INSTALLATION EFFECTS UFM, SKID CALIBRATION, NONSENSE OR NECESSITY?

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1 SUMMARY:

It is common practice to calibrate custody transfer ultrasonic gas flowmeters with dedicated upstream piping and, in a more conservative approach also with a flow conditioner. Argument is this will create repeatable circumstances, meaning the flow profile in the field will be identical to the one seen during calibration. In recent years this approach has been complemented by a new generation of ultrasonic flowmeters that have reported to possess a very limited impact on measurement uncertainty in case of flow profile variations during, for example, OIML R137 disturbance tests.
Despite these arguments a discussion is ongoing whether it makes sense to calibrate entire Z-configuration measurement skids instead of only meters. Thought behind this is it will make the flow profile even more repeatable which could further reduce the measurement uncertainty. To conclude this discussion KROHNE calibrated multiple Z-configuration skids.

In this paper calibration results and flow profiles of the meters before and after installation in the skid will be compared, including a Z-configuration master-duty run with four 90 degree bends upstream of the master meter.

The outcome is mainly related to the balance between the costs of such a calibration in relation to its profit (lower uncertainty).

2 LOWERING INSTALLATION UNCERTAINTY:

Since the existence of (CT) ultrasonic flow meters in the mid 90’s the industry has focussed strongly on the installation effects of ultrasonic flowmeters. In some way it is surprising that installation effects on other type of flowmeters like turbine meters, orifices, mass flow meters, etc. were not so much debated as it was for ultrasonic flow meters. Most likely the ultrasonic flowmeter was setting a new standard for accuracy which made it possible for the first time to detect very small installation effects which leads to more doubts and questions.

The most important question is what the effect is of the “non- ideal” installation compared to the “ideal” calibration. A calibration station should have sufficient inlet length and as such the ultrasonic flow meter should experience a fully developed flow profile. During installation however there is no sufficient inlet length. E.g. the ultrasonic flowmeter is “closely” installed after bends, Tees and/or headers. The ultrasonic flow meter experiences a so-called disturbed flow profile. The transferability from the calibration result to the final installation is the so-called installation uncertainty.

The following solutions are applicable to lower this installation uncertainty:

1. Make sure that the flow profile during calibration and installation are identical or,
2. Use a meter which is unaffected by all sorts of upstream piping conditions.

To satisfy option 1 a flow conditioner is often used. However it has been reported many times that still the flow profiles after a flow conditioner will not be identical and still ultrasonic flow meters will deviate more than specified. Even nowadays solutions with two flow conditioners or a flow conditioner & tube bundle combination are used to create a “more” identical flow profile between calibration and installation. By doing so, unfortunately, also one of the major advantages of ultrasonic flowmeters, no blockage, no pressure drop is lost.

To create a “more” identical flow profile between calibration and installation more upstream piping could be calibrated with the flow meter. But how much of its upstream piping should then be calibrated. An answer could be to calibrate a complete skid.

The second option discussed above is to create an ultrasonic flow meter which is unaffected by different flow profiles. OIML R137, AGA 9 and ISO 17089 introduced type testing with a set of simulated flow profile disturbances by a series of perturbation tests. Some of these disturbances are related to real world circumstances but other disturbances could be regarded as extreme and not practical. But if the ultrasonic flow meter proofs that it can handle all of these circumstances with limited deviation an uncertainty class can be given to this ultrasonic flow meter.

The KROHNE ALTOSONIC V12 ultrasonic flow meter was the first who complied in full to the OIML R137 class 0.5. Nowadays more ultrasonic flow meter manufacturers have these classification however some of them can only meet these specifications if certain tests are excluded (high perturbation test). As such they do not fully comply.

3 MAINTAINING INSTALLATION UNCERTAINTY

If the installation uncertainty is known then from the first day of installation it is important to maintain this uncertainty over time. This can be done by using diagnostics, re calibration, ……. or in-line verification. In this paper the use of in-line verification is addressed by using a z-bridge skid configuration. In Figure 1 such a Z-bridge configuration skid is presented.

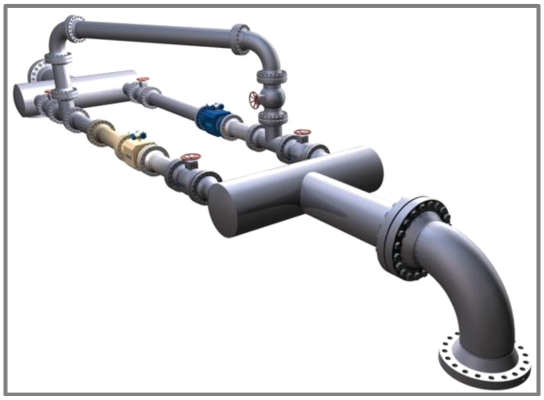

Figure 1: Z-bridge configuration skid

This skid consists of two parallel lines with an in- and outlet header and an interconnection (the Z-bridge) which makes it possible to place the two parallel lines is series.

The skid can be operated in:

1. Normal operation mode:
   The line with the master meter is blocked. Gas is flowing only through the duty meter.

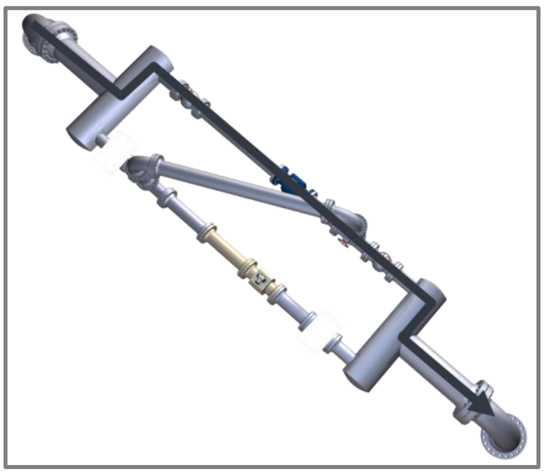

Figure 2: normal operation

2. Verification mode:
   The line with the duty meter and the line with master meter are installed in series by using the Z-bridge. Gas is flowing through the duty meter, across the z-bridge, through the master meter. As such the master meter can verify the duty meter.

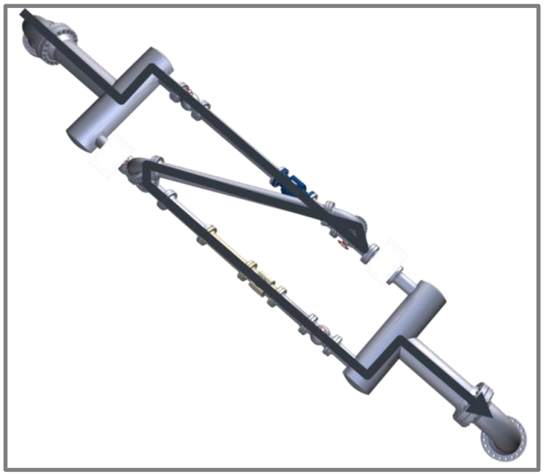

FIGURE 3: VERIFICATION

Clearly this skid will produce a non-ideal flow profile due to the present headers and z-bridge. The effect of such construction on the ALTOSONIC V12, being fully certified according to class 0.5 of OIML R137, is evaluated in the next paragraphs.

4 SKID CALIBRATION RESULTS

4.1 SKID NUMBER 1

The first skid that has been tested is presented in Figure 4.

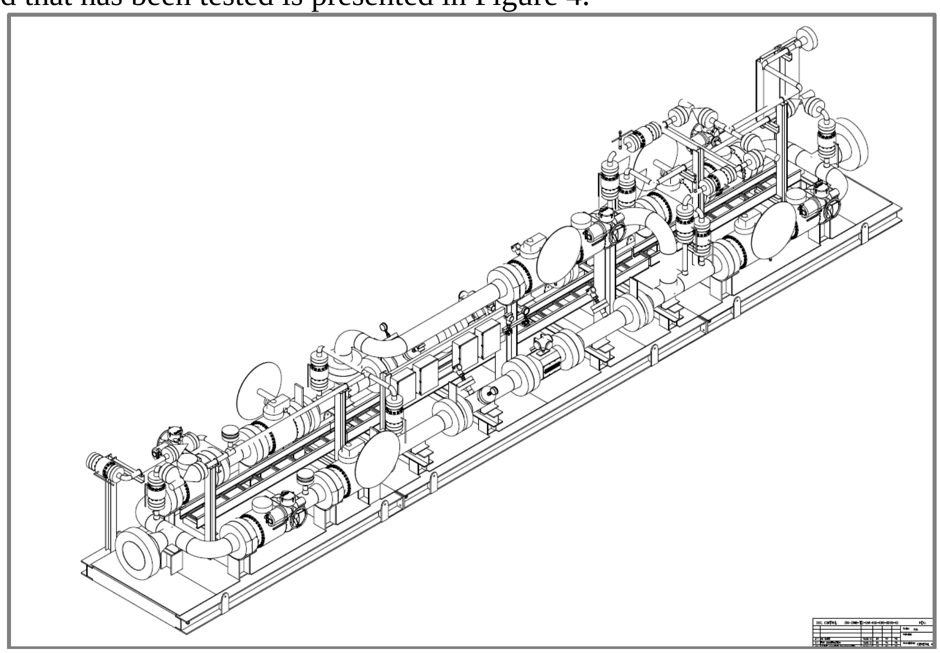

FIGURE 4: SKID #1

Installed are two 8”, 1500 lbs, ALTOSONIC V12 (ref: #55 & #56). Installation details of the meter can be seen in Figure 5. Two flow conditioners are mounted up and downstream of the meter at 5D, making it a bi-directional application. On the inlet two thermowells are positioned, on the downstream side only one thermowell.

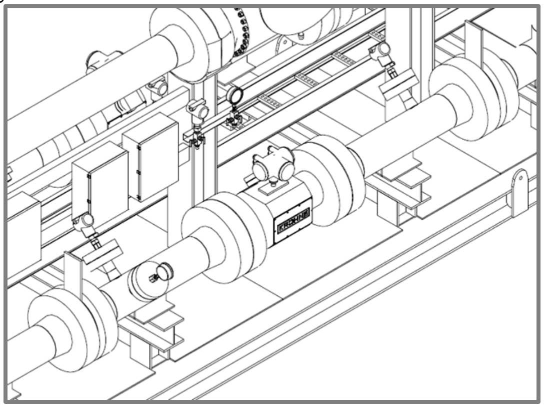

FIGURE 5: INSTALLATION DETAILS OF ALTOSONIC V12

The in Figure 4 presented skid is simplified in Figure 6, the forward flow direction is from left to right.

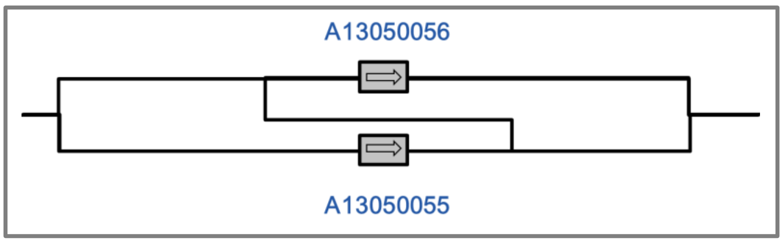

FIGURE 6: SIMPLIFIED SKID CONFIGURATION

The following calibrations were performed at the calibration facility of FORCE Technologies, Vejen, Denmark:

TABLE 1: PERFORMED CALIBRATIONS ON SKID 1

1	Forward (FW) baseline meter #55	7	Reverse (REV) baseline meter #55
2	FW baseline meter #56	8	REV baseline meter #56
3	FW skid direct meter #55	9	REV skid direct meter #55
4	FW skid direct meter #56	10	REV skid direct meter #56
5	FW skid Z-bridge meter #55	11	REV skid Z-bridge meter #55
6	FW Skid Z-bridge meter #56	12	REV Skid Z-bridge meter #56

FIGURE 7 : SKID 1 AT THE CALIBRATION STATION OF FORCE TECHNOLOGIES

4.1.1 FLOW PROFILE DIFFERENCES:

4.1.1.1 Baseline and skid configuration meter #55 (meter #56)

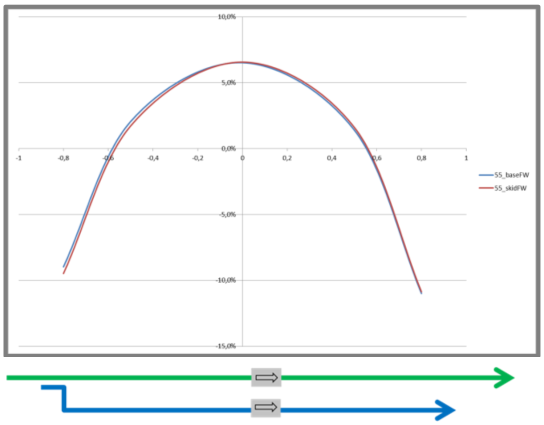

FIGURE 8: FLOW PROFILE DIFFERENCE BASELINE & SKID FW METER #55

In Figure 8 the flow profile of the baseline (with flow conditioner) and when installed in the skid are presented. As to be expected the flow profiles are similar. The difference in FMWE was -0.03% with respect to the baseline.

When the REV baseline is compared to the REV skid of meter #55 the difference in FMWE is only -0.08%. Again the flow profiles are similar (Figure 9).
There is a difference between the forward flow profile (Figure 8) and the revers flow profile (Figure 9). This difference is due to the difference in number of thermowells up & downstream of the meter

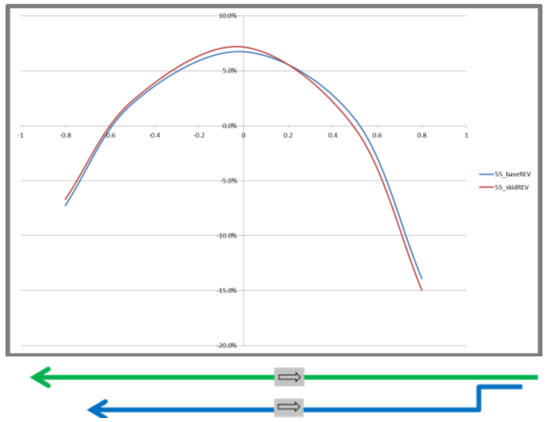

FIGURE 9: FLOW PROFILE DIFFERENCE BASELINE & SKID REV METER #55

Similar behavior can be seen on meter #56.

- Flow profile baseline & skid are similar
- Flow profile forward and reverse are different
- Change with respect to the baseline 0.01% in forward direction and -0.08% in reverse direction

4.1.1.2 Baseline and Z-skid configuration meter #55 & meter #56

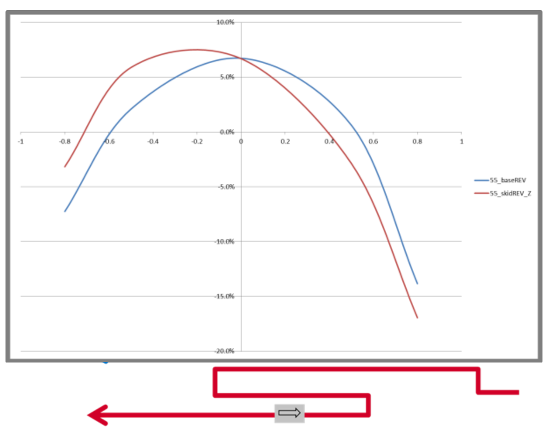

FIGURE 10: FLOW PROFILE DIFFERENCE REV BASELINE & Z-SKID CONFIG METER #55

In Figure 10 the flow profile difference between baseline and z-configuration is presented. In this situation the gas is coming out of the Z-bridge via a Tee shortly before the flow conditioner into the pipeline section of meter #55. Despite the flow conditioning a clear difference in flow profile can be seen in relation to the base line. The FMWE difference in relation to the baseline is 0.12%.

For meter #56 similar flow profile conditions are present in the forward direction using the Z-bridge. The flow profiles are presented in Figure 11. The difference in FWME with respect to the baseline is 0.01%.

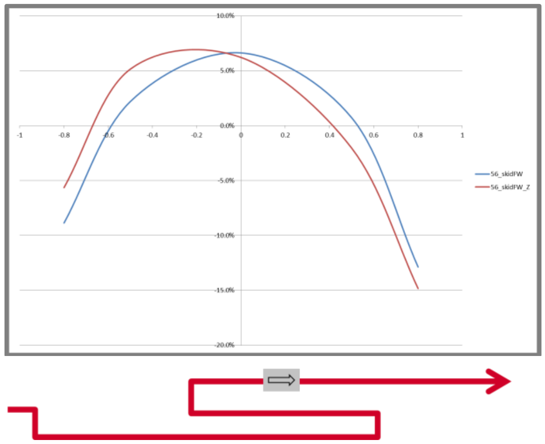

FIGURE 11: FLOW PROFILE DIFFERENCE FW BASELINE & Z-SKID CONFIG METER #56

4.2 SKID NUMBER 2

The second skid that has been tested is presented in Figure 12

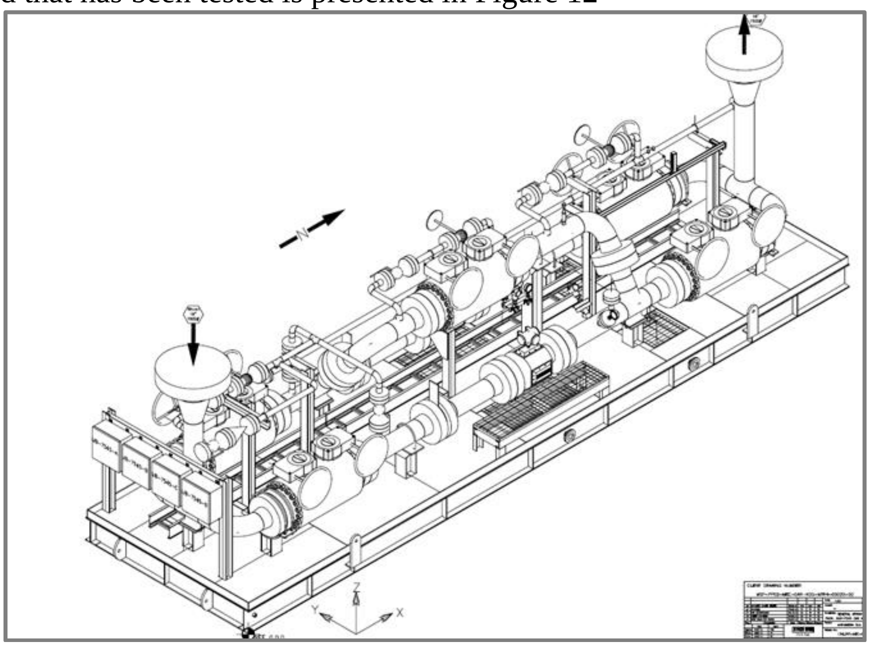

FIGURE 12: SKID #2

Installed are also two 8”, 1500 lbs, ALTOSONIC V12 (ref: #90 & #91). Installation details of the meter can be seen in Figure 13. In this skid only one flow conditioner is mounted upstream of the meter at 5D making the installation unidirectional. Two thermowells are positioned downstream of the meter.

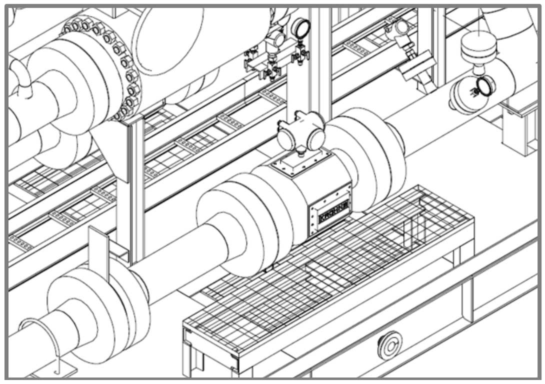

FIGURE 13: INSTALLATION DETAILS OF ALTOSONIC V12

In Figure 14 the top view of the skid (Figure 12) can be seen..

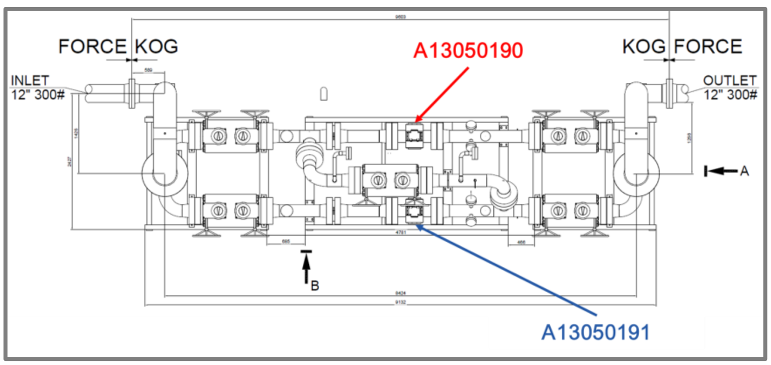

FIGURE 14:TOP VIEW SKID 2

For this skid the total length could not fit within the measuring line as such the skid was positioned next to the main line and a parallel connection was made.

The following calibrations were performed:

TABLE 2: PERFORMED CALIBRATIONS ON SKID 2

1	Forward (FW) baseline meter #90
2	FW baseline meter #91
3	FW skid direct meter #90
4	FW skid direct meter #91
5	FW skid Z-bridge meter #90
6	FW Skid Z-bridge meter #91

FIGURE 15 : SKID 2 AT THE CALIBRATION STATION OF FORCE TECHNOLOGIES

4.2.1 FLOW PROFILE DIFFERENCES:

4.2.1.1 Baseline and skid configuration meter #90 & #91

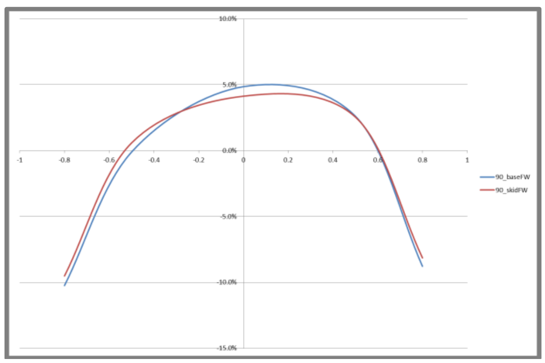

FIGURE 16: FLOW PROFILE DIFFERENCE BASELINE & SKID FW #90

For meter #90, the flow profiles between FW skid direct and FW skid Z-bridge are similar (Figure 16). The difference in FWME is small, +0.05% with respect to the baseline.

For meter #91 similar flow profile differences can be found with a FMWE of -0.03%

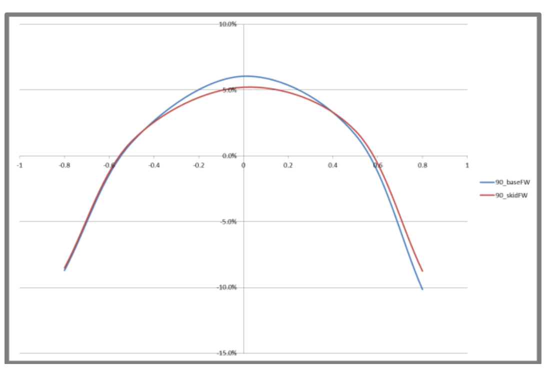

FIGURE 17: FLOW PROFILE DIFFERENCE BASELINE & SKID #91

4.2.1.2 Direct skid and Z-skid configuration meter #90

When skid 2 is operated in Z-configuration the inlet conditions of meter #91 does not change. Only the inlet conditions and flow profiles of meter #90 changes. The changes in flow profile are significant, as can be seen in Figure 18.

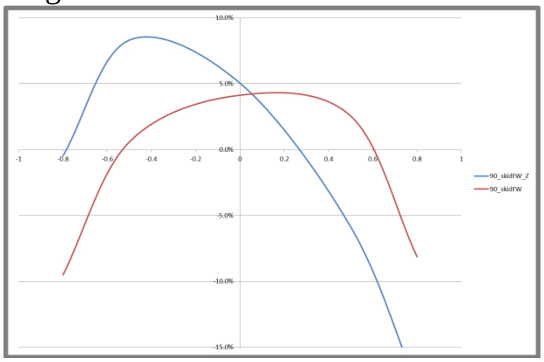

FIGURE 18: FLOW PROFILE DIFFERENCE: DIRECT SKID AND Z-SKID CONFIGURATION METER #90.

Despite the large change in flow profile the FMWE difference is only 0.11%

4.3 SKID NUMBER 3

The third skid that has been tested is presented in Figure 19

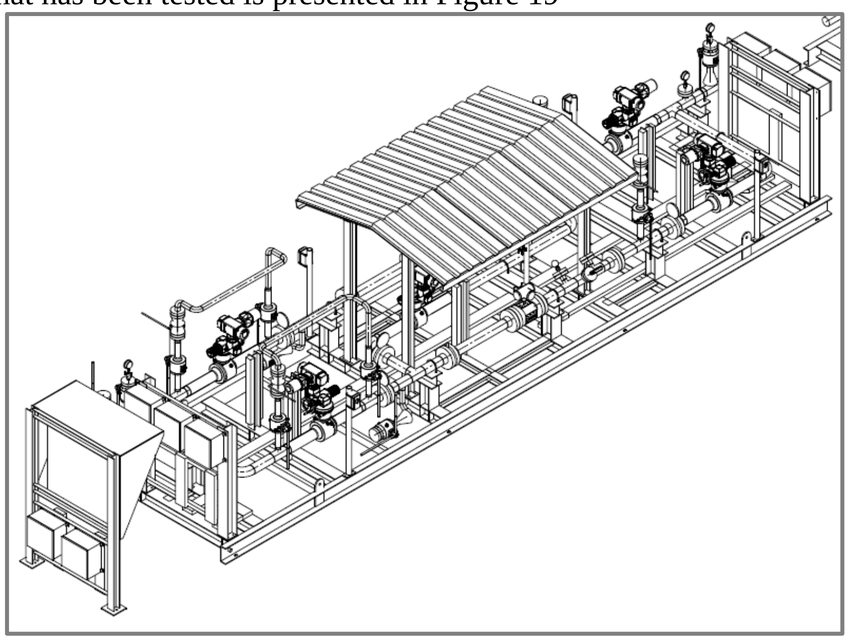

FIGURE 19: SKID #3

Installed are two 4", 300 lbs, ALTOSONIC V12 (ref: #19 & #20). Installation details of the meter can be seen in Figure 20. One flow conditioners is mounted upstream of the meter at 10D (unidirectional). Two thermowells are positioned after the meter.

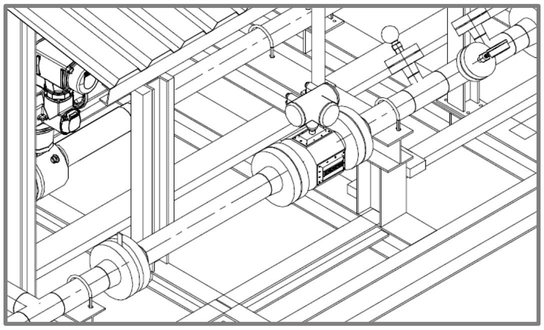

FIGURE 20: INSTALLATION DETAILS OF ALTOSONIC V12

The following calibrations were performed:

TABLE 3: PERFORMED CALIBRATIONS ON SKID 3

1	FW skid direct meter #19
2	FW skid direct meter #20
3	FW skid Z-bridge meter #19
6	FW Skid Z-bridge meter #20

FIGURE 21 : SKID 3 AT THE CALIBRATION STATION OF FORCE TECHNOLOGIES

4.3.1 FLOW PROFILE DIFFERENCES:

In this case only the Skid configuration and Z-skid configuration of meter #20 is interesting to review.

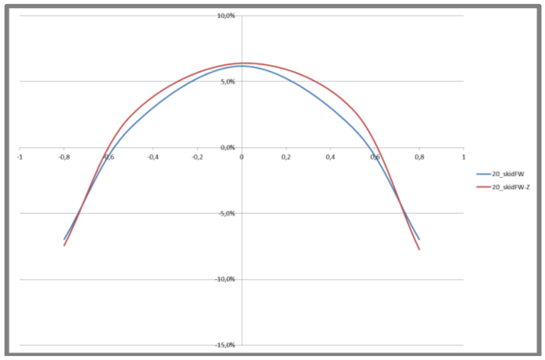

FIGURE 22: FLOW PROFILE DIFFERENCE SKID & A-SKID #20

The difference in flow profile between the skid calibration and the skid calibration with Z-configuration is much less than previous results on skid 1 (Figure 10) & skid 2 (Figure 18). The reason for this is:

- Inlet condition before flow conditioner is longer
- Distance between the flow conditioner and meter is longer
- The Z-crossing stays in one plane

Those adjustments give a reasonable similar flow profile if it is compared Figure 10, Figure 11 and Figure 18. The difference in FWME is negligible, +0.01% with respect to the baseline.

4.4 SUMMARY OF RESULTS

In Figure 23 an overview of the three skid calibrations are given including the OIML class R137 limit of 0.16%

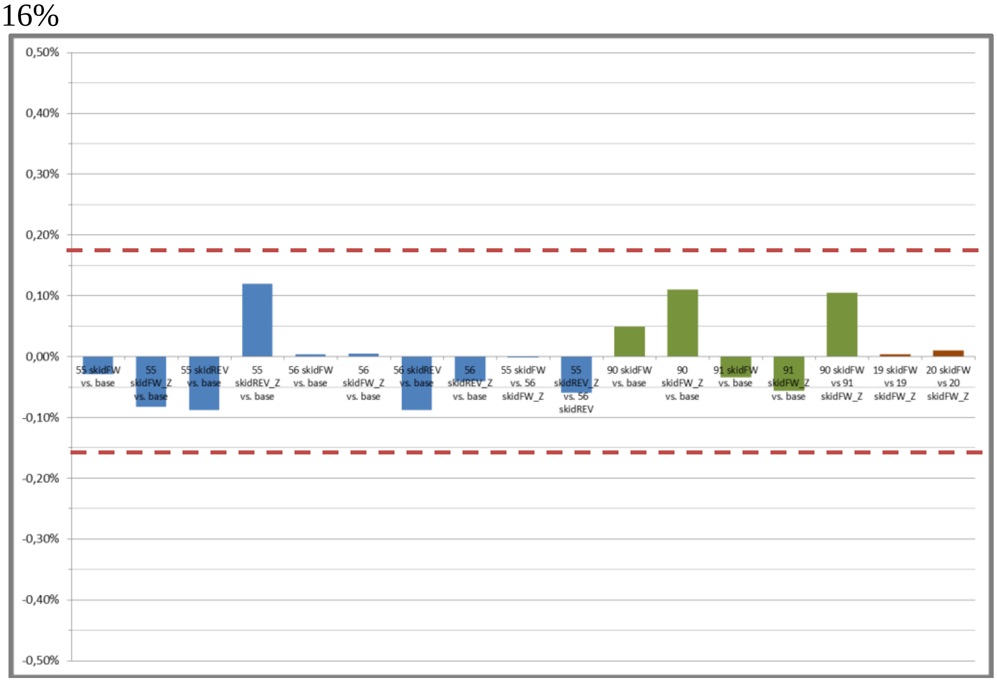

FIGURE 23: OVERVIEW CALIBRATION RESULTS

Clearly all results are within the OIML R137 class 0.5 limit. The largest observed difference were all using the z-bridge configuration with a maximum observed deviation of 0.12%.

5 THE PROS AND CONS

The pros and cons of a skid calibration are:

<u>Pros</u>

- The installation effects will be minimized.
  By calibrating the whole skids instead of a single ultrasonic flowmeter, with or without a flow conditioner, it is assumed that the flow profile during calibration and during installation is almost identical. The installation uncertainty could then be regarded as negligible. In that case, only the reproducibility of the ultrasonic flow meter and of the calibration station plays a part in the uncertainty calculation
- In-line comparison of two meters in z-bridge configuration is known
  When a z-bridge construction is installed, the two meters should be compared during start up. Knowing the changing flow conditions of especially the second meter (after the z-bridge (e.g. Figure 18), a deviation between both meters is to be expected. Based on an installation uncertainty of 0.16% (OIML R137, class 0.5) the difference between both meters could be (k=2 with 95% conf. int.):
  $$\sqrt{0.16\%^2 + 0.16\%^2} = 0.23\%.$$
  If during first installation a similar or lower difference is observed, then this difference should be used for future references. In case the difference is much larger additional evaluation is required before this initial deviation can be used for future references.
  By calibrating the whole skid, the initial difference between two meters in series can be measured under controlled conditions and can be directly used during the first in-line comparison (during start up). Doing this comparison in the field is however almost as good.

<u>Cons</u>

- A calibration of a skid is very costly.
  The price of the calibration done were between 150k€ and 250k€. Those prices are applicable for small meters (up to 8”); also the delivery time will increase.
- For larger size skids it is almost impossible to calibrate.
  The costs increase significantly, the handling and transportation will be more and more difficult and most likely no availability of a calibration station.
- Recalibrating a skid.
  Sending the complete skid back for re-calibration is almost not doable. The solution used for skid 1 and 2 is to make a baseline of the metering package (meter, inlet and flow conditioner) before calibrating the whole skid. As such only the metering package could be sent back to calibration station for recalibration. The assumption is that any observed differences between initial and re-calibration is also applicable for all other installation effects within the skid, which is debatable.

If it is nonsense or a necessity is based on which of the above mentioned “pros” and “cons” will have the overhand. It is in general costs against lower installation uncertainty. Keep in mind that the lowest installation uncertainty is limited by the repeatability.

When reviewing the results as presented in Figure 23 the following statements on uncertainty and repeatability are applicable:

1. It is logical that the largest deviations occur during the z-bridge operation on the second meter positioned after a z-bridge. These results for the short coupled flow conditioner installation were slightly above 0.1%. All others were well below 0.1%

2. From the results the repeatability can be evaluated. The following calibrations had identical installation conditions during different calibrations.
   a. Skid 1: FW skid direct meter #55 & FW skid Z-bridge meter #55
      Difference: -0.06%
   b. Skid 1: REV skid direct meter #56 & REV Skid Z-bridge meter #56
      Difference: +0.05%
   c. Skid 2: FW skid direct meter #91 & FW Skid Z-bridge meter #91
      Difference: -0.03%
   d. Skid 3: FW skid direct meter #19 & FW skid Z-bridge meter #19
      Difference: +0.01%

   A repeatability of +/- 0.05% seems to be applicable.

Almost all calibration results seem to lie close or even below the repeatability band except for the Z-cross installation results. So it seems to be profitable to calibrate the skid for these situations. However the objective of the Z-configuration is to initially measure within its final installation what the deviation is between both meters is (0,23% for 95% confid. int.). So after first comparison the observed deviation is regarded as the new reference point. As such the installation uncertainty for future references becomes negligible.

6 CONCLUSION: NONSENSE OR NECESSITY?

The ALTOSONIC V12 is known about its lowest installation uncertainty. Already in 2009 the ALTOSONIC V12 complied with the class 0.5 of OIML R137 without any exceptions on the high perturbations and without the use of a flow conditioner.

A. In normal operational mode the observed deviations of the ALTOSONIC V12 during the skid calibrations were lower or close to the repeatability band. Calibrating the ALTOSONIC V12 within the skid does not have any improvement.
B. In Z-bridge configuration the maximum deviation observed of the ALTOSONIC V12 was 0.07% outside the repeatability band. But as soon as the initial Z-configuration will be put in operation this installation effect will be removed as well. It has limited value to know this deviation during the skid calibration.

The conclusion is: Skid calibration has limited effect. So it is **NOT a necessity** (with an ALTOSONIC V12). If it is nonsense, I will leave that open to the end-user. At least there is no true technical base to perform a skid calibration but end-users tend to look for some sort of security. A skid calibration can give this feeling of security but if it is worth the money? I have my doubts.

7 EPILOGUE: FOOD FOR THOUGHT

The new generation of ultrasonic flow meters has set a new standard. This report shows very low uncertainties of 0.1% and repeatability of 0.05% in challenging installations. While at the same time the calibration facilities present uncertainties of 0.15% up to 0.3% and repeatability also around 0.05%.
On top of that the ultrasonic flow meter is at this moment the most tested meter in many different situations, installation and application wise. And still the technique is questioned.

For an ultrasonic flow meter manufacturer it is surprising to notice how other flow measurement techniques are relatively easily accepted without any of the questions like: What are the flow profile influences of mass flow meters or a positive displacement meter? What is the fouling effect on orifice and vortex meters? What is the temperature effect of a turbine meter? Why questioning ultrasonic flow meters on many different topics and accept other techniques easily?

Of course the other techniques exist for many years. Long before the ultrasonic flow meters even exist. But still why not ask the same questions for other techniques. Is this because the other techniques are more mechanical and easier to understand? Maybe ultrasonic is magic and as such always questionable: “How do they do that?”

Nevertheless large steps have been taken with custody transfer ultrasonic flow measurement and the doubts and questions of our customers has let to new insight and new improvements. The new generation of ultrasonic flow meter and particular the ALTOSONIC V12 has proven its capabilities in many ways to guarantee high accurate easurement in many circumstances. How about the others?

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.