PERFORMANCE OF MULTIPATH ULTRASONIC FLOWMETER IN LIQUID MEDIUM

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ABSTRACT:

Ultrasonic flowmeters have gained popularity in recent years and have become the standard for large volume custody transfer applications. Flow calibration is needed to ensure meter performance and estimate overall measurement uncertainty. Transit time difference type ultrasonic flowmeters are used to measure liquid products where reliable performance is critical.

Commercially available 4 inch, 6inch and 8-inch multi path flow meter have been tested at Water and Oil Flow Facilities at Fluid Control Research Institute to assess baseline accuracy and repeatability over a range of flowrates. Three flowmeters were calibrated with sufficient upstream and downstream straight runs with flow straightener.The flowmeter were subjected to endurance tests at nominal flow for 100 hrs. Calibration checks were carried out before and after the endurance tests. The performance of test meter were analysed for flow disturbance created by presence of dual bends at upstream piping configurations in water medium. The multipath ultrasonic flowmeters tested showed accuracies to within ±0.15% with repeatability better than 0.05% for flow velocities above 1m/s in both water and oil media .

KEYWORDS:

Multipath ultrasonic flowmeter, SOS, Profile factor, Endurance, Flow Disturbance.

1.0 INTRODUCTION:

The primary function of the ultrasonic meter is to measure the actual volume flow rate. The commercially available model is a four path (eight transducers), in line ultrasonic flowmeter that measures transit time of ultrasonic pulses passing through the liquid on four parallel planes. Each of four paths has two integrally mounted ultrasonic transducer that acts alternatively as receiver and transmitter. The difference in transit times of downstream direct pulses and upstream direct pulses are proportional to measured velocity.

This paper discusses the performance of commercially available four path ultrasonic flowmeter and its diagnostics features which was calibrated at fluid flow facilities of FCRI.

The flow test was conducted at Water Flow Laboratory of FCRI (Fluid Control Research Institute)using static weighing method, as also known as gravimetric method in accordance with ISO 4185 .The test facility comprise of different sized calibration lines (from 15mm to 900mm).Each line is equipped with an appropriate flow diverting device and weighing machine. The diverting device represents a highly accurate component part whose function is to direct the liquid flow, alternatively, either to the weighing tank or to the storage tank without disturbing the flowrate through the flow meter under calibration.

2.0 FLOW METER DESIGN AND INSTALLATION:

Multipath Ultrasonic flowmeters comprise a spool piece housing the ultrasonic transducers which measure the velocity across four paths or chords arranged crosswise. Each chord has two transducers which serve alternately as transmitter and receiver to measure the transit time with and against the direction of flow. This permits determination of the mean velocity across the chord and the velocity of sound for diagnostic purposes.

The associated electronics consists of a drive unit and a flow computer. The drive unit determines the transit times and the flow computer calculates the volumetric flow rate from the chord mean velocities in conjunction with appropriate weighting factors and the dimensions of the spool piece.

Before installation of test meter, all metering components are inspected at the laboratory. The upstream and a downstream straight run with flow conditioner was supplied along with MUT. Meter run piping was also inspected for internal dimensions and damages (if any) during transportation. The installation of MUT begins with the upstream pipe with flow conditioner and next sequential downstream component as per meter run schematic diagram. The installation of flow conditioner shall be done in accordance with manufacturer procedure.

3.0 EXPERIMENTAL SET UP:

The calibration of Flowmeter was conducted at Water Flow Laboratory of Fluid Control Research Institute (FCRI), Palakkad, Kerala. The Water Flow Facility is devoted for the calibration / testing of flowmeters for the size up to 900mm and max. flow of 4500 m^3/h @3 bar pressure as shown in Figure 1. The Flowmeter to be calibrated was installed in a pipeline through which water is pumped from a sump having capacity of $320m^3$. As mentioned earlier, the laboratory consists of different pipe lines, in which the calibration flow can be diverted to any one of the three weighing systems.

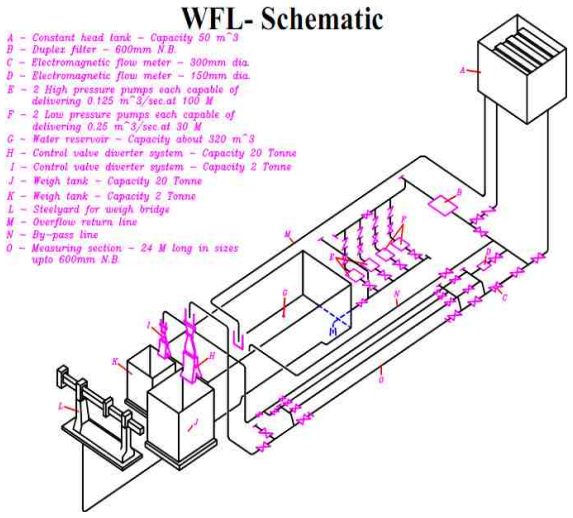

Fig.1 – Schematic of Water Flow Laboratory

The discharge is controlled by the valve placed at the downstream end of test section, immediately upstream of the flow diverter. A diverter down-stream of the test section enables the flow from the flowmeter to be directed either to the sump or diverted to a tank of sufficient water collecting capacity, attached to a very accurate weighing system. At the commencement of a calibration run, the flow from the flowmeter is directed to the sump. When the flow has stabilized, the diverter is activated to direct the water into the tank. When the mass of water in tank reaches a pre-determined level, diverter is activated again, causing water to return to the sump. Simultaneously, the time is measured by photo sensor which is attached to the diverter. The lab is also equipped by universal counters for generating pulses from the flowmeter, average current output at the time of run acquired through Data Acquisition Software and online density of the fluids measured through density meter.

From above data, the mass of the water collected in the weighing tank is converted into volume. The volume, together with the collection time, gives the average flowrates during the calibration run. This procedure is repeated for different flowrates.

A similar procedure was repeated for other flowmeters for verifying the accuracy at ideal and disturbed conditions.

4.0 INITIAL DIAGONISTICS:

The flowmeter configurations are checked initially before the commencement of calibration. The meter configuration includes factors, meter dimensions, chord lengths, communication parameters etc. Once parameters are programmed, the signals are verified. After verification, the minimum operating flowrange is allowed to pass through the flowmeter. During the minimum flow range, meter performance areverified. The flowmeters are corrected for velocity of sound per path, profile, gain levels and signals are all verified. This ensures the flowmeters are functioning healthy prior to calibration. The downstream valve is closed and zero verification test is performed. At zeroing process, the log files are recorded using software, analog output reading at zero flow is averaged and noted in order to avoid bais which may lead to skew calibration results.

After zeroing, the meter is subjected to different flowrates provided by the customer on the pre-calibration checklist. The calibration begins with nominal flowrates. The MUT is allowed to stabilize and flowmeters are checked for accuracy. The output pulse, flow indicated and output current averaged from data acquisition module are noted. At the same time, second system is used by the manufacturer software to acquire logged data for meter diagonistic. These diagnostic information are typically related to various ratios of the meters multiple velocity paths to each other. The most fundamental element of meter performance is determination of transit times. The determination of ultrasonic signals are used for transit time measurement. Pre-checks are made as part of signal detection such as signal to noise ratio, standard deviations of transit times, signal quality between transmitted and receiving signals, signals between upstream and downstream signals, etc. Pre-checks are done for all the above cases.

Along with pre -check of signals, meter dynamic performances are also evaluated. These information include transducer gains, speed of sound, velocity profile, profile factor, flow symmetry, comparisons of chordal velocity. The diagnostics are based on the chordal geometry of the flowmeter.

5.0 FLOW LOOP CALIBRATION

In order to analyse the performance of ultrasonic flowmeter in water medium, experiments are conducted at zero flow and under flowing conditions. The experiments were conducted on commercially available 100mm, 150mm and 200mm multipath ultrasonic flowmeter. A flow conditioner was installed at 8D upstream of the meter under test.

All calibrations consist of six flowrates with five repeated points at each flowrates. The flow velocities were ranging from 1m/s to 12m/s. These flowrates were measured by flying start and stop gravimetric method of Water Flow Laboratory. The same test section which includes test meter and straight runs including flow straightener was also installed in Oil Flow Calibration Facility. The layout of loop for this calibration is shown in Figure 2.

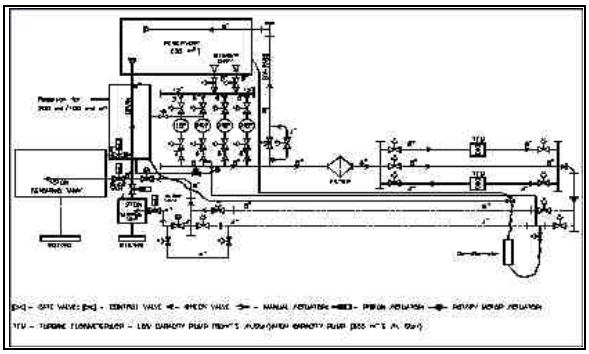

Fig.2 – Schematic of Oil Flow Laboratory

The sequence of experiments was :

1. Accuracy test at ideal conditions at Water Flow Calibration Facility.
2. Repeatability before endurance test.
3. Accuracy test at ideal conditions at Oil Flow Calibration Facility.
4. Repeatability test in Oil Medium.
5. Endurance test.
6. Accuracy test after endurance.
7. Repeatability after endurance test.

The following data were logged during calibration for each meter:

1. Chord SOS and average SOS for ultrasonic flowmeter
2. Profile factor
3. Average flow rate obtained from analog output.
4. Pulse factor.

Profile factor, symmetry cross flow are basic methods of analyzing the flow characterisation. This reflects shape in basic velocity profile. These are defined as:
Profile factor is a dimensionless ratio of inner chord to outer chord velocities.
Symmetry is a dimensionless measure which compares the flow symmetry of upper chord to lower chord.
Cross Flow is a dimensionless measure of flow symmetry comparing the chords on one side of the meter to chords on the other side.

As a typical case, 8" ultrasonic flowmeter was initially calibrated at ideal conditions with flow conditioner. The profile was logged at different flow velocities. The diagnostic parameters can be monitored to indicate any changes in meter performance.

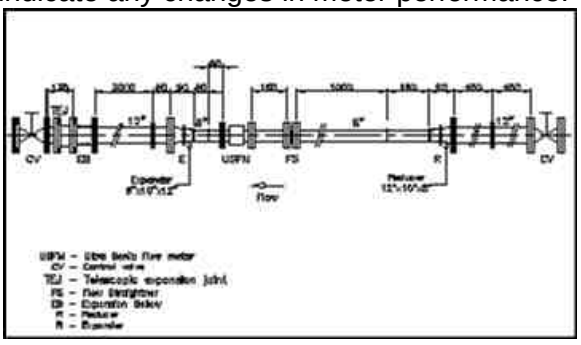

Fig.3 Schematic of test set up

The diagnostic data collected initially suggest that profile is developed and symmetrical. These are directly available from the meter output. The graphical representation below shows an ideal profile at 5.6m/s chordal velocity.

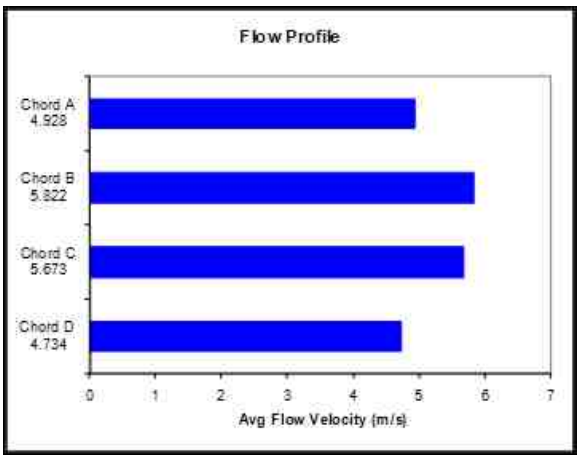

Fig.4 Chord velocity @ 5.6 m/s

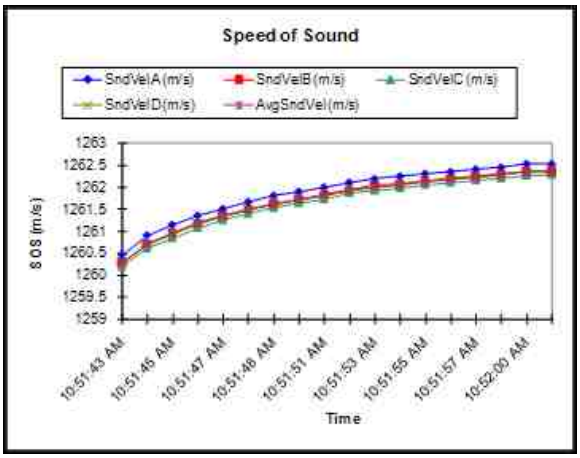

Fig.5 Speed of sound

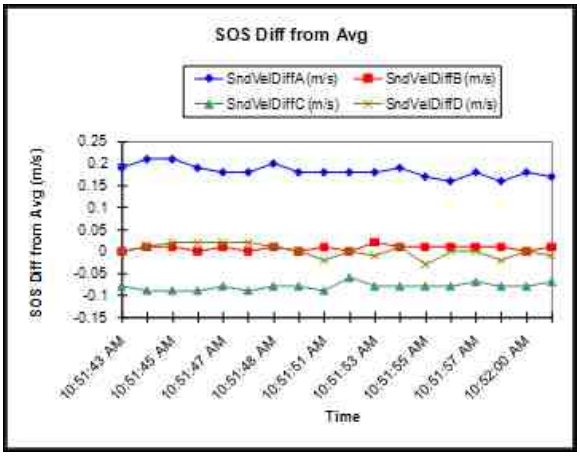

Fig.6 Deviation of SOS from Average

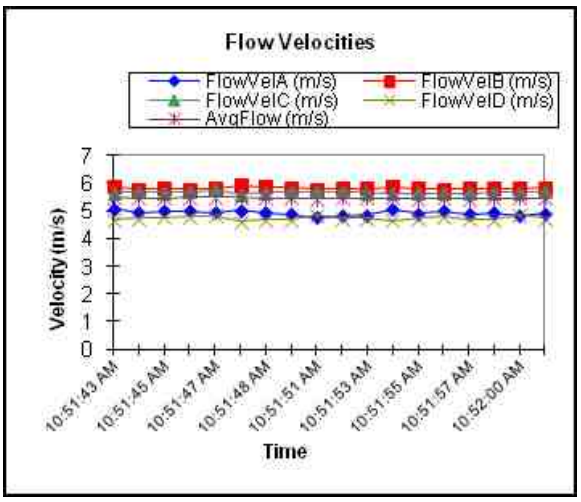

Fig.7 Comparison of chord flow velocities

The flowmeter was calibrated from 1m/s to 12m/s. The accuracy was checked at different velocities and repeatability of the meter was also estimated as shown in Table 1 and is plotted in Figure 8.

Flow rate (m3/h)	Velocity m/s	Error (%)	Repeatability (%)
1409.69	12.22	0.030	0.010
1152.67	9.99	-0.033	0.014
913.50	7.92	-0.022	0.013
670.30	5.81	-0.028	0.009
405.00	3.51	-0.026	0.007
145.35	1.26	-0.012	0.005

Table.1 - 8" ultrasonic flowmeter @Water Flow Laboratory before endurance test

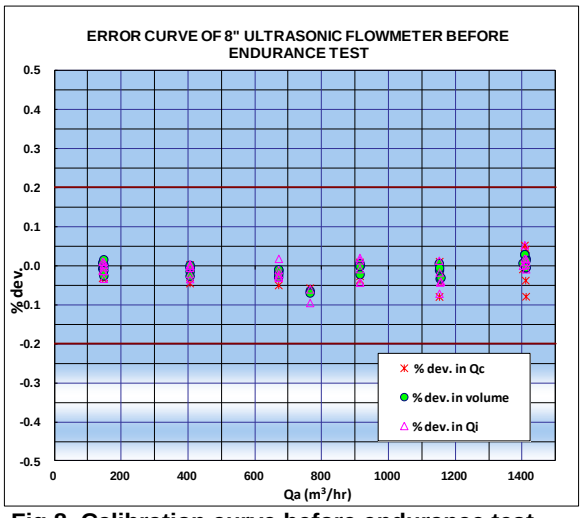

Fig.8. Calibration curve before endurance test

The accuracy of flowmeter was also verified at different medium as a part of OIML 117.The flowmeter was calibrated in oil medium and checked for repeatability. Due to system limitation, 8" flowmeter was checked at low velocities. The accuracy was found within ±0.2% as specified by manufacturer.

ENDURANCE TEST

An endurance test was conducted on the flowmeter after accuracy test in both mediums. The meter was allowed to run for a cumulative period for 100 hrs at nominal flowrate. The flowmeter was again subjected to accuracy test after endurance test run. The results are shown in Table 2 and is plotted in Figure 9.The linearity obtained after endurance test was verified and found within the acceptable limits of ±0.2%.

Flow rate (m3/h)	Velocity m/s	Error (%)	Repeatability (%)
1398.05	12.12	-0.034	0.010
1159.06	10.05	-0.021	0.005
905.67	7.85	0.032	0.013
646.63	5.60	-0.036	0.004
402.25	3.49	-0.061	0.011
148.35	1.29	0.038	0.003

Table.2 - 8" ultrasonic flowmeter @Water Flow Laboratory after endurance test

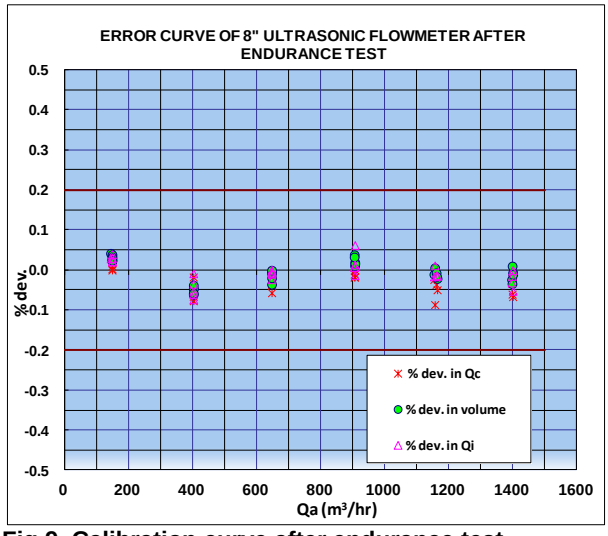

Fig.9. Calibration curve after endurance test

DISTURBED FLOW CONFIGURATIONS:

The disturbance in test loop was created at upstream side of test section with two bends installed in the same plane. The schematic layout of loop is shown below.

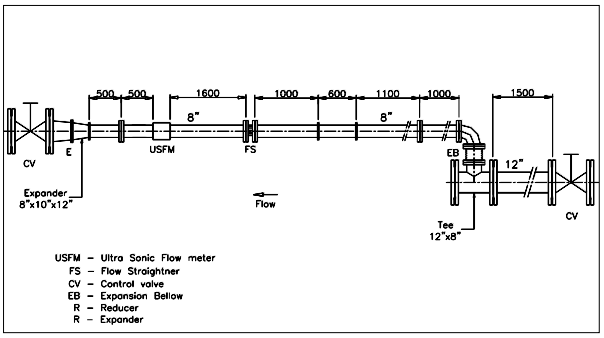

Fig.10. Schematic of test set up for disturbance test

The test on the ultrasonic flowmeter with dual bends at upstream side of the test section with flow conditioner gave generally consistent results. The % error with respect to flowrate was well within limits specified by the manufacturer as shown in Fig.11. This suggest that flow conditioner has ability to reduce measurement deviations due to flow perturbations.

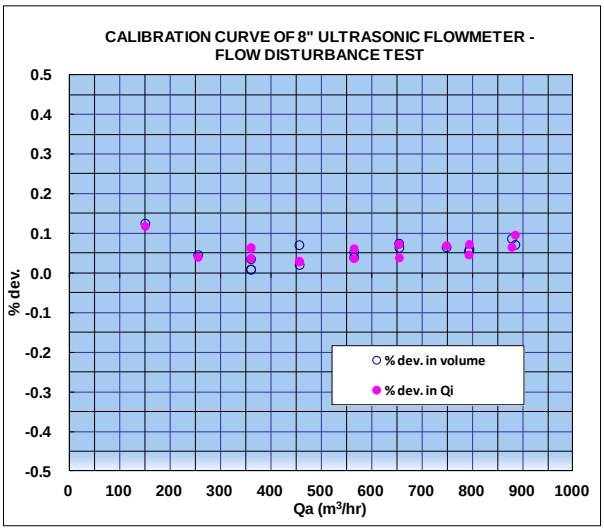

Fig.11. Calibration curve with flow disturbance test.

Similar series of tests were conducted for 4” and 6” multipath ultrasonic flowmeters to verify the performance in liquid medium. The calibration curves are plotted in Fig. 12 and Fig.13.

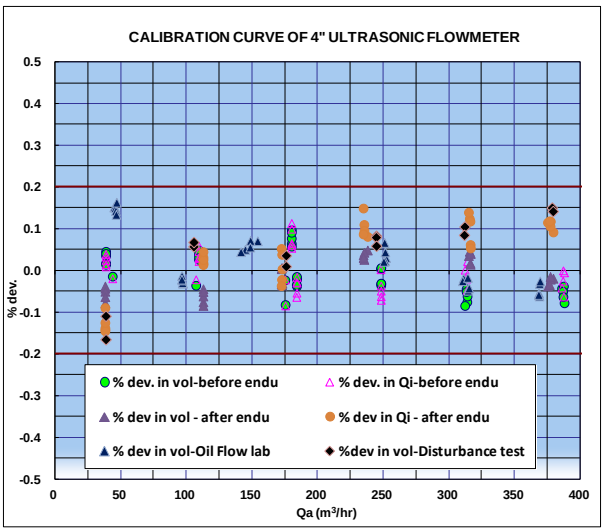

Fig.12. Calibration curve of 4” ultrasonic flowmeter

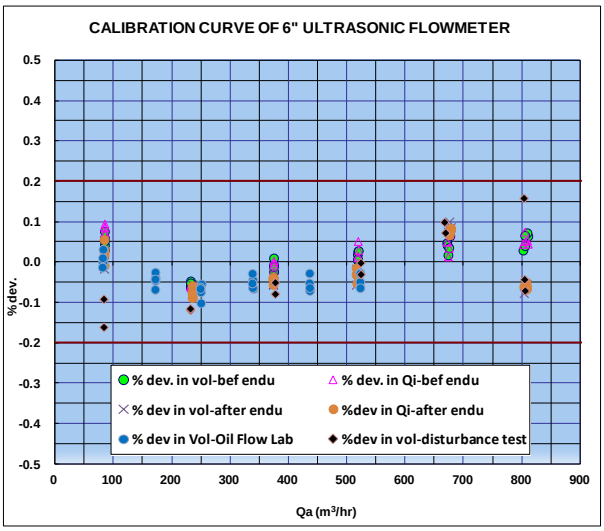

Fig.13. Calibration curve of 6” ultrasonic flowmeter

6.0 RESULTS AND CONCLUSION:

The calibration of multipath ultrasonic flowmeter was undertaken at Water Flow and Oil Flow Facilities at Fluid Control Research Institute, Kerala. In addition to correcting the meter bias, calibration facility also provides data logging of critical diagnostic information related to baseline performance of flowmeter were also performed to identify errors.

A series of tests were performed for 4”, 6” and 8” multipath ultrasonic flow meters from 1 m/s to 12 m/s. Accuracy test was performed before and after the endurance test followed by verification at disturbed piping configuration. Since the test was performed

for commercial purpose, all calibrations was performed with straight runs and flow conditioner provided by manufacturer.

The accuracy results before endurance test was found within the manufacturer specification of ±0.15%. Repeatability obtained during the test was also within specified limit of ±0.02%.

The test meter was undergone endurance run for 100hrs cumulatively at nominal flowrate. An accuracy test was conducted immediately after endurance test to verify the meter accuracy. The meter was well within the limits value of ± 0.20% specified by manufacturer. The test was also conducted on disturbed piping configuration at upstream side by installing two double bends in same plane. The accuracy of meter was found satisfactory and within the specified limits.

In addition to these results, it is recommended that maximum possible additional upstream and downstream straight lengths be provided apart from the straight lengths specified by the manufacturer. As per data available, the impacts of straight lengths are not completely evaluated.

The flow meter along with the required piping needs calibration for each installation. Once the flowmeter or the associated piping is removed from the test line, zeroing of flowmeter, initial diagnostics and re-calibration are advisable to confirm the meter performance.

ACKNOWLEDGEMENT:

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Mr.K.G.Jayesh is a Mechanical Engineering Graduate from University of Calicut, Kerala. He has over 12 years of experience of working in fluid flow laboratory at FCRI.He has played a crucial role in Flow products evaluation at Liquid Flow Laboratory. He is mainly concerned with the calibration of liquid flowmeters, testing of valves and conducting the endurance testing / pattern approval test of flowmeters. In addition, he is also involved in verification of flow products at various sites.

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