Advanced Application of Liquid Flow Computers
Class # 3010.1

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Abstract

Technology is advancing at an ever increasing rate this increase can be judged by reviewing the US patent office data sets that show a 10 fold increase in yearly patent submittals from the late 1800's to 2010, this rate of increase applies to all branches of engineering. This increase achieves around 120,000 patents per year for all technology types submitted in the USA to the year 2011.

Flow computer measurement technology has also changed in its operating mode and design over the years from an original black box stuck into a control room or in the field with basic functions, to a fully developed supervisory computing device with many features of diagnostics and self-checking and redundancy.

One feature that has not changed however is the need to comply with national and international standards depending on the fluids being measured and the contractual uncertainty needed. This paper details pertinent information and technical details regarding the application of flow computing devices in the oil and gas marketplace. This paper is designed to help the end user decide some of the things to consider when applying a flow computer application in the field.

What Do I Want to Measure

In reality the flow computer does not usually measure anything it is a tertiary device that is pre-programmed to correctly calculate flow within specific limits using data streams received from primary and secondary devices. Some types of electronic flow meters have built in flow calculation devices but it is important to know that a dedicated flow computer designed to interpret a set of flow data is usually preferred due to the auditing capability that is normally built into these devices.

These tertiary devices can be **a)** basic flow computer**, b)** SCADA (supervisory control and data acquisition system). **c)** any other device that can calculate either quantity or quality of the fluid with a traceable protocol to allow auditing of the device and confirm its data security.

A word of caution - " Rounding of Calculations", the way that a flow computing device handles a calculation is a function of the effort placed into the design using both, standardization and experiential knowledge, all flow computers are not the same despite claims by some companies that theirs is better !

Selection of a device is a matter of preference based on the needed fidelity, ease of integration into an existing architecture or company protocol and is usually defined by the measurement team at that respective company."

Usually these systems meet custody transfer standards in simple terms - "custody transfer" is the transfer of ownership or responsibility for a liquid hydrocarbon from one party to another. Since ownership is being transferred, either immediately or eventually, it is essential that accurate accounting be used so that all parties involved in the transaction receive thier fair measure of the equity.

With the prices for hydrocarbons escalating these days, it is obvious how important an accurate accounting/measurement system is needed hence, "accurate" measurement becomes a main goal. The words "custody transfer measurement" (CTM) have become synonymous with accurate measurement.

Rounding of Numeric Calculations in a Flow Computer
(a simple overview)

API MPMS Chapter 12.2 details the calculations and rounding methods that are used in a custody transfer flow measurement application, and generally what level is to be maintained regarding calculation needs. The API document Chapter 12.2 is under revision currently by a working group and is being modified to improve the overall effectiveness and fidelity of the calculation methods. An example of rounding methodology which is shown in flowchart figure1.0 next for information only and to prompt the user to think about this aspect of the accuracy of a flow computer.

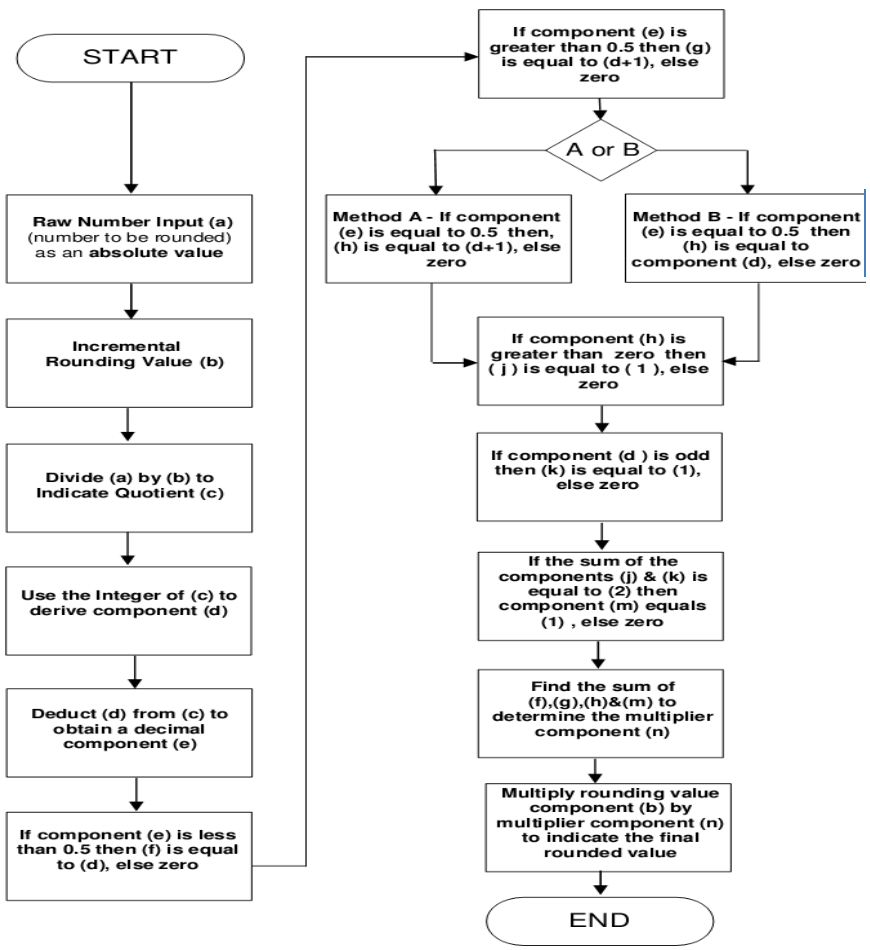

Figure 1.0 Typical Flow Chart Used to Facilitate Rounding of a CTM calculation

This standardized approach (one of a few) is necessary to make sure that incremental calculation rounding additions or subtractions in a fiscal or custody flow calculation (in the computer) follow the same agreed methods between partners, stakeholders, parties and taxation or royalty authorities for each machine in the CTM chain.

The measurement process and calculations should be traceable from the start to the final result and also have some element of redundancy available to protect the asset or point of measurement in case of a hardware failure.

Selecting the Correct System

Correctly implemented measurement practices are established to minimize uncertainty in the determination of the 'custody transfer' volume (or sometimes mass) of products in a system. Understanding the fundamental cause and effect relationships and doing an evaluation for the liquid/liquids to be measured will lead to a volume determination that most closely matches the 'true' volume at the referenced 'standard' pressure and temperature.

When designing a new measurement station it is up to the measurement people / engineers , to understand the product to be measured and its properties, apply the correct equipment, and implement the appropriate correction equations and thus select the correct type of flow computer to enhance the system based on the accounting and operational needs Proper procedures should be implemented to install the system selection process and some up-front thought is needed as shown next -

1.0 What is the Composition or Fluid / Fluids to be Measured.
(Can the flow computer handle the need - which standardized calculations are used)

a. Crude Oil (is it onshore / offshore – clean or non-processed see - c)

b. Light Liquid Hydrocarbon – Condensate – Natural Gas Liquids

c. Pure Product

i. Propane

ii. Butane

d. Refined Product

2.0 What is the operating Pressure and Temperature?
(Correct sizing of interconnected secondary devices)

3.0 How does the operating Pressure and Temperature affect:

a. Density

b. Expansion/Contraction Characteristics

c. Viscosity

d. Vapor Pressure (important with energy extractive devices)
(Any special algorithms needed)

4. What other operational factors affect proper measurement?

a. Basic Sediment and Water *(monitoring in the computer?)*

5.0 Based on the answers to the above questions, what is the best flow measurement combination of equipment to handle the product? (Primary Secondary Tertiary)

6.0 What types of standardized flow computer calculations are implemented to correct the volume, or mass, - measured at process conditions corrected to 'standard conditions' with standardized volumes for Liquid Hydrocarbon Measurement. *(Anything Special Needed- Review)*

The Data Stream Input (primary device)

The flow computer receives its flow data stream from the primary and secondary devices some liquid metering primary devices examples being a turbine, positive displacement, ultrasonic, Coriolis force mass meters or other designated flow meter that satisfies the contractual obligation. Usually digital pulses from the meter are integrated by a flow computer to calculate the flow based on the devices K factor , when using a mechanical (rotating) metering device, the pulse stream is usually supplied directly in a uniform manner to the computer on a continuous basis (pulsed voltage).

If the primary device is an electronic flow meter care must be taken to review the devices output as these units develop what are called electronically simulated pulses and some issues can occur with the update time due to the nature of the device type. The update time, is particularly important in regards to a proving operation which we will talk about later in the paper.

Note that the quality of the fluid measurement is also a concern as well as flow rate, so data from on line sampling systems must be handled effectively and properly and incompliance with the required standardization for the location and contractual obligation. Some modern turbine meters are designed with 2 helical blades to allow the measurement of more viscous fluids these devices do not give enough pulses to generate a minimum 10,000 pulses per pass from a prover so, the flow computer usually has incorporated an onboard system called "double chronometry" or pulse interpolation.

This method uses very accurate timing clocks to measure the times between a prover's start and finish run detectors and also compares it with the overall turbine meter pulses which are also timed by the second clock, this allows a smaller sized prover to be used than would be required due to the low pulse output if the system where not applied the system still maintains good fidelity when being used.. Small volume provers must also be used with 'double chronometry' or 'pulse interpolation' to attain the 1 part in 10,000 resolution required by API standardized process A typical drawing of the idea is shown in Figure 2.0 next.

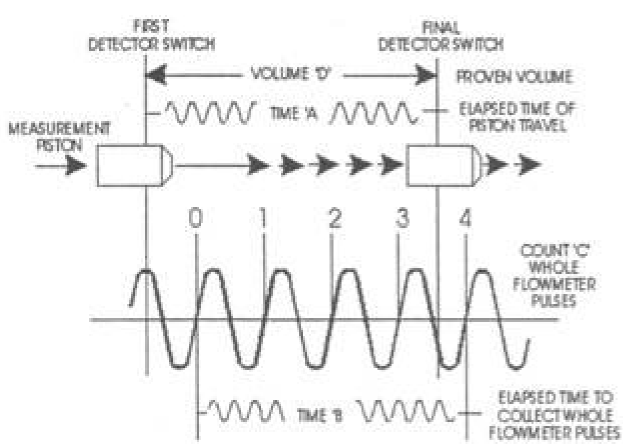

Figure 2.0 Typical Double Chronometry Concept

One note of caution regarding this method and turbine meters, the meter rotational stability and blade robustness (non-shifting during rotation) is key to maintaining a good fidelity since any errors in the meter rotation will be incorrectly amplified by this method. ISO international standards detail the level of rotational stability in the ISO TC 30 documents.

Interfacing - Flow Computers with Electronic Flow Meters

Liquid Ultrasonic Flow Meters using **“**Transit Time Technology”.

Ultrasonic meters also being velocity or inference type devices require flow stream conditioning for their accurate performance unless the manufacturer can prove otherwise. The detailed requirements for flow conditioning can be found in API MPMS Chapter 5, section 8

Typical flow conditioning consists of upstream and downstream straightening sections. The upstream section usually contains a tube bundle, which allows the upstream section to be reduced in length. This tube bundle serves to eliminate any “swirl” in the flow stream before reaching the meter presenting a Symmetrical velocity profile to the turbine rotor.

Some ultrasonic flow-meters produce a non-uniform pulse output which can exhibit a wide span of repeatability when proving the flow computer must be able to interpret this data stream when proving the meter this is usually also reviewed in line with the measurement system procedures and measurement team directives.

Coriolis Meter—the liquid Coriolis force flow meter is an inferential type of volumetric measurement device installed directly inline in a flowing system. The Coriolis force flow meter is a mass meter, which measures mass flow rate directly and infers volume. The Coriolis meter is device that by means of the interaction between a flowing fluid and the oscillation of a tube(s), measures mass flow rate. The Coriolis meter consists of a flow sensor and a transmitter. The flow sensor is a mechanical assembly consisting of -

• Flow Housing - a means for providing environmental protection.(It may or may not provide secondary containment)

• Measurement sensor - sensors to monitor oscillations and detect the effect of the Coriolis forces. These may also be referred to as pickups or pickoffs.

•Support structure: a means for supporting the vibrating conduit.

•Vibrating conduit: oscillating tube(s) or channel through which the fluid to be measured flows.

•Vibration drive system: the means for inducing the oscillation of the vibrating tube.

The Coriolis meter also generates simulated (K factor) pulses which may also be non-uniform.

When proving these devices similar concepts are used as per the USM meter, one other thing to remember regarding these devices is they are developing mass weighted answers.

This means that a density number is used from the device to obtain a standardized volume when using a flow computer with this device the proving and also the density input from an external densitometer may need to be considered because of the following effects thus making a review of the computer I/O (inputs &output connectivity) necessary, some typical information regarding the use of the Coriolis onboard density to calculate custody transfer volume are discussed next.

Temperature Effects on the Meter

If the temperature changes there is a change in the Young's modulus (stiffness) of the sensor materials.

In fiscal (CTM) measurement, at least one manufacturer uses NiSpan C as this has a very low temperature constant (about ten times better than stainless steel). Choice of materials can affect the performance and meter fidelity .

Temperature also causes a change in 3D geometry; as temperature increases the tube expands to contain more volume of fluid (control volume).

The tube expands length-ways as well. This increases the compression forces along the axis, which also affects the density. In bent tube mass meters this is possibly not as bad as we might otherwise expect since the tube geometry is quite flexible.

In straight tube sensors it can be very significant. In the vibrating wire type tube density meter the vibrating tube has isolation bellows at either end which serve two functions, the first of which is to minimize the effect of temperature on the tube.

Pressure Effects

As pressure increases the tube can stiffen

The tube also can balloon slightly and contain more volume.

In bent tube meters {e.g. most mass meters) pressure tends to try and make the tubes straighten out.

So temperature and pressure effects are a consideration, we may have changes to the enclosed volume and changes in tube stiffness which can affect the density output.

A good Coriolis meter can manage an expression of density accuracy around: +/-0.001gm/cc. (+/-10.0kg/m3)

A good vibrating wire densitometer can manage around +/-0.0001gm/cc
(+/-1.0kg/m3)

The Data Stream Input (secondary devices)

In general, when measured product experiences a positive temperature change , the volume of the product will increase, and when the product is cooled, the volume of the product reduces.

The Industry has determined factors that must be used when correcting Volumes of Liquid Hydrocarbon to standard temperatures. This CTL factor will be a function of the API (American Petroleum Institute) gravity of the product, and the vapor pressure in the USA some flow computers that are manufactured overseas may not have the API CTL calculation but an ISO (International Organization Standards) version its necessary to check that the device can manage the calculation for the country its operating in .

The American Petroleum Institute in MPMS Chapter 11 has defined tables of temperature corrections. These tables are based on the Gravity Ranges of the product. The API has also defined an algorithm for CTL correction to be used with on-line flow computers.

Standard Temperature and pressure calculations may differ around the world for example in Brazil 20Deg C at 1 atmosphere is used in a lot of Petrobras offshore and domestic applications, check the need and local requirements in regards to this correction need..

Quality of the Measurement
(things to consider)

The Composition of the fluid refers to the percentage of each type of molecules contained in the total volume of the Mixture. Hydrocarbon Liquids are classified as Homogeneous mixtures. This type of mixture has uniform chemical compositions, appearance and properties throughout a sample. A simple example would be Air, which is a homogeneous mixture of gases consisting primarily of nitrogen and oxygen, normally on clean products a simple PVT (pressure volume temperature) calculation is easy to perform in a flow computer however a situation can occur when upstream liquid stream (contaminated) fluids are measured using PVT modeling to simulate the density, updating the tables in a proprietary flow computer can be tedious but is necessary if sampling is not used. (multi-phase measurement)

A very important consequence of a Homogeneous Mixture is that many of the resulting properties, like Density, Energy Contents, and Vapor Pressures, can be calculated from the sum of the properties of the individual component example in a natural gas stream this can be done in real time using a gas chromatograph for liquids this may be slower and the use of standardized sampling is very necessary to achieve a correct fluid composition.

Generally the composition of the different mixtures will create fluids with different classifications, and very different physical properties. These different fluids will require different measurement equipment and also computations designed for the products being measured and can determine the measurement practices used in the systems. Natural Gas Liquids will typically have a composition that is comprised of Ethane through Decane. Crude Oils and Refined Products (Gasoline, Diesel),on the other hand, will have a composition that is comprised of very heavy molecules: C10 and greater. Making sure that the flow computer can handle the calculation need and has the correct contractual agreed algorithms (GPA,API,ISO etc) is necessary for accurate computation and is an important consideration.

Other Applications than CTM (Custody Transfer Measurement)

Advanced applications for flow computers can also include alongside the custody application many of the following concepts applied in the same hardware architecture or box -

- Multi-Well Pads for Shale Locations
- Plunger-Lift Wells
- Multiple Meter Runs
- Liquid & Gas
- Compressor Station Control / Anti Surge
- Sampler Control
- Wet Gas
- Water Cut
- Other Specialty Upstream Applications (multiphase)

Many of these applications are programmed and designed into the newer higher 32 bit 64 bit processing and high memory capacity devices. High speed computing power is essential for many of these applications as fast up-date times for monitoring the process may be essential.

A typical arrangement in figure 3 next shows a flow computer which is used for CTM application also being used to perform a BS&W calculation due to the extra I/O and algorithms on board.

Figure 3.0 Flow Computer for a CTM application also used for BS&W Application

Some other key elements of flow computers that are available with modern devices-

- Multiple K-factors and Linearization.
- Densitometer
- Proving
- Batching Reports
- Manufactured pulse meter conditioning
- Predictive maintenance through diagnostics.
- Multi-product measurement using density/phase detection.
- Leak Detection and ESD

There are many choices of Flow Computer Installs , not only the calculation type and meter standardization but the application may require selection of the right packaging filed mount or control room

- RTU/PLC
- Panel mount
- Remote/meter mount

Flow Computer /RTU/PLC

Combining PLC features and RTU function into the Liquid Flow Computer has many operational benefits. This design saves space, power, parts maintenance and training. These types of systems are not limited to traditional petrochemical and hydrocarbon measurement. Their applications can become very complex where multiple products and processes are being monitored along with several layers of device communications. API and ISO calculations required for flow computations must be done quickly in order to provide the necessary updates for control loops

The need to perform “hot” swaps may be required for redundancy purposes so that the I/O modules can be exchanged whilst being powered up. Modular architecture provides the ability to add or change process I/O requirements. RTU functionality enhances environmental robustness and reliability.

PLC’s are known for their speed and logic sequencing in a standalone mode. PLC’s are used for their ability to interface with multiple protocol and instrumentation buses. Combining this into one unit, greatly increases system compatibility while minimizing hardware however for a custody transfer application a PLC must have a secure password protocol applied that is fool proof..

This style of flow computer allows for custom displays to be added along with user custom program development. The packaging allows for mounting in out of the way areas or in NEMA weatherproof enclosures.

I/O type card slots for add-ons or “future” compatibility . Many of the new meter station designs are requiring more proactive health monitoring and smart device compatibility plus interaction Figure 4.0 shows such a commercial PLC device type.

Figure 4.0 Typical PLC Based Flow Computing System

Panel Mount Devices

Panel mount flow computers usually reside in traditional control room, 19” rack environment. In many oil and gas applications, this genre of flow computer is popular for fiscal metering, custody transfer, batch loading, meter proving, multi-stream measurement, station monitoring/control and other applications that high-performance measurement and control they usually have very secure password protocols

The metering and process devices are normally wired into cable marshaling panels and conduit and then are wired back to the control room mounted flow computer. Offshore applications and large refineries consider this a standard configuration. Keypads and displays allow operator monitoring and intervention. Although Panel mount flow computer can monitor and control several meter runs, the generally are limited to one or two per flow computer.

Meter proving functions are also a necessity on any Liquid CTM Flow Computer

Figure 5.0 Typical Panel Mount Custody Unit

Remote Meter Mount Units

Applications that require lower power, close-coupled metering, local display or keypad are prime reasons for utilizing remote or field mount flow computers. This style of computer is the norm for most gas metering. Liquid metering projects from pipelines to skids can connect to their SCADA center via field mounted metering alternatives one manufacturer has a field mount liquid custody transfer with proving capability .

Remote mount systems allows for a larger distributed device architecture on metering skids, also remote Prover computers are now being implemented around the world. Combining the communications system or package together with the remote flow computer is becoming a standard feature on a lot of devices in the market place today. Figure 6.0 below shows a typical remote system

Figure 6.0 Typical Remote Mounted System

A Remote Mounted Device's general ability and requirements are as follows -

- Volume Rate
- Volume Total
- Average Differential Pressure (if required)
- Corrected Volume
- Uncorrected Volume
- Average Density
- Total Mass
- Average Temperature
- Average Static Pressure

Control

A Flow Computer usually has a minimum ability to control the following (usually via Solid-StateContact Closure, Open – Collector or 4- 20mA Analog Output)-

- Composite Samplers
- Additive Injectors
- Alarm Annunciation
- Flow Rate
- Pressure

Smart Integration

Remote flow computers combine pressure and dP. flow transmitters in the unit as an integral system. This can reduce cost , weight and the wiring and process connections are also simplified. Accuracy, reliability and repeatability is improved due to this design type . This has been more traditional route for natural gas measurement service

Fieldbus

Connecting a set of measurement transducers to a flow computer traditionally has been an analog methodology, using a low power 1 to 5vdc frequency method and a 4 to 20 mA method for line powered applications.

Fieldbus methodology changes this in two ways. 1a) standard set of wires and connectors are used between devices and 2) a common communication protocol is used, so less field wiring is needed and also device interchangeability is added.

Device interrogation is done digitally now instead of by an analog protocol methodology ,which allows the availability of process variables as well as performance diagnostics at the device level which is a big improvement.

Communications and Telemetry

Most telemetry methods revolve around the decades old RS-232 and RS-485 communication standards. Software and hardware support for these make communication equipment connections fairly easy. The RS-232 serial interface is limited to a field useful baud rate of 33.6K. Whilst the RS-232 is limited to short single device connections, RS-485 is used for multi-drop applications. The baud rate for RS-485 is limited to 9600 baud rate. Field devices can be located several thousand feet away from the flow computer.

Ethernet

Ethernet connectivity is being used for most plant type operations involving line power flow computers. This is a common network medium that is spreading to more complex field and plant measurement scenarios. This combined with Internet technology, is hopefully going to be the next standard platform

Dial-Up Modems

When landline phone service is available; this is the least expensive option. A 202 or 212 series modem is usually used and typically operates between 300 baud and 1200 baud. The great majority are running at 1200 baud as that speed is usually fast enough for most applications whilst being low cost.

Cellular and GSM Radio

In areas where landline hookup is impractical and if the measurement site is within a "cell" area and has sufficient signal strength(most important) then a cellular phone modem system may be an obvious choice.

These are offered by many companies are powered by various means and some offer solar powered units some use gas driven thermo-pile technology . Newer GSM radios which offer high speed data transfer can also provide an Ethernet to internet link as part of their enhanced capability.

Satellite Radio Systems

Satellite radios have been used for flow data communications for several years. These small cellular type radios relay communications via satellites. The advantage of this system is global measurement coverage through a single link. This technology is coming down in price. Bundling of equipment, airtime and services, is currently available and makes On-Line flow data available to virtually any metering station in the world were a respective satellite covers that region.

Conclusions

Advanced Custody Transfer flow computers will continue to improve their performance and expandability as we continue to push the envelope with new primary devices with new algorithms such as multiphase wet gas and PVT predictive software. Further improvements in base integrated circuit design using nanotechnology will enable more complex measurement devices to be manufactured with better reliability .

The first three-dimensional carbon nanotube circuits, made by researchers at Stanford University could be an important step in making nanotube computers that will be faster and use less power than today's silicon chips. Such a computer is still at least 10 years off however it is an exciting prospect for the industry New types of primary meters are being introduced that can open up new applications that will have to interface with standardized flow computers. Flow measurement will continue to use new technology as long as there is an industry awareness, training and a necessity to do so.

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