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Norwegian Society of
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NORTH SEA FLOW METERING WORKSHOP

Rica Maritim Hotel, Haugesund
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"Full Bore Continuous BS&W Measurement and Fiscal Metering"

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FULL BORE

CONTINUOUS BS&W MEASUREMENT

AND

FISCAL METERING

Foreword: The only accepted method for water content measurement in the oil industry is flow proportional automatic sampling followed by laboratory tests. The method obviously has many inherent problems. It gives no real time information such that the measurement results are only available long after the transfer has taken place. Often it gives rise to disputes about how many "grabs" should be used and arguments about its validity is non uncommon. Results are affected by equipment, people, procedures, transportation and mixing. It is not very reliable **and it is definitely not high technology.**

Fortunately, there now exists a new technology capable of continuous measurement of water in crude with an accuracy better than that prescribed by current fiscal requirements. Its repeatability is better than 0.003% and being automatic, its reproducibility is the same.

This paper has previouly been presented at the Fourth Annual Seminar on Pipeling Protection & Maintenance Sept. 19th and 20th in Stavanger this year. It has also been presented at the Workshop on Hydrocarbon Analysis and Sampling in Haugesund, 26. -27. Sept. also this year. It gives non-proprietary information about the technology and results obtained. A separate paper to be presented at The North Sea: "Flow Metering Workshop" Oct. 24, 1989 in Haugesund, Norway, will present results from recent test runs witnessed and confirmed by representatives of BP British Petroleum Co.

ABSTRACT: This paper descibes a revolutionary technology that makes possible a 3-phase metering system - composition and flow.

Statoil has funded the R&D of a new and unique high frequency electromagnetic technique for accurately determining the complex dielectric constant of solids, liquids and gases. The technology has been demonstrated by rigorous testing of industrial prototypes. Combined with conventional density measurement it becomes the only real technology in the world for building a full bore (2 to 36 inches and larger) multiphase meter for continuously measuring the quantities of produced oil, water and gas without separation. No probes obstruct the flow and no special liners are required. *All research has been completed.* What remains is engineering, assembly and full scale field tests. The exclusive world wide commercial rights to this technology have been licensed to Fluid Monitoring System, Inc., USA of which Hitec A/S, Stavanger, Norway is a part owner.

State-Of-The-Art MONITORING SYSTEMS FOR MULTIPHASE FLOWS

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In a host of processes involving solids, liquids, gases and mixtures thereof where the components and mixtures may be stationary, moving in batches or flowing continuously, there are needs for accurate, relatively inexpensive composition monitoring means and methods. Further, it is often desirable that these monitoring means be capable of working in-line with the processes to avoid process detours or by-passes for monitoring reasons and that the monitor be non-intrusive so as not to interfere with the processes being monitored and/or to prevent the monitoring means from being degraded by, for example, processes that are highly corrosive and/or erosive.

Typically such composition monitoring needs are related to the qualities and quantities of products being bought and sold, products being produced or of products being stored. Equally great are the needs for composition monitoring for purposes of process control, production efficiency and safety.

Among the processes having needs for composition monitoring, one particular is oil production.

MULTIPHASE is today's catchword in the oil industry. An example is the article in the August '89 issue of The Oilman entitled "Multiphase Systems: The New Age Dawns".

Multiphase is a good word, but somewhat misleading in that in the oil industry it refers to the production, transportation and metering of comingled oil, water and gas having two phases, liquid and gas.

Today, produced oil, water and gas can only be measured by means of separation followed by the individual measurement of each component. Therefore, many of the "multiphase" on-going efforts concentrate on finding means and methods for measuring the fractional quantities and rates of the three components without separation.

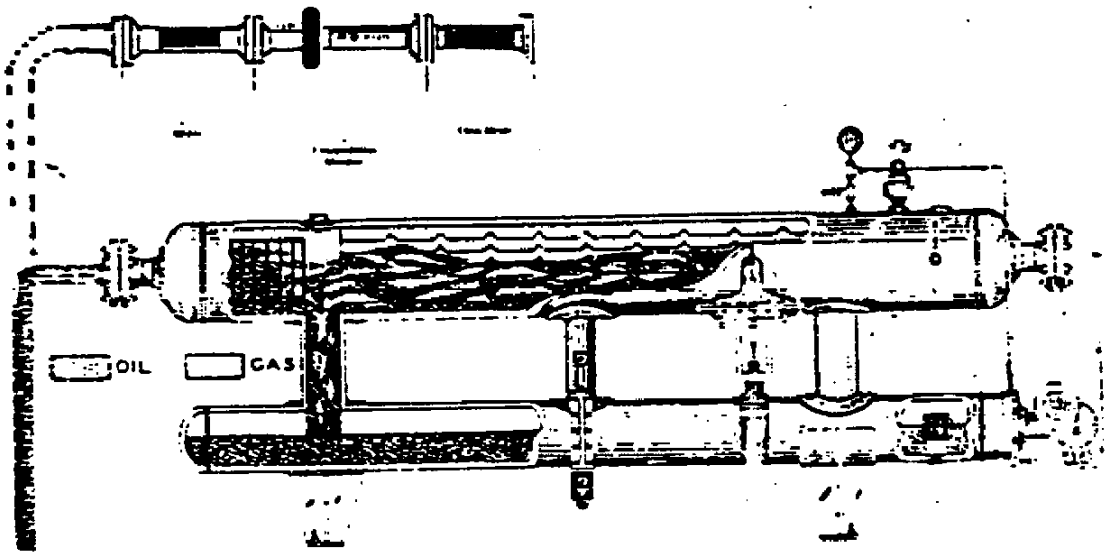
Being able to do so, means enormous cost savings.

This paper reports results obtained using a new, unique and proven technology that makes possible the continuous, unobstructed, full bore component metering without separation

Subsea, such a system could monitor the oil, water and gas productions from each well; and, thereby, eliminate both the test line and the platform test separator.

Ultimately, such a metering system could eliminate all platform separators resulting in significant structural cost savings and make un-manned platform operation a reality.

The figure below dramatically demonstrates the impact of this new technology by comparing a conventional test separator with the resulting "New System".



THE NEW MULTIPHASE TECHNOLOGY

Background:

In January of 1989, SRI International, California and Statoil, Norway completed the successful design, construction and testing of three prototypes for process compositional monitoring.

Statoil has funded the development which began in January 1987. The objective was to build an industrial prototype of a 3-phase monitoring system. From the R/D results it soon became clear that the technology had other applications, and the project was expanded to include the development of custody transfer and fiscal monitoring prototypes.

The above-mentioned three prototypes have been tested extensively in flow loops in the U.S.A. and in Stavanger, Norway at Hitec A/S. Each of the prototypes functions extremely well.

They bring significant new measurement capabilities to the petroleum industry. The tests have also proven the technology useful for application in many other industries.

In particular, the results demonstrates that the technology makes possible the continuous measurement of the fractional quantities of oil, water and gas flowing from individual wells and in pipelines. One important application of the technology is to eliminate the use of test separators. The results further show that the technology makes it possible to build the first, full sized, in-line continuous fiscal metering (BS&W/custody transfer) with an accuracy better than +/- 0,05% water.

The technology employs microwave dielectric spectroscopy in a novel and unique way that increases accuracy, simplifies construction and widens its application for measuring the quantities and rates of multicomponent mixtures. It is being commercialized by Fluid Monitoring Systems, Inc., California of which Hitec A/S, Stavanger Norway is a part owner.

Fluid Monitoring Systems, Inc. is a new corporation with an exclusive world-wide license to manufacture and market products based upon this new metering technology.

The New Technology

- The devices are non-invasive.
- They are real time, full bore in-line devices.
- They have no moving parts.
- They can easily be built into sizes from 2" to 36" diameters and larger. No special liners are required.
- They measure the cross-sectional average of the material flowing in the pipe; i.e. no sampling.
- The devices are extremely stable electrically and impervious to electromagnetic interference.
- The devices are relatively immune to drift problems.
- The devices are low power devices such that remote location of the instrumentation will not be difficult.
- Fast response time: 10-100 msec.

Some Application in the Oil Industry

- Continuous 3-phase metering of production wells.
- Real time custody transfer and fiscal monitoring of pipeline quality crude oil.
- Net oil metering of 2-phase mixtures.
- Custody transfer metering of the water content of liquid natural gas.
- Improved Lease Automated Custody Transfer (LACT) metering.
- Mist flow metering.
- Pipeline transport: Product interface detection device.

Performance Features

- None of the devices show any flow rate sensitivity.
- All the prototypes require good mixing for best results.
- The 3-phase prototype has proven itself capable of accurately measuring mixtures of oil, water, and gas that vary in composition from 0 to 100% in any of the components when the materials are evenly mixed.
- The 3-phase prototype can measure water or oil continuous mixtures and the water can be fresh water or brine.
- The 3-phase impedance monitor, when combined with a densitometer shows great promises in continuously measuring the volumetric ratios of oil, water and gas mixtures.
- The 2-phase prototypes have demonstrated sensitivity and accurace to better than +/- 0,05% over the 0-5% water cut in pipeline quality crude oil.

STATUS

The 3-phase prototype is capable of detecting which state the emulsion is in such that the appropriate calibration curve can be selected for determining the water content.

To date, three 4" prototypes for in-depth flow loop analysis have been built. One of these prototypes is designed for 3-phase monitoring and the results obtained with this prototype will be described briefly. Figure 1 shows the full measurement range of the 3-phase prototype from 0-100% seawater. The curve that starts at 0% water corresponds to measurements of oil continuous mixtures in the flow loop. The curve that extends from approximately 55% to 100% water corresponds to measurements of water continuous mixtures. Note the distinct jump in the measured properties when the emulsion undergoes a phase inversion. The step jump results from the large difference in electrical properties of an oil continuous emulsion versus a water continuous one.

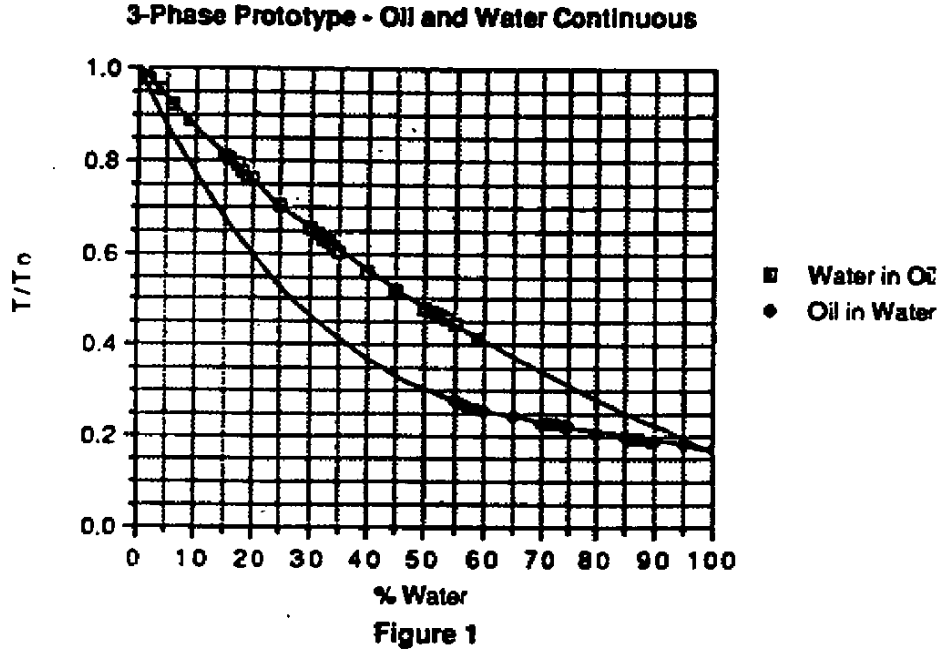


Figure 1

Figures 2 and 3 below show respectively oil continuous and water continuous mixtures at two different salinities.

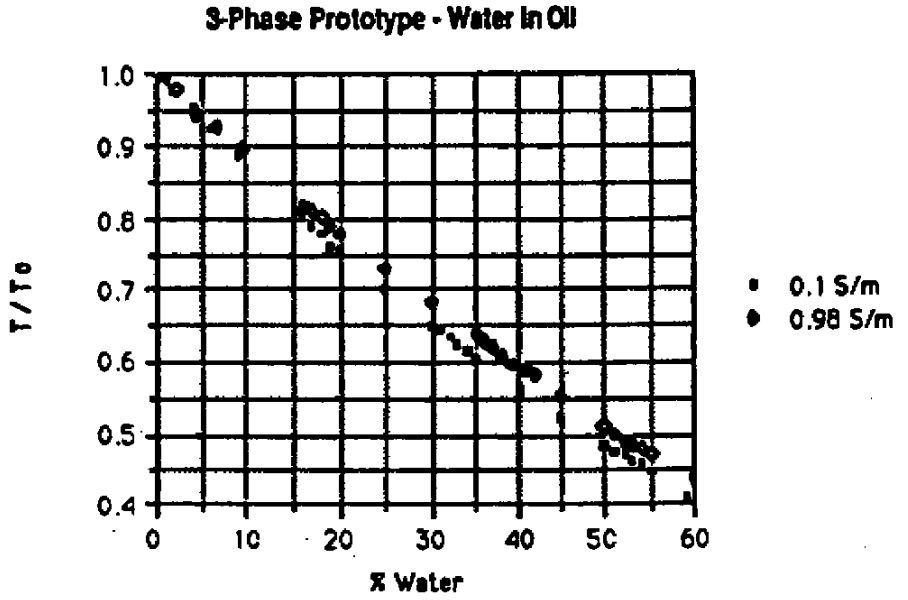


Figure 2

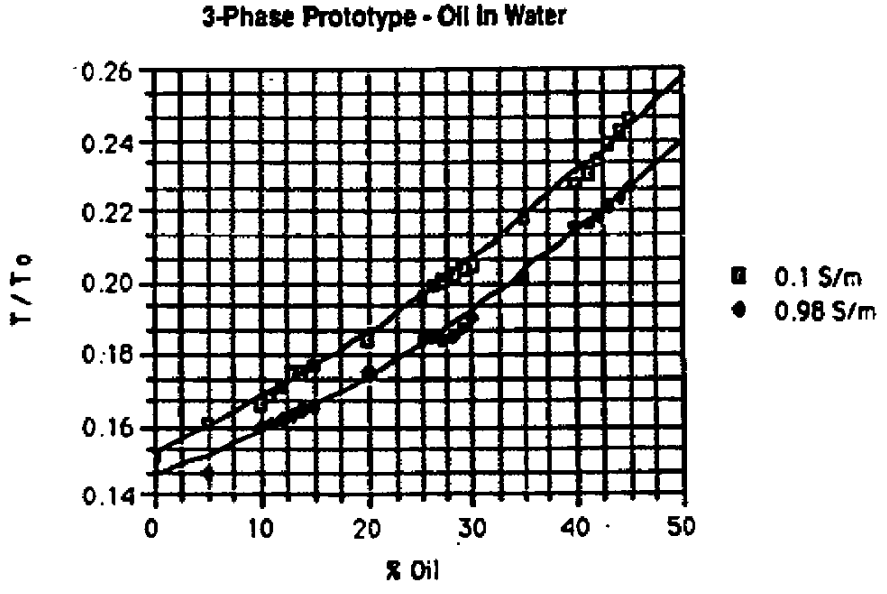


Figure 3

Figure 4 below is also water continuous, but here oil is added to North Sea water.

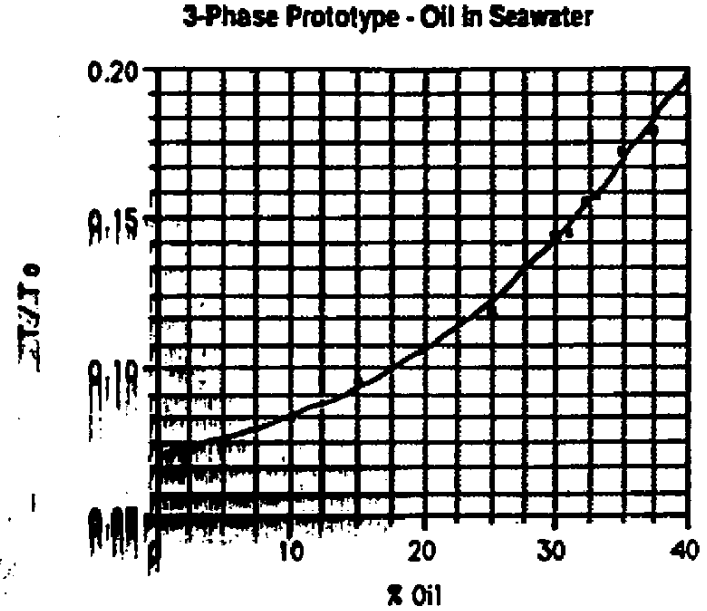


Figure 4

And finally, figure 5 shows the measurement when adding gas to a mixture having 20% water in oil.

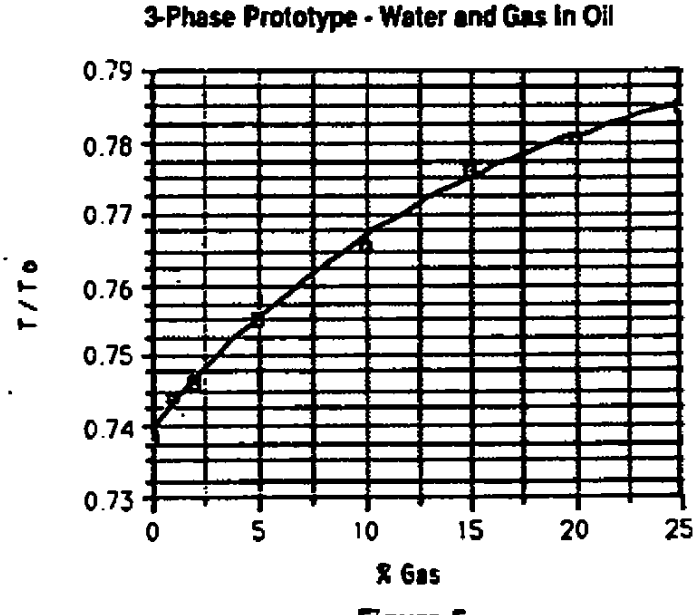


Figure 5

During our flow loop measurements, changes in water cut less than 0,01% or 100 pp could be detected. Flow rates varying between 0,05 m/sec. and 10 m/sec. had no effect. These are important performance features.

Two types of fiscal metering prototypes have been built. One is completely non-invasive while the other has small, non-moving, no-active parts introduced into the pipe. The latter prototype is the most sensitive and the most pressure resistant. The results for both prototypes have been equally promising. Only the results of the second of the fiscal metering prototypes will be described to avoid repetition. Figure 6 shows a typical calibration curve obtained with the fiscal metering prototype for 0-10% water in oil. The line through the points is the best curve fit.

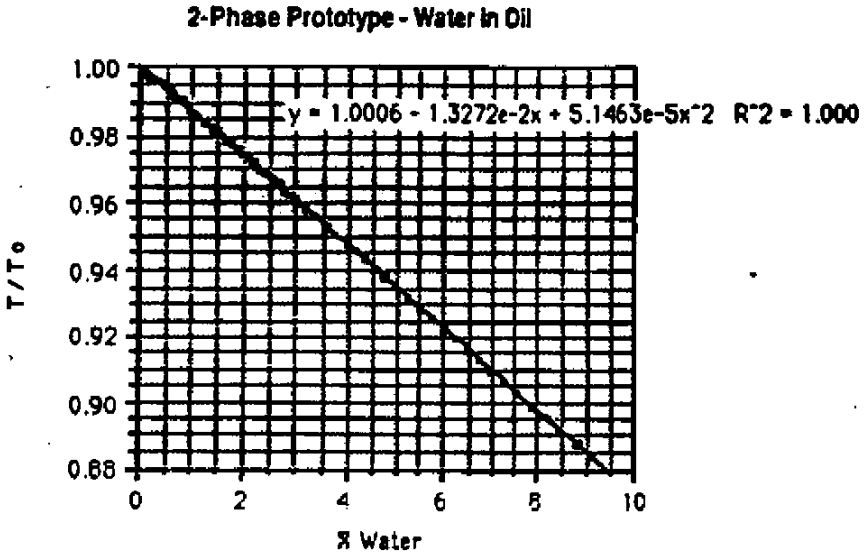


Figure 6

Figure 7 shows a more detailed look at the 0-1% water cut region. The data is very smooth and quite reproducible.

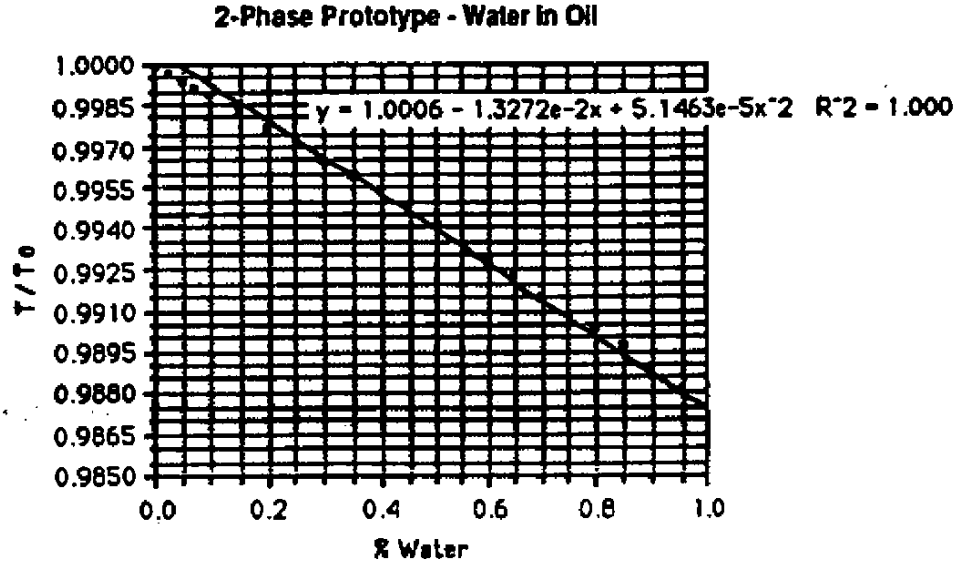


Figure 7

Figure 8 shows temperature calibration curves.
When the temperature changes, the calibration curve makes a parallel shift to a different level. The nominal temperature coefficient is 0,018% water per degree Celcius. In other words, without a temperature correction, the inaccuracy of the fiscal meter would be +/- 0,018% per degree changes in the temperature from the calibration temperature. An actual field unit will have a built-in temperature sensor for real time correction.

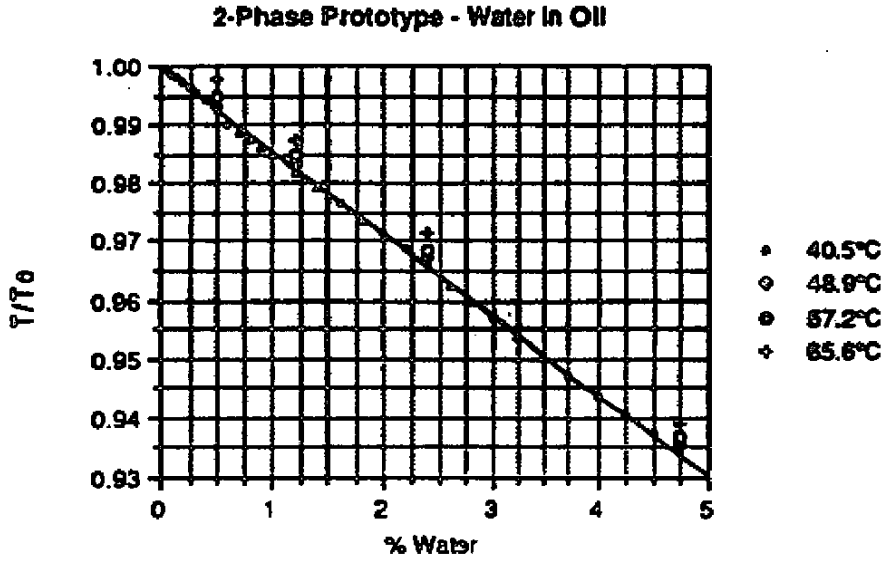


Figure 8

The Future Tasks:

Below follows a summary description of some specific future development objectives.

Oil or Water or Gas Continuous Well Stream Measurement System.

This system has the highest priority. It is a system for measuring well stream composition and flow rate continuously.
It will give the operating companies great savings from better reservoir management (enhanced recovery) and optimal field development. It can also replace the test separator. The results from tests in California and in Stavanger are very encouraging. It will detect water or gas breakthrough.

BS&W in Fiscal Metering, Custody Transfer and Quality Control Systems.

Fiscal metering is measurements where the government calculates tax or royalty (normally they take both). The oil companies usually are allowed to reduce the oil volume with the volume of Base Settlement and Water. The percentage of BS&W are always documented with samples. The operators have for a long time wanted an automatic and continuous way for doing that.

When buying oil or other products the client does not want to pay for unwanted water. That's the reason why the market for a long time have wanted a sensor to replace today's sampling methods with a continuous measurement of the total water content in the product. The custody transfer system of Fluid Monitoring Systems satisfies this market need. Similar equipment can also be used for quality control. Civilian jet fuel, for example, has a quality criterion regarding the maximum water allowed; namely, 30 parts per million.

Leak Detection System.

If there is leakage between a lubrication system and a water cooling system, water goes into the oil or oil into the water. This can easily be detected by our probe.
The same probe can detect the water content in electrical transformer oil. Thus the system can save people and equipment by detecting failures before accidents occur.

Mist Flow Monitoring and Net Oil Monitoring Systems.

The separator is among the largest equipment in oil production. Normally the sizing factor is the time it takes for oil to separate from water. A continuous measurement of the oil and water mixture and its flow rate give better control and increased efficiencies which reduce the size of the separators. **This system can also detect water breakthrough!**

In some separators, particularly in test separators, there can be large carryover of liquid in the gas stream (mist flow) which can lead to the wrong interpretation of the reservoir. **The 2-phase probe can measure both the oil/water ratios and the liquid content in the gas.**

Pipeline Transport:
Product Interface Detection Systems.

Pipelines are often used to transport different products separated by equipment known as "pigs". "Pigs" may be a mixing zone of the two products, a gel substance or a mechanical isolation. Refineries normally want to push the last product out of the line with the new product without mechanical pigs. To accomplish that requires rapid detection of the fluid or gel interfaces. **This new technology has this capability.**

Steam Quality Control Systems.

To monitor the quality of steam is important in many industries. In the oil industry steam is injected into the heavy oil reservoirs in order to lower the oil's viscosity by the heat generated when the steam condenses. Optimum steam quality is about 70%. **The new technology can monitor the steam quality by monitoring the water mist content of the steam.**

The above is by no means an exhaustive listing of the many applications envisioned by this new technology.

Practically every process industry imaginable needs this new kind of metering technology. It has the unique capability of being able to measure a wide variety of compositions, including those being water or brine continuous. Further, it has great sensitivity, is not affected by flow velocity and can be used to measure that very same velocity.

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.