Summary of Recent GRI MRF Tests Results for the Nova 50E Flow Conditioner

Prepared by Southwest Research Institute

Preface

Test results presented here are specific to the Nova (CPA) 50E flow conditioner, one of several flow conditioners included in the test matrix for the Gas Research Institute (GRI) Metering Research Facility (MRF) ultrasonic flow meter test program for 1999. The test program described below has been performed by Southwest Research Institute (SwRI), with oversight from the Gas Research Institute Measurement Technical Advisor Group (MTAG). All tests were performed at the GRI MRF High Pressure Loop (HPL). The GRI MTAG, with assistance from SwRI staff, selected the piping configurations, operating conditions, flow meters, and flow conditioners used in the test program.

Some of this information has not yet been published and should be held confidential to Canadian Pipeline Accessories until such time that the information is made public, either through publication of a GRI report or through a technical presentation by the GRI or MRF staff. This information will be included in a GRI Topical Report that will be published next year.

Test Flow Meters

Daniel Flow Products, Kongsberg Offshore/FMC, and Instromet Ultrasonic Technologies each provided a 12" diameter, schedule 40 bore (11.938 inch inside diameter) multipath ultrasonic gas flow meter for testing at the GRI MRF. The meters were installed in the Test Section of the MRF High Pressure Loop. All three of the test meters were commercially available in the United States as of the time of the tests. None of the meters had been flow calibrated prior to being tested as part of this program. Table 1 summarizes the test meter configurations.

Manufacturer	Number of Acoustic Paths	Acoustic Path Arrangement
Daniel Flow Products	4	Four parallel, non-reflecting, horizontal paths.
Instromet Ultrasonic Technologies	5	Two mid-radius double-reflecting paths and three centerline single-reflecting paths
Kongsberg Offshore/FMC	6	Four parallel measurement planes. Two of the planes contain two crossed paths. All paths are non-reflective.

Table 1. Test Meter Geometry

MRF Test Piping Configurations

The test plan was designed to experimentally determine the performance of 12-inch diameter ultrasonic meters when installed in various piping configurations and when used in combination with a flow conditioner. Single- and double-elbow combinations placed upstream of the test meters were used to create flow "disturbance elements" typical of those that can occur at field meter sites for natural gas transmission pipelines. The "baseline" test piping configuration placed the test meter 100 pipe diameters downstream of a single 90° elbow. The piping configurations placed upstream of each test meter to provide "disturbance elements" were (1) a single 90° elbow, (2) two 90° elbows, in-plane, with 10 pipe diameters of separation between the elbows, and (3) two 90° elbows, 90° out-of-plane, with 1.4 pipe diameters of separation between the elbows. The 90° elbows were all of the long-radius design. Figure 1 shows isometric views of the test piping installation configurations.

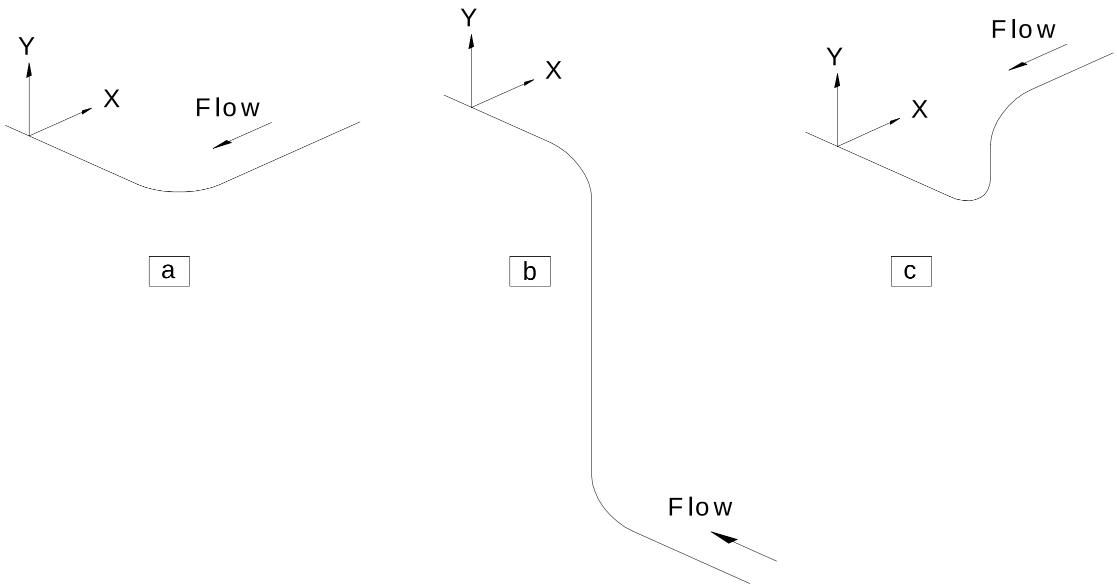


Figure 1. Isometric view of tested upstream piping configurations: (a) a single 90° elbow, (b) two 90° elbows in-plane with 10 pipe diameters of separation between the elbows, (c) two 90° elbows 90° out-of-plane with 1.4 pipe diameters of separation between the elbows.

All test piping spools were fabricated with 12-inch diameter, schedule-40, carbon steel pipe with all internal welds ground smooth. Immediately upstream of the HPL Test Section piping was a 12" diameter Gallagher (Type II) Flow Conditioner followed by 20 diameters of straight 12-inch diameter pipe.

Test Flow Conditioners

The Nova 50E flow conditioner was one of several included in the test matrix. The Nova conditioner was tested at separation distances of 10 and 3 pipe diameters between the conditioner and test flow meter. The 3 diameter separation distance was a special request of the GRI MTAG. Table 2 and Figure 2 summarize the flow conditioner installations.

Each meter was also tested in each piping configuration without a flow conditioner installed. For the tests involving no flow conditioner, each meter was located 10 and 20 pipe diameters downstream of the outlet of the given flow disturbance. For each test piping configuration, each meter was tested at two different rotation angles (0° and 90°) relative to the pipe axis. By rotating each meter, the acoustic paths sampled different portions of the flow field, as they might in different field installations.

Flow Conditioner	Flow Conditioner Length	Total Upstream Length (from disturbance outlet to meter inlet)	Distance from Conditioner Outlet to Meter Inlet
19-tube bundle	2D	20D	10D
Vortab™	3D	20D	17D
Nova 50E	0.15D	15D	10D
Nova 50E	0.15D	10D	3D
GFC™	3.5D	10D	3D

Table 2. Flow Conditioner Test Set-ups

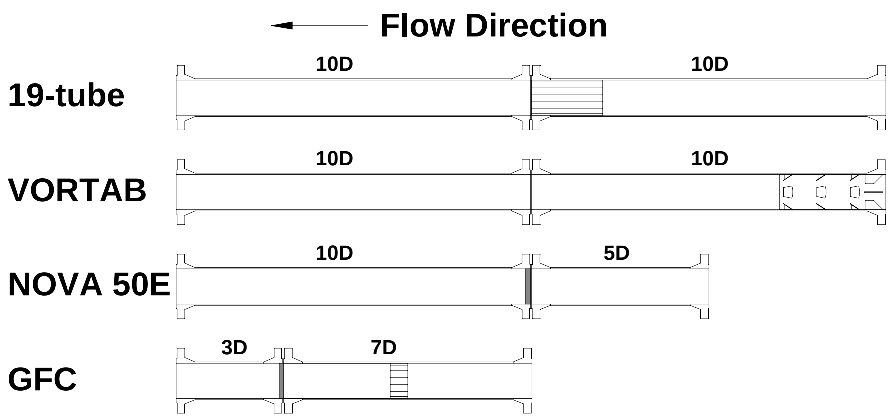


Figure 2. Flow Conditioner Installation Configurations

Flow Test Methodology

The meters were tested with transmission-grade natural gas (i.e., approximately 95% methane gas mixture) furnished by the local utility company. Line test pressure was nominally 400 psia and test gas temperature was nominally 70°F.

Test data were collected simultaneously from the ultrasonic meters and from the MRF High Pressure Loop critical flow nozzle bank, which served as the flow rate reference. Five binary-weighted sonic nozzles in the HPL nozzle bank were calibrated in-situ, at different line pressures, against the HPL weigh tank system (Park, et al.[1]). Flow rate data were also collected simultaneously from other flow meters in the HPL to verify the consistency of the experiments, including the long-term reproducibility of the test facility.

An on-line gas chromatograph and equations of state from A.G.A. Report No. 8[2] were used to determine gas properties for all engineering calculations. The static line pressure, relative to a reference pressure in the HPL system, was measured two pipe diameters downstream of each test meter. The gas temperature was measured three pipe diameters downstream of each meter using a 1/8-inch diameter platinum Resistance Temperature Detector (RTD). The temperature and pressure measurements were used in combination with the measured gas composition and the volumetric flow rate reported by each ultrasonic meter to calculate the mass flow rate at the ultrasonic meter. The test meter mass flow rate was then compared to the rate determined by the HPL critical flow nozzles to establish the flow measurement error.

The volumetric flow rate reported by each ultrasonic meter was acquired via the meter's digital interface. The data were sampled from each meter at the maximum rate available from the meter. Meter output data were updated at 1 to 5 second intervals, depending on the meter. Individual path status, gas velocity, and speed of sound data were also recorded.

A typical test sequence consisted of recirculating gas through the closed flow loop for a period of time to allow the gas temperature and pressure to stabilize. Steady flow was established by selecting and choking different HPL sonic nozzle combinations. A test point consisted of the average values of flow rate and other variables, computed over a period of 90 seconds. Test points were typically repeated six times back-to-back to calculate average values and standard deviations.

Velocity Profiling Methodology

Velocity profiles were determined by replacing the test flow meter with a pipe spool designed specifically for profile measurement and carefully constructed such that the location of the profile measurement point was well defined. Four circumferential positions on the spool allowed an automated probe traversing system to be externally mounted. The test probe was traversed across the flow along a radial path.

For the profile traverses, dynamic pressure measurements were made at 45° increments using a 0.25-inch step size across the inside diameter of the pipe. The pressure probe used for the measurements was a 3-hole "W-probe" manufactured by United Sensor. The center hole of the "W-probe" arrangement allowed the determination of the total dynamic pressure, which was used to calculate the local velocity. The probe was rotated until the pressures at the two side ports were balanced. The probe rotation angle provided a measurement of the circumferential flow angle. Probe traverse, rotation, dynamic pressure measurement, and control of the system were performed through a combination of a stepper-motor-based motion control system and a personal computer-based data acquisition system.

The gas velocity profile acquisition system was controlled through the MRF data acquisition system, so that profile measurements were made simultaneously with measurements of the MRF critical-flow-nozzle reference flow rate. The average velocity, as computed from the reference flow rate, was used to normalize each individual velocity profile point.

Test Results

The MRF test results to date are provided below. Figures 3, 4, 5, 6, and 7 were presented either to the GRI MTAG in August 1999 or at the TNO Institute of Applied Physics flow metering seminar in September 1999. The three brands of ultrasonic meters were tested in the four piping configurations described above (i.e., baseline, single 90° elbow, two 90° elbows in-plane, and two 90° elbows 90° out-of-plane). Results for the two elbows in-plane test configuration are still being analyzed and are not included in this report. Those test results will be available in the near future.

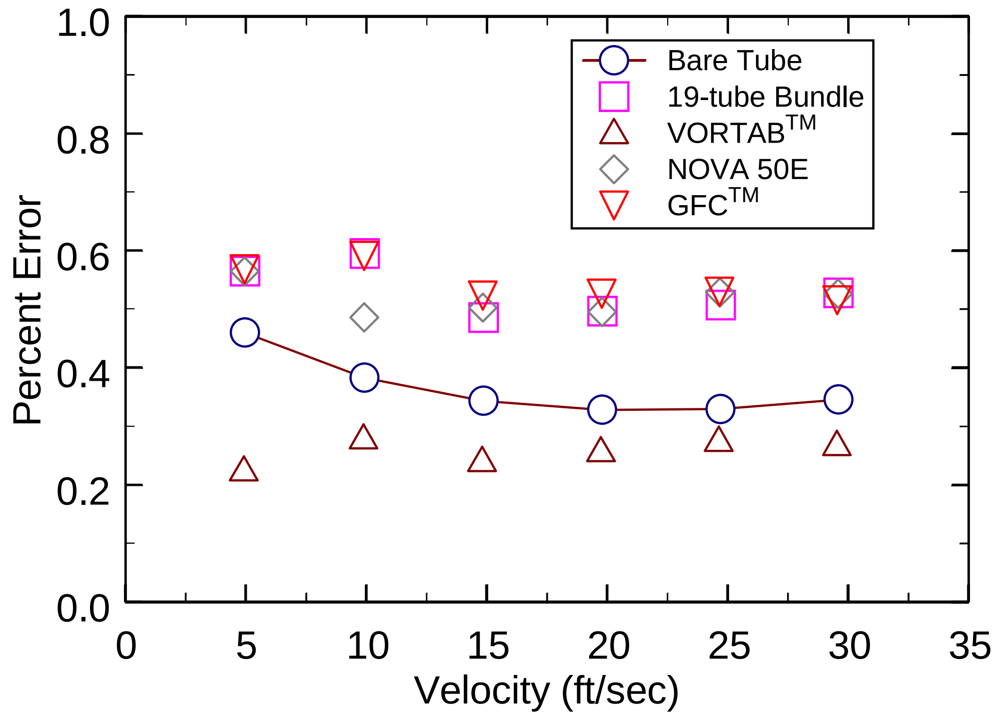


Figure 3. Daniel Meter "Baseline"
(Test meter 100 pipe diameters downstream of a 90° Elbow)

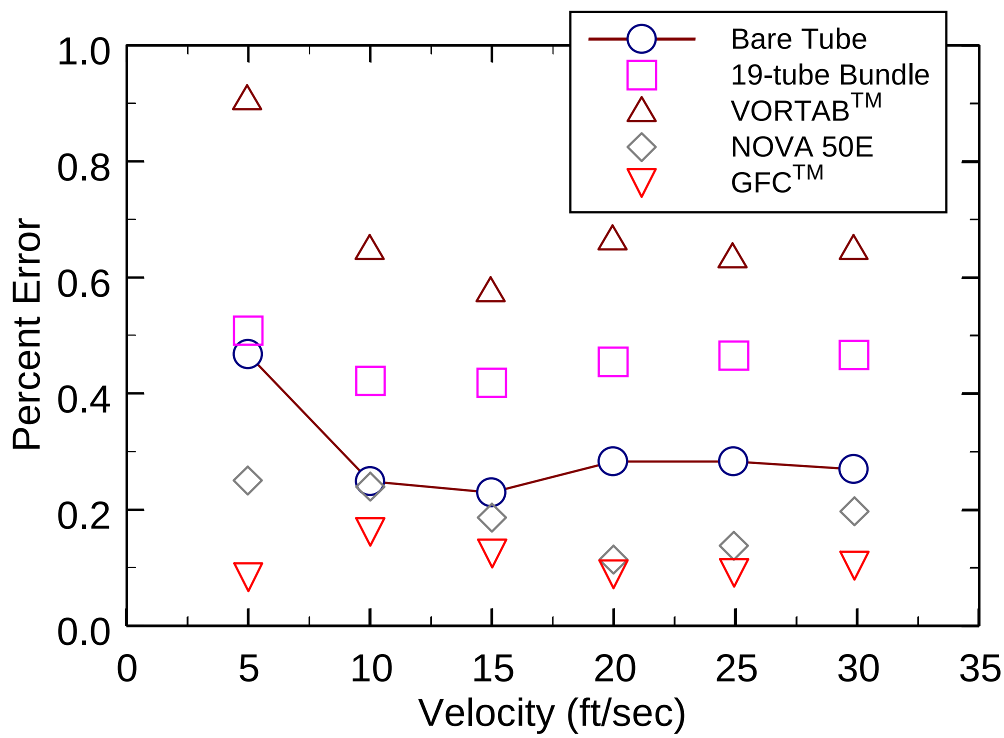


Figure 4. Instromet Meter "Baseline"
(Test meter 100 pipe diameters downstream of a 90° Elbow)

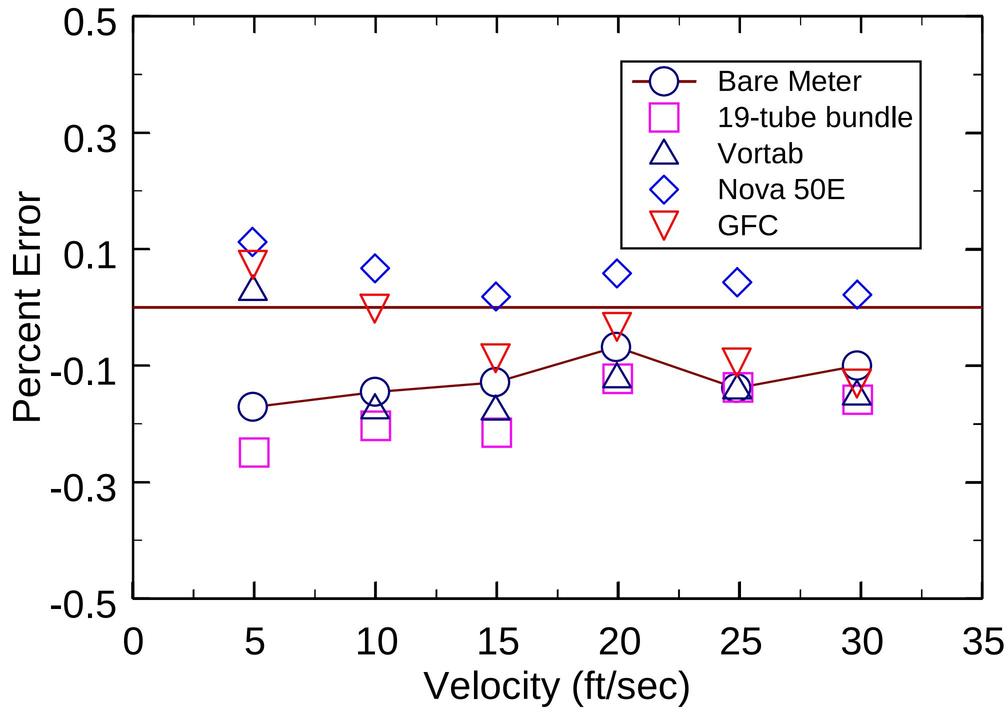


Figure 5. Kongsberg Meter "Baseline"
(Test meter 100 pipe diameters downstream of a 90° Elbow)

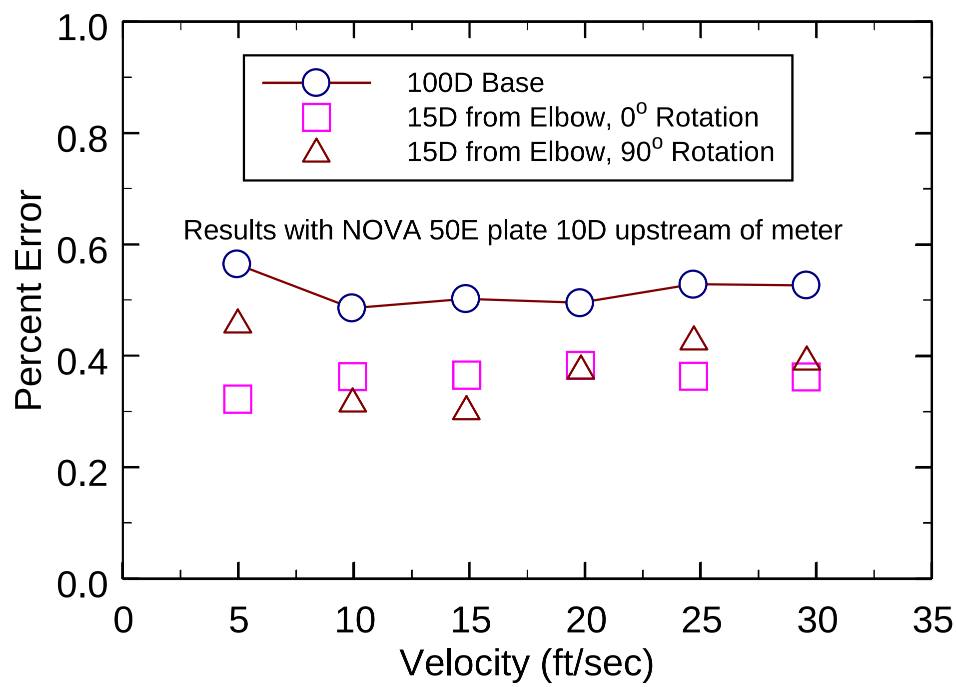


Figure 6. Daniel Meter: Single 90° Elbow

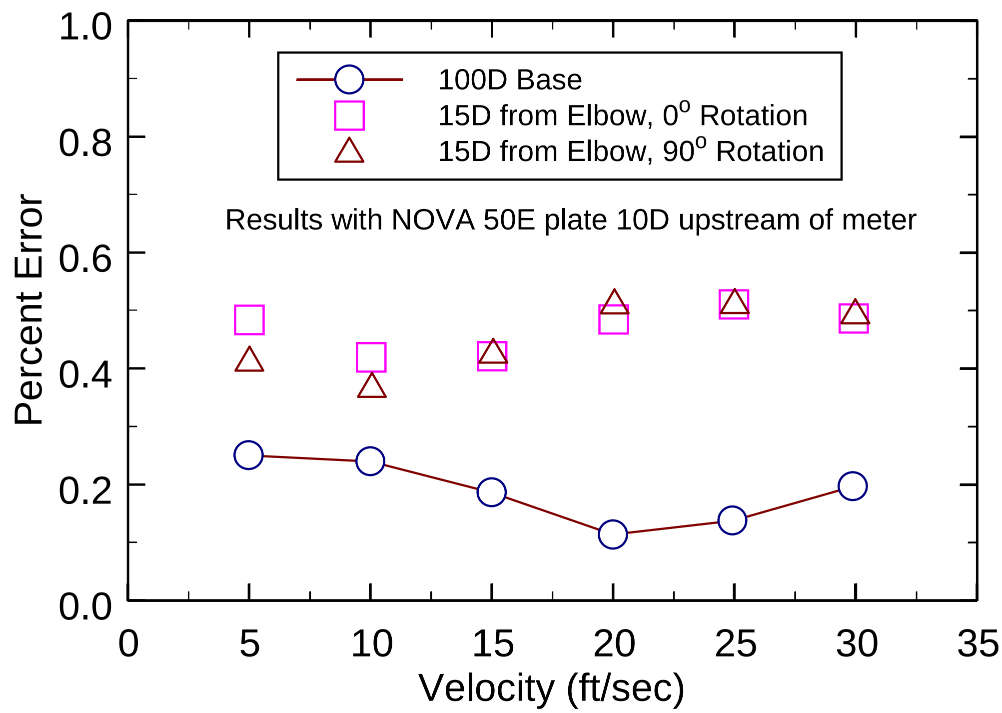


Figure 7. Instromet Meter: Single 90° Elbow

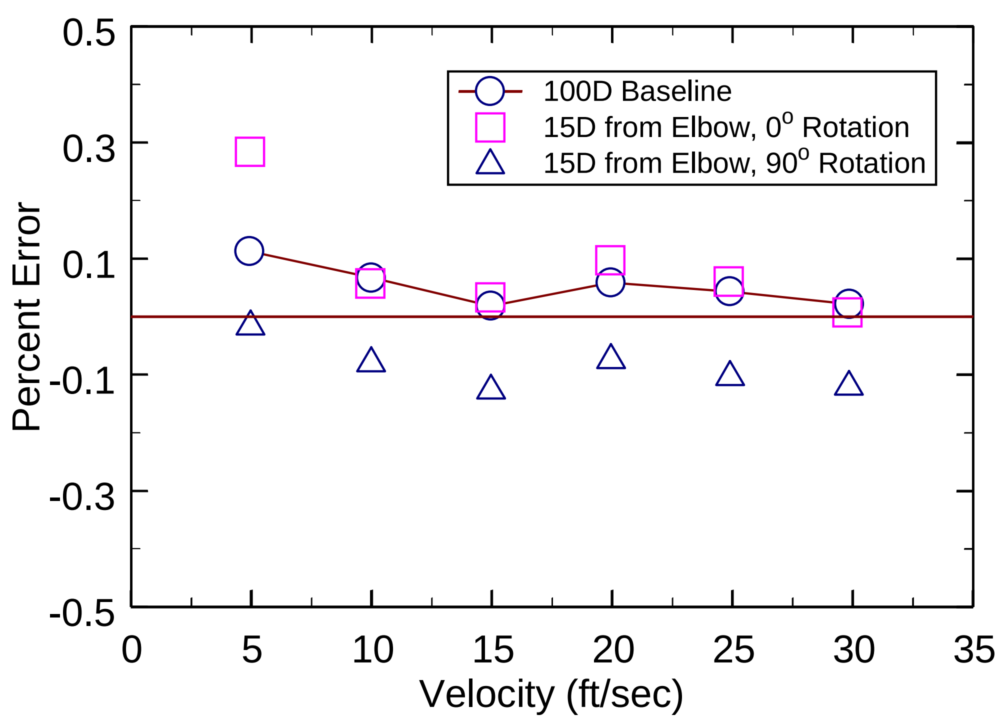


Figure 8. Kongsberg Meter: Single 90° Elbow (unpublished result)

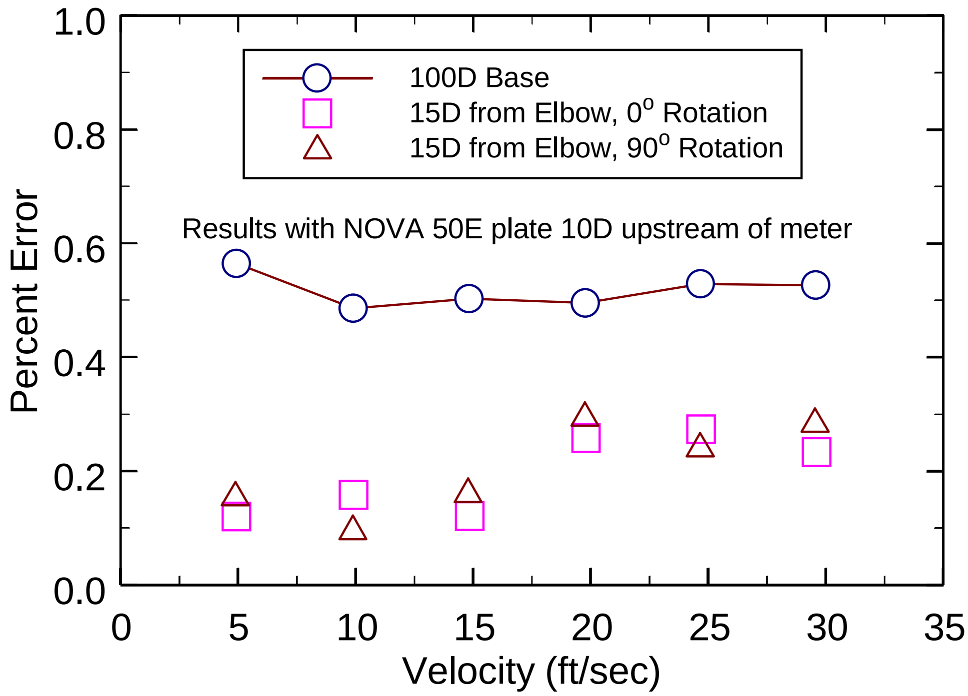


Figure 9. Daniel Meter: Two 90° Elbows, 90° Out-of-Plane (unpublished result)
(with 1.1 pipe diameters of separation between elbows)

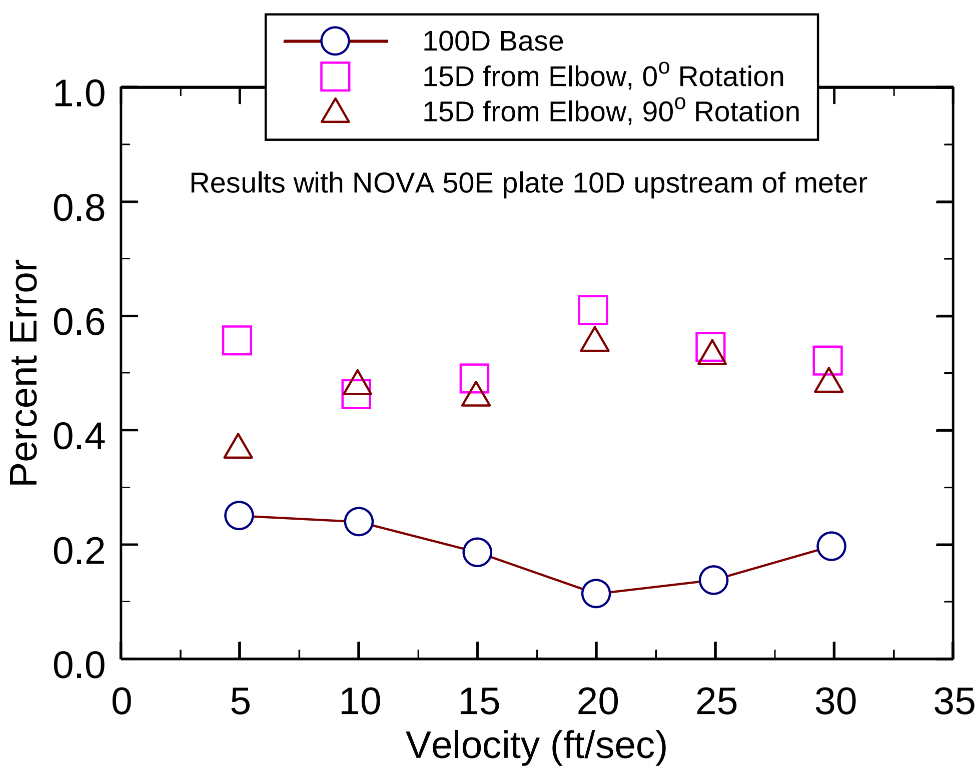


Figure 10. Instromet Meter: Two 90° Elbows, 90° Out-of-Plane (unpublished result)
(with 1.1 pipe diameters of separation between elbows)

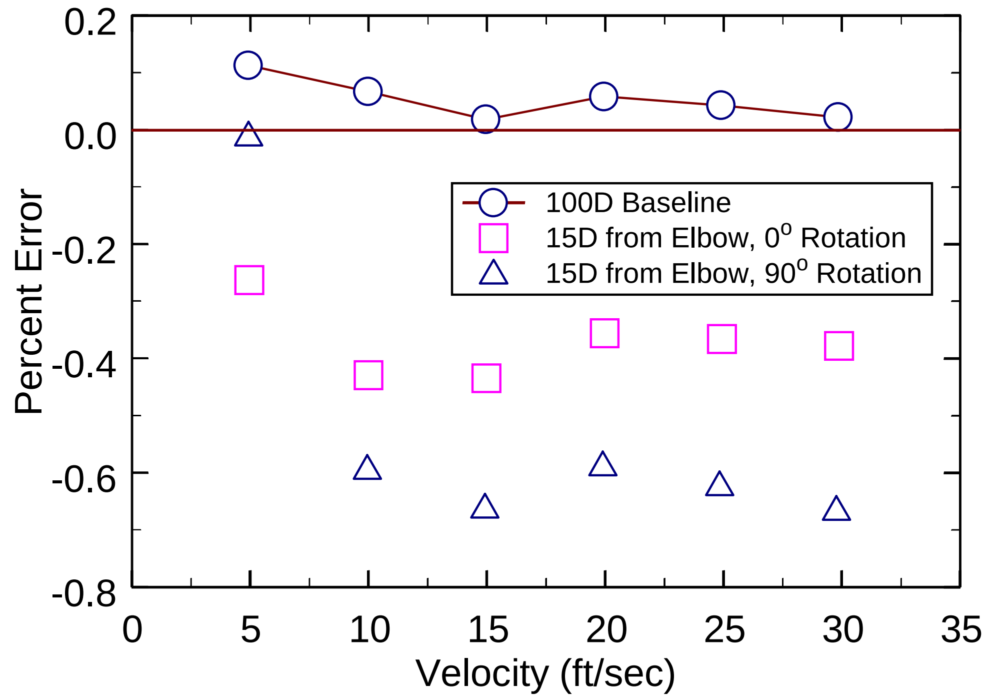
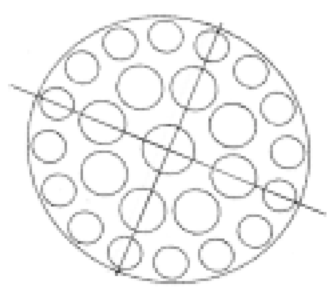
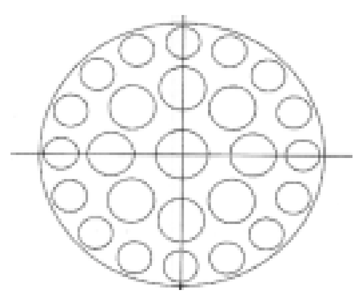


Figure 11. Kongsberg Meter: Two 90° Elbows, 90° Out-of-Plane (unpublished result)
(with 1.1 pipe diameters of separation between elbows)

Additional tests using the Nova 50E flow conditioner were recently conducted for the baseline configuration using the Daniel 4-path ultrasonic meter. These tests were repeats of earlier tests in which the flow weighted mean error (FWME) (as calculated using the methodology specified in Appendix A of A.G.A. Report No. 9[3]) had a value equal to 1.20% when the flow conditioner was installed 3 pipe diameters upstream of the test meter (with a total of 100 pipe diameters of straight pipe upstream of the test meter). The repeat tests produced a FWME of 1.26%, or no significant change from the original test result. However, when the flow conditioner was rotated to a different plane of symmetry (see Figure 12 below), the FWME changed to 0.17%. Tests run with the Nova 50E flow conditioner placed 10 pipe diameters upstream of the meter produced a FWME value of 0.74%. When the flow conditioner was rotated as shown on Figure 12, the FWME was 0.35%. The original baseline test for this configuration produced a FWME value of 0.52%. Clearly, for some test piping/meter design combinations, there were measured sensitivities to the orientation of the Nova 50E flow conditioner.



MRF "Standard" plate orientation

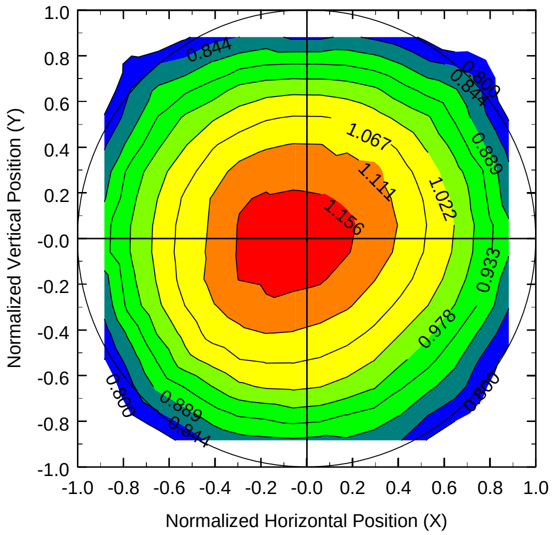


"Rotated" plate orientation

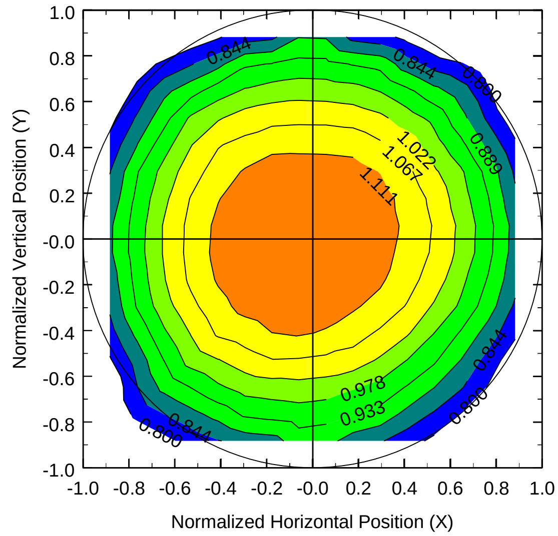
Figure 12. Nova 50E Flow Conditioner Installation Orientation

Regarding the performance of the Nova 50E conditioner in a swirling flow field, velocity profile data taken with the flow conditioner downstream of the two elbows out-of-plane indicated that the swirl angle of the flow downstream of the conditioner was less than approximately 1°, which was the measurement uncertainty level for the velocity profile probe. For this test case, examination of the individual acoustic path test data for both the Instromet and Kongsberg ultrasonic meters (where the acoustic path configurations were positioned to detect the presence of a swirling flow) indicated that the flow conditioner changed the direction of swirl downstream of the two elbows out-of-plane. Both meters indicated swirl angles less than 1°, but with a sign opposite the swirl angle produced when no flow conditioner was installed downstream of the out-of-plane elbows. This test result was the same when the flow conditioner was placed 10 pipe diameters upstream of the meters (and 5 pipe diameters downstream of the exit of the elbow combination) and when the flow conditioner was placed 3 diameters upstream of the meters (and 7 pipe diameters downstream of the elbow combination). Figure 13 shows the velocity contours for the Nova 50E flow conditioner tests for both the baseline and the out-of-plane elbow test configurations.

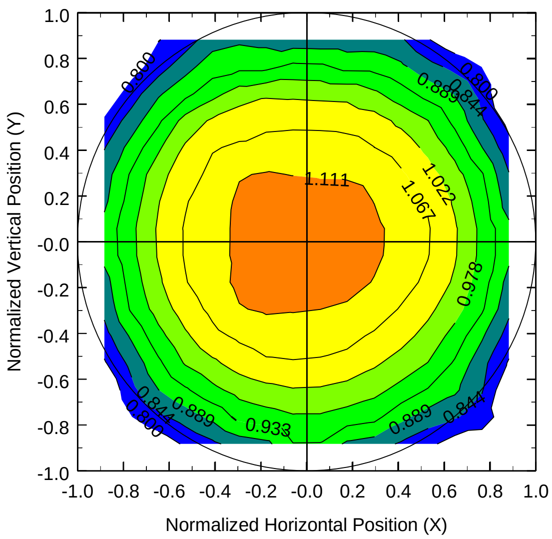
For the highest flow rate tested at the MRF, in which the mean gas velocity was approximately 30 feet per second, a swirl angle of 1° would produce a circumferential velocity component of about 0.5 feet per second. However, since the acoustic paths in the Instromet and Kongsberg meters that are capable of detecting swirl rely on opposing path directions, the two paths would indicate a velocity difference of 1 foot per second for the example given (i.e., ignoring the shape of the velocity profile, one acoustic path would indicate a velocity of 30.5 feet per second and the other would indicate 29.5 feet per second).



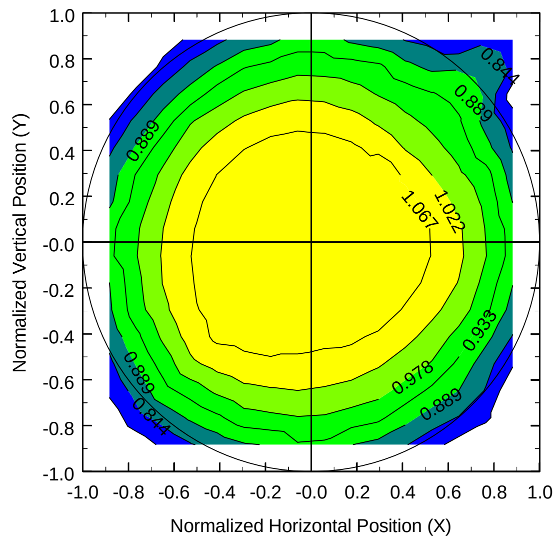
Test meter placed 100 pipe dia. downstream of a single elbow, and with the flow conditioner placed 10 pipe dia. upstream of the meter



Test meter placed 100 pipe dia. downstream of a single elbow, and with the flow conditioner placed 3 pipe dia. upstream of the meter



Test meter placed 15 pipe dia. downstream of two elbows out-of-plane, and with the flow conditioner placed 10 pipe dia. upstream of the meter



Test meter placed 10 pipe dia. downstream of two elbows out-of-plane, and with the flow conditioner placed 3 pipe dia. upstream of the meter

Figure 13. Nova 50E Flow Conditioner Velocity Contours

References

1. Park, J. T., K. A. Behring, and T. A. Grimley, "Uncertainty Estimates for the Gravimetric Primary Flow Standards of the MRF," 3rd International Symposium on Fluid Flow Measurement, San Antonio, Tx., Apr. 1995.
2. *Compressibility of Natural Gas and Other Related Hydrocarbon Gases*, A.G.A. Transmission Measurement Committee Report No. 8, American Gas Association, Arlington, Virginia, 1985.
3. *Measurement of Gas by Multipath Ultrasonic Meters*, A.G.A. Transmission Measurement Committee Report No. 9, American Gas Association, Arlington, Virginia, June 1998.