**Acadiana Flow Measurement Society Show**
**13 – 14 April 1999**

# Case History: New Gas Flow Computer Design Facilitates Offshore Measurement In Gulf Coast Project

**Mike Chunn and Wayne Bonin,**
**Chevron USA Ltd.**
**Danny E. McFarland, Ken Jenkins and Kevin D. Fink,**
**Halliburton Energy Services, Inc.**



Chunn:, M., Bonin, W, McFarland, D.E., Jenkins, K., and Fink, K.D.: "Case History: New Gas Flow Computer Design Facilitates Offshore Measurement In Gulf Coast Project," Paper No. OTC 8798 presented at the 1998 OTC held in Houston, Texas, 4–7 May 1998.

## Abstract
Electronic gas measurement has evolved from providing a simple replacement for circular chart recorders to including requirements for instantaneous remote access of flow information. Coupled with this capability is the need to have access to this same information in multiple locations simultaneously. With existing equipment unavailable to meet these requirements, one operator and manufacturer allied themselves to develop a new flow computer. This new flow computer incorporates features to meet not only the specific and unique requirements of the operator's communication system, but also provides adaptation for future requirements. Installation of this new flow computer has resulted in significant operating cost reductions for the operator by requiring fewer trips to offshore locations and providing instantaneous flow information for engineers, technicians, and gas accounting personnel.

## Introduction
Electronic Gas Measurement (EGM) systems have grown in popularity in recent years due in large part to their ability to provide both on-site viewing of real-time data and historical recording of the same data. The typical EGM system (**Fig. 1**) has been used to replace two- and three-pin chart recorders. These systems were required to input physical parameters such as differential pressure, static pressure, and temperature to produce a volume total and calculated instantaneous flow rate. In addition, EGMs were capable of recording flow information to be retrieved at a later time. However, EGM systems have been increasing in requirements to contain additional features normally associated with remote terminal units (RTUs) and programmable logic controllers (PLCs). Requirements related to communication within a wide area network are often weighted evenly with measurement and recording capabilities when evaluating new EGM systems**.**

These systems must be configurable, both with regard to normal EGM functions and expanded communication system functions, yet easy to operate. These requirements, brought about by the increase in use of Supervisory Control and Data Acquisition (SCADA) computer systems, have shifted the role of the EGM device from that of a simple chart recorder replacement to full-featured communication equipment. In addition, the SCADA systems themselves have advanced to include a multitude of communication media options ranging from simple hardwire to microwave.

Prior to the introduction of flow computers, differential pressure, static pressure, temperature, and flow-rate data was interfaced to SCADA systems by connecting analog voltage or current outputs from a transmitter to analog inputs in a PLC or RTU, which was then connected to the SCADA system. Even with the introduction of flow computers, volume totals were often interfaced to a SCADA system by connecting a pulsed digital output, with the number of pulses corresponding to a scaled version of the total volume, to a pulse input in the PLC or RTU. This setup tends to be both costly to install and difficult to maintain.

In addition to the added SCADA support requirements, new EGM devices are expected to incorporate features that allow their use in many more varied applications than the early flow computers. New EGM devices are expected to retain the key features of traditional EGMs but allow for applications such as liquid measurement and storage in order to incorporate them into well test and allocation applications.

This paper presents a case history of a joint development of a new flow computer by one operator in the South Louisiana Gulf Coast and a manufacturer to produce a solution to the new problems in EGM applications. An outline of the operator's problems and the corresponding solutions are discussed along with benefits provided to the operator as a result of joint development with the manufacturer. Problems encountered during the development cycle and their solutions are also described. As more capabilities of this new flow computer became apparent, derivatives of the flow computer provided the operator with solutions to new instrumentation requirements not yet addressed.

## Increasing Battery Factors

The battery factor can be defined as the ratio of the total battery production, measured at the sales check point, to the sum of all wells in a particular battery. In other words, if one were to consider the total production of combined wells in a battery and the sum of each well's contribution to the total, the ratio desired would be one to one. To achieve this, reliable measurement techniques must be used. Electronic gas measurement has produced more accurate results, which have allowed battery factors to approach a value of one. Battery factors are important in that allocation and auditing requirements dictate having reliable and accurate data for each producing well. Most EGM devices perform accurate measurement, also providing historical data recording in electronic formats, which gives the added benefit of secure data to the user.

The flow computers being used by the operator in this case study were providing the desired measurement results. However, current and archived historical data could only be accessed directly at the flow computer. This presented a problem in that the costs associated with transporting personnel to offshore locations would limit the number of feasible trips to retrieve data. The operator desired to have this information available immediately and from various locations within the communication system.

## Communication (SCADA) System Specifics

The communication system in place used Square-D® Sy-net industrial network protocols. These protocols provide network routing of messages from a master terminal unit (MTU) to remote terminal units (RTU) located at various locations in the network. These protocols operate using multilevel network routing, which allows any number of RTU devices to be connected to the network.

In the case of the operator's SCADA system, several connection types are required to connect RTU devices (in this case the EGM device) to the MTU (a personal computer). The five primary connection types: direct connection via EIA RS-232E with a laptop computer, direct hardwire between flow computers via two-wire EIA RS-485, radio between offshore locations, microwave between offshore locations, and microwave between an offshore location and on-shore data link, are each shown in **Fig. 2**. With the use of remote network interface modules (RNIM), this communication system allows simultaneous access to any RTU device connected to the network by multiple users at different locations. For example, a local user might connect to the local network of flow computers and other RTU devices with a polling cycle of 30 seconds at a single offshore location, while a second user on-shore connects to the same flow computer with a polling cycle of 10-20 minutes. At the same time, a third user retrieves information from the same flow computer from a different offshore location. All three users seemingly connect to the same flow computer from different locations and simultaneously retrieve the information required by each.

With this system in place, the operator was required to evaluate new flow computers that were capable of meeting their measurement accuracy needs as well as tie in with the existing SCADA communication system.

Representatives of the operator's engineering, SCADA, and measurement groups and the manufacturer met to cooperatively develop a new flow computer that would meet these requirements. The manufacturer was able to integrate the operator's requests for implementation of Square-D protocol into the design of their own new flow computer.

In the development of the flow computer, the operator was able to provide specific requirements for the type and amount of data to be accessed via the SCADA network. In particular, frequently accessed parameters must be gathered in single access reads of the flow computer. Square-D RNIM protocol provides a maximum of 128 RTU registers to be accessed in a single read.[1] Therefore, the most frequently accessed parameters of the flow computer were located in the first 128 registers. Further, additional frequently accessed parameters were located in the next 128 registers to allow up to 256 parameters to be accessed in two reads. The remaining registers in the definition table of the flow computer contained many of the same parameter values as the first 256 registers. These registers also allowed access to many more parameters related to diagnostic system information, flow data records, and communication system check parameters not located in the first 256 registers. This method of constructing the register definition table provided unchanging locations to access all parameters of the flow computer, both calculated and user-specified, as well as user-specified locations for the operator's most frequently accessed parameters. The first 256 registers could be somewhat application specific since they contain the most frequently access parameters, which may change from operator to operator and application to application.

By providing access to all flow computer setup and configuration parameters, as well as runtime and historical data, the operator is able to completely monitor and control operation of the flow computer from a remote location. Keeping track of different versions of the flow computer register table was simplified by providing a version number to both the execution program of the flow computer and the register table.

## Enhanced Operational Features

As the development cycle progressed and additional personnel within the operator's organization became aware of the new flow computer development, it became apparent that two communication ports would not be sufficient to meet the needs of each application. Specifically, requirements were to include one direct communication port with a laptop computer, one connection to the Square-D SCADA network, and a third to a distribution control system (DCS), which would be at certain locations to allow access by a third-party contract company employed by the operator. The DCS system added the further constraint of communicating via Modbus protocol.

To meet the operator's established communication requirements, the manufacturer incorporated three separate communication ports. Each communication port is capable of operating independently of the other two. Each port is capable of communicating via Square-D™ RNIM or either of two accepted versions of Modbus. This was a requirement not addressed in the original specification of the design. However, meeting this need was simplified with the use of the 32-bit microcontroller system designed by the manufacturer. This capability allowed the flow computer to efficiently function as a communications processor for three separate communication systems, while at the same time performing all the calculations and data storage required to accurately characterize well production.

Each feature provided in the new flow computer design allowed the operator flexibility in the information that was available to the SCADA system, making monitoring of each individual producing well simple and complete. Likewise, the needs of local operators at offshore locations were addressed by providing immediate viewing of data using the keypad and display of the flow computer. Local operators were capable of performing all calibration and configuration required to maintain the flow computers with the alphanumeric keypads. Using this feature of the flow computer, the operator could perform routine calibrations, change gas characteristics, add new operators (with security access), and configure all operational parameters without the need of a laptop computer or other hand-held device. In addition, the local operator was capable of selecting up to twenty parameters to view as scanned information. This capability allowed each operator to customize the flow computer for the information most important.

## Testing

Testing of the new flow computer began at the manufacturer's facility with the assistance of personnel from the operator's SCADA groups. This testing focused on the ability of the flow computer to communicate via Square-D RNIM protocol. Once confident that the protocol implementation was reliable, testing of the flow computer shifted to the SCADA laboratory of the operator. This testing was done to verify operation of the flow computer within the framework of the operator's communication network.

With these tests concluded, validating the communications capabilities, a prototype was installed at an operator-designated location offshore. Shortly after this, the first preproduction instruments were installed at a different offshore location.

After introduction of the first pre-production flow computers, some problems became apparent. Communication requirements increased for the flow computer with additional data requests being made from MTU devices at different locations. In one instance, a local MTU was polling the flow computer about once per second. At the same time, a second MTU at the same location was polling about once every 30 seconds, while a third MTU located on-shore was polling about once every 15-20 minutes. Each MTU was attempting to gain access to the same communication port on the flow computer. With connection being made through the RNIM module, this should not have been a problem. However, communicating via RS-485, the operating current of the flow computer was more than the power supply could handle. With the increase in operating current, the operating voltage was decreased. This caused unreliable communication with the flow computer. The solution was to select a different power supply so that the additional operating current would not cause data dropout during the communication cycles.

Separate from this problem was another that caused unreliable results when communicating via Modbus protocol using radios. This problem involved the MTU device interpreting the squelch tail of the radio as part of the response message from the flow computer. Features within the flow computer allowed this problem to be solved by providing a Pre- and Post-Transmission delay time for enabling transmission of radio messages. It was found that if the Post-Transmission delay time were increased somewhat, the MTU could correctly interpret the end of the Modbus message. However, if this delay time was set too large, the MTU would time out waiting for a response. Time out errors in this configuration, communicating via Modbus, were also related to the number of data requests from the MTU. As the number of accesses per second is increased, the number of message dropouts (or communication time outs) increases. The binary (or RTU) version of Modbus requires that there be no more than 1.5 character transmission times between transmission of characters within a single message.[2] If the SCADA system was using a high polling frequency using Modbus protocol or a large amount of data was requested within a single access, the return message from the flow computer would at times contain data delays larger than 1.5 character transmission times. The manufacturer reviewed the operation of the flow computer to find that the transmission of large reply messages would be interrupted to perform measurements and calculations. The flow computer makes use of a real-time operating system (RTOS). The RTOS allows multiple functions of the flow computer to be performed seemingly at the same time. In the present case, the measurement functions of the flow computer would interrupt the transmission of large communication messages. The solution was to increase the priority of the communication function during the transmission of reply messages, which reduced the delays to less than 1.5 character transmission times.

This testing provided valuable information to the operator verifying that the choice of Square-D RNIM protocol was a better choice in their communication system configuration. Using Square-D RNIM protocol at a scan rate of about two scans per second, zero errors were detected out of 39,351 data accesses, whereas the same configuration produced 165 time out errors out of 31,053 total access using Modbus protocol at a scan rate of about once per second.

During the evaluation of the initial pre-production flow computers, the operator was able to provide the manufacturer with additional input to the operation and design. This provided the manufacturer with vital information, which was used to improve the overall acceptance of the flow computer by the operator. The cooperative evaluation of the new flow computer by both the manufacturer and the operator led representatives of both to suggest new applications and operational enhancements that would meet changing needs within the operator's measurement and communication systems.

One of these changes was the request for measurement of oil, condensate, or water production for use in well tests and production separator applications. The flow computer designed by the manufacturer already had multiple-pulse input capacity, but the operator required further improvement to the input capability. One such request led to the enhancements of the flow computer that allowed it to store historical data records for both liquid production inputs as well as the gas input. The historical data records for each contained (1) 1440 interval log data records, (2) 24 hourly log data records, (3) 35 daily log data records, and (4) 60 monthly log data records. A primary benefit of this large number of data records is that well tests could be controlled and evaluated remotely with data recorded at a rate of once per minute for a full 24 hour period.

In addition to the ability to record the flow data for the two liquid inputs, the manufacturer provided the ability to estimate daily production totals, further improving the well testing and allocation measurement capabilities of the new flow computer. Well testing capabilities became a point of emphasis for the operator during the evaluation of the flow computer and the realization of its capabilities. To further validate the well testing capabilities, the manufacturer added compensation calculations to improve the estimated production totals for the liquid inputs. These calculations could be used to compensate for either temperature only for one or both liquid inputs or temperature and pressure for one input (see **Fig 3** and **Fig 4**).

## Results and Evaluation

The evaluation of the designed flow computer led the operator to install several of these flow computers at various locations in the South Louisiana Gulf Coast Area. By combining the efforts of the operators engineering, measurement, and SCADA personnel with the product development staff of the manufacturer, the operator was assured that their unique requirements would be addressed in the resulting flow computer. Likewise, the manufacturer was able to evaluate the requirements of new EGM applications and align the development of their new flow computer to match the changing requirements of the operator.

By incorporating the new flow computer into their existing measurement and SCADA systems, the operator has shown to reduce the number of required trips offshore to gather information. This has freed personnel to focus their attention on evaluating new applications, new installation locations, and problem areas. By reducing the number of required trips to offshore locations, the operator has shown significant operating cost reductions related to EGM support.[3,4]

With acceptance of the new flow computer design, the operator is now able to evaluate new applications for derivatives of the original product. New applications of the flow computer and its derivatives include gas lift optimization and surface/subsurface flow control.

## Conclusions

1. By jointly developing specifications for the new flow computer, the operator and manufacturer were able to present a solution that would best meet the needs of the operator while improving the overall marketability of the instrument for the manufacturer.
2. Personnel from gas accounting, engineering, measurement, and SCADA groups can each retrieve flow information, simultaneously, from a single flow computer or multiple flow computers. This has allowed each to more accurately evaluate the production of the well to which the flow computer is connected.
3. The incorporation of the flow computer into the operator’s existing SCADA system has increased economic efficiency by reducing the need for helicopter or boat trips to offshore locations for routine checks and data collection.
4. The new flow computer design provides user-friendly operation, while at the same time providing the ability to configure the instrument in the field to meet different application requirements. This has provided the operator with the ability to purchase a single flow computer for different applications.

## Acknowledgments

We thank Steve Simonson of Chevron USA, Inc. for valuable information on the background of Chevron’s EGM strategy. We would also like to thank David Boroughs, Dave Dixon, Greg LaFramboise, David Stevens, Jerry Cox, and the countless others at Chevron who made the development of this flow computer a success for both Chevron and Halliburton.

## References

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2. AEG Modicon, Inc.: “Industrial Automation Systems Modicon Modbus Protocol Reference” Guide PI-MBUS-300 Revision E , March 1993
3. Perkins, D., Godfrey, C., Plunkett.J., and Olszewski, K. “Development of a Safety and Production Automation System Utilizing Open-System Philosophy” SPE Paper No. 27237 presented at the 6th Abu Dhabi International Petroleum Exhibition and Conference, 16-19 October 1994, Abu Dhabi
4. Perkins, D., Godfrey, C., Plunkett.J., and Olszewski, K. "Alternatives to Proprietary Systems For Safety and Production Automation," SPE Paper No. 28805. SPE 1994 Asia Pacific Oil & Gas Conference (APOGC), 7-10 November 1994, Melbourne

**Fig. 1— Typical EGM instrument shown as a replacement for a circular chart recorder.**

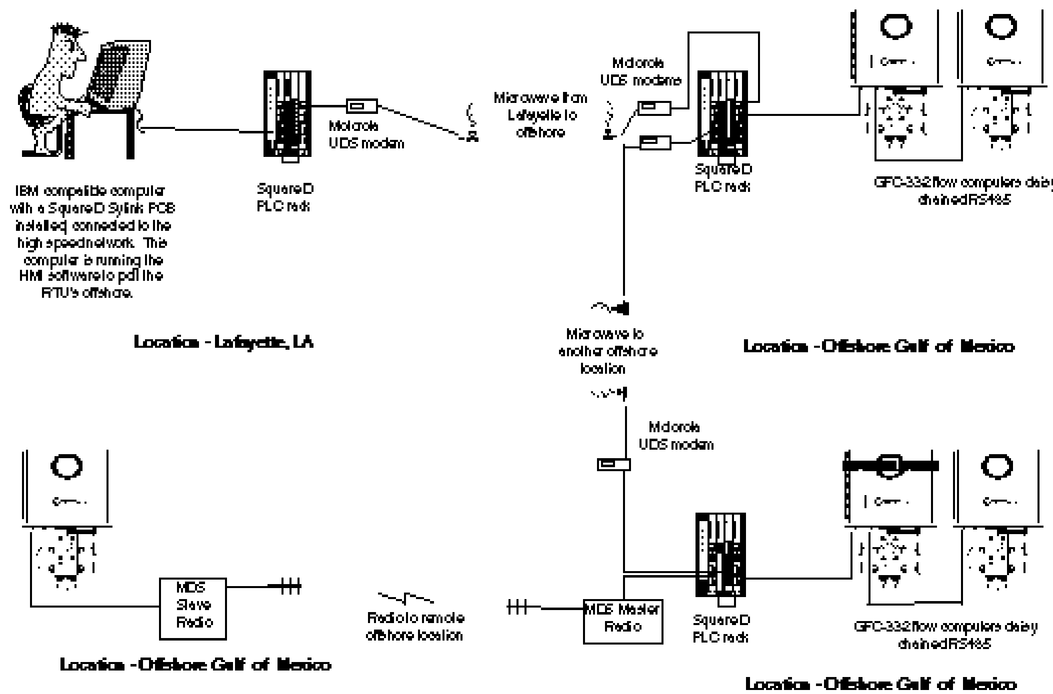


**Fig. 2— Chevron HMI network example depicting data transfer between offshore locations and with onshore SCADA**

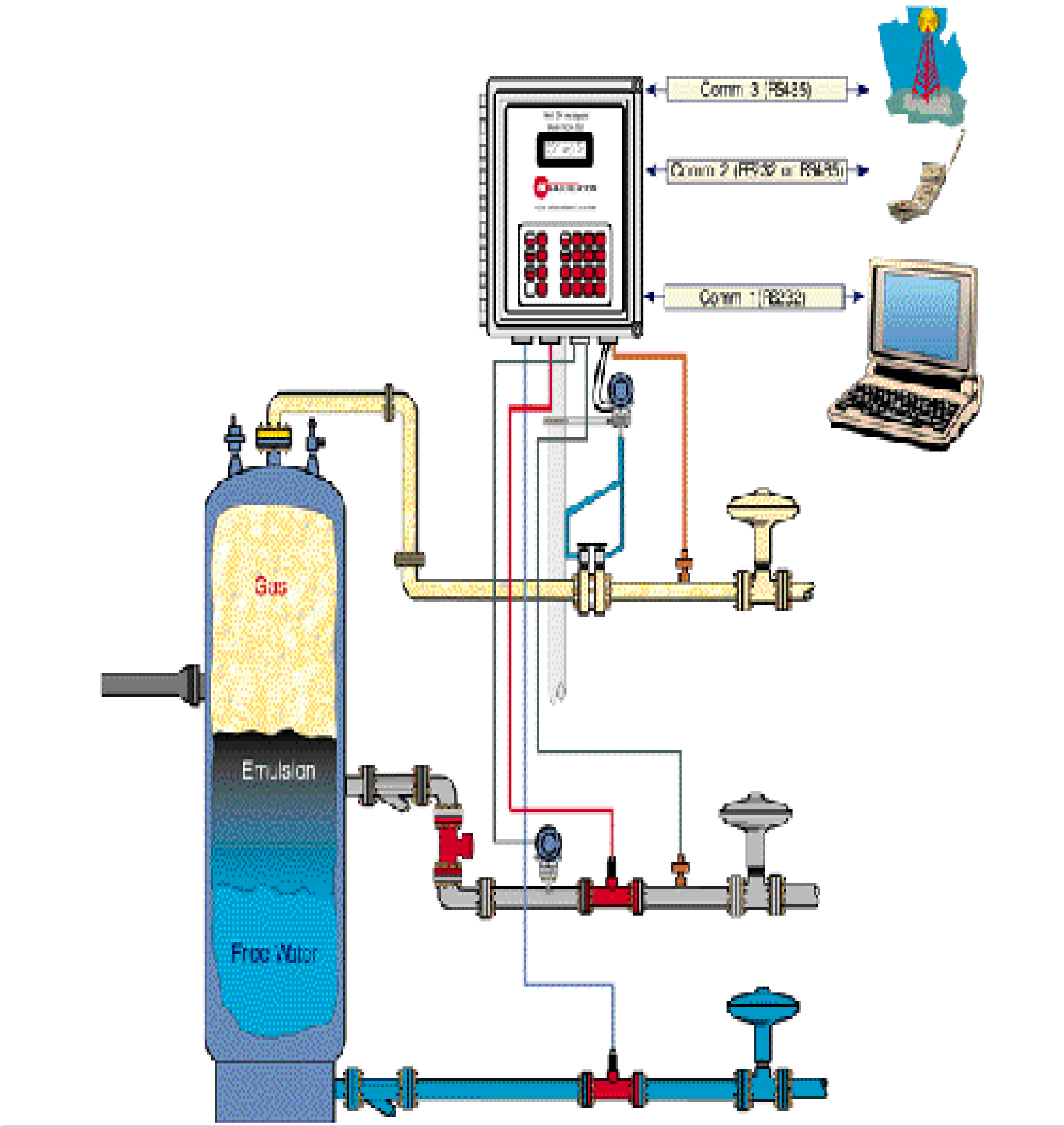


**Fig. 3— Typical test separator well test application using flow computer's liquid temperature and pressure compensating inputs. Shown also are various connections to the operator SCADA system**

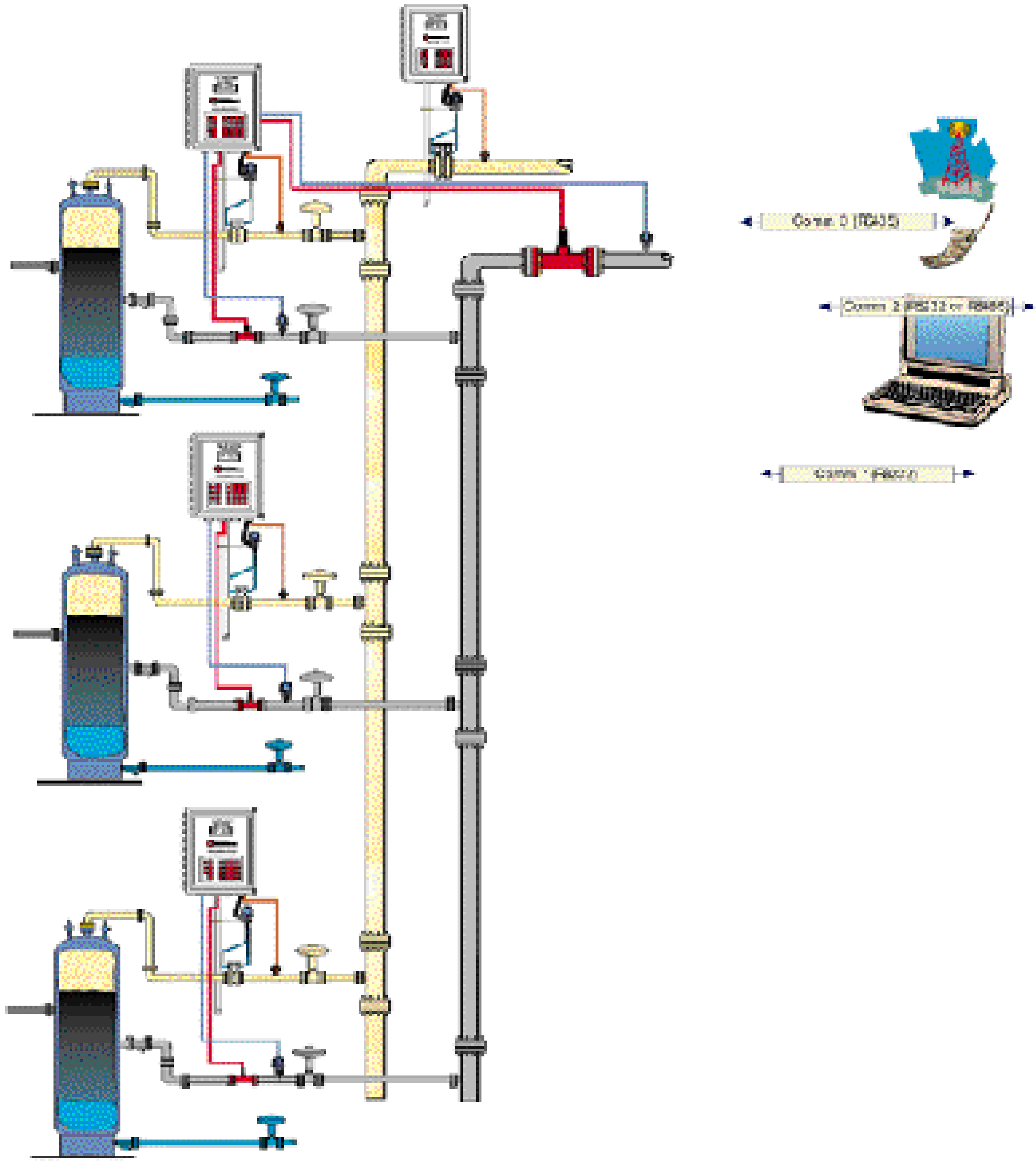

**Fig. 4— Offshore oil and gas production configuration showing measurement at sales point as well as individual well contributions.  An additional pressure measurement for each oil line allows determination of a correction factor resulting from gas breakout.**