

Energy Metering Basics

■ Two Methods for Energy Determination

■ Direct

- Usually refers to some form of combustion of the gas and measurement of the heat generated. To obtain “Energy” this heat must be combined with volume or mass flow
- Some recent devices claim to measure Energy or Energy Flow directly
- Energy can be converted from Mass Flow, but this may be considered “Indirect” because composition and/or “heat” content must also be known

■ Indirect

- Usually refers to some analytical method that yields the component composition, that is, the analysis of the gas
- The heating value or energy can then be calculated by a single virial summation of the mole fraction times the heat on a volume or mass basis
- This then must be combined with with volume or mass to obtain Energy and Energy flow.



Energy (Heat) From Natural Gas



- US Energy Units For Natural Gas
 - MMBtu = Btu / CF * MMCF
 - Also Called Deka-Therm



Energy Metering Basics

- An primary device (Orifice, turbine or ultrasonic for example) and a flow computer unit(Gas Volume Metering) :
 - Accumulate raw data proportional to flow
 - Compensate flow for Pressure
 - Compensate flow for Temperature
 - Apply AGA flow formulae for metering (AGA 7 for ultrasonic)
 - Measure **Quantity** of gas
- Btu and Composition (On-line Analysis for Energy Metering):
 - Take a sample of the flowing gas
 - Analyze for all components
 - Calculate Component concentrations
 - Calculate Heating value per GPA 2172
 - Measure **Quality** of gas
- Energy (Natural Gas Energy Metering System):
 - Quantity times Quality equals Energy (see next slide)



Energy Metering Basics

$$\text{MMcf} \times \text{Btu/cf} = \text{MMBtu (Energy)}$$



Energy Metering Basics

- This talk describes a unique system for Indirect energy measurement using a new ultrasonic technique in conjunction with an industry standard electronic flow computer and an industry standard Btu gas Chromatograph.
 - First the flow computer will be described
 - Next the Ultrasonic Meter will be described
 - Next the Host software for data gathering and integration will be described
 - Then the Btu Chromatograph will be described
 - Finally the Energy Measurement System will be described



Gas Volume Metering

Typical Ultrasonic Gas Distribution Application:

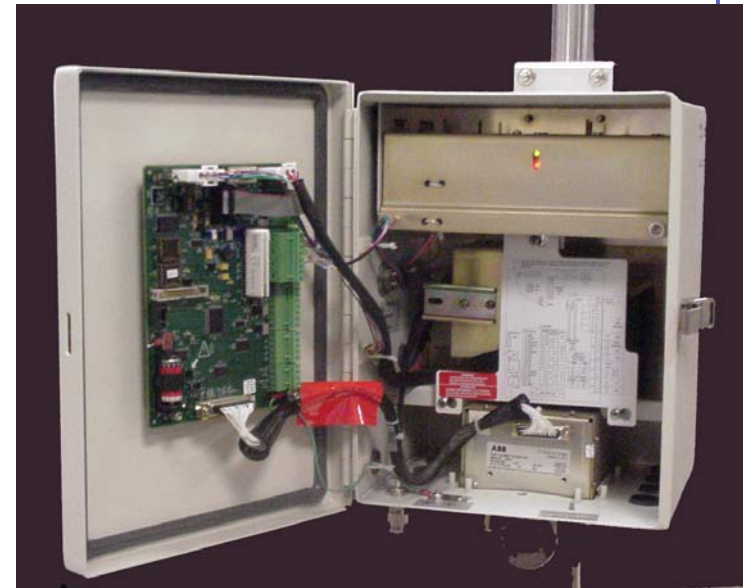


Gas Volume Metering

■ Standard Features

(XFC 6410 / 6411 & 6413 / 6414)

- Low-cost single run design, yet multi-tube capable
- Aluminum powder coated enclosure
- CSA DIV 2 / ATEX ZONE 2
- Calculations per AGA / ISO standards
- Integrated Multivariable transducer
 - Differential Pressure
 - Static Pressure
 - 100 ohm RTD Temp element
- Conforms to API 21.1 Custody Transfer Std.
- Differential and Linear Meters Supported
- 3 Com Ports on Base Board (1 Local, 2 Remote)
- Additional onboard I/O
 - 2 AI, 2 DI/PI, 2 DO
 - Battery & Charger Voltage
- Extendable IO, Comm. and Software capability
 - Up to 3 DIN mount IO modules
 - IEC 61131 Languages for application specific math, alarming and logic

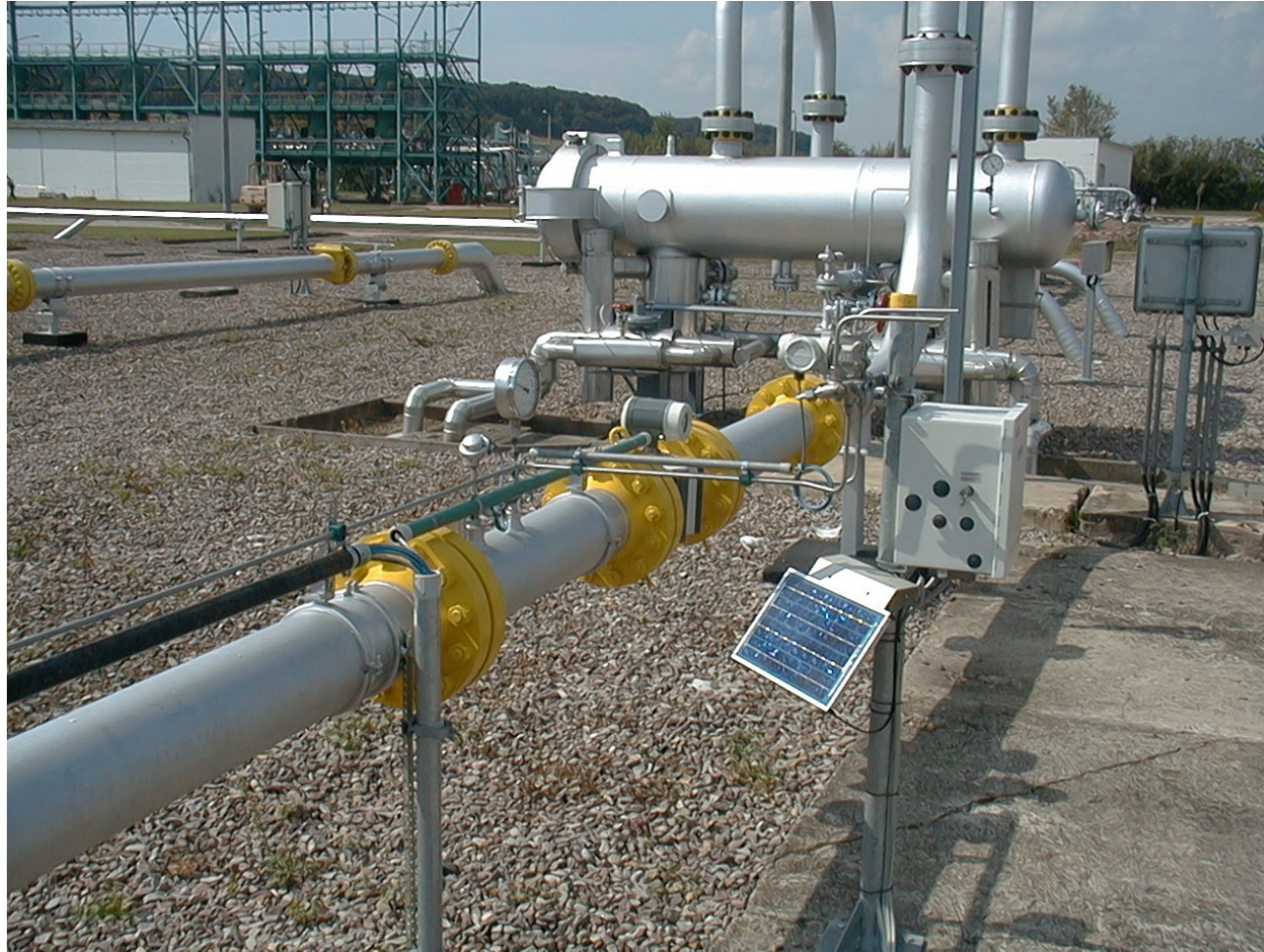


*XFC 6411 Linear
(ultrasonic) Meter*

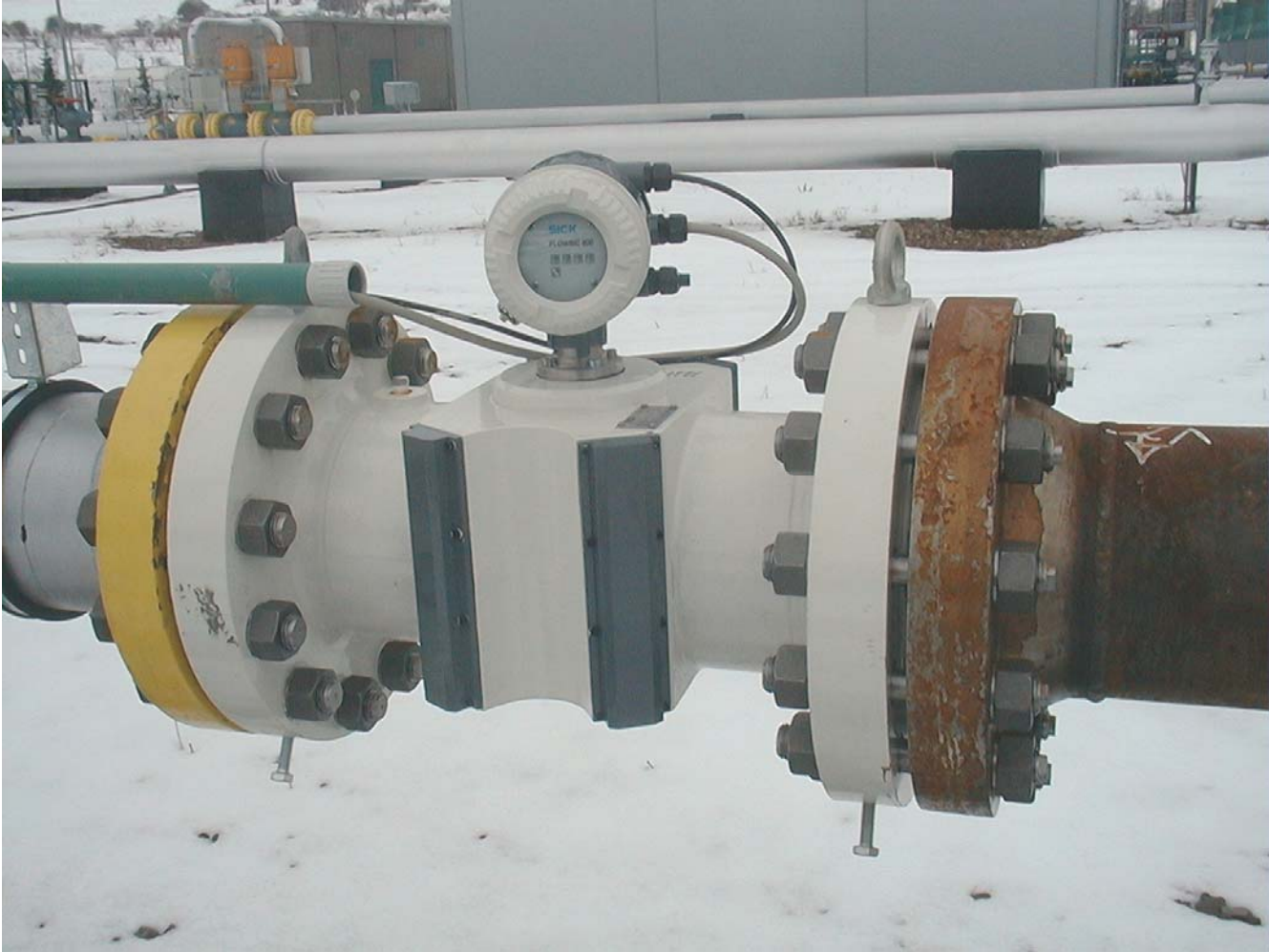


Gas Volume Metering

Underground Gas Storage Application: Typical Ultrasonic Gas Volume Metering System

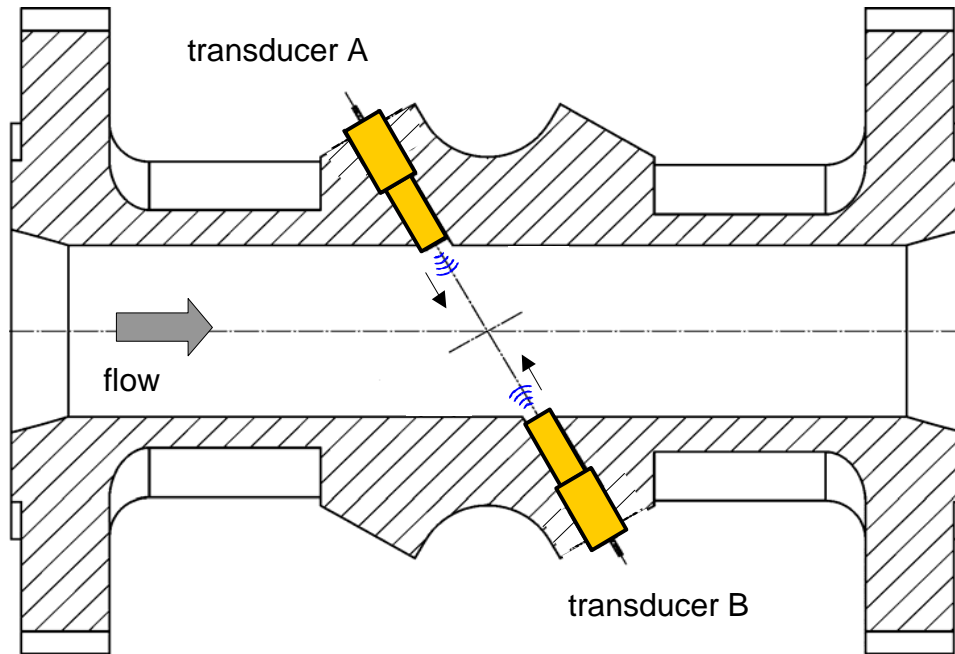


Ultrasonic Primary Meter for Gas Volume



Ultrasonic Primary Meter for Gas Volume

Theory of Operation



TotalSonic transducer

top view with one transducer pair

Functional principle of the ultrasonic transducer

- The transducer can send and receive ultrasonic signals through the gas
- The transducer can work as a transmitter and also as receiver, like microphone and loudspeakers
- Transducer B works as a receiver if transducer A sends a signal and reversed
- Signal from point A to point B is accelerated by the flow and from point B to A is braked by the flow
- With electronics we measure the transit time in both directions
- The electronics calculate the difference between the times with the direction of flow and against the flow
- The difference of the times is dependent of the value of flow



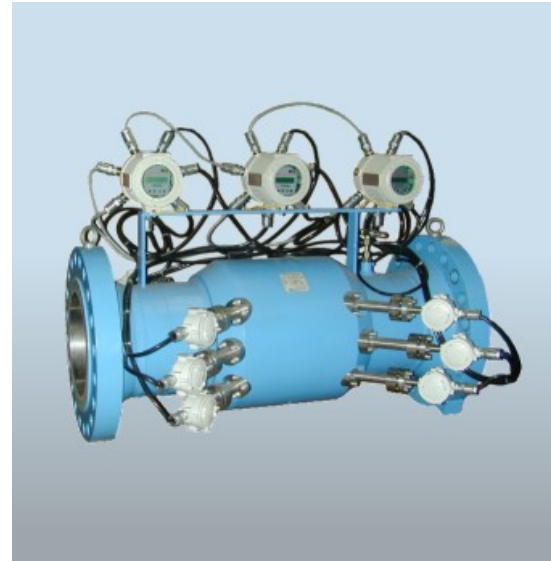
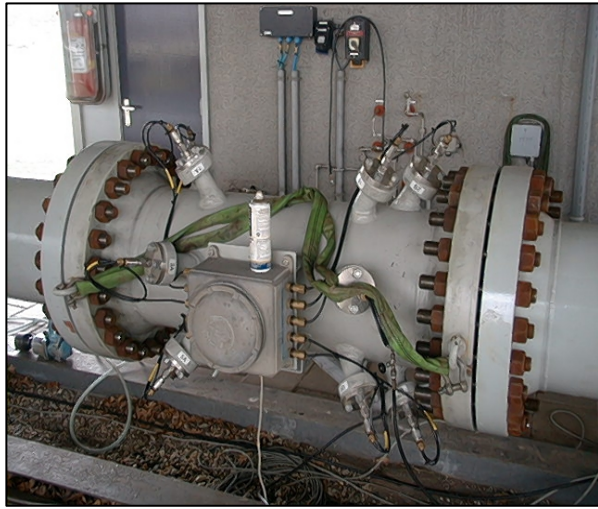
Ultrasonic Primary Meter for Gas Volume

Why Ultrasonic Technology?

- Wide Turndown Range from 1 to 100
- Non-Intrusive Design Results in No Pressure Drop
- Extensive Weight and Space Reduction
- Substantial Cost Reduction
- Bi-Directional Operation
- Improved Accuracy and Repeatability
- No Moving Parts
- Virtually Maintenance Free



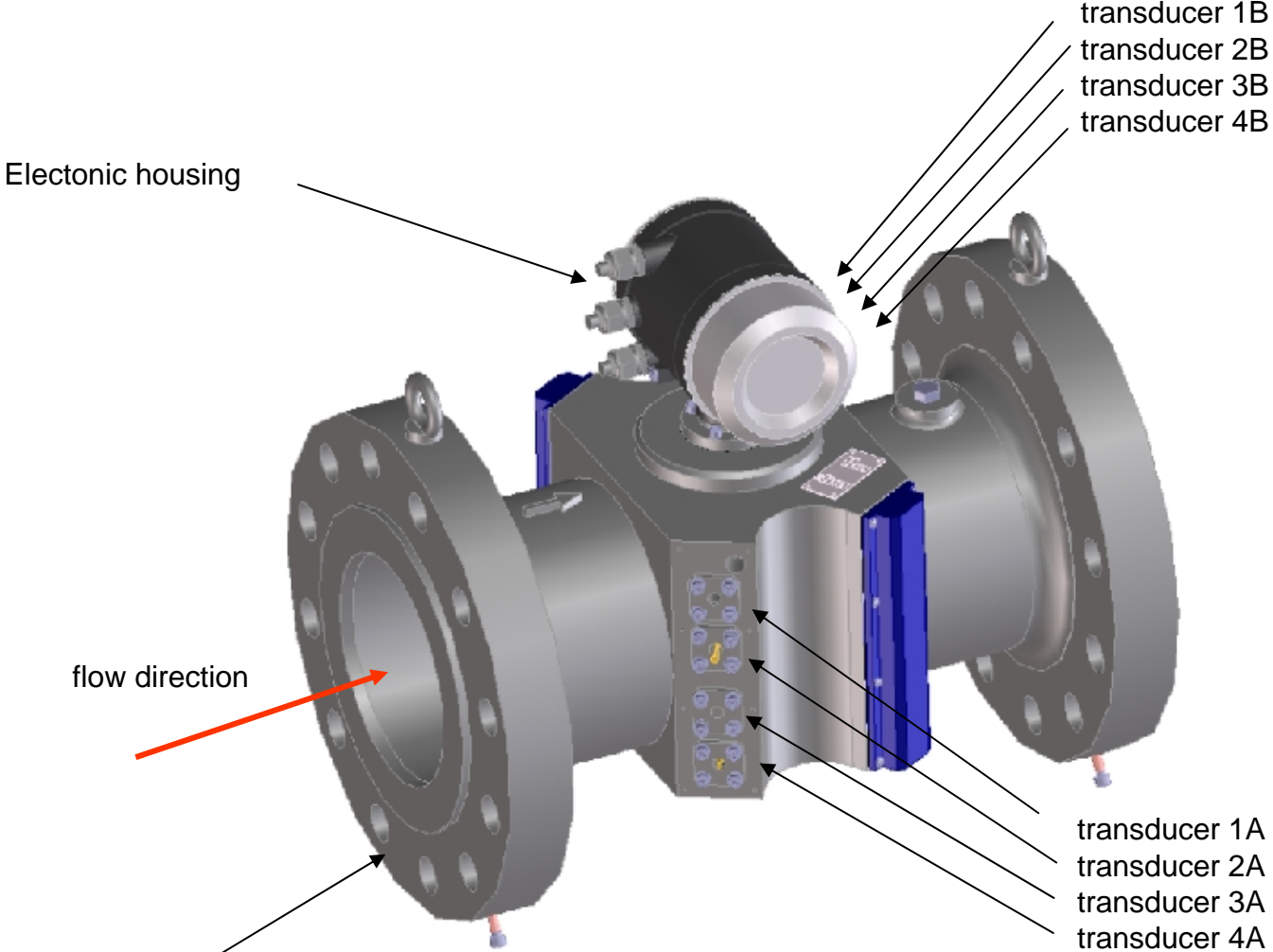
Ultrasonic Primary Meter for Gas Volume



Typical Ultrasonic Meter Configurations



Ultrasonic Primary Meter for Gas Volume



TotalSonic Flow Meter



Ultrasonic Primary Meter for Gas Volume

Why this particular unit?

- Extended Turn Down Range of 1 to 150
- Low sensitivity to ultrasonic noise
- Four (4) Transducer Pairs
- Path Configuration and Path Location is Optimized for Swirl & Cross Flow Compensation
- Miniaturized Balanced Transducers
- Reduced P and T sensitivity
- Self Diagnostic & Failure Detection Capabilities
- Extensive Interface Capabilities
- Compact Meter Design
- No External Transducer Cables
- Low Power Consumption (less than 1 Watt)



Ultrasonic Primary Meter for Gas Volume

Meter Design

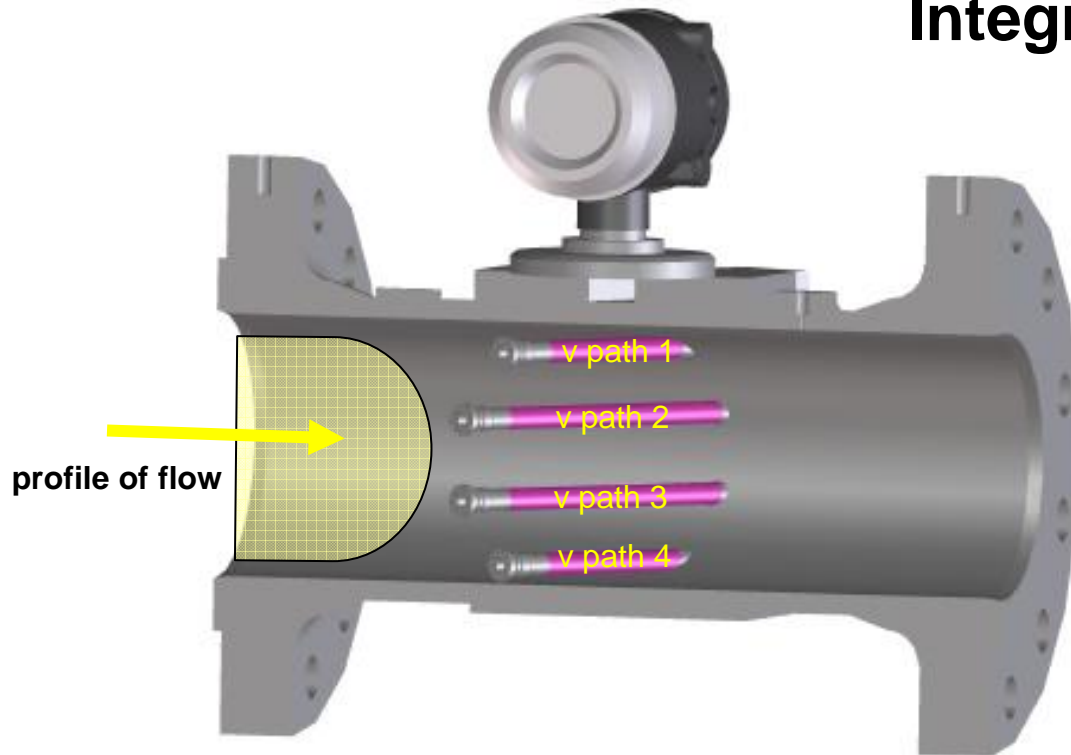


Rugged construction,
no external cabling



Ultrasonic Primary Meter for Gas Volume

Integration Area Velocity



- with the following equation the area velocity is calculated

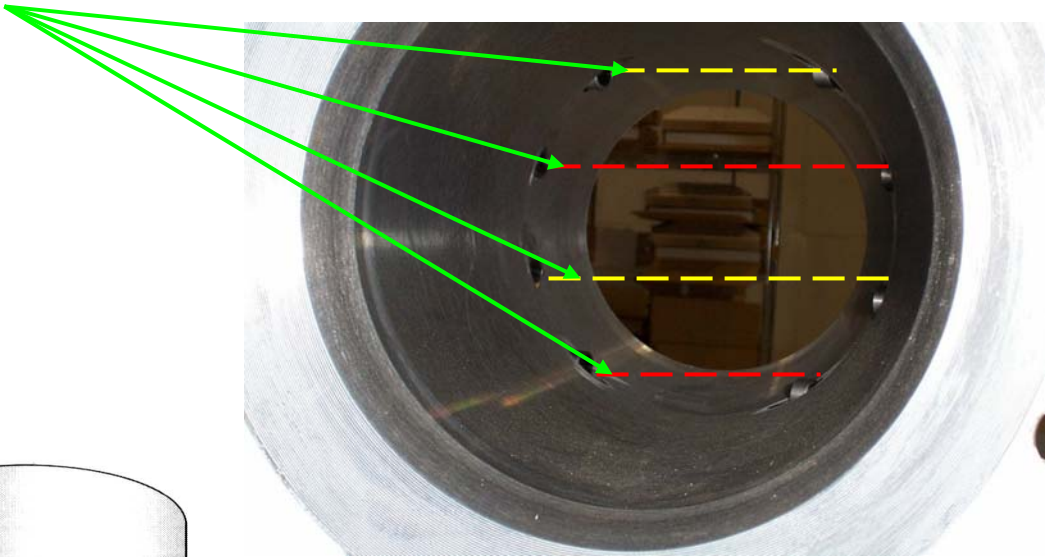
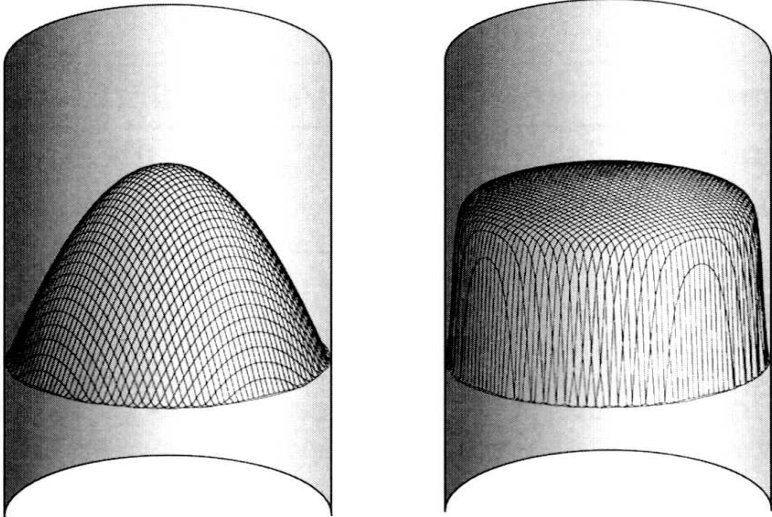
$$v_A = \frac{1}{N} \sum_{i=1}^N w_i \cdot v_{Pfad\ i} \quad \text{equation 2}$$

- every path speed is multiplied by a weight factor w_i in this equation
- the weight factors are constant and dependent of path position



Ultrasonic Primary Meter for Gas Volume

- Four (4) parallel path's to integrate difficult flow profiles



Multiple Paths for Higher Accuracy

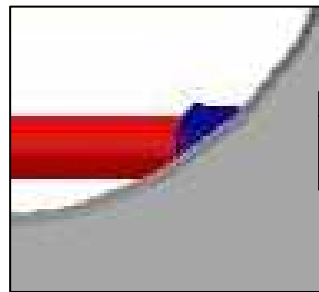


Ultrasonic Primary Meter for Gas Volume

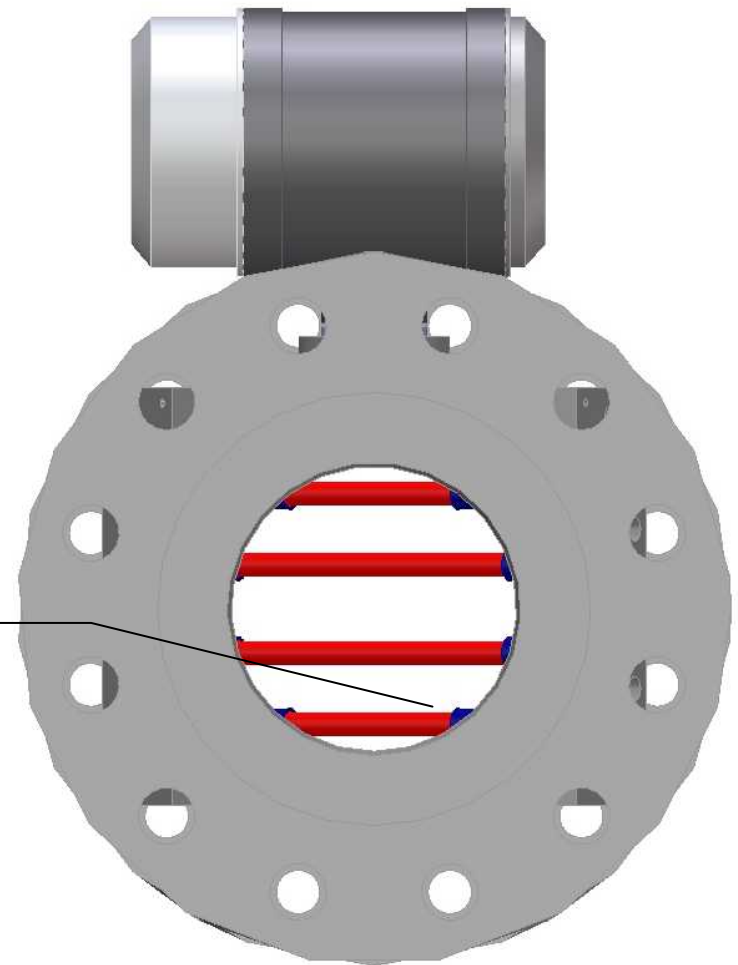
Advanced Full Metal Transducer Design

Miniaturization allows:

- Increase in operating frequency (better time measurement precision, noise reduction)
- Reduce protrusion into flow
- Allow compact meter design even for small diameters (fits into turbine meter footprint)



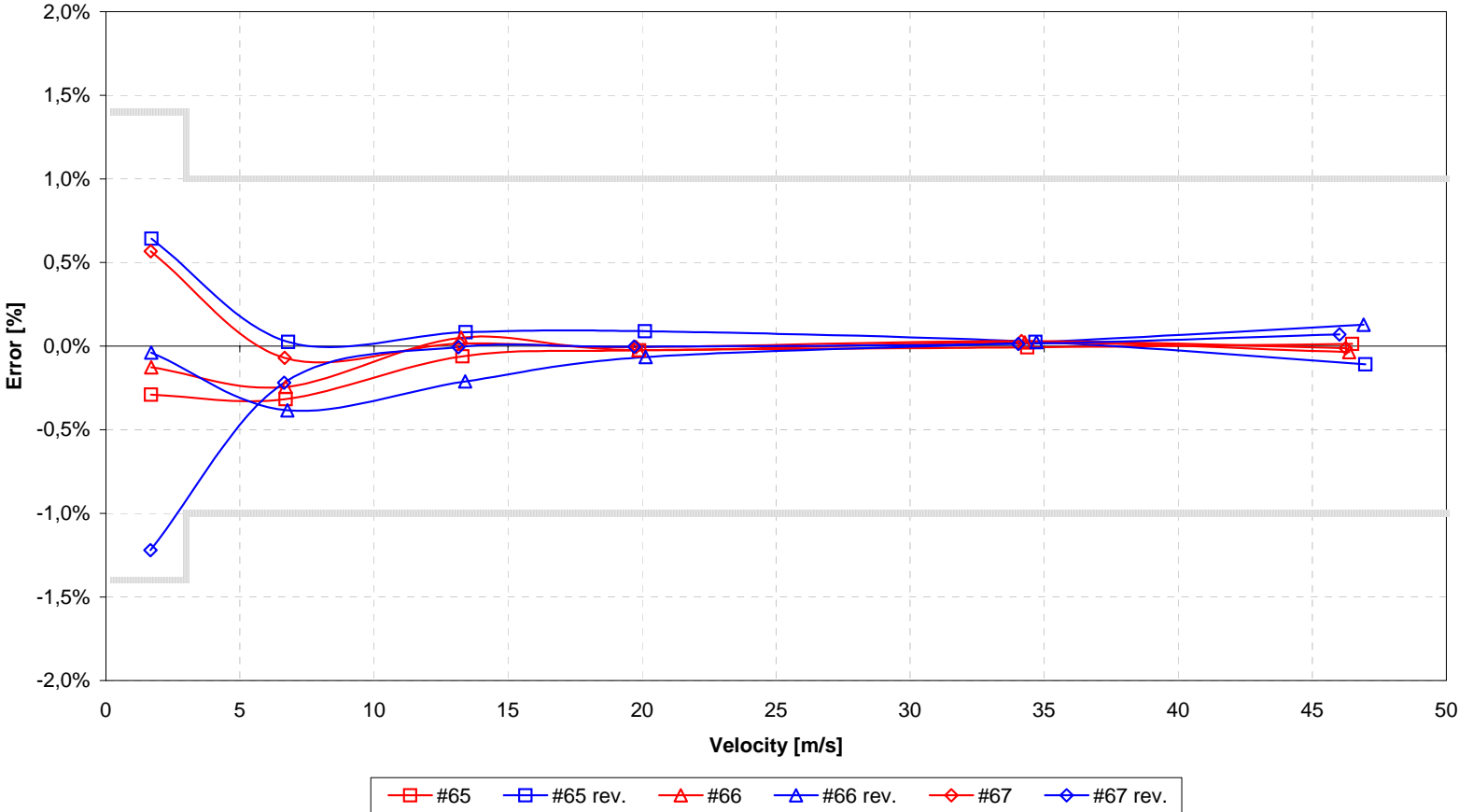
Transducer protrusion minimized



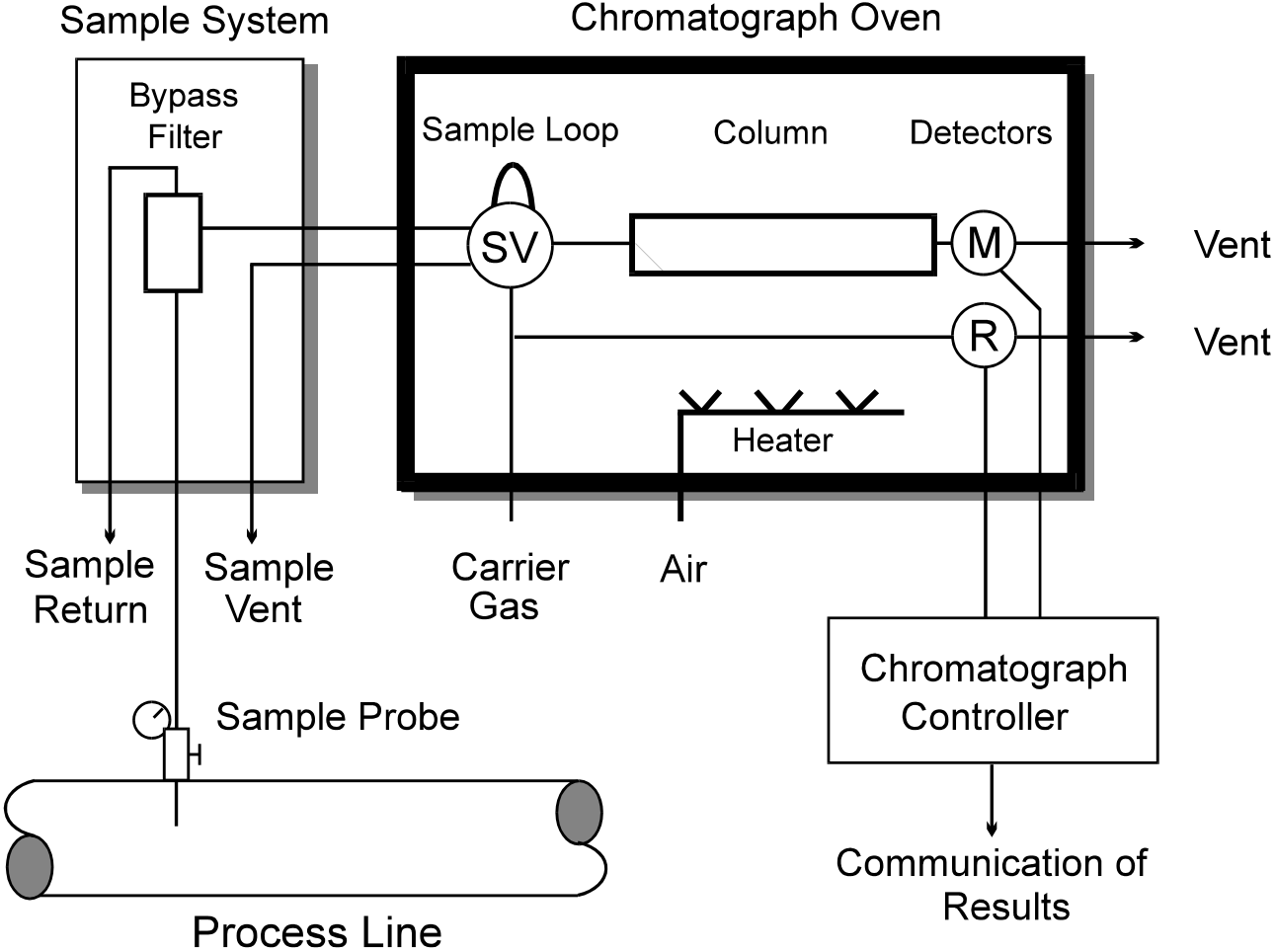
Ultrasonic Primary Meter for Gas Volume

Example Field Tests at SwRI 2002

Adjusted Meter Performance Forward and Reverse flow, Size 4"
ideal flow (100D inlet)

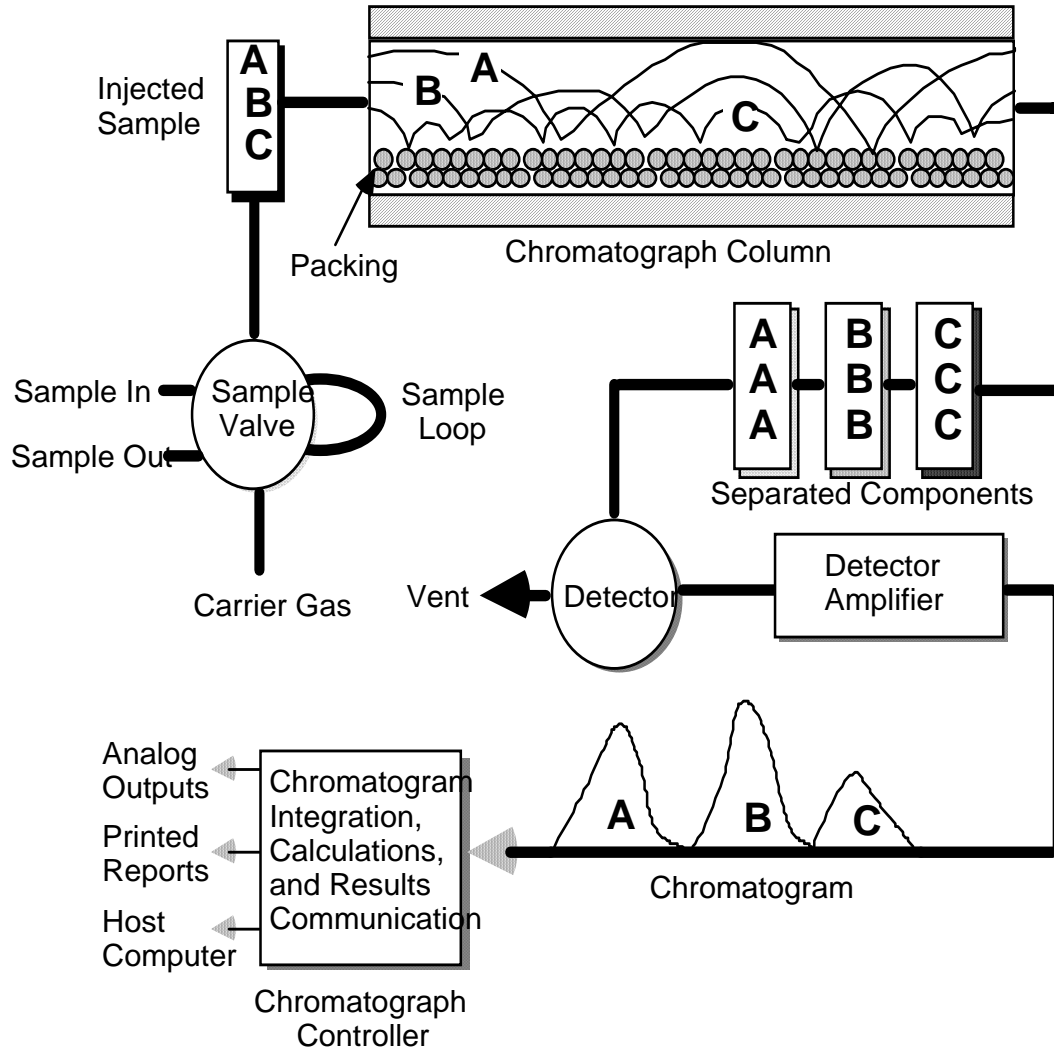


On-line Analysis for Energy Metering



On-line Analysis for Energy Metering

Chromatography Theory



On-line Analysis for Energy Metering

Typical Analysis for On-line Energy Metering

• C6+ Analysis

- Air (N₂, O₂, and CO)
- Carbon Dioxide (CO₂)
- Methane (C1)
- Ethane (C2)
- Propane (C3)
- Iso-Butane (IC4)
- Normal Butane (NC4)
- Iso-Pentane (IC5)
- Normal Pentane (NC5)
- Neo-Pentane (NeoC5)
- Hexanes Plus (C6+)(that is: C6, C7, C8, C9, C10, C11, etc.)



Interchangeable GC
Module shown



On-line Analysis for Energy Metering

Typical Natural Gas Analysis

- Below is a typical composition of a natural gas calibration blend in Mole Percent:

N₂ = 0.24 % = 0.0024 Mole Fraction

CO₂ = 1.31 % = 0.0131 Mole Fraction

C₁ = 86.39 % = 0.8639 Mole Fraction

C₂ = 6.16 % = 0.0616 Mole Fraction

C₃ = 3.46 % = 0.0346 Mole Fraction

IC₄ = 1.08 % = 0.0108 Mole Fraction

NC₄ = 0.80 % = 0.0080 Mole Fraction

IC₅ = 0.27 % = 0.0027 Mole Fraction

NC₅ = 0.15 % = 0.0015 Mole Fraction

C₆₊ = 0.14 % = 0.0014 Mole Fraction

Total = 100.00% = 1.00 Mole Fraction



On-line Analysis for Energy Metering

Calculation of Energy from Analysis

$$\text{BTU/SCF} = X1 * C1 + X2 * C2 + X3 * C3 \dots X11 * C11$$

■ WHERE:

- X1 = Mole fraction of C1 or methane
- X2 = Mole fraction of C2 or ethane
- X3 = Mole fraction of C3 or propane
- “ “
- “ “
- X11 + Mole fraction of C6+ or hexane's and heavier

■ AND:

- C1 = Molar heating value of C1 (1010 BTU/SCF)
- C2 = Molar heating value of C2 (1769 BTU/SCF)
- “ “
- “ “
- C11 = Molar heating value of C6+ (~4943 BTU/SCF)



On-line Analysis for Energy Metering

Typical On-line Analyzer for Energy Metering

Features

- 3 minute analysis of N2 (air) through C6+
- +/- 0.5 BTU @ 1000 Btu Repeatability (+/- 0.05%)
- Analyzes up to 3 streams plus Auto cal stream
- Designed for operation in 0 to 120 degrees F (provided sample dew point allows this)
 - -18 to 50 degrees C
- Weatherproof package (no shelter required provided sample dew point allows this)
 - Designed to meet NEMA 4X
 - Designed for pipeline or wall mounting



NGC Btu Gas Chromatograph shown



On-line Analysis for Energy Metering

NGC 8200 BTU GC System Overview

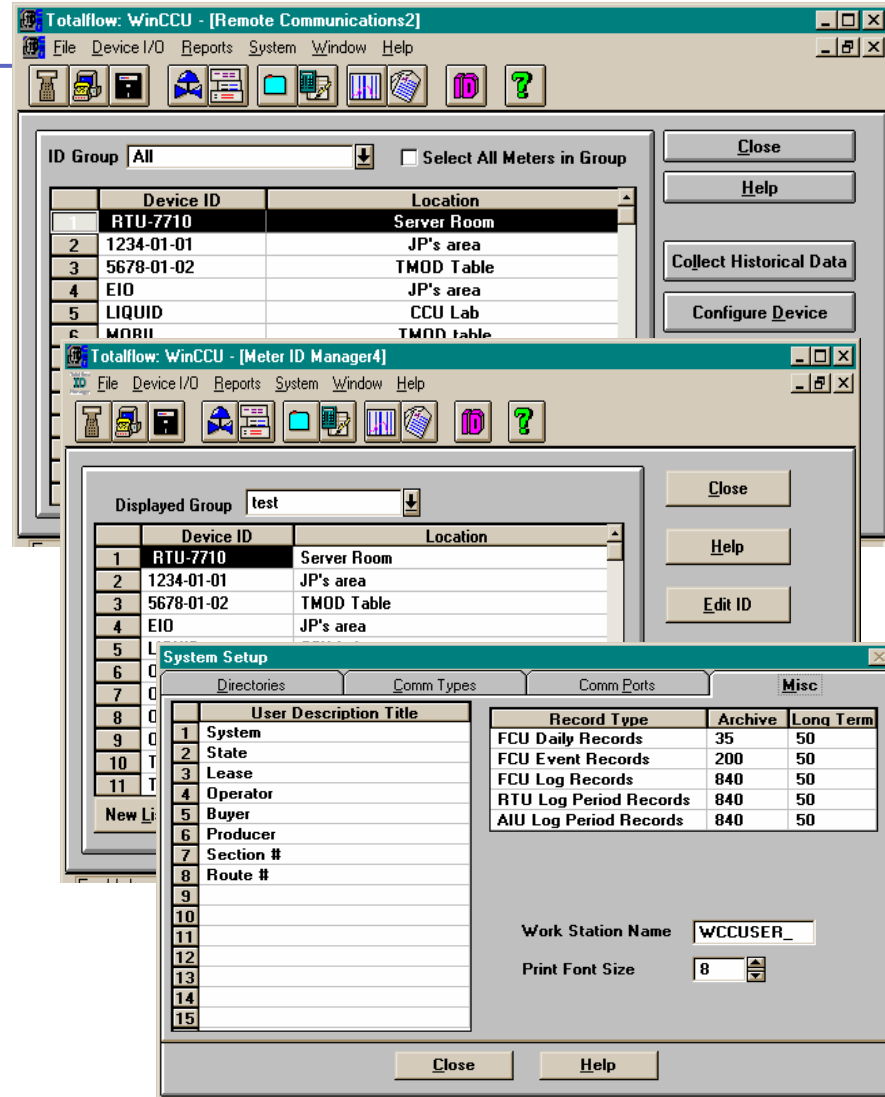
- GC delivered “Off the shelf” with interchangeable components (Modular)
 - Automatic carrier pressure control (PRM)
 - Low power analyzer (6 to 13 Watts nominal)
 - Windows based MMI
 - Automatic start up/Peak Find for initial Chromatographic settings
 - Plunger-less diaphragm GC valves (no moving parts)
 - Zone 1/Div.1 hazardous area operation
 - Serial, Ethernet and USB communications capability
 - Variety of Modbus Protocols
- Built in controller with Analysis Audit history
 - Minimum Utilities
 - No Instrument Air
 - Solar Power Option
 - Low carrier gas consumption
 - 1 to 2 bottles per year
 - Depends on cycle time



ABB

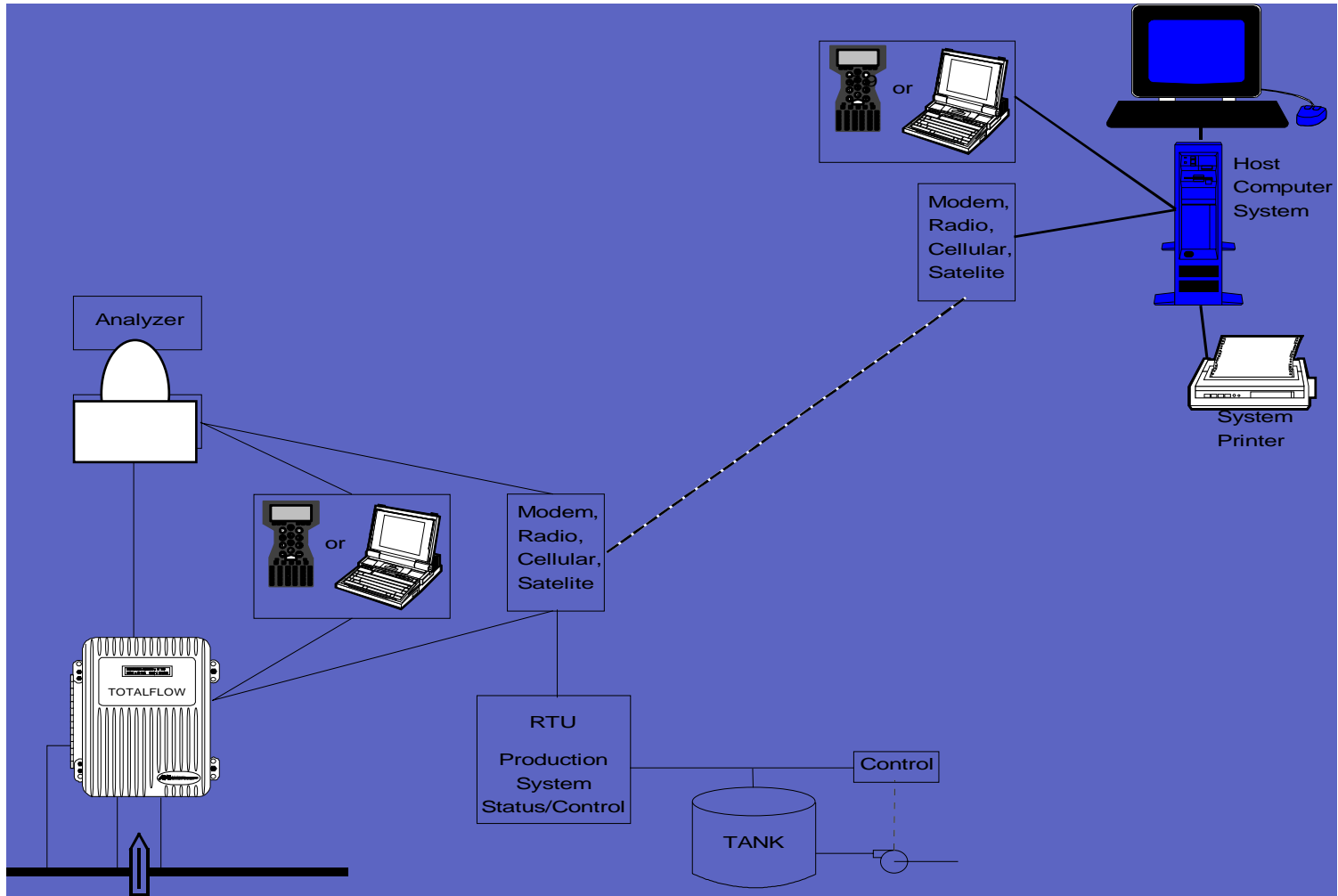
Gas Volume/Energy Data Gathering

- Tool for collection energy data (WinCCU)
- Primarily for management of Custody Transfer Flow Computer Generated Data
- Integrates all parts of energy data
- Provides Energy Audit Trail
- Windows NT/2000/XP
- Network Capable
- Functions
 - Collect - direct, radio, modem, etc
 - Archive - Long Term Audit
 - Reports – Several Standard
 - Edit - Volume Adjustments
 - Alarm - Polled or Exception
 - Export - To Other Systems
 - Interactive User Interfaces



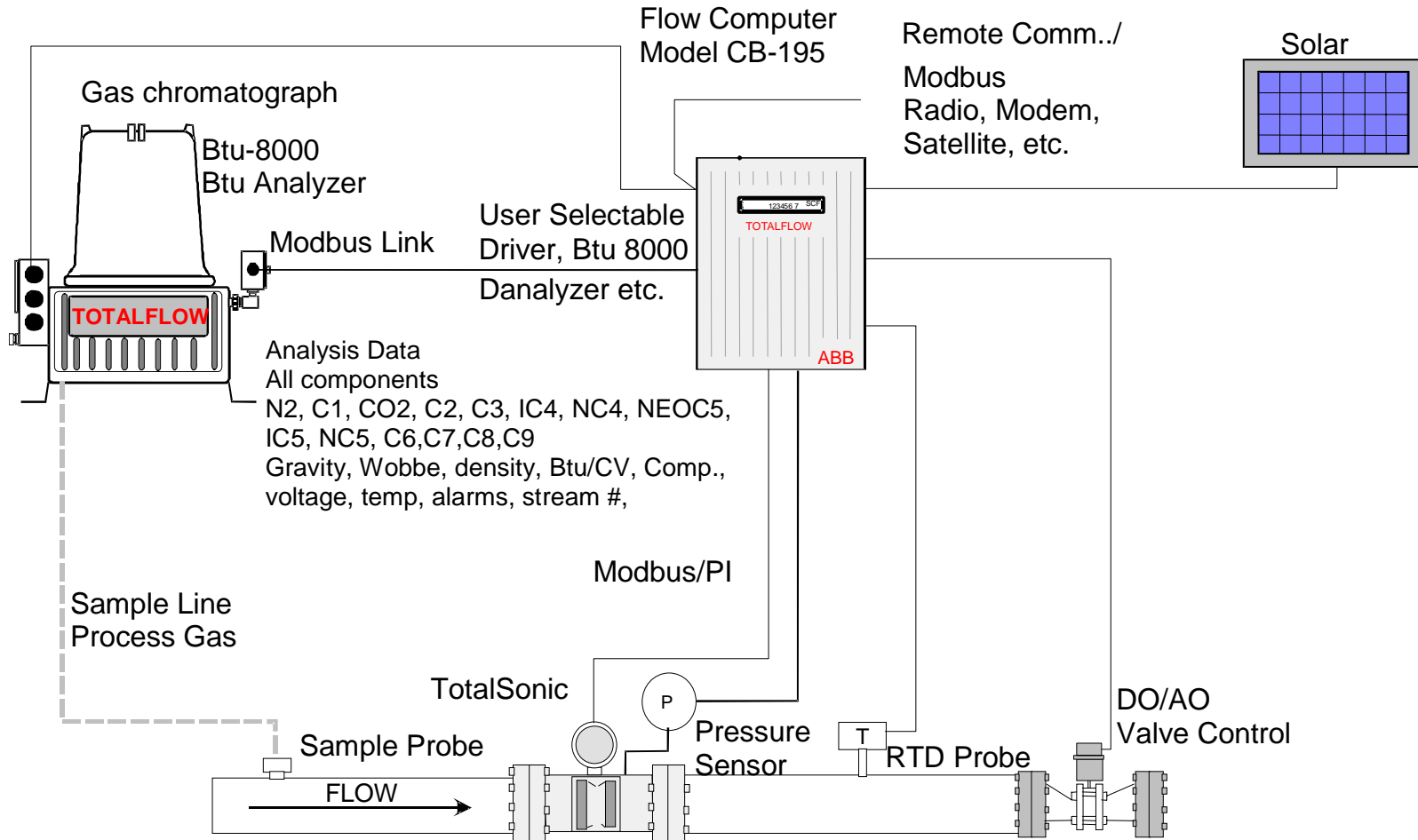
Natural Gas Energy Metering System

Over all system considerations



Natural Gas Energy Metering System

At site equipment



Natural Gas Energy Metering System

Totalsonic



+

NGC 8206



XFC or XRC
Flow computer or
Remote Controller

- ABB Totalflow manufactures all three measurement devices which provide the user with complete energy packages.
- Each System is designed using the BTU 8000, RTU or Low Powered Flow Computer & Low Power TotalSonic ranging from sizes 4" and larger.
- Each System is supported by a host systems supporting both fiscal metering audit trail and SCADA requirements.



WinCCU, SCADA Vision &
TF.Net Host Systems



Natural Gas Energy Metering System:

Summary

- Ultrasonic flow meters integrated into an energy metering system enhances the pipeline's operation and gas marketing performance
- Analysis availability allows comparison of measured to calculated speed of sound data can be used as health check for the ultrasonic meter and calculation of energy in the metering system
- New analyzer technology allows a compact design suitable for pipeline mounting
- Low power consumption of all system components make remote installations possible
- Primary device, Analysis, Flow Measurement, and Host Software allows complete, Auditable Energy Measurement System



ABB