<u>ENI Agip Division - Operational experience with commercial multiphase meters</u>

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1.0 Introduction

ENI Agip Division has been deeply involved in the development, testing and implementation of the multiphase technology (pumps, metering, computer codes, fluid problems) since the early 90,s. Several multiphase meters and pumps has been tested in the Trecate test loop and applied for the production, as well as one of the main transient computer codes (OLGA) has been qualified and used for the multiphase transportation system design and process analysis. At the present, in addition to the identification of the standard applications of the above mentioned components, new application fields and a more integration among the several multiphase components are evaluated. This is performed in order to optimise globally the production, with the goal to reduce the operative costs (OPEX) as well as the capital costs (CAPEX). In this view the multiphase meters play a very important role since they supply data that can be used not only to perform the reservoir management (well testing), how it occurs normally today, but also to optimise the transportation line and well management. Linking, through a iterative process, the tools (computer codes) applied to simulate these two main parts of the production plant (reservoir/transportation line), the whole production system can be optimise and a close loop, able to control the whole process, may be developed. To reach this goal the design limits, related to the slug length, hydrate formation, corrosion, erosion and wax deposition, have to be defined and the physical laws relating these fluid problems to the fluid dynamic and the fluid composition have to be known.

2.0 Summary

This paper gives a synthetic description of all the main commercial multiphase meters applied world wide by ENI Agip Division, given particular emphasis to those applications quite different from the standard ones performed for well testing. For the well testing applications, two different measurement situations are reported. Indications of how the multiphase meters can be used to improve the transportation flow line and more in general the overall production plant management are also given.

3.0 Field Applications

In this chapter are described the main installations of the commercial multiphase meters performed, for well testing scope and non, by ENI Agip Division up today. Others two multiphase meters prototypes (not described in this paper) have been installed for well testing in Sicily. One is installed topside on Prezioso platform and the other one on shore in the Ponte Dirillo field. The two meters have been developed in collaboration with CPR/TEA (Centro Pisa Ricerche/TEA Systems).

3.1 Trecate Villafortuna field (Italy)

The Trecate Villafortuna field is developed mainly with three satellite areas: Trecate 2, Trecate 4 and Villafortuna 1, as it is shown in Fig. 1. A cluster with production and test manifolds, air coolers banks (production and test) and test separator is installed in each area. The average length of the well flow lines (4" and 6 ") is about 2 Km. A multiphase test loop has been built in the years 1991-92 in the Trecate 2 area to test with real fluids, multiphase meters, pumps, ejectors, novel separators and to collect fluid dynamic data for the multiphase code qualifications. A schematic configuration of the loop is reported in Fig. 2. The loop has been used to test several of the above mentioned components and at the present two ROXAR multiphase meters are installed in the loop for well testing and research scope. After an initial qualification campaign against the reference measurements the two meters has been used for the well testing. Being the two meters installed in the loop, it has been possible to verify the long term performance of them in the full operative range. For well testing scope and now also to control a multiphase pump, has been installed in the Trecate 4 area a FRAMO multiphase meter. The two applications are described more in detail in the following sections.

3.1.1 Trecate 2

The two ROXAR multiphase meters installed in the Trecate test loop have a size of 2 and 3 inches respectively. Both the meters are equipped with the standard MFI components (microwave and gamma) and venturi. The 3" meter has been installed in the December 1997, while the 2" one in May 1998. The 2" meter, after some qualification tests alone, has been integrated in a flow conditioner as is shown in Fig. 3. The two metering systems are installed in the loop in the two locations identified in Fig. 2. They can be used alone or in series for well testing as well as for fluid dynamic data collection for the multiphase codes qualification. Figs. 4-7 show standard well testing measurements performed with the 3" meter. Fig. 4 and 5 report the main measured parameters with an intermittent flow having small gas and liquid slugs. Fig. 6 and 7 report the same parameters but with a flow having large slugs. In the first case it is possible to see that the water cut (WC) is mainly constant, while in the second case the WC is fluctuating as well as the flow temperature. These WC trends are quite important for the flow lines management since they allow to collect information concerning the water behaviour along the flow line. Being, in the first case, the WC mainly constant, there is no water separation and water and oil are travelling in emulsion. Instead in the second case there is a water separation with some accumulation of the water along the flow line. Consequently in this last case there are more corrosion problems than in the first one. Figs. 8-10 report measurements performed with both the 3" and 2" meter when they were used in series, with the flow going from the 3" to the 2" meter. Fig. 8 reports the measurements performed with the 3" one and Fig. 9 those performed with the 2" meter. Fig. 10 reports the total flow rates measured by the two meters. As is possible to see from this last figure the two trends have about the same shape. This means that the perturbations at the flow line inlet are propagated through the flow line itself, about in the same way how they are generated. The discrepancy between the two measured values of Fig. 10 is mainly due to the gas flashing and gas expansion connect to the line pressure drops. These flow measurements as well as the pressure drop measurement between the two meters has been largely used to qualify the OLGA multiphase code. In Fig. 11 and 12 are reported some measurements performed with the integrated system, 2"meter/Flow Conditioner (see Fig. 3). The main function of the Flow Conditioner (FC) is to remove a sufficient amount of gas to the multiphase meter, located on the liquid stream, to assure a GVF at the meter inlet, inside its upper limit. This limit has been identify, for mostly of the commercial on line multiphase meters as well as for the 2" ROXAR meter, to be in the range 90-95%. In the FC of Fig. 3 the separated gas flow rate is measured with an orifice installed in the gas stream. The total gas flow rate of the integrated system is calculate adding to the gas measured with the orifice the gas flow rate measured by the 2" meter. Fig. 11 shows the measurements performed with the instrumentation in the FC, while Fig. 12 reports the measurements performed with the 2” meter during the test performed in date 25.06.1999. In Fig. 11 is also reported the reference gas flow rate measured in the loop with a turbine. The test was performed delivering only gas to the FC, with the control valve in the liquid stream close. As is possible to see from the gas flow rates comparison, there is a very good agreement between the two measurements. In Fig. 13 and 14 are reported essentially the same measurements of the two figures before, but with the test performed in date 29.06.1999. In Fig. 14 is shown the level increasing in the FC due to the gas condensation through the flow line. Since the FC free volume is a know parameter, on the base of the level increasing and time, it has been possible to calculate the condensation flow rate. This resulted to be around .35 m3/h and the GVF about 98.5% (gas flow rate about 22 m3/h; see Fig. 13). These results have shown the 2”meter/FC integrated system to be an useful tool for well testing of high GVF streams. Fig. 15 and 16 show respectively a comparison of the gas and liquid flow rates, measured with the integrated 2”meter/FC system, and the same flow rates measured with the 3” meter. The two systems were used in series and the test was performed in date 10.06.1999. The total gas flow rate measured with the integrate system has been not reported in Fig. 15 and so, a direct comparison of the measurements performed with this system against the 3” meter, is not immediate. However, from the Fig. 15 as well as from Fig. 16 is quite easy to see that in the first part of the test, until the liquid flow rate was decreased to 10 m3/h from about 30 m3/h, both the gas and liquid measurements performed with the integrated system were not in good agreement with the flow rates measured with the 3” meter. Instead after then the liquid flow rate was decreased to 10 m3/h (see Fig. 16) both the two measurements were in quite good agreement. This is an indication that the integrated flow meter is working quite well down to GVF of about 70%.

3.1.2 Trecate 4

A 4” FRAMO meter has been installed in the TR4 satellite area in the March 1997 mainly to perform the well testing of some wells having a flow rate exceeding the separator capacity. Problems with the gamma detector occurred just from the beginning and after about one year from the installation was needed to replace the gamma detector. With the new detector the meter performance was quite good up to now. Since the meter can be used in series with the test separator it has been possible to verify its performance, time by time. In the year 2000 the meter has been integrated also with a multiphase buster system to bust a well (TR19) that has not a sufficient pressure to enter into the main transportation line with an acceptable production. This integration as well as the connections to the production plants are shown schematically in Fig. 17. Since the used screw pump has a limitation on the inlet GVF (about 90-92%) and the GVF at well head was expected to exceed this limit, the multiphase meter was applied mainly to verify the gas fraction at the pump inlet. On the base of the multiphase meter measurements was possible to verify, during the commissioning tests, that the GVF at the pump inlet was inside the limit and that the oil flow rate increasing, due to the pump, was too low to justify the continuous running of the pump (see Fig. 18). In Fig. 18 as well as in Fig. 19 are reported some multiphase meter measurements connected to a plant transient due, first to the air cooler start up and then to the start up and shut down of the pump. From the two figures is quite easy to identify the several events. In this integration the meter is mainly used to define the liquid flow rate from the test separator that it is necessary to add to the well flow in order to maintain the GVF at the pump inlet into the limit. In the future, to maximise the pump efficiency, the multiphase meter should be used to control automatically the recircolation liquid flow rate.

3.2 Ashrafi field (Egypt)

This field is developed with two platforms, South West (SW) and Main Platform (MPA). From the SW platform the flow is delivered to the MPA platform through a 3 flow lines (6", 4"1/2, 4"1/2) having a length of about 6 Km. On the MPA platform all the field production is combined and delivered to the oil centre on shore through a 16" flow line, about 17 Km long. The test separator installed on this last platform is used to perform the well testing of the entire field. In the normal operation the production of the SW is split freely among the three flow lines and the lines pressure drop is minimised. During the well testing with the test separator one of the two 4"1/2 flow lines have to be used only for the well to be tested and this brings to a flow increasing in the others two lines with a consequent increasing of their pressure drop. Due to the wells back pressure increasing there is a production reduction on the SW platform. In August 2000, a 3" FLUENTA meter was installed on the SW platform. The meter was pre-calibrated in the Trecate test loop, where the acceptance tests were performed. The field commissioning tests, to calibrate and to verify against the test separator the multiphase meter, were completed in about one week. During these tests a very important operative result was immediately achieved. In fact the real WC of the SW2 well was verified to be around 15% instead of 70% how it was measured through sampling before. This allowed, after a further verification, to stop a work over already scheduled on the well, with a lot of money saving. Given the installation configuration of the meter on the SW platform, the flow distribution among the transportation lines remains, during the well testing, about the same as in the normal operation. This allows a production gain compared to the well testing performed with the test separator.

3.3 Portfouad field (Egypt)

The field is developed with two mono pod platforms, Portfouad 1 and 2. They are without test separator and a ROXAR multiphase meters has been installed on each of them for well testing. The produced flows from the two platforms are commingled through a sub sea Tie-in to a 16" sea line of about 12 Km long and delivered to the Portfouad main platform. On this last platform production and test separators are installed, but due to the high field production, also the test separator is now used as production separator. The two separators perform a three phase separation (condensate, water and gas) and the three separated phases are then delivered to the treatment plant onshore, each through a dedicated flow line having a length of about 50 Km. The wells to be tested have a quite high GVF and for this reason a venturi meter has been added to the ROXAR basic components (microwave and gamma) to improve the meter performance. The two meters have been installed since the spring 2000, but due to energy problems on the platforms their utilisation started only in spring this year. For these two applications a direct comparison with the separator is not possible, for the reason mentioned above, but comparisons with the total flow measured by the two separators are showing an acceptable agreement.

3.4 Karachaganak (Kazakstan)

In this field a 6" ROXAR multiphase meter has been installed this spring. Since the meter is in series with the test separator, it is possible to verify its performance against the test separator. These comparisons are showing not a very good agreement between the two measurements and now an investigation is performed on both the measuring systems.

3.5 Zatchi (Congo)

This field is developed with three platforms (ZAP, ZAF 2, and ZAF 4). The meter is located on the ZAF 4 platform after the production manifold to measure the total multiphase flow. The ZAF 4 platform is producing through 4 wells with ESP pumps. The pressure at the multiphase meter is about 13 bar. The gas produced through the casings of the 4 wells is commingled and delivered alone to the ZAF 2 platform through a 4" sea line of about 730 m. The total pumped multiphase flow, measured by the meter, is delivered to the ZAF 2 platform through a 8" sea line. In ZAF 2 platform the wells are producing with ESP pump like in the ZAF 4 and there is a production separator used to separate the pumped flow of both the platforms. The separated gas, the gas coming from ZAF 4 as well as the gas produced through the casings in ZAF 2 are commingled to a flare on ZAF 2 without to be measured. The separated liquid (oil, water) is busted with single phase pumps and delivered to the ZAP platform where a three phase production separator is installed. The liquid phases are measured with PD meters. The distance between the ZAF 2 and ZAP platforms is of about 1.5 Km. The total liquid production as well as the oil and water production of the ZAF 2 platform are obtained as difference between the total production measured in ZAP and the liquid flow rates measured with the multiphase meter in ZAF 4. Since all the wells of the ZAF4 platform are producing with ESP pumps, the gas at the multiphase meter is quite low. The 3" ROXAR meter selected at the beginning did not give good results since the initial production rates was much lower than the minimum design rates. The original meter has been replaced with a 2" meter that now it gives quite good results. The initial verification/calibration tests of this new meter were performed with a Schlumberger mobile test separator. During these tests the meter has also allowed to set up the right speeds of the ESP pumps, with a significant energy save. This was due to the fact that the optimum pump speeds (maximum production) were lower than the originals ones.

3.6 Gabon

A 3" ROXAR multiphase flow meter is installed on a platform producing with 4 wells. The meter is in series with a test separator also installed on the same platform. The GVF is quite high 70-90% and the WC quite low (5-10%). The pressure at the meter is about 13 bar. The meter performance, compared with the test separator, is not in very good agreement and a factor 0.7-0.8 is applied to the meter liquid flow rates to meet the separator liquid flow rates. At the present the meter is not in operation due to computer configuration problems. A supplier intervention is required for the next future.

4.0 Transportation flow line management improvement

In addition to the applications mentioned above the multiphase flow meters can useful be used, in combination with multiphase computer codes, to perform the diagnosis and the control of the transportation flow lines. The wells flow rates, measured, possibly continuously, by multiphase meters on each well and the pressure at the flow line outlet, can be used as input to a transient multiphase computer code (OLGA) to simulate, mostly in real time, the fluid dynamic of the transportation line. From this simulation it is possible to identify the pressure and temperature profile along the transportation line as well as the flow regimes. Since the operative limits of the transportation line (hydrate formation, corrosion, erosion, maximum slug length) are depending by these parameters, it is possible to verify in real time if the flow line is operating inside the operative domain or not. If not, and some operative limits are exceeding the allowed limits, the operator can modify some boundary conditions to the transportation line (production, back pressure etc.) to maintain the flow line inside the allowed domain. When the plant operations, required to keep the flow line inside the operative domain, will be very well known, a close loop able to control automatically the flow line will be possible to develop.

6.0 Conclusions

On the base of ENI Agip Division experience acquired with the application of several commercial multiphase meters for the production, as well as with the performance tests performed in the Trecate test loop, the following conclusions can be drawn:

1. The actual commercial multiphase meters can be applied with an acceptable accuracy for the well testing measurements, if they are properly selected in type and size.
2. The actual "on line" commercial multiphase meters have accuracy limitation at gas void fractions above 90-95% and to apply them above this range some improvements are required.
3. A possible solution to apply the "on line" commercial meters to high GVF well testing measurements can be the integration of these meters with flow conditioners able to perform a partial gas separation, enough to keep the GVF at the multiphase meter inlet inside the limit.
4. The field calibration/verification is required not only to define the meter calibration parameters that have to be measured in field (gamma counting), but also to define the right fluid property data, required for the meter calibration. Very good PVT data are required especially at high GVF.
5. A direct measurement, with the multiphase meter itself, of the fluids (oil, water, and gas) parameters required for the meter calibration, is an auspicious.
6. To reach the above goal the multiphase meter installation configuration and the consequent steady state flow condition are very important.
7. The multiphase meters measurements, especially if update with the above mentioned fluid property measurements and possibly with the oil/water viscosity measurement, can be very important for the flow line management.
8. The multiphase meters can be useful integrate with the actual multiphase buster system to control the flow conditions at the inlet of the pump, allowing an improvement of the whole buster system efficiency.
9. For fields operating with ESP (Electrical Submersible Pump) or with gas lift, the multiphase meters could help to set up respectively, the right pump speed and gas flow rate in order to maximise the efficiency of the producing systems.
10. Flow blockages problems, quite often encountered using test separators at high WCs and relatively low temperatures, can be avoided using multiphase meters.
11. The multiphase flow meters have to be operated by qualified personnel in order to guaranty not only reliable well testing data, but also to picked up those information related to the continuous on line measurements that can be very useful for the well/flow line management (corrosion and slug control)
12. To extend the multiphase meters applications it is very important to avoid negative feedback from the field operators. For this, it is fundamental a continuous exchange of information between the operative people and the people that have the responsibility to maintain update the technology in the company as well as it is very important the quick and satisfactory support of the suppliers.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.