Design and Development of High Capacity Steam Trap Unit

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***Abstract*— This project deals with design and development of steam trap unit. Mechanical float type steam trap is focus of the project. Steam trap is an integral part of a steam system. Steam trap plays an important role in maintaining the productivity and efficiency of steam system. A Steam trap an automatic drain valve which distinguishes between steam and condensate. A steam trap holds back steam and discharges condensate under varying pressures or loads. The project involves designing completely new steam trap with an innovative or new mechanism that will serve the purpose of condensate recovery. The mechanism so developed will either amplify or lower the forces acting on the system and thus the float will either be lifted or lowered and thus the steam traps will operate. The mechanism is checked for its workability in ADAMS View. The analysis of the mechanism is also done in ADAMS View. The modification in the design is also included.**

Keywords—two opening steam trap; mechanism; condensate recovery; high capacity; casing and enclosure.

I. Introduction

A Steam Trap is an integral part of a steam system. Steam trap plays an important role in maintaining the productivity and efficiency of steam system. A Steam trap an automatic drain valve which distinguishes between steam and condensate. A steam trap holds back steam & discharges condensate under varying pressures or loads Over the period, different types of steam traps have been developed to suit different applications. The essential property of a steam trap is to be able to distinguish between steam and condensate. Different types of steam traps employ different working principles and mechanisms to distinguish between steam, condensate and air. When classified according to these operating principles, each design has advantages and limitations which must be considered while selecting a steam trap for a specific application.

Density operated or mechanical types of steam traps distinguish between steam and condensate based on difference in their densities. Steam is always lighter and hence, has a density much lower than condensate. A mechanical type of steam trap will allow only the heavy condensate to get discharged and hold back the steam.

Simply stated, steam traps are used to remove condensate and non-condensable gases from the steam network. Steam generated by a boiler contains heat energy which is used to heat the product.

When steam loses it energy by heating the product, condensate is formed. After losing this heat, steam gets converted into condensate. If this condensate is not drained immediately as soon as it forms, it can reduce the operating efficiency of the system by slowing the heat transfer to the process. Presence of condensate in a steam system can also cause physical damage due to water hammer or corrosion. As the condensate builds up, it can form a solid slug of incompressible water traveling at high velocities. When the slug of water is suddenly stopped by a pipe bend, fitting or a valve, it can result in mechanical damage to the pipe or fitting.

Float traps are designed in such a way that the valve seat is always submerged under water preventing any steam loss. The discharge is continuous and modulates with the condensing rate. It is unaffected by changes in inlet pressure.

In the Fig 1 as condensate enters the trap body, the ball float being hollow, floats over the condensate. As condensate level increases, condensate causes the ball float to rise and place the modulating discharge valve in a position that will pass the condensate continuously as it enters the trap. The condensate level in the trap body is maintained above the discharge valve to provide seal against the loss of steam.

Frederick R. Dunn [2] has developed a steam trap unit where the objective was to develop a universal steam trap unit. Here the author mentions the conditions for operation of the steam trap, he mentions two cases, such as pressure operation and vacuum operation. Emphasis is given on compactness and hence could be a favorable mechanism, hence this mechanism along with few changes is taken for study for this application. The trap has a provision for opening and hence cleaning the trap is possible which was a difficult task for the earlier trap. Here the valve and valve seat has a unique arrangement as per the author.

Milton Hilmer in [3] discloses a mechanism in which he uses a float actuated valve mechanism for automatically removing predetermined amount of accumulated condensate from a sump of gas pressurized drain trap. The four bars of the linkages are loosely joined by four pin joints to permit limited self alignment movement of the valve plug relative to valve seat with which it mates. By minimizing the movement of the float more efficient space conserving package is provided. The mechanism provides non linearly varying mechanical advantage. The mechanism shown here has a single opening for condensate discharge, but the requirement in this project is of two openings and hence there is a need for two opening design. As the level of condensate rises, the buoyant float moves upwards, about the base pin. In response to this upward movement of the float the connecting arms pivoting about the float arm pin joint and valve plug arm pin joint pull the valve plug away from the valve seat, to establish a open valve condition.

Katsuji Fujiwara, Osamu Miyata, Tadashi Oike in [5] developed a mechanism in which the float was in an inverted fashion and the float was free to move. There were no linkages and the opening and closing was simply due to buoyancy and the float weight. But the problem with this mechanism was that it was suitable for low loads, low discharge values. The float was getting worn out faster in this case.

Dean Jeffrey Stephens in [8] discloses a mechanism for high pressure application. Advantage of this device in accordance with the invention consequently has relative low profile float occupying small vertical space. This means that the chamber and consequently the device itself may be reduced in height by comparing it with equivalent device employing spherical float. Aspect ratio is defined as ratio of maximum dimension of the float in horizontal direction to the maximum direction of the float in the vertical direction.

Pranil Chavan Patil in [11] discloses a mechanism for two opening steam trap. Here the two orifices are provided side by side and the orifice seating will be opening one after the another in a sequence. The delay between the opening of the seating is adjusted such way that maximum discharge is given out at the discharge outlet. The orifices open in response to level of condensate in the chamber. The mechanism is so developed to operate under high and variable condensate load. During the initial conditions the first orifice will get opened and as the condensate in the cavity increases, the second orifice gets opened and the condensate gets discharged.

There was need to develop an entirely new mechanism which will be able to discharge condensate at a rate of 20,000 kg/hr. A modulating mechanism which would work according to the loads and pressures.

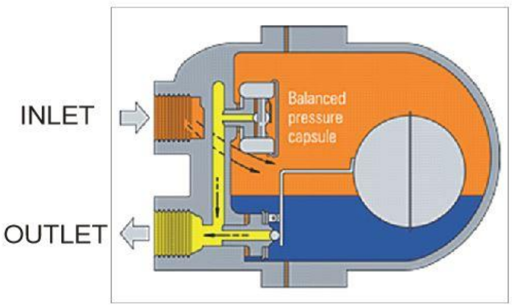


Fig 1 Conventional Float Type steam Trap with condensate collection at the bottom

II. ANALYTICAL DESIGN:

Analytical design here includes design approach, project specifications, calculations related to selected mechanisms, selecting variables etc.

A. *Design approach:*

Concept stage is inclusive of various mechanisms those will be favoring the application. As we want to discharge condensate at a discharge capacity of 20,000 kg/hr, there must be some mechanism which will suit the application.

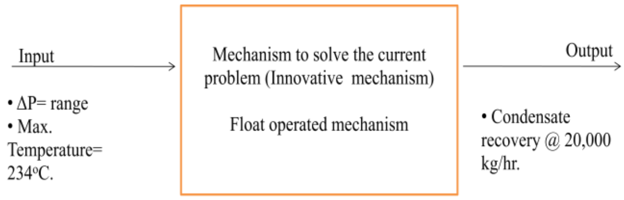


Fig 2. Design Approach

TABLE 1:

SPECIFICATIONS

Sr. No.		Specifications
1	Max. Operating pressure	17 bar
2	Max. Operating temperature	234°C
3	Pressure Differential (ΔP)	4.5 bar 10 bar 17 bar
4	Capacity	20,000 kg/hr
5	Material for mechanism	SS 304/316

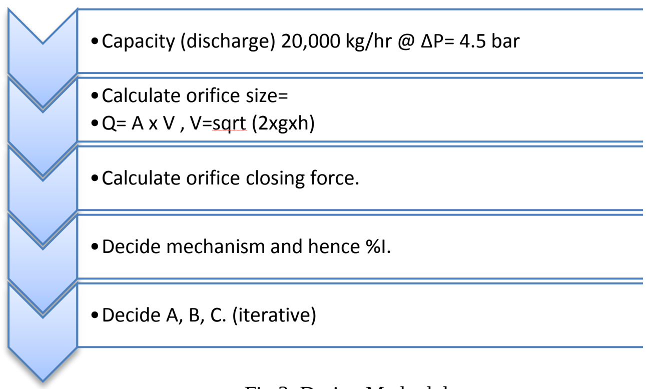


Fig 3. Design Methodology

Fig. 5 where all the forces acting on the mechanism and the lever and mechanism lengths are shown. The depth of immersion maximum allowed is 90%. Total of 7 conceptual mechanisms were taken into account, the various free body diagrams were drawn and the final selected free body diagram is shown in Fig 4

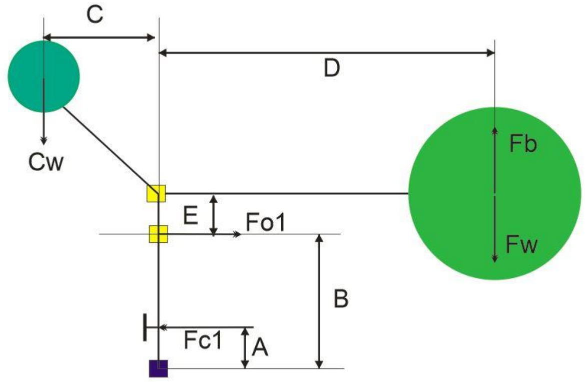


Fig 4. Free body Diagram of the final mechanism

Link parameter A,B,C are the amplifying and lowering factors (link parameters) for the forces. These parameters are important as they change the mechanical advantage of the system. The workability of the mechanism is dependent on these parameters.

By applying equivalent moment equations and then by a number of iterations by changing the values of A,B,C,D,E the depth of immersion is calculated. The limiting value of this depth of immersion is 90%. The table 2 shows the link designations and table 3 shows the equivalent magnitudes of the forces and the link dimensions

TABLE 2:

LINK PARAMETERS

Parameter	
Fb	Buoyancy force
Fc	Closing force
Fw	Float Weight
Cw	Counterweight
Link Dimensions	
A	Location of the opening 1 from the base pivot
B	Connecting link length
C	Position of the counterweight from the pivot point
D	Lever (float link) length. This is the important part as far as the mechanism is concerned, its the leverage length
E	The length from the pivot point, from which the contact is done.

The orifice sizing calculations is done on the basis of the required discharge rate which is 20,000 kg/hr. The calculations for various diameters of the orifices were done, the diameter for which the discharge was above 20,000 kg/hr was selected. The diameter of the opening 1 and the opening 2 were taken as same. Also as the pressure changes the diameter of the orifice changes, hence the discharge capacity. This trap is designed for a pressure differential of 4.5 bar. The diameters were also computed for 10 bar and 17 bar. Hence even if there is a change in the inlet pressure or outlet pressure the mechanism will be working. The details of the calculations is mentioned in table 9,10,11.

TABLE 4:

CALCULATED DISCHARGE RATE FOR DIFFERENT PRESSURE DIFFERENTIAL

	Pressure (bar)		
	4.5	**10**	**17**
Diameter (both openings)	17 mm	11.4 mm	8.5 mm
Discharge	22514.2642	15092.575	10939.965

The buoyancy force is the force which is due to the condensate present in the trap housing. This force is responsible for opening and closing the mechanism. This force depends on the density of the condensate, the outer radius of the float and the depth of immersion. This force is calculated by knowing the density of the condensate and the volume of the float.

Float weight is the continuous acting force on the float and hence the float link. The float weight depends on the float dimensions. The float is a hollow sphere. By knowing the volume of the sphere and the density this force is calculated. The mechanism should contain two connecting links, one float link with two members which are responsible for the contacts at the connecting links, supporting plate. The mechanism workability is checked into ADAMS View, by giving the necessary joints between the part members. The mechanism works in two ways. First is opening and the second is closing.

TABLE 3:

CALCULATED FORCES AND LINK LENGTHS

Forces:		**Units:**
Fb	0.51 x %I	kg
Fw	0.23510	kg
Fc	10.45	kg
Link Lengths:		**Units:**
A	20	mm
B	75	mm
C	20	mm
D	125	mm
E	20	mm
%I	83.33	%

On the basis of the above selected and calculated dimensions the 3 dimensional model of the selected mechanism is made.

The workable mechanism was finalized on the basis of the movement of the connecting link and the float link. The parts associated with the mechanisms as shown in the table 4 were redesigned so that the mechanism works in best possible manner without any blockages.

TABLE 5:

MECHANISM WORKABILITY

Mechanism:	**Features:**
Mechanism rev 1	This was the basic design with all the components. The mechanism was opening correctly and while closing the mechanism was getting locked.
Mechanism rev 2	Small changes done in the return mechanism, still path was not followed. There was no contact between the members.
Mechanism rev 3	Mechanism opening and the closing was improper
Mechanism rev 4	Contact elements were changed, but the mechanism showed flutter, there was a locking observed in the connecting links. Also the mechanism was getting locked in the return mechanism.
Mechanism rev 5	Now, while opening the path travelled by the connecting link should be the inner profile, but the observed path was outer as shown in Fig. 5
Mechanism rev 6	Contact element design was changed, they were inbuilt in the float link, hence the contact action was proper.
Mechanism rev 7	The leverage length is changed for having compactness, the clearance between the moving parts was changed. Counterweight design was rechecked, the return profile was changed which showed no fouling or locking.
Mechanism rev 8	The desired opening angle should be 28 degrees, but the shown angle was only 15, hence the return profiles were redesigned. The manufacturing considerations were also taken into study and hence the mechanism was redesigned as shown in Fig 5.

The Fig 5 below shows the selected mechanism along with the earlier calculated geometries. The exact workability of these geometries were studied in ADAMS View and in this way the final mechanism was finalized. In the final mechanism the leverage length was changed from 180mm to 120 mm. The change was essential because the casing was becoming very big and heavy. The profile traversed by the connecting links was redesigned to prevent lockage. The total number of main parts involved in the mechanism are 10. In the earlier mechanisms the parts involved were minimum 15.

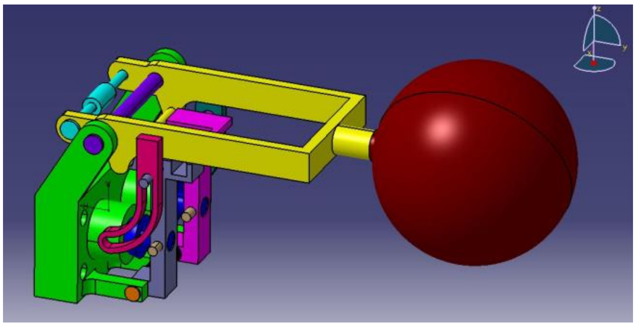


Fig. 5 Selected 3 Dimensional Model of the mechanism as per the earlier design

TABLE 6:

DETAILED PARTS:

Parts:	**Function:**
Backplate	Used for supporting the linkages and pivot points.
Float Link:	Float link supports the float and moves in up and down motion.
Return Link	Aids in opening the mechanism due to its profile on the inner side, the profile on the outer side helps in closing action.
Float	Float actually lifts the float link and hence the opening and closing action is possible
Counterweight	Counterweight is used for reducing the length of the float link. To make the design more compact, counterweight is essential
Connecting link 1 and 2	Connecting link is an assembly of orifice seating and the pin used to support the it. This joint is not permanent, as the pressure changes the orifice diameter changes and hence the seating
Float pin	Float pin supports the float link into the pivot.
Connecting pin	Connecting pin supports the connecting link into the pivot.
Split pins	Used to arrest the horizontal movement of the parts.

The table 6 above shows the detailed parts associated with the mechanism.

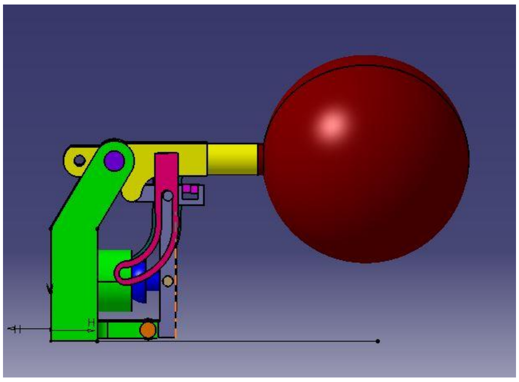


Fig 6 Final mechanism

The material for all the parts is decided to be stainless steel 304. The reason behind is the properties of stainless steel. Stainless steels are most commonly used for their corrosion resistance. The second most common reason stainless steels are used is for their high temperature properties; stainless steels can be found in applications where high temperature oxidation resistance is necessary, and in other applications where high temperature strength is required. The high chromium content which is so beneficial to the wet corrosion resistance of stainless steels is also highly beneficial to their high temperature strength and resistance to scaling at elevated temperatures. The material was selected from ASME section 8 UG 23. The following propertied were taken into consideration. The table 7 shows the properties of the material.

TABLE 7:

MATERIAL PARAMETERS:

Material: SS304			
Sr. No.	**Description**	**Magnitude**	**Unit**
1	Minimum Tensile Strength	515	MPa
2	MinimumYield Strength	205	MPa
3	Maximum temperature the material can sustain	427	^{o}C
4	Maximum allowable stress at 234 ^{o}C	122	MPa

On completion of the mechanism design and checking the workability of the mechanism, the casing or the enclosure is designed. For designing the enclosure standard parts were taken into account. The various parameters taken while deciding the diameter of the enclosure are given in the table 8 below.

TABLE 8:

CASING DESIGN PARAMETERS:

Sr. No.	**Parameters:**
1	Opening angle of the float link
2	Volume in the shell
3	Distance from the extreme position of the float and the back plate

The opening angle gives the basic idea about how the mechanism will operate. The final position of the mechanism which is the topmost position of the float. The float should not foul with the enclosure. The float must not collide against the walls of the casing. This is avoided by taking the travel length of the float link from the centre of the float to the lowermost point of the back plate. This travel length comes about 251.425 mm. Hence the final length comes about 272 mm. The inner diameter of the selected enclosure should be more than this distance. The parts include a 300 NB 40 schedule pipe, a dished end with an inlet port, a slip flange, a blind flange, bolts, nuts and washers for mounting. The fig.8 below shows the casing model. The mechanism in its final position is shown in Fig. 7. The design of dished end is done by ASME standard, standard components such as pipes, flanges and gaskets were selected from the available standard charts.

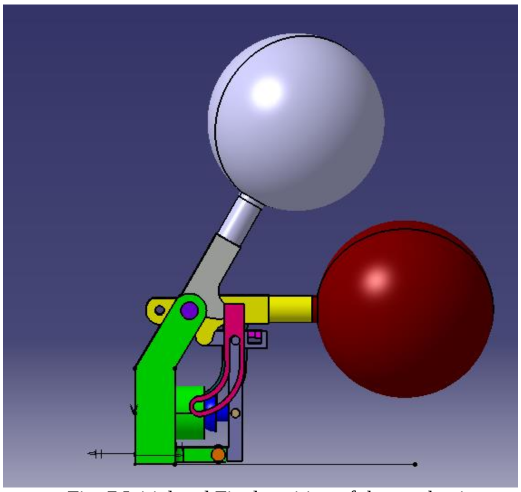


Fig. 7 Initial and Final position of the mechanism

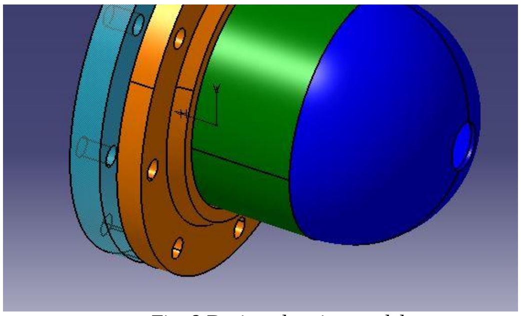


Fig. 8 Designed casing model

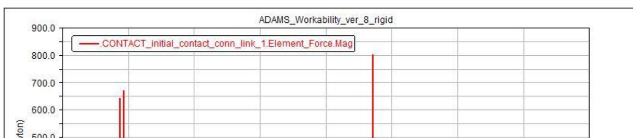
The dimensions and the geometries of the flanges were taken and decided according to ANSI B 16.5 Class 300 flange standard. The pipe was taken from equivalent pipe standards. The hemispherical dished end is selected. This dished end is designed from ASME standard section 8.

III. NUMERICAL ANALYSIS:

The numerical analysis of the mechanism was done in ADAMS View 2012. The numerical analysis is in two ways. First rigid body analysis and the second the flexible body analysis. The purpose of this numerical analysis was to observe the stress variations and the stress zones into the part members. The discharge rate is validated by experimentation results.

The mechanism was imported in ADAMS View and after applying the joints, contact parameters were applied on the part members. On simulation for 4 seconds the contact force plots were generated. The contact force so obtained was appreciable enough.

Figure 9 below shows the contact profile for the opening 1 and Figure 10 for opening 2. Suitable program was written



into ADAMS View Script Simulation for correct simulation. Under the working conditions the when the contact generated overcomes the closing force, hence on contact the closing force becomes nil. The same process is applicable for second opening. The buoyancy force is not able to overcome both the closing forces at a time. Hence the delay is provided.

As shown above the contact force is maximum at the start and it goes on reducing after 1 second. Due to fluctuating condensate in and out the mechanism is under flutter. The return mechanism 1 helps in the opening action as the initial contact disappears after a period of time. The initial contact between the float link and the connecting link is only for the initial push. Once this contact becomes nil the return profile opens the mechanism.

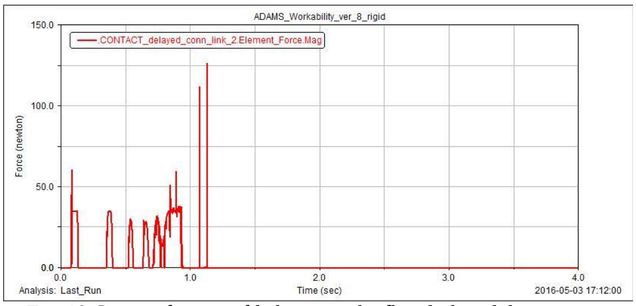


Fig. 10 Contact force profile between the float link and the connecting link 2 for opening 2

The contact observed in the Fig 9 is not enough to overcome the closing force initially but after 1.5 seconds the contact becomes appreciable enough to overcome the closing force due to contact between the float link and the return mechanism 2. In the same way the contact force between the connecting link and the return mechanism is calculated and the graphs are plotted.

In this way the contact force is calculated and analyzed for the various versions of mechanism. The Fig 9 and 10 show the contact force profiles for the final mechanism. The mechanism was then converted to flexible body for analyzing the stresses within various parts. Various other parameters such as the reaction force at the pivot points was also calculated through ADAMS View. The results were well under the limits.

Back plate, connecting link 1, connecting link 2, float and connecting pins, float link were converted to flexible bodies with suitable meshing parameters. The earlier thickness of the float link was 3.5 mm of the plates, but it was found that on numerical analysis the stresses within this link were high enough. Hence now the selected dimension is 6 mm. Again the changes were done in the model and analyzed into ADAMS View. The stresses were sustainable for the float link and all other parts. The stresses were observed at a small distance, near the fitting of return mechanism with the float link. The maximum allowable stress of the selected material is shown in the table 7. The stresses obtained on analysis are shown in the table below.

TABLE 9:

STRESS DUE TO NUMERICAL ANALYSIS:

Sr. No.	Part	Stress (MPa)
1	Connecting Link 1 and 2	115.873
2	Orifice seating 1 and 2	104.675
		107.724
3	Float Link	125.764
4	Float Pin	106.736
5	Connecting pin	122

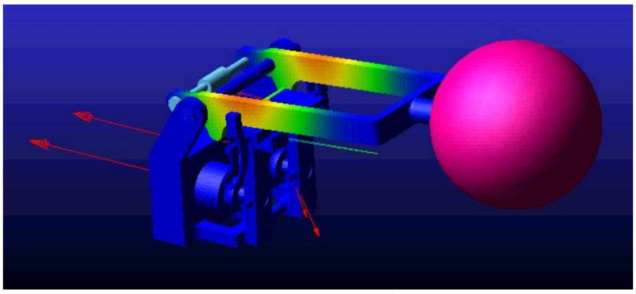


Fig. 11 Stress zone in the float link

IV. EXPERIMENTATION:

A prototype based on the earlier calculations is made. Its a Rapid Prototype. Thereafter there were changes in the design and the prototype of this mechanism is under process. This mechanism once made will be tested on the experimental test setup available at Forbes Marshall, Kasarwadi. The figure 12 below shows the experimental setup for the testing. Testing standard for testing this automatic steam trap is BS EN 27842: 1991 and ISO 7842:1988.

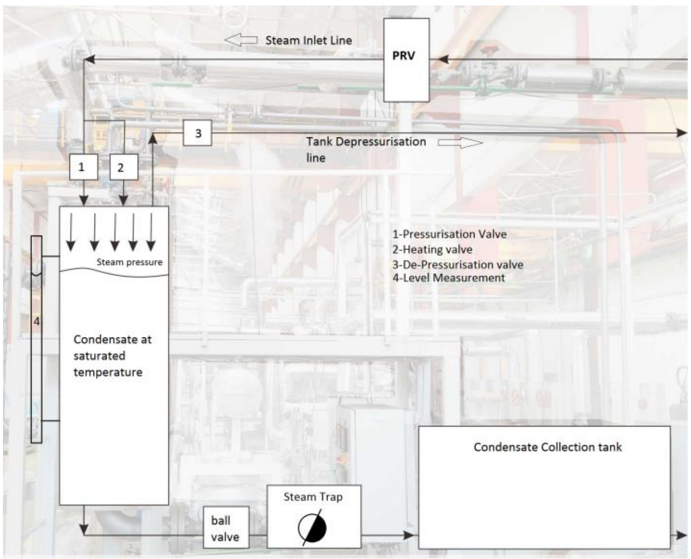


Fig. 12 Line Diagram Experimental Test Setup for testing steam trap

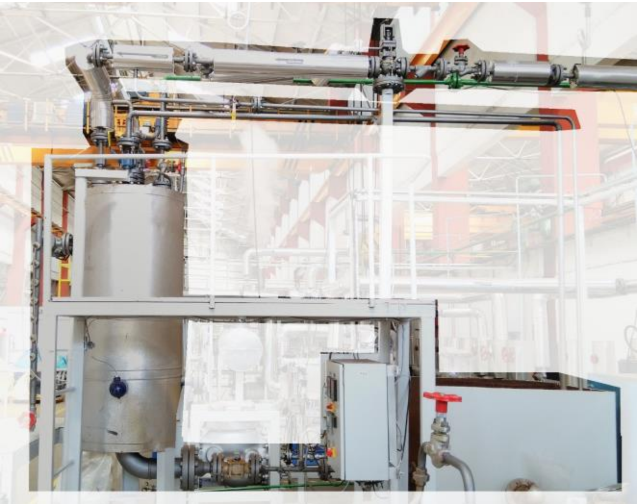


Fig 13. Actual Test Rig

valve.

- The pressure in the tank is adjusted by pressure reducing valve installed upstream of the tank.
- The Steam line is used to heat the water to its saturated temperature corresponding to set steam pressure & steam line is used to apply pressure on the heated water. The temperature is measured using temperature sensor installed on tank outlet & indicated on temperature indicator. Pressure gauge is used to indicate the tank pressure.
- In this way the condensate at required pressure & temperature is prepared in the tank. As per standard used for this testing the condensate temperature throughout the testing should be maintained within 3 degree sub cool limit than saturated temperature.
- Isolation valve on downstream side of trap used to close the discharge of trap as soon as timer stops counting the time.
- The counter starts time when level is at conductivity sensor-1 and stops time when level is at sensor-2.
- The time given by the counter is the time taken by the condensate level from sensor 1 and sensor 2.
- Distance between sensors is known (100 mm between two consecutive sensors) and diameter of the tank is known by using which we can calculate volume flow out in the time given by counter.
- The discharge can be calculated from this data in kg/h by multiplying volume flow rate with density. The discharge at different pressure can be calculated.

V. RESULTS:

Analytical calculations of discharge for three different pressure differentials is mentioned below in table 10,11,12

A Pressure differential of 4.5 bar:

TABLE 10:

DISCHARGE CALCULATIONS FOR 4.5 BAR PRESSURE DIFFERENTIAL

Orifice 1					
Pressure	**diameter of orifice (mm)**	**Area**	**Cd=0.5**	**mass flow rate**	**Total Discharge calculated**
4.5	17	226.9800	0.5	11257.13	22514.26421
Orifice 2					
Pressure	**diameter of orifice (mm)**	**Area**	**Cd=0.5**	**mass flow rate**	
4.5	17	226.9800	0.5	11257.13	

B Pressure differential of 10 bar:

TABLE 10:

DISCHARGE CALCULATIONS FOR 10 BAR PRESSURE DIFFERENTIAL

Orifice 1					
Pressure	**diameter of orifice (mm)**	**Area**	**Cd=0.5**	**mass flow rate**	**Total Discharge calculated**
10	11.4	102.0703	0.5	7546.288	**15092.57565**
Orifice 2					
Pressure	**diameter of orifice (mm)**	**Area**	**Cd=0.5**	**mass flow rate**	
10	11.4	102.0703	0.5	7546.288	

C Pressure differential of 17 bar:

TABLE 11:

DISCHARGE CALCULATIONS FOR 17 BAR PRESSURE DIFFERENTIAL

Orifice 1	

Pressure	diameter of orifice (mm)	Area	Cd=0.5	mass flow rate	Total Discharge calculated
17	8.5	56.745	0.5	5469.983	
Orifice 2					
Pressure	**diameter of orifice (mm)**	**Area**	**Cd=0.5**	**mass flow rate**	
17	8.5	56.745	0.5	5469.983	10939.96

TABLE 13:

DEPTH OF IMMERSION CALCULATIONS FOR 4.5BAR, 10 BAR AND 17 BAR.

According to fig 4 the final iteration of dimensions is shown below:

For 4.5 bar		
Force (kg)	**Value**	
Closing Force (Fc)	10.214	
Float Weight (Fw)	0.23510	
Buoyancy Force (Fb)	0.5147	
Dimension	**Value**	
A (mm)	20	
B (mm)	75	
C (mm)	20	
D (mm)	125	
E (mm)	20	
F (mm)	35	
Δ P (bar)	4.5	
Cw	1.8	
Fo1 (kg)	2.7237	
%I	88.202	
Reaction at pivot		
(FwxD)+(FlxF)		CwxC
38.277		36

For 10 bar		
Force (kg)	**Value**	
Closing Force (Fc)	10.207	
Float Weight (Fw)	0.23510	
Buoyancy Force (Fb)	0.4973	
Dimension	**Value**	
A (mm)	20	
B (mm)	75	
C (mm)	20	
D (mm)	125	
E (mm)	20	
F (mm)	35	
Δ P (bar)	4.5	
Cw	1.8	
Fo1 (kg)	2.7218	
%I	91.219	
Reaction at pivot		
(FwxD)+(FlxF)		CwxC
38.277		36

For 17 bar		
Closing Force (Fc)	9.8749	
Float Weight (Fw)	0.23510	
Buoyancy Force (Fb)	0.4819	
Dimension	**Value**	
A (mm)	20	
B (mm)	75	
C (mm)	20	
D (mm)	125	
E (mm)	20	
F (mm)	35	
Δ P (bar)	4.5	
Cw	1.8	
Fo1 (kg)	2.6333	
%I	91.19450018	
Reaction at pivot		
(FwxD)+(FlxF)		CwxC
38.277		36

VI. CONCLUSION:

In the present work a steam trap with two openings is designed. The sizing and the detailing related to different parts as mentioned earlier is done. The sizing and the other details is done by checking the workability of these parts into ADAMS View. The orifice diameters are calculated for three different pressure differentials. Hence the mechanism with few modifications in the seating size and the back plate can further be used for these pressure differentials also which is an added advantage of the mechanism. Further, the contact force required for initial push for opening the mechanism is studied and plotted. The diameter of pins required for the said mechanism is calculated and studied. Split pins are selected as per the available standards. The stresses are calculated using ADAMS View by converting the parts into flexible bodies where it can be seen that the stresses are below the allowable stress of 122 MPa for stainless steel.

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REFERENCES

[1] Mckee, John F, " Steam Trap" , US Patent 2051732A, August 18, 1936.

[2] Dunn, Frederick R, " Steam Trap", US Patent 2097401A, October 26, 1937.

[3] Hilmer, Milton, " Drain Trap valve mechanism", US Patent 4192341, March 11, 1980.

[4] Winiasz, Michael E, " Steam traps or the like", US Patent 4276354, June 30, 1981.

[5] Katsuji Fujiwara, " Steam Trap with spherical inverted bucket float", US Patent 4300588, November 17, 1981.

[6] Balazs, Les, Winiasz, Michael E.," Dual fulcrum steam trap", US Patent 4387733, June 14, 1983.

[7] Tadashi Oike," Free float steam trap", US Patent 5287878, February 22 1994.

[8] Dean Jefferey Stephens, " Float operated devices" US Patent 6174138B1, January 16, 2001.

[9] Masahiko Aoki, " Float type steam trap", US Patent 7096880B2, August 29, 2006.

[10] Soon Kyo Joo," Steam Trap with float", US Patent 7171976B2, February 6, 2007.

[11] Pranil Chavan Patil, " Steam Trap" US Patent 8230872B2, July 31,2012

[12] Pranil Chavan Patil, "Steam Trap", European Patent 2049827B1, May 13, 2015.

[13] ASME Standard, Section 8, Material and Material Selection, UG-23

[14] ASME Standard, Section 8, Design,UG-34

[15] ASME/ANSI B-16.5 Flange Selection, Class 300.

[16] R.S.Khurmi, Saturated Water and Steam (Pressure) Tables, *Steam Tables,* New Delhi, India:

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