# Flow Tele-Metrology

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## Abstract

*The current paradigm used to deliver flow meter calibration services relies on the operation of in-house calibration facilities for providing metrology infrastructure. This approach has led to the construction and operation of many similar calibration facilities worldwide. The recent emergence and popularity of information technology offers an opportunity to change the way in which metrology services are provided to customers by enabling the use of existing calibration facilities by more than one metrology team.*

*This paper outlines efforts by a government-industry team to develop the first gas flow tele-calibration facility in the world. The program seeks to make use of the high-speed information infrastructure to connect to a privately owned calibration facility in Colorado, to the Fluid Flow Group of the National Institute of Standards and Technology (NIST) in Maryland. The plan calls for modifications to the calibration facility infrastructure that will enable tele-presence of NIST scientists during calibrations at the remote site.*

## 1. Introduction

In recent years, the Fluid Flow Group of the National Institute of Standards and Technology (NIST) has been asked by the U.S. industry to increase the range of the national gas flow standards from their present range ($3.72 \times 10^{-2}$ to $7.76 \times 10^{4}$ standard liters per minute, or slm) [1] to approximately $1.0 \times 10^{8}$ slm. However, the construction of NIST facilities capable of handling such large flows is impractical due to capital and space constraints. A solution to this problem may lie in the small number of secondary metrology laboratories in the U.S. that are capable of calibrating gas flow meters at these large flow rates. Unfortunately, these laboratories have no direct traceability to an U.S. national flow standard, and thus the question becomes how to make results obtained by these secondary metrology facilities our national standards.

Any flow calibration facility used by NIST to realize a national standard undergoes rigorous evaluations that include the following elements. Initially, its performance characteristics are carefully evaluated to assess the total uncertainty of the facility. As part of this evaluation, the metrological environment used for testing meters is carefully studied to assure it provides ideal conditions during testing. Once completed, the assessment is documented and subjected to peer review. Subsequently, the individual sensors used by the facility are kept directly traceable to their corresponding national standard. Finally, for each and every test, NIST metrologists confirm that the procedures stated in the calibration report have been strictly followed during testing. Similarly, calibration facilities at a secondary metrology laboratory would be required to satisfy these elements if they were to be used as national standards. A new experimental concept known as *tele-presence* has the potential to enable calibration facilities anywhere in the U.S. to be operated as NIST national flow standards.

## 2. Approach

NIST has a long tradition of achieving goals by taking advantage of the scientific diversity of its staff and by establishing partnerships with U.S. industry. Following in this tradition, the Fluid Flow Group elicited the support of the Manufacturing Engineering Laboratory (MEL) which is the NIST branch that supports research in areas of machine control using information technology (IT). MEL has placed the resources of their National Advanced Manufacturing Testbed (NAMT, a program established to promote the use of IT for advanced manufacturing) at the disposition of the Fluid Flow Group. The NAMT has provided the Fluid Flow Group with Next-Generation-Internet/Internet II access which has enabled scientists to experiment with these new Internet technologies that are expected to be widely available in the U.S. within the next five years. Additionally, MEL brought to the table expert support in tele-presence, sensor interfacing, and machine control. Using this broad base of talents and resources, NIST commenced its *Tele-Calibration of Gas Flow Meters* (*http://www.nist.gov/tele-cals*) project in May 1998, with the objective of demonstrating the feasibility of using IT to expand NIST's calibration services via tele-presence to U.S. secondary metrology laboratories. The project seeks to remotely annex (via the Internet) primary gas flow calibration facilities located at secondary metrology laboratories to provide a framework for remote calibration, traceability, and accreditation of laboratories.

NIST has been fortunate enough to be joined in this experimental effort by the Colorado Engineering Experimental Station, Inc. (CEESI). The partnership with CEESI has provided NIST with a primary flow calibration facility, of the Pressure-Volume-Temperature-time (PVTt) type, capable of producing flow rates five times larger than those available at NIST. In addition, CEESI has been willing to invest its own resources in the project, and the candidate facility (known as Primary A) shares many operational features with smaller PVTt systems at NIST. This common technology was very attractive given that it will facilitate the execution of the project by allowing in-house development of tele-presence applications at NIST's Maryland campus prior to transfer to CEESI's Colorado facilities.

With CEESI's Primary A selected as the demonstration site, the next item on the agenda was the development of an instrumentation/control/tele-presence architecture for the remote facility. Figure 1 shows the proposed tele-presence architecture, as it would be used in a generic PVTt facility. From left to right in the figure, a compressor is used to supply the gas needed by the calibration test, and a *digital flow control valve* is used to control output of the compressor. Following the digital valve, a long run of pipe (in excess of 100 diameters) helps establish fully developed flow to provide an ideal velocity profile to the meter under test (MUT). Prior to the MUT, a *flow assessment unit* is used to determine the quality of the flow entering the MUT (*i.e.*, velocity profile, pressure, and temperature). From the flow assessment unit, the gas flows through the MUT and is subsequently collected by a *flow determination system* (a PVTt system in Figure 1).

The use of a flow assessment unit to monitor the performance of equipment upstream of MUT constitutes a novel approach. For the Tele-Calibration project, NIST has consulted Daniel Industries for the development of an *advanced ultrasonic flow meter* (AUFM) to serve as part of the flow assessment unit. The AUFM will make use of

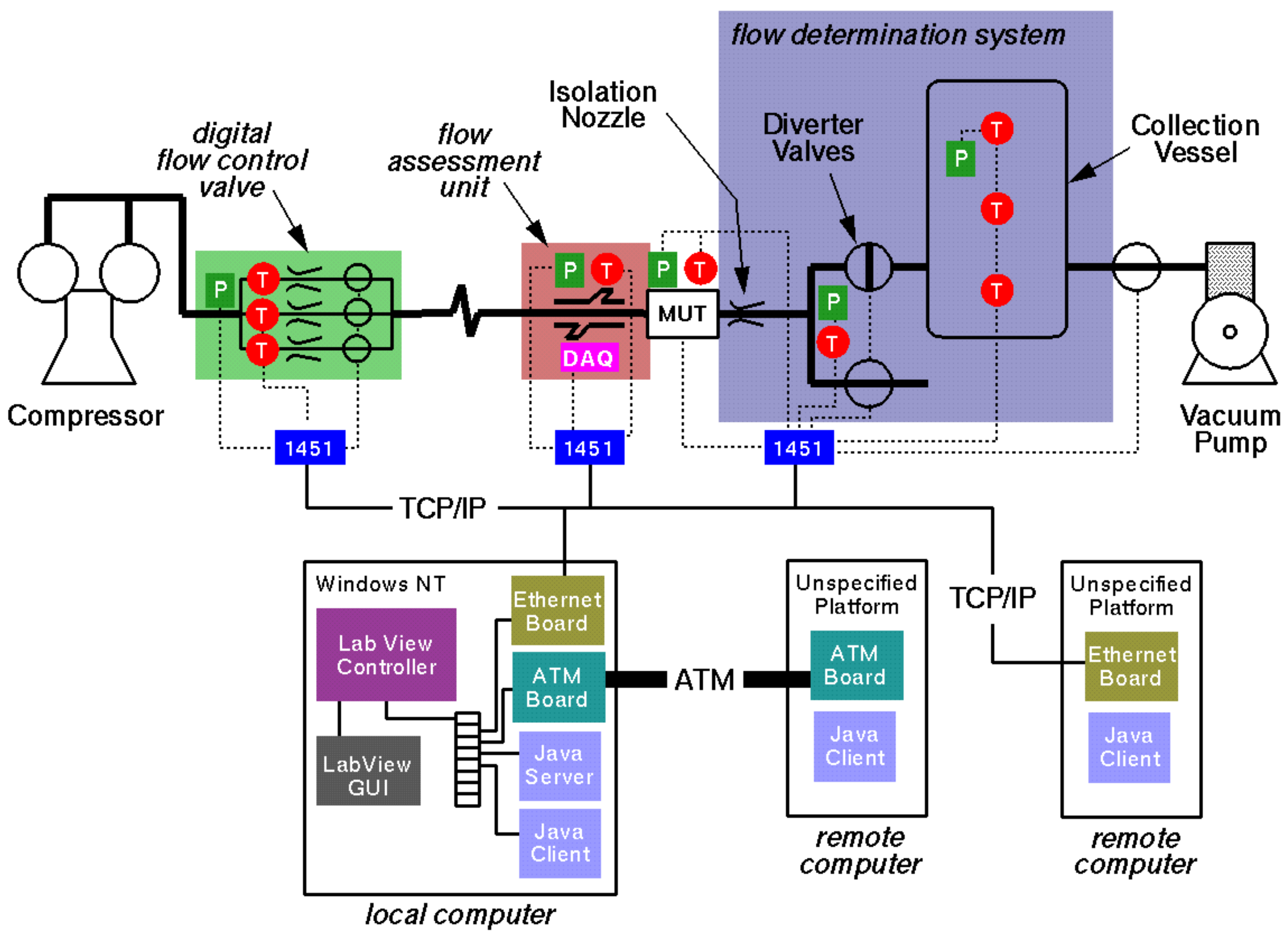


**Figure 1. Tele-presence architecture as implemented in a PVTt calibration facility.**

an eleven-path ultrasonic transducer arrangement (see Figure 2) which was developed by NIST scientists using computer modeling of pipe flow fields and simulations of their corresponding ultrasonic signatures [2]. According to these simulations, the proposed sensor arrangement for the AUFM should have enhanced velocity profile diagnostic capabilities for deviations from non-ideal pipe flows. Interpreting the signals produced by the ultrasonic sensors will be a pattern recognition system capable of classifying the approaching unknown flow among one of a number of typically occurring flows contained in its electronic library. The extensive diagnostic capabilities of the flow assessment unit make it an additional asset to improve the quality of the calibration service provided by remote facilities.

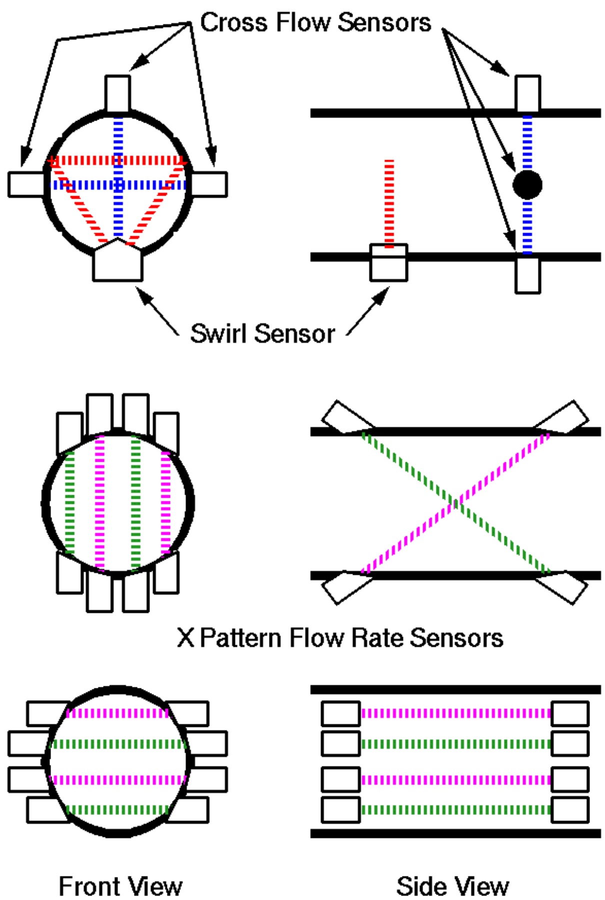


**Figure 2. Schematic diagram of advanced ultrasonic flow meter (elements to be connected in series).**

Controlling the flow calibration facility described above is a distributed-control architecture based on the IEEE Std 1451.2-1997 smart sensor interface [3] (see Figure 1). Delivering control tasks to the IEEE 1451's is the *local computer* that communicates with the IEEE 1451 controllers via an Ethernet board. During processing, the Ethernet board will be accessed by a data acquisition and control (DAC) program that will be in charge of all the high level data-acquisition, control, and task scheduling. The operator will be able to access the DAC program in two different ways: using a vendor provided graphical user interface (GUI), or running a Java® client program in a web browser. The vendor provided GUI would allow the operator to rapidly modify the control program per the requirements of any particular calibration job. The Java client-web browser combination will enable remote access to the flow calibration facility by anyone having a connection to the Internet and a computer running a web browser.

Tele-presence in the flow calibration facility in Figure 1 is possible using two different IT media: today's Internet or tomorrow's Next-Generation-Internet/Internet II. Present day Internet is a *shared* media, which has the disadvantage of stochastic transmission rates that can hinder the real-time control of remote calibration facilities. In contrast, some of the designs being considered for the Next-Generation-Internet/Internet II would render it a *dedicated* media, which has the advantage of deterministic transmission rates thus simplifying the implementation of real-time control architectures.

The point-to-point connectivity provided by dedicated networks has many advantages for tele-presence applications. Real-time data, voice, and video can be simultaneously transmitted over this media thus allowing full immersion in the remote site; real-time remote control of the flow calibrator is possible; and once the connection is established its capacity is guaranteed regardless of the network use. Given its performance characteristics, more industrial applications of dedicated network technology are expected as fiber-optic networks expand throughout the U.S.

## 3. Present Status and Future Plans

The Tele-Calibration project is in its infancy, but work is presently being conducted in many of the subsystems that are needed for implementation of the previously described architecture. In November of 1998, NIST and its partners held a tele-calibration workshop that was attended by a cross-section of the international flow metrology community. NIST, CEESI, Daniel, and the Air Force Metrology Calibration Laboratory provided tele-presence demonstrations, and guests were invited to participate in the effort. As a result, a number of parties have expressed their interest in bringing tele-presence capabilities to their daily operations.

By this fall, the project is scheduled to demonstrate the tele-calibration concept within the NIST campus using the local dedicated fiber-optic network. In the year 2000, the technology will be transferred to CEESI for a cross-country demonstration by the fall of 2001. Meanwhile, other metrology laboratories will be provided with expertise for the implementation of their own tele-presence capabilities. In addition, NIST is actively seeking collaboration in this effort with other national metrology institutes to enhance our international standard comparisons program – so far, the response has been positive.

## 4. Acknowledgements

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## 5. Disclaimer

Identification of specific commercial products is made for technical completeness but does not constitute an endorsement, nor does it indicate that the products are preferred for the application.

## 6. References

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