Turnkey Well Testing Services: A successful Modality Measurement in Mexico

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SUMMARY

As part of the program to modernize the surface production facilities, many oil companies have implemented the use of new technologies such as the multiphase flow measurement systems among others. These technological advancements have allowed companies to automate and simplify the operations required to measure flow in oil wells.
In most cases, the implementation of this technology has been achieved by acquisition of the necessary equipment and in some cases through leasing. However, in Mexico after throughout studies had proven its feasibility, it was decided to apply a totally new concept for an specific application. It consists in contracting an integrated well measurement service directly from a company equipped and qualified to provide it efficiently. The company then follows a measurement activity program prepared by Pemex Exploration and Production.

The project scope included 1,656 measurements in 2 years (69 per month) to be performed at 2 separation batteries and 5 individual well collection manifolds located in the Comalcalco District of the Pemex Exploration and Production Southern Region which did not have the necessary infrastructure to adequately measure the flow of oil, gas and water. For this purpose, 2 mobile autonomous measurement units were used, each one equipped with 2 multiphase flow meters, which were designed specifically to cover the flow rates handled in the above mentioned facilities.
This paper discusses the Mexican experience; the details involved in a typical mobile measurement operation; the way information is handled and results reported; the usefulness of the measurement results; and the numerous advantages of implementing the multiphase metering through this new modality as well as recommendations for future applications.

INTRODUCTION

One of the multiple services that the Instituto Mexicano del Petróleo (IMP), offers to Petróleos Mexicanos is the technical support in optimizing and modernizing its production facilities; particularly those used for well testing, by means of the testing, evaluation and adaptation of new technologies, as the multiphase flow meters
The traditional approach to measure the produced fluids has required separation and independent measurements of the oil, water, and gas. These systems are bulky and require of big spaces for their installation; their operation imply risks of accident for the operative personnel, and contamination of the environment. It is not possible to measure the produced fluids by two or more wells that arrive in a single stream from a remote manifold to the process facilities.

Because of the above facts, the multiphase flow meters were considered a viable alternative to measure the produced fluids, since also they present additional advantages as the immediate readiness, its remote handling, as well as the automation of the well testing operations.

This technology was introduced in Mexico by means of a project developed at the Instituto Mexicano del Petróleo [1] whose scope includes a feasibility study and the acquisition of a multiphase flow meter manufactured especially for a gathering battery located in the southern region of México, where it was installed at the end of 1993.. The functionallity of this meter was evaluated by comparing its results with those obtained with the traditional measurement system used in that battery, and the satisfactory results marked the beginning of an era of multiphase flow measurement in México

PRODUCTION FACILITIES CONSIDERED TO IMPLANT THE USE OF MULTIPHASE FLOW METERS

The production facilities considered to implant the use of multiphase flow meter for well testing operations are located in the Comalcalco district, (See Figure 1). Their distances from the monitoring and supervisory center located in the city of Comalcalco are shown in Figure 2. These facilities include the following gathering batteries and remote manifolds, those in which the framework to carry out well testing operations with conventional measurement systems is very limited.

Manifolds:	**Batteries**
Sen Norte	Pijije
Chinchorro	Luna Modular
Mora	
Bellota 114	
Yagual	

The gathering batteries are facilities where the produced fluids are separated, measured, stored and pumped . The produced fluids arrive to these batteries in flow lines that may contain the production from individual wells, or the production from two or more wells. In this last case, it is not possible to measure the individual production of each well.

The remote manifolds are collectors that are located at long distances from the gathering batteries. The fluids produced by several wells are collected in these manifolds and they are sent from here to the gathering batteries. In some cases a flow line for the purpose of measuring the production from an individual well connects the manifold with a battery. One of the manifolds has the arrangements to install portable meters, and others are lacking of any installation for metering purposes. None of them has neither electric power nor phone line.

Operation conditions and fluids properties. The operation conditions and the ranges of oil, gas, and water flow rates, as well as the percentage of water in the liquid handled in each one of the facilities are shown in Table 1. The values of the properties of the fluids are shown in Table 2.

ALTERNATIVES TO IMPLANT THE USE OF MULTIPHASE FLOW METERS

In order to define the best way to implant the use of multiphase flow meters in the Comalcalco district, a project was developed whose scope included the feasibility study to define the convenience of contracting the turnkey well testing services. The following ones were the analyzed alternatives:

Purchase of multiphase flow meters. In this modality the meters are the user´s property, and they are operated with qualified own personnel. The manufacturer generally provides a lot of spare parts and he is responsibly for assuring operation of the meters during the period of guarantee.

Rent of multiphase flow meters. In this case the user operates the multiphase meters with their own personnel, but the manufacturer is the owner of the equipment and has the obligation of providing the appropriate maintenance that guarantees the good operation of the system

Turnkey well testing services. In this modality, the user defines a measurement program, the information and parameters required as a result of such measurements, as well as the way and place in that this information should be available. The manufacturer is the owner of the equipment, and is the reponsible for its operation. He has the commitment of providing the user the ageed reports in the established formats.

ACTIVITIES CARRIED OUT BEFORE BEGINNING THE WELL TEST SERVICE

Before beginning the well test service, it was necessary to carry out the following activities:

Bases for biding and technical specifications. In these documents the PEP requirements were captured, to carry out the well test operations by using multiphase flow meters in the previously defined facilities; the properties of the produced fluids and the operation conditions were also described.

Call for bid. The international public bid SRS-CO-PR-TLC-052/96 was published in april 30, 1996. In this publication were made of the public knowledge the dates for purchase of the bases, technical visits, and reception of offers, among others.

Evaluation of offers and assignment of the contract. To make the technical evaluations, 86 concepts of the characteristics of the offered meters were considered; after this evaluation, a technical opinion was elaborated. From those that qualified technically, their economic offers were then revised, selecting that of smaller cost to assign the contract.

Manufacture of the meters and trucks. The multiphase flow meters were built in Norway and the trucks for their transportation were manufactured in Houston, USA.

Adaptation of the facilities. The adaptations to the facilities to install the multiphase flow meters were in charge of the PEP personnel. These consisted basically on building pipe lines for feeding and discharging the flow, and to condition the place for the access of the mobile units.

Factory acceptance tests. The multiphase flow meters were evaluated in the factory, prior to be shipped to México for their test and field evaluation. The factory acceptance tests included hydrostatic tests and the simulation of the measurement process.

Tests of functionality in field. The field tests were carried out from june 10 to july 16, 1997, and they consisted on measuring three times the oil, water and gas flow rates from 8 wells whose productions converge to the gatherin batteries Mora y Luna Modular. These tests were covered satisfactorily since when comparing the measurement results obtained with multiphase meters and with conventional meters, the deviation obtained were smaller than the specified tolerances.

SCOPE OF THE SERVICES

The turnkey well testing service included the measurement of the produced fluids, oil, water and gas, of the wells and stream that arrive to the following facilities:

Facilities	Number of wells	Number of stream
Sen Norte	7	
Chinchorro	3	
Mora	11	
Bellota 114	9	
Yagual	2	
Pijije	11	
Luna Modular	11	1

According to the contract they were carried out 1656 measurements during a two year period, 69 monthly, according to a program established by the PEP personnel.

Duration. The established duration for the service was 880 days, with date of beginning september 1, 1996 and finishing january 28, 1999, including 150 days for the manufacture of the the meters. However, for accidental causes, the measurement service began in August 1997 and it finished in June 1999.

Deliverables. According to the contract, the supplier of the service provided the transmission of data and measurement parameters, via cellular phone, from the measurement point to the Monitoring an Control Center located in the city of Comalcalco. This Center was also given and installed by the supplier of the service.

During the operations the supplier delivered the results obtained from the measurement, in digital electronic way, in real time, in a computer of the Monitoring and Control Center , in Comalcalco. Additionally, the supplier deliver to the operative personnel the printed reports with the following information:

*Well name
*Date and time
*Oil flow rate (m3/d)
*Gas flow rate (m3/m3)
*Water flow rate (m3/m3)
*Liquid flow rate (M3/d)
*Test duration (hr)
*Gas oil ratio (m3/m3)
*Water cut (%)
*Pressure (kg/cm2)
*Temperature (oC)

Tolerances. For the batteries Pijije and Luna Modular, as well as for the manifolds Sen Norte, Yagual, and Chinchorro, it was established that the deviations between the volumes measured with the multiphase flow meter and with the conventional test separator use traditionally in PEP, than should not be greater 10%. For the manifolds Mora and Bellota 114 the deviations should not be greater than 5%.

DESCRIPTION OF THE MULTIPHASE FLOW METERING SYSTEM

Mobile units. The measurements were carried out using two completely equipped trucks which operate as autonomous unit; in each one of them it was istalled a control room, an electric power generator, computation and remote comunication system, two multiphase flow meters, security equipment, drainages and containers of liquid. In the control room there was a small laboratory to determine the content of water in liquid phase.

Meters. The meters were designed to measure the produced fluids at extreme operation conditions, and they should be able to manage any fraction of free gas and any pattern of flow that it could be present during the well testing operations.

During the service, four Fluenta 1900V multiphase flow meters were used, two 1” meter and two 3” meter, to allow a wide range of flowrates to be covered. Each meter was placed in a skid with flange in the ends , to allow a quick connection with the test system, by means of flexible hoses. These meters are non intrusive, they don´t contain mobile parts, and they don´t require to separate the phases to estimate the oil, gas, and water flowrates.

In each truck there were installed two meters, one 1” meter and one 3” meter, in such a way that any one of the units could manage a broad range of flowrates.

Remote communication equipment. Each one of the mobile units had a communication system integrated by a cellular modem coupled to a computer. This modem was connected to a cellular phone with a directional antenna that allowed the transmission of information in less than one minute.

Monitoring and Control Center. This Center was used for storing the information and integrating a data base for its statistical handling. A computer, a cellular phone, a modem, and a printer were the main components. From this Center it was possible to have access, in real time, to the generated information in any production facility.

Auxiliary services. Since the measurement system should operate in an autonomous way, the mobile units had the following services:

*Electric power generation
*Water for diverse use
*Security an against fire equipment
*Drainages and collectors
*Containers for liquids

PRINCIPLE OF OPERATION OF MULTIPHASE FLOW METERS

A multiphase flow consists of the three components oil, gas and water. In the process of determining the individual volumetric flow rates of these phases, the fractions and velocities of each of the components are found.

To determine the three fractions, three independent equations are needed. These equations are obtained by 1) measuring the permittivity of the mixture, 2) measuring the density of the mixture, and 3) the fact that the sum of the three fractions always will be one.

A venturimeter is used to determine the velocity of the multiphase mixture. The venturimeter measures the differential pressure before and after a slight narrowing down of the pipe diameter, a technology which has been used with single phase flows for decades. Cross-correlation is used to determine two velocities for the multiphase mixture. Simplified, the velocity of the large gas bubbles gives the velocity of the gas phase, and the velocity of the small gas bubbles gives the velocity of the liquid phase. These two velocities are found by utilizing two different cross-correlation techniques.

Determination of oil, water and gas fractions
The permittivity and density is different for each of the three components of an oil/gas/water mixture. If these permitivities and densities are known, and the total permittivity and density of the mixture can be accurately measured, the fractions of each of the three components can be determined. If the mixture is employed as the dielectric medium between two electrode plates, the electrical field between the plates will be a function of the permittivity of the mixture. If the same medium is positioned in a gamma radiation path, the measured absorption of gamma particles will be a function of the density of the mixture. The Capacitance sensor thus provides the permittivity, and the gamma densitometer the density, of the mixture.

This principle, which relates the fractions of the different components to the mean permittivity and mean density of the mixture, is used by the multiphase flow meter to obtain two independent equations describing the dependency of the three components. The third, and last, equation is the obvious fact that the sum of the three fractions always will be one.

Determination of liquid an gas flowrates
The multiphase flow meter system determines the velocities of the large and the small gas bubbles. Simplified, these indicate the gas and liquid velocities. The sensor contains a number of electrodes with different sizes and patterns, and the two velocities are determined by cross-correlating signals obtained from pairs of electrodes.

When the two flow velocities are determined, these are combined with information from the fraction measurements in a process based model in order to determine the individual flowrates of oil, gas and water.

Even though cross-correlation of signals is a well-defined mathematical method, its use in multiphase flow requires careful selection of a large number of parameters for the results to be satisfactory. Through systematical testing, the parameters are chosen, and the complete algorithm is implemented on an industrial PC.

OPERATION

For carring out the operations, the PEP personnel provided in advance to the supplier of the service, a monthly program with the list of the wells or stream to be measured. The measurement process began once the trucks were transferred to the production facilities and the system were connected. The procedure carried out for making the measurement was the next.

- - Connect the measurement system to the feeding and discharge pipelines.
- - Start up the electric power generator
  (both communication and computation equipments must be energized)
- - Align the flow to the multifphase meter for their stabilization
- - Select the meter to use, depending on the flowrate to be handled
- - Begin the measurament process.
- - Register, store, and transmit the measurament parameters.

The generated information, operation parameters and flowrates were sent to the Control Center in Comalcalco using a portable computer Notebook, modem and cellular telephone.

In order for the PEP personnel to verify the usefulness of the above activities, it was established that a PEP representative could supervise, in any time, the execution of all those works, and also to supervise the materials used during operations. The system was totally operated by the supplier of the service.

Once the operations were finished, the liquids contained into the metering system were pumped to the process pipes, in such a way that the equipment was cleaned and ready for transfering it to another place.

A diagram of the installation of the mobile unit for realizing the measurement is shown in **Figure 3.**

CONCLUSIONS

The use of multiphase flow meters in the Comalcalco District, through a turnkey well testing service, demostred to be a successful option for well testing operations in México.

The portable multiphase flow meters allow the measurement of oil, gas and water produced from wells in production facilities where it is not feasible to use convencional systems, because the lack of infrastructure and auxiliary services, or in production facilities with few wells, where the investment in fixed installations are not justified..

Since multiphase flow meters use technical principles that are in a constant evolution and improvement, the turnkey well testing service modality allows the use of this technology, without the need to acquire models that in a little time will be obsolete.

When the multiphase flow meters are used, the time for well testing operations is at least 50% smaller than the time required when using conventional system.

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Table 1. Operations Conditions

GATHERING	Qo(m3/d)		Wcut (%)	Qg(m3/d)		GOR (m3/m3)		P(Kg/cm2)		T (°C)	
BATTERIES	Max	Min		Max	Min	Max	Min	Max	Min	Max	Min
PIJIJE	7.989	67	54,1	1.034.883	14.405	519	215	82	6	70	30
LUNA MODULAR	626	9	70	802.280	8.856	1.318	646	84	5,5	70	55
MANIFOLDS											
SEN NORTE	1.269	228	1,3	565.974	104.196	457	446	395	81	100	65
BELLOTA 114	361	24	4,2	91.800	7.416	412	179	38	12	38	
YAGUAL	988	71	10,13	219.336	17.324	244	222	106	12	80	
MORA	341	71	2,6	85.932	10.947	312	123	120	12	43	

Table 2 Fluid Properties

GATHERING	SGo			mo (cp@37 °C)			SGw	SGg(air=1)
BATTERIES	Max	Min	Avg	Max	Min	Avg	Avg	Avg
PIJIJE	0,836	0,822		3,84	2,1		1,114	0,71
LUNA MODULAR			0,802			2	1,113	0,7074
MANIFOLDS								
SEN NORTE			0,823			3,05	1,057	0,72
BELLOTA 114	0,9	0,83				3,4	1,006	0,779
CHINCHORRO	0,84	0,862		4,6	8,6		1,008	0,912
YAGUAL			0,84			4,6	1,008	
MORA			0,832			3,7	1,002	0,855

Fig. 1. Mexico and Comalcalco District

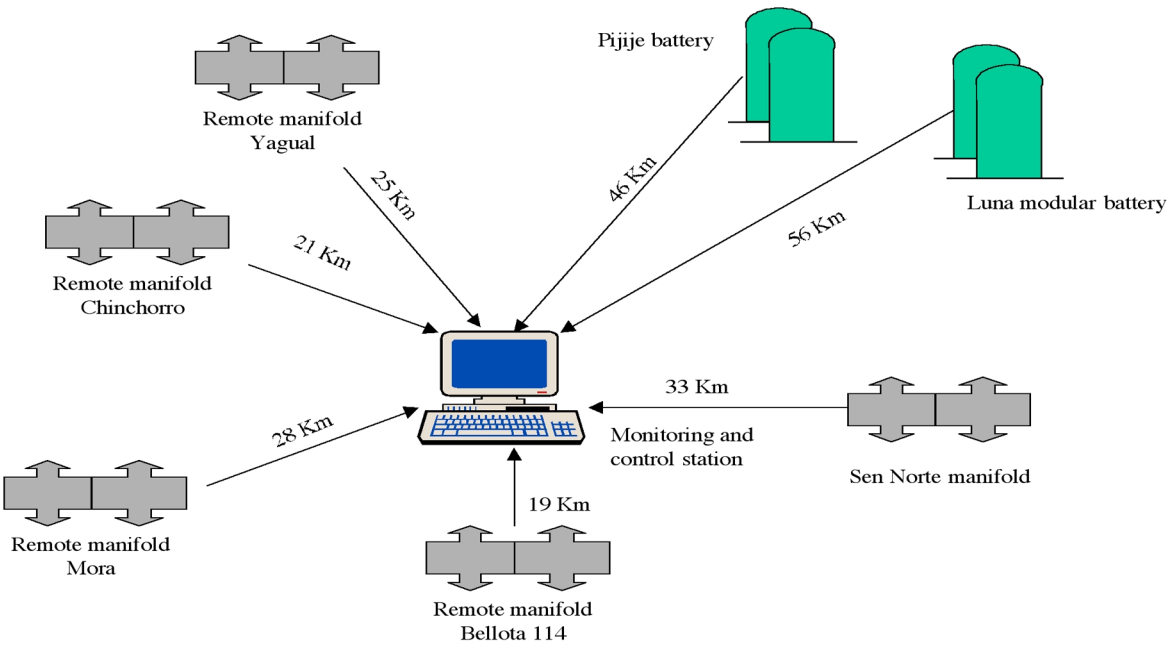

Fig. 2. Gathering batteries and manifolds

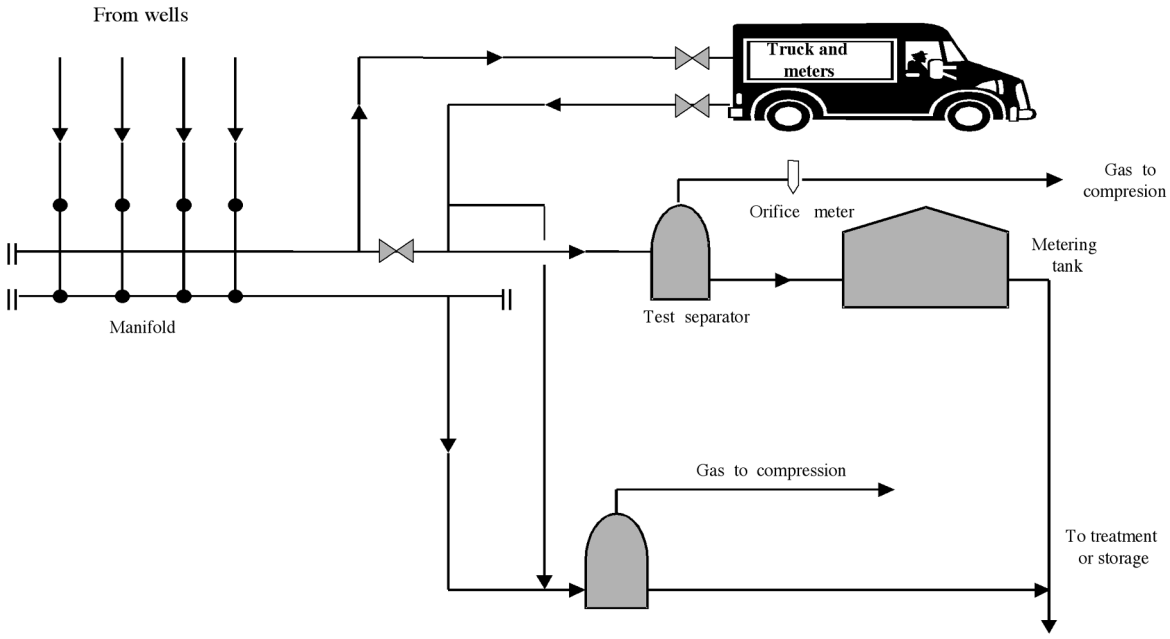

Fig. 3. Configuration in gathering battery