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WHITE PAPER

FLOWSIC600-XT – TESTING OF DIFFERENT INLET PIPING CONFIGURATIONS WITH AND WITHOUT CPA FLOW CONDITIONERS 50E AND 55E ACCORDING TO AGA REPORT NO. 9

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SUMMARY

The FLOWSIC600-XT family of ultrasonic gas meters is OIML R 137 accuracy class 0.5 certified. Focusing on the metrological standards and recommendations Measurement Canada and AGA 9, this paper shows detailed results of extensive disturbance tests of the 4- and 8-path devices with traditional and very short pipe inlet lengths. The tests were performed with and without CPA50E and CPA55E flow conditioners at the TCC natural gas high pressure test facility in Canada.

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1. Introduction

According to international recommendations such as OIML R 137 1&2:2012 (section 8.2) and ISO 17089 (section 5.9), there are no specific requirements for piping and flow conditioning configurations. It is the flow meter manufactures responsibility to recommend certain piping and flow conditioning configurations to meet the uncertainty requirements specified by the international standards and recommendations.

In accordance with the American Gas Association (AGA) Report No. 9 guidelines Ultrasonic Flow Meters are installed with flow conditioners and a recommended inlet piping configuration of 10 diameters, flow conditioner, 10 diameters. Since the Third Edition of AGA9 issued in 2017, that was reaffirmed with the Fourth Edition Released in 2022, it is stated that the upstream piping installation can be defined by the flow meter manufacturer. This could be interpreted as an effort to align closer with other international standards and recommendations and is further described in appendix C of the AGA9. This refers to the OIML R137-1&2:2012 test procedures given in its “Annex B: Flow disturbance tests, Table B.1 Piping configurations for flow disturbances”.

Driven by our pioneering spirit, SICK since 2012 has been testing its gas flow meter family (FLOWSIC600) in accordance with OIML R137-1&2:2012 accuracy classes 1.0 and 0.5 using different inlet piping and flow conditioning configurations. SICK’s continued product innovation and evolution led to the FLOWSIC600-XT product family (featuring e.g., 8-path meters and advanced diagnostics with i-diagnostics™), which has also been proven to meet the OIML R 137 class 0.5. Thus, the FLOWSIC600-XT gas flow meter family is OIML R 137 class 0.5 certified by NMi, Netherlands.

OIML testing is heavily focused on European market requirements. To further strengthen our position as market leader in North America, SICK has invested in various testing campaigns featuring AGA9 and Measurement Canada PS-G-06 piping and flow conditioning configurations. The CPA flow conditioner types 50E and 55E have been tested with different upstream piping configurations including ten, five and three pipe diameters.

2. AGA9 Testing Campaign – Test Facility and Setup

2.1 Test Facility

"Transcanada Calibrations (TCC) is the highest capacity High Pressure Natural Gas Meter testing and calibration facility in the World. TCC is ISO 17025 CLAS accredited as well as Measurement Canada government recognized, accredited and audited. TCC is traceable to the Internationally recognized European reference value for natural gas and is the representative Canadian flow laboratory for participation in international ISO BIPM fluid flow inter-comparison activities. TCC is a past and present participant author on AGA North American measurement best practices documents, AGA Report #9, AGA Report #7, AGA GMM 16 as well as the ISO 17089 international measurement standard."[1]

Due to the superior capabilities mentioned and the long-standing relationship between SICK and TCC, the Winnipeg calibration lab has been chosen to conduct this test campaign.

2.2 Test Setup

2.2.1 Upstream Piping Configurations

Initially a base line of the meter was performed at 30 diameters straight pipe upstream before the disturbance testing. The upstream piping configurations for the disturbances are defined by OIML R137-1 & 2:2012 "Annex B: Flow disturbance tests, Table B.1 Piping configurations for flow disturbances". SICK did select the main relevant arrangements. In addition, the meter has been rotated at some inlet configurations by 90° from a 12 o'clock to a 3 o'clock position. All test arrangements have been performed at gas velocities of 20, 40 and 70 ft/s at a pressure of 900 psi using natural gas. Each flow test point was repeated three times with a hold time of 100 seconds each.

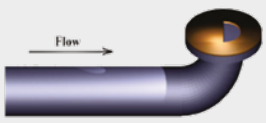
Test		Test conditions	Remarks	Turbine	Ultrasonic	Thermal mass	Vortex
a		Reference conditions	approx. 80 D straight line	-	x	x	x
			approx. 10 D straight line (see note)	x	-	-	-
b		A single 90° bend	radius elbow: 1.5 D	x	x	x	x
c		Double out-of-plane bend	rotating right; radius elbows: 1.5 D	x	x	x	x
d			rotating left; radius elbows: 1.5 D	x	x	x	x
e		Half pipe area plate	image shows first bend in piping and mounting of halfmoon plate	x	x	-	-

Fig. 1: Extract of the OIML R 137 Piping configurations for flow disturbances[2]

The test piping for all the named meter tests in this paper has been provided by testing facility TCC.

[1] TCC: https://www.tccalibrations.com/; 01/2022
[2] OIML R 137-1&2 Edition 2012 (E), Annex B: Flow disturbance tests, Table B.1 Piping configurations for flow disturbances, 2012

2.2.2 Flow Conditioners

Flow conditioners type 50E and 55E from Canada Pipeline Accessories Company Ltd. (CPA) have been used for the tests.

“The CPA 50E is the most tested flow conditioner in the industry and is supported by more than 20 years of test data by independent flow laboratories. The CPA 50E is designed to produce a swirl-free, fully developed flow profile, improving reliability and reducing error, while also shortening the meter run.”[3] (Figure 2: CPA 50E)

“The CPA 55E uses an innovative unique stepped design that has been optimized with fluid dynamic fundamentals in mind, giving greater capability over other flow conditioners. The flow conditioner provides lower turbulence and noise generation and create a swirl free flow with a fully developed flow profile.”[4] (Figure 3: CPA 55E)

Fig. 2: CPA 50E

Fig. 3: CPA 55E

2.2.3 Test Devices

Two test campaigns have been performed. The first test campaign with 10 diameter (10D) and 5 diameter (5D) inlet piping configurations a FLOWSIC600-XT 2plex meter, (serial no. 18030002) with a 4+1-path Westinghouse cord design has been chosen in the diameter of 8 inch and ASME class 600 pressure rating. In this paper only the 4-path results are shown, since this is the fiscal meter which can be used in AGA9 and Measurement Canada. Figure 4: FLOWSIC600-XT 2plex illustrates the meter used for testing.

For the second test campaign with all 3 diameter (3D) inlet piping configurations a FLOWSIC600-XT Forte (serial no. 21221007) with an 8-path Westinghouse cord design has been chosen, in the diameter of 8 inch and ASME class 600 pressure rating. Figure 5: FLOWSIC600-XT Forte shows the meter used for 3D testing.

Fig. 4: FLOWSIC600-XT 2plex

Fig. 5: FLOWSIC600-XT Forte

[3] https://www.flowconditioner.com/flow-conditioner/
[4] https://www.flowconditioner.com/flow-conditioner/

3. AGA9 Testing Campaign – Results

3.1 FLOWSIC600-XT 4-path installation using CPA 50E flow conditioner

For full transparency the errors at specific piping setups as deviation to the initial base line are displayed at different gas velocities. For better visibility all test results show the Weighted Mean Error (WME) for the specific piping arrangement. The test results clearly indicate that the FLOWSIC600-XT performs well within both, AGA9 and Measurement Canada error limits of ±0.3%. Even the OIML R 137 Class 0.5 accuracy band of ±0.166% is well achieved, for the 10D/50E/10D configuration featuring different piping arrangements (covering mild and severe disturbances). When looking at the 5D/50E/5D configuration with different piping arrangements, we realize that the 4-path meter is reaching its limits for class 0.5 but performs well within the AGA9 / MC error band of ±0.3%.

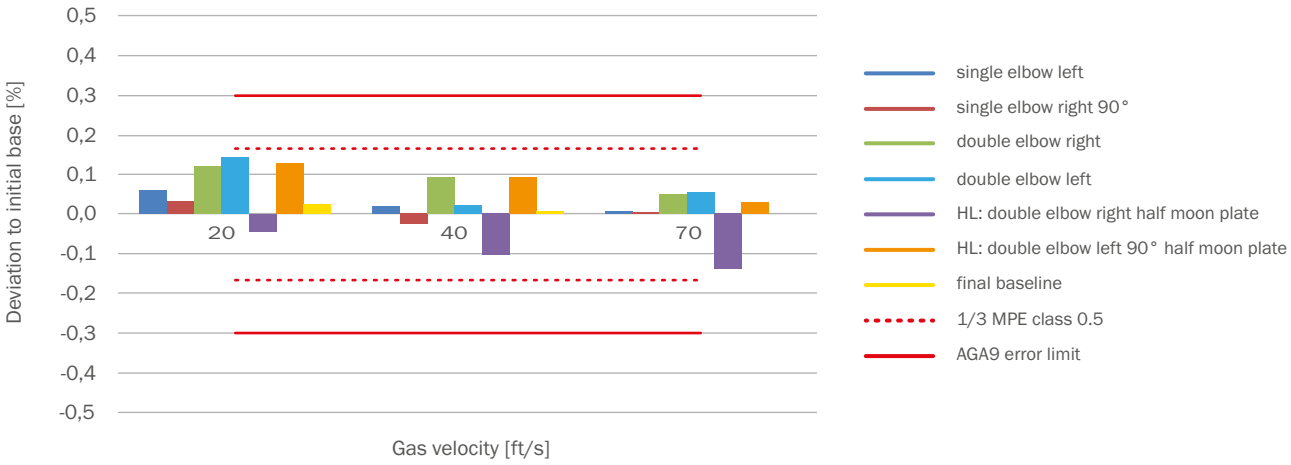


Fig. 6: Error of FLOWSIC600-XT 4-path; 10D | CPA50E | 10D, 900psi

Fig. 7: WME of FLOWSIC600-XT 4-path; 10D | CPA50E | 10D, 900psi

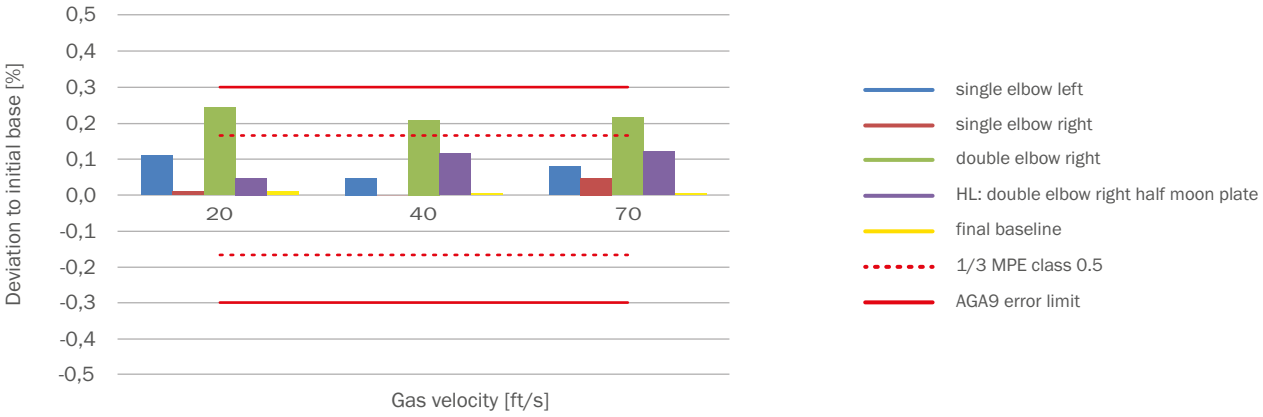


Fig. 8: Error of FLOWSIC600-XT 4-path; 5D | CPA50E | 5D, 900psi

Fig. 9: WME of FLOWSIC600-XT 4-path; 5D | CPA50E | 5D, 900psi

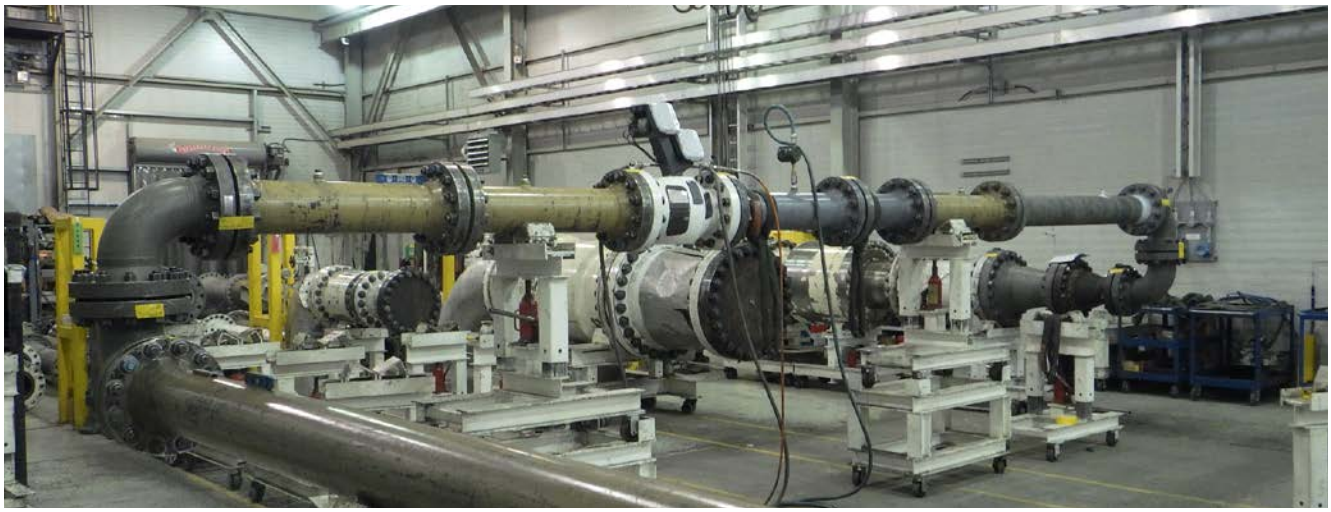


Fig. 10: FLOWSIC600-XT 2plex - “double elbow out of plane right” testing with 5D|CPA50E|5D

3.2 FLOWSIC600-XT 4-path installation using CPA 55E flow conditioner

The test results clearly indicate that the FLOWSIC600-XT performs well within AGA9 / MC error limits of ±0.3% and OIML Class 0.5 accuracy band of ±0.166%, for both, the 10D/55E/10D as well as 5D/55E/5D configuration featuring different piping arrangements (covering mild and severe (HL=high level) disturbances).

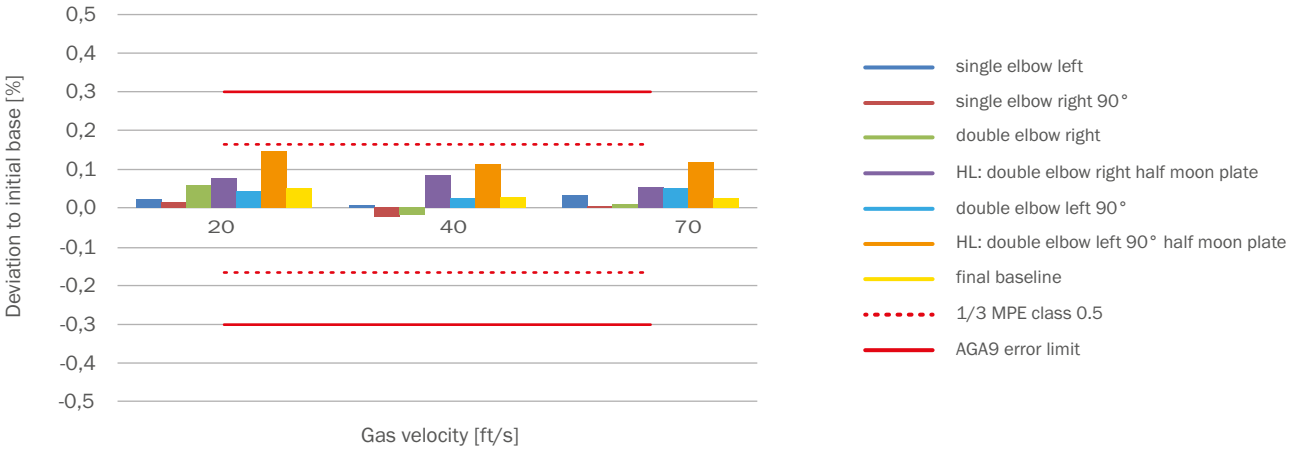


Fig. 11: Error of FLOWSIC600-XT 4-path; 10D | CPA55E | 10D, 900psi

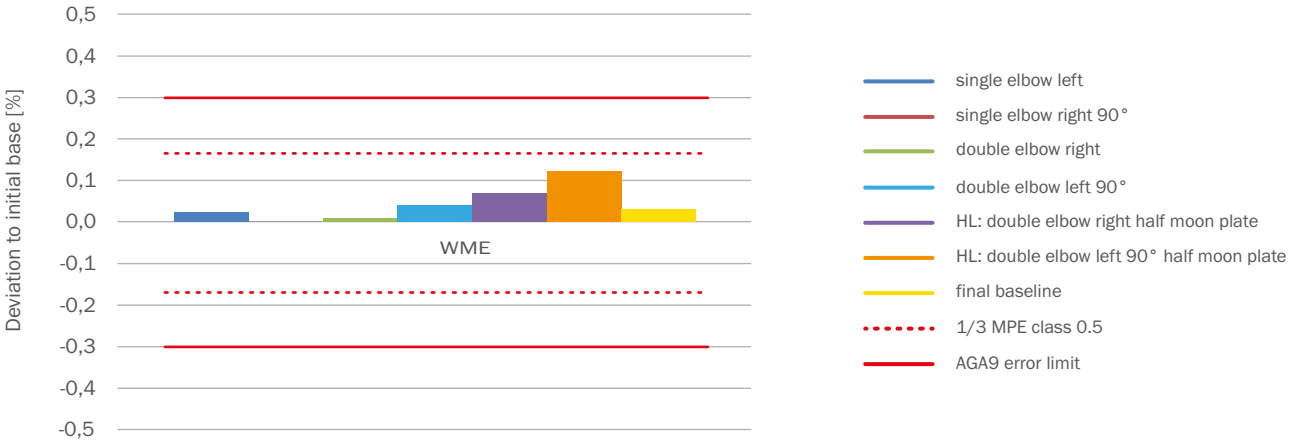


Fig. 12: WME of FLOWSIC600-XT 4-path; 10D | CPA55E | 10D, 900psi

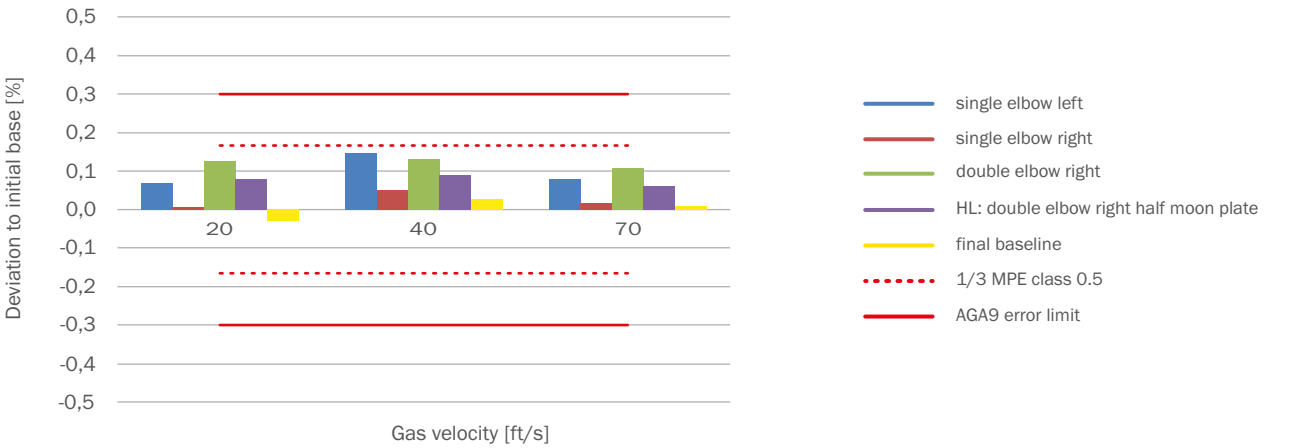


Fig. 13: Error of FLOWSIC600-XT 4-path; 5D | CPA55E | 5D, 900psi

Fig. 14: WME of FLOWSIC600-XT 4-path; 5D | CPA55E | 5D, 900psi

Fig. 15: FLOWSIC600-XT 2plex - “single elbow left” testing with 10D|CPA50E|10D

3.3 FLOWSIC600-XT 4-path installation – Conclusion of Testing

The test results indicate that the error limits of AGA9 and OIML R 137 for accuracy class 1.0 and 0.5 can be met using both flow conditions CPA 50E and 55E in a 10D inlet piping configuration. Furthermore, they illustrate the benefits of using a CPA 55E flow conditioner over a CPA 50E flow conditioner for 5D inlet piping configurations when accuracy class 0.5 is required.

3.4 FLOWSIC600-XT 8-path installation using CPA 50E flow conditioner

The test results clearly indicate that the FLOWSIC600-XT Forte 8-path has an offset using the CPA 50E flow conditioner at the inlet piping configuration 3D/50E/3D. With this offset the meter is not compliant to both AGA9 and OIML Class 0.5.

The FLOWSIC600-XT 8-path meter has primarily been designed to perform without a flow conditioner at 5D inlet installations and within the OIML R 137 class 0.5 error band of ±0.166%, as shown in this paper later on.

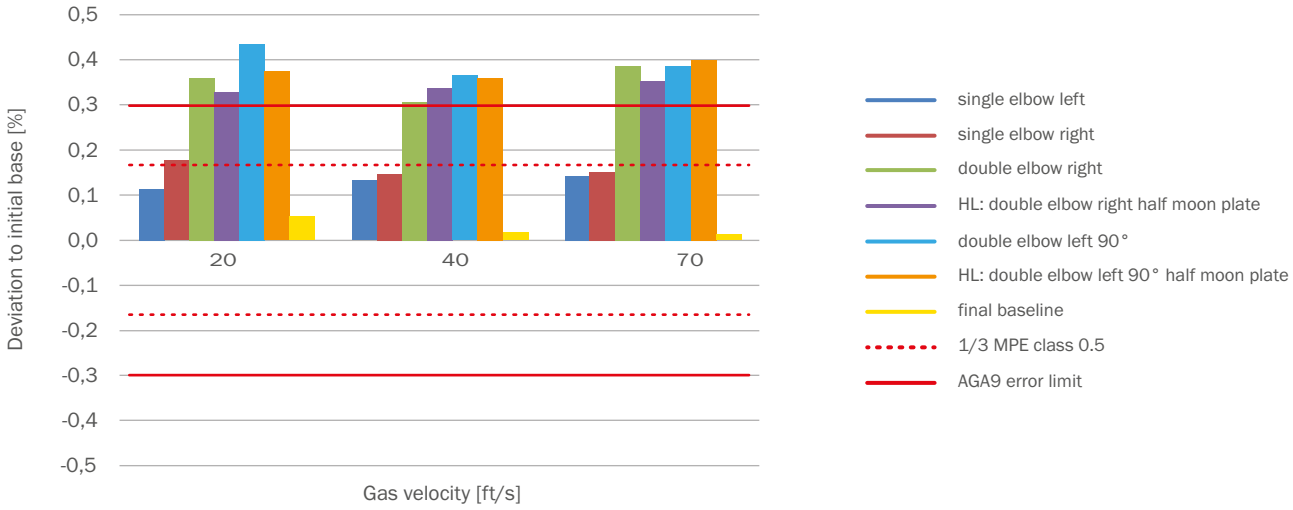


Fig. 16: Error of FLOWSIC600-XT Forte 8-path; 3D | CPA50E | 3D, 900psi

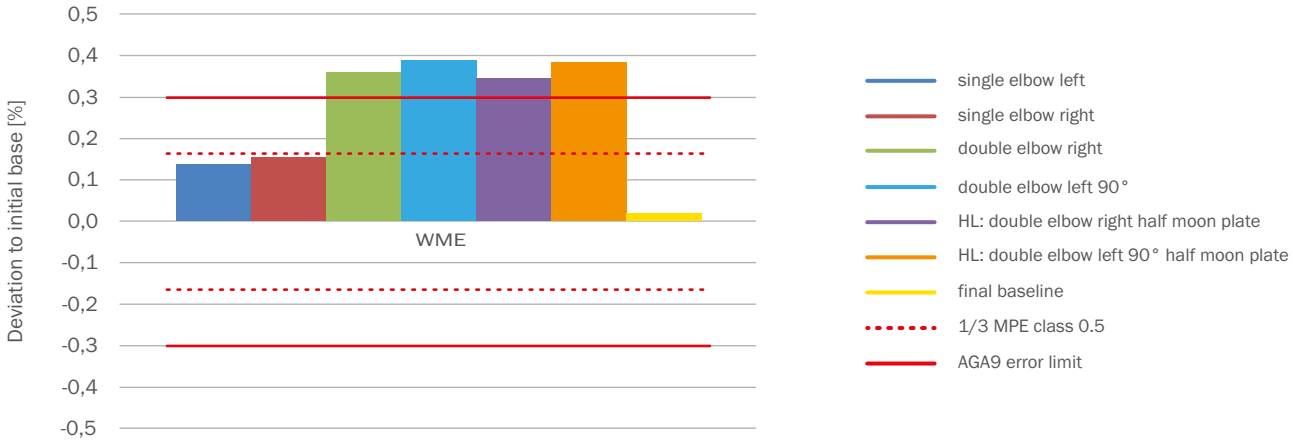


Fig. 17: WME of FLOWSIC600-XT Forte 8-path; 3D | CPA50E | 3D, 900psi

For special applications requiring very short inlet configurations an offset factor of 0.975 can be applied to the meter using the “fitting offset factor” function to get the meter within an AGA9 error band before calibration and linearization.

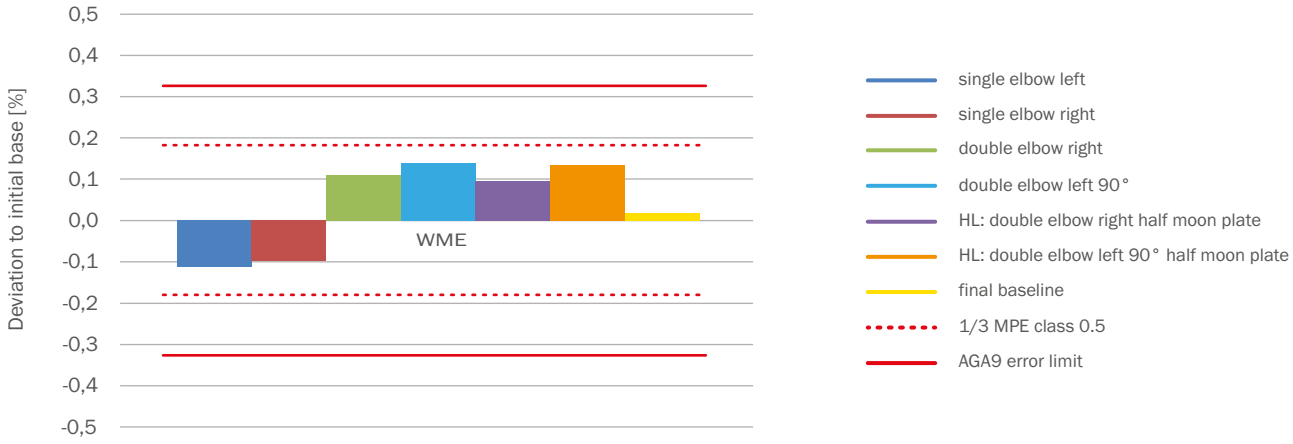


Fig. 18: WME of FLOWSIC600-XT Forte 8-path; 3D | CPA50E | 3D, 900psi, offset corrected

3.5 FLOWSIC600-XT 8-path installation using CPA 55E flow conditioner

When using the CPA 55E flow conditioner in a 3D/FC/3D setup the flow profile can stabilize resulting in a compliant OIML Class 1.0 measurement. With this setup the meter is also compliant with OIML accuracy class 0.5 for mild disturbances. Only severe disturbances would cause the measurement to fall outside the OIML Class 0.5 in the described setup.

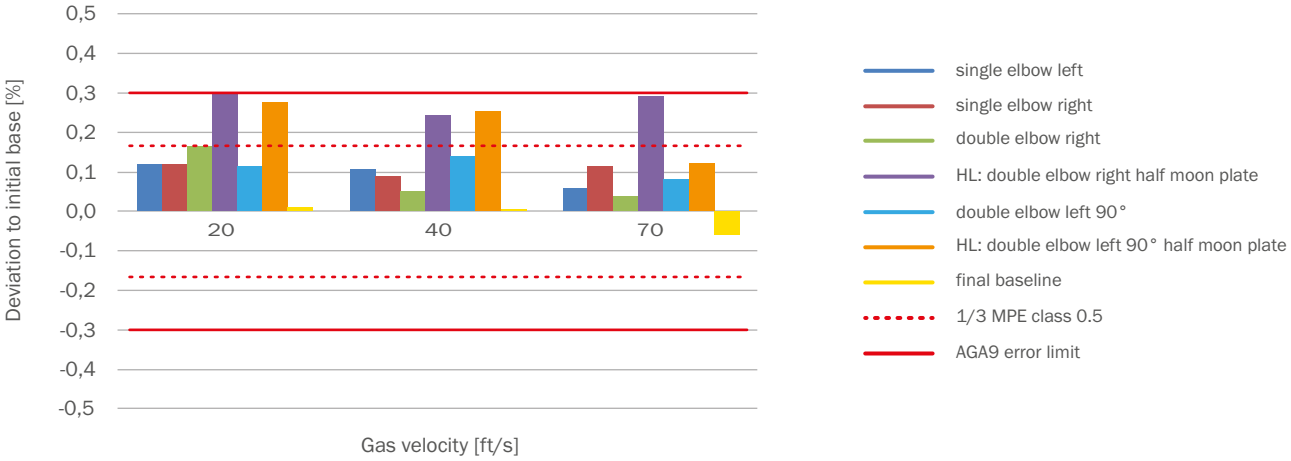


Fig. 19: Error of FLOWSIC600-XT Forte 8-path; 3D | CPA55E | 3D, 900psi

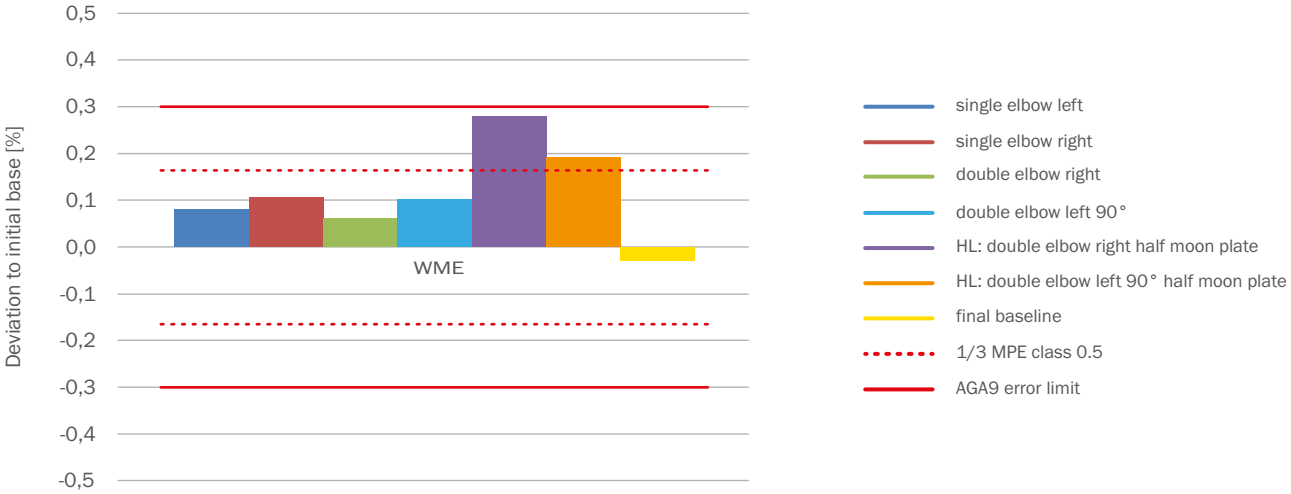


Fig. 20: WME of FLOWSIC600-XT Forte 8-path; 3D | CPA55E | 3D, 900psi

As Figure 21: WME of FLOWSIC600-XT Forte 8-path; 3D | CPA55E | 3D, 900psi shows, the flow weighted mean error for the 8-path meter installed with 3D/CPA55E/3D is for all mild disturbances around 0.1%. The half-moon plate installed in front of the disturbance causes a higher error on the measurement. But still this challenging configuration is well within the accuracy limits of an AGA9 measurement.

This behavior is also reproducible on other test facilities. When selecting a 3D/55E/3D inlet piping, SICK can automatically select the fitting offset factor to get the meter within an AGA9 and OIML R 137 class 0.5 error bands before calibration and linearization for all disturbances (mild and severe).

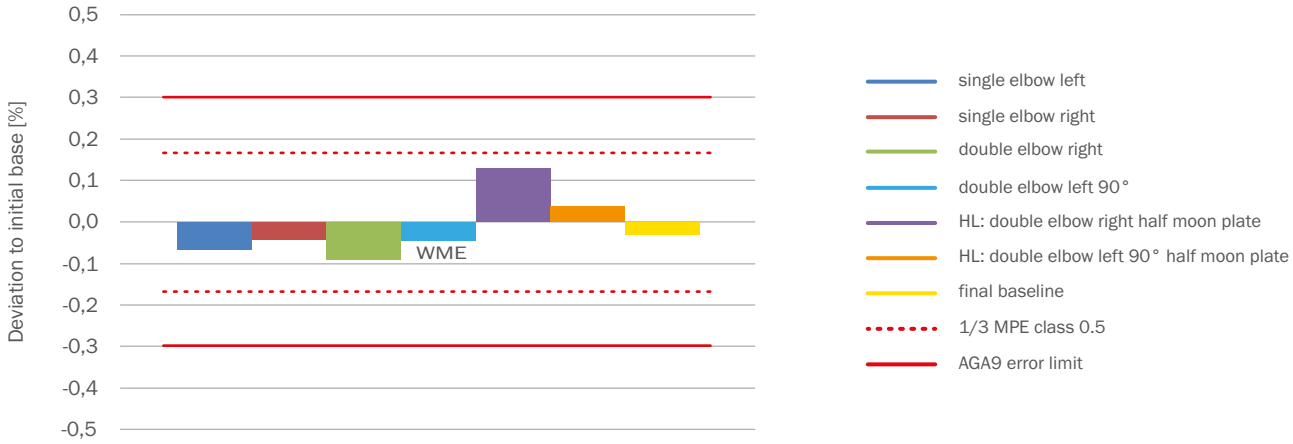


Fig. 21: WME of FLOWSIC600-XT Forte 8-path; 3D | CPA55E | 3D, 900psi, offset corrected

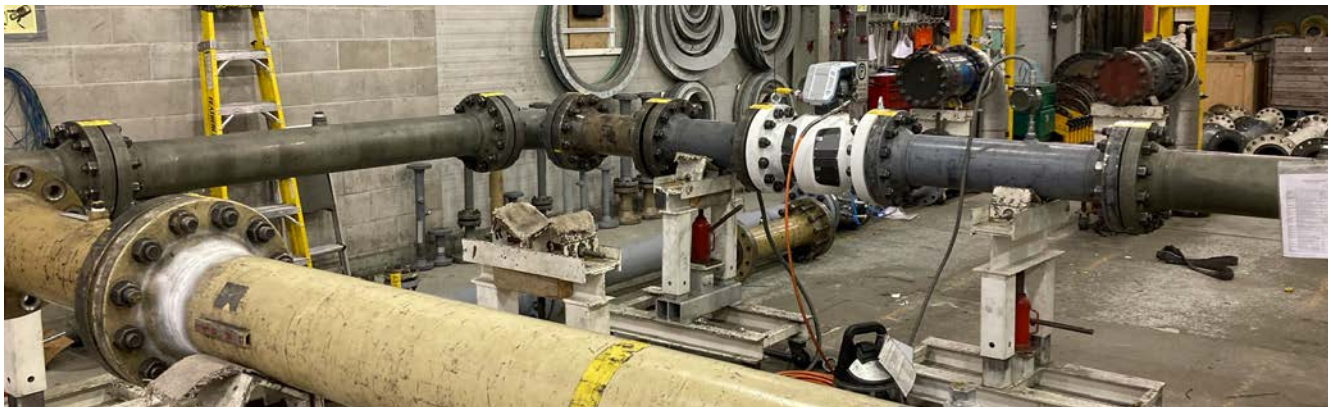


Fig. 22: FLOWSIC600-XT Forte - “single elbow right” testing with 3D|CPA55E|3D

3.6 FLOWSIC600-XT 8-path installation without flow conditioner

Even without any flow conditioning the test results for the installation of the 8-path meter with only 3D inlet piping indicate an OIML Class 1.0 compliance for mild and severe disturbances.

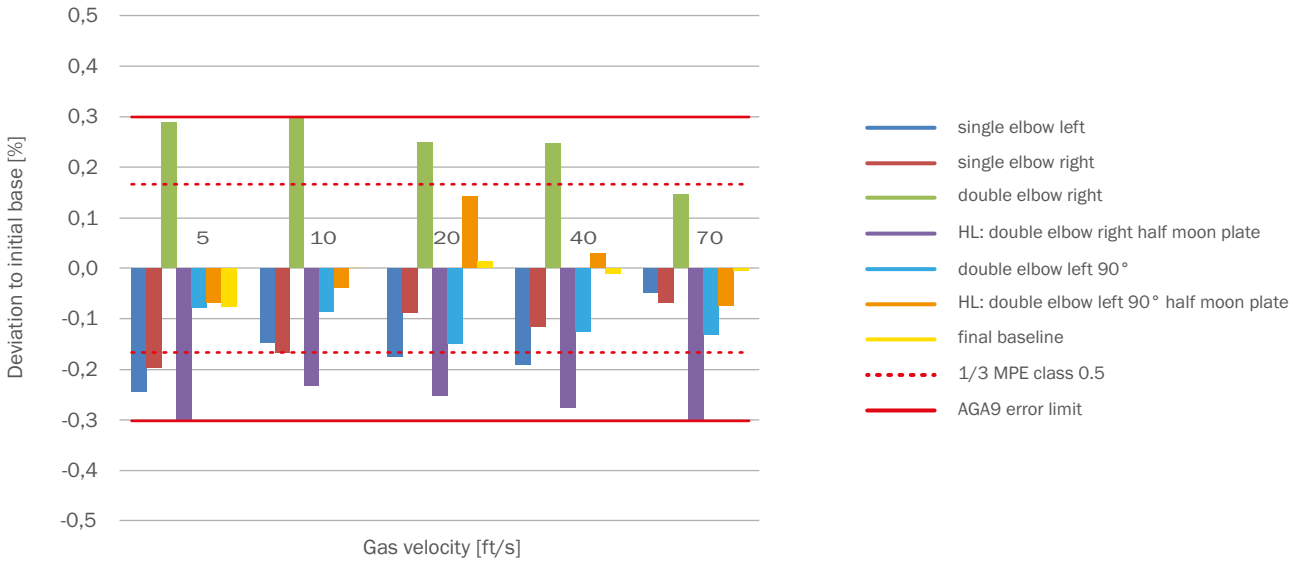


Fig. 23: Error of FLOWSIC600-XT Forte 8-path; 3D w/o flow conditioner, 900psi

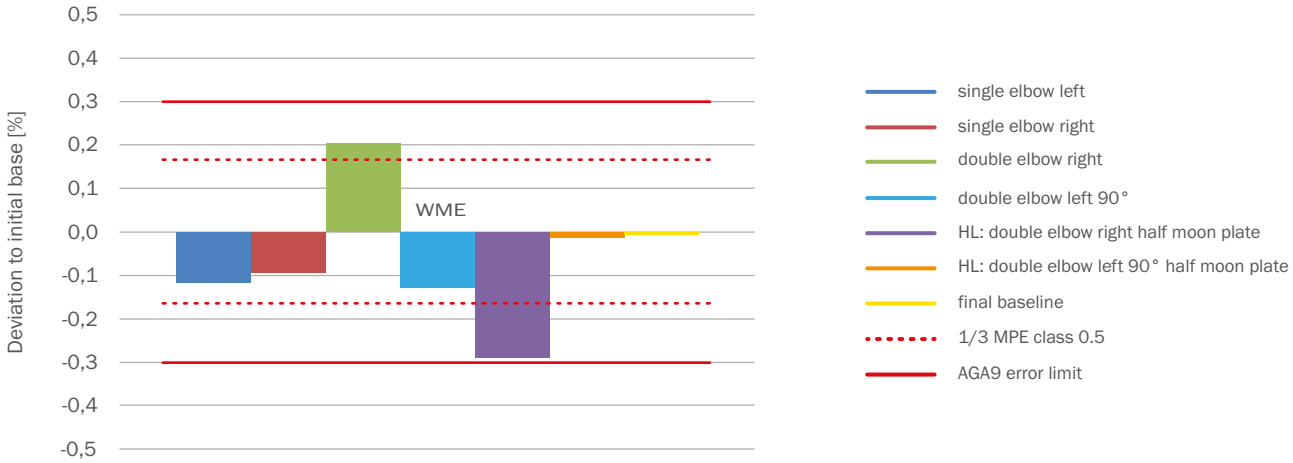


Fig. 24: WME of FLOWSIC600-XT Forte 8-path; 3D inlet w/o flow conditioner, 900psi

Fig. 25: FLOWSIC600-XT Forte - “double elbow out of plane right” testing with 3D w/o FC

4. OIML R 137 Testing Campaign – Results

4.1 FLOWSIC600-XT 8-path installation without flow conditioner

As mentioned in section 3.4 the FLOWSIC600-XT 8-path meter has been designed primarily to perform without a flow conditioner at 5D inlet installations and within the OIML R 137 class 0.5 error band of ±0.166%. Figure 27: WME of FLOWSIC600-XT Forte, 8 inch, 8-path; 5D inlet w/o flow conditioner, 14.5 psi shows the WME results of the latest OIML R 137 class 0.5 certification.

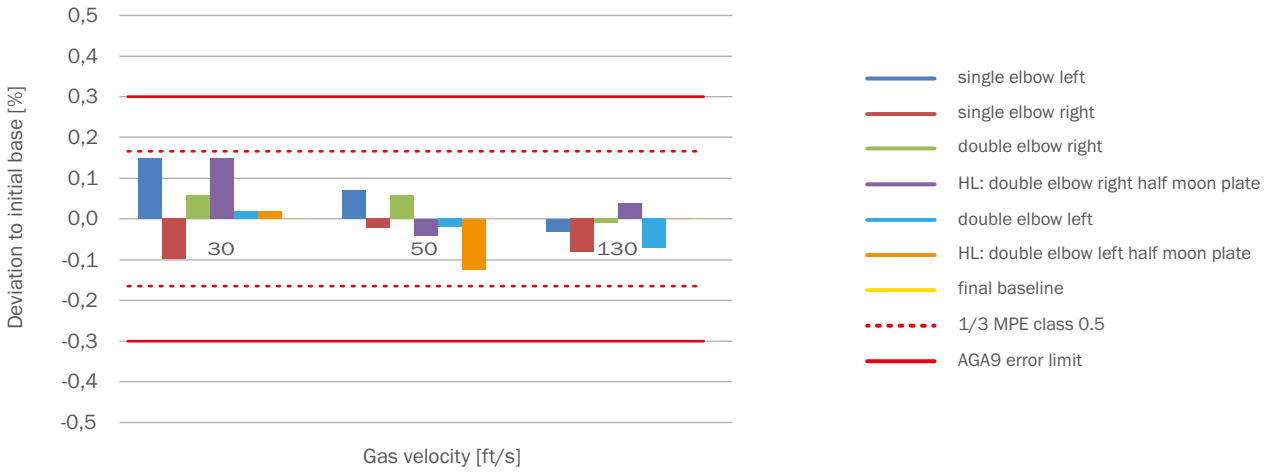


Fig. 26: Error of FLOWSIC600-XT Forte, 8 inch, 8-path; 5D inlet w/o flow conditioner, 14.5 psi

Fig. 27: WME of FLOWSIC600-XT Forte, 8 inch, 8-path; 5D inlet w/o flow conditioner, 14.5 psi

5. Conclusion

The conducted series of tests outline the benefits of using a CPA 55E flow conditioner over a 50E for shorter (5D) inlet piping configurations in combination with a 4-path ultrasonic flowmeter. While AGA9 and Measurement Canada error limits can be met using both flow conditioners for short (5D) inlet piping configurations, a CPA 55E flow conditioner should be utilized to meet OIML accuracy class 0.5.

When using an 8-path ultrasonic flowmeter in conjunction with the CPA 55E flow conditioner the AGA9 error limits are attainable with short inlet piping configurations of 3D. Even without a flow conditioner the benefits of using an 8-path meter are obvious. AGA9 class 1.0 accuracy can be achieved for 3D inlet piping. OIML R 137 class 0.5 accuracy can be achieved using 5D inlet.
These results show that 8-path ultrasonic meters can save CAPEX money on both, inlet piping length as well as potentially flow conditioning. As pipe sizes increase the monetary benefit grows.

6. References

[AGA9] AGA Report No. 9, Measurement of Gas by Multipath Ultrasonic Meters, Third Edition, July 2017

[AGA9] AGA Report No. 9, Measurement of Gas by Multipath Ultrasonic Meters, Fourth Edition, January 2022

[MC] Measurement Canada PS-G-06, Provisional specifications for the approval, verification, reverification, installation and use of ultrasonic meters, Revision 4, 2017-11-15.

[OIML R 137] OIML R137-1&2 Edition 2012 (E), Annex B: Flow disturbance tests, Table B.1 Piping configurations for flow disturbances, 2012, Including Amendment 2014, International Organization of Legal Metrology.

[ISO17089] ISO17089-1:2019(E), Measurement of fluid flow in closed conduits — Ultrasonic meters for gas — Part 1: Meters for custody transfer and allocation measurement, Second Edition 08-2019

[TCC] Trans Canada Calibrations: https://www.tccalibrations.com/; 2022-01

[CPA] Canada Pipeline Accessories, https://www.flowconditioner.com/flow-conditioner; 2022-01

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