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TESTRESULTS KROHNE 8" ULTRASONIC FLOWMETER

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SUMMARY

A new development in the field of ultrasonic liquid flowmeasurements has resulted achieved with the multichannel liquid ultrasonic flowmeter; the first for use in maintenance-free custody transfer applications. Although ultrasonic flowmeters are used for standard applications in the oil industry for many years, this new development will have a big impact on custody transfer flow measurement. Not only because of the compactness, but also because of the low investment and operating cost of this flowmeter. This paper describes the system and the method of operation as well as practical experiences and achieved test results of this flowmeter.

PART I THEORY OF OPERATION

1. GENERAL BACKGROUND

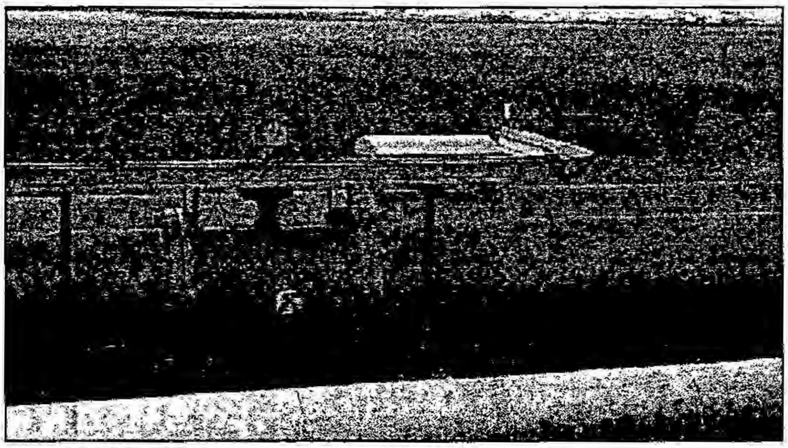

Figure 1: Double beam ultrasonic flowmeters in use in an pipeline sampling system

The development of a multichannel ultrasonic flowmeter was started some 3 years ago. It was based on the 15-year long existing practical experience in the field with single and dual beam ultrasonic flowmeters. Today many ultrasonic flowmeters (mainly dual beam technology) are used in a wide variety of applications in the oil industry.

Examples are applications in which ultrasonic flowmeters are used in batch representative sampling systems (see fig. 1) in (crude oil) blending applications or in pipeline transport. The experience gained in those applications was an important ingredient in the development of the multichannel ultrasonic flowmeter, which was aimed at reaching higher accuracies (linearity and repeatability) to within custody transfer specifications, even under rough process conditions and in a wide range of viscosities, densities, temperatures and pressures. In fact, when using such a multichannel flowmeter, a water calibration only should be sufficient to characterise the flowmeters behaviour also when used afterwards on other, higher viscous, liquids. How, in practical situations, this flowmeter performs is described in this paper.

2. SYSTEM AND THEORY OF OPERATION

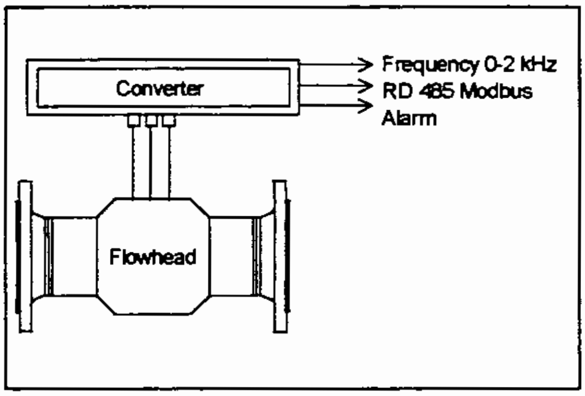

Figure 2: Total system

The newly developed ultrasonic multichannel flowmeter for custody transfer applications uses the well-known transit time, or time of flight, principle to measure the flow velocity. It consists of two main components. These are the flowmeter tube (flowhead) and the field mounted electronics (converter). The flowmeter system can be used like any other conventional flowmeter, i.e. pulses as output that represent a certain flow volume under operating conditions. Next to the flow information this system can also provide additional valuable status and process data. This will be discussed when dealing with the system layout in detail.

3. THE FLOWHEAD

The flowhead consists of a middle part made from a solid block of metal that holds the acoustic measurement paths. To this middle part an in- and outlet cone, with flanges, are welded. The flowmeters construction is symmetrical which means it can measure bi-directional flows. The cones play an important role in the shaping of non-axisymmetric flowprofiles, ensuring a symmetrical flowprofile inside the measurement section of the flowhead, which is also supported by earlier research (e.g. Teijema [1]). The angle of the cones is chosen such that a negligible pressure drop, identical to 2 m of straight pipe run, remains. With respect to the number and location of the measurement beams consideration was taken with respect to the requirements of insensitivity of flowprofile shape (transition from laminar to turbulent flowregimes, symmetricity), swirl and redundancy of information. This resulted in a flowhead with 5 measuring paths. With one measuring path in the centre and the other four two by two symmetrically aligned. Two paths of the five are turned by 90 degrees allowing for a swirl measurement.

4. THE FIELD MOUNTED CONVERTER

The field mounted converter consists firstly of the electronics for driving the sensors in the flowtube and secondly holds an electronic block that combines all data coming from the 5 individual measurements lines into an average volumetric flowrate, overall viscosity and status of the instrument. The driving of the sensors (10 in total, 2 per measurement line) is done in parallel. Each individual measurement line has its own driving electronics. Each driving electronics measures the flowvelocity for its measurement line every 40 msecs.

Thus consequently every 40 msecs 5 flowvelocities, representing the flowprofile, are sent to the supervisory electronic block for further processing. Next to the high measurement rate these 5 driving electronics also represent a certain redundancy. Comparison of the sonic velocities measured per measurement line (5 times) allows the supervisory system to detect failures of the driving electronics, when not already detected by the driving electronic itself.

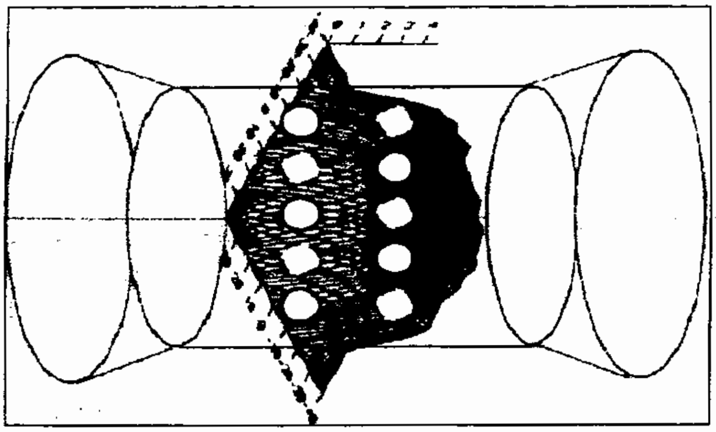

Figure 3: Flowhead with 5 measuring paths

Also checks on the shape of the flowprofile are performed. Should one, or even two, measuring paths fail then, using the redundant information, the correct value will be interpolated allowing the instrument to continue to measure. Additionally continuously the swirl component in the flow is measured and compensated for, when within tolerances. The outputs coming from this field mounted electronics are two phase shifted pulse outputs 0-2 kHz, a digital RS485 output with MODBUS protocol and status outputs. These outputs allow the ultrasonic multichannel flowmeter to be connected to many flowcomputers in use today.

5. PRACTICAL EXPERIENCE

During the development of this system a number of prototypes were constructed. Many tests were performed to investigate the behaviour of the flowmeter on non-symmetric flowprofiles, liquid viscosity change and temperature. During the development stage these in-house tests all showed very promising results upon which external tests were started. The fist test, still in operation, was installed October '95 at DOW Chemical Terneuzen.

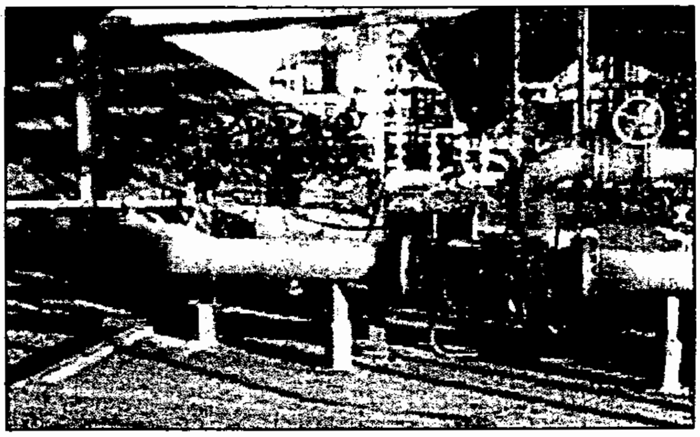

Figure 4: Dow Chemical Terneuzen

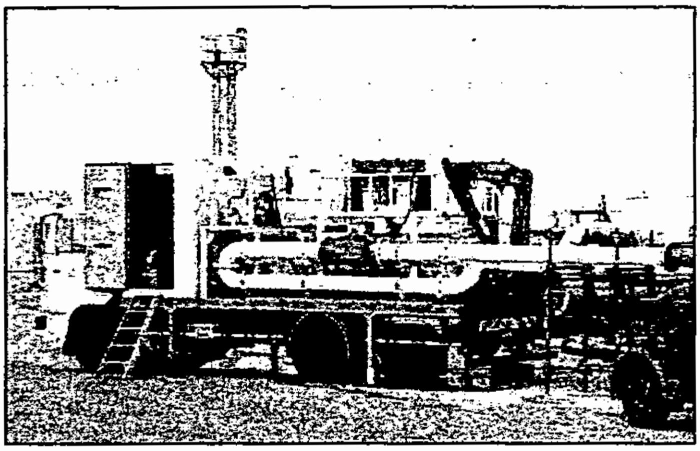

Figure 5: Nerefco Europoort

There cumene (viscosity 0.7 cSt.) is measured in a 10" pipeline ship loading application. The flowmeter is in operation since December 1995 and the flowmeter output is compared to the ship measurement. A second important set of measurements was obtained at Shell Pernis, where an 8" flowmeter was calibrated against a ball prover on liquids such as gasoline and naphtha. The results obtained here proved that the flowmeter could work well within the requirements set by the NPD.

With this as background a plan was devised to calibrate one flowmeter on water which would then be calibrated in the field on various hydrocarbons in a wide viscosity and temperature range. Since these tests were going to serve as input for the custody transfer type approval of this instrument the Dutch authorities, the NMI, were invited to witness all tests.

PART II TESTRESULTS

6. INTRODUCTION

In 1996 KROHNE Altometer contacted NMi to inquire about the legal requirements applicable to their ultrasonic flowmeter both in Norway and in The Netherlands. The purpose of this inquiry was to establish the possible necessity of changes in the construction and functionality of the meter, which at the time was still under development.

The legal requirements in Norway are stated in the NPD (Norwegian Petroleum Directorate); the legal requirements in the Netherlands are stated in the "Weights and Measures Act", which is very similar to OIML International Recommendation R117. When studying both documents, one can observe that if the device meets the requirements stated in the NPD, also compliance with OIML R117 is achieved.
In short this means:

- the meter accuracy has to better than ± 0.2 % for the complete flowrange ± 0.15 % for the flowrange is which the meter is intended to be used most
- the repeatability error has to be smaller than ± 0.2 %
- the correctness of datatransmission and calculations has to be guaranteed from the wetted parts to the BOL (Bill of Lading).

7. TESTREFERENCES

Depending on the application, compliance with several "legal" documents is mandatory for the US-meter. The requirements stated in OIML International Recommendation R117 usually cover National requirements applicable in many countries.

In Norway two sets of requirements are operational at present. The NPD has formulated a document, which applies for offshore measuring systems, including systems installed in pipelines that run from oil/gasrigs in the Northsea to refineries and factories on the mainland. Although harmonisation is in progress, there still are significant differences between OIML R117 "Measuring systems for liquids other than water" and "Regulations relating to fiscal measurement of oil and gas etc." issued by the Norwegian Petroleum Directorate.
The main differences are:

- Accuracy, repeatability and linearity requirements stated by NPD are stricter
- Accuracy, repeatability and linearity requirements stated by NPD apply to measuring device, without correction device
- According to NPD, all computerparts, which have a meteorological influence, must be provided in duplicate

Other, less significant, differences can be overcome by small adaptations in the testprocedures, thus achieving compliance with both R117 and the NPD-regulations.
See the Norwegian Petroleum Directive and OIML International Recommendation R117 for more detailed information.

8. TESTMETHOD

Unless otherwise stated all tests have been performed under the following conditions:

- measuring device mounted rigidly
- inlet: 20 D straight pipe
- outlet: 10 D straight pipe
- ambient conditions: varied
- testfluid(s):

Name	**Viscosity [cSt]**
Fuel oil	125 at 66 °C
Light cycle oil	1.5 at 70 °C
Water	1 at 8 °C

The accuracy of the meter has been determined at several (five or six) flowrates between the minimum and maximum flowrate. At each flowrate at least 5 measurements have been performed. All testequipment used, was certified.

9. TESTEQUIPMENT

In all of the accuracy tests performed thus far, a 24" Brooks compact prover has been used as a reference. During testing it turned out that the US-meter had an unexpectedly high repeatability value. In the near future extra tests will be carried out to establish the exact cause of this phenomenon.

At the moment the cause is thought to be one of the following:

- In contrast to conventional measurement principles, the US-meter picks up every change in liquid-conditions (pressure waves caused by opening and closing of valve) because of the high speed of the electronic processing of the measurement signals. How the sample-time, flowrate and pulse-interpolation interact is, at the moment, still to be found out.
- The way that the meter-pulses are generated.

Preliminary investigations show that a sufficiently high number of runs eliminates this problem. In future research the US-meter will be tested against a larger prover and a calibrated turbinemeter to eliminate the influence of typical compactprover properties. Tests on KROHNE Altometer's installation (testvolumes up to 10 m3), using water, show a repeatability error better than 0.05% on five consecutive measurements.

10. TEST SETUP

During the tests on Fuel oil and Light Cycle oil the testequipment was set up as given below.

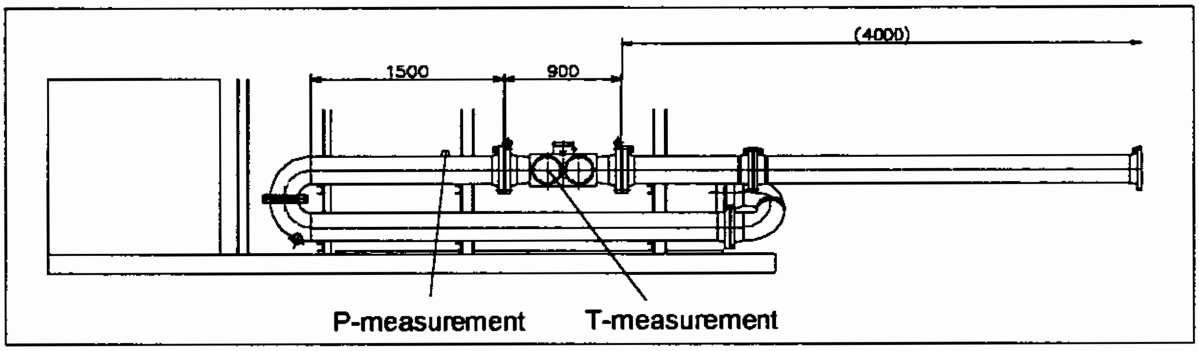

Figure 6: Testequipment

11. ACCURACY TESTS

OIML International Recommendation R117 and the NPD state the following values applicable to the accuracy tests on a measurement transducer installed in pipelines:

Document	Accuracy [%]	Repeatability [%]	Linearity [%]
OIML R117 (0.1 to 1 Qmax)	± 0.20	0.08	± 0.20 (*)
NPD (0.1 to 1 Qmax)	± 0.25	± 0.02	± 0.25
NPD(**)	± 0.15	± 0.02	± 0.15

(*) OIML R117 states that the measurement transducer meets this requirement, including a correction device.

(**) Flowrange in which the meter is commonly used

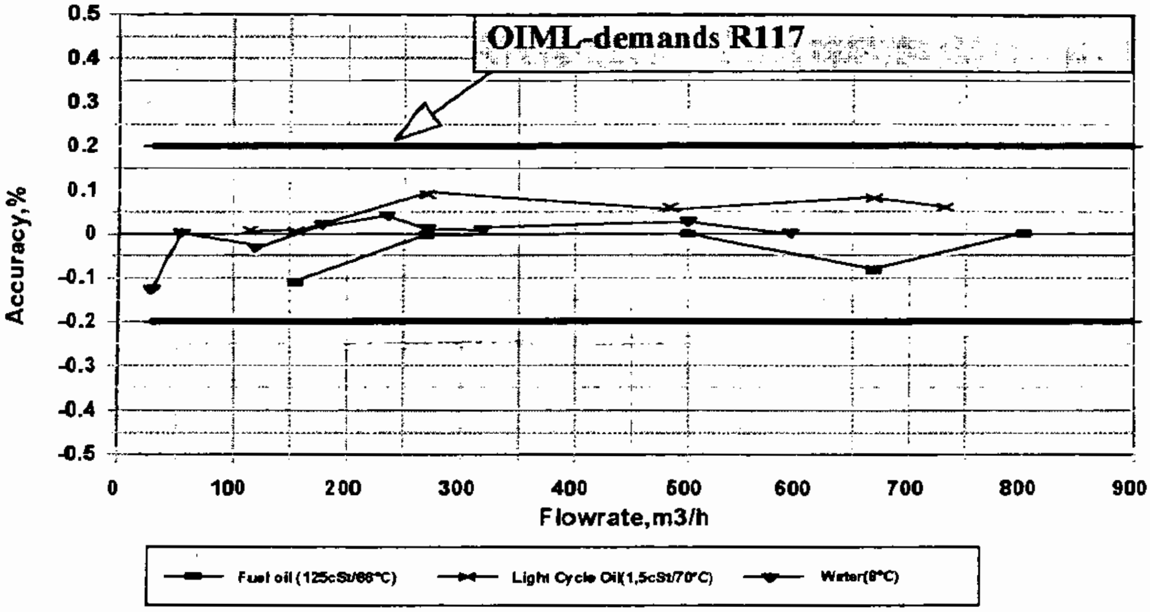

Figure 7: Testresults accuracy

During one test (1 run consisting of 84 strokes of the prover) the liquid-temperature did not vary by more than 0.2 °C and the liquid-pressure by no more than 0.15 bar. Because of the built in viscosity correction, as illustrated by Mr. André Boer, the meter characteristics prove to be almost independent of liquid-properties and flow profile. Even the transition from a turbulent to a laminar flowprofile has a negligible influence.

12. OTHER TESTS

Other tests that have been performed thus far are:

Description	Required by ...-regulations	Passed Yes/No
Dry heat	OIML / CE	
Cold	OIML / CE	
Damp heat	OIML / CE	
Power voltage variation	OIML / CE	Yes
Short time power reductions	OIML / CE	Yes
Bursts	OIML / CE	Yes
Electrostatic discharge	OIML / CE	Yes
Electromagnetic susceptibility	OIML / CE	Yes
Surges	CE	Yes
Emission	CE	

13. CONCLUSIONS

The KROHNE US-flowmeter meets the requirements applicable to the measurement of liquids for Custody Transfer purposes.

REFERENCES

[1] Teijema, J., "Nieuwe inzichten flowmeterinstallatie", Syllabus of workshop "Flowmeting : nu en morgen", KIVI/NIRIA/MRBT, Amsterdam, October 1990