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The **CCM** - Compact Cyclone Multiphase System

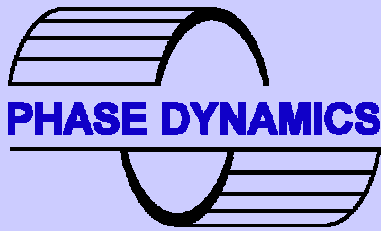
- Metering Concept
- Design Criteria
- Benefits
- Performance
- Field Experience
- Summary

Compact Cyclone Multiphase Metering Concept



- **Simple and Complete Electronics Without Extra PLC's**
- **Easy Maintenance By Local Personnel**
- **High accuracy - Determined Only By Separation Efficiency**
- **"Off the shelf" Standard Flow & Measurement Meters**
- **All meters are calibrated at factory - no need for field calibrations.**
- **Special Design Cyclone Separator Is Small In Size but, Large in Capability of Flow Ranges**

COMPACT CYCLONE MULTIPHASE SYSTEM



PHASE DYNAMICS

Technology for Precision Measurements

**Control System
Water Analyzer**

Micro Motion

**Gas and Liquid
Flow Meters**



Cyclone Internals by



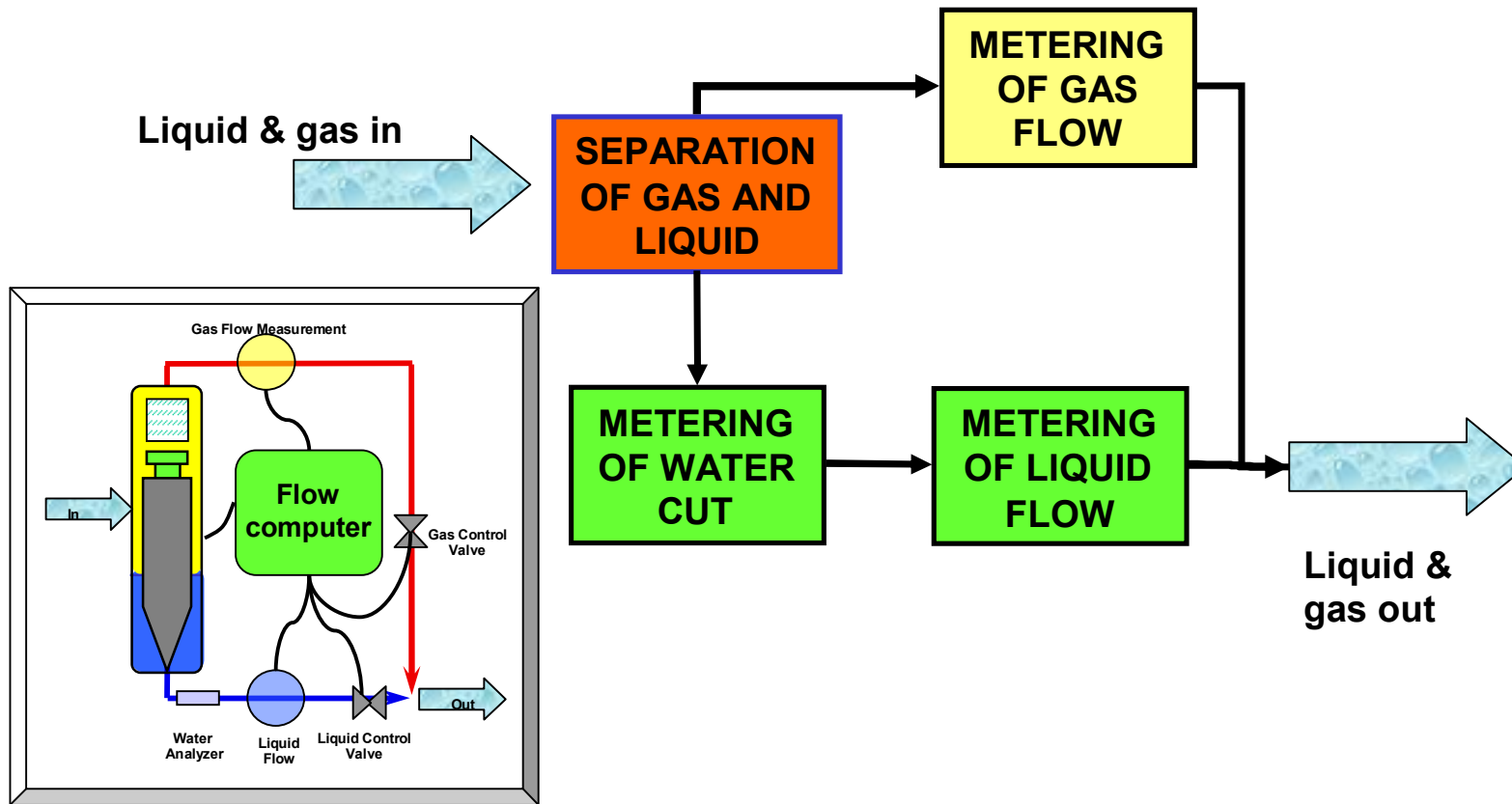
Trondheim, Norway



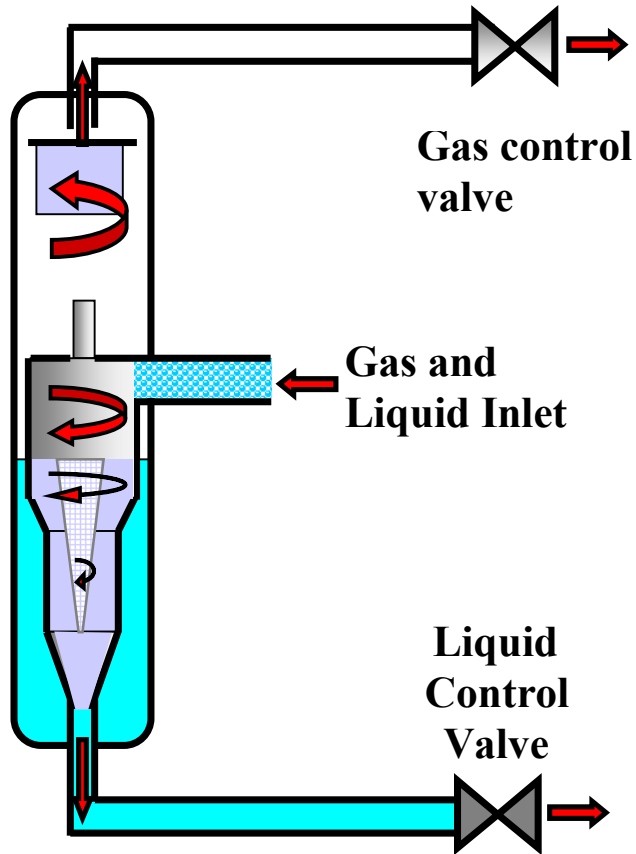
EMERSON™
Process Management

Gas & Liquid Valves

CCM metering principle



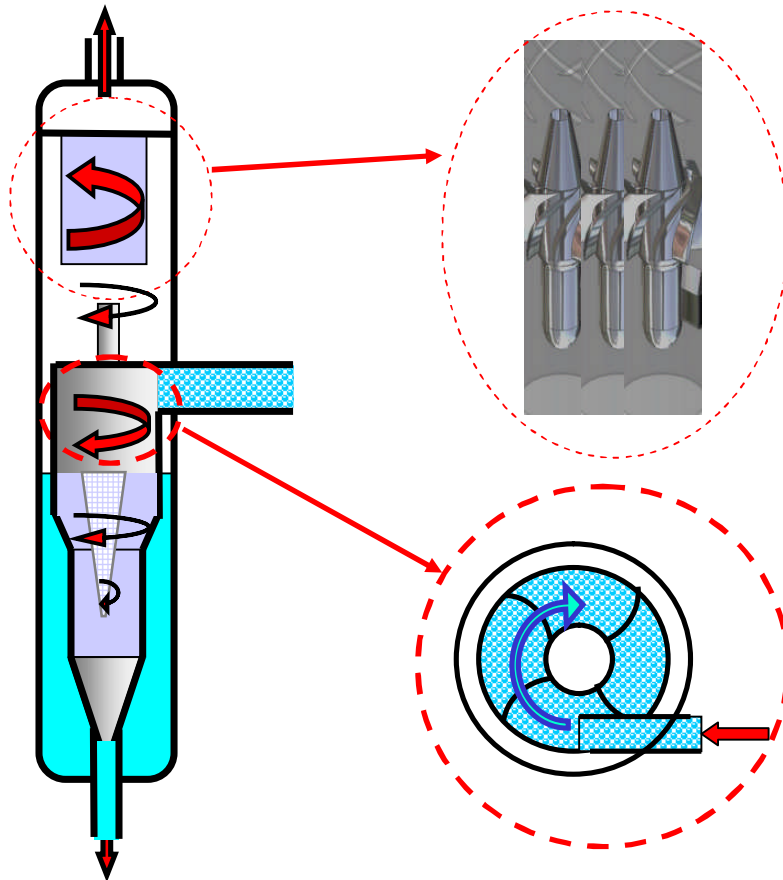
CCM Cyclone Operation



Key Advantages:

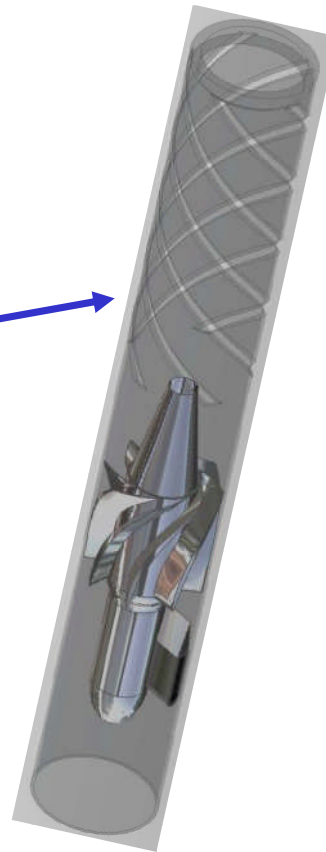
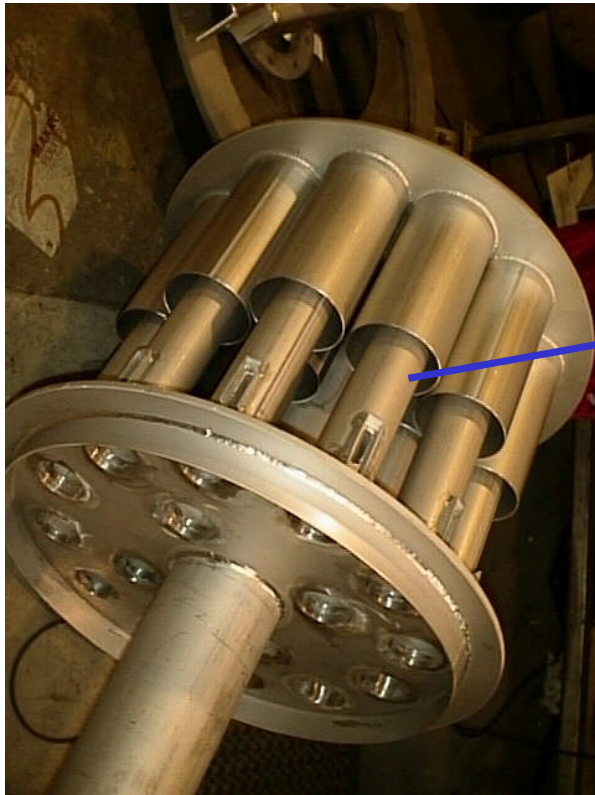
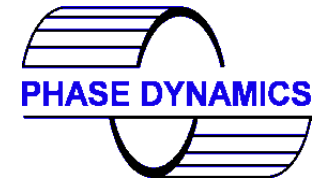
- 1.) Level Control Using Stable Liquid Level Between the Outer and Inner Vessels Using Delta Pressure
- 2.) Cyclone is Inside The Center Chamber Not Where the Delta Pressure Level Control Located
- 3.) Very Efficient Gas Scrubbers and Therefore Excellent Separation
- 4.) Simple to Control - Gas And Liquid Valves Control System Pressure and Liquid Level

First, Second & Third Stage Gas Liquid Removal

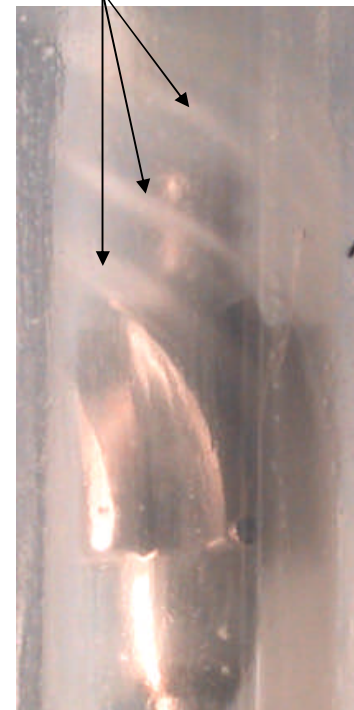


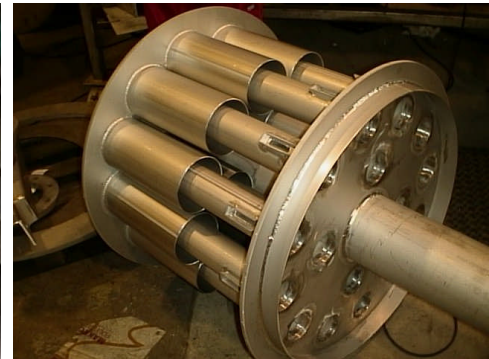
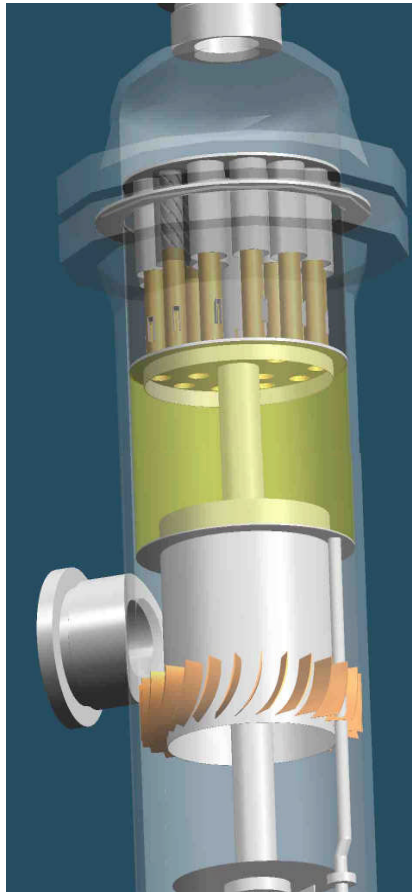
- **Upper Section**
 - Special Cyclones in Gas Section
 - Removes Liquids Very Efficiently
 - Patented Design
- **Middle Section**
 - Aids In Ability to Handle Slugging
 - Further Removes Liquids from Gas
- **Lower Section**
 - Tangential Vanes
 - Inner Vessel
 - Vortex Finder

Demister Section



Liquid bands formed





Gas Liquid Separator Joint Relationship

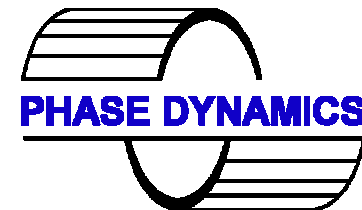


- Gas Liquid Separator Internal Design by
A Norwegian Engineering Company
15 Years Fluid Dynamics Engineering Experience
CCM System Exclusive to Phase Dynamics

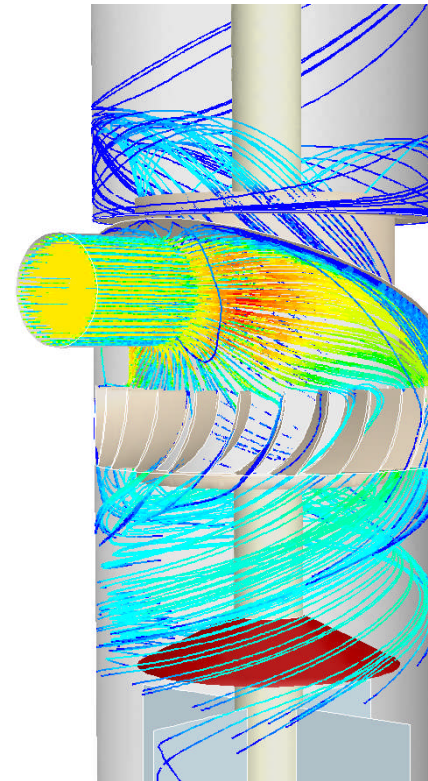
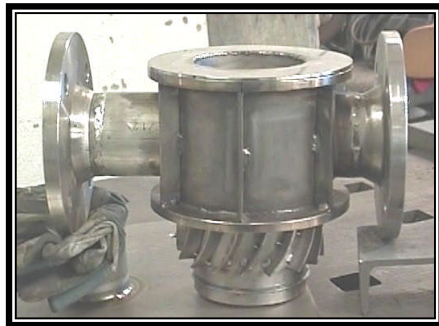


ConSepT

- Control System, Electronics, System Design by
Phase Dynamics - An American Company
Over 3,700 Analyzer Systems Installed Across the World
- A Uniquely Qualified Engineering Team for Well Test Systems
« **CCM - Compact Cyclone Multiphase System**



Modeling Using Computational Fluid Dynamics



Provides Real
Systems That Work
by Design

Why This Configuration



- **Separation Assures Best Measurement**
 - Complex Statistical Based Algorithm Not Necessary
 - Oilfield Technician Can Understand Each Portion of the Measurement
- **Coriolis Meters Are Best Because:**
 - Mass Based Measurement - Density and Flow Rate
 - If Gas Carry Under (With Liquids) Density Indicates This Fact
 - If Liquid Carry Over (With Gas) Density Indicates This Fact
 - Determines If Measurement Is Good
- **Accuracy is Dependent Upon Separation Efficiency**
 - Instead of Flow Regime, Amount of Gas and Other Hard To Define Parameters
- **Computational Fluid Dynamics Is Used During Design To Assure Proper Turn Down Capability by Calculating the Forces from the Tangential Velocity**

CCM Accuracy



- **Determined by Measurement of Flow and Water Analyzer**
- **Depends Upon Good Separation**
 - High Enough Flow Rate to Create Tangential Velocity for Separation
 - Large Enough Diameter to Have Residence Time of Liquids
- **Surging Well Performance is Determined by:**
 - Large Enough Diameter to Provide Liquid Reservoir for Handling Slugging Wells
 - Fast Acting Valve Actuators
 - « Use Pneumatic Only
 - « Electric, Electric/Hydraulic Too Slow and Cannot Handle the Duty Cycle

Water Analyzer CCM Calibration



- **Water Analyzer Calibration**
 - *The Phase Dynamics, Inc. water cut analyzer is designed not to require calibration for years. This is due to the solid state electronics and elimination of drift through design techniques used in military electronics.*
 - *The analyzer is fully factory calibrated with flowing mixtures of oil and salt water to generate a family of curves. The fluid path is mostly sealed with fully welded and brazed seals in the main measurement path.*
 - *Field calibration is simply an offset for the difference between the factory calibration oil density and the field oil density.*

Performance for a 3 inch Liquid Coriolis Meter



Micro Motion® ELITE® Mass Flow and Density Meters Liquid flow performance

Mass Volume

Nominal flow range

(1) Micro Motion has adopted the terminology "nominal flow range." The upper limit of this range is the flow rate at which water at reference conditions causes approximately 15 psid (1 bar) of pressure drop for ELITE sensors.

	lb/min	kg/hr	m3/day SG=0.860	gal/min	l/hr
CMF300	0 to 5000	0 to 136,080	3795	0 to 600	0 to 136,080

Maximum flow rate	lb/min	kg/hr	m3/day SG=0.860	gal/min	l/hr
CMF300	10,000	272,160	7595	1200	272,160

Mass flow

Accuracy

(2) Accuracy includes the combined effects of repeatability, linearity, and hysteresis. All specifications for liquids are based on reference conditions of water at 68 to 77 °F (20 to 25 °C) and 15 to 30 psig (1 to 2 bar), unless otherwise noted.

Transmitters with MVD Technology $\pm 0.10\%$ of rate

(3) When flow rate is less than , accuracy equals of rate and repeatability equals of rate. All other transmitters $\pm 0.10\%$ of rate

Mass flow

repeatability⁽²⁾

Transmitters with MVD Technology $\pm 0.05\%$ of rate⁽³⁾

All other transmitters $\pm 0.05\%$ of rate

Zero stability	lb/min	kg/hr
CMF300	0.25	6.80

Performance - 3 Inch Coriolis Gas Meter



Gas flow performance

Accuracy

(1) *Flow accuracy includes the combined effects of repeatability, linearity, and hysteresis.*
Transmitter with MVD Technology $\pm 0.35\%$ of rate

(2) *When flow rate is less than , accuracy equals of rate and repeatability equals of rate.*
All other transmitters $\pm 0.50\%$ of rate of rate

Repeatability₍₁₎ Transmitter with MVD Technology $\pm 0.20\%$ of rate₍₂₎
All other transmitters $\pm 0.25\%$ of rate of rate

Zero stability	lb/min	kg/hr
CMF300	0.25	6.80

Performance of Phase Dynamics Analyzer



Water Cut Analyzer Operational Specifications

PARAMETER	Low Range		Mid Range	Full Range	High Range
RANGE	0-4% & 0-10%	0-20%	0-Inversion	0-100%	80-100%
UNCERTAINTY*	+/- 0.04% (0-4%) +/-0.1% (4-10%)	+/- 0.2% Oil Phase Only	+/- 0.5% Oil Phase Only	Oil Phase +/- 0.5% Water Phase +/- 1%	+/- 0.6% Water Phase Only
REPEATABILITY	+/- 0.02%	+/- 0.1%	+/- 0.1%	Oil Phase +/- 0.1% Water Phase +/- 0.5	Water Phase +/- 0.3%
RESOLUTION	0.01%	0.10%	0.10%	0.10%	0.10%
FLUID TEMPERATURE	60 - 160° F	60 - 160° F	60 - 160° F	60 - 160° F	60 - 160° F
HIGH TEMP. VERSION	60 - 220° F	60 - 220° F	100 - 600° F	100 - 600° F	100 - 600° F
SALINITY	Not Applicable	Not Applicable	Not Applicable	0.5% - 8% Water Φ Oil Φ Not a Factor	0.5% - 8% Water Φ

* All percentages are expressed as absolute water content percentages

CCM System Performance Statement



COMPACT CYCLONE MULTIPHASE METER (CCM)

Performance

Measuring range

Water Cut	0 to 100%
GVF at operating conditions	0 to 100% GVF: Gas Void Fraction
Liquid and gas flow rates	The configuration of flow meters and instruments to be designed according to the actual flow rates and specifications
Flow regimes	All, but for some special conditions, such as severe slugging flow, contact manufacturer.

Individual flow meters

Gas flow meter	Coriolis
Liquid flow meter	Coriolis
Water Cut Meter	Phase Dynamics Inc. Microwave Water Cut Meter

Typical overall uncertainties

Liquid flow rate	Relative error of +/- 5 %
Gas flow rate	Relative error of +/- 5 %
Water Cut	Absolute error of +/- 3 to 5 %, according to application

- **Individual Analyzer/Flowmeters Have Much Better Accuracy**
 - **Cannot Prove Better Than +/-5% As System In Field**
 - **Best Three Phase Tests Loop Errors Are +/- 5% or Worse**
- **A Manufacturer Should Not State Better Than It Is Possible to Prove!**

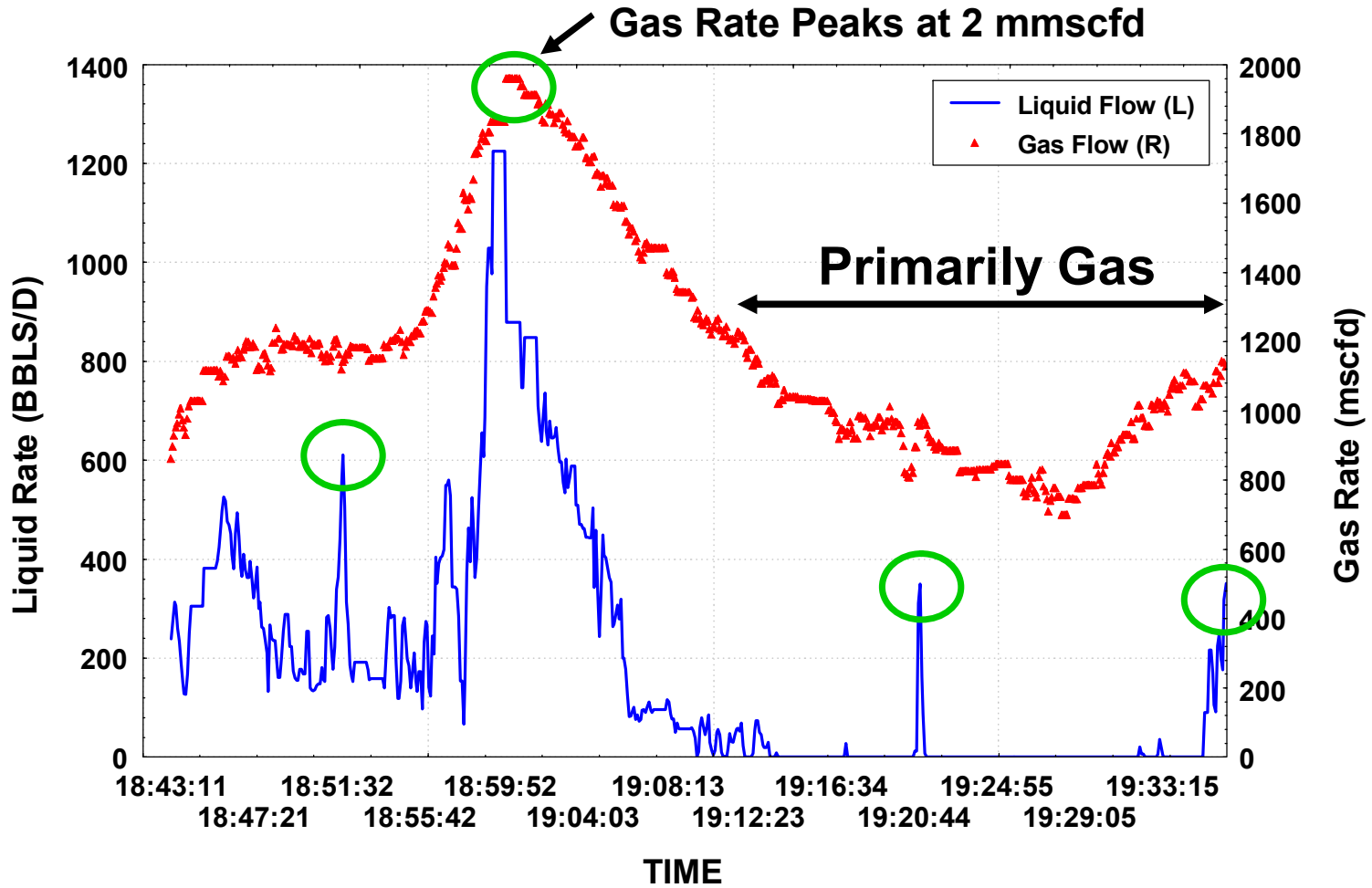
Alaska Pad Well Test Building



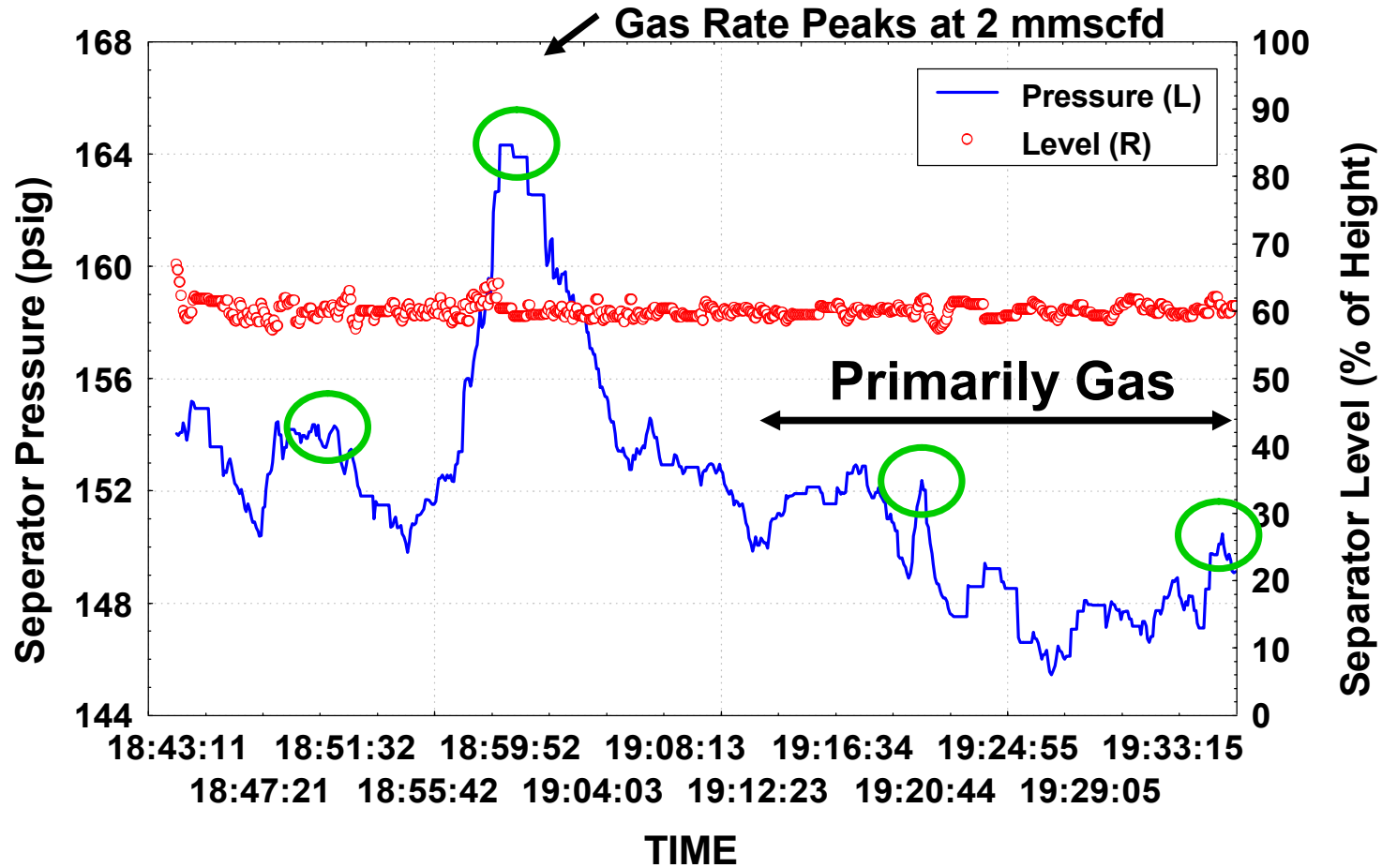
**New CCM Installation
Next to Old Three Phase
Separator** →



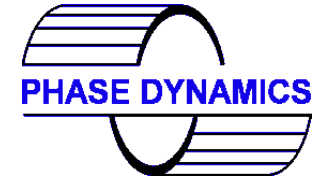
Well B-16 Real Time Data - 5 Second Interval



Well B-16 Separator Level and System Pressure



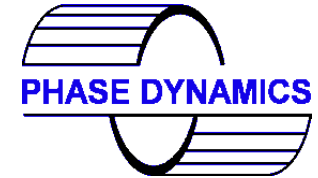
Another Pad CCM



- Existing Well Head Building
CCM Installed Inside
- Replaced Two Phase Separator
At One Mile Distance



Well Test Setup Screen



CONFIGURATION

STREAM **START**

ACCUMULATORS

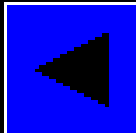

ENABLE

CLEAR

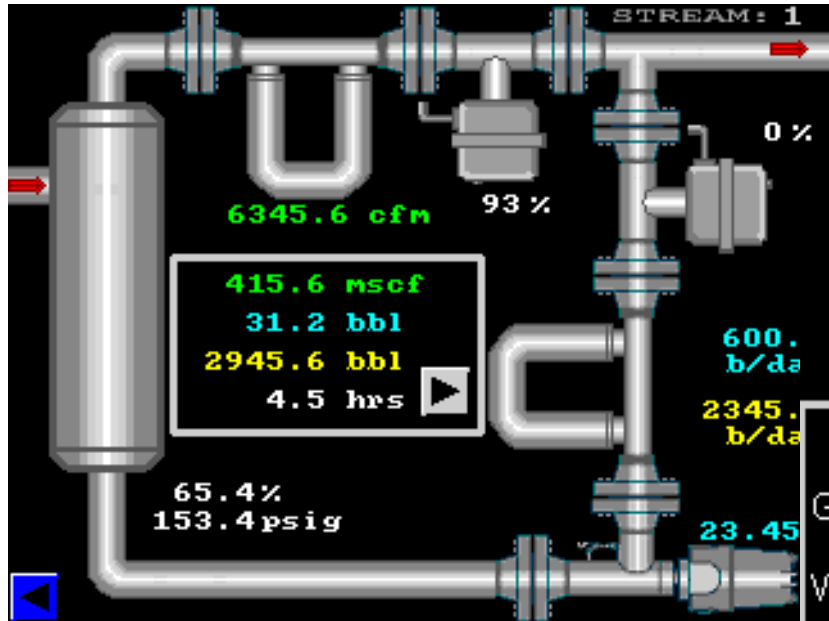
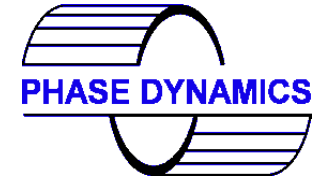
PURGE **TIME** **bb1**

DURATION **hrs**

Remaining **hrs**

Operator Screens



INFORMATION

	Flow Rate	Total Volume	24 hrs
GAS	6345.6 cfm	415.6 mscf	415.6 mscf
Water	600.0 b/day	31.2 bbl	31.2 bbl
Oil	2345.6 b/day	2945.6 bbl	2945.6 bbl

DURATION	5.0 hrs
Remaining	4.5 hrs

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Summary



- **CCM Provides Most Accurate Measurement:**
 - Partial Separation Improves Data Quality
 - Only The Highest Quality Components
 - World Class Electronics
 - Mass Measurement:
 - « Provides Density and Flow
- **Compact Cyclone Design**
 - Most Advanced Design
 - The Only Cyclone With:
 - « Highest Turn Down Ratio
 - « Three Stages of Gas Separation
 - « Unique Vessel Within a Vessel for Superb Level Control
- **The Minimal Electronics for Maximum Reliability and Flexibility**
 - « Level Control, Flow Computer, Data Logging, Operator Interface