Armstrong
Machine Works

OPERATING CHARACTERISTICS OF INVERTED BUCKET STEAM TRAPS

Intermittent Mode of Operation

When the proper combination of body size and orifice size is selected to suit the operating pressure differential and condensate flow rate that exist in a given application, the inverted bucket steam trap will discharge intermittently as illustrated in figure 1. The valve is either wide open with full continuous capacity discharge of condensate and flash steam or tightly closed with no discharge.

When the valve is open, only condensate, flash steam, and non-condensible gases are discharged. The water seal between the valve at the top of the body and the steam trapped under the bucket prevents steam from reaching the valve eliminating the possibility of significant live steam loss when discharging. When the valve is closed, the free floating valve lever mechanism permits the force of the pressure differential to move the ball valve to a position on the seat which will establish a water tight seal so that nothing flows from the trap outlet. Nonetheless, although there is no discharge from the trap, condensate freely flows into the trap, therefore, there is no back-up of condensate ahead of the trap. The entire system ahead of the trap is drained continuously of condensate although the trap discharge is intermittent.

Non-condensible gases rise through the air vent at the top of the bucket to collect above the water seal to be discharged when the valve opens. Some steam also rises through the vent hole with the non-condensible gases, but since the entire inside of the trap is at the same pressure, the only differential existing across the air vent to provide flow through the vent is the height between the water level under the bucket and the top of the bucket. This is a differential of only inches of water, so the flow rate is extremely small. The air vents are normally sized so that steam flow through the vent is less than 1/2 the radiation rate of the trap body. Consequently, any steam rising through the air vent is condensed in the surrounding water seal, and non-condensible gases only rise to the top of the trap for discharge when the valve opens.

Thus, non-condensible gases are separted from the steam in the trap to be discharged along with the condensate without the discharge of live steam. Also, because the entire trap body is at the pressure of the system and at or near saturation temperature, no sub-cooling of condensate and non-condensible gases occurs. As a result, no corrosive condensate is contained in the system ahead of the trap or in the trap, and no corrosive condensate is discharged from the trap.

In the past, inverted bucket traps were applied primarily to heat exchanger and critical steam main drain applications. In these applications the trap could be sized to suit the existing differential pressure and condensate flow conditions, so the intermittent discharge mode of operation has been the one associated with "normal" inverted bucket trap operation.

Another mode of operation commonly referred to as "dribbling" and characterized by a seemingly continuously modulating discharge is also "normal" under certain conditions.

Low Pressure Continuously Modulating Mode of Operation

Today's energy consciousness suggests the use of inverted bucket traps in all applications to take advantage of their unique combination of energy efficiency and long life. In order to minimize the number of different trap and orifice size combinations used in plants with multiple pressure levels in steam main drain and steam tracing applications, the orifice size for the highest pressure is applied to all pressure ranges. When orifices suited for high pressures are used at low pressures, the "normal" mode of operation will not be an intermittent discharge. The discharge will appear to be continuous.

A 5/64" orifice in an 1811 suitable for operation at a maximum pressure differential of 460 psi will require a force of 30.4 oz. to open the valve. The weight of the bucket times the lever arm ratio supplies this force. A high level of water under the bucket is required to provide sufficient force. The same orifice used at 80 psig requires only 6.08 oz. to open the valve. Only 1/5 as much force is required so only 1/5 as much bucket length must be filled with water. A much lower water level is adequate to provide the necessary force. This is illustrated in Figure 2.

At 80 psi differential, an 0.32 oz. force is required to open the valve. This amount of water must be removed from under the bucket with each discharge. If 200#/hr. or 0.9 oz/sec of condensate load is present, the cycle rate of the trap must be 3 cps. Obviously, a 3.29 oz. bucket submerged in water cannot move this rapidly so the bucket merely positions the valve to provide the continuously modulating flow.

Low Load Continuously Modulating Mode of Operation

The same operating mode is exhibited in inverted bucket traps which are used in extremely low condensate load applications even if the orifice is closely matched to the pressure differential.

When the valve in an inverted bucket trap is closed, the bucket weight, WB in Figure 3, is low and the forces attempting to hold the valve closed exceed those trying to open it. As the condensate level under the bucket rises, the net buoyancy of the bucket decreases until the opening forces balance and begin to exceed the closing forces as shown in Figure 3-1. At this point, the valve begins to crack open and a small flow of condensate starts through the cracked valve. Because the opening at this point is small and there is a pressure drop, flashing of the condensate occurs increasing velocity through the orifice. This increased velocity decreases pressure momentarily in the restriction which increases the pressure drop across the valve. This increases the net closing force.

If the condensate flow into the trap is large enough relative to the instantaneous flow rate out through the cracked open valve, the water level under the bucket rises fast enough to reduce bucket buoyancy sufficiently so that the opening force grows to overcome the increased closing force permitting the valve to be pulled fully open.

If the condensate flow into the trap is small enough relative to the instantaneous flow rate out through the cracked open valve, water level under the bucket does not increase rapidly enough'to reduce bucket buoyancy sufficienty and the increased closing force snaps the valve closed. This partially opening instantly closing mode of operation then continues at a relative rapid cycle rate which gives the appearance of continuous flow.

Conclusion

For reasons of standardization, it may not be possible to match the valve orifice size to all operating conditions. The use of small high pressure orifices, at low pressure or extremely low condensate loads relative to the capacity of'even the small orifices will'result in the continuously modulating ("dribbling") mode of operation which is characterized by a visible continuous flow of hot condensate and flash steam. However, it should be stressed that this mode of operation is of no consequence.

In any case, whether the result of low pressure or low load or the combination of the two, "dribbling" will not affect the maintaining of the water seal in the trap, consequently no live steam reaches the valve. Effectively only hot condensate is discharged which will flash out in the atmosphere just as in the intermittent mode of operation.

If for aesthetic reasons intermittent operation is desired under all conditions, two methods are available to promote intermittent operation:

1. A reduced orifice can be used. This is two orifices in series. The first orifice upon which the valve seats would be sized to suit the pressure. In the same seat assembly after the main orifice a smaller orifice is drilled to a size to suit the anticipated flow rates.

   The reduced orifice restricts flow ot condensate and flash Steam from the trap causing a rapid build-up of pressure in the chamber between the main orifice and the reduced orifice to provide a large addition to the opening force which pushes the valve open to give a clear intermittent discharge operation in most cases. This is illustrated in Figure 3-3.

   One caution in the use of restricted orifices is their small size, usually 0.040". These small orifices can be susceptible to plugging in applications where dirty conditions exist.

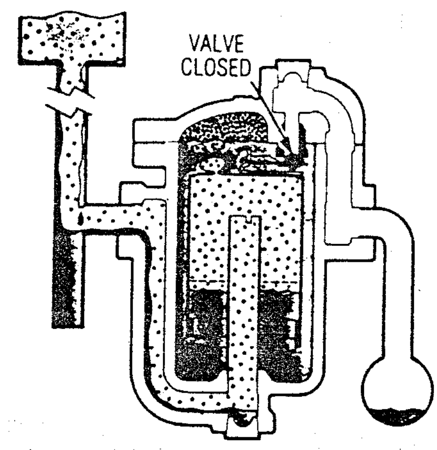
2. The size of the bucket air vent has an effect on how rapidly the bucket can be moved. If-the bucket air vent is reduced in size, the bucket movement is slowed, and the tendency for "dribbling" can be reduced. In using reduced bucket vent sizes, consideration should be given to the possibility'of plugging of the vent hole in dirty conditions, and to the reduced air handling capabilities of the trap.

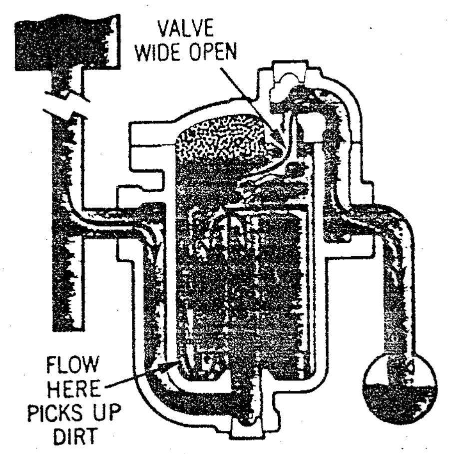
   The use of wiggle wires or vent scrubber wires will eliminate the susceptibility to air vent plugging.

   In steam main drain and steam tracing applications non-condensible gas quantities are relatively minor and the air handling capabilities of a trap are not critical.

Fig. 1
OPERATION AT PRESSURES CLOSE TO MAXIMUM

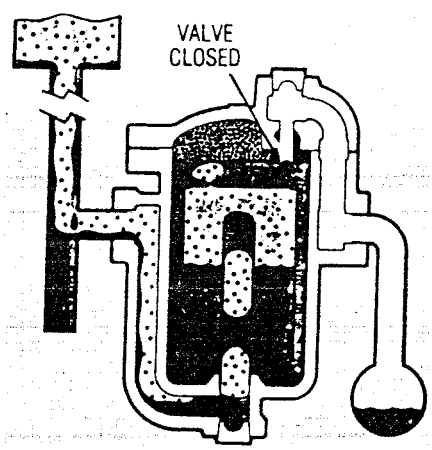
KEY Steam Condensate Air flashing Condensate

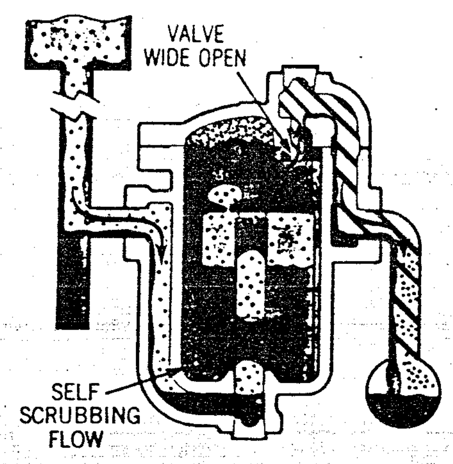




2. Steam also enters trap under bottom edge of bucket, where it rises and collects at top, imparting buoyancy. Bucketthen rises and lifts valve toward its seat until valve is snapped tightly shut. Air and carbon dioxide continually pass through bucket vent and collect at top of trap. Any steam passing through vent is condensed by radiation from trap.

1. Steam trap is installed in drain line between steam heated unit and condensate return header. At this point, bucket is down and valve is wide open. As initial flood of condensate enters the trap and flows under bottom edge of bucket, it fills trap body and completely submerges bucket, Condensate then discharges through wide open valve to return header.

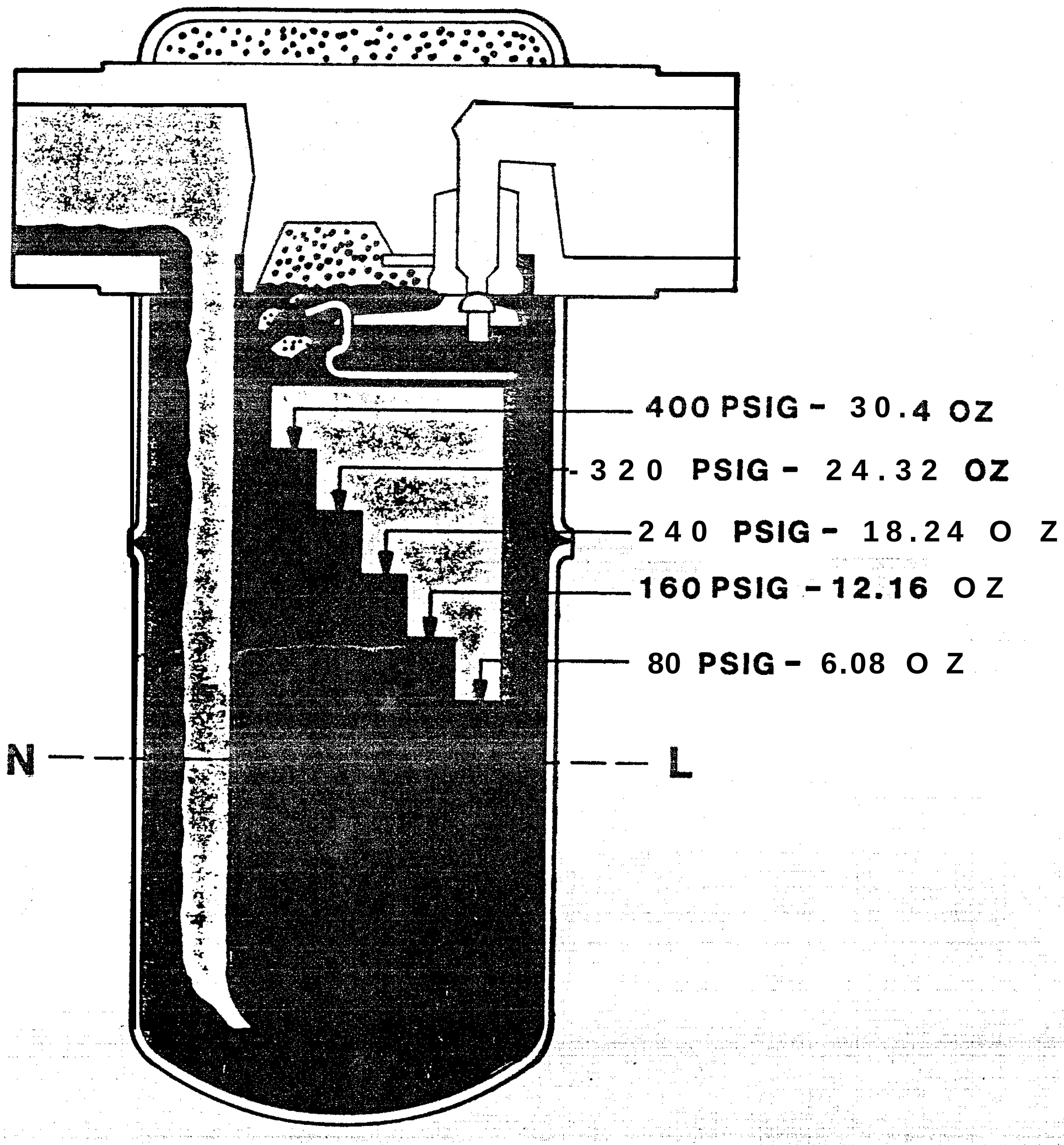




3. When entering condensate brings the condensate level slightly above the neutral line the bucket exerts a slight pull on the lever. The valve does not open, however, until the condensate level rises to the opening line for the existrng pressure differential between the steam and the condensate return header.

4. When the condensate level reaches opening line the weight of the bucket, times leverage, exceeds the pressure holding valve to its seat. Bucket then sinks and opens trap valve. Any accumulated air is discharged first followed by condensate. Discharge continues until more steam floats bucket at which time cycle begins to repeat.

Figure 2


400 PSIG - 30.4 OZ
320 PSIG - 24.32 OZ
240 PSIG - 18.24 O Z
160 PSIG - 12.16 O Z
80 PSIG - 6.08 O Z
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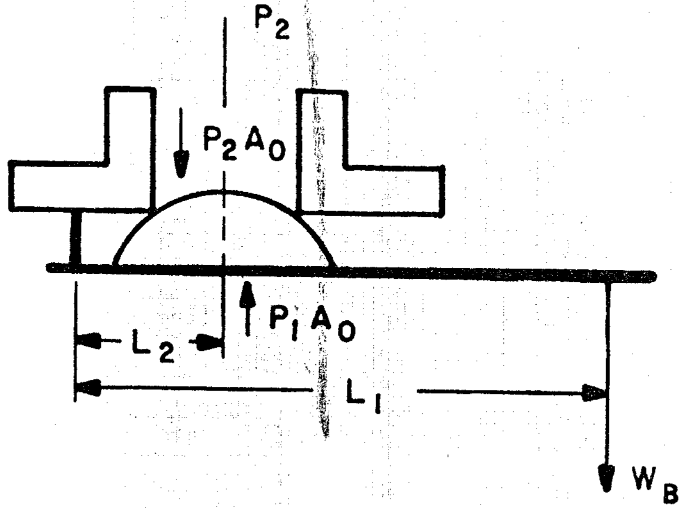
L

Figure 3

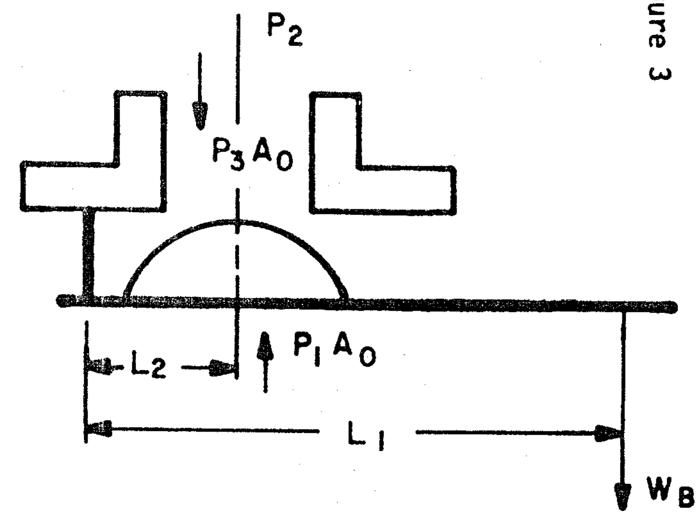
3-1



$P_1 A_0 L_2 > P_2 A_0 L_2 + W_B L_1$ — CLOSED

$P_1 A_0 L_2 \overset{=}{<} P_2 A_0 L_2 + W_B L_1$ - OPENING

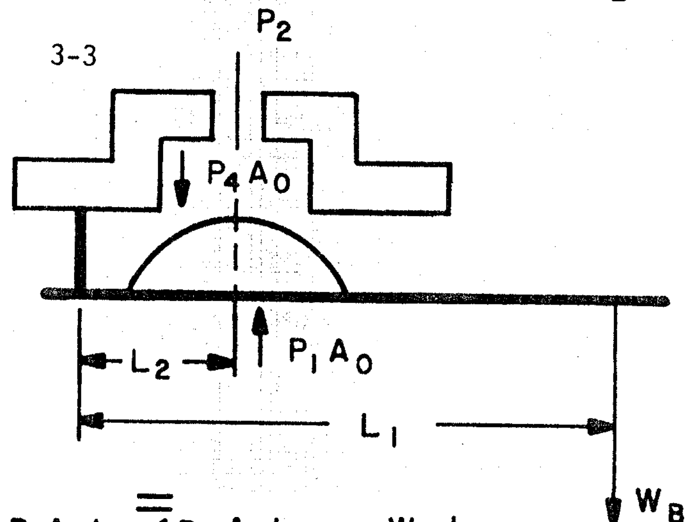
3-2



$P_1 A_0 L_2 > P_3 A_0 L_2 + W_B L_1$

$P_2 > P_3$

3-3



$P_1 A_0 L_2 \overset{=}{<} P_4 A_0 L_2 + W_B L_1$

P_4 RAPIDLY BECOMES GREATER THAN P_2