Coriolis Multiphase Measurement Systems using partial separation technology - An alternative to traditional production well testing systems

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Introduction

Effective operation, production management, and reservoir management of producing oil & gas fields rely on the accurate determination of net oil, net water, water cut, and gas volumes from individual wells. As margins decrease due to economic issues, such as the increasing demand for production, the continuous increase of operational costs, the decline of production in existing fields, and the rising cost of exploration, production companies are challenged to look for innovative methods to increase the confidence and remove measurement uncertainties from conventional well testing.

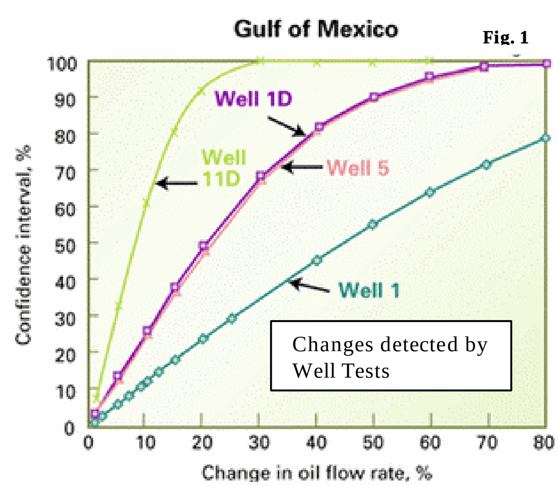
Conventional well testing practices and procedures, while widely accepted, can be unreliable and not necessarily representative of the dynamic conditions that exist within a producing well. A number of factors contribute to measurement uncertainty: separator inefficiencies associated with fluid level control and interface detection, mechanical and instrumentation failures, separator damping effects, residence time, operational errors, leaky manifold valves, varying purge requirements, data averaging, and periodic rather than continuous testing. Many of these factors can be reduced or eliminated by the use of a multiphase metering system based on partial separation technology and Coriolis measurement.

A multiphase measurement system based on partial separation technology and Coriolis measurement adds the reliability and versatility required to handle a wide range of well testing applications. With the use of this system, more representative well production data can be achieved, either by increasing the frequency and duration of well tests or by moving to the continuous measurement of individual wells. More accurate, reliable, and representative well production data allows producers to optimize production, reduce operational costs, and increase reservoir yields.

This paper focuses on the improvements in production measurement provided by a multiphase measurement system employing Gas Liquid Cylindrical Cyclone (GLCC) and Coriolis technology, and the resulting effects of `profitability

Effects of Measurement Uncertainly on Performance

As measurement uncertainty increases, the producer's ability to optimize production decreases. The Process Capability Index (PCI), a statistical method for determining the accuracy (detecting changes in flow rate) and confidence at different error levels, (described in Reference 1) has been used as a tool to identify possible production losses due to not optimizing well test frequencies or measurement uncertainties. For example, Figure 2b[2] shows that, for Well 1, even with a 40% change in oil flow rate, the producer has less than a 50% confidence level that he will know that a change has occurred. With this level of uncertainty, it is very difficult to operate and optimize well production effectively.



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Separator Technologies

Several separator technologies are available for the determination of net oil, net water, water cut and gas volumes from individual wells.

Gravity-Based Separators

The most widely used technology for the separation of the different fluids in a well's output is the gravity-based separator. The fluids from individual wells are diverted to a test separator via a manifold system. This system relies primarily on retention time to separate the oil, water and gas. Each well is tested for a predetermined amount of time, usually no more than 24 hours. Tests are repeated according to a set schedule that typically varies from 10 day to 30 day intervals, depending on the number of wells on the manifold. The normalized production values from these tests are then used to estimate total well production to determine an allocation factor, which in turn establishes tax and royalty payments.

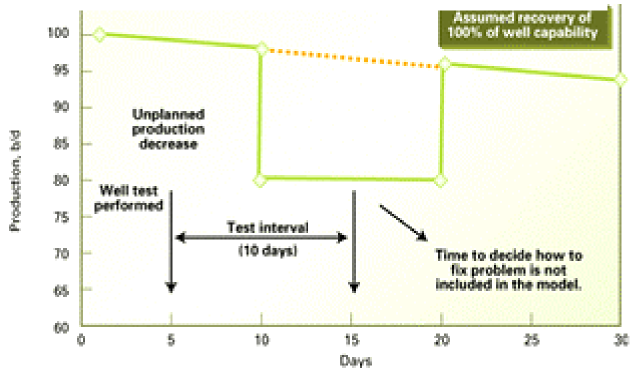
Figure 2 shows what can happen with periodic testing.[3-4] On day 5 of a 10 day test cycle, an unplanned drop in production occurred. This event went undetected until the next planned test cycle. This type of event can have several financial implications. In the short term:

- Lost production, as corrections could have been made when the drop in production first occurred
- Lower return on daily operational costs
- Flawed production allocation due to non-representative test data

And in the longer term:

- Increased field allocation factors due to increased discrepancy between well test data and oil sales data
- Loss of valuable reservoir modeling and characterization data

Figure 2. The impact of periodic well testing



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The following table summarizes the general advantages and disadvantages of traditional gravity-based separators.

Advantages	Disadvantages
• Widely accepted • Familiar equipment and process • Perceived low risk	• Mechanical and instrumentation failures • Operational errors • Leaky manifold valves • Varying purge requirements • Operation & maintenance costs • Data averaging • Cyclic testing resulting in long well downtime • Back pressure from long flow lines • Single rate testing • Damping of dynamic flow conditions • Interface detection • Residence time • Large footprint

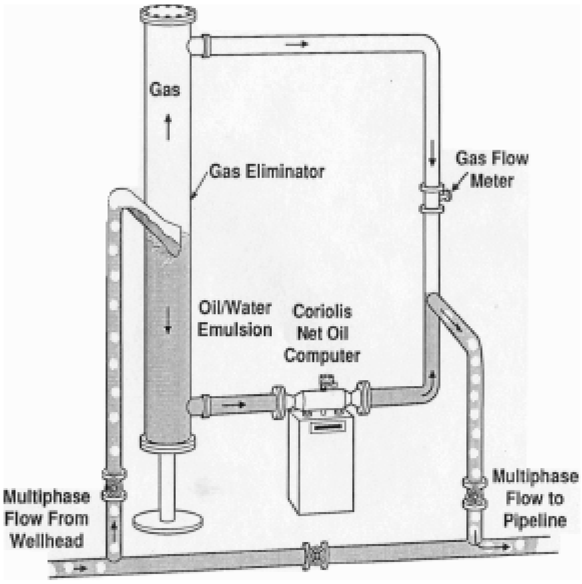
Gas-Liquid Cylindrical Cyclone Separators

The Gas-Liquid Cylindrical Cyclone Separator (GLCC) was developed by a Joint Industry Project (JIP) at the University of Tulsa. The GLCC can remove 100% free gas from low to medium viscosity crude oils, at low or high Gas Oil Ratios (GOR), and can achieve better than 99% serration efficiencies.

The GLCC operational principle uses a cyclonic flow pattern in a vertical pipe to separate the gas from the liquid. The GLCC can be designed to handle a wide range of three phase conditions. The three phase fluid enters the main body of the GLCC through an inlet arm on the main vertical section. The inlet arm enters the main body tangentially on a decline, which starts the separation process. A nozzle at the end of the inlet arm forces the liquid and gas to accelerate through the inlet and around the vertical axis of the main body, creating a vortex (cyclone). The lateral forces created by this tangential acceleration are designed to range from 15 -50 G. The more dense liquid quickly moves to the exterior walls of the main vertical section, while the gas is forced to the interior, creating a very efficient liquid-gas separator.

Although this concept and its advantages have been known for some years, recent advances in technology have enabled its widespread use. The major advantage is the use of Coriolis technology, with its proven flow measurement and water cut determination capabilities. This allows for the replacement of large, complex, and maintenance intensive two and three phase separators.

Figure 3. Fluid flow through a GLCC-Coriolis System



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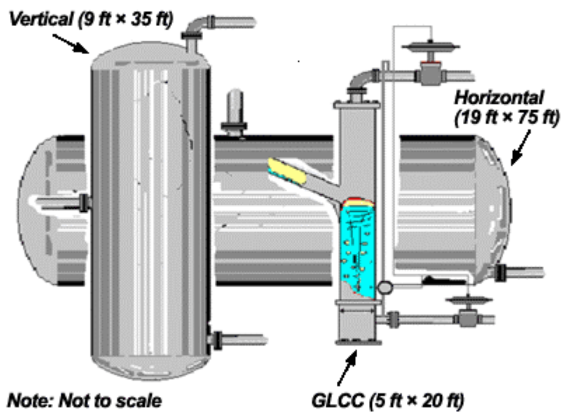
The GLCC is very compact, has a small footprint, and is approximately 1/8 the weight of vertical separators and 1/64 the weight of horizontal separators, making this technology suitable for anywhere space or weight is a consideration.

Figure 4 provides size comparisons of these three separators.

Figure 4. Size comparison: vertical, horizontal, and GLCC separators



Significant improvements in the measurement of multiphase fluids has been achieved using Coriolis meters in-conjunction with gas – liquid cylindrical cyclone (GLCC) separators. The application of these systems allows for continuous measurements of net oil, net water, water cut, and gas volumes from individual wells. This provides for more reliable, accurate, and representative well production data.

The GLCC has the ability to handle a wide variety of slugging conditions. A standard design can handle approximately four times the normal instantaneous gas flow rates and two times the normal maximum instantaneous liquid flow rates. Recent technological enhancements, such as "slug dampeners" can facilitate up to 10 times the normal instantaneous flow rates for gas and/or liquids. Figure 5 shows a photograph of a slug catcher on a GLCC system.

Figure 5. Slug catcher on a GLCC system

Improving Multiphase Fluid Measurement – GLCC with Coriolis

Significant improvement in the measurement of multiphase fluids has been achieved using Coriolis meters in-conjunction with Gas – Liquid Cylindrical Cyclone (GLCC) separators. These systems enable continuous measurement of net oil, net water, water cut, and gas volumes from individual wells, thereby providing more reliable, more accurate, and more representative well production data.

Combining the GLCC with Coriolis technology enables a broader range of measurements and well test functionality. Electronic platforms support telemetry, data storage and data sharing of real time production information on a continuous basis. When automation is added to the GLCC, it can utilize field device information, enabling control of the well test system under rapidly changing conditions. This can drastically increase the dynamic performance range of the system.

Because the GLCC-Coriolis multiphase system is low in cost and in simple design, it can be employed as a cost effective, real time well monitoring system that operates in continuous mode rather than in batch mode, giving continuous production information. As retention time is not required, the data provided is representative of dynamic conditions in the well. For example, multiple flow rate tests can be done at any time to obtain the optimum rate verses choke setting. Continuous monitoring also allows for the early detection of changing well conditions which can minimize costly workovers and maximize production. Figure 6 shows a fully automated GLCC-Coriolis Multiphase System

Application advantages	Operational advantages
• Can handle a wide range of flow applications • Continuous multi-phase measurement • Application flexibility • Individual or multiple well testing • Reliability and versatility to handle a wide range of well testing applications • More representative well production data • Increased frequency and duration of well tests • Provides continuous measurements on individual wells • More accurate, reliable and representative well data	• No moving parts • No maintenance involved • No operator intervention required • No sand build up – enables high velocity fluid flow • Tolerance to paraffin buildup • Small footprint • Relatively light weight • Lower capital cost • Less complex • Simple design for high reliability and low maintenance

Financial Impact

Advantages and Benefits

The Combination of a GLCC separator and Coriolis metering technology increases well and reservoir profitability in a number of ways.

Operation and maintenance

Both the GLCC and Coriolis meter are simple in design, with no moving parts. The System requires minimal operator intervention, and can be designed for remote operation. Daily operation and maintenance costs are lower than for competing technologies.

Improved production data

Production data can be improved by more frequent testing, longer test duration, or continuous testing. Improved production data enables improvements in many aspects of production management, including:

- Optimizing artificial lift operations
- Optimizing water or gas injection
- Optimizing oil recovery programs

By installing a GLCC-Coriolis system at each production well, continuous data can be used to improve overall allocations, as well as to optimize the yield from the reservoir, thus maximizing profits.

Lower installation costs

When the GLCC-Coriolis system is installed at each production well, the need for individual production flow lines to a central tank battery are eliminated. Each well can be piped to a shared trunk line going to the central tank battery. This type of “networking” offers tremendous savings in piping costs, instrumentation and on going maintenance. As new wells are added to an existing facility (infill drilling) production facilities must be modified to handle the new wells. This typically means new flow lines, modifications to the manifold system, additional valves and reduced testing of existing wells. Coriolis Multiphase Measurement Systems using GLCC separation technology maybe less costly than the required modifications to the production facilities and the cost added to the overall drilling budget, further reducing operational and maintenance costs.

A financial impact of measurement uncertainty

At some point in a producing wells life, the difference between revenue and production costs is not great enough to continue production. Uncertainly in the breakeven point, due to the uncertainty in % water produced or water-cut, can result in either too early or too late abandonment decisions, with accompanying lost revenues or unnecessary expense. The chart in Figure 7 illustrates the impact of absolute water-cut uncertainty based on a high water-cut, low production well, with the flowing assumptions:

- Gross well output :100 bbl/day
- Water cut breakeven point: 97%
- Price of oil: 28 $/bbl
- Gross lifting costs: $.80 per barrel

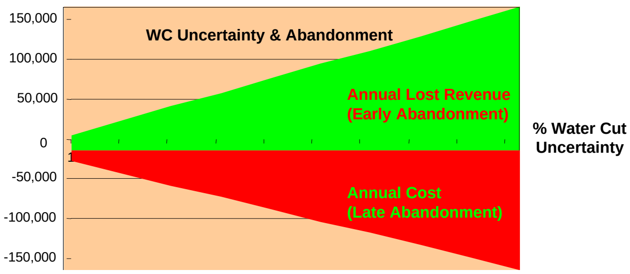


Figure7. Financial impact of early or late abandonment

The table illustrates the impact on annual lost revenues and annual costs at 2%, 5% and 9% water-cut uncertainties

Water Cut Error	**Revenue Loss (Early Shut-in)**	**Added Cost (Delayed Shut-in)**
2%	$20,400	-$20,400
5%	$51,100	-$51,100
9%	$91,980	-$91,980

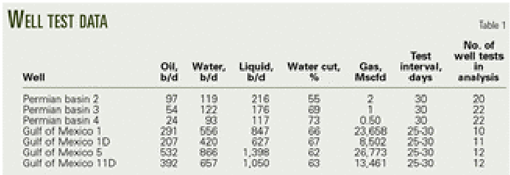
Conclusion

In conclusion, improved production data, including continuous real-time data for individual wells, is obtainable through the implantation of multiphase measurement systems using GLCC and Coriolis technology. As a result, well test measurement uncertainty is significantly reduced, while increasing the confidence level of the resulting data. This enables management decisions that can optimize production from individual wells and reservoirs, thus increasing profitability.

Profitability is also increased through the simplified operations of Coriolis Multiphase Measurement Systems. These systems reduce maintenance costs, and have the ability to incorporate proactive diagnostics to trouble shoot or flag potential device or system problems. These real time measurements play a key role in improving operational efficiency and maximizing profits.

References:

1. Christianson, B.A., "More Oil form Better Information: New Technological Application for Testing Producing Wells," SPE Paper No. 37526, 1997.

2. 

WELL TEST DATA

Table 1

Well	Oil, b/d	Water, b/d	Liquid, b/d	Water cut, %	Gas, Mscfd	Test interval, days	No. of well tests in analysis
Permian basin 2	97	119	216	55	2	30	20
Permian basin 3	54	122	176	69	1	30	22
Permian basin 4	24	93	117	73	0.50	30	22
Gulf of Mexico 1	291	556	847	66	23,658	25-30	10
Gulf of Mexico 1D	207	420	627	67	8,502	25-30	11
Gulf of Mexico 5	532	866	1,398	62	26,773	25-30	12
Gulf of Mexico 11D	392	657	1,050	63	13,461	25-30	12

3. Christianson, B.A., and Burger, E.L., "San Ardor Field Production Testing System Upgrade," SPE Paper No. 21533, 1991.

4. Means, S.R., and Mehdizadeh, P., "New Technology Improves Well Testing Units," OGJ, Oct. 30, 2000, p. 36.