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Setting the STANDARD
- Integrating Meter Diagnostics Into Flow Metering Standards

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Abstract

Many flow meter designs now have internal diagnostic systems to help verify their performance. However, although well publicized, in reality few meter operators as yet actively utilize these diagnostics. This paper discusses the various reasons why industry is taking so long to utilize such an obviously beneficial set of tools. None of these reasons are truly defensible. In the long run the obvious advantages of using flow meter diagnostics systems will assure their use. The sooner flow meter diagnostic techniques are widely adopted the better for industry. This paper argues that an important step in encouraging and expanding the use of flow meter diagnostics is to include the technology in prominent flow meter standards. This would assure their subsequent use in flow metering contracts.

Keywords

Flow Meter, Verification, Diagnostics, Standards, Contracts

1. Introduction

Traditional diagnostic methods to verify a flow meter's serviceability are still widely used, such as mass balance checks, and the associated liquid prover / check meter techniques. However, these methods are known to have severe limitations. The latest flow meters tend to have internal diagnostic systems that can help operators monitor a meter's health. Although imperfect these diagnostic systems are a great advance over the traditional check methods. Nevertheless, industry has been slow on the uptake of such an obviously beneficial development.

In this paper the authors discuss the history of flow meter verification and the issues that hinder the permeation of flow meter diagnostic use throughout industry. It is argued that the flow meter diagnostic systems have reached a maturity where they could and should be discussed in considerably more detail in the flow meter standards. Once included in flow meter standards, diagnostic techniques for meter verification will become included in contractual obligations, and applying such techniques which is presently the exception, should gradually become the general rule.

2. Verification vs. Diagnostics

Operators talk of "verifying" that a flow meter's performance. "Verification" is described in dictionaries as:

- To prove, show, find out, or state that (something) is true or correct.

Flow meter diagnostics are the methodology utilized to achieve this meter verification. "Diagnosis" is described in dictionaries as either:

1. The act of identifying a problem by examining something, or,
2. A statement or conclusion that describes the reason for a problem.

These two definitions of diagnostics are quite different propositions to the flow meter engineer. It is an order of magnitude easier to (1) show ***something*** is wrong, i.e. highlight an unspecified malfunction, compared to (2) stating precisely ***what*** is wrong.

3. A History of Flow Meter Verification

Reputable flow meters have a known good performance when they are installed. However, whether it is an orifice meter installed according to a reputable standard, or a calibrated ultrasonic, Venturi or Coriolis meter etc., the performance stated in the standards or by a calibration is not automatically guaranteed in operation. The rigors of industrial use can create various problems that adversely affect a flow meter. So how does the operator check the integrity of the in-service flow meter output? This conundrum has blighted flow metering since the earliest days.

Early methods of checking a flow meter's integrity are still used today. These include using due diligence, i.e. due care in selecting, calibrating, installing and operating a flow meter, possibly coupled with routine scheduled maintenance.

3.1 Mass Balance Checks

Pipe networks with multiple flow meters allow a mass balance check across the system. However, the mass balance method has severe limitations. Mass balance checks require knowledge of the process (which is a recurring theme in flow meter verification). Perceived mass balance issues can be caused not just by meter malfunctions but by incomplete understanding of a process (e.g. flow being diverted down other pipe lines, line pack, or leakage). Also, multiple meter flow rate uncertainties combine to make a mass balance check across a large pipe network relatively imprecise. Furthermore, even if a mass balance check identifies a problem, it doesn't identify if the problem is loss of fluid from the pipe (e.g. leaking by-pass valves), or a flow meter error, or which flow meter is in error. These verification methods are external to the meters themselves and even if a problem is suspected these methods can do little to pin point a specific problem. Mass balance is too coarse a technique lacking in sufficient resolution to identify many specific flow meter errors.

3.1.1 Check Metering –Meters in Series

A more precise mass balance check is to compare two separate meters in one pipe section in close proximity. However, there are still limitations to this approach. If the two meters are of the same design principle they may encounter a common mode problem. That is, they may have similar flow rate errors induced by the same underlying issue thereby masking a flow meter problem instead of highlighting it. A partial solution is to use dissimilar meters in series, i.e. meters that operate on different physical principles. It is less likely (but still possible) that such a meter combination will encounter a common mode problem.

The dissimilar meters in series method is still not an ideal check. It still requires two separate meters and some problems can still affect dissimilar meters in similar ways. In order to be noticeable a problem must cause a discrepancy in flow rate prediction greater than the combined uncertainty of the two meters. Therefore, the smallest noticeable flow rate discrepancy is larger than either individual meters stated uncertainties. Unfortunately, this is a recurring theme with flow meter diagnostics, even for the latest internal diagnostic systems. Furthermore, check metering only gives an indication on the probability of meter serviceability. If there is a big enough problem it should show a discrepancy between the meter outputs, but it gives little to no information on which meter is in error or why.

A disagreement between two meters in series guarantees a problem exists. However, these two meters agreeing doesn't guarantee a problem does not exist. If the two meters agree on the flow rate within their combined uncertainties then it is only **probable** that the meters are operating correctly. There is still a possibility that both meters are in error together due to some common mode problem. This issue highlights a fundamental *truth about instrument diagnostics. Diagnostic suites seldom if ever offer absolute proof a meter is fully serviceable. Rather, diagnostic suites significantly increase the probability that the meter is serviceable*. A consequence of this fact is although diagnostics can be extremely useful, they cannot completely replace the requirement for due diligence and good metering practice.

3.1.2 Check Metering with Liquid Provers

Liquid flow meter "proving" is a form of periodic check metering. The advantage a liquid prover has over a regular check meter is that its uncertainty is so small that the root sum square of the prover and flow meter uncertainties is practically the uncertainty of the meter. The disadvantages are that it is a spot check, effectively a periodic re-calibration of a meter in service, and fundamentally the process still only produces the basic diagnostic of showing if the pair of meters disagree for some unspecified reason. Due to the intermittent nature of proving, if a discrepancy is found the operator does not know when in the time period between 'proves' the meter malfunction developed. Proving is also limited to liquid flow meters, due to compressibility it isn't practically possible to prove gas meters. Hence, flow meter designers have developed internal ("integrated") flow meter diagnostic systems (particularly for gas flow measurement) to verify a flow meter's performance.

3.2 Integrated (or 'Internal') Diagnostics

A definition of "external meter diagnostics" is a diagnostic system that uses information external to the meter readings, such as mass balance, the associated method of check meters, or other process information. A definition of "internal meter diagnostics" is a diagnostic system that uses information obtained solely from the internal workings of the meter. Internal and external methods are not mutually exclusive and operators can, do, and should combine both methods.

In the last twenty years designers have made great advances in internal meter diagnostics. There is a slow acceptance of the inherent truths that a flow meter's stated uncertainty is only truly valid when there is a guarantee the meter is operating correctly. The most assured and precise way to continually guarantee meter serviceability is to use a reputable diagnostic system internal to the meter system. Strictly speaking, a flow meter's uncertainty rating is only as good as its diagnostic system's ability to verify the meter is fully serviceable. As no flow meter's diagnostic system is perfect, this obvious truth leads to a less spoke truth, *the uncertainty rating of **any** flow meter is more notional than factual.* Even with diagnostics it is still a faith based measurement. It is a 'best estimate' based on the engineer's judgement when accounting for the meters calibration performance, installation & process conditions, and the capability of its diagnostic system, and that diagnostic system's output. This is the true state of the art, and the underlying driver for improvements to meter diagnostic suites. The better the internal diagnostic system and the better the knowledge of the process, the less uncertainty in the flow meters output.

Internal diagnostics have been developed for various flow meters. However, compared to the basic operation of the meter they are relatively complex, and although these diagnostic systems (or 'suites') are well understood by experts and a great advance in the art of flow metering verification, as yet they are not well understood or utilised by the majority of flow meter operating staff.

4. Challenges with Adopting Modern Flow Meter Integral Diagnostics

To understand the diagnostic suite of modern flow meter it is necessary to have a good grounding in the fundamental principles governing the operation of the basic meter design. Unfortunately, flow meter designs are based on various combinations of fluid mechanics, mechanical, electronics and mathematical principles, and this can be quite daunting to the average operator, who is not a meter specialist and often has many other duties to attend to other then checking the flow meters.

Many operators of flow meters see them as 'black box' devices and are content to use them without understanding the details of how the operate. Standard meters predict the flow rate via a flow computer output the operator can read, believe, and use. They do not need a detailed understanding of the internal metering system. Unfortunately this level of understanding hinders the adoption of the present diagnostic suites. Many operations require (by legal contract) that flow meters are used for fiscal, custody transfer, and allocation flow metering, and hence the operating staff are obliged to have ***basic*** knowledge of how they operate. But, the same is not true of the meter's associated integral diagnostic suites.

Legal contracts tend to state that flow metering will be conducted according to some standards document (e.g. ISO, AGA, API documents etc.). If the stated standards document does not promote the use of the relevant flow meter diagnostics, then use of diagnostics to verify the flow meter will not be required by the legal contracts. As much of industry considers the use of these diagnostics complicated, and they are not being forced by legal requirements to adopt the use of such diagnostics / meter verification, then it is natural that many do not pursue their use. However, such an obviously useful and beneficial advance in technology cannot and will not fail to be adopted in the long term.

4.1 Meter Diagnostics and Standards Documents

There is passing comments to the ultrasonic meter diagnostic suite in AGA 9 [1] & ISO 17089-1 [2]. However, there is no comprehensive description, nor any concise statements on the benefits, or necessity, of applying these diagnostics as part of a comprehensive meter verification process. The DP meter standards say nothing regarding their respective various diagnostics. Therefore, in this 21st Century world, the standards, and hence the legal contracts are promoting use of 20th Century technology.

The reasons for this are varied. One reason is the fact that standards traditionally lag the state of the art (on the grounds that they are meant to discuss mature accepted technology). As yet there has been no strong drive to update relevant flow meter standards to include the now matured diagnostic methodologies. Another reason is different manufacturers use different diagnostic suites (which in reality are very similar) with different user interfaces, which makes the diagnostics more difficult for operators to understand.

Although different manufacturers do have different diagnostics and interfaces, for a given meter type (such as ultrasonic or Coriolis meters), or a given meter sub-system (such as DP transmitters), the diagnostics and user interface tend to be a variation on a common theme. This perception of difference is in part caused by the meter manufacturers aim to be seen as different and unique. For commercial reasons they tend to want their diagnostics to be seen as different and better than their competitor. However, in many cases they are close enough that a generic description in a standard document is possible. All that is really hindering such a development in the relevant standards is the political will. Such an addition to the standards would benefit the meter operators, who in the long run would then adopt the very useful tool of flow meter internal diagnostics.

4.2 The Incomplete Nature of Flow Meter Diagnostic Suites

"*Part of the problem is when we bring in a new technology we expect it to be perfect in a way that we don't expect the world that we're familiar with to be perfect.*" - Esther Dyson.

Great advances in the diagnostic suites of various flow meter designs have made in the last twenty years. However, although flow meter diagnostic suites are very useful they are not "all seeing". No developer of a diagnostic suite can (or will ever) guarantee that it will see any and all problem/s, from any source, before a flow meter bias exceeds the meters stated uncertainty.

For any given generic flow meter its internal diagnostic system does not have the same sensitivity to different problems.

Different problems can induce different flow rate prediction biases before the diagnostic system can identify that a problem exists. Furthermore, no diagnostic system of any flow meter type can guarantee it will see ***all*** potential problems or combination of problems.

The fact that diagnostic systems are inherently imperfect has been cited as one reason they are not adopted. But this is a weak argument. Such an argument is practically saying, "… if it cannot tell me ***everything*** I'd rather know ***nothing***." Ignorance is bliss. Such an argument cannot stand for long when discussing commercially sensitive metering applications.

4.3 Desired Improvements in Meter Diagnostics and Their Operator / Machine Interface

"*It takes a lot of hard work to make something simple, to truly understand the underlying challenges and come up with elegant solutions.*" – Steve Jobs

A significant obstacle to industry adopting internal flow meter diagnostics has been that the advance in flow meter diagnostic suites has not generally been matched with advances in the machine / operator interface, nor operator training[1]. It is unreasonable to assume that the average operator has advanced knowledge of a flow meter operation principle and its associated diagnostics suite. Hence, just as many flow meter operators wish to simply receive a flow rate prediction from their "black box" flow meter, they would also appreciate a ***simple*** diagnostic output. Complex diagnostics screens may contain very valuable information, but it's of little practical use if the average operator does not understand what he or she is looking at. Presently, diagnostic suites make the flow meter far 'smarter' but also far more difficult to understand and use.

Let us consider an "ease of use vs. smartness" graph (as used by the late Steve Jobs of Apple to discuss smart phones). Fig 1 shows the industry perception of where standard traditional flow meters are. Not so smart but easy to use. It also shows the industry perception of where present flow meters with diagnostics are. Quite smart, but difficult to use. The long term goal is to make flow meters with diagnostics very smart and easy to use.

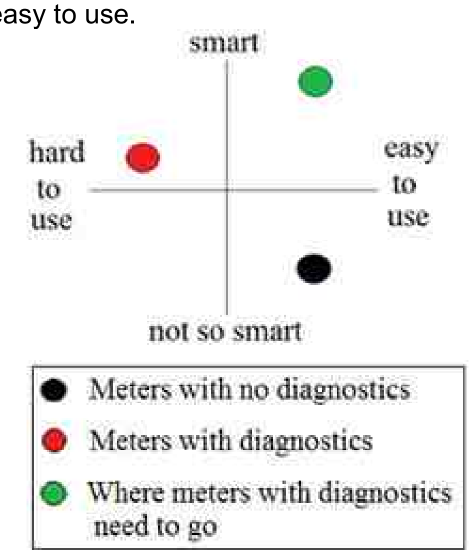

Fig 1. Perceived Meter Diagnostics Usefulness vs. Ease of Use

This will only be achieved by both meter manufacturers improving their diagnostic suite, improving the operator interface (to make it more user friendly), and by training of the operating staff.

Some meter manufacturers presently have the mind-set that their diagnostic interface is fine, and the onus is on the end users to learn the meaning of their diagnostic display. After many years of practice and familiarity, some are so used to their diagnostic display that its meaning is obvious to them. They cannot see a need for a simpler representation of the diagnostics. They attempt to educate the users on what the complex display means. However, this is effectively asking the non-specialist end user to become a specialist. The client (i.e. the meter user) is

[1] It does go both ways. Whereas the meter manufacturer could simplify the diagnostic output to make it easier for the end user to understand, there is some onus on the end users to put in some effort to improve their understanding by actively training on how to read the diagnostic output.

effectively being told to put the effort in to work with the meter manufacturer's system, rather than the meter manufacturer putting the effort in to work with their client's needs. In reality, the essential long term requirement of industry is to significantly simplify the diagnostic output display. This of course is easier said than done. It is difficult to simplify a complex system, and this is why it is still a major issue. Regardless of difficulty, such is the obvious benefit to industry, and such is the marketability of user friendly diagnostics, that it is inevitable that this will be achieved to a certain degree in the long run. The question then, is when, not if these developments will take place.

Fig 1 indicates that the authors consider it necessary that there is not only an improvement in the ease of use of diagnostics but an increase in the diagnostic capability. Presently, many flow meter diagnostic suites can indicate that there is a problem, but few make any serious effort to tell the operator what that problem is. This is partially as the meter manufacturers are seldom pushed to do so, and partially as the state of the art of diagnostic suites makes this a very difficult challenge. Nevertheless, various diagnostic suites allow the operator the ability to eliminate certain common problems while short listing other common problems. Hence, the present state of the art potentially allows some diagnostic suites to make at least limited predictions on the likely causes of a problem. Few however do.

4.4 Psychological Resistance

4.4.1 Technician Resistance – Fear of Change (Resulting in Redundancy)

Technicians providing flow meter maintenance are a mandatory requirement for many companies that use flow meters. Such flow meter technicians can become these companies flow metering specialists. Any new metering development is often passed to these company experts for their opinion. However, these metering technicians can perceive diagnostics as a potential threat to their own and their team's livelihood. It is not always in their personal interest to highlight the great benefits to their employer, they can perceive a flow computer with diagnostics as a "technician in a box". That is, technology coming to make them redundant. It is only natural that there is resistance.

Many operators have too few flow meter technicians for too many meters, spread over too far an area. Typically most of these meters have no diagnostics, or if they have diagnostics they are not monitored as they are not fully understood. As such the technician can be blind to many problems and is very inefficient as he carries out routine scheduled maintenance (RSM) on meter after meter that did not need maintenance[2], while other meters with unseen problems are untouched. The use of diagnostics would allow this technician to carry out the philosophy "… if it ain't broke don't fix it", while continually going to the meters that do need work. That is, diagnostics allow the technician to carry out a Condition Based Maintenance ("CBM") scheme. CBM schemes are far more efficient than RSM schemes, making the technicians efforts far more valuable to his employer. CBM also reduces unnecessary staff exposure to high pressure hydrocarbon systems. If there is proof that a meter does not need maintenance then there is no need to break containment. Yet, by human nature technicians tend to be nervous of the introduction of diagnostics, as it is something new, it is change.

4.4.2. What You Don't Know Won't Hurt You / Plausible Deniability

The vast majority of meter operator technicians naturally want to do a good job, be part of a good team, and want the

[2] Routine scheduled maintenance can cause as many problems as it solves. For example, an orifice meter may operating correctly before scheduled maintenance and after the maintenance the technician leaves it with a problem, e.g. a plate re-installed backwards, a not completely re-sealed equalization valve on the 5 way manifold etc.

meters to operate correctly. They take pride and satisfaction from their work. But, naturally they also want a quite life and to defend their job function. Their management too want a quite life. Nobody likes problems. Management like to hear that all is well. Successful mass balance check across plants, agreement between buyer and seller metering stations, no metering alarms etc., all lead to a happy management and harmony among the team. Ignorance is bliss. **But**, if you have comprehensive flow meter diagnostic suites, they just might find a problem, a problem you otherwise would have been ignorant of. To know of a problem, is to give the technician the conundrum of what to do about it?

The product being flow metered is not the property of the meter operator technicians. Not at least in a financial sense. The meter operator typically gets paid the same regardless of their employers profit levels. If the operator is losing money by giving product away due to an under-reading meter, or accidentally over charging due to an over-reading meter, it doesn't directly financially affect the metering staff. If a flow meter diagnostic system shows a problem they otherwise wouldn't have noticed, the diagnostic system has ***created a dilemma*** they would otherwise not have had to deal with. Now, thanks to the diagnostic suite, if they admit such a problem they get the satisfaction of doing their job properly and honourably, but potentially give themselves the pressure of fixing it (while perhaps being unfairly blamed by a demanding management). If they do not admit such a problem they know they are not doing their job properly and honourably, but they avoid the pressure of fixing it (and perhaps being unfairly blamed). However, if they can avoid using flow meter diagnostics in the first place then "ignorance is bliss", and they may never face this dilemma. This is a rather cynical observation, but it's also human nature, and therefore undoubtedly a real issue. So, here again, some technicians responsible for flow meters have natural reasons for not wanting diagnostic systems. Still, many technicians want flow meter diagnostics regardless of these problems. Some promote the use of diagnostics to senior management, but find some of their senior management obstructive.

4.4.3 Resistance from Management

"*New ideas pass through three periods: 1) It can't be done. 2) It probably can be done, but it's not worth doing. 3) I knew it was a good idea all along!* " – Arthur C. Clarke

Most operator management who are in charge of, or advise on, flow meter issues served their time over several decades as instrument technicians or engineers. They are well versed, and opinionated, on how flow metering should be conducted. However, along with the valuable experience age brings, it also brings a greater resistance to change, and a tendency to not follow or understand new technology as well as the younger generation who are brought up with it. With flow meter diagnostic suites being one of the latest, most significant and complex changes in flow meter technology for many years, it is only natural that many (although not all) senior engineers with the authority to drive flow meter diagnostic use have not been proactive in doing so.

There is an exception to this. Ultrasonic meters have been extensively marketed for the last two decades. The ultrasonic meter diagnostic suite was one of several claimed benefits. Many middle managers of the time 'hanged their hat' on the new ultrasonic meter technology, and these managers are now senior managers. Nevertheless, it is curious that even though they still promote these claimed benefits, few actively drive the use of ultrasonic meter diagnostics in practice. For other meter designs, such as Coriolis and DP meters, the proponents of diagnostics amongst senior instrument / flow meter engineers is significantly less, probably as fewer have any personal 'buy in' to those technologies, and not all fully understand them. Nevertheless, for hydrocarbon industry flow metering practice to evolve to include the benefits of diagnostics it is necessary that the senior managers of the major operators support diagnostic suite use with generic meters. This will be achieved in the long run, by some senior managers realising their benefit, but also by the natural process described by Max Planck:

"*A new scientific truth does not triumph by convincing it's opponents and making them see the light, but rather it's opponents eventually die, and a new generation grows up that is familiar with it.*"

The hydrocarbon industry has been long used to operating without flow meter diagnostics. The standard (and therefore the contracts) do not tend to demand the use of diagnostics. Adding meter diagnostics may add capital cost, i.e. in the case where the diagnostics are supplied external to the basic meter, such as proving or check meters, or a stand-alone optional diagnostics system procured separately to the basic meter. Use of flow meter diagnostics, even those that come pre-installed as part of the basic meter price, will add operating costs in the form of staff training and time. Hence, some managers can resist due to the perceived increase to the project budget.

In an effort to reduce in-house engineering staff costs many companies now out-source large engineering projects (such as refineries, platforms, metering stations etc.). This makes the budget issue more acute. By senior management policy some companies do not get involved in detailed engineering design decisions of these large projects. That is left to the bidding engineering house contractors. However, such is the competitive nature between these engineering houses, that for fear of losing a contract on price, they will not add any equipment beyond the basic requirements of the "cookie cutter" specifications specifically requested by the clients. Hence, the operators tend to trust the engineering houses judgement, but the engineering house doesn't use any judgement regarding extra equipment (such as meter diagnostic considerations) for fear of over bidding and losing the job. Therefore, metering diagnostics equipment like provers, check metering (including ultrasonic meter Z configurations), or diagnostic systems not automatically supplied with a flow meter are often not considered. The operator and the engineering house may both individually think the addition sensible, but due to the political set up of the relationship neither party has the authority to add the diagnostics. They both claim it's the other party's responsibility. Inclusion in the standards and therefore contracts would induce companies to specify the relevant flow meter diagnostic systems in the system specification and therefore help alleviate this issue.

4.5 Problems Selling Insurance Policies

Fundamentally a flow meter diagnostic system is an insurance policy. A diagnostic suite is not required for the flow meter to be fully functional. Industry has long been using flow meters with no diagnostics. If there is no flow metering problem, the meter operates without diagnostics just as well as it does with diagnostics. Hence, you do not need diagnostics to meter a flow rate correctly. You just require diagnostics to give a significantly greater level of certainty to the flow rate prediction uncertainty, and to tell you of the occasion when a meter malfunctions.

The decision to buy into a flow meter diagnostic methodology is inherently a decision to buy flow meter malfunction insurance. To the neutral 3rd party observer such insurance is obviously beneficial. It can and does reduce the flow rate prediction (and money flow) uncertainty. That is, it will reduce exposure to potential large financial losses if a meter mis-reads the flow rate. Nevertheless, selling the concept of insurance to conservative industries that often operates on inertia and habit can be difficult.

The application of flow meter diagnostics may take a paradigm shift in the long established way that some meter users think about their needs. Mis-measurement of fiscal, custody transfer and allocation flows has always periodically occurred, long before comprehensive flow meter diagnostics were available. Hence, industry has long accepted the inefficiency of finding a flow metering bias, not knowing when the bias developed, and therefore compromising on a mis-measurement / reallocation agreement between the affected parties. However, this practice always produces a winner and loser. With no way of telling when the problem arose and if it became more acute over time, there is no way to know the scale of the mis-measurement. Hence, they don't know the financial cost of such a mis-measurement, and any re-allocation is no better than an educated guess. Furthermore, without diagnostics they may not ever notice a problem exists. Nevertheless, as previously stated, all too often the meter operators have no personal financial investment in the meters performance. The historical procedure of using haphazard methods for checking meters without diagnostics and guessing appropriate re-allocations is entrained and routine throughout industry. Many have become blinded to the fact that this is now becoming an obsolete methodology of conducting their affairs which exposes them to greater financial risk. It is a legal artefact from an early period in technology when there was no alternative.

4.6 Resistance From IT Depts.

If a corporation Information Technology (IT) Dept. doesn't want to do something it may not get done, regardless of senior management wishes. IT departments can and do resist new flow meter diagnostic system deployment because of two largely false perceptions.

The first perception is of it taking a lot of time and effort to implement flow meter diagnostic software into their supervisory and quality control systems. However, in many cases the flow meters dedicated flow computer holds the relevant software and the IT departments have minimal work to do to arrange communications to transfer the output. In cases where the flow meter diagnostics software is stand-alone software requiring downloading into an existing pre-existing computer it may take some time to integrate the first meter diagnostic results. However, all subsequent flow meter diagnostics will have the same requirements and therefore the work is a one off and not repeat work required for every metering system being upgraded to have diagnostics.

The second perception is that diagnostic systems demanding large data storage capacity which they will have to supply. This could be true, but for the fact that most flow meter diagnostic software is developed such that it can run in real time without storing data, or when continuous monitoring and logging operational data it is periodically compressed, averaged and stored in simple low memory format such that large files do not get created.

4.7 Resistance From Legal Depts.

If a corporation's legal dept. does not want something to happen it most likely will not happen. Flow meter verification systems have diagnostic outputs that usually consist of the flowrate prediction and an indication of whether that prediction is trustworthy or not via the diagnostic outputs. Hence, flow meter diagnostic systems hold information that a company will consider commercially confidential. A flow meter diagnostic suite's output is therefore often treated as requiring the same security as the standard meter flow rate information. Therefore, if the diagnostic suite software lacks the appropriate level of security, or a 3rd party external to the meter operating company is sub-contracted to monitor the meter diagnostics, then legal departments can and have stop the use of diagnostics. Again, this is not a technical objection but a practical objection that is easily overcome by making the diagnostic output confidential and secure.

4.8 Meter Manufacturer Resistance

Some flow meter manufacturers can play down the importance of diagnostic suites for their type of meter design. This may sound counter-intuitive but there are (unethical) commercial reasons for them doing this. Flow meter diagnostics are the cutting edge of flow meter technology. Some diagnostic principles for set metering principles are patent protected, or at least the details of their operation kept confidential by the developers. Therefore, not all diagnostic concepts for a given flow metering principle are available to all companies that produce a flow meter based on that metering principle. Without access to certain diagnostic tools some companies therefore think they need to play down their usefulness before those that do have such technology are (correctly) seen to have a distinct commercial advantage.

Even when 3rd parties patent protected diagnostic tools are available to all industry as an optional supplementary system some meter manufacturers still ‘forget’ to mention this option or play down its importance. Most meter manufacturers see and promote themselves as experts in the field of that metering principle. To admit that a 3rd party developed useful diagnostics for that metering principle (and they did not) is tantamount to admitting that a 3rd party knew more than they did about their metering system. This can be seen as a potential loss of face, and undermines their self-image.

Furthermore, most meters are supplied by large corporations that offer multiple products. These corporations and the meter end user often have a close relationship that includes regular business, repeat orders, meter order leading to orders for other products. However, if a 3rd party is required to supply the flow meters supplementary diagnostic product then there is now three in that relationship. And ‘three is a crowd’. The equipment supplier sees that 3rd party as a threat. They therefore do not promote the 3rd party diagnostic system, and even undermine it in an effort to keep the 3rd party away from their clients. This of course is not in the clients or general industries best interest but it happens all the same.

4.9 Resistance From Calibration Facilities

It has been suggested by some that flow meter calibration facilities could resist the use of flow meter diagnostics. When a flow meter has no diagnostic suite it tends to be operated on a RSM. This can mean regular re-calibrations (typically ranging from one to five year periods). However, if a diagnostic suite allowed the meter operator to switch to a CBM, then the meter would only require recalibration when the diagnostics indicated it was necessary. This could reduce the calibration work. However, the authors (who are employees of a calibration facility) have seen little evidence of calibration facilities undermining the spread of diagnostic suite use. On the contrary, flow calibration facilities tend to be honourable advocators of best practice, and educators on the technical details of flow meters. Flow meter calibration facilities have always been happy to calibrate a meters diagnostic system at the same time as the meters general calibration.

5. Examples of the Present State of the Art of Flow Meter Diagnostic Technologies

Only when flow meter diagnostics are generally accepted as mature enough to be of general use can inclusion in the standards be considered. The state of the art of various flow metering principle diagnostic techniques has now long reached this stage. There are many technical papers dedicated to examples of flow meter diagnostics showing their worth to industry. To strengthen this point it is deemed necessary to show real field examples, but for length restraints only two examples are chosen. The first discusses an orifice meter in gas service where the diagnostic system ‘Prognosis’ identified the problem and stated the associated flow rate prediction error. The second discusses an ultrasonic meter in liquid service where the diagnostics identified a problem and subsequent pipeline maintenance investigation identified the problem.

5a. Orifice Meter with Erroneous DP

A 12” orifice meter with the diagnostic suite ‘Prognosis’ was being commissioned for natural gas supply to a power station (see Rabone [3]). See Fig 3. Seven diagnostic results are plotted on a graph in the form of four points. If all is well these points fall within the allowable range indicated by the points being within a box. On commissioning it was found that one diagnostic point (associated with DP reading integrity) was outside the box (see Fig. 3). A resulting maintenance check initially indicated that the DP transmitters were fully serviceable, and hence the DP readings appeared correct. Without diagnostics the technicians would have been very sure the DPs were read correctly. However, the diagnostic system ‘Prognosis’ continued to show a DP reading error. The operator trusted ‘Prognosis’ and therefore

Fig 2. Gas Custody Transfer Orifice Meter

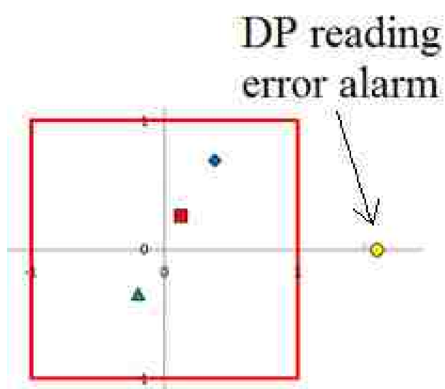

Fig 3. Normal Operation Result & Abnormal Operation Diagnostic Result.

continued to investigate. After further maintenance (only carried out because of the diagnostic system) it was found that the flow computer was applying an erroneous scaling error causing a DP reading bias of +1.6%, which corresponds to a +0.8% flow rate bias on this power stations custody transfer meter.

5b. Ultrasonic Meter with Flow Profile Problem

An operator was periodically proving a 4 path liquid ultrasonic meter (USM). After years of successful quarterly proving the prove indicated a significant shift in meter performance. The meter factor shift was approximately 0.8%. The operator immediately surmised that there was a fault with the flow meter.

Fig 4. USM Installation

Figure 4 shows a schematic of the API 5.8 compliant installation. Flow passes through two bends and then a 19 tube before reaching the USM. The meter operator had declined to log the meters diagnostic output. After checking the prover was fully serviceable the auditors checked the USM diagnostic suites live output. Fig 5 shows the meters calibration flow profile. Fig 6 shows the meters in-service flow profile. The diagnostics indicated a problem with the inlet flow profile. This problem typically means the USM mis-measures the flow, although it is not possible to derive from the diagnostics the induced flow rate bias.

The auditors surmised from the USM diagnostic output that the tube bundle had become partially blocked. However, on inspection it was found that the tube bundle was missing. It had become detached and had moved through the meter and was found downstream. The flow profile change was caused by there being no tube bundle present. As the meter operator had chosen not to monitor the diagnostics it was not possible to tell when this event had happened, and hence what the total mis-measurement of flow was. If the operator had chosen to monitor the diagnostics this would have been possible.

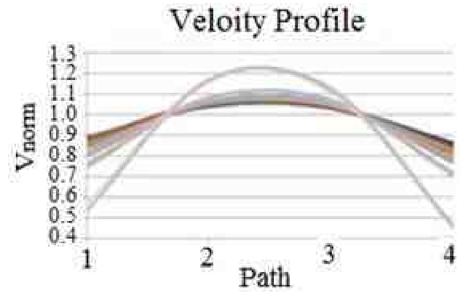

Fig 5. USM Diagnostics Baseline Profile

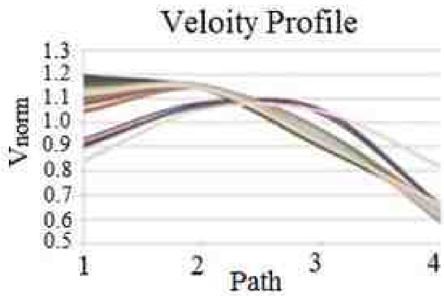

Fig 6. USM Diagnostics Field Result

6. Comments on Existing Authoritative Flow Meter Documentation

There are limited comments in the authoritative literature promoting the use of flow meter diagnostics. Although these documents demand adherence to other good flow meter practice they support but do not demand the use of flow meter diagnostics. Those that wrote these authoritative documents clearly understand the benefit and value of flow meter diagnostics. However, these documents (which at least address diagnostics – many authoritative documents don't) only promote meter diagnostic use with words like 'should' and 'can', while other good practice is described with language like 'shall' and 'must'. In the following examples the bold underlined italics are added by these authors to highlight the optional aspect of the comments.

DECC "Guidance Notes for Petroleum Measurement, Issue 8", released in 2012

For DP meters in section 6.7.7 the UK's OGA (formally DECC) states:

> "The use of diagnostic systems based on the use of an additional measurement of the fully-recovered pressure is gradually becoming well established. Experience has shown that this technique enables the Operator to detect significant deviations from normal operating conditions as they arise. It ***may*** therefore form the basis of a condition-based maintenance strategy, as described in Chapter 4 of these Guidelines; DECC has already agreed to the adoption of such a strategy at a major UK terminal. Operators of new developments are ***strongly encouraged*** to consider the adoption of such a strategy. The provision of an extra pressure tapping costs relatively little at the design and manufacturing stages, but ***may*** permit significant operational savings to be made during the life of the field."

For ultrasonic meters (called "USFMs") in section 6.8.12 DECC states:

> "…condition-based maintenance (CBM) of gas USFMs ***may*** be the most appropriate strategy in many instances."

The Alberta Energy Regulator's Directive 17, "Measurement Requirements for Oil & Gas Operations", released 2015

In section 2.5.2 (on gas meter internal inspection) Canada's Directive 17 states an exception (#9) to the demanded routine scheduled maintenance / re-calibration period for a gas meter:

> "Internal metering diagnostics ***may*** be used to determine if the structural integrity of the primary measurement element is within acceptable operating parameters and checked at the same required intervals as an internal inspection. Then internal inspection is not required until an alarm or error is generated by the device or as recommended by the manufacturer."

ISO 17089-1 [2]

In the Introduction:

> "USMs ***can*** deliver extended diagnostic information through which it ***may*** be possible to demonstrate the functionality of an USM." And,

> "Due to the extended diagnostic capabilities, this part of ISO 17089 ***advocates the addition and use of*** automated diagnostics instead of labour-intensive quality checks."

All these standards documents promote the use of flow meter diagnostics but stop short of demanding there use. All comments related to flow meter diagnostics are advisory. Although the authors of these standards obviously recognize the benefit and advantages of flow meter diagnostics there is no requirement that the end user must use them to be compliant with the standard.

Why is this? After years of research, development and field experience internal meter diagnostics have been comprehensively demonstrated to be of great value. Flow meter internal diagnostics have come of age. So why do the standards not demand their use? Perhaps this is a legacy issue, with diagnostic suites tending to be newer attributes to the original meter designs. The standards committees (even those working on current draft standards) are notoriously conservative and still baulk at demanding adherence to even the most established meter diagnostics. No flow meter standards committee working on any flow meter technology as yet has stepped up and made the not so bold step of stating what is now surely self-evident. That is, flow meter diagnostics have come of age and now should be an integral part of flow meter best practice. There is no real technical argument against using modern flow meter internal diagnostics. So surely it is time standards said as much?

Flow meter diagnostics can now be made integral to the meters such that future generations will automatically see them as integrated vital parts of the core meter system. Today, there is still a lingering historic perception that somehow these diagnostic systems are superfluous, not essential to guarantee the correct operation of the meter, but it is fast becoming a false perception. Technology has moved on, and such an obviously beneficial advance cannot, and will not be ignored indefinitely. Sooner rather than later, these diagnostic systems will become engrained in the operators mind as essential to professional flow meter operation conduct, and they will be automatically used. The sooner the flow meter standards board grasp this reality and make authoritarian demands about the use of diagnostics the quicker this change in mind set and practice will occur, to the benefit of all industry.

7. Comments

Modern flow meter internal diagnostic systems are capable of seeing many common problems before significant flow rate prediction errors occur. If the operator applies the meter's internal diagnostics flow metering has never been so assured. However, the majority of industry still does not understand or use these internal meter diagnostics. Industry still tends to run the majority of flow meters "blind".

Although modern flow meter internal diagnostics cannot always state what specific problem exists, or what the size of the associated flow prediction bias is, they sometimes can. What's more, the diagnostic output of many meter designs is now good enough that cross referenced with process knowledge a competent operator can often deduce the specific problem. Without diagnostics a competent operator is often effectively blind and often cannot even deduce the meter is in error.

A root cause of the slow uptake in use of flow meter diagnostics is the lack of standardization. Without standardization there is no political pressure for operators to even use flow meter diagnostics, never mind for the diagnostic systems to be further developed and operator training to be increased. Standardization requires that in order to be compliant with the standard a user shall use diagnostics, not should use diagnostics. With such standardization, the use of internal meter diagnostics will become included in contracts and fiscal regulators will also enforce their use. This in turn will drive the permeation of flow meter internal diagnostics into the main stream of industrial flow metering to the long term benefit of industry and society.

Inclusion in standards, and therefore contracts, would inevitably result in a significant increase in use. This in turn would offer meter manufacturers commercial incentive to put more resources into further developing flow meter diagnostics. It would also produce more scrutiny of the various meter manufacturer's diagnostic claims and in turn control their claims. This increase in use would focus the industry into developing better, clearer, simpler more intuitive, user friendly ways of displaying diagnostic outputs. Such a development would inherently make flow meter diagnostics more accessible and understandable to more meter operators. Standardization of flow meter internal diagnostics and their displays would also facilitate an increase in formal meter operator training which in turn would further increase their use.

The authors can only think of a couple of minor potential disadvantages. The first is that as a diagnostic system is inherently imperfect, of course there will be occasions where it could give a false alarm (i.e. "cry wolf"). This is inevitable. However, these cases would be relatively few, especially if the operator is initially pragmatic about choosing the sensitivity settings of the diagnostic output until he has experience with the system. The second is the perceived cost of change. However, these capital and operational costs are typically a relatively modest investment. In the hydrocarbon industry they are small relative to the potential savings by avoiding mis-measurement. Furthermore, nobody expects an operator to continually monitor a diagnostic system. Modern diagnostic systems run in the background unmonitored until the operator chooses to periodically look, or they are alerted of a problem by the diagnostic system. Therefore, these few claimed disadvantages are more false perception than reality.

Such is the benefit that modern flow meter diagnostics bring to industry that it is obviously only a matter of time (although without inclusion in the standard a rather long time) before they are universally adopted. In the long run operators will come to wonder how they managed without them. The sooner their use permeates throughout industry the better for industry. A catalyst to accelerating their use is their inclusion in the industry standards as required practice. This development would help the conservative hydrocarbon industry depart from its habit of using 20th Century metering methods and bring its metering methods into the 21st Century.

References

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