# Proving ultrasonic flowmeters with small volume provers

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## 1. Introduction

Custody transfer flowmeters for hydrocarbons may have to be calibrated or verified in the field using provers. Provers come in several variants. There are provers with a large volume. These ball or pipe provers are generally stationary. In some regions mobile provers are used for reasons of flexibility or based on available space. For practical reasons mobile provers can be small volume or compact provers. Also stationary or mobile master meters may be used for calibration and/or verification.

In North America ultrasonic flowmeters must be proven in the field as there are no regulations to control the installation effect or viscosity (Reynpolds) dependency. For proving of ultrasonic flowmeters in the field API chapter 5.8 was created.

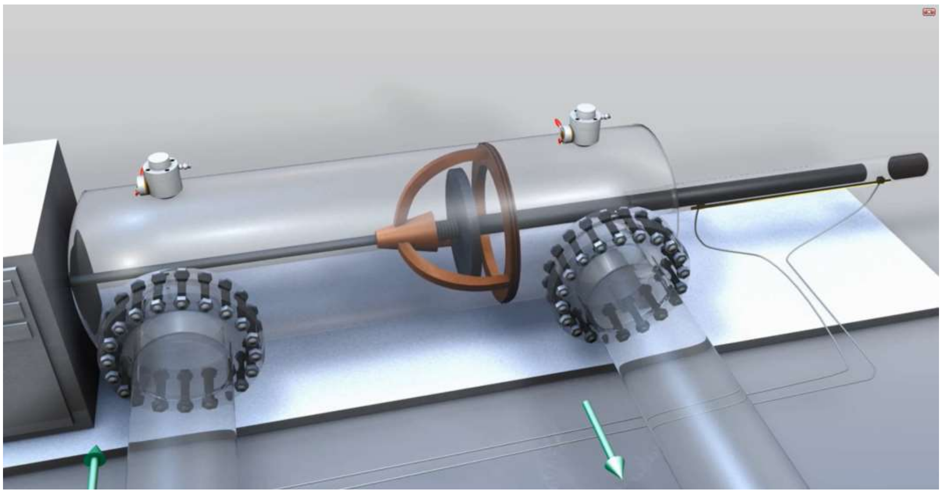
| Runs | Repeatability Band % (R) | Uncert. % |
|---|---|---|
| 3 | 0,02 | 0,027 |
| 4 | 0,03 | 0,027 |
| 5 | 0,05 | 0,027 |
| 6 | 0,06 | 0,027 |
| 7 | 0,08 | 0,027 |
| 8 | 0,09 | 0,027 |
| 9 | 0,10 | 0,027 |
| 10 | 0,12 | 0,027 |
| 11 | 0,13 | 0,027 |
| 12 | 0,14 | 0,027 |
| | | |
| 20 | 0,22 | 0,027 |

*Table 1: Relation between runs, repeatability and uncertainty (API chapter 5.8)*

In 2007 KROHNE started to test its liquid UFM CT meters for calibration with small volume provers including compact provers. This provided a positive result but required careful tuning of the compact prover and/or setting off certain conditions that would not be practical (e.g. high number of passes/runs).

# 2. Issues of proving ultrasonic flowmeters with compact provers

Different than a turbine meter which directly measures volume, the ultrasonic flowmeter is a flow speed meter. It measures the flow speed at a certain location in the tube at a specific moment in time. Multiple results of multiple paths are combined into one volume flow and averaged over time. Finally the result is integrated into a totalised volume.



*Detail of a compact prover, left the input connection and right the output connection. In the main pipe cylinder the piston (plunger) with the poppet valve closed, moves from left to right (1 pass) and back (with poppet valve open).*

With a movement of the plunger of a compact prover some dynamic effects occur that influence the result of the ultrasonic flowmeter. In particular with the start and stop of it combined with the opening and closing of the poppet valve. This mainly results in an increase of on the short term repeatability of the ultrasonic flowmeter.

Tuning and adjustment of the compact prover, which is specific to its design, may be required to reduce dynamic effects. For example the plenum pressure can be adjusted. A lower pressure results in a smaller dynamic effect and thus a better repeatability. However as the poppet valves closes slower the liquid slippage increases and an offset in the K-factor will occur. A higher pressure will prevent this but will increase dynamic effects. With a proper tuning a good calibration result can be obtained as has been shown in tests.

A second issue that is specific for electronic flowmeter is that the pulse output is created via software also called “manufactured pulses” (with a mechanical meter the pulses are generated using a pick-up and are as such “natural”. There may be a delay between the volume passed and the occurrence of the pulse generated for it or even a pulse generation completely asynchronous from the volume passed. This can also be a source of variation of the volume counted for one pass.

A third issue is the resolution of the pulse output provided by the flowmeter. As the time of one pass can be below 1 second, partial pulses may have to counted. This is a general issue. Although this can be solved in several ways, this can be completely removed with an electronic flowmeter if it provides a sufficiently high pulse frequency.

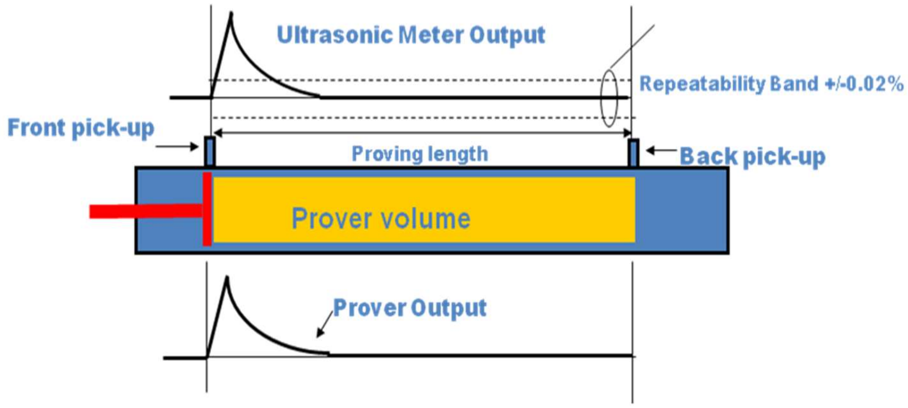



*Figure 2: Dynamic effects during start of plunger of a compact prover*

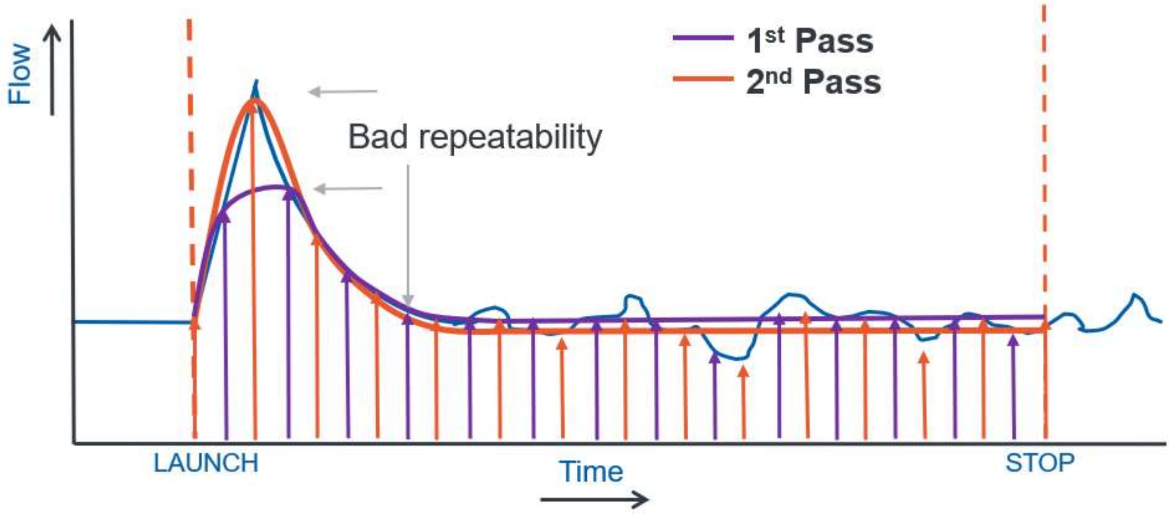



*Figure 3: Bad repeatability as a result of too low sampling rate*

# 3. The solution

To create repeatable results between measurements (passes/runs) independent of the fluid conditions and specific behaviour of the compact prover the ultrasonic flowmeter must be fast enough to make a complete recording of the dynamic effects that are occurring.

Fortunately processors for digital signal processing have become available to increase the speed of the ultrasonic flowmeters. This means that the interval between individual ultrasonic transit time measurements has been reduced and more measurements are done per unit of time.

The ALTOSONIC 5 has been developed using latest available digital signal processing technologies.

The electronics for this flowmeter has been designed to be flexible with regards to the number of paths. The standard for the ALTOSONIC 5 is a configuration with 7 paths in a parallel (chordal).

In ultrasonic flowmeters only one transit time is measured at a time. The interval between 2 measurements is determined by the transit time and the signal processing time. The transit time is determined by the path length and the velocity of sound of the fluid and thus can not be changed. The processing time which always was longer, has been reduced however by increasing the processor capacity.

By doing this the interval between 2 single transit time measurement has been reduced with a factor of 10.

Also the processing of the individual measurement results in to a pulse signal was made fast enough to be real time with the proving process. Every time a transit time different is processed into an individual flow result it is included in the moving average of the general flow result.

Finally a sufficiently high pulse frequency (e.g. 10 kHz) is used to provide a good enough output signal resolution so the receiving flow computer does not to miss any part of the relatively small volume included in one pass.

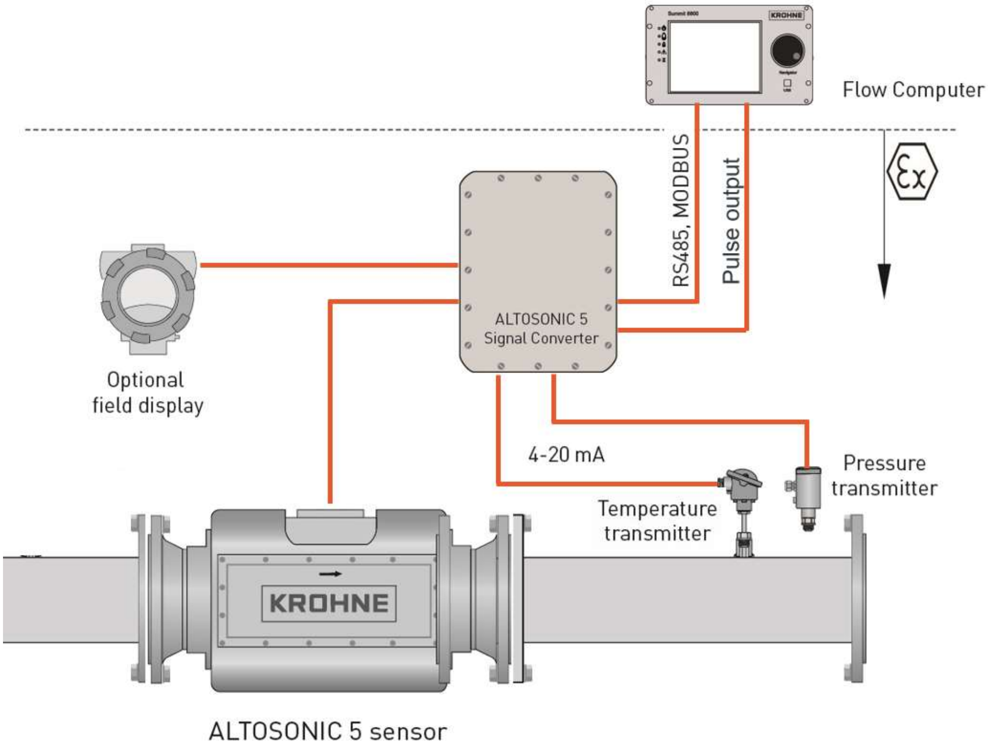



*Figure 4: ALTOSONIC 5 including a flow computer that controls the proving process.*

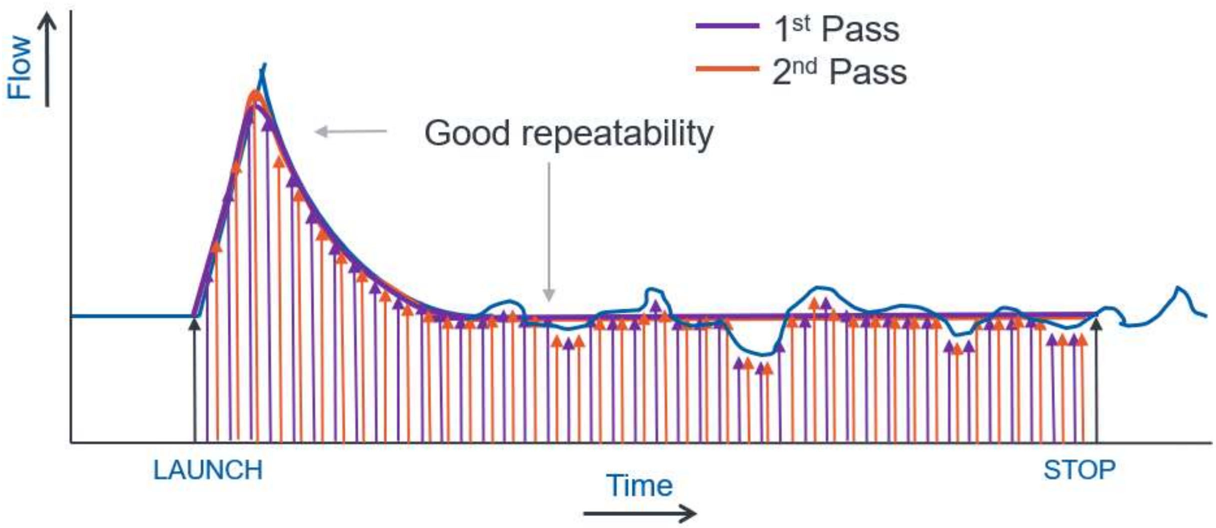



*Figure 5: With a sufficiently high sampling rate the repeatability between passes is improved*

As the sampling rate is sufficiently fast, all dynamic effects are detected by the ALTOSONIC 5, which is the basis a sufficiently good repeatability to achieve a good proving result with compact provers.

# 4. Testing and results

In the past years several calibrations were executed with good results. Below some results of tests are shown:

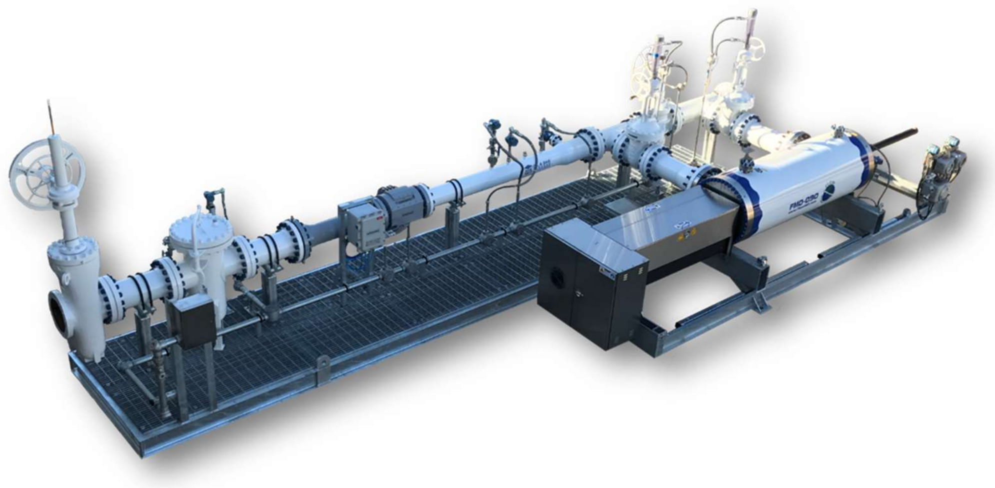


*Figure 6: Test setup of the ALTOSONIC 5 with the compact prover downstream of it.*

- Line size : 8 inch
- Base volume SVP : 284 litres
- Max flowrate : 800 $m^3$/hr
- Velocity A-5 : 3,5 and 7 m/s
- Number of runs : 5
- Passes per run : 3
- Criterion : API
- Medium : water

| Flowmeter size (inch) | SVP Base Volume (litres) | Flowrate ($m^3$/hr) | Pass duration (sec) | Number of passes/run | Number of runs | Avg Pulses per run | R (%) | Uncertainty (%) |
|---|---|---|---|---|---|---|---|---|
| 8 | 284 | 800 | 1.3 | 3 | 5 | 8920.7 | 0.039 | 0.012 |
| 8 | 284 | 800 | 1.3 | 3 | 5 | 8918.6 | 0.040 | 0.015 |
| 8 | 284 | 400 | 2.6 | 3 | 5 | 8936.3 | 0.050 | 0.018 |
| 8 | 284 | 400 | 2.6 | 3 | 5 | 8937.6 | 0.048 | 0.014 |

*Table 2: test results SVP test on water*

All results are in compliance with API Ch 5.8 uncertainty criterion.

- Line size : 8 inch
- Base volume SVP : 151,4 litres
- Max flowrate : 800 $m^3$/hr
- Velocity A-5 (m/s) : 1,75; 3,5; 7
- Number of runs : 5
- Passes per run : 5
- Criterion : API
- Medium : Oil, 1cSt

*Figure 7: test setup at Euroloop with a Honeywell compact prover*

| Test | Flowrate (m3/h) | Passes per run | Required consecutive runs | Repeatability result |
|---|---|---|---|---|
| 1 | 200 | 5 | 5 | 0,029 |
| 2 | 400 | 5 | 5 | 0,042 |
| 3 | 800 | 5 | 5 | 0,046 |

*Table 3: test results show a repeatability below 0,05% as is required for 5 runs to comply with API Chapter 5.8.*

Analysis: The volume of the compact prover is only 151,4 litres, which is quite small for the flowmeter diameter and flowrates to be tested. As a result more passes (5 instead of 3) were required to meet the uncertainty requirement.

## 5. Conclusion

Proving of an ultrasonic meter with a compact (small volume) prover is very well possible, provided that the processing speed of the ultrasonic flowmeter is fast enough.

Given the flowmeter diameter and flowrates, the right volume of the compact prover must be selected. Rule of thumb is that the measurement time for one pass is at least one second.

Even with a smaller volume of the compact prover, a good result can be achieved however more passes per run may be necessary.