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Fabrication and performance study of a cost effective digital turbine flow meter

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Abstract- *A digital turbine flow meter has been generated, where a turbine is placed inside the pipe through which fluid is passing. In this turbine meter a reed switch is used to get a pulse for one revolution of turbine, as fluid flow through the pipe will cause the turbine blades to rotate and this rotation is proportionate to the flow rate. The pulse is presented to the timer 0 of micro-controller (ATMEGA16). A Real time clock (RTC) is also attached with ATMEGA16 which serves to get real time for measuring flow period. A Standard calibration for the device is made by bucket and watch method and therefore an equation is derived for the calculation of flow rate corresponding to the number of pulses. A Computer Program is written for getting the output in the desired form by using that equation. The final output is presented in an LCD display. Result shows the meter's performance quite accurate over a wide range of fluid flow. This device may be employed for measuring fluid flow through pipes of different sizes and shapes.*

Keywords: Digital Turbine Flow Meter, Flow Rate Measuring, Microcontroller

1. INTRODUCTION

1.1 Background:

The transportation of fluids (gas or liquid) from one point to another is usually accomplished through the use of conduits (pipes) which are constructed in various shapes of different types of materials. These transportation grids are made up of sections of conduits with fittings, such as valves, connectors and measuring devices through which the fluid is moved. Measurements of flow constitute an essential part in all flow systems. Whether it is a fluid flow in a pipe line or liquid flow in an open channel, it is of a primary importance to know the quantity of fluid passing through the system. Direct measurement of flow either gravimetric or volumetric is the most accurate method of flow measurement. However, the direct measurement of flow may not be practicable in large and continuous flow systems such as the main pipeline of a city water distribution system. This method can nevertheless be adopted for flow through small experimental pipelines and open channels generally used in laboratories. [1]

To measure the discharge by volume, it is necessary to have a calibrated tank or container into which the fluid can be discharged for certain period of time. The tank has to be calibrated so that the volume at various elevations is known. Knowing the volume rate of flow, commonly known as discharge, can be determined. [2]

Measurement of flow by gravimetric methods involves determination of weight of fluid collected in a weighing tank. Such a tank is either mounted on a platform scale or in case of large tanks special supporting systems and balance must be designed for this purpose. [3]

1.2 Objectives:

The main objectives of this work are :

1. To study different types of flow measurement methods.
2. To know the comparison between the working principle of various types of flow meters.
3. To design and fabricate of a turbine flow meter.
4. To calibrate the fabricated turbine flow meter.
5. To test the performance of the meter

2. THEORY

2.1 Turbine Flow Meters for Liquid Measurement:

Turbine type flow metering devices are applied worldwide for the measurement and control of liquid products in the industrial, chemical and petroleum marketplaces. Significant advantages associated with the use of turbine flow meters, in lieu of other metering principles, make increased future use inevitable. Newcomers to the field of flow measurement should become familiar with fundamental characteristics and conditions surrounding the turbine flow meter in order to better understand its usage. Consequently, this article is provided as a brief guide to the operation and application of turbine flow meters for liquid product measurement. [4]

2.2 Construction of Turbine Flow Meter:

The basic construction of the turbine flow meter incorporates a bladed turbine rotor installed in a flow tube. The rotor is suspended axially in the direction of flow through the tube. The turbine flow meter is a transducer, which senses the momentum of the flowing stream. The bladed rotor rotates on its axis is proportion to the rate of the liquid flow through the tube. [4]

2.3 Turbine Rotation:
As the liquid product strikes the front edge of the rotor blades, a low-pressure area is produced between the upstream cone and the rotor hub. The blades of the turbine rotor will tend to travel toward this low-pressure area as a result of this pressure differential across the blades. The pressure differential (or pressure drop) constitutes the energy expended to produce movement of the rotor. The initial tendency of the rotor is to travel downstream in the form of axial thrust. Fluid flowing through the meter impacts an angular velocity to the turbine rotor blades, which is directly proportional to the linear velocity of the liquid. The degree of the angular velocity or number of revolutions per minute of the turbine rotor is determined by the angle of the rotor blades to the flowing stream of the approach velocity. [4]

2.4 Rotor Balance:
With axial thrust forcing the turbine rotor downstream, the friction resulting from contact between the turbine rotor and the downstream cone would cause excessive wear if there were not some means of balancing the turbine rotor on its axis between the upstream and the downstream cone.
Bernoulli's Principle states that when flow velocity decreases, the static pressure increases. Therefore, a high-pressure area exists at the downstream side of the turbine rotor exerting an upstream force on the rotor. As a result, the turbine rotor is hydraulically balanced on its axis. [4]

2.5 Signal Output:
Signal output of the rotor can be generated in following three different ways:

1. Electrical output using the principle of reluctance.
2. Electrical output using optical sensor.
3. Electrical output by using the magnetic attraction which open a switch

2.5.1 Electrical Output Using The Principle of Reluctance
Electrical output is generated using the principle of reluctance. A pickup coil, wrapped around a permanent magnet, is installed on the exterior of the flow tube or the meter body immediately adjacent to the perimeter of the rotor (Figure 3.1) the magnet is the source of the magnetic flux field that cuts through the coil. Each blade of the turbine rotor passing in close proximity to the pickup coil causes a deflection in the existing magnetic field. This change in the reluctance of the magnetic circuit generates a voltage pulse within the pickup coil. Each pulse generated represents a discrete amount of volumetric throughput. Dividing the total number of pulses generated by the specific amount of liquid product that passed through the turbine flow meter determines the K-Factor.

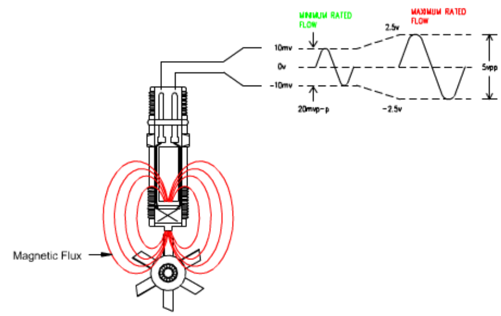


Figure 2.5.1.1: Signal output by using the principle of reluctance

The K-Factor, expressed in pulses per unit volume, may be used with a factoring totalizer to provide an indication of volumetric throughput directly in engineering units. The totalizer continuously divides the incoming pulses by the K-Factor (or multiplies them with the inverse of the K-Factor) to provide factored totalization. The frequency of the pulse output, or number of pulses per unit time, is directly proportional to the rotational rate of the turbine rotor. Therefore, this frequency of the pulse output is proportional to the rate of the flow. By dividing the pulse rate by the K-Factor, the volumetric throughput per unit time of the rate of flow can be determined. Frequency counters or converters are commonly used to provide instantaneous flow rate indication. Plotting the electrical signal output versus flow rate provides the characteristics profile or calibration curves for the turbine flow meter. Electrical output is also generated using the principle of inductance. A pickup coil is installed on the exterior of the flow tube immediately adjacent to the perimeter of the turbine rotor. The magnetic source of the flux field in this type of output is either the rotor itself or small magnets installed in the rotor. In the case of the rotor, the material of construction would be nickel or some other easily magnetized flux field. The results are identical to that of the reluctance principal. [4]

2.5.2 Electrical Output by Using Optical Sensor

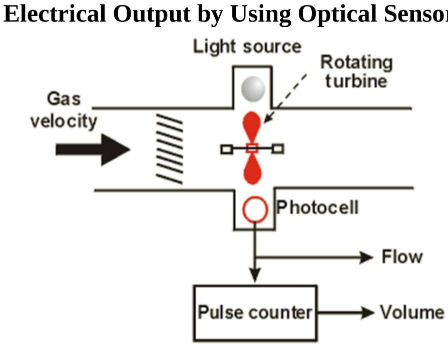


Figure 2.5.2.1: Signal output by using the principle of reluctance

Optical sensor shows change of resistance if it finds any opaque object in the way of light. The change of resistance is converted in to change of voltage by using a circuit. The circuit consist of LDR (which receive light), optical sensor, resistor, IC, transistor etc. The source of light may be a LED or laser light. Light passes through transparent pipe. When any blade comes in the way of light .The circuit with optical sensor gives a respective change of voltage.[5]

2.5.3 Electrical Output by Using Magnetic Attraction

In this case magnet is attached on every blade of the rotor. When this blade with magnet come closer to a magnetic switch, the switch closes the circuit .Thus electricity flows in the circuit from an external source.

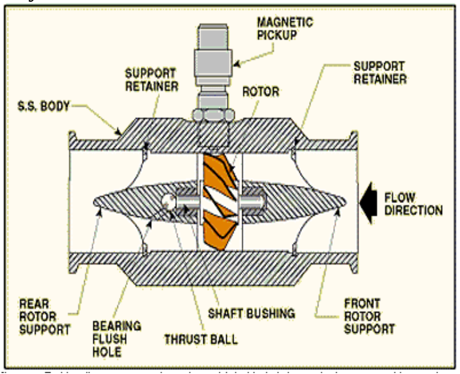


Figure 2.5.3.1: Signal output by using the principle of reluctance

2.6 Calibration of a Turbine Flow Meter:

Turbine flow meter will be required to calibrate either to check its calibration or to determine its range of flow rates .The main objectives of this calibration process is to obtain data in order to prepare a calibration curve for a specified turbine flow meter. This can be done by direct measuring techniques.

The flow rate of a non-volatile liquid like water may be measured by a direct –weighing technique.

Water or any liquid is to flow through the pipe. Turbine flow meter will be fitted in the pipe. After passing the pipe, water will be collect from the other end of pipe by a bucket. The weight of the water passed will be measured by the bucket and the time will be measured by a stop watch. Dividing the volume of water by time we get the flow rate. During this operation the rotation of turbine is obtained from the signal output. The whole is done repeatedly. Then a curve **flow rate vs. Rpm** will be plotted.

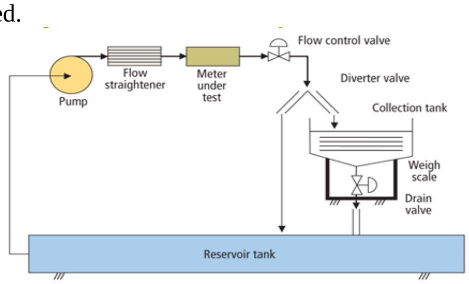


Fig: 2.6.1: calibration of turbine flow meter

2.7 Accuracy:

The accuracy of a turbine flow meter is derived from its output (electrical or mechanical) and is the measure of the deviation of an indicated measurement from the referenced standard. Turbine meter accuracy is dependent upon several items. The accuracy must include the error associated with the calibration standard. In the USA, the National Institute of Standards and Technology represents the flow standard. Linearity is the variation of the flow meter K-factor from a nominal value of a point on a curve. Normally during calibration, a value is chosen which makes linearity fall in line with accuracy. Linearity may remain constant during meter life although the absolute accuracy level has changed. Repeatability is the ability of a turbine flow meter to reproduce its output indefinitely under constant operating conditions at any point over its specified operating range.

2.8 Flow Range:

The minimum flow rate of a turbine flow meter becomes a factor of viscosity versus the degree of accuracy. As product viscosity increases, the minimum flow rate required to maintain a specific degree of accuracy increases. The maximum rate of flow allowable becomes a factor of viscosity versus the pressure drop across the flow meter. As the product viscosity increases, the maximum flow rate decreases in accordance with the maximum allowable pressure drop across the flow meter. In order to arrive at the minimum and maximum rate of flow limits for a particular turbine flow meter size and application these factors must first be determined: · The viscosity of the product to be metered (or maximum value of viscosity for products with varying viscosity's at 37.8B (100BF). · The degree of accuracy required. · The maximum amount of pressure drop allowed across the flow meter.

Operating the flow meter within this flow range will meet the operating requirements unique to that application. Technical bulletins providing area of operation for turbine flow meter sizes with varying viscosity fluids can be obtained from the various meter manufacturers.[6]

2.9 Installation:

The term swirl is used to describe the rotational velocity or tangential velocity component of fluid flow in a pipe or tube. Depending on its degree and direction, swirl will change the angle of attack between the fluid and the turbine rotor blades, causing a different rotor speed at a constant flow rate to non-swirling conditions at the same flow rate. Swirl may be effectively reduced or eliminated through the use of sufficient lengths of straight pipe or a combination of straight pipe and straightening vanes installed upstream of the turbine flow meter.[4]

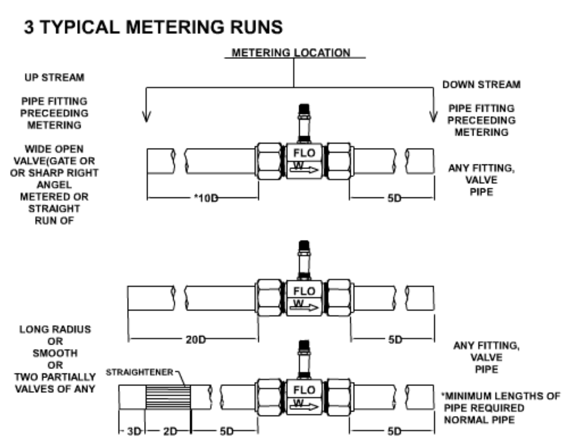


Fig: 2.9.1 typical metering runs

2.10 Applications:

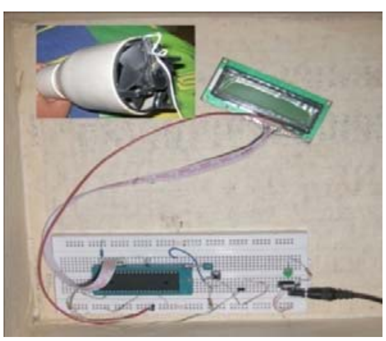
Turbine flow meters, when first introduced, were used mainly by the aircraft industry in small sizes. Turbine flow meters are now used on many applications. Reasons for this increased used are sizes up to 12",weight and size versus flow rate, extended flow ranges, operating pressures up to 10,000 pounds per square inch, temperature range of -450° to 1000°F and a wide variety of construction materials including stainless steels. In recent years, turbine flow meters have been competing successfully with positive displacement flow meters in many applications due to the economy of installation, low maintenance costs, weight, size and high flow rates per comparable connection size. One must exercise caution when making this comparison, especially on viscous products. Following the parameters outlined previously will prevent most misapplications of the turbine flow meter. When products are used in which viscosity changes with seasonal temperature, a proving run should be done at a time when the product temperature would be changing. For instance, fuel oil may change 50°F in ambient temperature between summer and winter. A change of this magnitude would affect the flow meter curve and directly affect the flow range. Increased expertise with electronics such as linearization is permitting turbine flow meters to be used more widely.[4]

Typical application of turbine flow meters

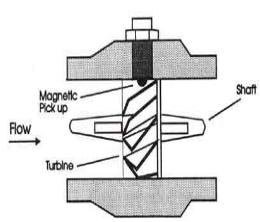
1. Superheated steam measurement.
2. Liquid flow metering, particularly fluids with lubricating properties. As with all liquids care must be taken to remove air and gases prior to them being metered.

3. WORKING PRINCIPLE:

3.1 Turbine Flow meter which uses The Signal Output by Using Magnetic Attraction:



Fig; 3.1.1 Turbine flow meter



Fig; 3.1.1 Schematic diagram of a turbine flow meter

Water flows through this system, the rotor inside the tube rotate. The rotor has five blades and two blade has magnet attached on its surface. When any blade of rotor comes closer to the reed switch, then the blade closes the switch and the switch closes the circuit. As a result electricity flows in the circuit. The circuit is connected to a external circuit .so when the rotor closes the switch; a voltage pulse goes to the external circuit. So from the pulse counted by the micro controller we can easily find the rpm of rotor. Fluid flow is directly proportional to the rotor rpm. So by counting the rotor rpm we can find the fluid flow.

3.2 Circuit Diagram:

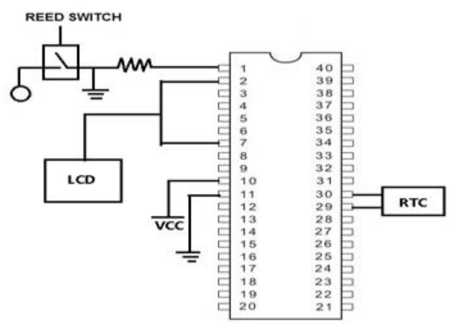


Fig 3.3.1: Circuit diagram

3.4 Block Diagram:

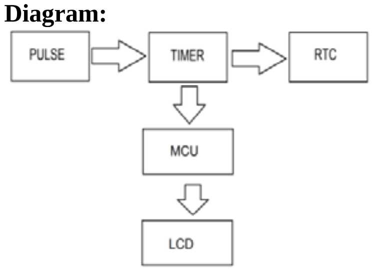


Fig 3.4.1: BLOCK DIAGRAM of the system

4. WORKING PROCEDURE:

1. At first we took a PVC pipe of suitable dia and length. The pipe we use is of 10.5 inch length and 3 inch dia.
2. Then we took a rotor of five blade. We found that the outer dia of the rotor is greater than the inner dia of the tube. So we increase the inner dia meter of the pipe by heating it.

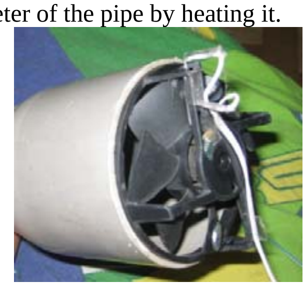


Fig 3.4.2: rotor inside the tube

3. After making the pipe equal to the rotor. The rotor is attached to the pipe.

4. Magnet is attached to the two blade of the rotor. We have to be careful about the balancing of the rotor.

Fig 3.4.3 rotor with magnet and reed switch inside the tube

5. For the purpose of leak proofing we use thread tape.
6. Reed switch is placed in the frame of the rotor. So that it can be operate by the magnet attached to the blade.
7. External circuit is made using a project board, micro-controller, zip socket, led display, wire.

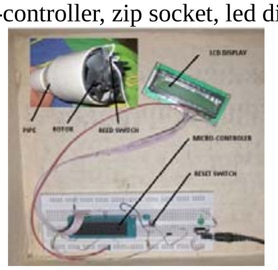


Fig 3.4.4: external circuit micro-controller unit

5. EXPERIMENTAL DATA:

5.1 Data Table (Before Calibration)

Data taken for one liter of water passed through the turbine flow meter

No of observation	Time	Number of pulse (p)	Number of revulation(n) N=p/2	Average revulation
1.	2	26	13	14.5
2.	2	28	14	
3.	2	30	15	
4.	2	28	14	
5.	2	29	14.5	
6.	2	31	15.5	
7.	2	27	13.5	
8.	2	32	16	
9.	2	29	14.5	
10.	2	26	13	
11.	2	31	15.5	
12.	2	28	14	
13.	2	31	15.5	
14.	2	29	14.5	
15.	2	30	15	

5.1.1 GRAPH FOR PULSE vs. OBSERVATION:

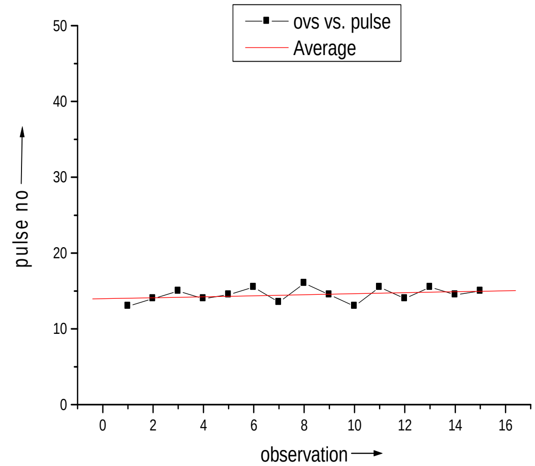


Fig 5.1.1: graph for pulse vs. Observation

5.2 Data Table (After Calibration):

Data taken for one liter of water passed through the turbine flow meter

No of obs	Volume flow (v)	Avg volume flow	Revolution (n)	Avg revolution	% of error
1.	.82	0.9684	12	13.6	18
2.	1		14		0
3.	1.137		16		13.7
4.	.965		14		3.5
5.	.793		11		20.7
6.	1.103		14		10.3
7.	.896		13		10.4
8.	1		14		0
9.	.965		14		3.5
10.	1.137		16		13.7
11.	.931		13		6.9
12.	.827		12		17.3
13.	.862		12		13.8
14.	1.1		16		10
15.	1.068		13		6.8

5.2.1 VOLUME FLOW VS. REVOLUTION:

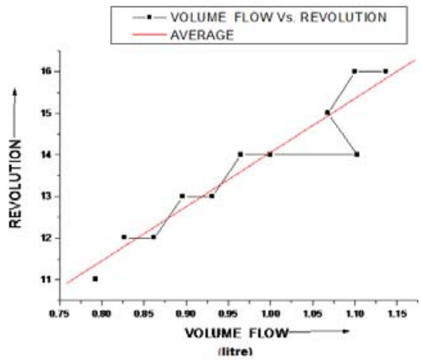


Fig 5.2.1: volume flow vs. Revolution

5.2.2 VOLUME FLOW VS. % OF ERROR:

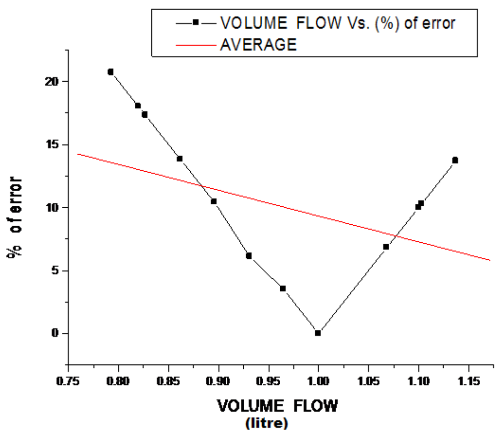


Fig 5.2.2: volume flow vs. % of error

5.2.3 REVOLUTION VS. % OF ERROR:

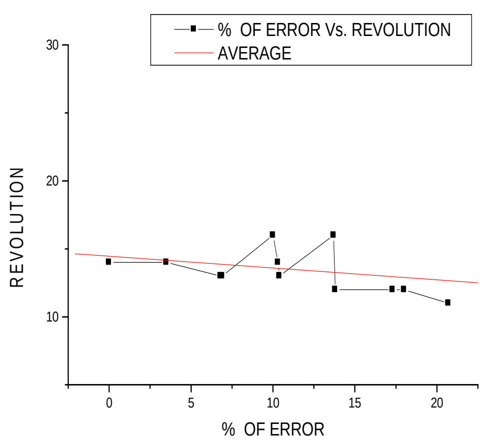


Fig 5.2.3: revolution vs. % of error

6. DISCUSSION:

A turbine flow meter is basically a device which is used to measure any kind of fluid flow

In our project we used a rotor to rotate under fluid flow and measure the revolution of the rotor to measure the flown volume of the fluid. By observing the data and result it is clear that this device can measure fluid flow. In such a way our objectives are fulfilled. This turbine flow meter can measure fluid flow between wide ranges of flow. Using this meter we can measure total volume flown, discharge, and number of revolution of the turbine rotor.

7. CONCLUSION:

In this project a turbine flow meter was fabricated and calibrated. The flow meter was calibrated by passing a known volume of water (1 liter of water) through it, and the elapsed time was measures. Dividing the volume flow by the time gives the discharge rate. The flow rate vs. revolution (of the turbine blade) curve was plotted. Then the performance of the flow meter was tested by passing a known volume of water through it. And taking the reading both manually (bucket and stopwatch method) and from the flow meter display readout. Then the % of error vs. volume flow curve was plotted.

8. REFERENCE:

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