DESIGN REVIEW, TESTING AND VERIFICATION OF FLOAT VALVE PROTOTYPE FOR ACHIEVING PRESSURE DROP ACROSS HEAT GENERATORS IN A VAM

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ABSTRACT

The High Temperature Generator and the Low Temperature Generator of a typical Vapour Absorption machine needs to achieve a considerable pressure drop while keeping the flow rate of the refrigerant (Li-Br) constant. In order to achieve this pressure drop before the refrigerant could enter the High temperature heat exchanger, a float valve needs to be installed which would help with the pressure drop, while compensating slight variations in the pressure and also maintaining the flow rate constant. This new design of a float valve is primarily meant for a Triple Effect Chiller where the Pressure drop is measure across HTG to MTG to LTG. The following prototype has been designed analytically along with its meshing in Hypermesh and Max velocity Flow analysis in Flo-express. The prototype is then tested using a water test bay by maintaining a constant flow for a particular pressure drop. Slight adjustments have also been made to the final design so as to match the theoretical and practical values of pressure drop achieved.

KEYWORDS: Float Valve, Vapour Absorption Machine, High Temperature Generator (HTG), Low Temperature Generator (LTG), Triple Effect Chiller

INTRODUCTION

A flow control valve is mainly used to regulate the pressure or flow of a fluid. Control valves respond to signals generated by independent devices such as flow meters or temperature gauges. They can be classified into two types:

- Pressure compensated
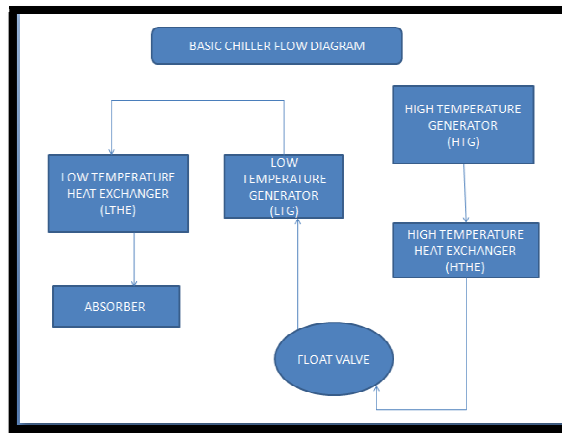
- Non-pressure compensated.

Pressure compensated valves are used to maintain a constant pressure drop and regulating the required flow rate. It also changes the flow rate across the valve when the required system load changes and the flow rate needs to be varied. Normally the pressure compensated flow control valves are fitted with a spring and a stem which compensate for pressure accordingly. The pressure compensated valves are classified in two types: By-pass and Restrictor type.

The By-pass valve allows the diversion of fluid flow in case of development of excess pressure. The pressure across the valve must be such that the load pressure is sufficient to overcome the spring pressure. An orifice or adjustable throttle is installed after the stem which controls and maintains the flow accurately[3].

Working of a VAM

Boiling point of the water is a function of pressure. At atmospheric pressure water boils at 100 deg. C. When maintained at high vacuum, water will boil and sub-cool itself.

The boiling point of the water at 6 mmHg (abs) is 3.7 deg. C. Lithium Bromide (LiBr) has the property to absorb water due to its chemical affinity. At higher concentration and lower temperature Li-Br absorbs water vapour (refrigerant vapour) very effectively. As Lithium Bromide becomes dilute it loses its capacity to absorb water vapour. It thus needs to be re-concentrated using a heat source. Heat source may be Steam or Flue gases or even Hot water. The heating causes the solution to release the absorbed refrigerant in the form of vapour. This vapour is cooled in a separate chamber to become liquid Refrigerant.

Figure 1: Flow Chart of a Double Effect VAM

Working of a Pressure Compensated Flow Control Valve

This design can incorporate a hydrostat which is able to maintain a constant pressure of approximately 20psi across the orifice (throttle) whose is adjustable by an external setting which can control flow rate. The hydrostat is held normally open by a light spring which start to close as inlet pressure increases and overcomes the spring force. This closes the opening through the hydrostat and thereby blocks all the flow in excess of the throttle setting. The only fluid that which passes through the valve is the amount that can be forced through the throttle at 20psi. Here Li-Br used as an absorbent which is highly corrosive in nature. Hence the spring would corrode and lead to contamination inside the chiller. Thus we need to modify the design[1].
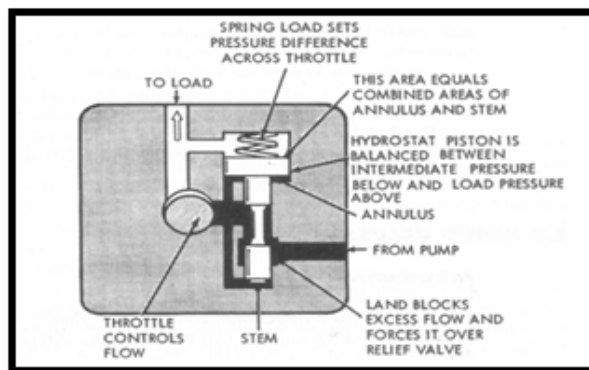
Figure 2: Pressure Compensating Flow Control Valve [3]

Pressure Reducing Valve

This type of valve is normally open is used to maintain reduced pressures in specific locations of hydraulic systems. It can be actuated by pressure on downstream and tends to close as the pressure will reach setting of the valve.

A pressure reducing valve has a spring-loaded mechanism which is essentially a spool to control the downstream pressure. If this pressure is below the required setting, the fluid flows freely across the valve. There is an internal pressure sensing passageway at the outlet which transmits outlet pressure to the spring and spool mechanism end. When the downstream pressure at outlet increases to the valve setting, the spool block the outlet port partially. Just enough flow is allowed to pass to the outlet and preset pressure level can be maintained. When valve is completely closed, leakage after the spool causes downstream pressure to build up above the valve setting. This is prevented as a continuous bleed to the tank is allowed through a separate line to the tank[3,6].
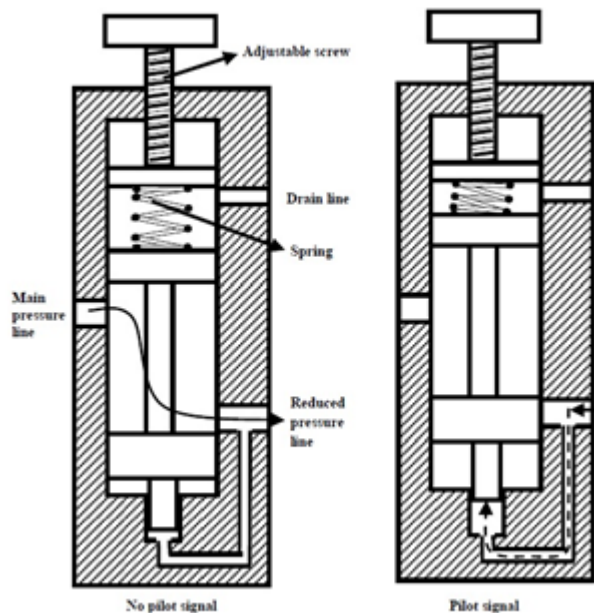

Figure 3: Pressure Reducing Valve [3]

As this valve is normally open, it reads the downstream pressure. It also uses an externaldrain. This is represented by a line connected from the valve drain port to the tank.

The disadvantage of using this valve is that the pressure drop acrossit represents the energy that is lost and converted into heat energy. If the pressure setting of the reducing valve is set extremely low with respect to the pressure in the rest of the system, which is very high, which may result in extreme heating of the fluid. This may cause component wear due to high oil temperatures [11].

Design of Float Valve

Pressure Profile and Allowable Pressure Drop

Flow of fluid through a float valve obeys the basic laws of conservation of mass and energy that is the Continuity Equation. The orifice/annular ring acts as a restriction in the path of the flow. When the stream reaches this restriction, the velocity increases and allows the full flow to pass through the restriction. Energy for this increase in velocity comes from a corresponding decrease in pressure [7]. Maximum velocity and minimum pressure occur immediately downstream from the

throttling point at the narrowest constriction of the fluid stream, known as the annular ring. Downstream from the annular ring, the energy is converted back to pressure as the fluid begins to slow down. A simple profile of the pressure exerted by the fluid is shown in Figure 4. The slight pressure losses in the inlet and outlet passages are due to frictional effects. The major changes in pressure are due to the velocity changes in the region of entry and exit to the annular ring and chamfer at the spool (labeled as vena contracta)[6].
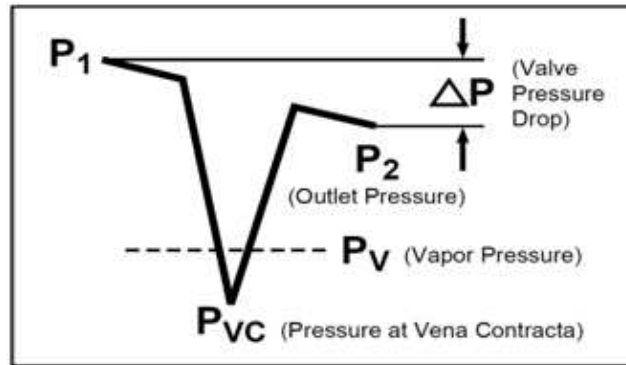

Figure 4: Pressure Drop across Vena Contracta [7]

The curve shown in Figure 5 is known as the capacity. It represents that with constant upstream pressure, flow rate, is proportional to the square root of pressure drop through the proportionality constant C_v. The curve separates from a linear relationship at a point called choking described using the F_L factor. The flow reaches a maximum, q_{max}, at the completely choked condition due to cavitation for liquids. The choked flow may occur gradually or abruptly, depending on valve design. ANSI/ISA equations use a pressure recovery factor, F_L, to calculate the ΔP_{ch} at which choked flow is assumed for sizing purposes. When a compressible fluid is considered, a pressure drop ratio at terminal point similarly describes the choked pressure drop for any specific valve. The smaller of the actual pressure drop or even a choked pressure drop is always used to determine the correct C_v while sizing the valve. This is allowable pressure drop, ΔP_a[6-7].
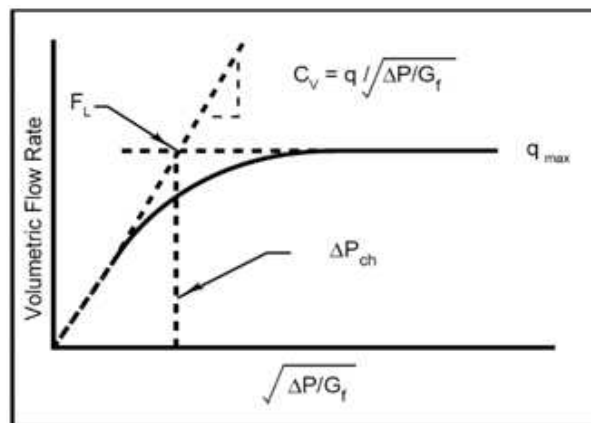

Figure 5: Capacity Curve [7]

Calculations for the L-180 Float Valve Assembly [2]

- Design of annular ring
- Height of liquid required to lift float valve
- Theoretical pressure losses

Design Review, Testing and Verification of Float Valve Prototype for Achieving
Pressure Drop Across Heat Generators in A Vam

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- Practical pressure losses

Design of Annular Ring

Given: Discharge (Q) = 0.0007 m^3/s

Velocity (V) = 15.86m^2/s

Outer diameter (D) = 60 mm

Q=A*V

0.0007 = A * 15.85

A= 44.123 mm^2

$$A = \frac{\pi}{4}[D^2 - d^2]$$

d = 0.05953 mm

Hence as discharge changes, we will change inner diameter (d) as outer diameter is fixed due to chiller tube constraints.

Height of Liquid Required to lift the Float

Given: Drum diameter (d1) = 160 mm

C/s area of drum (A$_1$) =   =0.0201062 m^2

Weight of assembly (W) = ρ* A$_1$ * h

7.2852 = 995.42 * 0.0201062* h

h = 0.3640 m

Hence this much height of liquid is required to lift the body.

Practical Pressure Losses

Given: HTG pressure = 522mm of hg

Static head of liquid column = 188 mm of hg

Friction loss in line- HTHE = 31.5 mm of hg

Total head at float inlet = 678.5 mm of hg

LTG pressure = 37.9 mm of hg

Static head of liquid column = 229.6 mm of hg

Friction loss in line- LTHE = 55 mm of hg

Pressure at inlet of float (P$_{in}$) = 522 + 188 - 31.5   =678.5

Pressure at outlet of valve (P$_{out}$) = 37.9 + 229.6 – 55   = 212.5

Head to be killed in float = P_{in} - P_{out} = 466 mm of hg

Theoretical Pressure Losses[5]

Given: Internal radius at chamfer (r_i) = 0.029765 m

Outer radius at chamfer (r_0) = 0.0305 m

C/s area of chamfer = $\pi[r_0{}^2 - r_i{}^2]$

=0.000139 m^2

Discharge (Q) = A * V

0.0007 = 0.000139 * V

Velocity at chamfer (V) = 5.03 m/s

Total losses = 0.079 m of liq column

=5.79 mm of hg

Table 1: Calculations of L-180 Float Based on Water as the Flowing Fluid

| Parameter	Units	Value
Volumetric Flow rate	m^3/s	0.0007
Velocity	m/s	15.86
Area	m^2	4.4E-05
Outer diameter (do)	m	0.06
Inner diameter (di)	m	0.05953
(do2-di2)/ln(do/di)		0.0071
dp/dl	N/m^3	2757838.367
Length of annular section	m	4.00E-06
dp in annular section	N/m^2	1.10E+01
	mlc	1.13E-03
2. Height of Liquid Required to Lift Float		
Parameter	**Units**	**Value**
Drum diameter	m	0.16
Area	m^2	0.02011
Weight of assembly	kg	7.2852
Density	kg/m^3	995.42
Height	m	0.3640
3. Pressure Drop Across Chamfer		
Parameter	**Units**	**Value**
Internal radius	m	0.029765
Outer radius	m	0.0305
Viscosity	kg/m.sec	0.0008
C/s area for flow	m^2	0.000139
Entry velocity at chamfer	m/s	5.03
4. Losses		
Parameter	**Units**	**Value**
Pressure loss across chamfer	mlc	1.1E-03
Gradual Expansion Losses	mlc	6E-02
Gradual Reduction Losses	mlc	2E-02
Total losses	mlc	0.079
	mm of Hg	5.79

BASIC CONSTRUCTION AND GEOMETRY OF FLOAT VALVE
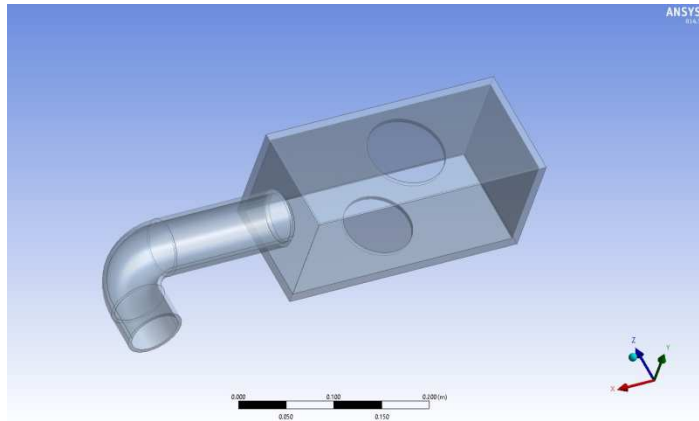
Figure 6: Rectangular Box with Cutouts for Spool Assembly
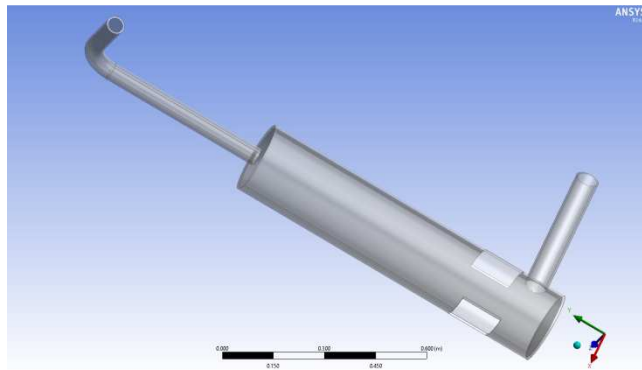
Figure 7: Outer Housing of the Assembly
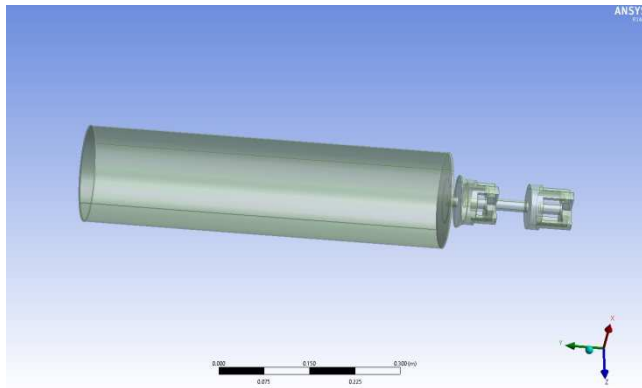
Figure 8: Float Body with the Spool Welded in Place

Figure 9: Complete Assembly of Float

FLUID FLOW ANALYSIS OF FLOAT VALVE ASSEMBLY

- Flow analysis primarily to study the flow of the fluid at various parts of the float valve.

- To determine the velocities at specific points inside the assembly.
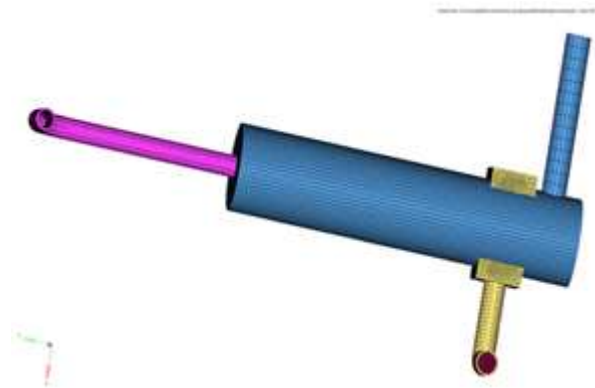
- To determine the max velocity inside the assembly[2,12].

Figure 10: Mesh of Float Valve Assembly in Hypermesh

Analysis Carried out Taking Environment Pressure

Table 2: Inlet Volume Flow 1

Type	Volume Flow Rate
Faces	Face<1>@BODY-1-1
Value	Volume Flow Rate: 0.0009 m^3/s Temperature: 300.00 K

Environment Pressure 1

Type	Environment Pressure
Faces	Face<2>@PRT0001-1-1
Value	Environment Pressure: 101325 Pa Temperature: 300 K
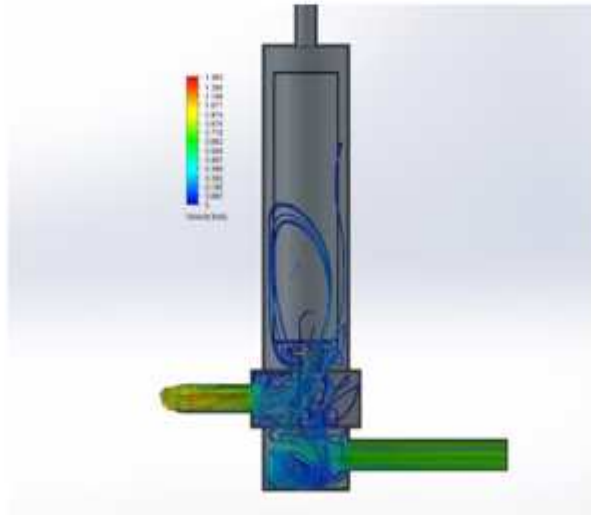
Figure 11: Streamline Flow inside Float Assembly

Table 3: Velocities across Various Points inside Float

Name	Unit	Value
Maximum Velocity	m/s	1.363
Velocity at Entry	m/s	0.682
Velocity at Exit	m/s	0.779
Velocity Near Annular Entry	m/s	0.390
Velocity at exit to Rect. Box	m/s	1.169
Velocity Near Chamfer	m/s	0.487

TESTING OF FLOAT VALVE

Procedure for Testing of Float Valve

- For 1 m fall of water column in the overhead tank, corresponding time was recorded for calibration of orifice.

- Pressure drop across orifice was changed by approximately 30-40 mm of Hg in consequent reading by varying the valve position of a control valve connected after the orifice and pressure drop across float was measured.

- Same readings were repeated from higher to lower value of pressure drop across orifice to counter check.
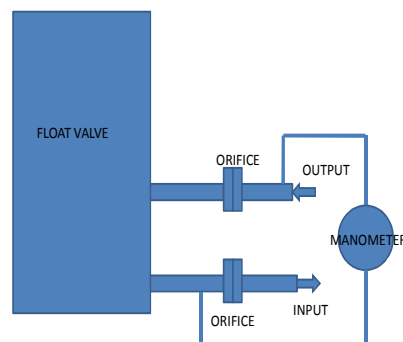

Figure 12: Arrangement for Testing of Float Assembly

Calculation for Set 1 and Reading 1

1. Pressure drop Across Orifice = 15 mm hg

     Hm =215mmHg

     Qrated =10m3/sec

2. Actual flow by orifice = $\sqrt{\frac{\Delta P}{H_m}} \times Q_{rated}$

          = 2.64 m3/sec

3. Hm=185mmHg

     Qavg=11.05m3/sec

4. Actual flow by calibration = $\sqrt{\frac{\Delta P}{H_m}} \times Q_{rated}$

     = 3.15 m3/sec

Table 4: Flow and Pressure Readings across Float Valve (SET 1)

Sr. No.	Pressure Drop across Orifice	Actual Flow by Orifice	Actual Flow by Calibration	Pressure Drop across Float Valve
1	15	2.64	3.15	3
2	35	4.03	4.81	6
3	60	5.28	6.30	8
4	90	6.47	7.71	12
5	110	7.15	8.53	15
6	130	7.78	9.27	18
7	160	8.63	10.28	22
8	185	9.28	11.06	27
9	210	9.88	11.78	30
10	240	10.57	12.59	36
11	280	11.41	13.60	44
12	320	12.20	14.54	50
13	340	12.58	14.99	52
14	390	13.47	16.05	64
15	450	14.47	17.24	72
16	495	15.17	18.08	80
17	520	15.55	18.54	85
18	560	16.14	19.24	91

Table 5: Flow and Pressure Readings across Float Valve (SET 2)

Sr. No.	Pressure Drop across Orifice	Actual Flow by Orifice	Actual Flow by Calibration	Pressure Drop across Float Valve
1	15	2.64	3.15	2
2	35	4.03	4.81	6
3	55	5.06	6.03	9
4	80	6.10	7.27	11
5	110	7.15	8.53	13

Table 5: Contd.,

6	130	7.78	9.27	18
7	170	8.89	10.60	26
8	210	9.88	11.78	32
9	250	10.78	12.85	39
10	300	11.81	14.08	45
11	340	12.58	14.99	55
12	370	13.12	15.64	62
13	430	14.14	16.86	70
14	460	14.63	17.43	76
15	500	15.25	18.18	80
16	570	16.28	19.41	96

SUMMARY AND CONCLUSIONS

The critical part where the pressure reduction takes place is at the entry and exit of the annular section as well as the chamfer region. The increase in the pressure drop comes at a sacrifice of the flow rate. For keeping the optimum flow rate inside the VAM, annular area needs to be sufficient enough to pass the required flow. This prototype has been tested on a water test bay and is capable of reducing pressure across HTG and LTG on a Double Effect Chiller. This float will also solve the problem of uncondensed Li-Br to exit through the overflow back into the HTG without disturbing the flow of the chiller. Higher Pressure drop at high flow rate can be achieved if so required for a Triple Effect Chiller by making modifications to the chamfer and by increasing the weight of the Float Body.

ACKNOWLEDGEMENTS

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