumes that operating a thermal fluid above its flash point will result in an immediate and thoroughly destructive fire if the fluid leaks out. Actually liquid heated above its flash point produces combustible vapor and the “flash” ends as soon as the vapor has been consumed. For a thermal fluid to burn, it must remain hot enough to continuously generate vapor. Because liquid-phase thermal fluid systems operate under moderate pressure — typically a maximum of 100 psig at the circulation pump discharge — a leak will result in a fluid discharge into the surrounding area. Most thermal fluids have a flash point between 300°F and 450°F (some have a flashpoint as high as 530°F but their high viscosity limits their usefulness) and can't produce ignitable vapors below 300°F. So unless a combustion event (like a fire) already is in progress around the leak, even a heater room in Arizona in August is cool enough to reduce the temperature of the leaking fluid rapidly below its vapor region.

The potential for vapor ignition becomes the most problematic when either the air volume is small or the leak volume is large. In enclosed areas such as ovens with limited air to cool and react with the vapor, even small leaks can pose risks. What often misleads investigators is that fires in these confined spaces can result from autoignition caused by the partial degradation of the leaked fluid. Large leaks become a problem when the quantity of vapor released overwhelms the capacity of the ventilation available to cool the leaked fluid as well as react with the vapor. If the vapor cloud, which resembles gasoline vapors in appearance, gets large enough,



Figure 2. If a cooled sample won't pour, don't shut down your system until you have a plan to remove and replace the fluid.

it may eventually reach an ignition source. So why don't insurance companies, international fire codes or government regulators prohibit thermal fluids? The truth is that one of the requirements for a fire — air — actually can prevent these fires from occurring. As most users know, the telltale sign of a thermal fluid leak is smoke. Smoke is the visible byproduct of the hot (>300°F) thermal fluid vapor reacting with air. Good ventilation not only cools the fluid so vapor no longer is produced but also increases the quantity of vapor that can be safely converted without an actual fire. While no current specifications exist for “good ventilation,” a useful rule of thumb for a heater room is that room temperature shouldn't exceed ambient temperature by more than 40°F.

DON'T BE MISLED

The common thread through these myths is that thermal fluid systems are mysterious and unpredictable and, as a result, potentially dangerous. Like any myths, these can be debunked with an understanding of what really causes the problems and, more importantly, how to prevent them. ●

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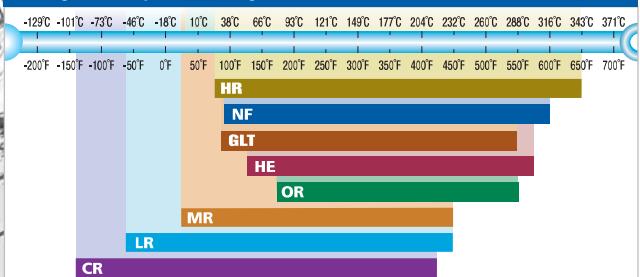
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Listing and temperature range chart for all Paratherm heat transfer fluids.





Avert Oxidation

Nitrogen can serve as an inert barrier to prevent heat-transfer fluid from contacting atmospheric air through the expansion tank

By Zak Shums,* Liquid Process Systems Inc.

PROCESSES REQUIRING indirect heating in chemical, petrochemical and several other industries often use hot oil or heat-transfer fluids as the heat-transfer medium instead of high-pressure steam. Facilities apply heat-transfer systems to indirectly heat reactor jackets, extruders and more. Temperatures as high as 700°F can be achieved at relatively low system pressures, less than 100 pounds per square inch gauge (psig).

The primary components of all hot-oil or heat-transfer heating systems include an electric, oil or gas-fired heater; a primary circulation pumping system; side-stream filtration; and an expansion tank. The expansion tank:

- Provides space for expansion of the heat-transfer fluid with a change in the temperature.
- Provides positive pressure at the suction side of the circulation pump.
- Provides a means to vent vapors and gases from the closed-loop heater.

The expansion tank generally is located at the highest point of the closed-loop liquid-phase heating system, situated on the suction side of the primary pump, connected by a riser pump. An open-to-atmosphere expansion tank contributes to oxidation under two conditions: when the temperature of the expansion tank is above 300°F (150°C), and when the heat-transfer fluid is force-circulated through the expansion tank and comes into contact with cooler atmospheric air.

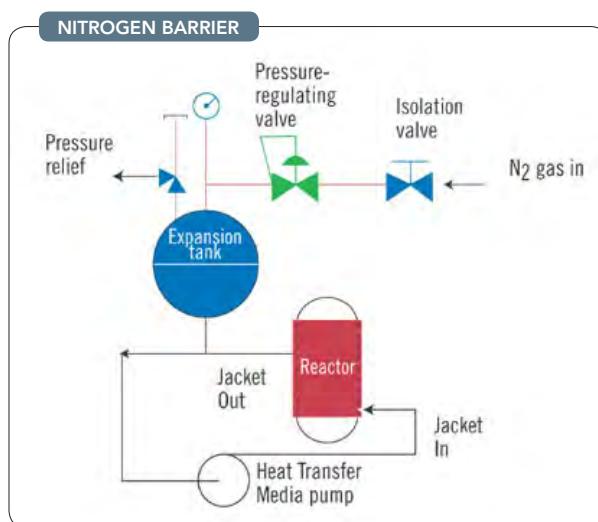


Figure 1. Nitrogen blanketing not only creates a barrier between the heated fluid in the expansion tank and the outside air, but also helps prevent the fluid's vapors from escaping into the atmosphere.

To prevent heat-transfer fluid oxidation, chemical facilities can use nitrogen as an inert barrier in the expansion tank (Figure 1) or can use a cold-seal venting configuration on the tank (Figure 2). These two methods will prevent the heat-transfer fluid from contacting atmospheric air through the expansion tank.



Cold-seal venting is a cost-effective alternative to nitrogen blanketing. However, in cases in which the heat-transfer fluid has a foul odor or undesirable fumes, nitrogen blanketing is advisable. In addition, some insurance carriers might prefer the use of nitrogen blanketing over cold-seal venting for fire protection purposes. Moreover, several commercially available heat-transfer fluids are considered hazardous fluids after being circulated through a heating system. For these types of fluids, the oil supplier probably will recommend nitrogen blanketing over cold-seal venting.

This article focuses on the proper use of nitrogen blanketing applications in expansion tanks.

NITROGEN BLANKETING

Nitrogen provides a barrier between atmospheric air and the heated fluid in the expansion tank. It also serves as a source for creating and maintaining a set pressure in excess of 250 psig, above the vapor pressure of certain heat-transfer fluids at temperatures at or above 650°F, to prevent fluid vaporization and the escape of vapors into the atmosphere.

Inert gas blanketing helps to maintain an artificial “atmosphere” above the heat-transfer fluid in the expansion tank. This prevents the entrance of air, which could react with the heat-transfer fluid to oxidize the oil, generate moisture resulting in condensation within the expansion tank, and/or cause tank corrosion. Another objective is to dilute and lower the vapor space’s oxygen content to the extent that the vapor-air ratio is raised well above the upper flammable limit.

The pressures typically used for blanketing are dictated by the expansion tank’s pressure rating for handling nitrogen gas pressure, as well as by the type of heat-transfer fluid, its maximum operating temperature and its vapor pressure at the operating temperature.

Chemical facilities should keep the pressure in old tanks

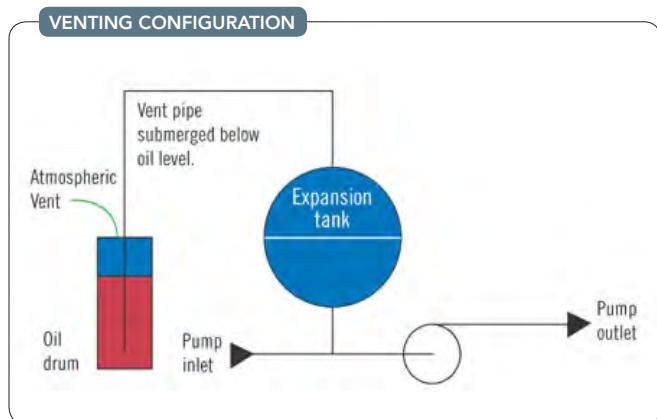


Figure 2. Cold-seal venting configurations provide a cost-effective alternative to nitrogen blanketing when vapors from the heat-transfer medium are not hazardous or undesirable.

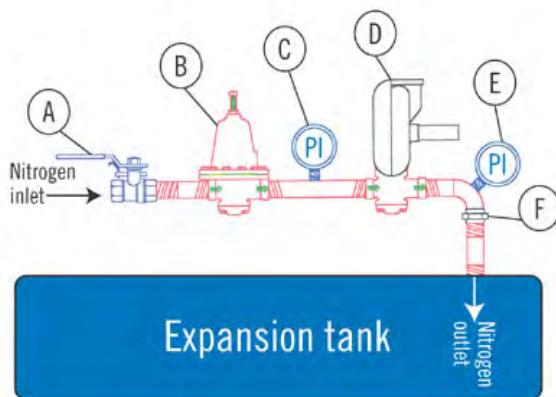
and converted atmospheric expansion tanks as low as possible, maintaining it slightly over atmospheric barometric pressure. A typical pressure used is 0.5-in. water column (WC), equal to 0.0368 in. of mercury. By keeping the tank pressure at such a low level, plants will be able to keep nitrogen usage at a safe minimum level.

This is an application of Boyle’s Law ($P_1V_1=P_2V_2$), which states that, as a given quantity of confined gas is compressed or expanded at a constant temperature, the volume varies inversely to the absolute pressure.

You must size the components for expansion-tank blanketing for the application. In most cases, a simple gas regulator is not accurate or responsive enough for blanketing. Even though a very low (in. of water) regulator may be used, it cannot possibly maintain a pressure with accuracy under varying conditions or when conditions are static, “i.e., constant liquid level,” because of its inherent droop characteristics (droop-deviation-offset is defined as the decrease in outlet pressure as flow increases).



NITROGEN-BLANKETED EXPANSION TANK



TANK COMPONENTS

- A. Shutoff ball valve designed for handling gas, including nitrogen.
- B. Supply pressure regulator with built-in relief valve for reducing and regulating a high inlet pressure to a lower outlet pressure and holding the reduced pressure within limits.
- C. Pressure gauge to provide positive indication of the pressure prior to the main regulator.
- D. Self- or pilot-operated regulator. This valve is the heart of the nitrogen regulation system for the tank. The pressure relief should be set for pressure not to exceed 1 psig. The inlet pressure can range from 25 psi to 5 psi.
- E. Pressure gauge to provide positive indication of the pressure at the tank.
- F. Check valve to ensure flow in one direction into the expansion tank.

Figure 2. The expansion tank generally is located at the highest point of a closed-loop heating system.

Spring-loaded gas regulators primarily are designed to maintain the downstream pressure of a flowing gas. They tend to overshoot before tight shutoff and are not responsive to small pressure drops. Pressure must drop significantly for the regulator to be wide open. Therefore, you must employ some sort of a modified pilot-loading system to get the accuracy and speed of response needed.

Figure 3 shows a typical nitrogen-blanketed expansion tank. Ideally, at least two or three openings are provided on the top of the tank for introducing the inert gas, monitoring and relieving pressure, and relieving vacuum.

In addition to the components noted in the figure, you might want to consider a rupture disc and a vacuum breaker, installed separately on the expansion tank independent of the nitrogen system. These are good options for existing tanks with questionable pressure-handling capabilities. They can also help in situations requiring added safety to prevent over-pressurization or implosion of the expansion tank. In such cases, temperature swings during heating and cooling of the system's fluid can create a vacuum condition.

Select materials of construction suitable for the

temperature of and around the expansion tank. In addition, choose elastomers and springs that are compatible with the temperature and the vapors of the heat-transfer fluid to be used. Install a heat sink between the nitrogen system and the expansion tank to ensure a cooler environment within and around the nitrogen system. Commonly used materials of construction include stainless steel, carbon steel, bronze and aluminum, as well as Teflon or Viton elastomers.

To maintain low heat-transfer fluid vapor pressures at elevated operating temperatures, ensure that the expansion tank is designed for the given temperature and pressure, and is built to the American Society of Mechanical Engineers (ASME), Section VIII, Div. I standards. ●

ZAK SHUMS was president of Liquid Process Systems Inc., Indian Trail, N.C. When this article was released in 2003. He is now deceased. The company provides heat-recovery and filtration systems for hot oils or heat-transfer fluid systems. Doug Vargas of Invensys Systems, Melinda Schnell of Tyco Valves and Claude Strick of HVAC & industrial Controls also contributed to this article. For more information, call 704-821-1115 or e-mail info@lps-filtration.com.



Heating Raises More Than Temperature

A key tradeoff complicates the choice between steam and a hot oil system to heat water

By Andrew Sloley, Contributing Editor

AN INDUSTRIAL facility needed to heat 2,600 gpm of water to 60°F from 35°F to prepare it for biological treating. The site had no existing steam or other thermal loads generating low-level heat. The only major sources of energy available were pipeline natural gas and electricity.

Both the water rate and temperature varied seasonally. In addition, contaminants made the water highly fouling. An initial experiment using a small direct-fired heater quickly failed due to high fouling rates.

Liquid velocity and liquid temperature affect fouling — the faster the velocity and the lower the temperature, the lower the fouling rate. Usually the most important temperature in exchanger fouling in a heater is the film temperature of the fouling fluid, not the bulk temperature. Fire-exposed tube heaters have high fireside metal temperatures, which lead to high film temperatures. The high film temperatures created extremely high fouling rates.

Water rate variations made the problem worse. Occasional low flows decreased velocity and increased residence time in the heater. Low velocity allows fouling

to stick more readily. Long residence time results in rapid fouling because liquid stays longer in the high-temperature liquid film.

Techniques for raising velocity and residence time include using multiple small heaters and recirculation systems. Multiple units boost capital requirements. Recirculating some hot water from the outlet fluid back to the inlet increases velocity and decreases residence time but elevates water temperature. The benefits, or costs, of circulation systems depend on the tradeoff between velocity and time versus temperature.

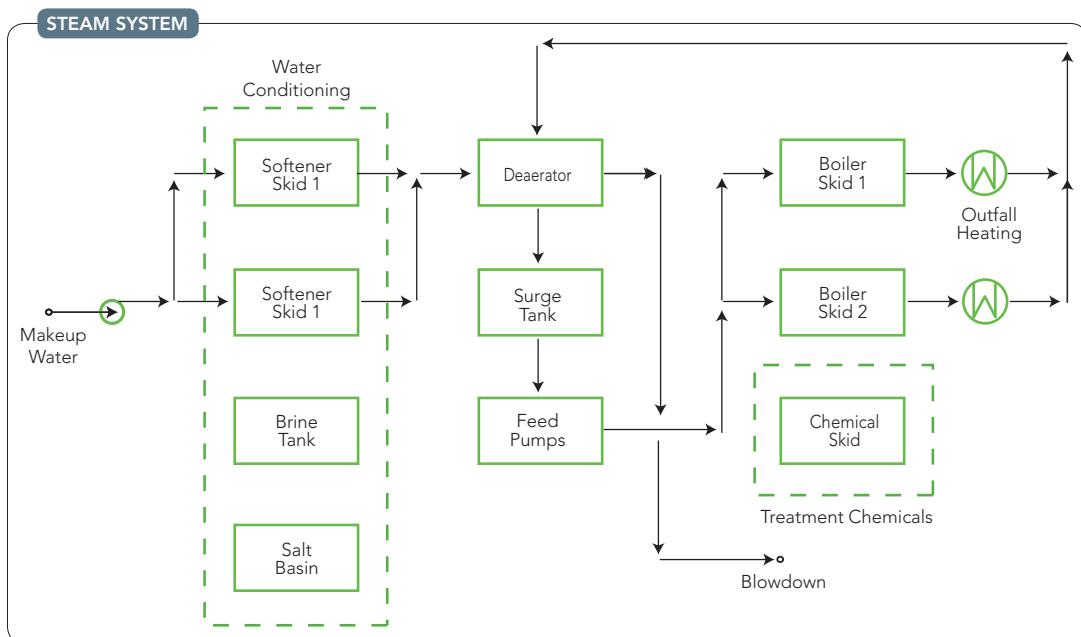


Figure 1. The relatively complex flow scheme sprawls over 14 P&IDs.

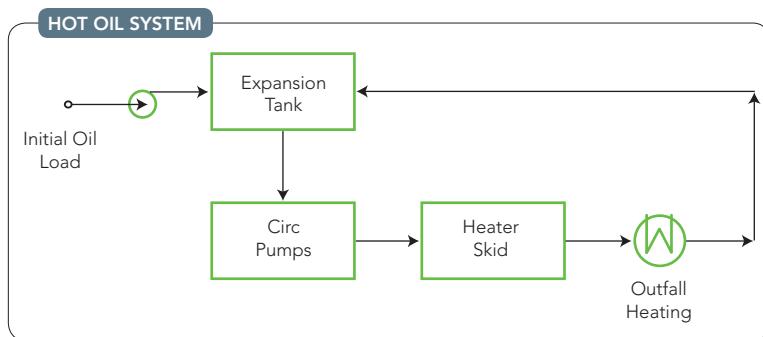


Figure 2. This simpler and cheaper option requires only four P&IDs.

The site leaned toward a steam generator system, particularly because of the operating company’s experience (and comfort) with steam systems at other sites. Relatively low-pressure steam could provide the heat.

However, without infrastructure, even a modest steam system quickly becomes complex. The total system ends up including:

- water make-up pumping (from a drinking water system);
- water softening, including two skid-mounted units plus a brine tank, salt basin and associated equipment;
- deaerator;
- boiler feedwater system;
- steam generators (two 50%-capacity skids);
- chemical treating (one skid); and
- steam condensers (four shells, to allow on-line cleaning) to heat the water.

One quick way to measure system complexity is to count the number of piping and instrumentation diagrams (P&IDs). The steam-driven heating system

sprawled over 14 P&IDs. Even with most control done via programmable logic controllers (PLCs) integrated with the skid modules, the system would require a fair amount of field construction.

The prospect of a highly complex unit for an apparently simple task leads to a natural question: “Is there a simpler and cheaper way to do this job?” We quickly checked other options.

A hot oil system became a leading contender. It’s relatively simple and requires little maintenance. The key

equipment include a surge drum, circulating pump, fired heater and hot-oil/water exchanger. The entire system requires only four P&IDs. The controls also are much simpler and reside in the PLC on the unit’s single major module. Plus, fuel costs are slightly lower.

However, the hot oil system gives a higher average film temperature in the water heater. Because the hot oil uses sensible heat, inlet temperature exceeds steam condensing temperature. So, fouling rates are higher.

The choice becomes (A) a cheaper and simpler system with higher fouling rates or (B) a more expensive and complex system with minimum fouling rates. The unknown maintenance costs of the two options further complicate the decision.

The final recommendation was to use the hot oil system — but to design the final water exchangers to both minimize fouling and make them as easy as possible to clean. ●

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