PURPOSE

Steam is the most commonly used heating medium for maintaining process temperatures. Compared to other heating media, steam contains a significant amount of heat energy, and this heat is transferred when the steam condenses into liquid water (often referred to as condensate). Condensate must be effectively removed from the system to continually allow heat transfer from fresh steam. As long as the steam pressure is held constant, the saturated steam temperature will also be constant, thus maximizing the heat transfer capability of the system.

Most problems encountered with steam heating systems are caused with issues with the steam utilities rather than the steam jacketing. The primary root causes of steam system performance issues can be broadly categorized as:

- Inadequate steam pressure
- Inadequate condensate removal

The purpose of this document is to provide a troubleshooting guide to help determine if the steam system is operating properly and, in the case of poor performance, to help identify the root cause(s) performance issues.

STEAM SYSTEM OVERVIEW

Every steam heating system consists of the following major components (at a minimum):

- Boiler. In the boiler, heat is added to liquid water to generate steam at a certain pressure. Boiler pressure is used to control the thermal capacity of the steam and to motivate the steam through the jacketing system.

- Steam Header. Steam exits the boiler through piping referred to as the steam header. The header also serves as a reservoir that feeds steam to the individual heating circuits. The steam header must be large enough to virtually eliminate pressure drop between the boiler and the beginning of the circuit.

- Steam Manifold. Smaller diameter piping connects the steam header to a steam manifold. The manifold serves as the branch point for supplying the individual heating circuits. Steam manifolds commonly have 4-16 branches, and each branch contains an isolation valve. A steam trap is located at the bottom of the manifold for keeping the manifold clear of condensate.

- Heating Circuits. The heating circuit is comprised of a group of heating elements (jacketed pipe, bolt-on jacketing, or tube tracing) which are connected in series. Typically, pre-insulated tubing is used to transport steam from the steam manifold to the first heating element in the circuit. Flexible metal hoses are commonly used to allow the steam to flow from one heating element to the next element in the circuit. Pre-insulated tubing is also used to transport steam and condensate from the last element in the circuit to the condensate manifold. The length and configuration of each heating circuit must be carefully designed and analyzed to ensure fresh steam is supplied to the jacketing system before the steam has lost too much pressure.

- Condensate Manifold. The condensate manifold resembles the steam manifold with the exception that each branch contains a steam trap in between 2 isolation valves. The steam trap serves to remove condensate from the system while “trapping” steam in the system. The steam trap has a critical role in determining the overall success of the steam heating system.

- Condensate Header. Condensate from each of the condensate manifolds flows into a common pipe header referred to as the condensate header. The condensate header returns liquid water to the boiler so that it can be reheated into steam. Special attention must be given to the piping design of the condensate header to avoid excessive pressure drop which could impede operation of the steam jacketing system. This can have particular impact upon the type of steam trap that can be used with the system.

TROUBLESHOOTING STEPS

1.0 Identify the suspected heating circuit.

2.0 Confirm the heating circuit is connected in series from the steam manifold to the condensate manifold.

2.1. Confirm the steam manifold valve to the circuit is fully open.

2.2. Confirm the condensate manifold valves on either side of the steam trap are fully open.

2.3. Confirm there are no steam leaks at any connections.

2.4. Confirm two or more circuits do not share a common steam trap. Circuits may share a common branch on the steam manifold but cannot be combined into a common steam trap.

3.0 Measure the pressure at key points in the circuit:

- Pressure A = Steam header
- Pressure B = Downstream side of the steam manifold valve
- Pressure C = Inlet connection of the first heating element in the circuit
- Pressure D = Outlet connection of the last heating element in the circuit
- Pressure E = Upstream side of the steam trap
- Pressure F = Downstream of the steam trap

Pressure measurements should be taken using a pressure gauge with a range of 0-5 barg (for 3.5 barg steam systems) or 0-10 barg (for 5 and 10 barg steam systems). If pressure measurements are not possible, temperature measurements can be substituted. Acceptable temperature measurement devices are listed below in order of priority:

- Thermocouples. Thermocouple bead should be attached directly to the piping being measured and then completely insulated. If the thermocouple bead is not insulated, it will register a mixture of the pipe temperature and the ambient temperature. Up to 15 minutes may be required after installation to allow the thermocouple to reach temperature.
- Temperature measuring sticks, such as Tempilstik industrial temperature indicators, are high-temperature chalks with varying melting points. The typical accuracy is

±1% of the temperature rating. Sticks should be used for several temperatures near the expected steam temperature. For example, troubleshooting a 3.5 barg steam system should make use of sticks at 150°C, 149°C, 146°C, 142°C, 140°C, and 135°C.

- Infrared pyrometer. Infrared pyrometers are highly sensitive to the surface emissivity, which varies from material to material. Infrared devices cannot be used on shiny surfaces. Ideally, each surface to be measured should be painted with a black dot to ensure accurate readings.

If temperature measurements are used instead of pressure measurements, the temperatures must be correlated to pressures using a steam table. A reference steam table is included in Attachment A.

4.0 Analyze pressure measurements (from 3.0).

4.1. If Pressure A is less than the system design pressure, this most likely indicates the steam output of the boiler is not sufficient to meet the steam demands of the heating system.

4.2. If Pressure B is more than 0.15 bar below Pressure A, there is too much steam pressure loss between the header and the steam manifold. Possible causes include:

4.2.1. Diameter of piping/tubing between steam header and steam manifold is too small for the steam load of the circuit. If the diameter is 19 mm or larger, diameter is not the cause of the pressure loss.

4.2.2. The steam manifold valve is partially closed, partially clogged, or too small for the steam load of the circuit.

4.2.3. Steam trap in the steam manifold has failed open, causing steam pressure loss in the manifold.

4.3. If Pressure C is more than 0.15 bar below Pressure B, there is too much steam pressure loss between the steam manifold and the circuit. Possible causes include:

4.3.1. Diameter of tubing between steam header and steam manifold is too small for the steam load of the circuit. If the diameter is 19 mm or larger, diameter is not the cause of the pressure loss.

4.3.2. Tubing run from manifold to circuit allows condensate to pocket in the run and impede the free flow of steam to the circuit.

4.3.3. Steam trap in the steam manifold has failed closed, causing condensate to back up in the manifold and impede the free flow of steam to the circuit.

4.4. If Pressure D is less than 90% of Pressure C, there is too much steam pressure loss in the circuit. Possible causes include:

4.4.1. Significant amounts of steam are leaking out of the system at tubing/hose connections.

4.4.2. Steam trap at the end of the circuit is failed open. The same result can be created by manually bypassing or disassembling the trap to “try to get more steam through the circuit”.

4.4.3. Circuit is too long (either in terms of number of hoses or length of piping). The circuit should be compared with the jacketing installation drawings to ensure there are not more jacketing spools/elements included in the circuit than those shown on the installation drawings.

4.4.4. Two or more circuits share a common steam trap. In this case, steam will preferentially flow through the circuit with the least resistance and can cause condensate to back up in the other circuit(s).

4.4.5. Steam is “dead-headed” at a jacketing spool/element. For a jacketed spool/element with more than one steam chamber, it is possible to mistakenly connect the steam/condensate in such a way that steam inlet is connected to one chamber and the outlet is connected to a different chamber. This results in a “dead-head” where the steam can enter the spool/element but not flow to the next spool/element.

4.5. If Pressure F is more than 50-80% of Pressure E, the condensate return pressure may be too high for the system. Possible causes include:

4.5.1. Total lift of condensate downstream of the circuit should be minimized. This includes the: (a) tubing connecting the circuit to the condensate manifold, (b) piping/tubing connecting the condensate manifold to the condensate header, and (c) piping in the condensate header.

4.5.2. Condensate manifold is over pressurized. This could result from any of the following:

4.5.2.1. A steam trap in a nearby circuit has failed open.

4.5.2.2. Flash tank is operating at an abnormally high pressure, creating high back pressure at the trap outlet. The flash tank establishes the minimum pressure in the condensate return system. Typical flash tank pressures are less than 0.5 barg.

4.5.2.3. Two steam systems operating at different steam pressures are discharged into the same condensate header. This prevents the free discharge of condensate from the lower pressure system.

5.0 Measure the temperature at key points in the circuit, using the methods described in 3.0:

- Temperature X = Outlet connection of the last heating element in the circuit
- Temperature Y = Steam trap

6.0 Analyze temperature measurements (from 5.0).

6.1. If Temperature X is below 135°C for a 3.5 barg system (or below 170°C for a 10 barg system), either the steam has lost too much pressure (as already discussed) or condensate is backing up in the jacketing. Possible causes of condensate back-up include:

6.1.1. Condensate manifold valve on either side of the trap is partially closed or clogged.

6.1.2. Steam trap has failed closed due to debris in the orifice and/or strainer.

6.1.3. Thermostatic steam trap is causing condensate to back up in the jacketing. Thermostatic traps operate by sensing the temperature difference between steam and subcooled condensate. These traps feature either a bi-metallic strip or a gas-filled diaphragm. When the strip/diaphragm is hot, it expands and closes off the orifice. When the strip/diaphragm cools to a pre-set temperature, it contracts enough to open the orifice and allow condensate to exit the trap. In order for a thermostatic trap to open, condensate must dwell in the trap long enough for its temperature to drop well below the steam temperature. The amount of subcooling required varies by trap manufacturer, but a typical amount is 10°C. To achieve the necessary subcooling, condensate must back up in the tubing upstream of the trap, and this can cause condensate to back up inside the jacketing. For this reason, thermostatic traps are not recommended for steam heating systems.

6.1.4. Condensate return pressure is too high for the use of a thermodynamic steam trap. Thermodynamic traps operate based on a pressure difference on either side of a disk. The disk is free to move in the vertical direction. Steam from the jacketing system pushes upward on the disk through an orifice. Steam above the disk pushes downward on the disk across the entire disk surface area. When the steam above the disk condenses, system pressure lifts the disk, allowing steam and condensate flow out of the trap. When the disk is up, and all of the condensate has exited the trap, fresh steam re-enters the chamber above the disk and pushes the disk down. In essence, thermodynamic traps operate based on heat loss to ambient rather than responding to the presence of condensate in the steam jacketing. Thermodynamic traps are very sensitive to the pressure in the condensate return system. If the condensate return pressure exceeds 50-80% of the steam pressure just upstream of the trap, the disk will never close, and the jacketing will not operate with the designed steam pressure. The condensate return pressure has to be very carefully considered for successful system operation with thermodynamic traps.

6.1.5. Air is locked in the steam trap and preventing the free flow of condensate into the trap. This is particularly problematic with float traps that do not have a continual air purge capability. Float traps feature a ball inside the trap housing. When steam or air is in the trap, the ball rests on the trap floor. When condensate enters the trap, the ball floats on the condensate and rises, the orifice opens, and condensate escapes. Since the orifice is located in the liquid level, additional air purging capability is required to avoid air lock.

6.1.6. It should be noted that inverted bucket traps are the most robust choice for steam jacketed systems as they require no special considerations. Inverted bucket traps feature an upside down bucket inside the trap housing. The bucket is free to move in the vertical direction. When steam is in the trap, it lifts the bucket which causes the orifice to close. When the steam in the trap condenses and/or when condensate enters the trap, the bucket falls, the orifice opens, and condensate escapes. Most inverted bucket traps incorporate a small bleed hole to allow any air in the system to escape.

ATTACHMENT A— Saturated Steam Table

psig	°F	barg	°C
0	212.0	0.0	100.0
1	215.0	0.1	101.7
5	227.1	0.3	108.4
10	239.4	0.7	115.2
15	249.8	1.0	121.0
20	258.8	1.4	126.0
22	261.2	1.5	127.8
24	265.3	1.7	129.6
26	268.3	1.8	131.3
28	271.2	1.9	132.9
30	274.1	2.1	134.5
32	276.8	2.2	136.0
34	279.3	2.3	137.4
36	281.8	2.5	138.8
38	284.4	2.6	140.2
40	286.7	2.8	141.5
42	289.0	2.9	142.8
44	291.2	3.0	144.0
46	293.5	3.2	145.3
48	295.5	3.3	146.4
50	297.7	3.4	147.6
52	299.9	3.6	148.7
54	301.6	3.7	149.8
56	303.6	3.9	150.9
58	305.4	4.0	151.9
60	307.4	4.1	153.0
62	309.2	4.3	154.0
64	310.8	4.4	154.9
66	312.6	4.5	155.9
68	314.2	4.7	156.8
70	316.0	4.8	157.0
72	317.7	5.0	158.7
74	319.3	5.1	159.6
76	320.9	5.2	160.5
78	322.3	5.4	161.3
80	323.8	5.5	162.1
85	327.6	5.9	164.2
90	331.2	6.2	166.2
95	334.6	6.5	168.1
100	337.8	6.9	169.9
105	341.1	7.2	171.7
110	344.1	7.6	173.4
115	347.2	7.9	175.1

120	350.1	8.3	176.7
125	352.9	8.6	178.3
130	355.6	9.0	179.8
135	358.3	9.3	181.3
140	360.9	9.7	182.7
145	363.4	10.0	184.1
150	365.9	10.3	185.5
155	368.2	10.7	186.8
160	370.6	11.0	188.1
165	373.9	11.4	189.4
170	375.3	11.7	190.7
175	377.4	12.1	191.9
180	379.6	12.4	193.1
185	381.7	12.8	194.3
190	383.7	13.1	195.4
195	385.9	13.4	196.6
200	387.9	13.8	197.7