PURPOSE

The purpose of this document is to help determine the root cause of heat-related problems in a ControTrace steam heating system. The guide is tailored for ControTrace applications, but most of the material is also relevant to other steam heating systems. Problems with steam heating systems can broadly be divided into four categories:

- Installation-Related Issues: Poor ControTrace installation, inadequate insulation, incorrect steam circuitry, etc.
- Steam-Related Issues: Low steam supply pressure, steam trap failure, etc.
- Process-Related Issues: Problems whose root cause is process related; often these problems are independent of, and unrelated to, the heating system.
- Design-Related Issues: Design based on inaccurate assumption, components that require heating overlooked, etc.

Most problems are either installation or steam related. This guide is focused on these two categories, but also briefly addresses the other two. The guide is organized in several distinct sections:

- Purpose**:** An introduction to the guide
- Steam System Overview**:** An introduction to steam systems
- Level 1 Troubleshooting**:** Items that are easily performed by maintenance personnel
- Level 2 Troubleshooting**:** Items that can be performed by maintenance personnel but have greater time and/or resource requirements.
- Level 3 Troubleshooting**:** Items that require some in-depth knowledge of steam, ControTrace systems, heat transfer, and process details.
- Appendix A**:** Steam saturation temperature table
- Appendix B**:** Instructions for testing the operation of various steam trap styles.
- Appendix C**:** Description of strainer blow-down discharge clues.
- Appendix D**:** Thermocouple and IR gun instructions.
- Appendix E**:** Permanent end-of-circuit steam temperature gauge source.

The guide is designed to be followed progressively, starting with Level 1, Item 1. CSI involvement in not required to successfully perform troubleshooting. However, CSI is happy to assist as needed. Do not hesitate to contact CSI for assistance with troubleshooting ControTrace systems.

Controls Southeast Inc
704-644-5000
P.O. Box 7500
Charlotte, NC 28241

STEAM SYSTEM OVERVIEW

In general, a steam heating system will consist of the following major components (reference Figure 1 for a conceptual sketch):

- Boiler. In the boiler, heat is added to water to generate steam at a certain pressure. Boiler pressure is used to control the temperature 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 minimize pressure drop between the boiler and the steam manifold.
- 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 to keep the manifold clear of condensate.
- Heating Circuits. A typical heating circuit is comprised of a group of heating elements (jacketed pipe, bolt-on jacketing, or tube tracing) which are connected in series. 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 within the circuit. Pre-insulated tubing is also used to transport steam and condensate from the last element in the circuit to the steam trap. 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.
- Steam Trap. The steam trap is located between the steam circuit and the condensate return system. The purpose of the steam trap is to maintain the steam pressure in the circuit while allowing the condensate that is generated to escape. A working steam trap is crucial to the operation of the heating system. Two separate supply points (circuits) cannot be combined into a single steam trap or the condensate may build up inside one of the circuits.
- Condensate Manifold. The condensate manifold resembles the steam manifold with the exception that each branch contains a steam trap. The steam trap is usually preceded by a strainer and is located between two isolation valves.
- 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 design of the condensate header to avoid creating excessive pressure drop which leads to high condensate return pressure. High condensate return pressure inhibits steam trap operation; different steam trap styles have different levels of tolerance for high condensate return pressure.

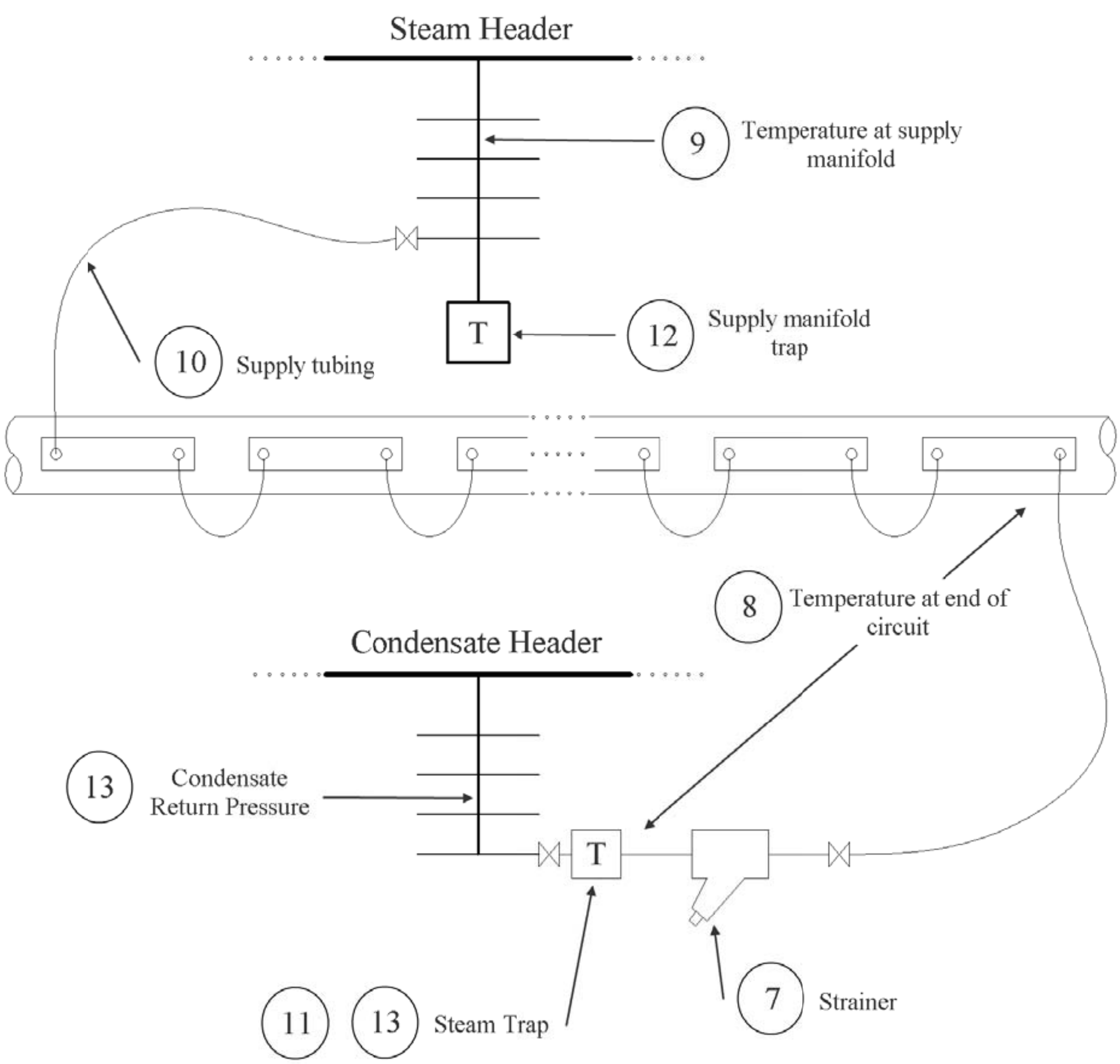

Figure 1: System Overview Diagram (numbers correspond to troubleshooting steps)

LEVEL 1 TROUBLESHOOTING (Process Conditions and System Installation)

Diagnostic Tools Required:
- CSI ControTrace installation drawings

1. Design Conditions

<table>
<tr><td colspan="2"><u>Description</u>
The ControTrace system design is based on a set of design assumptions and a specific thermal objective. While the complete list of design assumptions may not be readily available, several key assumptions are listed on the installation drawings.</td></tr>
<tr><td colspan="2"><u>Action</u>
Locate the area of the piping that is suspected to be the source of the problem and obtain the ControTrace installation drawings for that area; Verify that the assumptions listed in the ‘CT Design Data’ box match the as-built system. The major assumptions are:
• The process
• The thermal objective
• The steam supply pressure
• The pipe size
• The insulation type and thickness.</td></tr>
<tr><td colspan="2"><u>Response</u>
If any of the design assumptions do not match the actual system contact CSI for an analysis of the impact.</td></tr>
<tr><td><u>Results/Notes</u></td><td><u>Initials / Date</u></td></tr>
</table>

2. Confirm the Problem is Heat Related

Description Sometimes process related issues will cause plugging, corrosion, etc. These can appear to be heat related, but are actually independent issues.	
Action Verify that there are no process related issues that could be the source of the problem. The following list gives several examples of process issues that can appear as heating issues (Refer to Appendix D if making temperature measurements): • Mixing of different temperature process streams resulting in quenching of the hotter stream • Leaking valves allowing unwanted process to enter a line • Damaged equipment (e.g. catalyst) physically plugging the line • Chemical reaction forming solids in the line (e.g. carsul, sulcrete) • Operating procedures outside of the design conditions (e.g. process enters the line colder than anticipated)	
Response If a process issue is a likely problem source it may make more sense to investigate the process concerns before investigating the heating system.	
Results/Notes	*Initials / Date*

3. Steam Circuitry

Description

Incorrect circuitry can result in condensate back-up, excessive steam pressure drop, excessive steam heat load, and other problems.

Action

Verify that the ControTrace circuits are routed according to the installation drawings provided by CSI. Verify that:

- All jump-overs are looped down
- All jump-overs are CSI supplied components
- The steam flow direction is as indicated on the drawings
- Only the components shown on the installation drawing are included in the circuit (no unexpected components)
- Each circuit has a single supply and a single steam trap (note that a single supply can feed multiple steam traps, but not visa-versa)

Response

If any portion of the circuitry differs from the installation drawings, correct the circuitry or contact CSI for an analysis of the impact.

Results/Notes	*Initials / Date*

4. Unheated Components

Description

In general, all in-line components (valves, fittings, etc) require heating. Depending on the specific conditions, other items, such a branch connections, flange pairs, large supports, etc. may also require heating.

Action

Check the line for any unheated in-line components. Also check for any conspicuous items that might require additional heating. For example, an unheated trunion on a line with several heated tee shoes could be problem. The following list contains some generic items to look for:

- In-line valves and instrumentation
- Pipe supports
- Jacketed components without a steam supply
- Branch connections

Response

Contact CSI to discuss the impact of unheated components.

Results/Notes	*Initials / Date*

5. Insulation Quality

Description

Proper insulation is critical to the operation of a ControTrace system.

Action

Verify that the line is fully insulated including all:

- Fittings
- Valves
- Flanges
- Instrumentation
- Branch Connections
- Supports
- ControHeats

Response

Fully insulate any portion of the line that is found to be lacking.

Results/Notes	*Initials / Date*

6. Steam Leaks

Description Significant steam leaks increase the steam load of a circuit and reduce the operating pressure. Small steam leaks are not likely to have a significant impact.	
Action Check the line for steam leaks.	
Response Repair any significant steam leaks; while it is prudent to repair any small steam leaks, these are not likely a problem source.	
Results/Notes	*Initials / Date*

LEVEL 2 TROUBLESHOOTING (Steam System Diagnostic)

Diagnostic Tools Required:

- CSI ControTrace installation drawings
- Surface thermocouple probe and meter (or IR gun)
- Steam trap diagnostic tools (varies by trap style)
- Reference the diagram in the 'Steam System Overview' section

7. Strainer Blow-Down

Description A clogged strainer will inhibit condensate removal.	
Action Open the blow-down valve on the steam trap strainer (if equipped) and observe the discharge. A properly operating circuit should have a strong, clean discharge of steam with some condensate.	
Response If the strainer has become clogged with contaminants, it is possible that opening the blow-down valve will remove the contaminants and restore proper circuit operation.	
Results/Notes	*Initials / Date*

8. Steam Temperature (end of circuit)

Description The steam pressure/temperature gradually reduces as it progresses through the steam circuit. The end of the circuit is the worst case location; if the steam pressure/temperature is acceptable here, it is acceptable throughout the circuit.	
Action Measure the temperature of the steam at the end of the circuit (either at the last CT element or just before the steam trap). The temperature should typically be no colder than 10°F below the supply steam temperature, though this number will vary from process to process. Contact CSI for process by process instructions. (Appendix D contains procedures for measuring temperature.)	
Response • If the temperature is acceptable: skip to **Level 3** items. • If the temperature is below specification: proceed to item **9**.	
Results/Notes	*Initials / Date*

9. Steam Temperature (supply manifold)

Description If the steam pressure/temperature in the circuit is low, it may be a result of low steam system supply pressure.	
Action Measure the temperature of the steam at the supply manifold in the same manner. The temperature should correspond with the steam supply pressure listed on the installation drawing (reference the steam table in Appendix A).	
Response • If the temperature is acceptable at the manifold (but too cold at the last element / steam trap): There is either excessive pressure drop in the supply tubing / circuit or the circuit is filled with condensate; proceed to item **10**. • If the temperature is below specification at the manifold: The steam supply pressure is too low. Investigate the steam utilities (boiler set-point appropriate, steam distribution header properly sized, etc.), also check item **12**.	
Results/Notes	*Initials / Date*

10. Supply Tubing

Description In order to minimize the pressure drop in the supply tubing, CSI typically specifies that 3/4” tubing / pipe be used, and that the length not exceed 100ft. If the supply tubing/pipe does not meet these specifications, it is possible that excess pressure drop in the supply tubing may occur.	
Action Measure the supply tubing diameter and length.	
Response • If the supply tubing meets the 100ft of 3/4” requirement proceed to item **11**. • If the supply tubing does not meet the 100ft of 3/4” requirement, measure the temperature of the first element of ControTrace in the circuit. The temperature should typically be no colder than 5°F below the supply steam temperature, though this number will vary from process to process; contact CSI for process by process instructions. If the temperature is reasonable, proceed to item **11**. If the temperature is low, replace the supply tubing with 100ft of 3/4” tubing or contact CSI to analyze the impact.	
Results/Notes	*Initials / Date*

11. Steam Trap Operation

Description

Steam trap failure is a common cause of steam circuit failures. Steam traps can fail open (passing steam uncontrolled) or closed (completely or partially blocking the flow of steam). Steam trap diagnostic methods vary from trap style to trap style. The following two diagnostic methods work for any type of steam trap, but require that the trap be disconnected. Appendix B contains more advanced diagnostic procedures which do not require the steam trap to be removed but require a greater level of familiarity with steam trap operation.

Action

CSI recommends that one of the following fool-proof methods be used to verify proper steam trap operation:

- Disconnect the steam trap from the condensate return system and observe the discharge. In general, the discharge should be a mixture of flash steam and condensate. If the discharge is pure condensate or live steam, the trap should be considered faulty.
- Replace the steam trap with a known good unit.

*Note that thermostatic steam traps back up condensate into the steam circuit; this can compromise the thermal performance of the circuit even if the steam trap is operating correctly. Note that thermodynamic steam traps are sensitive to condensate return pressure (reference item **13**).*

Response

- The steam trap is operating correctly: Proceed to item **12**.
- The steam trap is failed (either open or closed): Replace the steam trap.

Results/Notes	*Initials / Date*

12. Steam Supply Manifold Trap

Description If the steam trap on the steam supply manifold were to fail closed, excessive condensate would be routed from the supply piping into the circuits that feed from the lower manifold taps. The excessive condensate load would create excessive pressure drop in the circuit. If the steam trap on the steam supply manifold were to fail open, the leak could reduce the supply pressure.	
Action Check the operation of the steam trap on the supply manifold.	
Response • The steam trap is operating correctly: Proceed to item **13**. • The steam trap is failed (either open or closed): Replace the steam trap.	
Results/Notes	*Initials / Date*

13. Steam Trap Size / Condensate Return Pressure

Description

The rate at which a steam trap can discharge condensate is a function of the differential pressure across the trap. If the condensate return pressure is too high, the trap will be unable to discharge the condensate at the rate it is being generated by the circuit. If the condensate return pressure is very high, the trap may not be able to discharge the condensate at all.

Action

Measure the condensate return pressure and verify that the steam trap is rated to handle the steam load at the measured differential pressure. Note that:

- The differential pressure across the trap is the steam supply pressure minus the circuit pressure drop (usually about 10psi) minus the condensate return pressure. (e.g. 50psi steam supply pressure – 10psi pressure drop – 20psi condensate return pressure = 20psi differential pressure)
- A typical ControTrace circuit steam load is less than 150 lb/hr.
- The condensate return pressure can often be measured indirectly by measuring the condensate temperature and looking up the pressure on a steam table. (reference Appendix A and Appendix D)
- Thermodynamic steam traps are especially sensitive to high condensate return pressures.

Alternatively, disconnect the steam trap from the condensate return system; if correct circuit operation is restored, the condensate return pressure is too high.

Response

- The steam trap is properly sized and the condensate return pressure is reasonable: Proceed to **Level 3** items.
- The condensate return pressure is too high for the steam trap size / style being used: Investigate the steam utilities or, if the condensate pressure is not too excessive, replace the steam trap with one capable of handling the condensate return pressure.

Results/Notes	*Initials / Date*

LEVEL 3 TROUBLESHOOTING (CSI Involvement Recommended)

14. Design Conditions (Advanced)

Description

The ControTrace system is design is based on a set of design assumptions and a specific thermal objective. Each of these design assumptions should be verified. While a few basic assumptions are listed on the ControTrace installation drawings, the complete list of design assumptions may not be readily available to the end user.

Action

Contact CSI to compare the design assumptions to the as-built system. In addition to the assumptions listed on the installation drawing, CSI will likely require:

- Copies of applicable P&IDs
- The process name
- The process flowrate
- The process temperature
- Piping material, and schedule

Response

- Contact CSI for assistance.

Results/Notes	*Initials / Date*

15. Poorly Heated Areas

Description Poorly heated areas are difficult to spot once a system is insulated. Additionally, the extent to which flanges, supports, fittings, etc require heating is dependent on the specific process conditions.
Action Contact CSI for help spotting poorly heated areas on an insulated line. As a starting place: • Compare the observed locations of ControTrace connections to the expected locations based on the ControTrace installation drawings. • Look for items that may require additional heating, though the heating requirements will vary from process to process. (e.g. supports, flanges, instruments, branch connections, etc) • Photograph suspect areas.
Response • Contact CSI for assistance.

Results/Notes	*Initials / Date*

16. ControTrace Installation

Description Poor quality installation will result in inadequate heat transfer between the ControTrace and the pipe. The installation quality can be difficult to ascertain once the system is insulated.
Action In general, look for: • Missing heat transfer compound. • Large gaps between the pipe and the ControTrace elements (The thickness of the heat transfer compound should not exceed 1/8”). • Poorly spaced ControTrace elements (longitudinally or circumferentially).
Response • Contact CSI for assistance.

Results/Notes	*Initials / Date*

17. Blockage in the Circuit

Description It is rare, but possible for foreign material to become lodged in the supply tubing or the ControTrace circuit. This will result in excessive pressure drop through the circuit.	
Action It may be possible to locate an obstruction by measuring the steam temperature/pressure along the circuit; a sudden drop in temperature/pressure indicates an obstruction. If an obstruction is suspected the easiest approach may be to attempt to clear the obstruction without locating it by forcing water or air backwards through the circuit.	
Response • An obstruction is present: Clear the obstruction using appropriate means. • The circuit is clear: Contact CSI for assistance.	
Results/Notes	*Initials / Date*

APPENDIX A (Saturated Steam Table)

psig	°F	barg	°C
0	212.0	0.0	100.0
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

psig	°F	barg	°C
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

APPENDIX B (Steam Trap Diagnostic)

Diagnostic Tools Required:

- Mechanics stethoscope or appropriate trap diagnostic tool
- Trap manufacturer consultative support

Inverted Bucket Traps

- Failure modes:
  - Plugged vent: *fail cold* due to inability to discharge air.
  - Lost prime: *fail hot*, characterized by continuous discharge with bouncing bucket. Restore prime by closing valve after trap for a few minutes and re-opening.
  - Damaged, worn, or bound mechanism: *fail cold or hot* due to trap either stuck in closed or open position.
- Verifying normal operation:
  - Listen to trap with mechanics stethoscope. Normal operation is either a light, quiet continuous discharge (characteristic of light steam loads) or an intermittent open-close discharge (characteristic of normal to heavy steam loads).
  - If trap is failed open the discharge will be continuous and a louder, higher pitch sound than other, properly working traps.

Float and Thermostatic Traps

- Failure modes:
  - Float collapsed or punctured: *fail cold* due to inability of float to open discharge.
  - Damaged, worn, or bound mechanism: *fail cold or hot* due to trap either stuck in closed or open position.
  - Air vent plugged or failed closed: *fail cold* due to inability to discharge air.
  - Air vent failed open: *fail hot*; the primary trap mechanism is operational but the trap continuously discharges live steam; this may or may not cause significant steam pressure drop in the circuit.
- Verifying normal operation:
  - Listen to trap with mechanics stethoscope (compare to known good traps). Float traps discharge continuously. A failed open trap's discharge will be louder and a higher pitch than a properly working trap.
  - If a downstream valve is closed for a minute and then re-opened, a failed open trap will return to the continuous discharge sound right away. A properly operating trap will discharge its condensate rapidly and then settle down to a slow discharge as the trap returns to steady state.
  - A failed open air vent may be difficult to detect by listening. Disconnecting the trap from the condensate return system is a fool-proof method of detecting a failed open air vent.

Thermodynamic Traps

- Failure modes:
  - Trap seat/disk worn: *fail hot* due to inability to seal properly.
  - Debris in trap: *fail hot or cold* due to debris preventing disc from seating or plugging a passageway.
- Verifying normal operation:
  - Listen to trap with mechanics stethoscope. Normal operation is a periodic discharge every 10 to 30 seconds. Discharge duration will depend on the circuit steam load.
  - Discharging every 5 seconds or less is a sign of either (1) a worn trap, (2) excessive condensate back-pressure, or (3) an undersized trap.
  - Disconnecting the trap from the condensate return system is not a reliable way to verify trap operation as the condensate return pressure plays a significant role in the trap operation.

Thermostatic Traps

- Failure modes:
  - Damaged, worn, or bound mechanism: *fail cold or hot* due to trap either stuck in closed or open position.
  - Debris in trap: *fail hot or cold* due to debris preventing trap from closing or plugging a passageway.
- Verifying normal operation:
  - In some cases (typically with near-to-steam temperature models) the trap may discharge intermittently, this indicates a properly functioning trap.
  - If the trap is cooled by spraying it with water the discharge should increase briefly, then stop, then return to steady state.
  - Close valve after trap to allow condensate to build up in the trap. Open the valve and listen to the discharge. If the trap is failed open, the discharge sound will increase in volume and pitch when the discharge transitions from condensate to live steam.
  - Thermostatic traps can usually be tested by placing them in a pot of boiling water, consult manufacturer for proper procedure.

APPENDIX C (Blow-Down Discharge)

The blow-down discharge will provide some insight into the steam conditions in the circuit. The following list shows likely problems based on the strainer discharge.

- <u>If there is no discharge</u>: The circuit is not supplied with steam; the circuit is plugged, or the strainer is plugged.
- <u>If the discharge is primarily condensate</u>: The steam trap is failed closed; the circuit steam load is too high due to improper routing; the circuit pressure drop is too high due to improper routing, small supply tubing, or a restriction; excessive condensate is being routed into the circuit; the steam supply pressure is too low; the condensate return pressure is too high.
- <u>If the discharge is weak</u>: The circuit pressure drop is too high due to improper routing, small supply tubing, or a restriction; the strainer is partially clogged; the steam supply pressure is too low.
- <u>If the discharge contains a lot of contaminants</u>: Excessive debris has built up in the circuit, and possibly the trap.
- <u>If the discharge is normal</u>: The steam trap is failed open; the steam supply pressure is too low; the circuit steam load is too high due to improper routing; the circuit pressure drop is too high due to improper routing, small supply tubing, or a restriction.

APPENDIX D (Temperature Measurement Procedure)

The best method of measuring the steam temperature is to have a temperature gauge installed with a probe that directly contacts the steam. However, this type of temperature equipment is rarely used with steam systems. It is usually necessary to measure the steam temperature at a given point in the system by measuring the surface temperature of the piping/tracing. There are two common methods for measuring the surface temperature, thermocouples and infrared guns. No matter which method is used, great care must be taken to assure that the ambient conditions are not impacting the pipe temperature; in general, this is accomplished by ensuring that the area being measured remains fully insulated.

Thermocouple Method: The thermocouple method is generally the most accurate as it is not impacted by the emissivity of the pipe and the piping can easily remain insulated while performing the measurement. In general, use the following procedure:

1. Remove a small amount of insulation from the piping/tracing in the area to be measured. Remove dirt, debris, scaly rust, insulation remnant, etc from the pipe surface.
2. Attach the thermocouple bead to the pipe/trace in the exposed area. It is important that the bead is pressed against the pipe/trace surface; any air gap will cause erroneous readings. Several methods of attachment may be used:
   - For single measurement use a piece of high-temperature tape is usually adequate.
   - If multiple measurement over several days are desired it is better to attach the thermocouple with an appropriate epoxy such a JB weld.
   - For small bore piping when the entire circumference of the pipe is exposed, a heavy plastic zip-tie or a metal hose clamp may be used. If using a metal hose clamp, insulate the thermocouple bead from the clamp using a layer of insulating material.
3. Replace the insulation over the thermocouple and the pipe/trace around the thermocouple. Make sure that there are no air gaps that allow ambient air to contact the pipe/trace around the thermocouple.
4. If directly measuring the trace or steam piping, wait approximately 30min before taking a temperature reading. If measuring process piping, wait approximately 2hr before taking a reading.
5. Read the thermocouple temperature with a meter that is properly programmed for the thermocouple type being used.

Infrared Gun Method: An infrared gun can successfully be used to measure the pipe/trace temperature, but extra care must be used to prevent the pipe/trace temperature from being negatively impacted by the ambient air temperature. In general use the following proceedure:

1. Remove a small amount of insulation from the pipe/trace in the area to be measured. Remove a little insulation as possible while still exposing sufficient area for the IR gun. Remove dirt, debris, scaly rust, insulation remnant, etc from the pipe surface.
2. Note the material and condition of the surface to be measured (stainless steel, galvanized steel, rusty steel, fresh steel, etc.) Refer to the IR gun manual and adjust the IR gun emissivity setting as appropriate for the surface.

3. Re-insulate the area to be measured with a patch of insulation that can be easily and quickly removed. Make sure that there are no air gaps that allow ambient air to contact the pipe/trace around the area to be measured.
4. If directly measuring the trace or steam piping, wait approximately 30min before taking a temperature reading. If measuring process piping, wait approximately 2hr before taking a reading.
5. Remove the insulation patch and quickly take the temperature using the IR gun. Take the temperature as quickly as possible as even brief exposure to the ambient air will impact the pipe/trace wall temperature.

Note that once the IR gun emissivity is set correctly, it may be possible to take measurements in additional locations by pealing back existing insulation and quickly measuring the surface. Also note that the IR gun emissivity can be calibrated by measuring the same surface with both a thermocouple and the IR gun; the IR gun can then be adjusted to match the thermocouple reading.

APPENDIX E (Permanent Steam Temperature Gauge)

Accurately measuring the steam temperature at the end of the circuit (Step 8) is a crucial step in diagnosing the operation of a steam circuit. The measurement process can be streamlined by installing a permanent temperature gauge at the end of each steam circuit. CSI has identified a suitable temperature gauge for this application. The total cost of the gauge and the fittings to install it will be approximately $50 for each circuit.

The gauge screws into a standard 3/4” tee fitting via a bushing. The tee fitting can then be placed in-line at the end of the circuit. The optimal location for the temperature gauge is either between the last element of ControTrace and the return tubing, or between the return tubing and the steam trap. The gauge must not be placed after the steam trap. If the gauge is to be installed in the branch of the tee it is important that only the tee and bushing listed below be used in order to achieve proper clearance between the gauge stem and the inside of the fitting. All parts can be ordered through McMaster-Carr. The following part list is current as of 4-Oct-2010.

Description	Part Number	Price
3/4" Straight Tee	44605K155	$2.24
Bushing	4513K347	$1.91
WIKA Gauge	3946K118	$43.60
	Subtotal:	$47.75

The specifications of the temperature gauge are:

- 3” dial
- Back connection
- 2-1/2” Stem length
- 1/2” NPT connection
- 50-400 ^{o}F temperature range
- 5 ^{o}F subdivisions
- ±1% full scale accuracy