Armstrong Fluid Handling
Understanding and Solving Equipment Stall

Everyone has heard of it, everyone has seen or experienced it. So why is there so much mystery surrounding equipment "stall". Stall can most easily be defined as a condition in which heat transfer equipment is unable to drain condensate and becomes flooded due to insufficient system pressure.
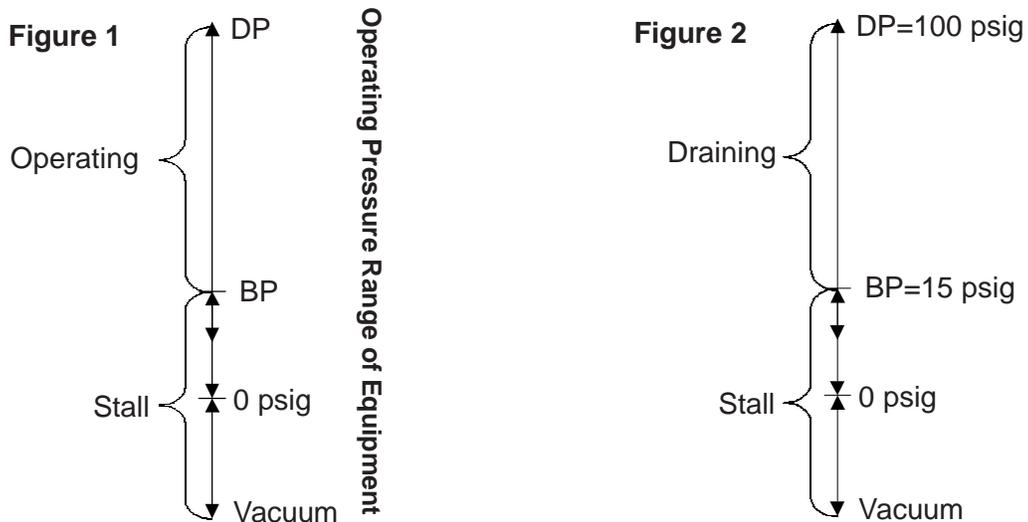
What causes stall?

Stall occurs primarily in heat transfer equipment where the steam pressure is modulated to obtain a desired output (i.e. product temperature). The pressure range of any such equipment (coils, shell & tube, etc.…) can be segmented into two (2) distinct operational modes: Operating and Stall

Operating: In the upper section of the pressure range the operating pressure (OP) of the equipment is greater than the back pressure (BP) present at the discharge of the steam trap. Therefore a positive pressure differential across the trap exists allowing for condensate to flow from the equipment to the condensate return line.

Stall: In the lower section of the pressure range the operating pressure (OP) of the equipment is less than or equal to the back pressure (BP) present at the discharge of the steam trap. Therefore a negative or no pressure differential exists, this does not allow condensate to be discharged to the return line and the condensate begins to collect and flood the equipment.

In Figure 2 we can see how this concept applies to a real world application. Assume the following operating conditions:


Figure 1 — Operating Pressure Range of Equipment

- DP
- Operating
- BP
- Stall
- 0 psig
- Vacuum

Figure 2

- DP=100 psig
- Draining
- BP=15 psig
- Stall
- 0 psig
- Vacuum

It is clear that any time the air heating coil in Figure 3 modulates below 15 psig the system will fall into a "stall" condition. This condition is most likely to occur when there is a light heating load, causing the coil to operate at a fraction of its capacity and a fraction of the design pressure

Table 1

Design Pressure (DP) = 100 psig	
Back Pressure (BP) = 15 psig	
Incoming Air Temperature (T1) = -10°F	
Exit Air Temperature (T2) = 70°F	
Design Condensate Load (DL) = 3,000 lb/hr	

Figure 3
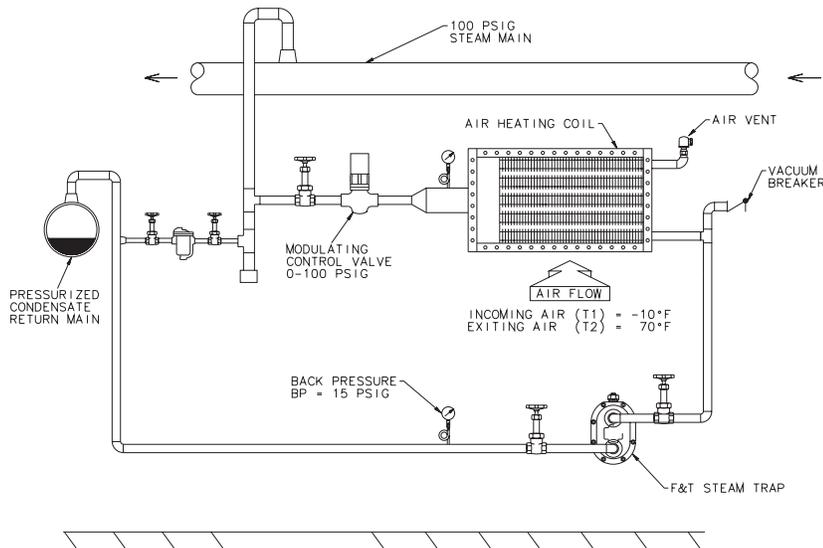
Effects of "stall"

In a stall condition condensate accumulates within the equipment. When equipment becomes flooded by stalled condensate a variety of problems ranging from minor to catastrophic failure will occur.

Problems associated with stall:
- Inadequate condensate drainage
- Waterhammer (Thermal shock)
- Frozen coils
- Corrosion due to cool condensate and the formation of Carbonic acid
- Poor temperature control
- Short equipment life
- Control valve hunting (system cycling)
- Reduction in heat transfer capacity

Factors contributing to "stall"

Stall happens for a variety of reasons, but it always comes back the fact that there is not always enough system pressure to return the condensate. The lack of sufficient pressure in the equipment may be caused by anyone of the following:

- Oversized equipment (excessive surface area)
- Overly conservative fouling factors
- Back pressure at equipment discharge due to elevation or pressure in the line
- Modulating control
- Equipment operating at lower pressures due to light load demands
- Vacuum

Many types of heat transfer equipment are susceptible to stall because they are designed with excessive safety factors built into the design. In attempting to provide an extremely robust heat exchanger, equipment manufactures and engineers often "over design" equipment which often lends itself to a stall scenario.

Solutions?

The problems of equipment stall are well known and well documented. Over the years there has been a variety of so called "solutions" that would all alleviate the stall scenario.

Installation of a vacuum breaker:

Objective:
To relieve a vacuum within equipment allowing for condensate drainage.

Shortcoming:
1. This practice will only help if the condensate is gravity drain to atmosphere, any pressure present at the discharge of the trap will not allow condensate drainage.

2. Allows undesirable air into the system.

3. Vacuum breakers often fail due to a poorly chosen location downstream of the equipment causing a build-up of scale/sediment impeding the operation. Such a location may also allow the hydrostatic pressure of a vertical water column to keep the vacuum breaker closed in a small vacuum.

4. Loss of valuable flash steam

Installation of a safety drain:

Objective:
The use of a second steam trap located above the primary trap which discharges condensate to drain when the system goes into a stall condition.

Shortcoming:
A significant amount of condensate/flash steam and valuable BTU's are lost down the drain when the system is in stall. Stall load may as high as 90% or more of the design load, therefore 90% of the condensate coming from the equipment goes down the drain

Installation of a positive pressure system:

Objective:
The use of air or other gas to maintain set pressure to ensure a positive pressure differential across the trap allowing for condensate drainage.

Shortcomings:
Injects a significant amount of undesirable air into the equipment. This large amount of air may cause multiple problems:

1. Air acts as an insulator thereby decreasing the heat transfer capacity of the equipment.
2. A heavy dependence on air vents to evacuate the air from the equipment.
3. Air vents may be open a significant amount of time allowing for loss of valuable BTU's.

The Solution

The application of a **"closed"** system pump trap on your modulating steam equipment can provide the following benefits:

■ Continuous condensate drainage, even in a vacuum
■ Eliminates the need for vacuum breakers
■ Saves valuable flash steam from escaping into the atmosphere

- No need to run expensive vent lines
- Size pump traps on stall load, resulting in smaller pumps and less cost
- No rotating seals, cavitation, or NPSH requirements
- Negligible operating cost
- Longer equipment life
- Reduced corrosion
- Better temperature control
- Reduced maintenance…….and more

The Closed Loop Concept

The closed loop application of a pump trap is based around one basic concept:

To equalize the pressure in the heat exchange equipment and the pump trap thereby allowing condensate to drain by gravity to the pump trap.

**The equalization of pressure is accomplished by:**
1. Connecting the vent of the pump trap to the inlet steam side of the equipment or to a condensate receiver upstream of the pump trap.

2. Placing the steam trap on the outlet side of the pump trap or eliminating the steam trap altogether (if DP<BP)

Figure 4 shows the appropriate piping configurations for a closed loop pump trap application. Connecting the vent line of the pump trap to the inlet steam side to the equipment is the preferred method of pressure equalization if the pressure drop across the heat exchange equipment is ½ psig or less.

If the pressure drop is greater, the vent line of the pump trap should be connected to the condensate receiver upstream of the pump trap. The vent line must be connected into a vapor space, not into liquid. (**Note:** Piping from the equipment should be increased one pipe size and be pitched towards the receiver to avoid water seal)

In either configuration the vent line should be increased one pipe size if the length is to exceed 6 feet.

Figure 4

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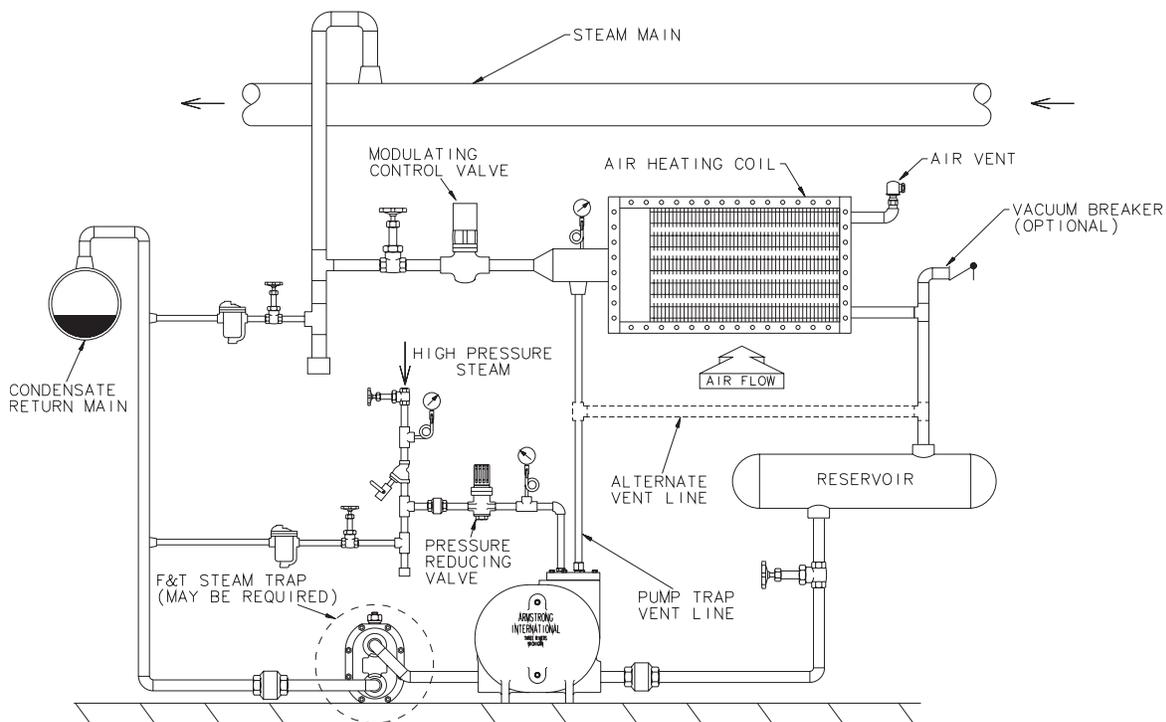
Equipment Sizing:

The main components to be sized in a closed loop pump trap application are the pump trap and the steam trap (if necessary).

Pump trap sizing:
One major benefit of using a pump trap in a closed loop system is the ability to size the pump based on the stall load as opposed to the design load. This will almost always result in a smaller required pump capacity since the stall load is generally some fraction of the design load. The pump trap can be sized based on the stall load because:

When the equipment operating pressure (OP) is above the back pressure (BP) the condensate is discharged into the return line by the positive pressure differential (draining mode). In this mode the pump trap is inactive, the condensate simply flows through the pump as if it were a piece of pipe.

When the equipment operating pressure (OP) is less than or equal to the back pressure (BP), condensate is unable to be discharged into the return line due to insufficient pressure and the system goes into stall. Usually the condensate would accumulate in the equipment, but in a closed loop system the condensate collects in the pump trap. Once the pump trap is filled to the appropriate level the pump trap is activated and pumps the stalled condensate through the steam trap and into the return line. Hence the pump trap only pumps when the system is in "stall" and thereby allowing the pump trap to be sized based on the stall load as opposed to the design load.

Sizing the steam trap in a closed loop system:
The recommended steam trap for modulating service is generally a Float and Thermostatic (F&T) trap. The F&T trap is chosen for its continuous drainage, air venting capabilities, and the ability to handle the high instantaneous loads when used in conjunction with a pump trap in closed loop system.

The steam trap in a closed loop system must be able to handle the demands of the heat exchange equipment and the instantaneous pumped loads of the pump trap. Therefore the steam trap must be sized twice, once for the equipment and once for the pump trap.

Sizing the steam trap based on modulating heat exchange equipment.

Table 2

Operating Pressure	Safety Factor
0 - 15 psig	2:1 @ 1/2 psi differential
16 - 30 psig	2:1 @ 2 psi differential
> 30 psig	3:1 @ 1/2 max. pressure differential

Sizing the steam trap based on the pump trap

Table 3

Operating Pressure	Safety Factor
Must handle maximum pressure of heat exchange equipment	Stall load @ 1/4 psi differential

The larger trap from either method is the correct trap to be used in a closed loop system in conjunction with a pump trap.

Determining Stall Load
Operating parameters of the equipment and system can be graphed on a stall chart to determine two very critical points:

1. The minimum allowable flow rate before the equipment goes into a stall condition. The stall load is expressed as a percentage of the design load (assuming T1 is constant).

2. The maximum incoming temperature (T1) before the equipment goes into a stall condition (assuming flow rate is constant).

To use the stall chart the following information must is required:
- Design Pressure (DP)
- Back Pressure (BP)
- Incoming Temperature (T1)
- Exiting Temperature (T2)

Using the parameters from Table 1, the stall chart is plotted using the following steps:

1. Plot T1 = -10°F on the vertical axis on the left, then plot T2 = 70°F on the vertical axis on the right and draw a line to connect the points.

2. Determine the Mean Temperature (MT)= (T1+T2)/2 = (-10+70)/2 = 30°F. Plot MT=30°F on the vertical axis on the right. Plot the Design Pressure (DP) =100 psig on the vertical axis on the left. Draw a line to connect points MT and DP.

3. Plot the Back Pressure (BP) = 15 psig on the vertical axis on the left. Draw a horizontal line at BP across the chart.

4. At the intersection of line BP and line MT/DP drop a vertical line to determine that the stall load percentage (SL) = 73%

5. At the intersection line T1/T2 and vertical line SL, draw a horizontal line to the left to determine that the stall temperature (ST) = 13°F

Figure 5
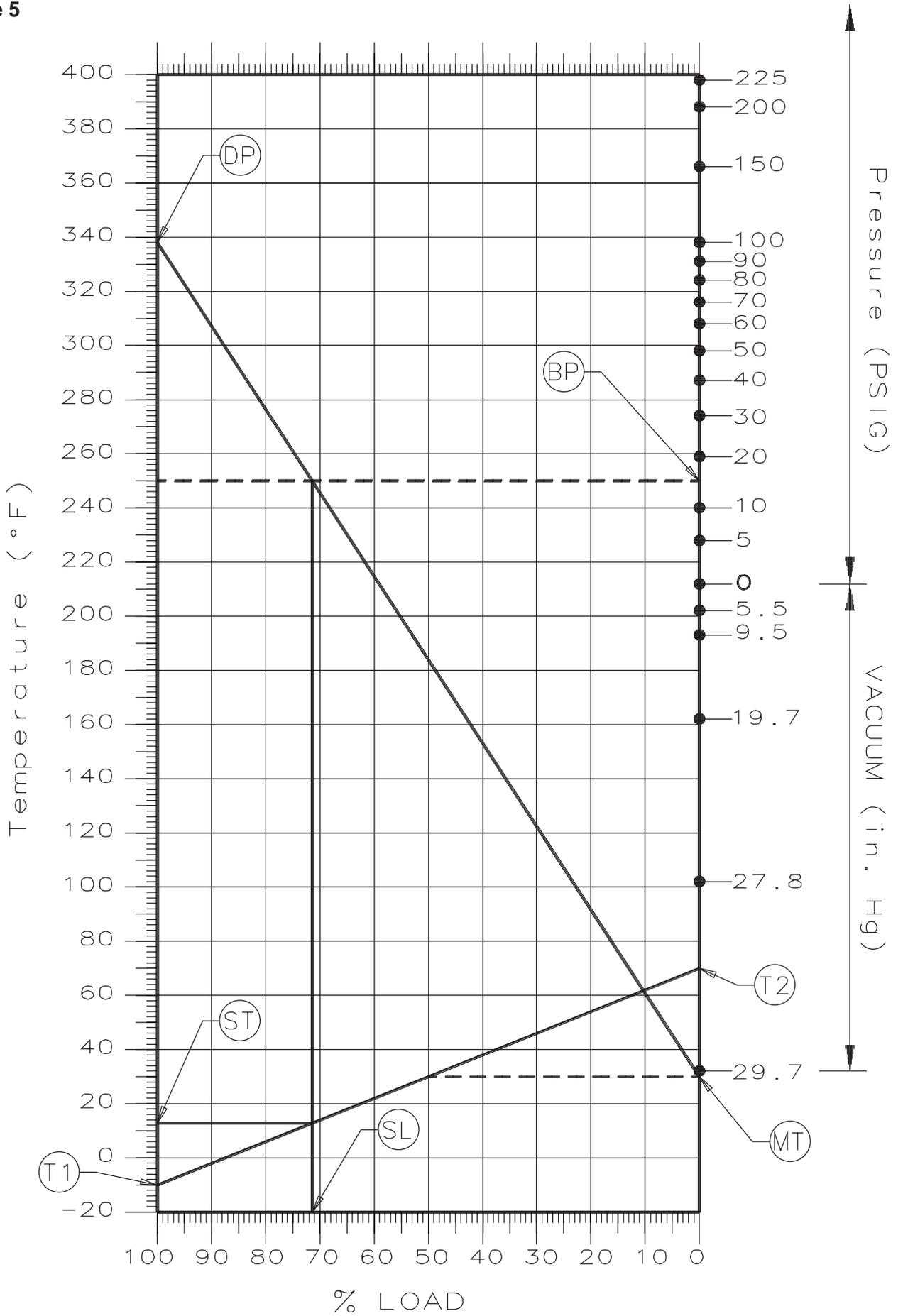
With the information from the stall chart to critical points can be identified:

1. The Stall Load percentage (SL) indicates the coil is in a stall condition anytime the load drops below 73% of the Design Load (DL). Therefore the maximum amount of condensate being produced when the coil is in stall is SL x DL = .73 x 3000 lb/hr = 2190 lb/hr. In a closed loop system the pump trap can be sized on the stall load of 2190 lb/hr instead of the design load of 3000 lb/hr, resulting in a smaller, less expensive pump trap.

2. The Stall Temperature (ST) = 13°F indicates the coil is in a stall condition anytime T1 is greater than 13°F. Anytime incoming air is warmer than 13°F the coil will not drain condensate with out assistance. How many days a year is the outside temperature greater than 13°F, almost everyday!!

Knowing the stall load, the pump trap and steam trap for our example in Figure 1 can be determined.

Pump trap sizing example:

Table 4

Required Load	Motive Pressure Available	Back Pressure	Pump Trap Model
2,190 lb/hr	100 psig steam	15 psig	PT-204*

*Assuming 12" fill head and 50 psig steam motive
In an open system the pump trap would be sized for the design load of 3000 lb/hr resulting in the use of a larger PT-206 pump trap.

Steam trap sizing example:

Based on Pump trap

Table 5

Stall Load	Safety Factor	Steam Trap Model
2,190 lb/hr	Stall load @ 1/4 psi differential 2,190 @ 1/4 psi differential	F&T 125-J8

Stall Load	Safety Factor	Steam Trap Model
3,000 lb/hr	3:1 @ 1/2 max. differential 9,000 @ 50 psi differential	F&T 125-J8

Based on heat exchange equipment

Both methods selected a 125-J8 steam trap, however if there were a difference the larger trap would be chosen.

Conclusion
Applications for applying pump traps in closed systems to eliminate problems with stall exist at almost every facility.

The benefits of using a pump trap in a closed system to solve the problem of "stall" can provide multiple benefits that reduce maintenance, improve performance, increase equipment life, and provide significant cost savings in installation and operation.

Figure 6