Wax Solvent Displacement in Atoll Development Project Using Ultrasonic Devices: Case Study in the East Nile Delta in Egypt

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***Abstract*—Ultrasonic device is used in many different fields. It is used to detect objects; measure distances and gives a lot of information about oil and gas flows. The flow in pipes can be measured by ultrasonic flow meters, which measures the average velocity of flowing Material. In this paper, we will go through a new application by injecting a solvent with a produced gas to resolve the gas blockage problem that caused by slugs creation in a pipeline by benefiting the Ultrasonic device usage, as it works with the same inner size of the pipeline, as well as getting pipe and flow information such as temperature, pressure and having accurate flow gas measurement.**

1. Introduction

As known, the ultrasonic flowmeter has a better response measurement Compared with any traditional flowmeter (Orifice Meter). Where it has many advantages such as: it isn't containing any moving parts, no pressure losses, it has a wide measuring range, excellent repeatability, and high precision, Vena Contracta Point Prevent, zero maintenance, and it is used in many industrial applications [1-4], especially the applications that contain large diameter pipes and larger flows as in the paper case study [5-7].

The case study uses the ultrasonic flowmeter devices to measure gas parameters in the line as well as any change in injection rate when using a new solvent.

2. Ultrasonic Gas Measurement and Orifice Plate

Orifice meters have used because a modest to understand and low cost for meter sizes. There are no moving parts and they always give you a number. In addition, orifice meters have the limitations. The only benefit for orifice meters over the ultrasonic flowmeters is too costly.

Now when the total cost is considered, the overall cost of an ultrasonic meter is will be more inexpensive compared to an orifice meter [6].

- **Range ability plate changes**

Orifice meters have some limitations that should be noted. The orifice can have a very large measurement range only if the engineer is willing to constantly change plates. The turndown of an orifice is strictly limited if you are not willing to spend the time and effort to change the plates as needed. However, in case of under and over ranged, the orifice will be given the reading number. So, if accuracy is important to your application, this may not be the best solution.

- **No moving parts, but not as robust**

Orifice meters do not have moving parts, but their design integrally places of an obstruction in the flow path in the plate. The plate's bore can be cracked from high flow rates or if slugging occurs. The orifice plate is turned into unclean and dirty and leaking from orifice rings are the common problems that an orifice meter may succumb to.

- **The Ultrasonic Flowmeter Benefits**

Ultrasonic meters are extremely simple devices. At the core of a transducer type of ultrasonic meter are one or more pairs of transducers. One transducer installed in upstream opposite and facing to downstream send a sound wave and received by its corresponding transducer located across the meter and downstream from the first transducer. A second sound pulse is generated from the downstream to the upstream transducer. The electronic head computer installs on the top of ultrasonic meters as shown in figure 5 is measures the difference between sounds wave which traveling from upstream to downstream. This calculated time difference is used to calculate the actual gas flow going through the meter in cubic feet per unit. The operation of a USM is additional diagnostic information and data that can be monitored and controlled which give the client a great amount of information on how the meter and the meter run is performing. USMs are also different from orifice meters because that there are no obstacles in a USM which mean there is no pressure drop and pressure loss.

2.1 An ultrasonic meter and an orifice meter at site

MPU Series B 1200 ultrasonic gas flow meter was installed in series with a single orifice meter at a pipe location in IDKU Hub – Egypt. The object of the test was to validate the ultrasonic claims close the benefits that are would provide. The test would provide a good step in establishing the acceptance of ultrasonic meter technology instead of Orifice Plates [6]. The test would be considered a success if the ultrasonic meter demonstrated the following:

- Lower maintenance cost through high range ability.

- Lowest possession of the ultrasonic meter's physical design.
- Better measurement quality as a result of ultrasonic diagnostics.
- Lower overall measurement uncertainty from the ultrasonic meter.

The test was conducted by FMC Company in January 2012 and updated in April 2017. The gas from the separators was combined in a single line where it flowed into a final vertical separator before entering the meter runs. An 8" pipeline exited the final separator and the ultrasonic and orifice meters run in the line.

2.2 ULTRASONIC FLOWMETER principles

The measurement principle of the fluid in a pipe in a single-path ultrasonic flowmeter can be observed from Figure 1 [9]. The figure assumed that the diameter of the pipe is mentioned by D, ultrasonic transducers are installed on A and B sides from the pipe, which could emit and receive the ultrasonic signals, the distance between A and B represents by L, and θ is the angle of AB with the pipe axis. The times t1 and t2 represent the elapsed times for the signal from A to B and from B to A respectively. The circuit delay is τ_1 and τ_2 for the signal from A to B and from B to A respectively. In addition, the actual pressure and temperature are P and T respectively.

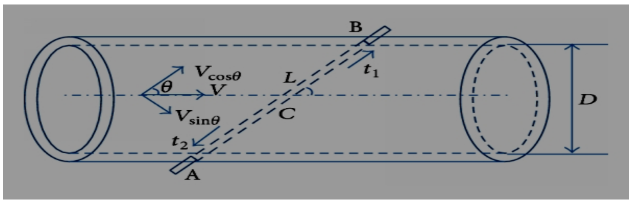

Figure 1: The principle of the ultrasonic flow meter.

The true photo of the case study pipe with the ultrasonic device attached is shown in Figure 2.

Figure 2: Photo of the pipe under study with the ultrasonic devices

The mathematical model of the flow in the pipe can be obtained from [10-13]:

$$Q = K\frac{\pi D^2}{4}V_L\frac{P}{P_o}\frac{T_o}{T} \quad (1)$$

where K is a power correction factor that can be defined as the ratio of the cross-section mean velocity and the linear velocity as given in (2):

$$K = \frac{V_A}{V_L} \quad (2)$$

Where there is an actual fluid velocity distribution in the pipe cross-section, therefore VL not equal VA. The power correction factor is estimated from many papers as 0.75 [14, 15].

The linear velocity of the fluid can be calculated as:

$$V_L = \frac{L}{2\cos\theta}\left(\frac{1}{t_1-\tau_1} - \frac{1}{t_2-\tau_2}\right) \quad (3)$$

where the time t1 and t2 can be determined from:

$$t_1 = \frac{L}{C+V_{cos\theta}} \quad (4)$$

$$t_2 = \frac{L}{C-V_{cos\theta}} \quad (5)$$

where C and $V_{cos\theta}$ are the acoustic velocity and the component of flow velocity that represent the propagation velocity of the ultrasonic signal.

2.1 Trial results

As explained above and from equations [16-17]. It is clear that measuring of the gas flow, pressure, and temperature will be known by the ultrasonic device in each case as usual with the normally used solvent. The initial atoll offshore line pressure scheme is shown in Fig.3. The figure shows the pressure in the pipe is very high which may damage the pipe after a few days if the pressure exceeding the umbilical design pressure limit.

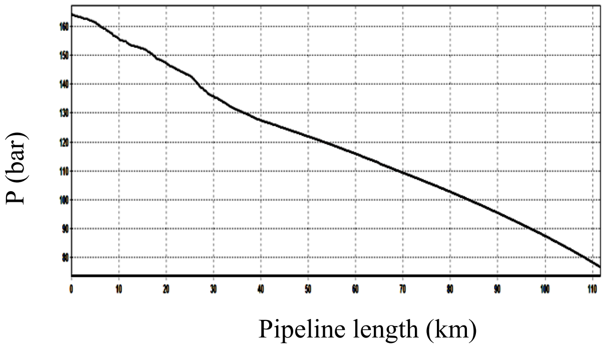

Fig.3. Initial Atoll sea line pressure profile

Due to the spare in the umbilical line which responsible for the injection any liquid or solvent from onshore to the wells direct and after we get the samples from the pipes to catch the new slugs and analyze it in the Lab to get the suitable new solvent to solve this problem and decrease the pressure to save the pipe from any future cracks and by Ultrasonic device readings we can select the new solvent that can react with the new slugs. However we use ultrasonic device or any others.

Fig.4. the figure shows the temperature profile in the pipe that is initially very high and decreases along the line length. Injecting solvent with uncontrolled quantities may cause temperature increase problems that mainly avoided by

monitoring ultrasonic flowmeter readings, that was not available in using old orifice meter.

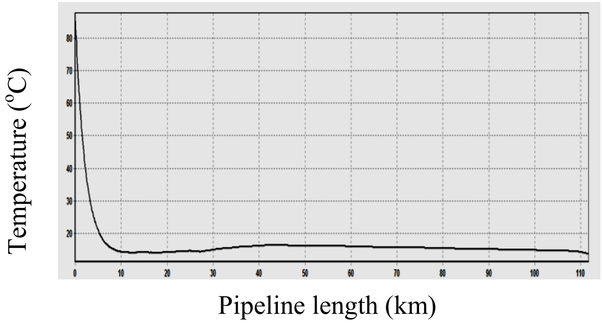

Fig.4.Gas Temperature at Pipeline End Manifold "PLEM"

The calculated amount of wax solvent needed for core filling (which most probably will be xylene due to a recommendation from the lab test) is 60 m3.
Umbilical displacement will be carried out using air pumps and one

3. Procedure Overview

Xylene injection Philosophy: Having All Atoll wells are producing with its full rate and keeping Atoll line operating pressure and temperature at the steady condition.
Figure 5 shows the ultrasonic gas and liquid profile speed for Atoll Sealine in m/sec.

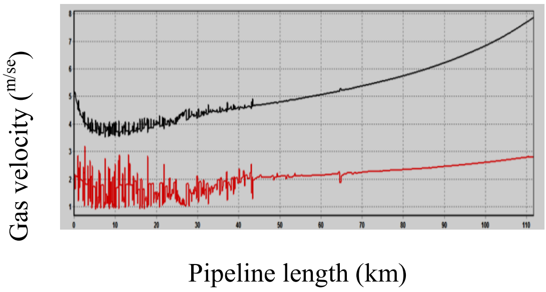

Fig.5. Gas and liquid profile speed for Atoll Sea line m/sec

The Xylene content animation at 11 p.m using distributed Control Systems (DCS) is shown in Fig.6.
After filling Atoll-1 with xylene, it is planned to open the well to allow forming xylene slug to dissolve precipitated wax.
The processor's step dates are summarized in the following table. Looking at the following table, the Wax Appearance Temperature "WAT" is above 14°C from 1st May, which is covering a period of approximately 3 months. Over this time then, it is possible to surmise that the system may be at risk of wax deposition over the first length of the flow line.

4. FINAL RESULT

Procedures Steps is to build the design in engineering by using YOKOGAWA DCS program software and insert the function blocks and parameters to get the results and compare with orifice plate with supporting by FMC software.
As shown in figure 3 that the graphics will demonstrate the engineering design page in DCS software and the Ultrasonic nameplate to shown all reading and measurements in the device itself and controlled from Control Room from the operator. The ultrasonic meter was installed according to the manufacturer's recommended layout and was in accordance with standard AGA 9 recommended practices. The ultrasonic and orifice meter was set up as 2 individual meter runs within a YOKOGAWA DCS Control System [7].

In table 1, the test data points towards the ultrasonic meter having the lower overall measurement uncertainty. For the lowest gas measurement uncertainty, orifice and ultrasonic meters should always be used to measure natural gas.
Consequently, the following section will focus more on other ultrasonic meter benefits and leave the reader, after reviewing the results, to decide on which technology might provide or choose a lower overall uncertainty over time.
Steps to build the design and implementation phases to solve the problem by using DCS software and certified simulation software for Oil and Gas field through ultrasonic flow challenges as like as Hydrate formation, Wax/scale precipitation and slugs flow racking. [13]
The following figures show the measurements of the ultrasonic devices and the distributed control system after adding the Xylene.

Figure 8 shows the Gas and water flow rate of the fluid after adding the Xylene. The figure shows that the profile in the pipeline reaches the currently tested WAT (18oC) after 5 km starting from Pipeline End Manifold "PLEM."
Figure 9 shows the Xylene content in the Atoll-1 flow line. Where the volume of Xylene begins with maximum values then reduced to a minimum value after around 1.5 seconds.

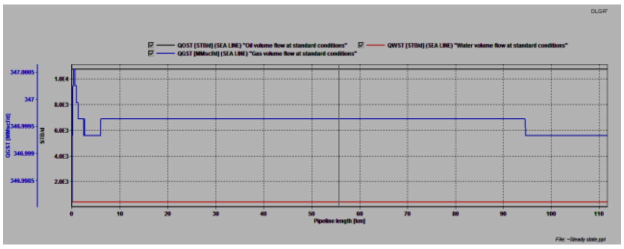

Fig.9. Gas Condensate and water flow rate

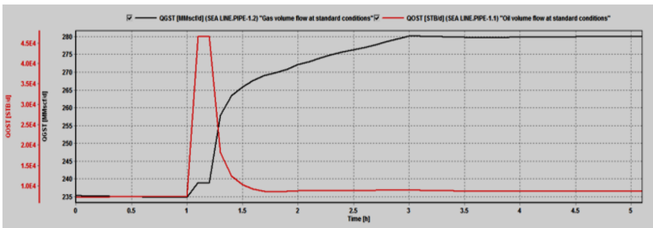

Fig.10. Gas and Water flowrate at PLEM.

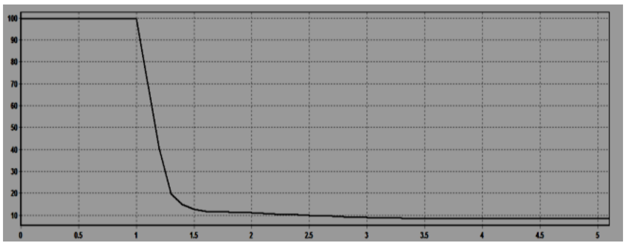

Fig.11. Xylene content in Atoll-1 flow line

It can be concluded from the operating procedures and the simulation DCS results that based on average injection rate of 240 BPD it will take around 2.5 days to fill Atoll-1 flow line with xylene this will be reflected in production defer of 300 MMSCF including ramp-up losses. [12]

5. Conclusion and Future Work

Solvent job confirmed its performance so that a plan will be in place to execute the job once get definite pressure drop across the sea line depending on the number of wax deposits and onshore handling facilities. The ultrasonic devices and DCS are important to measure and monitor the operation at each stage during the study, no matter the type of solvents.

Table (1): The processors steps dates

Date	Average Subsea Pressure	Wax Injection kg/hr	Raw gas mmscfsd	Raw condensate bbl	Wax Appearance Temp. (WAT C)	Pour point C
16/12/17	143.60	34.00	294.15	9372.00	9.00	-9.00
17/12/17	144.20	34.00	293.71	9200.00	10.00	-6.00
01/05/18	144.50	34.00	290.40	9171.00	18.00	0.00
20/02/18	161.70	35.70	346.62	11278.00	18.00	-3.00
22/02/18	158.80	35.00	329.57	10601.00	NA	NA
29/05/18	164.80	35.00	350.18	11101.00	18.00	-3.00
22/06/18	164.50	43.00	350.79	10970.00	15.00	-2.00
23/06/18	164.60	40.00	351.79	10693.00	16.00	-3.00

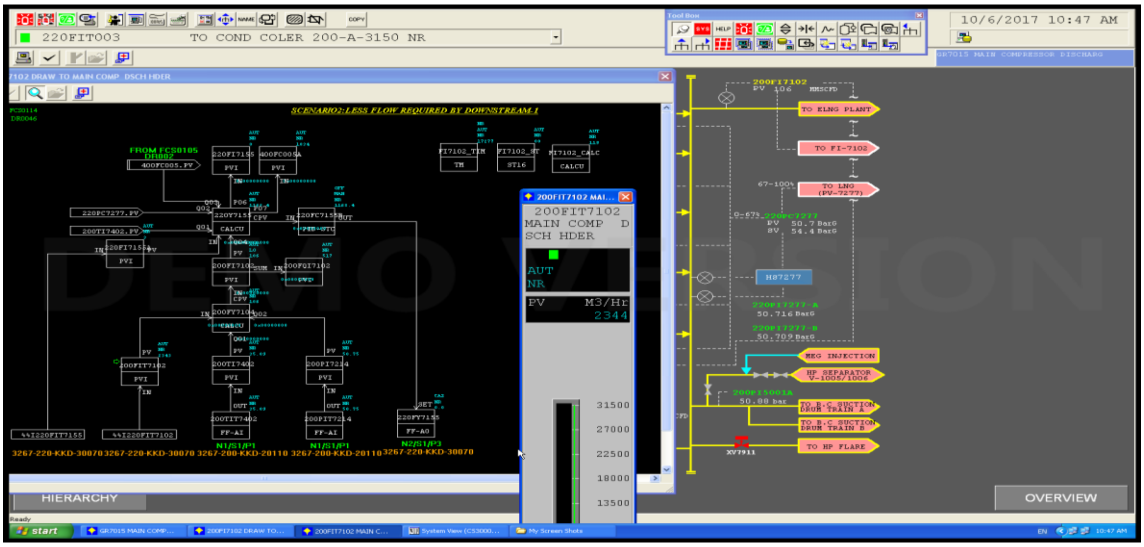

Fig. 7 Ultrasonic flow rate (Design Block Diagram).

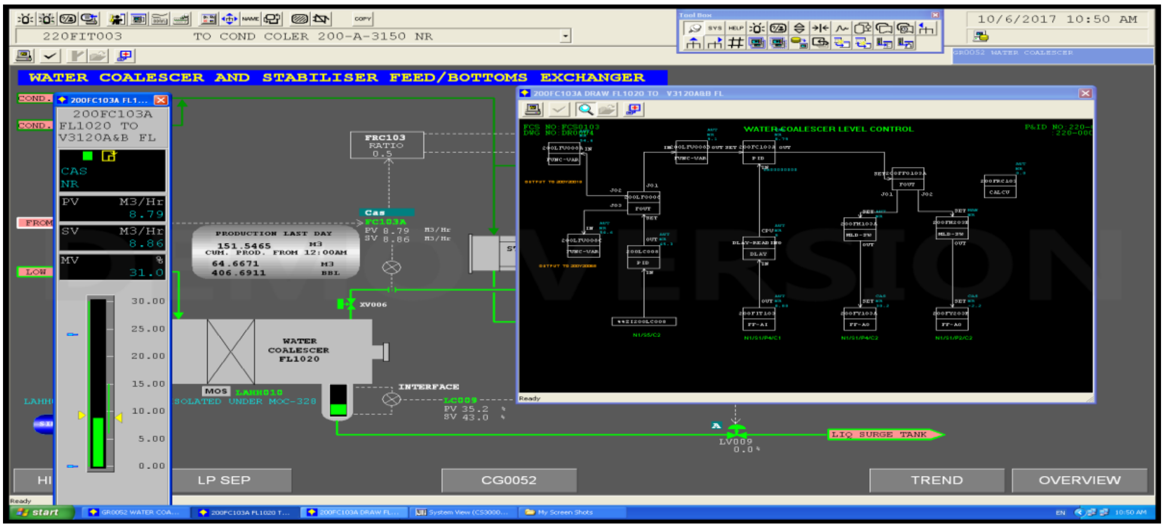

Fig. 8 Flow measurements.

Table.2: Ultrasonic and Orifice Gas Flowing Rate.

				Value of Gas Difference	
	Orifice	**Ultrasonic**	**Difference**	**Over Test Period**	**Estimated/Year**
Total Gas Flowing Minutes	**100567**	**144912**	**1435**		
Total Accumulated MCF	**216321**	**221380**	**5059**		
Value of Gas ($)	**$ 720,349.00**	**$737,195.00**		**$ 16,846.00**	**$ 67,386.00**

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