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Inter comparison of Flow measurement standards at Fluid Control Research Institute (FCRI), India and Czech Metrology Institute (CMI), Brno.

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ABSTRACT

Uncertainty is the most important quality criterion in any comparison between calibration facilities. The flow calibration facilities are proved beyond doubt by comparing it with similarly placed renowned standards. Any flow calibration system need to prove its accuracy through dynamic traceability. This is ensured by comparing the results of a transfer standard in flow calibration systems with comparable uncertainty values. In this paper the static gravimetric systems with water and oil as flow medium in Fluid Control Research Institute, India is compared with water laboratory of Czech Metrology Institute.

Successful completion of inter laboratory comparison increases the laboratory's confidence in measurement and its International acceptance.

A 3" NB coriolis mass flow meter was used as transfer standard. The mass flow meter was configured for volume flow measurement and its k-factor was determined by the participating laboratories in this program. The participating laboratories were

- Water flow laboratory , Fluid Control Research Institute (FCRI) , India
- Oil flow laboratory, Fluid Control Research Institute (FCRI) , India
- Regional Inspectorate Brno, Department of Primary metrology of flow of liquids, Czech Metrology Institute (CMI), Czech republic

The experiments were conducted at flow rates 30 m^3/hr, 60 m^3/hr, 90 m^3/hr, 120 m^3/hr and 150 m^3/hr. The results of comparison were evaluated by estimating En Numbers for mean k-factors at each flow rate and it was observed that the En numbers were less than one in all cases. The En number estimation was done with the assumption that CMI is the reference laboratory.

The excellent comparison proved once again that the International standards at Fluid Control Research Institute, India is at par with similar International facilities.

KEY WORDS

Coriolis mass flow meter, uncertainty, long term reliability, process capability, meter factor.

INTRODUCTION

Evaluation of calibration results of same item by two or more laboratories in accordance with predetermined conditions is known as Inter laboratory comparison. The inter comparison results are evaluated

by calculating normalized error (En value). The En number (expressed as the "E sub n" number) performance statistics is derived by dividing the difference between the participant's value and the reference value by the square root of the sum of squares (RSS) of the participant laboratory's uncertainty and the reference laboratory's uncertainty.

$$En = \frac{(x - X)}{\sqrt{(U_{lab}^2 + U_{ref}^2}}$$

Where x – result of participant lab
X – result of reference lab
U_{lab} – uncertainty of participant lab
U_{ref} – uncertainty of reference lab

The inter-comparison program explained in this paper was initiated by Fluid Control Research Institute, Kanjikode (west), Palakkad, Kerala with Czech Metrology Institute (CMI), Brno. The artifact used in this comparison is a 3" coriolis mass flow meter. The k factor of the meter was determined at the liquid flow laboratories of FCRI and was compared with the k factor of the same meter determined at Czech Metrology Institute. The results obtained at 100 mm water flow laboratory, 600 mm water flow laboratory and Oil flow laboratory (OFL) of FCRI were also compared each other. The measurement capabilities of participating laboratories and reference lab are given in table 1.

REFERENCE LABORATORY

Czech Metrology Institute (CMI) is chosen as the reference laboratory for this inter comparison program. CMI provides calibration of standards and working devices at the highest quality for customers from all over the country and abroad.

CMI offers its calibration services for all types of industrial companies, laboratories, customers from research and scientific institutions. For all performed calibrations CMI has a unified quality management system that meets the requirements of CSN ENISO/IEC17025.

CMI is (for the Czech Republic) a signatory of international arrangement CIPM MRA, which is based on the mutual recognition of national measurement standards, calibration certificates and results issued by national metrology institutes. In 2006, CMI was accredited as a uniform calibration and testing laboratory - it is the highest accredited calibration laboratory in the Czech Republic.

In this comparison only one meter was used as transfer standard and this may lead to contribution of uncertainties produced by the transfer standard itself. Another inter-comparison program is being organized shortly with a tandem arrangement of transfer standards to have a more precise comparison of results.

PARTICIPATING LABORATORIES

- **Oil Flow Laboratory, Fluid Control Research Institute, India**

The Oil flow laboratory has the capability to calibrate any type of flow meter, but is tailor made to do the calibration of flow meters used for the total volume measurement viz., Positive displacement flow meters, Turbine flow meters, Mass flow meters, etc., which are used to determine the total quantity of fluid. The facility makes use of static gravimetric calibration system for measurement and the calibration is

performed by “Standing start and stop” method.

A schematic of the system in Oil flow lab is given in Fig 1.The source of flow in oil flow laboratory is four pumps with a cumulative flow capacity of 650 m^3/h (2900 GPM). The oil flow laboratory is designed to handle a flow rate of about 650m^3/h at about 3.5 bar (40psi) pressure. The medium of flow is EXXSOL D80, with a kinematic viscosity of 2.06 Centistokes at 25 ^{0}C and a specific gravity of 0.78. The flow determination system consists of three weighing platforms of capacity 10,000 kg, 2000 kg and 300 kg. The system is also capable of determining time of collection of fluid using the signal from ON-OFF valves. The density is determined from an online densitometer. The laboratory is accreditted by National accreditation Board for testing and calibration Laboratories (NABL), as per ISO 17025 for calibration and testing of flow products.

- **100 mm Water flow laboratory, Fluid Control Research Institute, India**

Considering the requirement of a high accuracy set-up for calibrating new generation flow meters and the heavy demand in the existing 600 mm Water Flow Laboratory, an advanced high accuracy water flow laboratory was commissioned especially for sizes upto 100 mm. The Laboratory can accommodate meter sizes upto 100 mm and can achieve a maximum flow rate of 250 m^3/hr.

This is a high precision Laboratory with fully automated operating system with a measurement uncertainty better than 0.04%. The Laboratory works on static gravimetric method as per ISO 4185. The laboratory is accreditted by National accreditation Board for testing and calibration Laboratories (NABL), as per ISO 17025 for calibration and testing of flow products.

The Laboratory has a water sump from where water is pumped to a Constant Head Tank (CHT) using three service pumps of capacities 200 m3/hr 100 m3/hr and 50 m3/hr. The CHT is the flow source for calibration.

- **600 mm Water flow laboratory, Fluid Control Research Institute, India**

The 600 Water Flow Laboratory has specialized test rigs for the precise calibration of flow meters, testing of valves, pipe fittings and other flow products. The whole system is designed to handle a maximum flow rate of 4500 m^3/h through pipeline size up to 600mm. The gravimetric static weighing method as per ISO 4185 is adopted here for the measurement of flow rate. The two weighing tanks are of capacities 2T & 20T. Diverter systems are used to collect water in the weighing tank, for an accurately measured period of time. The mass measurement is by load cells. Direct pumping and CHT are the flow source to the test lines.

Laboratory	Flow medium	Max. flow rate	CMCs
OFL, FCRI	EXXSOL D80	650 m^3/h	0.05%
100 mm WFL, FCRI	Potable water	250 m^3/h	0.05%
600 mm WFL, FCRI	Potable water	250 m^3/h 2500 m^3/h 4500 m^3/h	0.05% 0.1% 0.15
CMI	Potable water	150 m^3/h	0.05%

Table 1. Measurement capabilities of laboratories

DETAILS OF THE ARTIFACT

Flow Element	: Mass Flowmeter
Size	: 3" NB
Make	: Micromotion
Model No. (Sensor)	: CMF300
Sl. No. (Sensor)	: 11020438
Model No. (Trans)	: 2700R11ABFEZZZ
Sl. No. (Transmitter)	: 3737203
Flow Cal. Factor	: 708.754.45
Frequency Factor	: 8000.0 Hz
Rate Factor	: 160.0 m^3/hr
K-Factor	: 180.0 Pulse/litre
Mass Factor	: 1.0000
Volume Factor	: 1.0000
Density Factor	: 1.0000

ILC PROGRAM

Inter - laboratory studies / comparisons are performed with the aim of evaluating the extent of similarity in the results obtained by different laboratories. The ILC program includes organization, performance, and evaluation of calibration / results for the same item/artifact by two or more laboratories in accordance with predetermined conditions.

In this program the parameter chosen for comparison is the k factor of a coriolis mass flow meter. The k factor of the meter determined at FCRI was compared with the k factor of the same artifact determined by CMI. The k factor (pulses / litre) is derived from the measured pulses output of the meter and the actual volume of fluid passed through the meter, which is measured by the gravimetric system in the laboratory. By this method, the capability of the laboratory for measurement of meter output, actual mass of fluid and density of fluid is established. K factor of the meter was determined at five different flow rates. Five measurements were taken at each flow rate and the average k factor at each flow rate was compared with that of CMI.

In FCRI, measurements were carried out in Oil flow laboratory, 100 mm water flow laboratory and 600 mm water flow laboratory. The artifact was sent to Czech Republic for measurement at CMI after completing measurements at FCRI. The k factors determined by the three laboratories of FCRI were separately compared with the results obtained in CMI.

After return of the artifact from CMI, a final measurement was made in the 100 mm laboratory of FCRI to check the reproducibility of the meter as well as the system.

RESULTS OF MEASUREMENT

The measurement results of Oil flow laboratory, 100 mm water flow laboratory and 600 mm water flow laboratory of FCRI is given in Table 2. In order to find the agreement in results between laboratories of FCRI, these results are compared with each other and En values are calculated.

Flow rates m^3/hr	Average K factor (ppl) obtained in different labs			En Values between labs		
	100 mm WFL	600 mm WFL	Oil Flow Lab	100 mm* 600 mm	100 mm* OFL	600 mm* OFL
30	180.0734	180.0536	180.0950	**-0.16**	**0.17**	**0.33**
60	180.0922	180.0374	180.1039	**-0.43**	**0.09**	**0.52**
90	180.0705	180.0349	180.0757	**-0.28**	**0.04**	**0.32**
120	180.0928	180.0325	180.0696	**-0.47**	**-0.18**	**0.29**
150	180.0760	180.0087	180.0571	**-0.53**	**-0.15**	**0.38**

The uncertainty in measurement of all labs is 0.05 %

* Reference lab

Table 2. Comparison of results of measurements carried out at FCRI

After completing the measurements at FCRI the results were sent to NABL for approval. On getting the approval from NABL the artifact were sent to Czech Metrology

Institute and the meter k factors were determined at the same flow rates. The results of CMI and FCRI were compared by calculating the EN values and the comparison results are given in table 3.

Flow rate	K - Factor (pulses per litre)				En Values of labs		
(m3/h)	CMI	FCRI			(FCRI vs CMI)		
	(Ref.)	100mm lab	600mm lab	OFL	100 mm	600 mm	OFL
30.0	**180.131**	180.073	180.054	180.095	-0.45	-0.61	-0.28
60.0	**180.077**	180.092	180.037	180.104	0.12	-0.31	0.21
90.0	**180.077**	180.070	180.035	180.076	-0.05	-0.33	-0.01
120.0	**180.097**	180.093	180.032	180.070	-0.03	-0.51	-0.22
150.0	**180.099**	180.076	180.009	180.057	-0.18	-0.71	-0.33
Uncertainty of FCRI is ± 0.05 % Uncertainty of CMI is ± 0.05 %							

Table 3. En values of three laboratories of FCRI with CMI.

The stated uncertainty is the expanded uncertainty based on a standard uncertainty multiplied by a coverage factor k=2. This provides a level of confidence of approximately 95%. The uncertainty estimate has been carried out in accordance with the methods recommended in international standards (GUM and ISO 5168).

The entire results are compared and visualised in a concise manner in the following graphs.

When the result of FCRI is compared with that of CMI, it is observed that they are very close to each other. The maximum deviation in k factor between CMI and FCRI is 0.05 % in 600 mm water flow laboratory. In case of 100 mm laboratory the maximum deviation observed is only 0.03 % and for Oil flow laboratory it is 0.02 %. The En values at all flow rates are less than one for all the three labs of FCRI, and hence within limits (En<1).

To determine the reproduceability of the system, measurement was again carried out in 100 mm water flow laboratory after receipt of the artifact from CMI Czech Republic. The measurement results in fig 5 shows that the maximum deviation in results between the initial measurement and final measurement conducted in 100 water flow laboratory is only 0.02 %, which is very much less than the claimed uncertainty in measurement (0.05 %).

CONCLUSION

The artifact, a coriolis mass flow meter, was calibrated in water and oil medium in FCRI and at water flow laboratory of CMI. The comparison shows very close agreement between the measurement results of CMI and FCRI. A maximum deviation in results between CMI and FCRI, observed in the entire range of calibration, is only ± 0.05 %. As per the requirement of National Accreditation Board for Testing and Calibration Laboratories (NABL), India the En value of the comparison should be less than one and this work is in agrement with the requirement of NABL.

The tests were conducted in a span of about five months. It is observed that the variation in k factor determined in water flow laboratory in this time period is very low (the highest variation being 0.02 %).

Therefore it may be safely concluded that the water and oil flow laboratories of FCRI is well comparable with International systems and the system reproducibility over a period of time is excellent.

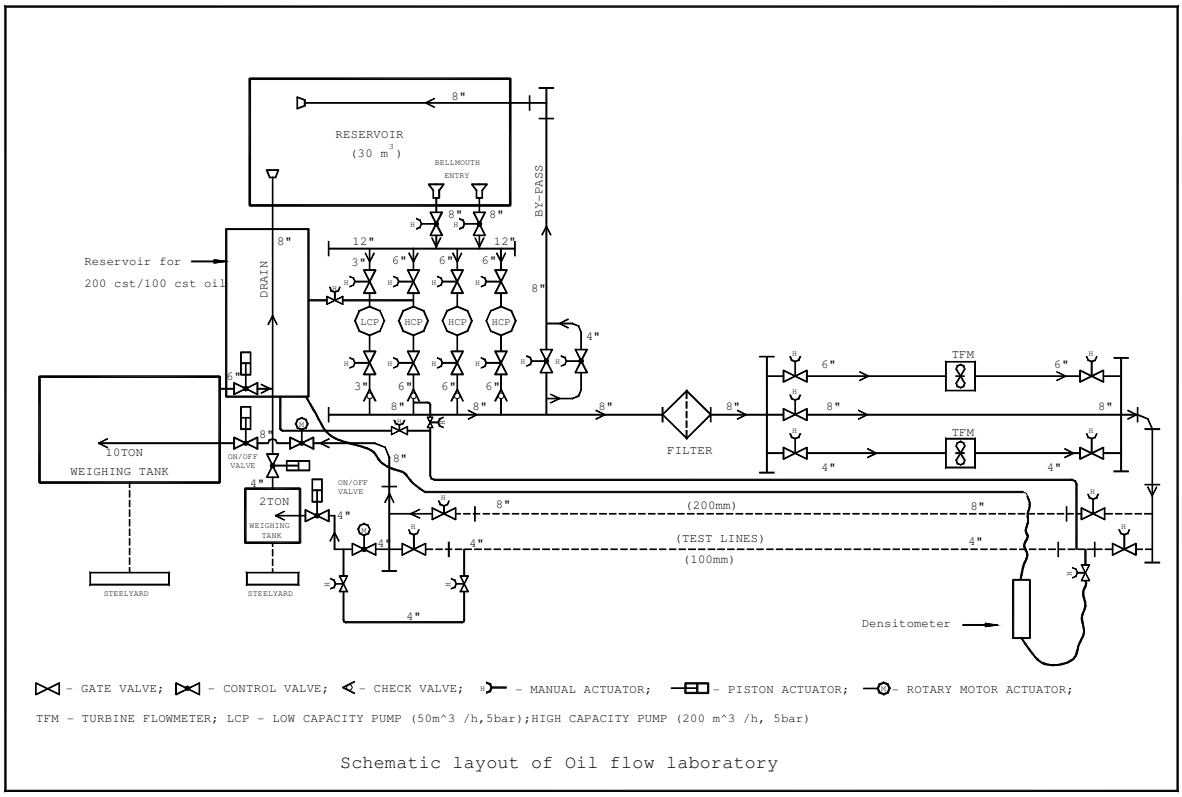

Figure 1. Schematic of the oil flow laboratory of FCRI

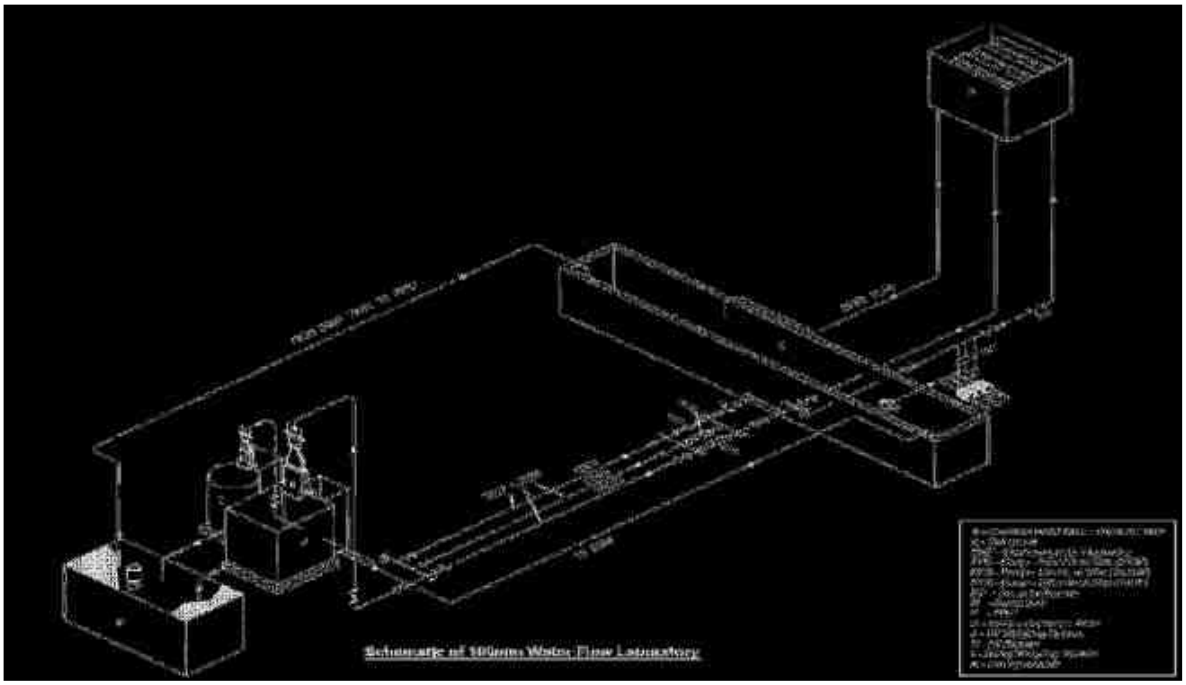

Figure 2. Schematic of water flow laboratory of FCRI.

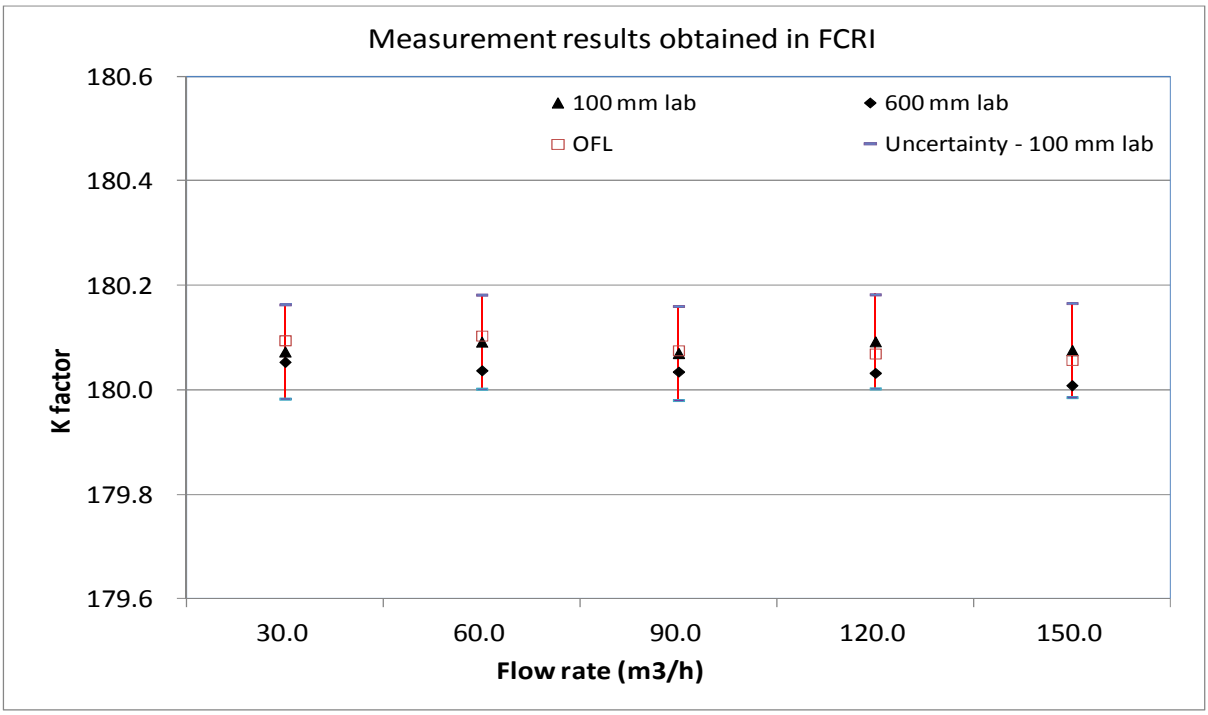

Figure 3. Comparison between results obtained in three laboratories of FCRI.

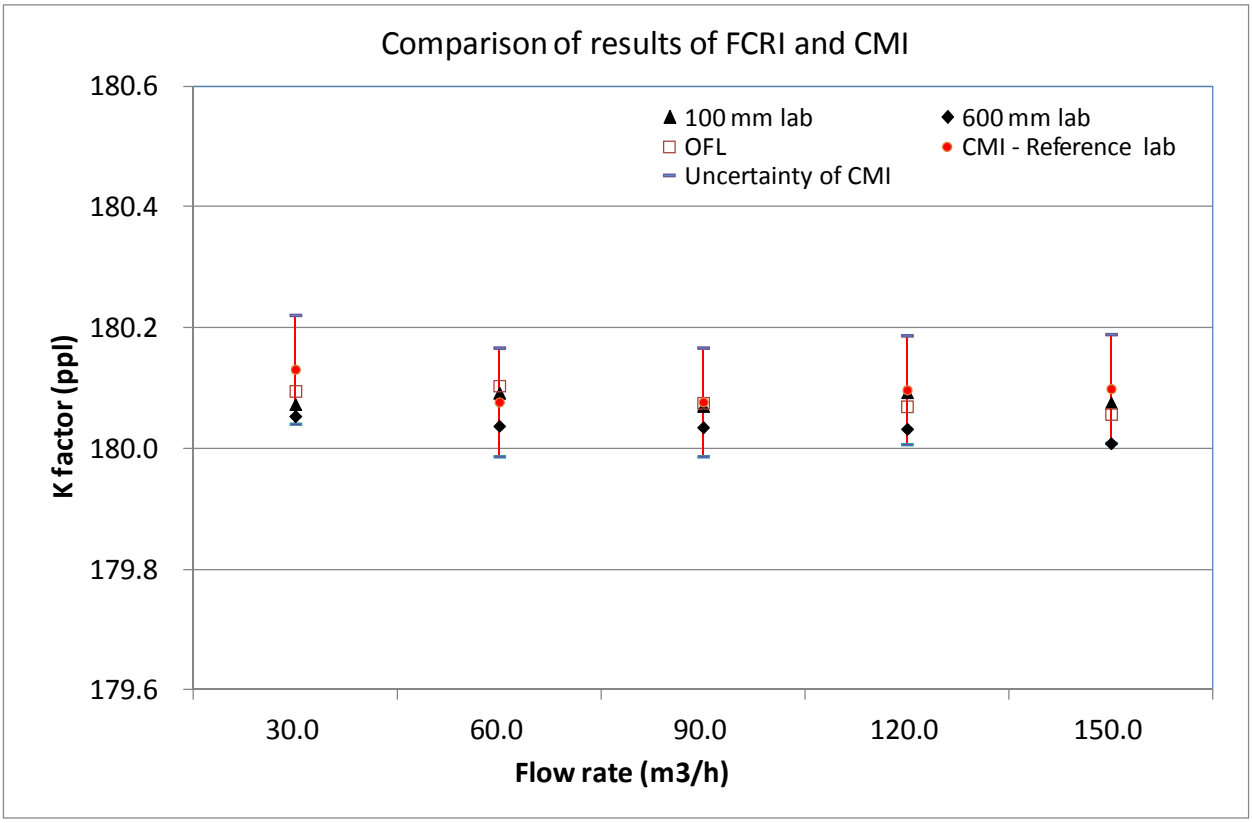

Figure 4. Comparison of results of FCRI with CMI.

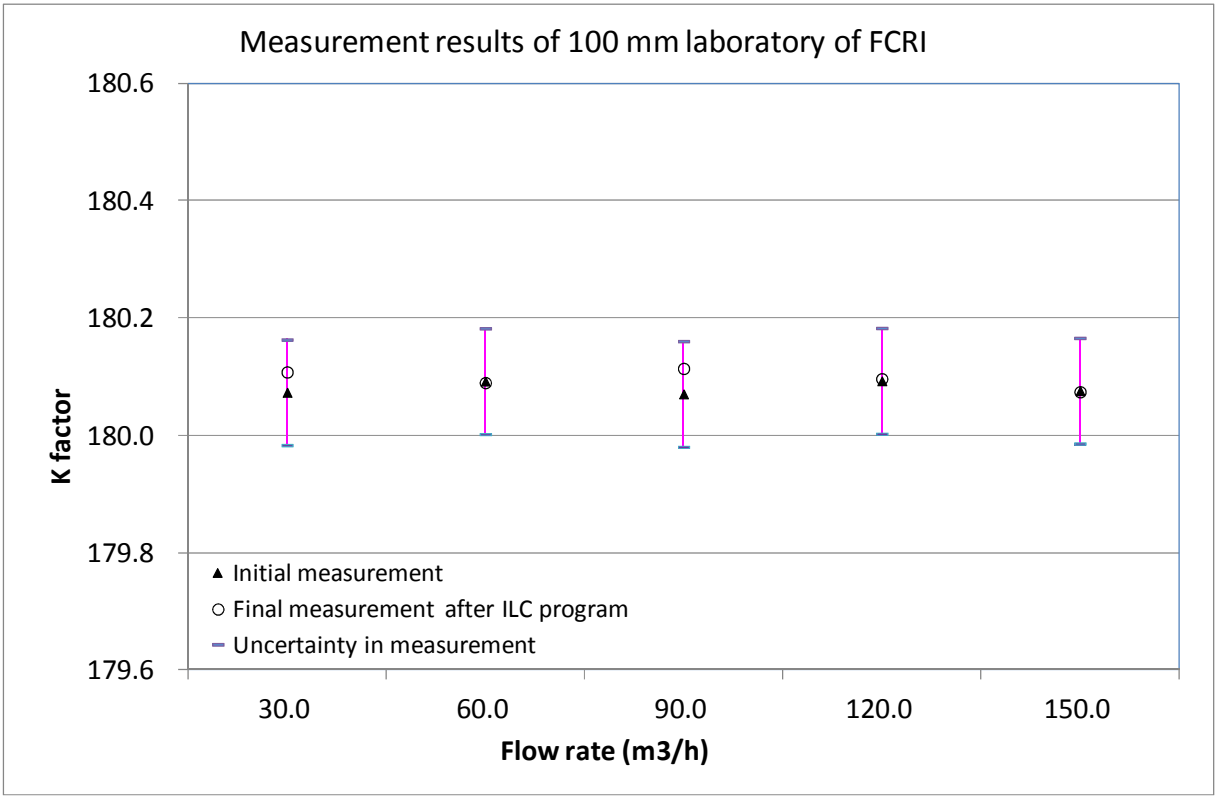

Figure 5. Results of initial measurement and final measurement conducted at 100 labpratory of FCRI.

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Significant Achievements:

- Design, Erection, Fabrication, Commissioning and qualification testing of an Oil Flow Laboratory using Exxsol D80 as flow medium, which is the first of its kind in India. Development of a customer base for the laboratory was actively pursued and established.
- A multiviscous oil test loop was designed and commissioned .
- Design , erection and commissioning of a state of the art 100 mm water flow laboratory which is fully automated
- Responsible for the pattern approval testing conducted on flow meters for legal metrological purpose .
- Responsible for the implementation of ISO9000, ISO 14000 and ISO 17025 in the liquid flow laboratory
- Associated with a variety of projects and well experienced in the costing, scheduling, execution and monitoring of projects
- Design verification of flow metering skids for various organizations including multinationals
- Model approval of more than 30 flow products
- Engineered an Isopropyl Alcohol calibration facility for LPSC
- Engineered special test rigs for Delphi, Liquid controls , GE,etc.
- Design , erection procurement and commissioning of transfer standard facilities for Regional Reference standard laboratories at Ahmedabad and Bhubaneshwar. Bangalore and Faridabad are also underway.
- Design validation and simulation of Pneumo Hydraulic System for missile launching system in submarines for Indian Navy

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