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Cavitation in pipelines and valves.

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Abstract
This paper is a practical study that deals with the case of cavitation in pipelines and valves. The study is carried out for both cases of either cavitation or non-cavitation. Experiments were performed by adjusting the water flow rate, pressure and temperature by monitoring the occurrence of cavitation and noise level in the pipeline.

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I. INTRODUCTION

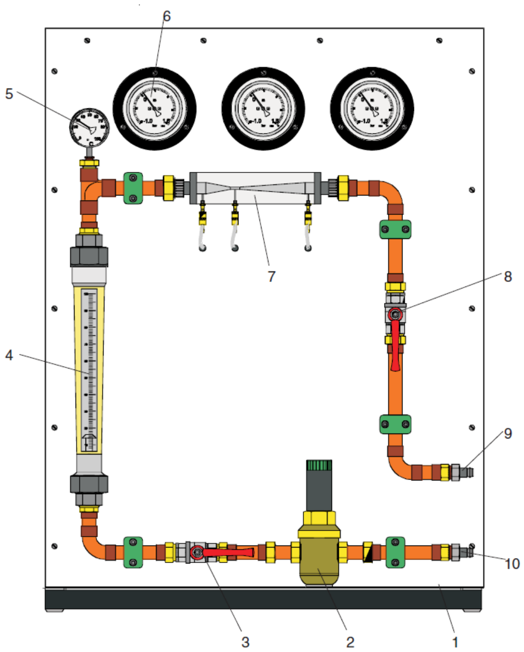
1.1 what is the Cavitation: Cavitation in general is a condition that occurs when fluid pressure drops below vapor pressure. Thereafter, steam bubbles form and explode when the pressure increases. This explosion causes erosion, and significant rapid damage to the valve or pipeline internally.
The water pressure inside the valve decreases when its opening is reduced, as well as when the diameter of the pipeline suddenly decreases. This areal reduction can lead to less pressure value than evaporation pressure, then water evaporates, causing steam bubbles. Then the pressure rises suddenly as a result of the increase in diameters right after the low pressure point and this explodes.

1.2 The collapse of these bubbles generates shockwaves that can result in a series of damaging effects, including:
1- Rapid wear of the valve or pipeline
2- Noise and vibrations, which lead to increased wear and mechanical failure
3- Cavities that occur can lead to decreased efficiency or the occurrence of leaks.

1.3 The G.U.N.T. ST 250 Demonstration Unit
The G.U.N.T. ST 250 Demonstration Unit offers the opportunity to make the process of cavitation visible using a transparent venturi tube. Pressure is converted to velocity in the venturi tube until the pressure is reduced below the vapor pressure associated with the ambient temperature. Then Vapor bubbles form at the smallest tube of cross-sectional area, which then collapses again on the expansion of the cross-sectional area of the flow. The tabletop apparatus is clearly laid out and contains equipment for all the necessary measurements. Specific settings can be made with valves so that several forms and various intensities of cavitation formation can be generated. The Demonstration Model requires only a water connection that has an inlet pressure of approx. 3-4 bar. Both the connection to the water supply and the drain are made using hoses with rapid action hose couplings.

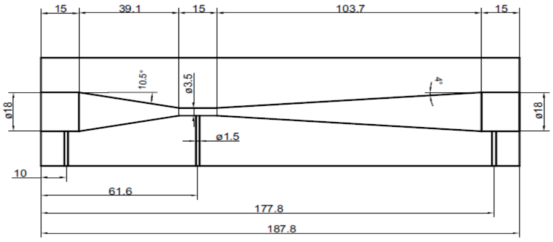
II. Unit Description

2.1 Unit Construction

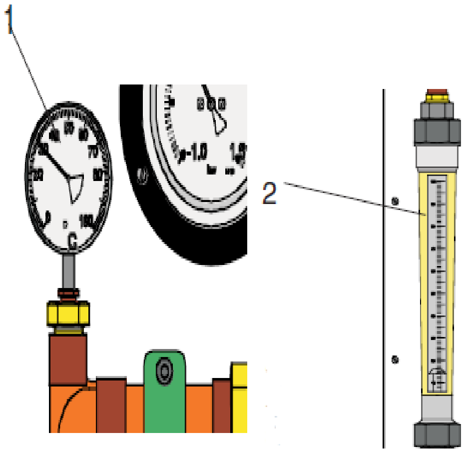


1. Tabletop Frame
2. Pressure Reducing Valve
3. Spherical Valve
4. Variable Area Flowmeter
5. Thermometer
6. Manometer
7. Venturi pipe
8. Spherical Valve
9. Water Drain Connection
10. Water Feed Connection

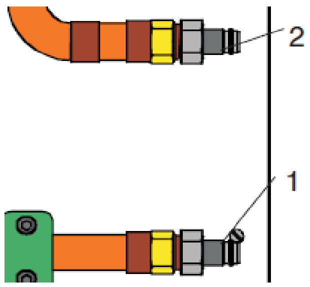
2.2 Venturi Tube
A dimensioned drawing of the venturi tube with the direction of flow and position of the tappings is given below:



2.3 Measuring Equipment



Along with three spring-tube manometers, the Demonstration Model is also fitted with a bimetallic thermometer and variable area flowmeter. The thermometer's (1) bimetallic strip is contained in an immersion sleeve that hangs directly in the flow, by this means the actual temperature of the flowing medium is measured. The variable area flowmeter (2) measures the flow rate. A float is drawn along a conical tube by the flow. The flow in ltr/h can be read off on a scale adjacent to the top edge of the float.



The Demonstration Model only requires a cold-water supply. This supply should be able to deliver an inlet pressure of 3-4 bar. The water feed (1) to the unit is to be connected to the water supply using a hose and rapid action hose coupling. The drain water should be fed from the output (2) of the Demonstration Model to a drain using a hose. At the start of the experiment both spherical valves should initially be open so that no pressure is built up due to lack of flow.

III. Theory and Experiments

In this section some general statements on cavitation will be made, these will then be demonstrated in an experiment using the unit. The values set on the unit are not to be seen as reference or calibration values that are applicable in all circumstances. Depending on the exact versions of the components used and the ambient conditions (water inlet pressure, water temperature), large deviations may occur to a greater or lesser extent during your own experiments.

3.1 Design of the Venturi Tube
The following assumptions were made initially when designing the flow cross sectional area of the venturi tube:
• Max. flow 1000 l/h
• Pressure after the pressure reducing valve p1= 1.5 bar
• Water temperature 15°
=> Vapor pressure 0.017039 bar
In order to ensure that the pressure actually drops below the vapor pressure and bubbles are formed at the constriction, the flow velocity in the middle of the venturi tube must be very high. The velocity prior to entry in the venturi tube has the following value at a flow cross-sectional area of d=20mm.

$$w_1 = \frac{\dot{V}_{max}}{\Pi \cdot \frac{d^2}{4}} = \frac{\frac{0.2778\,dm^3}{s}}{\Pi \cdot \frac{(20\,mm)^2}{4}} = 0.88\,\frac{m}{s} \qquad (3.1)$$

According to the general equation of continuity, w1 and w2 are related as follows:

$$\frac{w_1}{w_2} = \frac{A_1}{A_2} \implies \frac{w_1}{d_2^2} = \frac{w_2}{d_1^2} \qquad (3.2)$$

$$w_2 = w_1 \cdot \frac{d_2^2}{d_1^2} \qquad (3.3)$$

The Bernoulli equation is used as the second equation in the design process.

$$g \cdot z_1 + \frac{p_1}{\rho} + \frac{w_1^2}{2} = g \cdot z_2 + \frac{p_2}{\rho} + \frac{w_2^2}{2} \qquad (3.4)$$

Since z1 = z2 the first item on each side falls out.
By re-organizing and inserting the equation of continuity, the following intermediate result is reached:

$$p_2 - p_1 = \frac{\rho}{2} \cdot w_1^2 - \frac{\rho}{2} \cdot w_1^2 \cdot \frac{d_1^4}{d_2^4} \qquad (3.5)$$

The relationship of d1 to d2 can then be determined as follows:

$$\frac{d_1}{d_2} = \sqrt[4]{1 - \frac{2 \cdot (p_2 - p_1)}{\rho \cdot w_1^2}} \qquad (3.6)$$

$$\frac{d_1}{d_2} = \sqrt[4]{1 - \frac{2 \cdot (1.50 - 0.017039) \cdot 10^5 \cdot \frac{N}{m^2}}{1000 \frac{kg}{m^3} \cdot 0.88^2 \frac{m^2}{s^2}}} = 4.64$$

In order to be sure that bubbles are formed at the constriction, a diameter of d2 = 3.5 mm was selected for this point.

3.2 Experiments

we performed the following Before experiments

− Check the rapid action hose couplings (1) are secure.

− Connect the water supply to the water feed (2) and the outlet (3) to a drain.

− Open the spherical valves (4,5) fully.

Once the water supply has been turned on, the pressure reducing valve (6) is to be adjusted at its top ring so that a pressure of +0.2 bar is read on the first manometer (venturi tube inlet). All the other measured values and the process occurring in the venturi tube are then noted. The pressure reducing valve is then adjusted so that the pressure at manometer 1 increases by 0.1 bar. This process is repeated until a pressure of 1.0 bar has been achieved.

The values measured and observations made are entered in the following table.

Inlet pressure p_1	Constriction pressure p_2	Outlet pressure p_3	Flow V	Water temperature t	Observations in respect to cavitation
+0.2 bar	- 0.55 bar	0 bar	250 l/h	20°C	No bubble formation
+0.3 bar	- 0.95 bar	0 bar	330 l/h	19°C	A type of „Channel“ forms at the constriction
+0.4 bar	- 0.96 bar	0 bar	350 l/h	19°C	Small bubbles form at the end of the constriction
+0.6 bar	- 0.97 bar	0 bar	390 l/h	19°C	An increased number of larger bubbles is formed
+0.8 bar	- 0.98 bar	0 bar	420 l/h	19°C	More bubbles, increasing noise
+1.0 bar	- 0.98 bar	0 bar	450 l/h	19°C	Even more bubbles, loud noise

Cavitation is thus not only visible but also audible since the implosion of the vapor bubbles generates noise. At a water temperature of 20°C, the vapor pressure is 0.02337 bar absolute. The formation of bubbles therefore only starts from a manometer pressure of -0.96 bar.

Scheme of formation of gas bubbles in Venturi tube by hydrodynamic cavitation. P1/P3 static pressure before/ after throat, P2—static pressure in throat, P—vapor pressure of liquid

IV. Conclusion

Cavitation is a serious problem and once it starts it becomes larger. It is detrimental to every factor of pipe and valve operation, such as cost, efficiency, flow rate, noise and vibration.

From the recorded results it can be concluded that cavitation can be prevented. Cavitation will not occur when several measures can be taken as:

1- Selecting the correct materials of pipelines and valves that resist the cavitation and corrosion.
2- Regulate the pressure so that it does not reach the evaporation pressure value.
3- Control the flow rate so that the water flow speed does not reach a value that causes the pressure to drop to the evaporation pressure.
4- Control the water temperature so that it does not drop to the point of evaporation at operating pressure.
5- Decreasing the friction in the pipeline, and cleaning is done at regular intervals.
6- Using a large diameter pipe.

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