ABSTRACT

During the past few years, Saudi Aramco has installed and field-tested eight different types of multiphase flow meters (MPFM). These newly developed, compact MPFM are targeted for wellhead installation at remote onshore fields and unmanned offshore platforms, where weight and space are major concerns. MPFMs provide continuous well-test data, which leads to more accurate production allocation and better reservoir management. The application of MPFMs in company production operations, if successful, will provide continuous on-line well production monitoring and eliminate large conventional test separators, test lines and offshore test barges. As a result, tremendous economic savings could be realized due to a significant reduction in capital and operating expenditures associated with well-testing activities. The test installations cover a wide range of multiphase applications from more than six different oil fields. The objective of the field-testing program

Field Testing
Multiphase Meters

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was to establish the ability of each meter to accurately measure the three production phases (oil, water and gas) and to determine meter reliability in a field environment. Field test results of the multiphase meters are compared to reference conventional test separators. This paper presents an overview of the status of multiphase metering technology and discusses in detail the multiphase metering evaluation program at Saudi Aramco.

INTRODUCTION
As part of Saudi Aramco’s strategy to introduce and evaluate new oil and gas production technologies, different MPFMs are being tested to evaluate performance and suitability.

Accurate metering of three-phase well streams is important in onshore/offshore production operations. Measurements are used for well monitoring, reservoir management, production allocation and to evaluate the need for well workovers or stimulations.

MPFMs are light in weight, small in size and can be applied in remote onshore areas or offshore locations.

Multiphase meters combine techniques to measure oil-, gas- and water-phase fractions and flow rates in a multiphase flow stream. Two or more sensors were used in all MPFMs tested.

The company began field-testing multiphase well-metering systems in the early 1990s. Significant economic savings and improved well monitoring have been realized by this effort, with numerous units installed at remote onshore/offshore locations. Continuing development and evaluation of multiphase metering technology will provide additional benefits in offshore and onshore applications.

MPFM TESTING OBJECTIVES
Saudi Aramco’s multiphase meter field-testing program’s objective is to find accurate, relatively low-cost, compact metering systems for new development projects and in some cases, to replace existing conventional metering systems. The test program’s objective is to determine for each meter:

• Accuracy in typical Saudi Aramco production conditions;
• Operational reliability of the meter in field conditions;
• Ease of installation and use; and
• Vendor’s ability to provide technical and maintenance support.

The company has worked with vendors to improve their products. Ultimately, a variety of MPFM types will be approved for use, allowing competitive pricing and a wide selection of MPFMs for different applications.

SAUDI ARAMCO MPFM APPLICATIONS
Saudi Aramco has onshore and offshore MPFM applications.

Onshore
Onshore wells are typically remote; they can be 10 km (6 miles) or more from a centralized testing facility. They require a large capital expenditure for dedicated well test lines and manifolds. Purge times for wells are frequently very long. Landscape is often hilly, creating slugs and unstable production at the test facility. Production test accuracy for lower-rate wells suffers accordingly, and test frequency in general is lower than desired.

Doing well tests near the wellhead eliminates long test lines, nearly eliminates purge time and allows testing under more stable conditions. This results in economic savings, increased test frequency and potentially more accurate tests. Simple, compact metering systems that can be installed in remote, environmentally severe locations provide significant economic and technical advantages. Onshore locations with multiphase production-measuring requirements include both oil wells and wet-gas wells.

Offshore
Saudi Aramco has active offshore well platforms in five fields, including Safaniya, the world’s largest offshore field. Each platform typically has six wells. Platforms are small and cannot accommodate conventional test separators. A majority are unmanned and lack electricity.

Wells are tested by: (1) flowing production in a dedicated test flow line to a central testing facility on a larger production or tie-in platform, or (2) a jackup test barge periodically moving to the platform and performing a production test of each well.

When test lines are used, purge times are long, especially as well rates decline. Production at the central test unit is often unstable, with severe slugging. The consequences are less than desirable test frequency and potential test inaccuracies. Purge time and unstable production are insignificant problems for test barges, as they are near the platform during testing. The operational cost of test barges, however, is considerable, the workload is large, and well-test frequency is often not met.

As with remote onshore applications, multiphase meters on offshore well platforms would eliminate the need for long test lines and eliminate purge time and unstable production conditions. Test barges could be eliminated or used for wellwork operations. Again, economic savings, increased test frequency and tests that are more accurate would result.

MPFM size and weight is a more critical issue in offshore testing. Larger MPFMs are less suitable, but most could be accommodated. In most cases, offshore meters could be powered by solar panels to keep MPFM power requirements low.

BASIC METER TYPES
Multiphase meter designs fall into two categories: those that require full or partial gas/liquid separation upstream of the measurements, and those that do not (in-line meters).

Separation-type systems
Separation-type metering systems have a compact separator or
flow-diversion device upstream of the measurement equipment. The compact separation device provides a relatively liquid-free gas stream and a liquid stream. Each flow stream is metered separately. Key features include:

- Simple design, cost competitive;
- Not restricted to a particular flow regime;
- Design considerations pertaining to pressure vessels are usually waived;
- Components are usually commercially proven technology and low cost;
- Easy to operate; and
- Relatively immature compared to in-line metering systems.

Many oil companies have several separation-type installations. Saudi Aramco has developed and used these systems in three onshore fields. Vendors are bringing more of these systems onto the market.

**In-line metering systems**

In-line metering systems require no up-front separation of the liquid and gas. Some, however, require flow conditioning upstream of the meter. Full multiphase stream measurements are made by two or more sensors, and data is combined to yield individual phase flow rates. Key features of in-line MPFMs include:

- Smaller in size and lower in weight compared to separation-type metering systems,
- Applicable for offshore,
- Individual components are more sophisticated, relatively higher-cost and sometimes radioactive, and
- Relatively immature compared to separator-based systems.

**METERS TESTED BY SAUDI ARAMCO**

Saudi Aramco has field-tested five partial separation meters and three compact in-line meters.

Tested partial-separation meters include: Texaco, WellComp, Dual Coriolis Meter, Agar and Accuflow.

In-line meters tested include: KOS, Fluenta and Framo. Saudi Aramco is testing an MFI in-line meter. In addition, Saudi Aramco has successfully tested a compact wet-gas-metering system.

**General testing procedures**

Production results from all meters tested are compared with results from conventional test separators. The typical Saudi Aramco test separator uses turbine meters for liquid-rate determination and orifice plates to measure gas. A capacitance meter is used to determine watercut when the liquid phase is oil-continuous. Three-phase separation is used when the liquid phase is water-continuous.

Prior to initiating the test program, several steps are taken to assure high test-separator accuracy. All separator-metering devices are calibrated, and the general condition of the unit is checked. Recent tests are reviewed and compared with historical well-test data to determine if there are no discrepancies and if the test separator is repeating.

Test engineers and field operators discuss the purpose of testing and assure that everyone agrees how testing will be conducted. Issues discussed include specified turbine-rate ranges and if two-phase or three-phase test modes should be used for watercut tests, and data collection responsibilities are assigned. At MPFM installation, the vendor reviews the proposed test program and comments, and inspects the test-separator unit.

MPFMs are installed upstream of the test separator, exposing the meters to an undisturbed flow stream. In most cases, MPFMs are installed in a flow loop, bypassing and isolating the meter. Vendor installation requirements are followed, and vendor representatives perform required MPFM calibration. Tested meter flow computers are located either on the MPFM unit or remotely in a control room. Fluid samples, PVT data, water salinity, fluid density and compositional data samples are provided, as required, to the vendor. A program is often initiated to sample fluid streams during the test program to confirm input data validity.

**Actual testing begins**

After validation of the test separator as a reference to the MPFM, actual testing begins. Each well has an assigned purge time based on experience. The operator, however, reviews data from the test separator to establish that a stable production condition has been reached prior to initiating the official production test.

When the test is initiated, data is simultaneously collected from the MPFM and the test separator. Tests usually last five to six hours, but often extend up to 24 hours for wells with unstable production characteristics. There are often only minor differences between MPFM test pressure, temperature and the test unit. If significant differences occur, PVT tables are used to establish changes in standard condition-conversion factors and solution gas. The same well is often tested several times during the test program. This allows meter repeatability to be established, as well as repeatability for the test trap.

The vendor is invited to witness testing. The vendor is required to notify the Saudi Aramco test engineer prior to making any MPFM instrumentation, software or data input modifications. All modifications are logged. After reviewing initial test results, the vendor can modify the meter to improve performance. Several major meter design enhancements have resulted. Major MPFM operational problems are also logged.

After the test program has been completed, the validity of all collected data is checked. With a test separator, this involves comparing test results with historical data. If major discrepancies occur, tests are invalidated. A check of test-separator field records determines if correct turbine runs were used, the correct test mode (two-phase vs. three-phase) was used for the corresponding watercut and that the correct gas run was used. MPFM inputs are also
reviewed. A vendor may comment on the validity of any test. A final list of valid comparison tests is prepared and MPFM vs. test separator cross-plots produced. The final report covers meter operation problems and downtime issues.

Saudi Aramco general accuracy specifications are:

- **Liquid rate:** \( \pm 10\% \)
- **Oil rate:** \( \pm 10\% \)
- **Gas rate:** \( \pm 15\% \)
- **Watercut:** \( \pm 10\% \) absolute

It is not expected that every MPFM well test, when compared to the test separator, will fall within the above criteria. Even after the test separator is carefully calibrated and the data is validated, moderate test separator errors are likely. When reviewing the acceptability of an MPFM, major discrepancies and trends are more important than absolute accuracy. Operational problems are a major factor when considering the suitability of a meter, especially in a remote application.

### Test History

**Texaco multiphase flow meter**

The Texaco MPFM is a partial-separation meter. Flow enters a 15 cm \( \times \) 3.6 m (6 in \( \times \) 12 ft) riser, then goes into a 35.5 cm (14 in) horizontal pipe, followed by a 20 cm (8 in) downward inclined pipe (22.5° to horizon) where stratified flow is promoted. Total piping length is 12.1 meters (40 ft), and the tested system is set on a 2.4 \( \times \) 6.7 m (8 ft \( \times \) 22 ft) skid. Total flow rate is determined in the riser with capacitance probes. In the 20 cm (8 in) inclined pipe, liquid cross-sectional area and velocity are obtained by two gamma-ray densitometers mounted in series at a known distance apart. A side stream of liquid passes through a microwave meter where watercuts are determined.

The meter was installed and evaluated during three phases of testing from 1991 to 1994 at two onshore producing fields in Saudi Arabia. The first two testing phases primarily established the accuracy and the operating range of the meter. Meter modifications were made after each testing phase. A third phase ascertained unmanned operational capability and reliability of the unit.

Test results were discouraging (fig. 1). The meter had numerous operational failures. Its accuracy quickly deteriorated under slugging conditions. Watercuts were commonly inaccurate. Sand production tended to plug the microwave watercut monitor. The meter was tested to 14.0 MB/D. The test program concluded in 1994.

**Wellcomp MPF meter**

The 3.3 \( \times \) 2.1 \( \times \) 1.3 m \( (11 \times 7 \times 4.5 \text{ ft}) \) Wellcomp unit was skid-mounted. It consisted of a fluid conditioner with a level control, a coriolis meter, a sample chamber with capacitance probe, gas vortex meter and pneumatic actuated valves.

Initially, the combined flow stream enters a fluid conditioner, a small vessel with internal components designed to remove the majority of free gas. Liquid with some entrained gas exits at the bottom of the fluid conditioner and is fed through either the sample chamber (fluid analysis leg), or through the mass-flow-measuring coriolis meter. Most of the time, flow is through the coriolis meter. Periodically, actuated valves open and divert flow to the sample chamber, where a sample is captured and the valves shut and return the flow back to the coriolis meter. A modified capacitance probe in the sample chamber analyzes the sample to determine three phase fractions (oil, water and gas) based on the mixture's permittivity. Mixture density is measured by a differential pressure cell. Volumetric flow rates are calculated using: (1) the phase fraction determined by the sample chamber, (2) the gross mass-flow measurement from the coriolis meter, and (3) density inputs for each of the phases. Free gas, which exits the top of the flow conditioner, is measured with a vortex meter.

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Fig. 1. Test results were discouraging. The meter experienced numerous operational failures. Its accuracy quickly deteriorated under slugging conditions. Watercuts were commonly inaccurate. Sand production tended to plug the microwave watercut monitor. The meter was tested to 14.0 MB/D.
Initial testing of the Wellcomp began in 1993 and continued into 1995. Test results were in general satisfactory. The initial test meter was designed for 12 MB/D. It operated with minimal failures and accuracy, and when compared to the test separator, was acceptable (fig. 2).

The Wellcomp meter was relocated to another onshore location for permanent well testing. It continued to function, but had some coriolis meter problems. In addition, meter accuracy was unfavorable in some well tests. Investigation concluded that the 61 cm (24 in) fluid conditioner was undersized for high flow rates and had poor separation efficiency. This allowed a large quantity of gas to be entrained with the liquid stream, which caused the coriolis meter to cut out. A straight-tube coriolis meter, installed in 1997, replaced the U-tube coriolis meter. Improved performance was obtained with the straight-tube coriolis meter, which was less susceptible to cutting out due to excessive free gas.

Three units were purchased and installed in 1998. Numerous operational and accuracy problems encountered included poor fluid-conditioner level control, sampling chamber probe failure, inability to handle slugs, computer malfunctions and actuator problems.

Dual-coriolis meter

Saudi Aramco developed the dual-coriolis test unit and fabricated the prototype unit in-house. It consists of a relatively compact pipe spool, which acts as a gas-liquid separator. Liquid-level and pressure-control valves maintain relatively constant operating conditions. Two coriolis meters, one for gas and one for liquid, determine mass rates. Density measurements from the coriolis meters determine watercut in the liquid leg and any potential liquid carryover in the gas leg. Vessel design considerations and pressure relief issues do not apply because all components are pipe spools, designed to line operating pressure. Flow is recombined after the unit. Oil and water densities are required with computer inputs.

A prototype dual-coriolis meter was field-tested in 1996 at a remote onshore well. Production tests were done at liquid rates up to 7.2 MB/D and gas-volume fractions (GVFs) up to 88%. The test unit’s rates were generally within ±10% of the comparison test-separator results (fig. 3). Operational problems were minimal.

Since 1997, approximately 30 dual coriolis meters have been successfully installed and remotely operated in two new fields. These resulted in multi-million-dollar savings by eliminating central conventional test separators and associated test-flow lines. However, as currently designed, installation of this unit onto standard Saudi Aramco six-well offshore platforms may be unfeasible due to the large size.

Agar multiphase flow meter

The Agar 401 is a partial-separation-type metering system consisting of pipe spools and metering devices. The meter tested was skid mounted with a 1.2 × 1.8 m (4 × 6 ft) footprint and design for rates up to 4.5 MB/D. The Agar 401 meter consists of six parts:

1) Fluid-flow diverter: Separates gas from the inflow and diverts it into a gas-bypass loop, liquid with some gas is diverted to the main metering section;
2) Vortex meter on gas leg;
3) Positive displacement meter to measure volumetric flow;
4) Momentum meter (multiport venturi) to determine gas/liquid fraction;
5) Microwave watercut monitor; and
6) Capacitance interface detector, to determine the continuity state of the liquid (water or oil continuous).

This meter was trial tested in 1998 at a gas-oil separation plant (GOSP). The plant’s test separator was used as a reference measurement to evaluate meter accuracy. Approximately 30 comparison tests were made over a wide range of watercuts and gas fractions.
The meter compared well with the test separator (fig. 4). No significant problems or operational failures occurred. However, the meter tested was undersized for a large portion of company wells. Testing began in June 1999 on an Agar MPFM designed for 15 MB/D liquids.

Accuflow test unit

The Accuflow meter, like the dual-coriolis meter, uses a pipe spool as a gas-liquid separator. A vortex meter measures gas rate, while a coriolis meter measures liquid rate and watercut. The unit is skid mounted and is slightly smaller in footprint and lower in weight than the equivalent dual-coriolis test unit. This system is potentially suitable for offshore installations. Power requirements are low enough to be provided by solar panels. Liquid level is controlled by an electrical pressure-control valve on the gas leg. Oil and water density are required computer inputs.

Testing of a 15 MB/D design Accuflow meter began in April 1999. The U-shaped separation pipe spool is 30 cm (12 in) in diameter and approximately 12.1 m (40 ft) long. Initial results are encouraging for wells below 7 MB/D, with general agreement between the GOSP test separator and the Accuflow unit (fig. 5).

With higher-rate wells, performance degraded due to gas exiting the Accuflow separator pipe spool and entering into the liquid leg. The coriolis meter periodically shows fluid density dropping due to gas entrained in the liquid. Eventually the coriolis meter stops outputting data due to instability of the vibrating tubes caused by a gas/liquid fluid mixture. Zero flow is recorded during these intervals, and an under-reading of average liquid rate results. This problem resulted from a foaming crude condition.

Fig. 3. A prototype dual-coriolis meter was field-tested in 1996 at a remote onshore well in Saudi Arabia. Production tests were done at liquid rates up to 7.2 MB/D and gas-volume fractions (GVFs) up to 88 percent. The test unit’s rates were generally within ±10 percent of the comparison test-separator results. Operational problems were minimal.

Fig. 4. The meter compared well with the test separator. No significant problems or operational failures occurred. However, the meter tested was undersized for a large portion of company wells. Testing began in June 1999 on an Agar MPFM designed for 15 MB/D liquid.
Multicapacitor multiphase meter (KOS)

The KOS meter has a pipe spool with a pair of parallel sensor plates inserted into the pipe inline with the flow. This meter requires a slug-flow condition. Watercut is determined either by capacitance or induction measurements. Two plates each have a matched array of capacitance/inductance electrodes which measure the cross-sectional areas of the pipe occupied by liquid and gas, the velocity of the liquid and the velocity of the slugs in the pipe. An assumption is made that slug velocity is equal to gas velocity. Flow rates are calculated from the product of the cross-sectional areas occupied by the liquid and gas and their respective velocities.

A 10 cm (4 in), 15 MB/D meter was tested in 1996 at two onshore fields. GOSP test separators were used for comparison references. The meter was tested over a wide range of flow conditions, 1 to 16 MB/D, 0 to 70% watercut, 60 to 90% gas fraction.

The KOS meter performed poorly (fig. 6). Liquid and gas rates were commonly outside accuracy specifications. Watercut measurements were equally poor, especially above 60%. Testing of the meter was discontinued.

Fluenta MPFM

The Fluenta MPFM 1900 VI has an inline spool piece that measures flow without separation of phases. The meter was 7.6 cm (3 in) in diameter and 1.5 m (5 ft) long. It uses several sensors in combination, the main ones being:

2. Inductance sensor: Same purpose as capacitance sensor but

Fig. 5. The 15 MB/D Accuflow meter has a U-shaped separation pipe spool, has a 12 in diameter and is approximately 40 ft long. Initial results are encouraging for wells below 7 MB/D, with general agreement between the GOSP test separator and the Accuflow unit.

Fig. 6. The KOS meter performed poorly. Liquid and gas rates were commonly outside accuracy specifications. Watercut measurements were equally poor, especially above 60 percent. Testing of the meter was discontinued.
used when flow becomes water-continuous.

3. Gamma-ray densitometer: Measures the density of the flow and determines the cross-sectional area liquid/gas ratio.

4. Venturi: The venturi measures mass flow rate and extends the operating range of the MPFM into single-phase flows where cross-correlation techniques fail to operate.

This meter was trial tested at two different onshore GOSPs from January 1997 to February 1998. It was compared to test results of conventional test separators over a range of flow conditions, liquid rates of 1 to 15 MB/D, watercuts of 0 to 80%, GVF of 50 to 90%. The crude was 38° API.

The Fluenta MPFM required two major modifications during the trial test period due to operational problems and poor performance. The first upgrade was recoating the capacitance sensor liner with a higher-temperature coating. The second upgrade was a complete replacement of the capacitance sensor liner and a software enhancement.

The upgraded meter was trial tested from December 1997 to February 1998. For wells with below 90% gas fraction, meter performance was acceptable (fig. 7); however, additional testing was suggested, especially in an offshore environment. The meter’s performance with GVF over 90% was poor. The meter has been installed on an offshore test barge for additional testing.

Framo MPFM

The skid-mounted Framo MPFM was designed for a maximum liquid rate of 15 MB/D. The meter’s footprint is approximately 6 sq. m (7 sq. ft). It has three main sections:

![Graphs showing performance comparison](image)

Fig. 7. The Fluenta MPFM 1900 VI was acceptable for wells with below 90 percent gas fraction; however, additional testing was suggested, especially in an offshore environment. The meter’s performance with GVF over 90 percent was poor. The meter has been installed on an offshore test barge. Testing of offshore wells started in June 1999.

![Graphs showing performance comparison](image)

Fig. 8. Based on comparison with the test separator, the Framo MPFM is statistically one of the best MPFMs tested. However, its trial test period was limited. No significant operational problems occurred.
1. Flow mixer: An in-line static device consisting of a cylindrical vessel with internal mixing components. Its primary objective is to promote homogeneous flow into the measuring section of the meter and to act as a buffer to smooth out slug-flow conditions.

2. Venturi meter: The venturi is placed downstream from the flow mixer to measure total mass flow. A homogenized multiphase mixture can be treated similarly to a single-phase fluid.

3. Dual-energy gamma-ray fraction meter: Two different energy levels of barium 133 are used to determine phase fractions. This meter was tested in 1998 at an onshore GOSP. The GOSP test separator was used as the reference measurement. It was tested at liquid rates of 1 to 14 MB/D, watercuts of 0 to 70%, GVF of 50 to 80%. The crude was 38° API. Water salinity is a required input. Considerable error can result if incorrect values are used.

Based on comparison with the test separator, the Framo MPFM is statistically one of the best MPFMs tested (fig. 8). However, its trial test period was limited. No significant operational problems occurred. The meter's compactness is advantageous for offshore applications.

MFI meter

The MFI multiphase meter is compact, inline, does not depend on separation but utilizes a nuclear source. Microwave technology is used for watercut measurements and cross-correlation for velocity determination. Testing of the meter started in the fourth quarter of 1999.

High-GVF MPFM (wet-gas meter)

The tested wet-gas metering system consists of two parts: a permanent venturi meter unit and a portable tracer-dilution skid.

The tested meter consists of an inline venturi meter fitted with pressure, temperature and differential-pressure sensors. Pressure and temperature data is transmitted to the flow computer, where gas and liquid mass fractions at test conditions are calculated based on input PVT relationships. Differential pressure data is used to calculate an uncorrected gas-mass rate using conventional venturi equations. To compensate for the over-reading of differential pressure caused by entrained liquid, a modified Murdock equation is applied. The final output is corrected gas and liquid mass flow rates, which can be converted to standard condition volumetric rates.

As a method to periodically confirm calculated liquid rates, portable tracer-dilution technology was also tested. This technique involves injection of fluorescent tracers into the flowline and subsequent collection of a sample at a suitable distance downstream from the injection point. The tracer is either water or oil soluble so that it will mix with the liquid being investigated. By comparing the fluorescent intensity of the injected liquid and of the collected sample, an intensity ratio can be established. If the rate of tracer injection is known, the production liquid flow rate can be determined by multiplying the tracer injection rate by the intensity ratio.

Testing of the wet-gas venturi system began onshore during 1996. Comparison tests were made between the wet-gas metering system and a conventional test separator. The wet-gas meter was evaluated at gas rates from 20 to 57 MMSCFD, with 1.5 to 6% liquids by volume. Test results were promising, with gas rates within 5% and condensate rates within 10% of test-separator values (fig. 9).

Tracer-dilution technology tests were successful in determining the water and condensate flow rates to within ±15% of conventional test-trap rates.

Saudi Aramco plans to install venturi systems on most new gas development wells. This will allow continuous monitoring of production from each well and eliminate the cost of test manifolds and conventional test separators. The tracer-dilution system can be periodically used to confirm calculated liquid rates.

CONCLUSIONS

Field-testing of MPFMs has allowed Saudi Aramco to screen a variety of meters for suitability to company production operations. Testing has determined meter accuracy, operational ease, maintenance and downtime problems and operating envelopes (rate, watercut, GVF).

In considering the acceptability of an MPFM, major discrepancy
trends are more important than absolute accuracy. Saudi Aramco is aware that even after carefully calibrating the test separator and validating data, moderate test separator errors are still likely. Operational problems are also a major factor when considering the suitability of a meter, especially with remote application.

In conjunction with field-testing, the company participated in several joint industry projects where MPFMs have been tested in flow loops. Flow loops are in a laboratory-type setting, and reference measurements are considerably more accurate than a typical field-test separator. If similar trends or inaccuracies are observed in the flow loop and in field tests, there is added confidence in test conclusions. If results from field-testing and flow-loop testing differ greatly, the field-test data is reviewed and questioned. However, often, different test results are due to differences in flow conditions and fluid composition under which the meters are tested. A laboratory-type flow loop can never completely simulate field conditions. In addition, the interface between field operator and MPFM — the exposure of the MPFM to the Saudi Arabian outdoor environment — cannot be simulated in a laboratory setting. The combination of both field- and flow-loop testing results in the greatest understanding of the capability of the MPFM.

Field-testing has precluded the further use of some MPFMs and has allowed the acceptance of others for future use. Additional testing of some MPFMs is considered necessary prior to acceptance. The testing has permitted the actual installation and use of approximately 30 MPFMs.

Future Plans

Saudi Aramco is now installing an MFI inline MPFM for testing. Testing of the Agar meter, sized for typical Saudi Aramco wells, has just concluded.

Additional testing of the Fluenta MPFM on an offshore test barge began in the fourth quarter of 1999.

Saudi Aramco is proceeding with the first permanent installation of an MPFM on a six-well offshore platform; several meter types are being considered. Numerous wellhead wet-gas venturi-type meters will also be installed onshore in the coming years.

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