STEAM LOSS AND THERMODYNAMIC STEAM TRAPS

An Analysis of Trap Cycling Rate and Energy Loss

ABSTRACT

Testing demonstrates that steam loss is a normal and necessary condition for Thermodynamic Steam Traps to operate. These testing methods demonstrate how the TD Trap operates and how to measure the amount of steam lost during the normal operation of the trap.

STEAM LOSS AND THERMODYNAMIC STEAM TRAPS:
AN ANALYSIS OF TRAP CYCLING RATE AND ENERGY LOSS

Thermodynamic Disc steam traps (TD Traps) are widely used throughout the world for steam tracing and drip leg applications. The advantages of the TD Trap include an ability to operate over a wide pressure range (5-600 psi), a fail-open characteristic, and a relatively low price due to compact body castings or forgings. However, these advantages come at a high price when steam loss is considered. The purpose of this study is to quantify the amount of steam that is lost due to the normal operation of these devices and how it relates to the cycling rate commonly experienced under normal field conditions.

TD TRAPS DO NOT OPERATE ON FLASH STEAM

During the course of our investigation, we have tried to determine what is responsible for the cycling action of the TD trap. Many manufacturers claim that during the discharge cycle, hot condensate flashes to steam above the disc causing it to end its cycle and close without loss of live steam. **We have found this to be false.**

THERMODYNAMIC STEAM TRAP ON BOILER BLOWDOWN

Flash Steam Test: It can be easily proven that TD Traps DO NOT close on flash steam. To demonstrate this one needs simply to pass water at steam temperature through the trap and into a lower pressure environment and observe whether the trap closes. The most convenient source of saturated water in a steam plant is boiler blowdown. By connecting the TD Trap to the blowdown of a steam boiler drum one can test the effect that hot condensate flashing to atmospheric pressure has on a trap.

FLASH STEAM TEST PROCEDURE

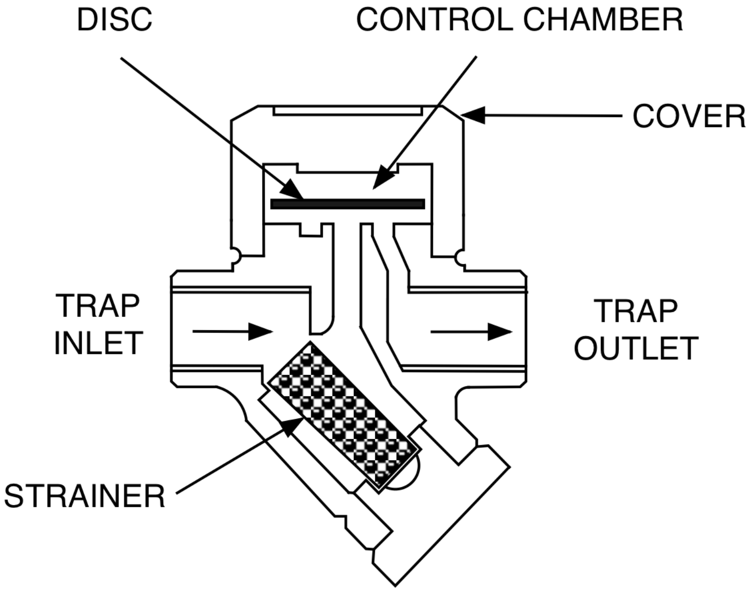
1. Upon opening the boiler blowdown valve, water at ambient temperature passes easily through the trap.

2. When the temperature of the water increases it begins to flash to steam upon exiting the trap.

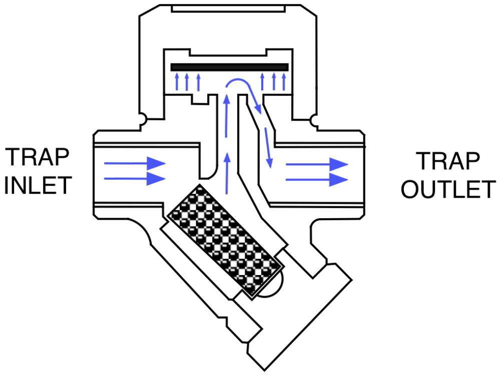
3. Flashing boiler water does not close the trap.

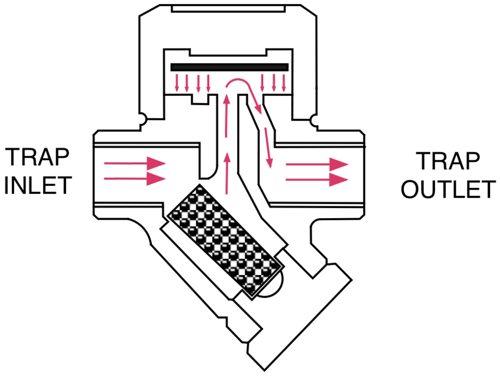
CONCLUSION: Flashing condensate will not cause a TD trap to close. Despite the saturated condensate flashing as it exits the trap, the trap will remain open. The TD Trap requires live steam flow in order to close.

HOW A TD TRAP OPERATES

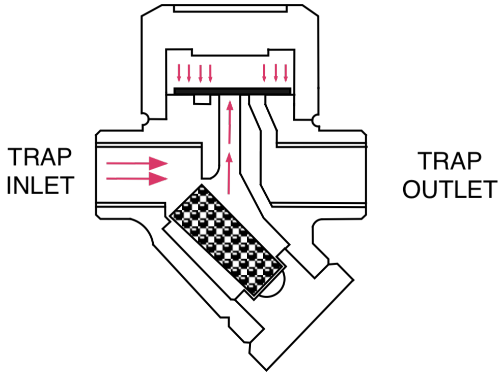


TD traps are comprised of a cast or forged steel body, disc, cover, and in some models an integral strainer.

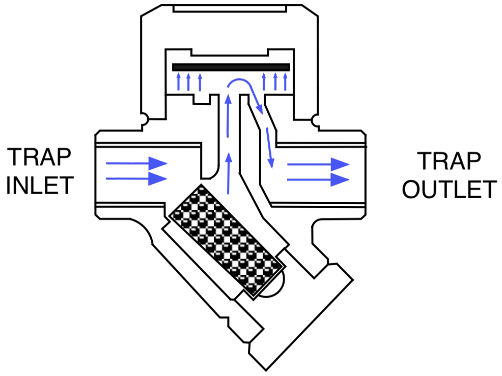




1. Upon startup, the differential pressure across the trap pushes the disc off of the seating surfaces and flow begins.
2. Condensate in the steam space is discharged through the TD trap and into the return system.
3. When the condensate is evacuated from the system, steam flows through the trap increasing the flow velocity and creating a low pressure area below the disc, pulling it onto the seating surface.
4. As the disc seats, the surface area of the disc stops the flow.



5. The steam trapped above the disc keeps the disc seated.



6. As radiant heat loss off of the cover and body of the TD trap causes the steam trapped above the disc to condense, the disc lifts off of the seat and flow commences, causing the cycle of discharge and shutoff to continue.

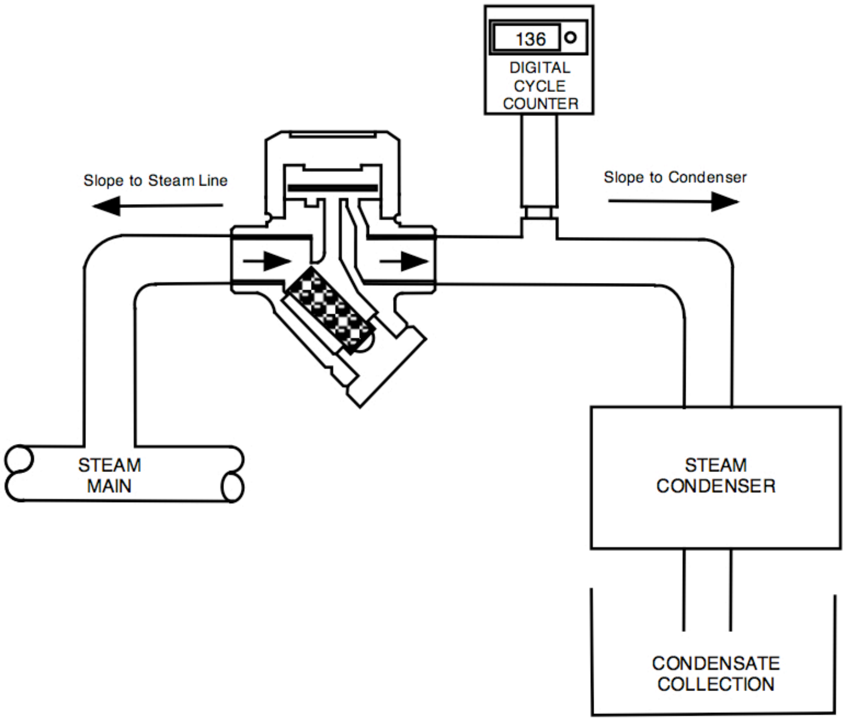
TD TRAPS CLOSE ONLY DUE TO LIVE STEAM LOSS

CONCLUSION: A TD Trap will not close due to flashing condensate. Saturated water will only flash to steam when given a great enough pressure drop, which occurs after the greatest restriction in the system. The greatest restriction in the system is the outlet orifice which occurs downstream of the disc and control chamber arrangement. In order to close, the TD Trap must pass live steam or air across the underside of the disc at a high enough velocity to create low pressure sufficient to close the disc against the cumulative force of the upstream and downstream pressure. THIS LOSS OF LIVE STEAM IS NECESSARY FOR THE TD TRAP TO OPERATE.

MEASURING STEAM LOSS THROUGH TD TRAPS

It is possible to measure the amount of steam that is lost each time a TD Trap cycles. To do this, a simple test arrangement can be constructed which isolates the TD Trap from all condensate loads and allows for collecting and condensing the steam which passes through the TD Trap during the cycle. Also, installing a device to count the total number of cycles will allow for the calculation of steam loss per cycle. A simple test configuration is shown below.

STEAM LOSS MEASUREMENT TEST CONFIGURATION



Trap Test Station

Digital Cycle Counter

Steam Condenser

Condensate Collection

TD TRAP TEST CONFIGURATION AND CONDENSER

The test configuration for measuring steam loss through TD Traps consists of the following elements:

1. A steam trap installed above the steam main with sufficient backward pitch to ensure that any condensate formed in the line drains back toward the steam supply instead of being passed through the trap into the collection system.
2. A cycle counter capable of recording each cycle of the TD trap being tested. We used a Digital Cycle Counter with manual reset.
3. A condenser system capable of converting all live steam into condensate prior to entering into the collection vessel. All discharge piping between the steam trap and condenser must be pitched such that condensate flows freely from the trap, through the condenser and into the collection vessel due to gravity. Trap discharge should be completely isolated from cooling water.
4. A collection vessel whose weight has been accurately determined and recorded.

TEST PROCEDURE

1. Start boiler and allow the system to warm up and stabilize sufficiently.
2. Open the inlet valve to the trap and allow the test configuration to warm up sufficiently (10 minutes minimum).
3. Break any vacuum in the piping after the trap to allow for complete drainage of the condenser system.
4. Empty collection vessel.
5. Zero the cycle counter.
6. After test period is complete (minimum 2 hours), close inlet valve to trap.
7. Break any vacuum in the piping after the trap to allow for complete drainage of the condenser system.
8. Record the total number of trap cycles during the test.
9. Weigh the condensate collection vessel and subtract the weight of the vessel to determine total condensate weight.

TEST RESULTS

We have found during the course of over 400 hours of testing that all TD Traps lose a significant amount of steam every time they cycle. We tested TD Traps from all major steam trap manufacturers and found little difference in steam loss per cycle between traps of similar capacity, regardless of manufacturer.

Based upon our testing of over 10 different models of TD Traps we found that **THE AVERAGE STEAM LOSS FOR A TD TRAP IS 0.032 POUNDS OF STEAM PER CYCLE**.

The rate at which TD Traps cycle is dependent upon many different factors, including the following:

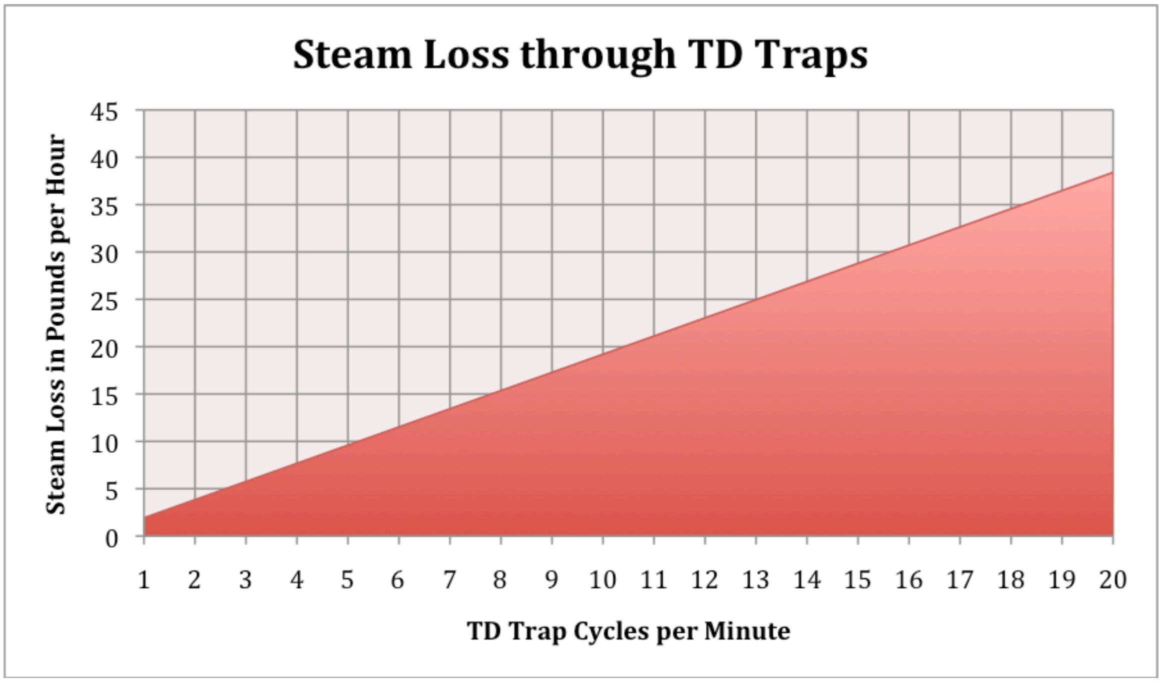
1. Integrity of the seating surface
2. Ambient temperature
3. Precipitation
4. Heat loss due to wind speed
5. Condensate load

Despite variations in cycling rate, it is possible to accurately estimate the operating steam loss of a TD Trap by recording the rate at which the trap cycles and multiplying it by the average steam loss rate of **0.032 POUNDS PER CYCLE.**

STEAM LOSS EXAMPLES

The following table shows steam loss through TD Traps at different cycle rates.

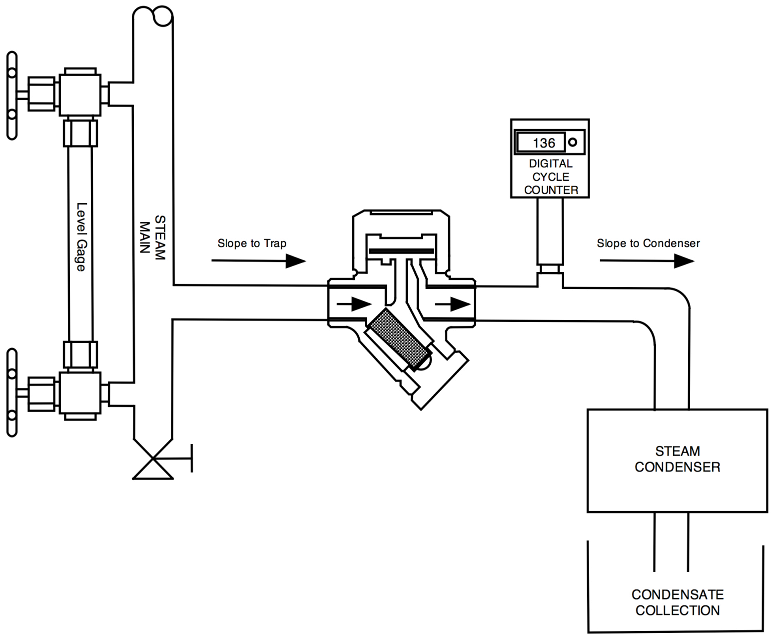
Cycles per Minute	Steam Loss per Hour	Annual Steam Loss per Trap
2	**4 lb/hr**	**$350**
10	**20 lb/hr**	**$1750**
20	**40 lb/hr**	**$3500**



OPERATIONAL STEAM LOSS COMPARISON
VELAN STEAM TRAP vs. THERMODYNAMIC STEAM TRAP

It is possible to perform a direct comparison of the operational steam losses between two different steam traps by simulating conditions similar to that of a plant environment. To do this, we modified the test configuration outlined above in order to provide a comparison scenario between different traps under stable pressure and condensate load conditions. Elements of this test configuration are as follows:

1. A steam main connected to a system stable in pressure and ambient temperature such that different traps installed on the test station at different points in time will experience the same condensate flow rate.
2. A steam trap installed at the end of a steam main with sufficient forward pitch to ensure that all condensate formed in the line drains toward the steam trap instead of being held in the main ahead of the trap.
3. A cycle counter capable of recording each cycle of the trap being tested.
4. A level gage installed on the steam main to verify that the steam trap on test is efficiently draining all condensate in the steam main.
5. A condenser system capable of converting all live steam into condensate prior to entering into the collection vessel. All discharge piping between the steam trap and condenser must be pitched such that condensate flows freely from the trap, through the condenser and into the collection vessel due to gravity. Trap discharge should be completely isolated from cooling water.
6. A collection vessel whose weight has been accurately determined and recorded.



LOAD TESTING CONFIGURATION

LOAD TESTING PROCEDURE

1. Start boiler and allow the system to warm up and stabilize sufficiently.
2. Open the inlet valve to the trap and allow the test configuration to warm up sufficiently (10 minutes minimum).
3. Break any vacuum in the piping after the trap to allow for complete drainage of the condenser system.
4. Empty collection vessel.
5. Zero the cycle counter.
6. Prior to completing the test period, verify by way of level gage that all condensate is being drained sufficiently from the steam main.
7. After test period is complete (minimum 10 minutes), close inlet valve to trap.
8. Break any vacuum in the piping after the trap to allow for complete drainage of the condenser system.
9. Record the total number of trap cycles during the test.
10. Weigh the condensate collection vessel and subtract the weight of the vessel to determine total condensate weight.
11. Repeat steps 1-9 using alternate trap in the comparison study, making sure that testing times and conditions are identical to that of the first trap.

LOAD TESTING DATA COMPARISON

The results of the comparison load testing scenario validated and confirmed the data collected in the no-load testing scenario for the TD trap. When comparing the total discharge during the load test for the TD Trap against that of the Velan steam trap we found the result to be the following:

The difference between the total discharge of the TD trap minus the total discharge of the Velan trap, divided by the total cycles of the TD trap, was equivalent to the results of the no load test for the TD Trap.

$$\frac{\textbf{TD Discharge – Velan Discharge}}{\textbf{TOTAL TD Cycles}} = \textbf{Loss/Cycle (no load test)}$$

The table below shows the results of several 10 minute tests.

RESULTS OF 10 MINUTE LOAD TEST COMPARISON

Test No.	TD Discharge	Velan Discharge	Net TD Discharge	Cycles	Loss/Cycle
1	6.1 lb	4.4 lb	1.7 lb	45	0.037 lb
2	7.02 lb	4.56 lb	2.46 lb	63	0.039 lb
3	6.5 lb	4.3 lb	2.2 lb	71	0.031 lb

LOAD TEST CONCLUSIONS

Comparative testing under load conditions demonstrated the following:

1. The steam loss per cycle for TD traps as demonstrated in the no load test can be validated by subjecting them to a load test in comparison with a steam trap design not requiring operational steam loss.
2. The zero steam loss of the Velan steam trap as demonstrated in the no load test can be validated by subjecting them to a load test in comparison with steam traps for which an operational steam loss requirement is known.
3. The steam loss per cycle for TD traps is not diminished by the presence of a condensate load.
4. The energy loss standard of 0.032 pounds of steam per cycle for TD traps is useful for estimating the actual operating cost of this design in plant environments and can be used to estimate the plantwide cost savings of retrofitting to a more efficient steam trap design.

CONCLUSION

A FUNCTIONING TD TRAP WILL LOSE BETWEEN 4 AND 40 POUNDS OF STEAM PER HOUR DUE TO CYCLING. THIS STEAM LOSS IS NOT DIMINISHED BY THE PRESENCE OF A CONDENSATE LOAD DUE TO THE FACT THAT A TD TRAP REQUIRES LIVE STEAM DISCHARGE AT SUFFICIENT FLOW VELOCITY TO CLOSE THE TRAP. TESTS HAVE PROVEN THAT IT IS IN FACT LIVE STEAM LOSS THAT IS RESPONSIBLE FOR THE CYCLING OF THE TD TRAP, NOT FLASH STEAM.

COST IMPLICATIONS

Based upon an average steam cost of $10.00 per 1,000 pounds of steam, a TD Trap will lose between $350 and $3,500 annually, based upon a cycling rate of between 2 and 20 cycles per minute.

In a plant with a population of 500 TD Traps, annual steam losses due to normal TD Trap operation can run between $175,000 and $1,750,000.

THE VELAN STEAM TRAP: A BETTER TECHNOLOGY

In 1950 Mr. A.K. Velan designed the Velan Steam Trap in Montreal Canada. The Velan Steam Trap uses a unique bimetal technology to ensure proper drainage of condensate without the loss of live steam. Instead of a violent blast discharge, the Velan Steam Trap modulates condensate discharge and ensures that live steam does not pass beyond the outlet orifice. This feature brings many advantages including 100% energy efficiency as well as a very long service life due to minimal wear.

VELAN STEAM TRAP ON NO LOAD TEST

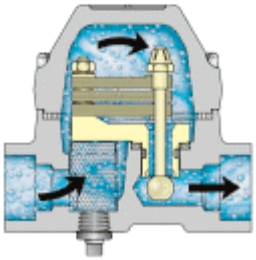
We subjected the Velan Steam Trap to the same testing conditions as the TD Traps. We found that the Velan Trap, when subject to zero load conditions, closed completely without losing any live steam. Without condensate present, the Velan Trap would not open, cycle, or operate, ensuring 100% efficiency

1. OPERATING PRINCIPLE OF VELAN STEAM TRAPS

The Velan steam trap operates on a heat/pressure principle, using the heat from the steam and hot condensate to cause a stack of bimetal plates to close the valve in the trap. At all times, the line pressure is opposing the closing force of the bimetals. The result is a steam trap that fully discharges air and cool condensate until the system is sufficiently warm, then closes tightly on steam.

a) STARTUP – SUPER CAPACITY AIR VENTING

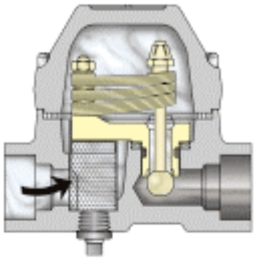
Discharge valve is wide open, allowing air and cold water to pass quickly. The hours of waiting in the morning for equipment to warm up are reduced to minutes. It is certain that no air-binding, water-logging or steam-locking will slow the heating up. Actual tests show that up to 2 ½ hours may be saved on each warm-up time of equipment due to 4-6 times greater venting capacity than average traps, due to the oversized orifice of ½ or 5/8 in universal traps, 7/8 in super traps and 2” in “piston” traps.



STARTUP MODE

b) STEAM TRAPPING

Incoming steam contacting the bimetallic element causes the bimetal to deflect and develops a thermal power of the bimetal acting on the valve stem, which overcomes the steam pressure and closes the valve. This thermal pull seats the ball valve tightly, preventing loss of live steam. This thermal power increases or decreases as a function of temperature in the same relation, as temperature and pressure of saturated steam. The same element can be used for varying steam pressures within the range of 0-350 psi.

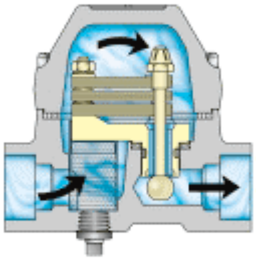


STEAM TRAPPING MODE

c) CONDENSATE DISCHARGE

When cooler condensate and air collects in the trap, the thermal pull of the bimetal is gradually reduced until the line pressure can overcome the thermal pull and the unbalanced pressure on the valve cracks the orifice and releases the flow of condensate.

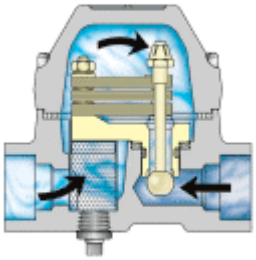
- This is the first step of the smooth and quick opening of the valve avoiding the noisy and violent opening of ordinary steam traps.
- When flow is released the unbalanced pressure acts now on the full valve area doubling its force to overcome the thermal pull and opens the orifice widely for full capacity. The ½, 5/8, 7/8 orifice in Velan steam traps is 2-6 times larger than in traps of equal size.



CONDENSATE DISCHARGE

d) 100% BACK-FLOW CONTROL

Back pressure in return line, sudden drop in steam pressure, rapid fluctuation or discharging to overhead lines causes back-flow of condensate. To prevent this possible back flow or entering of condensate into equipment not in service separate check valves should be installed as close to the steam trap as possible. In the unique design of the Velan steam traps the same discharge valve acts as check valve providing 100% back flow control.



BACKFLOW PREVENTION

2. ADVANTAGES OF THE VELAN DESIGN

a) **NO LIVE STEAM LOSS.** The Velan design employs a positive trapping concept, only opening when condensate is present. This ensures that no live steam will be lost during operation. TD Traps lose between 4 and 40 pounds per hour of live steam due to normal cycling.

b) **NO WATER PRIME REQUIRED.** The operation of the Velan bimetallic steam trap modulates condensate at a temperature slightly below that of saturated steam. When subjected to saturated or superheated steam, the Velan steam trap remains closed and will not fail due to loss of water prime.

c) **RAPID AIR VENTING AT STARTUP.** At startup, the Velan steam trap is fully open, venting air quickly and efficiently. This results in a faster startup with fewer plant personnel required to supervise venting of main lines during warmup.

d) **STELLITE 6 TRIM STANDARD.** All Velan steam traps are fitted with Stellite 6 seat facings to resist wear by high pressure flow, dirt and scale. Velan remains the only steam trap manufacturer to use Stellite 6 facings in their steam traps. Stellite 6 is the most durable material available today for valve trim in steam service.

e) **UNAFFECTED BY WATER HAMMER.** The valve of the Velan steam trap is held closed by the pull of the bimetal plates. When water hammer occurs, the force of the bimetals is overcome by the pressure, and it is released into the downstream piping without damaging the trap or the equipment.

f) **INTEGRAL STRAINER.** All Velan steam traps are fitted with integral stainless steel screens to protect the trap operating mechanism from damage by dirt and scale.

g) **INTEGRAL CHECK VALVE.** The discharge valve in the trap acts as a check valve providing full back flow control

ENERGY SAVINGS WITH THE VELAN STEAM TRAP

When compared to the TD Trap, the Velan Steam Trap will save between $350 and $3,500 PER TRAP annually. It also has a life expectancy that is over twice that of a TD Trap due to the use of Stellite #6 trim. Velan's extensive experience performing plant retrofits has produced decreases in steam consumption plantwide averaging over 131,000 pounds of steam per trap annually.

COST SAVINGS WITH THE VELAN STEAM TRAP

For a typical process plant with a population of 500 TD Traps, a total plant retrofit could save an average of 65 million pounds of steam per year. At current energy cost, this is $650,000 per year of steam savings.

In addition, the average life expectancy of a Velan Bimetallic Steam Trap is over three times that of a TD Trap. Factoring the energy savings and long life expectancy of the Velan Steam Trap into the equation give it the lowest total life cycle cost of any steam trap on the market.

CONCLUSION

When considering the steam losses associated with normal cycling of the TD Trap, it is prudent to look toward other designs of steam traps to increase plant efficiency.

The Velan Steam Trap has proven over 60 years to be highly efficient, long lasting, and a better choice for improving and maintaining plant efficiency. Moving away from the use of Thermodynamic Steam Traps and toward more efficient technologies such as the Velan Steam Trap can improve overall plant efficiency and lower maintenance costs substantially. When considering the normal operating costs associated with the use of TD Traps, converting your facility to the Velan Steam Trap can often be cost justified within a period of one year.