Did we miss anything?
An Executive Summary about the Overview about the use of Multiphase Flow Meter:
Past, Present, and Future.

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1. ABSTRACT

Over the last 20 years, the development, evaluation, and use of multiphase and wet gas flow meters have been one of the main evolution for well performance against standard equipment (separators). Many metering systems have been developed at the early stage (90's), some died, some have merged to provide most suitable products, and a rationalization have been going on over 10 years (2000-2010), but the last 5 years started to see some new multiphase manufacturer companies emerging on the market from different domains.

If it is clearly understood today that none of the technology or multiphase and wet gas meters on the market are capable to handle wide range of fluid types and Gas Volume Fraction (GVF) or Water Cut (WLR) with reasonable accuracy. Most of them cannot cope with all environmental conditions (pressure, temperature, H2S, Salinity, Solid…) and therefore caution must be applied when contemplating the use of any Multiphase Flow Meter (MPFM) and Wet Gas Meter (WGM) versus some given applications.

If multiphase metering has gained significant acceptance from the conventional back allocation toward fiscal allocation, we are still at the first step of trying understanding how to use them and how does the product work for a given application, and often more expertise needs to be present and generally out of the knowledge of one supplier of metering equipment.

This executive summary will highlight and propose some answers to the recurrent questions: Where are they the most suitable? Why are we having new comers (products)? Did the main companies miss anything over the years about the market trend/demand? Are there some revolution/evolution ongoing wit new comers?

This executive summary will look at succinctly, unfortunately, in a broad range the advantages and shortcomings of the technologies already implemented in various commercial meters in terms of operational issues, economic benefit, or advantages/disadvantages from the operator's point of view. Some lessons learned will be presented such as improvement of reliability, accuracy of some specific measurements but also highlighting the failures/issues to address the true need of the final users with current available technology.
The document will also come back to the real need/application of the MPFM and WGM and help in the definition of the true advantages of the old products and new products? Finally, a trend about the evolution (price, technology acceptance, and requirement) will be exhibited based on some facts.

We expect that the explanation will provide practical statement and recommendation practices to allow moving forward and helping all parties in this domain to understand what is their need and what they should look for.

2. EXCECUTIVE SUMMARY

Over the last 160 years, the multiphase flow meter was the test separator. This has been a great tool and it is still the most common instrument used for looking the well performance. The main issues stated over the years and sometime forgotten by the end-user is that the technology is based on gravity separation, this means a significant contrast between the phases is required to be able to split them correctly.
The horizontal wells development has been becoming more and more popular including smart wells with multiple downhole sections and overall led to much larger production of new wells. In the meantime, the constraint with movements of such equipment on road have not changed and then keeping the overall dimension identical. As conclusion, there is less retention time inside the separator leading to issue about the statement regarding quality of phase separation. Very seldom well test service companies will provide two stage separations (i.e. two separators in series) to ensure a good separation between gas and liquid for example. On the other side, numerous studies have shown that a gas wetness of few percent can lead to a significant overestimation of single gas phase metering device (i.e. 0.5% of liquid loading in gas line may lead to 2 to 8% overreading of gas flowrate versus line pressure). This mismeasurement could lead to wrong statement about the GOR and the behaviour or statement about the reservoir conditions. Additionally, the use also of higher line pressure has reduced such density contrast and then efficiency in phase separation. A lot of new devices have been added inside the separator to coalesce the liquid or spin the fluid (to create more “g” force), demister, etc… and overall trying to improve separation.
Not the least, the development of the heavy oil field (i.e. heavier oil density) and the poor contrast against water has led to use, in some cases, the separator in two phases and not three phases (i.e. gas and liquid as main output measurement) and with a use of manual sampling procedure for water cut measurement or use of equipment like Coriolis knows to provide inaccurate water cut when one phase is largely predominant against the other.
Over the last years, different papers have indicated that going better than an uncertainty of 5% to 10% for each phase measured by a test separator require a fair involvement of expertise, instrumentation, control, and maintenance which is not always achievable with the trend of lower cost of such field operation or the trend to reduce always the OPEX. This overall review raises some questions: Is the oil industry happy with such uncertainty? Is it what the market need? Do we need to address the problem in different manners?

Starting in mid-80s, the wish to use a new way to address the well performance was initiated with the objective to dream to have systematically a metering solution for each new well. The multiphase flow metering business started some years later around mid-90s. These first 10 years of researches and developments led to solution that were sometime unrealistic to be used in the field (size, weight, cost…) or having technology or interpretation closer to the voodoo concept than scientific approach. The disappointment was very big for the end-user (i.e. oil industry) and the fact that the concentration of multiple technologies was requiring a large level of expertise and knowledge for this tiny equipment was another significant parameter to reduce further the spread of the multiphase business. This legacy and frustration about statement or vision of MPFM from the end of the 90’s is still present today. Difficult to forget the large investment in some cases in such business with equipment not working well or not at all and where wells can be flowing for 20 to 40 years.

Mid-2000’s has seen a new business coming in with the Wet Gas Business which is only a subset of Multiphase Flow but for gassy conditions. New or some established manufacturers started a different approach of the problem for such conditions where the flow regimes conditions are simpler to handle (measurement and modelling). Multiple statements exist about what is a Wet Gas, and in a way, this shows the little convergence in this multiphase business around some simple concept or market segmentation. This is sometime driven more by manufacturers (marketing or sales pitch) than science again.

Where are we today?
By second half of 2010's, and with today more than 2.0 million wells around the world the penetration of the multiphase is less than 0.5%. Even if we were only looking for the number of wells drilled over the last 30 years the market penetration stays lower than 1%. The statement is much better subsea with a market penetration closer to 20%.

It is interesting to look at the evolution from the 1980 to 2015, with some significant changes that have been happening in the oil production with new players or with established players getting larger market shares like Kazakhstan, Angola, Norway, Qatar, Colombia, Brazil, Canada, UAE… If oil production of some countries like Saudi has been larger during this period, the overall percentage against the overall production was not significantly different. Looking closer to the list of countries mentioned above, it can be noticed that they have been either a new contributor thru gas business (with or not LNG technology) or by subsea or deep offshore installations.

This leads us to the following point, if the need of energy has been significantly growing over the 35 years mentioned above, the ratio over the last 10 years (circa 2005) stays more or less the same with 75% of the oil production from land and 25% from offshore. What is interesting to mention is now around 6% of the production is coming from deep-water (subsea) and more than 10% of the liquid hydrocarbon is coming from condensate. This indicates that a change with better oil quality (API) and more challenging conditions to get access to these oils have been faced by oil operators. Let's recognize for example that during the second part of the 80's the deepest offshore well was around 500m. The oil industry crossed the 2,000m water depth by second part of 2000's. The floating system with the largest water depth is today the FPSO Pionner with a water depth of 2,690 m in the Chinoock and Cascade fields, Gulf of Mexico [USA] operated by Petrobras. The deepest subsea tree is located in the Tobago field with a water depth of 2,934 m, Gulf of Mexico [USA] operated by Shell. The deepest system for separation and bombing is located in the Perdido field with a water depth of 2,480 m; Gulf of Mexico [USA] and operated by Shell. What an adventure! Including seeing production separation processed subsea.

On the other side the number of large discoveries (conventional oil and gas) is significantly down, and with a general agreement that the natural production decline for a given well by 3% on yearly basis it is roughly the production of either USA, or Russia or Saudi that is expected to be found each 4-years just to balance the current production or demand. Obviously, the oil business found a solution with a large effort coming thru the production of the unconventional oil and gas (i.e. Heavy Oil, Oil Sand, Tight Oil (Shale Oil), Shale Gas, and Oil shale…). Altogether, it is more than 8 trillion of barrel of additional oil accessible. It should be kept in mind that today the oil which is recoverable, in some of these applications, is lower than 10% but improvement of technology could make this recovery factor much higher in the coming years.

Based on the above review, the question coming is what makes this multiphase metering business more successful subsea than topside? Unconventional productions should have been driving this business too.
We are coming to the basis and where the multiphase business could be instrumental to the oil industry, it is by improving the knowledge of the reservoir thru the well performance and for example the GOR, WLR, Quality of water monitoring, and in general by looking the Recovery Factor. The Enhanced Oil Recovery can drastically improve the economics of a field from an average of 15% (solution gas drive) to more than 50-60% (gravity drainage drive). The maths is a killer, 1% global recovery factor improvement is 10MMbpd additional over 100MMbpd (close to the current daily production right now to make the calculation easier). This is the production of Saudi Aramco.
This is where the MPFM and WGM could be playing a role thru a proper understanding of the reservoir behaviour, a permanent optimization of the flowing wells in complement of the use

of additional technology (drilling, pump, gas lifting method, and so on). As example, the recovery factor in North Sea (a place for adoption of new technology) has been increasing from ~35% in 90's to 46% in 2015. This achievement was possible because the oil operators are working in these very harsh conditions with a clear vision/target to achieve over the years associated with challenging procedures to follow. Additionally, the productivity or production of these subsea wells are very high with completion way above 6in and a loss of one well thru mismanagement will be catastrophic or could seriously impact the field economics. These are some of the main drivers for such adoption of MPFM or WGM subsea and offshore. Essential to the spread of the multiphase meters is also the tie back of some marginal fields to an existing main pipeline or platform (i.e. custody transfer or fiscal allocation) which is requiring to have a proper understanding of the quality of the oil and the quantity of the oil produced. If a MPFM or WGM is not capable to increase the production on its own, it is an enabler to understand the reservoir behavior with measurement as close as possible of the reservoir (some of us are waiting for the right place for a MPFM to be inside the well close to the perforations). It should be noted that if an operator is flowing production thru a pipe of another operator the issue of "back out" can be very significant. This may need to be explained and it means when a newly developed third party field is tied back to an existing infrastructure, such as a pipeline system, there is the potential for the new field's production to cause an increase in back pressure and reduce the flow of the existing fields already producing through the system. This is named "back-out" and agreements are sometimes put in place, within the allocation system, to compensate the existing fields for the reduction in flow that they may experience. This may take the form of a transfer (or payment) from the new company so that in effect the first producing company does not experience deferment and suffer resultant economic loss. Obliviously to make such claim, it is important to justify the production before and after installation and then the MPFM or WGM are instrumental.

What did we miss to get the same success with onshore application?
As indicated earlier the population of wells is much bigger onshore and the number of sales should be extraordinarily much larger. Let's look at in details some main figures reviewed lately from some database (approximations were made to give a brief statement for this document). There are worldwide less than 1,000 wells producing above 10,000 bpd, where probably a solution with MPFM of 8inch or above will be required with the associated gas production (i.e. GOR high). A market is also possible for such size of meter with tie back of multiple wells. There are roughly 30,000 wells with flow rates above 2,000bpd and a requirement for 6in or slightly above could fit. Less than 70,000 wells with flowrate above 500bpd and a 3 or 4inch solution should be adequate. There are more than 200,000 wells with a flowrate in the 200-500bpd range and an optimal 2inch solution. There is almost 1MM wells below 200bpd and not classified as stripper wells which is representing the other part to get the global number given earlier in this document. The message to take out is at the opposite of the subsea or offshore business the largest number of wells is for small pipe solution or low flowrate. The matter is then the cost of the meter versus the accuracy proposed or exposure for the producer. It is obvious that today none of the MPFM or WGM on the market are capable to address the uncertainty (even with a target to achieve fair level), and the cost required by end-user being low or very low. There is a significant effort made by some manufacturers lately by having a modular MPFM and then being able to reduce the cost and proposed an optimal solution to the end-user, and it is probably the most interesting solution proposed over the last years at this stage.

An additional issue to express the lack for the MPFM and WGM penetration onshore has been associated with some used technologies, it is clear that the Nuclear Magnetic Resonance is too heavy and costly to be saleable for such application, but also the MPFM using radioactive sources can raise some concerns. If the number of MPFM should increasing drastically and be beyond few 10,000 units. How an oil company could handle, control, report, ensure the safety associated with few thousands of meters using such nucleonic devices with obviously a certain level of toxicity and the current unsafe worldwide conditions that we are facing now. What is clear, today, it is that such meters are currently filling the gap between the separator and then

the future Topside MPFM of the 21st century which will probably deviate from such architecture. Giving some prospective of the business evolution, we are probably close to the edge of technology rupture like this happen in mid-2000s with the iPhone coming to the market and then the collapse of the other traditional manufacturers and an entire redistribution of the business happen with two large players, as Nokia being out over the following 8 years, and Sony-Ericson over the last 2 coming years. It is interesting to note that the cost was not the main driver for the change not only the size but the real need of this phone for the end-user. Obviously, the oil and gas energy is more reliance and conservative and then the shift will happen slowly and much smaller in terms of amplitude. It is important to mention that even with an optimistic pace in terms of sales and tenfold the number of multiphase flow meter sold today, the business 50 years down the road whatever the acceptance rate selected the deployment (in percentage of meter versus new wells drilled during this period) will be still way below the current subsea acceptance. From a business and economical point of view a rupture or a technology leap will and should happen because we have been identifying earlier a real need for such MPFM and WGM technology but not yet the right fit even 20 years down the road.

As conclusion, the manufacturers of MPFM with the best of their resources and effort are not fulfilling and answering properly the need or providing the solution that the end-user is expected as consequence the full commitment or adoption of MPFM and WGM by the oil and gas operators are not there yet. More critical, looking the overall sales there is a large bias in the use of the MPFMs to middle-east and specifically one oil company for land application. The business is, in a way, sustained by one major oil company. At the contrary, the spread is much homogenous for the subsea business around the world. Looking the overall sales from a manufacturers point of view today, 4 of them are representing 75% of the market share when around the others 15 are contributing for the final 25%. Additionally, if the use of MPFM is instrumental for the recovery factor improvement and reservoir management, the overall cost (usually 3 times minimum the price of the meter), is for sure an issue for a more global acceptance.

On the other side, end-user should understand there is not a universal multiphase meter on the market today, there are different solutions more or less robust following the properties change that they are monitoring to distinguish the oil, water, and gas. Some may be more susceptible to salinity change, other to H2S change and all MPFM and WGM have their own characteristics or behaviours and pros/cons, a relevant selection and validation should be done and this should be updated over the years.

A MPFM or WGM is a concentration of multiple technology in a narrow space as built today and require some level expertise that is not easy to find. The third-party or regulation agencies should be more involved in such effort and review to state the level of these manufacturers to the oil and gas communities. A consequence of the lack of standard and continuous review in depth of the performance by independent regulatory agency/third party have been leading end-user to listen the manufacturers with sometime bias in the explanation or true performance by lack of time or condensed message passed by them in some cases.
The opening of the technology in simple word and the explanation of the true data processing to third party or to the community by manufacturers will be an enabler and bringing some clarity to the market. Let's be sure we do not duplicate what happen lately in the car industry with specific equipment or software allowing passing dedicated test and cheating the overall car industry and governmental agency. If this was happening in our business then it will be pushing even further back the general adoption of the MPFM and WGM. JIPs or shootouts/reviews planned by oil and gas operators with the help of third independent party should be a must. The upgrade or the development of new independent facilities to achieve higher rate or specific conditions, including the compulsory rules of using blind tests, will be a way to guarantee the integrity of the business.

As final statement, there is today space on the market for the MPFM and WGN of the 21st century and this may be something not yet available or thru some new concepts and designs, or thru new business model than what has been developed up to now.
It will not be, for sure, with nuclear measurement for land application on the long term, and it should be very cost effective, easily operable, and addressing low flow rate and low pressure. The access to the 3 phases will be compulsory and following the price the uncertainty statement will be established (based on the minimization of exposure for decision maker (good or bad), price of the meter, cost of installation, and uncertainty).

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.