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AN APPROACH TO DEVELOPMENT OF AIR LEAKAGE TEST RIG FOR AIR HANDLING UNITS HOUSING.

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ABSTARCT:
Flow measurement plays vital role in Air conditioning leak detection to measure leakages of conditioned air in a airconditioning system of the building. It is costlier process to convert properties of air into making of desired atmosphere of the building. The leakage of conditioned air is cause of loss of money. In this stems the need for accurate, economical measurement for leakages is essential to control the quality and quantity of air properties. Orifice metering is the popular and economical procedure used in satisfies most flow measurement applications and is the most common flow meter in use now a day. In this paper an orifice meter test rig developed, tested and calibrated for measurement of leakages in Air handling units of air management system for a building. Results of testing orifice plate recorded with precise instruments to find out significance of using orifice plate for air flow leakage measurement from Air handling units housing.

Keywords: *Orifice; Inclined tube manometer; U-tube manometer; Air handling unit.*

1. INTRODUCTION

The orifice meter is a type of obstacle measurement, sometimes called the head loss flow meter, is chosen most frequently because of its long history of use in many applications, versatility, and low cost, as compared to other flow meter available.

An orifice plate is a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. When the fluid reaches the orifice plate, the fluid is forced to converge to go through the small hole, the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called vena contracta point. As it does so, the velocity and the pressure changes. Beyond the vena contracta, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena contracta, the volumetric and mass flow rates can be obtained from Bernoulli's equation. The differential pressure is measured through pressure taps located on each side of the orifice plate.

2. FLOW RATE COMPUTATIONS: The fundamental flow equation is

$$h = C' \, df \, Pf$$

where:
h = Flow rate at base conditions
C' = Orifice flow coefficient
df = Differential pressure
Pf = Absolute static pressure

The orifice flow coefficient is calculated using other constants that identify diameter of the pipe, orifice bore diameter, base pressure and temperature with variables that relate to the physical properties of the fluid such as temperature, specific gravity, density, viscosity, and compressibility. Any change in the diameter of the orifice bore fluid composition or temperature will change the coefficient, thus, changing the rate of flow.

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3. METER TUBE LENGTHS

The flow of fluid through elbows, tees, and valves will cause turbulence, which adversely effects the fluid measurement. For accurate flow measurement, the fluid should enter the orifice plate free from swirls and cross currents. In order to achieve the desired flow profile, adequate upstream and downstream straight pipe is required and / or flow conditioners such as straightening vanes. The use of flow conditioners (straightening vanes) will also reduce turbulence within the meter tube while allowing shorter lengths of straight pipe.
Research continues on straightening vanes in regard to effect location and relationship to meter tube lengths.
An idea is given for Minimum lengths of straight pipe preceding and following the orifice plates in the figure 1.

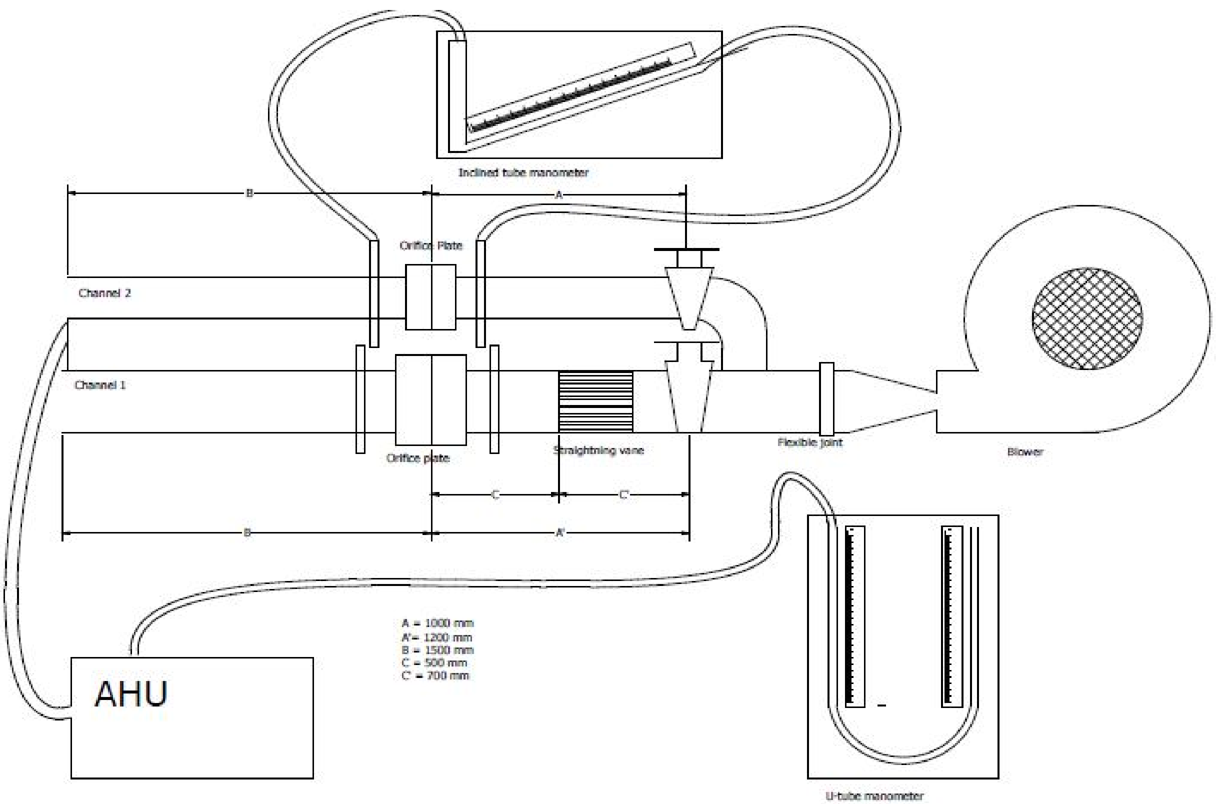

Fig.1: Arrangement of test rig.

There are to be no pipe connections within the minimum amount of straight pipe with the exception of the pressure taps, temperature probes, and/or straightening vane attachments. There is considerable research being conducted regarding minimum lengths of meter tube pipe required. The meter tube shall be checked for compliance with standards and available sizes of pipes.

4 Test Set up

The test rig fabricated with applying standard ISO 5167 for orifice and arrangement made as shown in Fig. 1. Globe valves were used for flow control in two channels. Channel 1 is high flow rate channel where channel 2 is for low flow rates. Diameter of channel 1 is 102.3 and for channel 2 it is 62.7 mm and β values are 0.636 and 0.51 respectively. Since the calibration is carried out on the actual setup, small deviations are unlikely to affect the general performance.
The Highest flow rate that could be obtained with the blower fan was found to be 100 l/s through channel 1, which implies that the total system pressure drop is 250 mm of water column (WC) based on the performance characteristic of fan.

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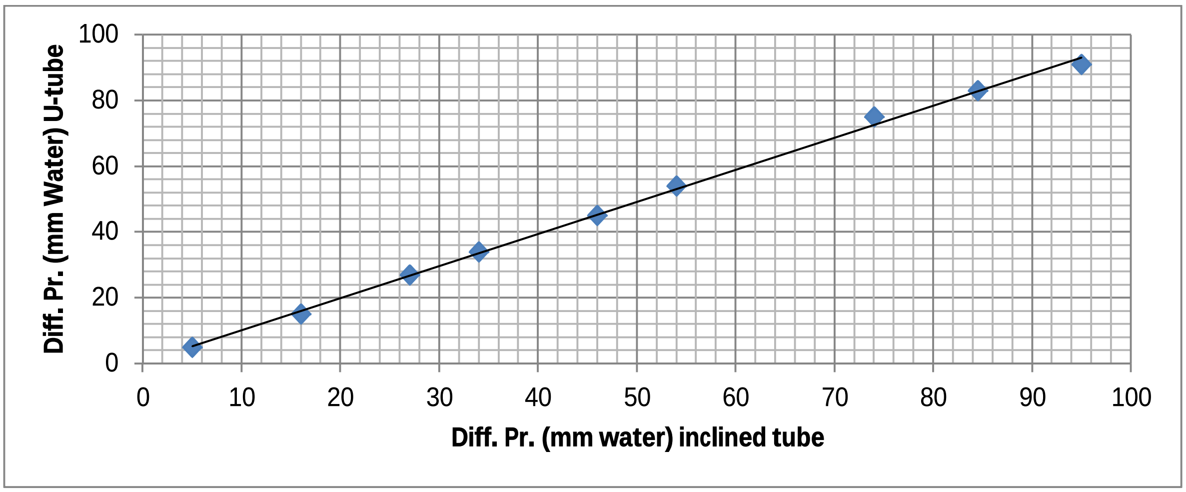
The pressure drop across the orifice plate at this flow rate was about 86 mm of WC. The pressure drop of the meter itself would be about 50 mm of WC. Thus it is implied that the pressure drop between discharge ends of the fan to the stream state pressure drop would be around 200 mm of WC. This could have been be contributed by the gradual expansion at the discharge of the fan, the vibration isolator, the dividing T and the flow regulating valve.

For measurement of differential pressure of orifice plate inclined tune manometer used and for static pressure measurement in the duct U tube manometer of 300 mm scale used. The fluid in the inclined tube manometer has a specific gravity of about 0.8 but the scale has been marked in mm WC. However, it was found that at differential pressures above 60 mm of WC the inclined tube manometer was not confirming to the reading of the U-tube manometer. Hence a calibration of the inclined tube manometer obtained against the U-tube manometer. Calibration chart shown in curve 1 below.



Curve 1: Calibration of the inclined tube manometer.

The least squares fit of the data yields the following equation with a regression coefficient of 99.95%.

Δp U tube = 0.97Δp inclined tube + 0.37 … … (1)

With the pressure units in mm water column.

Table 1

Pressure						Velocity				
U-tube	**Inclined**	**TSI**	**Testo**	**Solomat**	**Average**	**TSI Hotwire**	**TSI Pitot**	**Vane**	**Average**	**Discharge**
mm wc	**mm wc**	**Pa**	**mm wc**	**Pa**	**mm wc**	**m/s**	**m/s**	**m/s**	**m/s**	**l/s**
Descending										
86		836	86	837	86	11		10.5	10.67	94.13
76					76	10	10.05	9.6	9.88	87.22
66				620	66	9.2	9.35	9.2	9.24	81.52
57				530	57	8.5	8.55	8.3	8.45	74.57
45				410	45	7.6	7.65	7.5	7.58	66.92
35.5				320	35.5	6.75	6.85	6.7	6.77	59.71
25			24.13		25	5.75	5.7	5.8	5.75	50.74
15					15	4.33	4.4	4.45	4.39	38.77
8			7.1		8	3.05	3.2	3.2	3.15	27.8
Ascending										
	15				15	4.47	4.47	4.5	4.51	39.8
	25				25	5.7	5.8	5.6	5.68	50.08
	35				35	6.75	6.75	6.7	6.73	59.35
	45				45	7.5	7.45	7.4	7.44	65.63
	55				55	8.45	8.2	8.1	8.21	72.47
	65				65	9.15	9.1	8.9	9.04	79.75
	75				75	9.65	9.55	9.3	9.48	83.61
	85				85	10.25	10.2	9.9	10.09	89.02
	5				5	2.63	3.14	2.6	2.79	24.62

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5 TEST METHOD:

The test performed in two stages

(1) Decreasing and increasing flow rate for channel 1, (2) Same for channel 2.

The free ends of the both channels were allowed to discharge into the ambient with no obstructions for a substantial length such that no back pressure present. Flow rate from minimum to maximum were obtained by using the valve alone in channel 1. In the case of channel 2 for low flow rates first the valve in this section alone was used. However, at high flow rates the disturbances were too large to obtain a steady flow. Hence the valve in channel 1 was used as a bypass to stabilize the flow rate. Four different types of velocity probes were used to measure the velocity at the centre of the pipe section. A vane anemometer, Pitot tube. The dynamic pressure was transformed to velocity using a differential pressure transducer, Hotwire anemometer, Pitot tube along with the differential pressure input to TSI instrument. The pressure drop across the orifice plate was measured with an inclined tube manometer. The differential pressure across the orifice plates as measured by the manometer was also used to cross check the accuracy of the TSI differential pressure measurement. It was found that they are all commensurate with each other with in the specified precision of each instrument. Velocities are measured at the centre of the pipe. Since the Reynolds numbers of flow were above 10000 in both the channels for the range of flows proposed to be measured by the test rig (namely 8.5 l/s and above) and the diameters of both channels are small it is assumed that this represents the average velocity. However, near the wall it may not be true. Thus, the leakage rates measured by the test rig will be pessimistic.

The range of calibration is about 100-28 l/s for channel 1 and 28-8 l/s for channel 2.

TABLE 2: Experiment data for Channel 2

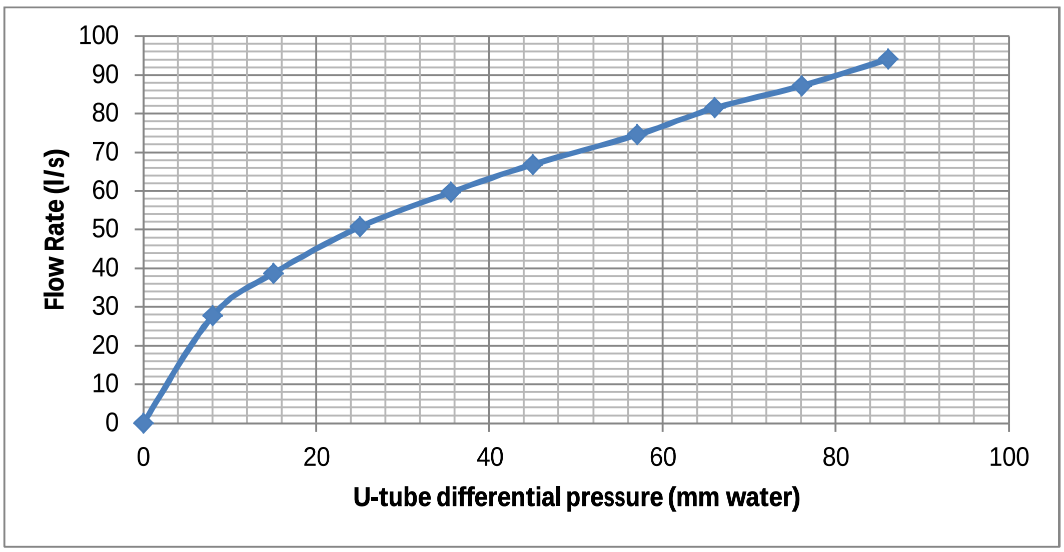
Pressure					**Velocity**					
U Tube	**Inclined**	**TSI**	**Testo**	**Average**	**TSI**	**TSI**	**TESTO**	**TESTO**		
	mm wc	**Pa**	**mm wc**	**mm wc**	**HOTWIRE**	**Pitot**	**Pitot**	**vane**	**Average**	**Discharge**
					m/s	**m/s**	**m/s**	**m/s**	**m/s**	**l/s**
Ascending	2.5			3	1.35	1.45		1.3	1.37	3.99
	10			10	2.77	2.86		2.7	2.78	8.11
	20			20	3.41	3.5		3.2	3.37	9.85
	30			30	4.21	4.37	4.3	4.1	4.25	12.41
	40			39	4.8	4.75	4.7	4.6	4.71	13.77
	50			49	5.65	5.5	5.3	5.3	5.44	15.89
	60			59	6	5.95	5.6	5.8	5.84	17.06
	70			68	6.45	6.1	6.1	6.2	6.21	18.16
	80			78	6.8	6.85	6.8		6.82	19.92
	90			88	7.55	7	7.1	6.9	7.14	20.86
	100			98	7.65	7.6	7.5		7.55	22.16
		1067	108.8	108.8	8.2		8	7.8	8	23.38
		1168	119.1	119.1	8.65		8.4	8.2	8.42	24.6
		1337	136.3	136.3	9.2	8.95	8.6	8.6	8.84	25.83
		1532	156.2	156.2	9.9		9.7	9.1	9.57	27.96
Descending										
		1440		146.8	9.5		9.2	8.8	9.17	26.79
		1270		129.5	9.05		8.9	8.7	8.88	25.96
		1100		112.1	8.45		8.3	8	8.25	24.11
		1000		101.9	8.05		7.8	7.7	7.85	22.94
		930		94.8	7.65		7.6		7.63	22.28
91	94.5	91		91	7.4	7.3	7.3		7.33	21.43
83	84.5	83		83	7.05	6.8	6.7	6.5	6.76	19.76
74	74.5	74		74	6.7	6.35	6.2	6.1	6.34	18.52
63	65	63		63	6.25	6.05	6.1	5.9	6.08	17.75
53	54	53		53	5.7	5.35	5.5	5.3	5.46	15.96
45	45	45		45	5.3	5.25	5	5	5.14	15.01
33	34	33		33	4.6	4.55	4.55	4.3	4.5	13.15
25	25	25		25	3.81	3.87	4.1	3.9	3.92	11.46
15	15	15		15	3.09	2.98		2.8	2.96	8.64
5	5	5		5	1.67	1.58		1.55	1.6	4.68

Coefficient	Channel 1	Channel 2
A6	-5.313 x 10 -10	-2.514 x 10 -11
A5	2.884 x 10 -7	1.468 x 10 -8
A4	-5.092 x 10 -5	-3.365 x 10 -6
A3	4.158 x 10 -3	3.817 x 10 -4
A2	-0.1749	-0.02251
A1	4.484	0.798
A0	0.2265	1.024
Regression Coefficient	99.89%	99.64%
Root mean square	1.40%	2.20%

For the testing two typical air handling housings were tested for leak. Very low flow calibration For flow lower than 8.5 l/s, the channel 2 can still be used, but the calibration equation (2) with coefficients in table 3 will yield large uncertainties. Hence, a separate calibration is provided for this range taking the data points at differential pressures below 30 mm of water column. The calibration equation is given below.

$$Q(l/s) = -3.7 \times 10^{-5} \Delta p^4 + 3.24 \times 10^{-3} \Delta p^3 - 0.09851 \Delta p^2 + 1.458 \Delta p + 0.1013 \ldots\ldots\ldots \quad (3)$$

In the above equation again Δp is mm of WC. The difference between measured and calculated values will be about 0.6 l/s in the range.



Curve 2: Readings for Channel 1

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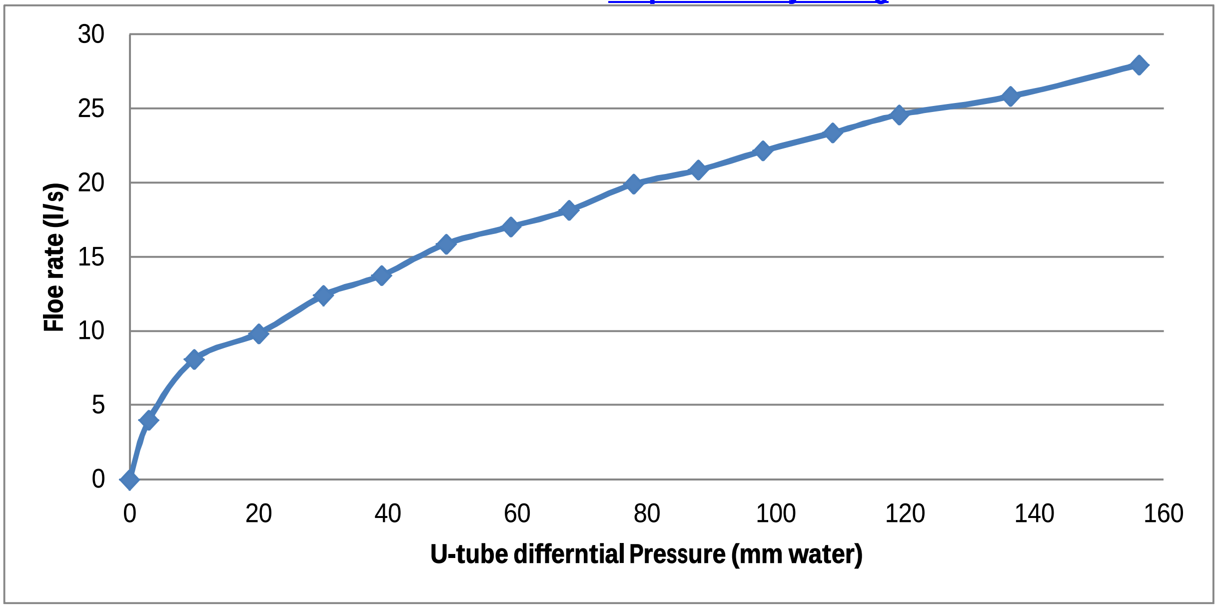
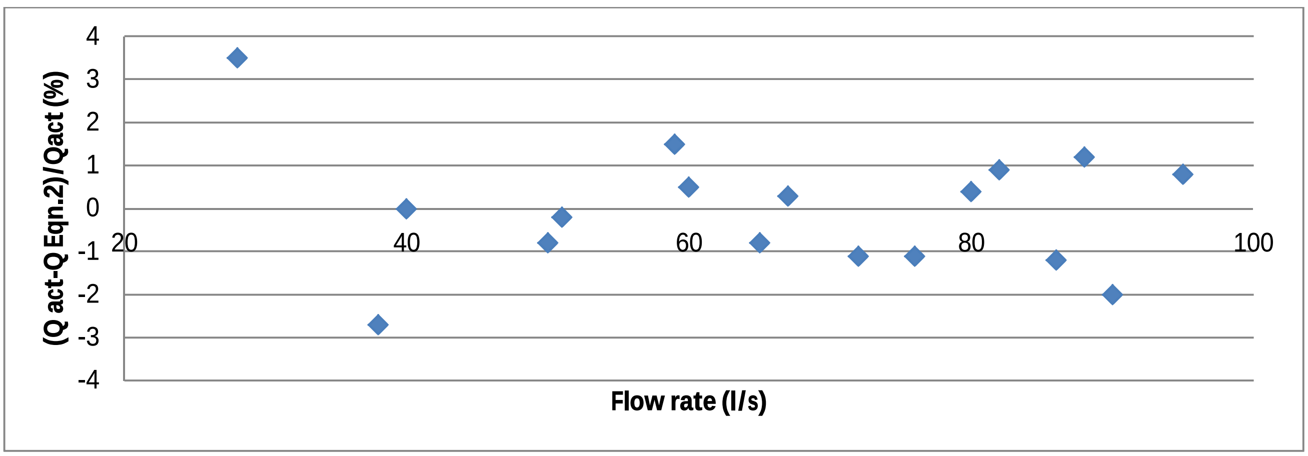
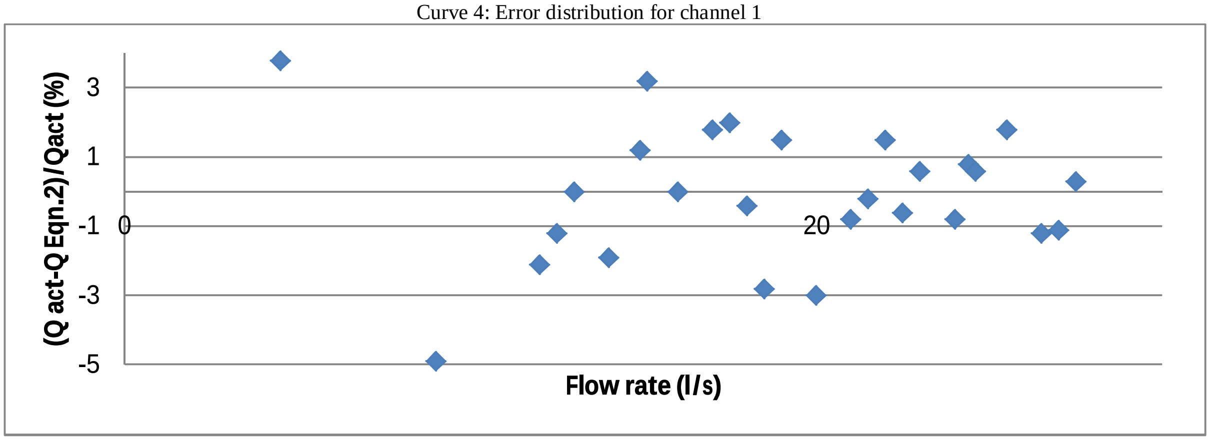


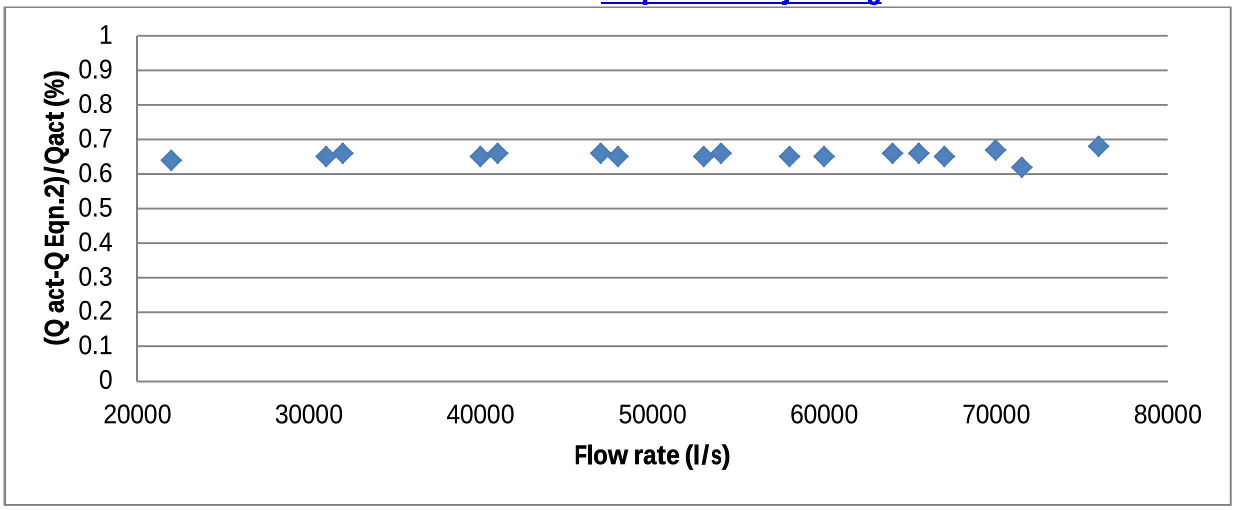
Curve 3: Readings for Channel 2



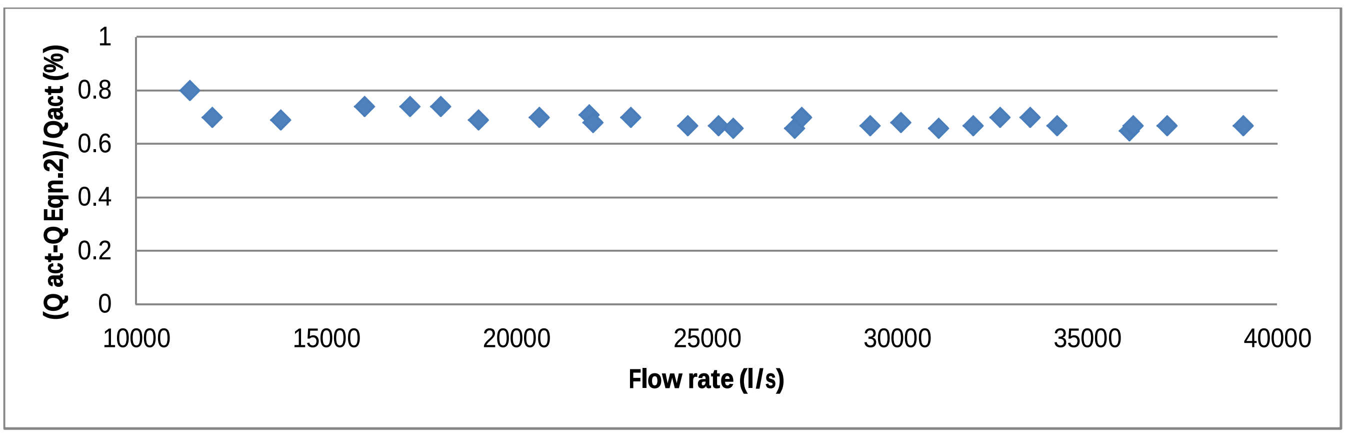
Curve 4: Error distribution for channel 1



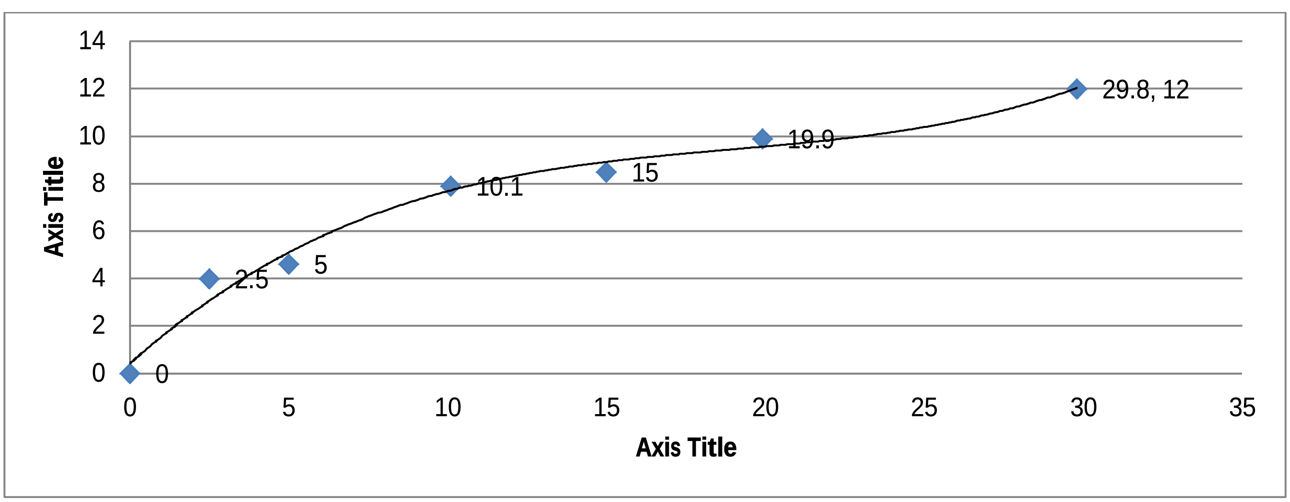
Curve 5: Error Distribution for Channel 2



Curve6: Coefficient of discharge distribution for channel 1



Curve 7: Coefficient of discharge distribution for channel 2



Curve8: Very low flow measurement channel 2

7.CONSIDERATIONS.

If the leak rate is not known always use the channel 1 and the U-tube manometer or the TSI differential pressure transducer for measuring the differential pressure across the orifice plate. If a TSI instrument is used, whose display is in Pa, multiply the displayed value with 0.102 to obtain the pressure differential in mm of WC. The constants in Table 3 are applicable only when differential pressure is in mm of water column. Ensure that there are no leaks between the upstream of the orifice plate and the connection to the air handling unit housing.

If the leak rates are below 28 l/s change over to channel 2 because at or below this flow rate the differential pressure across the orifice plate in channel 1 will be quite small.

For leak rates above about 20 l/s (equivalent to a differential pressure across orifice plate of about 80 mm of water column) when channel 2 is being used, It is possible that the differential pressure might fluctuate causing difficulties in getting a precise measurement. When this happens, bypass some amount of flow through channel 1 and open the flow regulation valve in channel 2 till the differential pressure stabilizes.

For leakage rates below 8 l/s use equation (3) for converting the differential pressure across the orifice plate of channel 2 in flow rates.

8. CONCLUSION: This test rig is most economical in measurement of leakages in ducting and Air handling unit housings. The flow measuring setup can be used for detecting leaks in the air handling unit housings from about 8 l/s to 100 l/s. It may also applicable for testing in compliance to National and International standard like DW32, EU1886 etc. Depending on the class of manufacture of the unit and surface area, it will be possible to guess the magnitude of possible leak. Based on this value choose channel 1 if likely leakage is > 28 l/s and channel 2 if < 28 l/s. Multiply l/s by 3.6 to obtain m3/hr.

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