# FLOW COMPUTERS
# METERING, MONITORING, & DATA ACQUISITIONS

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## GENERAL LAYOUT

This paper presents information about applications of flow computers in the oil and gas industry for (a) Upstream Production, (b) Midstream Pipeline, and (c) Downstream Refining, Process plants, and Chemical Plants. Different applications in those three areas are presented in this paper. Some of the applicable standards are discussed and examples of few hardcopy print out of the flow computer are presented to provide some idea about the capabilities of the Flow Computers.

## UPSTREAM APPLICATION

Upstream applications use the flow computer for metering production fluids coming out of the ground as produced water, hydrocarbon liquids (crude, condensate, etc.) and gas. Crude oil can be produced under natural underground pressure or through secondary recovery pressure, generated by injecting liquid or gas into the reservoir to increase pressure underground and thereby force the oil out. Sometimes steam is injected into the reservoir, especially for the fields with heavy crude, in order to reduce its viscosity and mix the crude with condensed stream as produced water. Sometimes high pressure $CO_2$ is also injected into the ground to increase production.

**Plate 1: Production Field Installation - Solar Powered Battery Backed System.**

All these processes require flow computers to measure, monitor, and sometime control the injected fluids and the production of the well. The flow computer outputs of the injection process and production rate provide necessary information to the reservoir engineer of how effective the injection process is and also the condition of the well. This information allows the reservoir engineer to better understand and estimate, if further action is needed to increase or optimize production of the reservoir or the well.

The measurement of the production gas flow rate is often monitored by differential pressure type flowmeters (e.g. orifice meter, cone meter, etc.) or others devices for measuring gas production and for produced liquids, typically turbine meter or PD (Positive Displacement) meter is most commonly used. Also, in many production fields, often separators are used, where a flow computer is needed to project daily produced water, oil, and gas for each well. Other parameters often monitored are tank levels, compressors inlet and outlet pressures and temperature, as well as compressor gas consumption.

**Plate 2: Flow Computer with Orifice Meter**

All these above data need to be reported back to the accounting department and production engineers. Even though they are in different departments, each need separate sets of data from the flow computer. Reservoir engineers are interested in tubing-casing pressures and other parameters related to response and behavior of wells, while accounting is interested in final production numbers in order to generate revenue or asset management ticket.

Prior method to obtain these information was manual that utilized chart recorders. In the last several decades many newer methods have developed that offer many advantages over the old method of using chart recorders. These methods include Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), satellite, radio, etc. Radio communication is based on licensed or no licensed frequency. The GSM or GPRS can be used for direct polling and as well as SMS messaging. Satellite is the most versatile, provided money is not an issue and unless it is used in short messaging structure with zipped data format. All of these communication methods require power. If locally power source is not available a solar package would be required. Solar packages have limitations when there is no sun for an extended period of time. That may cause the system to go down and computer data would be lost. Some alternatives like rechargeable backup battery or thermal or gas turbines power generator may be installed. These alternate systems are new and relatively expensive. These are some of the challenges in the power generation.

**Plate 3: E-Chart**

Test separators are employed to allocate production for each well. Wells often produce three phase flows where gas, oil, and water are mixed. Knowing how much liquid (oil/water) and gas are being produced is extremely important to better understand and optimize the performance of each well. A flow computer is installed to measure across the test separator and thereby, project daily production rate for each well. These data are very useful for the reservoir engineer in order to better understand their wells.

Tank levels and compressors are where water and condensate is stored for transmission or delivery. Operations need to know the liquid levels in order to send a truck to remove the liquid to avoid over filling or overflow. These data are monitored by the flow computer and transmitted to the control room or on displays for appropriate or necessary action.

## MIDSTREAM APPLICATION

Midstream pipeline are in the transmission or distribution mode for the gas, crude, refined products, LPGs, and also the petrochemical products. Pipelines need constant monitoring for line pressure, batches, temperatures, and all the parameters that has to do with operation and accounting at the base conditions or at conditions defined by the terms of the contract. Some of the applications for flow computers include metering, meter proving, valve control, batching, ticketing, and product interface. This is the most intensive application for flow computers and requires the flow computer to be versatile for all applications and handle all the different requirements. Most of the time multiple ports are used to transmit data to local operator, to pipe line monitoring system, to local printer, to the accounting department and possibly to other customers that need certain information.

**Plate 4: Pipeline Application**

The communication package used for that interface would be a real time SCADA application, where data are retrieved in real time. Ethernet, fiber optics, radio transmission, or satellite can be used to achieve this transmission.

Type of metering devices is usually different between liquid and gases. Liquid metering requires meter proving and batching for custody transfer measurement. Each batch might have to be proved to accommodate the differences in viscosity and product characteristics. Turbine meters, PD meters, ultrasonic flowmeters, as well as direct mass (Coriolis force) flowmeters are commonly used in these applications. Densitometer can be used for meters that measure flow rate in volume to insure correct product gravity and tables to be selected in the flow computer. Densitometers are not needed when the product gravity is known. There are different algorithms in the flow computer to accommodate temperature-pressure corrections and also achieve vapor pressure calculations.

**Plate 5: Prover Application with Flow Computer**

Flow computers in liquid pipeline also monitor pressure and flow rate information that can provide information to provide leak detection capability and valve control information. In many applications flow rate information can be utilize other pipeline control activities.

Gas pipeline would utilize variety of meters from differential pressure devices like the standard orifice flow meter, venturi, nozzle, or cone meters to direct mass meter and Ultrasonic flow meters. Data are normally transmitted by a radio infrastructure combined with satellite or GSM setup. Data are needed as fast as possible. Similar to liquid pipeline application, flow computer output is often used to monitoring, leak detection, and control.

## DOWNSTREAM APPLICATION

Downstream applications include refineries and chemical plants. In refineries and chemical plants flow computers are used, where accuracy for custody transfer measurement is required. when products are transferred between the buyer and the seller. A billing system that is approved by local regulatory agency and parties involved, which is the acceptable method to accomplish measurement, which can be achieved by a flow computer.

**Plate 6: Plant Application for Flow Computers**

Other measurements inside the plant is normally for indication or controlling purpose, which are not used for billing but only for monitoring and verification of process. Data are usually retrieved by modbus RS485 to DCS or simply the analog out to the DCS for compensated flow. The DCS will integrate the analog output into the plant system. Accounting would use the digital data (RS485) or a daily reading the operator makes inside the plant facility. All types of meters are used inside the plant from simple differential pressure type meter (orifice, venture, nozzle, averaging Pitot, Wedge, Cone, etc.) to MAG (magnetic flowmeter), turbine, PD, vortex, ultrasonic, and direct mass meters. The type of products inside the plant could range from crude oil, gas, process gas, steam (saturated and superheated), air, ethylene, propylene, and many other intermediate products.

## INDUSTRY STANDARDS

There are several industry standards that are applicable for flow computers. Primary Industry standards that flow computers has to comply with are API (American Petroleum Institute), AGA (American Gas Association), ISO (International Standards Organization), GPA (Gas Processors Association), and ASTM (American Standards of Testing and Material). Some of the applicable API standards are different sections of MPMS Chapters 2, 4, 5, 7, 11, 14, 12, 20, 21, and 22. Similarly applicable AGA Reports are 3, 4, 5, 7, 8, 9, 10, and 11. There are several GPA and API Tables that must be implemented into the flow computers to compute corrected liquid and/or gas volumes to the applicable base condition, which can vary between industries, states, and countries. Sometimes it is necessary to interface the flow computer with other instruments and analyzers to determine and/or calculate fluid properties using different tables and empirical equations to obtain corrected volume. In addition there are different devices that have empirical flow coefficients (e.g. orifice meter, cone meters, etc.) that must be programmed into the flow computer which often require iterative computation to determine the corrected flow rate within specified limits of precision. Those details depend on the type of metering device installed to determine the flow rate.

For liquid flows, flowmeters are often proved on site that require updating meter factors based on field proving of meters. Some flow computers can be configured to initiate proving if the flowing fluid properties change beyond acceptable range of application. These installations require dedicated on-site provers. Discussion of those configurations is beyond the scope of this presentation.

## GENERAL OUTPUT CAPABILITIES:

Flow computers can generate several reports depending on what is required by the user. For liquid meters, some of the possible reports are

- Alarm Report
- Audit Report
- Snapshot Report
- Hourly Report
- Daily Report
- Batch Report
- Prover Report

Similarly for Gas meters some of the outputs are:

- Snapshot Report
- Choke Report
- Batch Report
- Daily Report
- Hourly Report

Examples of a few of above reports are present here in this paper.

## CONCLUSION

The flow computer is the primary part of the custody transfer requirement. Its job is to read raw data at actual flowing conditions and correct them for the line conditions and to the reference or base conditions. Then provide the delivery ticket that reflects output the data and the supporting information and data for the ticket. The flow computer has certain requirements that must be met, which includes computation accuracy, audit trail, alarm log, and historical data. Additional functions may be needed, such as ticket printing and meter proving capability of proving information.


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# ALARMS REPORT

| | | | |
|---|---|---|---|
| **Company Name** | DFC | **Stream 1 ID:** | Stream1 |
| | | **Stream 2 ID:** | |
| | | **Stream 3 ID:** | |

| Date | Time | Description | Stream No | IV Cumulative |
|---|---|---|---|---|
| 03/14/10 | 05:40:28 | MTR1 (Meter 1) IV FLOW HIGH | Stream1.F | 0 |
| 03/13/10 | 14:34:29 | PVR_PT (Analog Input 2) FAILED OK | Stream1.F | 0 |
| 03/13/10 | 14:34:29 | PVR_PT (Analog Input 2) OK | Stream1.F | 0 |
| 03/13/10 | 14:34:29 | PVR_TT (Analog Input 1) FAILED OK | Stream1.F | 0 |
| 03/13/10 | 14:34:29 | PVR_TT (Analog Input 1) OK | Stream1.F | 0 |
| 03/13/10 | 14:34:24 | PVR_PT (Analog Input 2) FAILED | Stream1.F | 0 |
| 03/13/10 | 14:34:24 | PVR_PT (Analog Input 2) LOW | Stream1.F | 0 |
| 03/13/10 | 14:34:24 | PVR_TT (Analog Input 1) FAILED | Stream1.F | 0 |
| 03/13/10 | 14:34:24 | PVR_TT (Analog Input 1) LOW | Stream1.F | 0 |
| 03/13/10 | 14:17:00 | OK | Stream1.F | 0 |
| 01/01/00 | 00:00:01 | LOW | Stream1.F | 0 |

# AUDIT REPORT

| | | | |
|---|---|---|---|
| **Company Name:** | **DFC** | **Stream 1 ID:** | **Stream1** |
| | | **Srteam 2 ID:** | |
| | | **Srteam 3 ID:** | |

| Date | Time | Description | Old Value | New Value | Stream NO | IV Cumulative |
|---|---|---|---|---|---|---|
| 03/09/10 | 00:03:42 | MTR1 (Meter 1) Pressure Override | 0.0 | 500.0 | Stream1.F | 210 |
| 03/14/10 | 05:42:12 | MTR1 (Meter 1) Meter Factor Override | 0.0000 | 1.0000 | Stream1.F | 43 |
| 03/14/10 | 05:42:04 | Stream1 (Stream 1) SG Override | 0.0000 | 0.5600 | Stream1.F | 40 |
| 03/13/10 | 14:35:00 | MTR1 (Meter 1) Temperature Override | 0.00 | 80.00 | Stream1.F | 0 |
| 03/13/10 | 14:34:32 | (RTD Input 10) Fail Code | 0 | 2 | Stream1.F | 0 |
| 03/13/10 | 14:34:32 | (RTD Input 9) Fail Code | 0 | 2 | Stream1.F | 0 |
| 03/13/10 | 14:34:32 | (Analog Input 4) Fail Code | 0 | 2 | Stream1.F | 0 |
| 03/13/10 | 14:34:32 | (Analog Input 3) Fail Code | 0 | 2 | Stream1.F | 0 |
| 03/13/10 | 14:34:32 | (Mulit.Var.TF ) Fail Code | 0 | 2 | Stream1.F | 0 |
| 03/13/10 | 14:34:24 | PVR_PT (Analog Input 2) @20mA | 0.0 | 1200.0 | Stream1.F | 0 |
| 03/13/10 | 14:34:24 | PVR_TT (Analog Input 1) @20mA | 0.00 | 200.00 | Stream1.F | 0 |
| 03/13/10 | 14:34:12 | MTR1 (Meter 1) K Factor | 0.00 | 2440.13 | Stream1.F | 0 |
| 03/13/10 | 14:34:12 | MTR1 (Meter 1) Linear Factor#1 | 0.0000 | 1.0000 | Stream1.F | 0 |
| 03/13/10 | 14:34:12 | MTR1 (Meter 1) Product#1 Meter Factor | 0.0000 | 1.0000 | Stream1.F | 0 |
| 03/13/10 | 14:34:12 | MTR1 (Meter 1) Pressure Assignment | 0 | 2 | Stream1.F | 0 |
| 03/13/10 | 14:34:12 | MTR1 (Meter 1) Temperatuare Assignment | 0 | 1 | Stream1.F | 0 |
| 03/13/10 | 14:34:12 | MTR1 (Meter 1) Stream Number | 0 | 1 | Stream1.F | 0 |
| 03/13/10 | 14:34:04 | Stream1 (Stream 1) Product#1 SG Override | 0.0000 | 0.5600 | Stream1.F | 0 |
| 03/13/10 | 14:33:52 | Atmospheric Pressure PSIA | 0.000 | 14.696 | Stream1.F | 0 |
| 03/13/10 | 14:33:52 | GM/CC Conversion Factor | 0.000000 | 0.999016 | Stream1.F | 0 |
| 03/13/10 | 14:17:01 | System Start (Power Fail 01/01/00 00:00:01) | | | | 0 |

# BATCH REPORT

| | | | | | |
|---|---|---|---|---|---|
| Company Name: | DFC | | | Unit ID : | 1 |
| | Date | 03/11/10 | Time | 00:00:00 | |
| | Batch Opening Date | 03/10/10 | Time | 00:00:00 | |

| STREAM #1 | | | | | |
|---|---|---|---|---|---|
| ID | MTR1 | Batch ID | BatchID | Batch No | 4 |
| Location | Houston | Rec.From | Receive1 | Ship To | Ship1 |
| Product Name | IC4 | Table | NEW24 | | |

| | Meter 1 |
|---|---|
| Meter ID | MTR1 |
| K Factor | 2440.13 |
| Dens. Corr. Factor | 1.00000 |

| Open Total | Meter 1 |
|---|---|
| IV BBL | 253 |
| NSV BBL | 249 |
| Mass MLB | 48.9 |

| Batch Total | Meter 1 |
|---|---|
| IV BBL | 135 |
| NSV BBL | 134 |
| Mass MLB | 26.2 |

| Cumulative Total | Meter 1 |
|---|---|
| IV BBL | 388 |
| NSV BBL | 383 |
| Mass MLB | 75.1 |

| Average | Meter 1 |
|---|---|
| Temperature �F | 80.00 |
| Pressure PSIG | 500.0 |
| API | 124.6 |
| API@60 | 121.2 |
| SG | 0.5525 |
| SG@60 | 0.5600 |
| Meter Density | 0.5520 |
| Density@60 | 0.5594 |
| LMF | 1.0000 |
| CTL | 0.97523 |
| CPL | 1.01185 |
| CTPL | 0.98679 |
| BSW% | 0.00 |

# PROVER REPORT

COMPANY LOCATION

DATE: 00/00/00 TIME: 00:00:00 PRESET: OLD SEAL: NEW SEAL:

PROVER: MFG: MODEL: TAG: SER NO:

TYPE: SIZE: ID (in): 0.000 WT (in): 0.0000

RUNS: 0 PASS: 0 ELASTICITY E+7 (E): 0.0 SHAFT COEF E-7 (GL): 0.0

REPEAT %: 0.000 AREA COEF E-7 (GA) : 0.0 CUBIC COEF E-7 (GC): 0.0

METER : MFG: MODEL: TAG: SER NO:

TYPE: SIZE: TOTALIZER (L) 0

FLUID : TYPE: PE. BAR 0.000 API TABLE: 5/6A/CH.11.2.1.M

| **RUN NUMBER** | **1** | **2** | **3** | **4** | **5** | **AVERAGE** |
|---|---|---|---|---|---|---|
| FORWARD | 0 | 0 | 0 | 0 | 0 | |
| TOTAL PULSES | 0 | 0 | 0 | 0 | 0 | 0.0 |
| INTERP.PULSES | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TFMP (s) | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| TDVOL (s) | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| METER (C) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PROVER (C) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SWITCHBAR(C) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| METER BAR | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| PROVER BAR | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| DENSITY@15C | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FLOW L/HR. | 0 | 0 | 0 | 0 | 0 | 0 |
| FREQUENCY (Hz) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

_________________________ **CALCULATION DATA** _________________________

| **PROVER** | **AVERAGE** |
|---|---|
| A. BASE PROVER VOLUME (BPV) (m3)......................................................... | 0.0000000 |
| B. CORRECTION FOR TEMPERATURE EFFECT ON PROVER (CTSp)................. | 0.00000 |
| C. CORRECTION FOR PRESSURE EFFECT ON PROVER (CPSp)...................... | 0.00000 |
| D. CORRECTION FOR TEMPERATURE EFFECT ON LIQUID IN PROVER (CTLp). | 0.00000 |
| E. CORRECTION FOR PRESSURE EFFECT ON LIQUID IN PROVER (CPLp)....... | 0.00000 |
| P. COMBINED PROVER CORRECTION FACTOR (BxCxDxE)............................ | 0.00000 |
| F. CORRECTED PROVER VOLUME (AxP) (m3)............................................... | 0 |
| **METER** | |
| G. TOTAL INTERPOLATED COUNTS............................................................. | 0.0000 |
| H. K FACTOR (pulses/m3)........................................................................... | 0.00 |
| I. METERED VOLUME (IVM) (m3)................................................................ | 0.000000 |
| J. CORRECTION FOR TEMPERATURE EFFECT ON LIQUID IN METER (CTLm).. | 0.00000 |
| K. CORRECTION FOR PRESSURE EFFECT ON LIQUID IN METER (CPLm)....... | 0.00000 |
| Q. COMBINED METER CORRECTION FACTOR (JxK)..................................... | 0.00000 |
| L. CORRECTED METER VOLUME (IxQ) (m3)................................................. | 0 |
| M. METER FACTOR (F/L)............................................................................. | 0.0000 |
| N. ACTUAL K FACTOR (H/M)........................................................................ | 0.00 |
| O. REPEATABILITY % = (MAX-MIN)/MIN x 100........................................... | 0.000 |

______________________________ **PREVIOUS PROVE DATA** ______________________

| **DATE** | **TIME** | **TEMP C** | **PRESS BAR** | **DENS@15C** | **FLOW L/HR.** | **M.F.** | **REPEAT %** |
|---|---|---|---|---|---|---|---|
| 00/00/00 | 00:00:00 | 0.00 | 0.00 | 0.0 | 0 | 0.0000 | 0.000 |
| 00/00/00 | 00:00:00 | 0.00 | 0.00 | 0.0 | 0 | 0.0000 | 0.000 |
| 00/00/00 | 00:00:00 | 0.00 | 0.00 | 0.0 | 0 | 0.0000 | 0.000 |

**ADDITIONAL COMMENTS :** ___________________________________________________

**PROVER OPERATOR:** ________________ **WITNESSED BY** ______________________

## GAS REPORTS of FLOW COMPUTERS

### Hourly Report

| | | | | | |
|---|---|---|---|---|---|
| **Company Name** | DEVON | **Meter Location:** | TEST | **Unit No.** | 1 |

| | | | |
|---|---|---|---|
| Meter Number | 1 | Day Start Hour | 0 |
| Meter ID | 2" Run | Base Pressure | 14.7 PSIA |
| Pipe ID (Inches) | 30.00000 | Atmospheric Press. | 14.696 PSIA |
| Orifice ID (Inches) | 15.000000 | Base Temperature | 60 °F |
| | | Application | Gas |

| **Date:** 03/12/10 **Hour** | **Flow Time** (Hours) | **Net Flow Total** (MSCF) | **EnergyTotal** (MMBTU) | **Average Pressure** (PSIG) | **Average Temperature** (°F) | **Average DP** (Inch-H2O) | **DPExt** |
|---|---|---|---|---|---|---|---|
| 20 | 0.00 | 176.7 | 176.7 | 500 | 301 | 101.0 | 0.4 |
| 19 | 0.00 | 176.6 | 176.6 | 500 | 301 | 101.0 | 0.4 |
| 18 | 0.00 | 151.4 | 151.4 | 500 | 301 | 101.0 | 0.4 |
| 16 | 0.00 | 151.5 | 151.5 | 500 | 301 | 101.0 | 0.4 |
| 15 | 0.00 | 176.6 | 176.6 | 500 | 301 | 101.0 | 0.4 |
| 13 | 0.00 | 176.7 | 176.7 | 500 | 301 | 101.0 | 0.4 |
| 12 | 0.00 | 151.4 | 151.4 | 500 | 301 | 101.0 | 0.4 |
| 10 | 0.00 | 151.4 | 151.4 | 500 | 301 | 101.0 | 0.4 |
| 8 | 0.02 | 1,438.5 | 1,438.5 | 500 | 301 | 101.0 | 3.6 |
| 7 | 0.00 | 176.6 | 176.6 | 500 | 301 | 101.0 | 0.4 |
| 6 | 0.00 | 151.4 | 151.4 | 500 | 301 | 101.0 | 0.4 |
| 4 | 0.00 | 176.7 | 176.7 | 500 | 301 | 101.0 | 0.4 |
| 3 | 0.00 | 151.4 | 151.4 | 500 | 301 | 101.0 | 0.4 |
| 1 | 0.00 | 0.1 | 0.1 | 0 | 301 | 101.0 | 0.1 |
| 0 | 0.00 | 0.0 | 0.0 | 0 | 301 | 101.0 | 0.1 |
| **Date:** 03/11/10 **Hour** | **Flow Time** (Hours) | **Net Flow Total** (MSCF) | **EnergyTotal** (MMBTU) | **Average Pressure** (PSIG) | **Average Temperature** (°F) | **Average DP** (Inch-H2O) | **DPExt** |
| 23 | 0.00 | 0.0 | 0.0 | 0 | 301 | 101.0 | 0.1 |
| **Summary:** | **0.02** | **3,407.00** | **3,407.00** | **406.25** | **301.00** | **101.00** | **0.54** |

### Previous Daily Report

| | | | | | |
|---|---|---|---|---|---|
| **Company Name** | DEVON | **Meter Location:** | TEST | **Unit No.** | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Meter Number | 1 | Base Pressure | 14.7 PSIA | Application: | Gas |
| Meter ID | 2" Run | Atmospheric Press. | 14.696 PSIA | | |
| Pipe ID (Inches) | 5.0000 | Base Temperature | 60 °F | | |
| Orifice ID (Inches) | 3.0000 | | | | |

| **Date** | **Day Start Hour** | **FlowingTime** (Hours) | **Net Flow Total** (MSCF) | **EnergyTotal** (MMBTU) | **Average Pressure** (PSIG) | **Average Temperat.** (°F) | **Average DP** (Inch-H20) | **DPExt** |
|---|---|---|---|---|---|---|---|---|
| 03/11/10 | 0 | 0.18 | 2.0 | 2.0 | 0 | 301 | 101.0 | 0.3 |
| **Summary:** | | **0.18** | **2.00** | **2.00** | **0.00** | **301.00** | **101.00** | **0.30** |