Flowmeters

Selection, Sizing, Troubleshooting

From Basic Design to Start-up

Educational Institute for Equipment and Process Design

CONTENT

Topic	Duration
General Procedure	1 min
Selection Pattern	5 min
Examples	10 min
Sizing- Coriolis flowmeter	5 min
Sizing-Vortex flowmeter	5 min
Sizing-Orifice flow meter	5 min
Piping Design Consideration	6 min
Algorithm of calculation	6 min
Our Mistake and Experience	5 min
Summarization	7 min
Vendor List	2 min
Total	1 hour

General Procedure

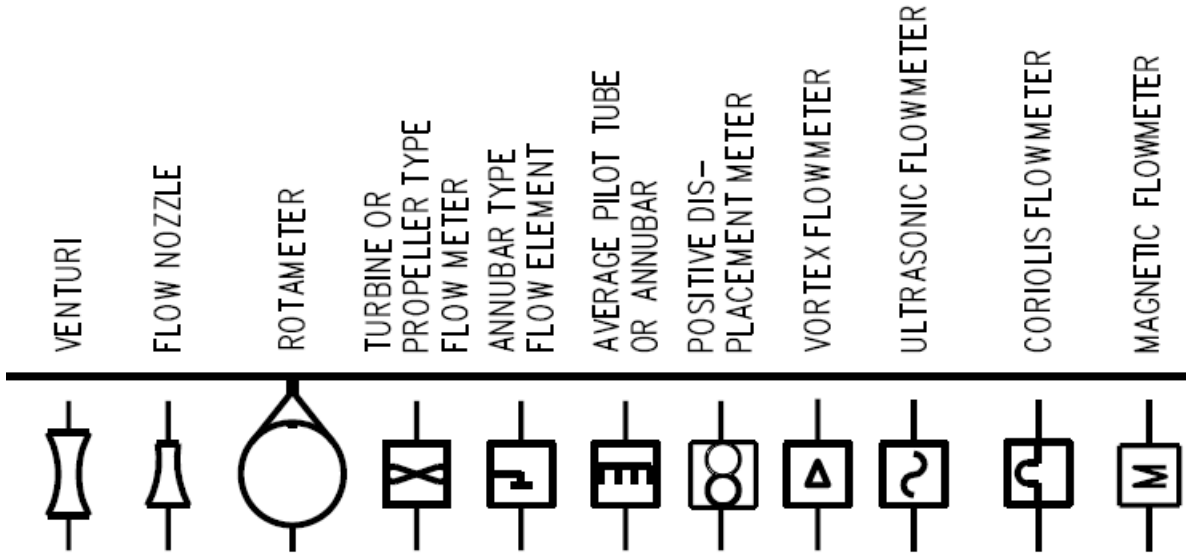
1. Selection
2. Sizing
3. Installation
4. Start-up
5. Normal Operation

FLOW METERS

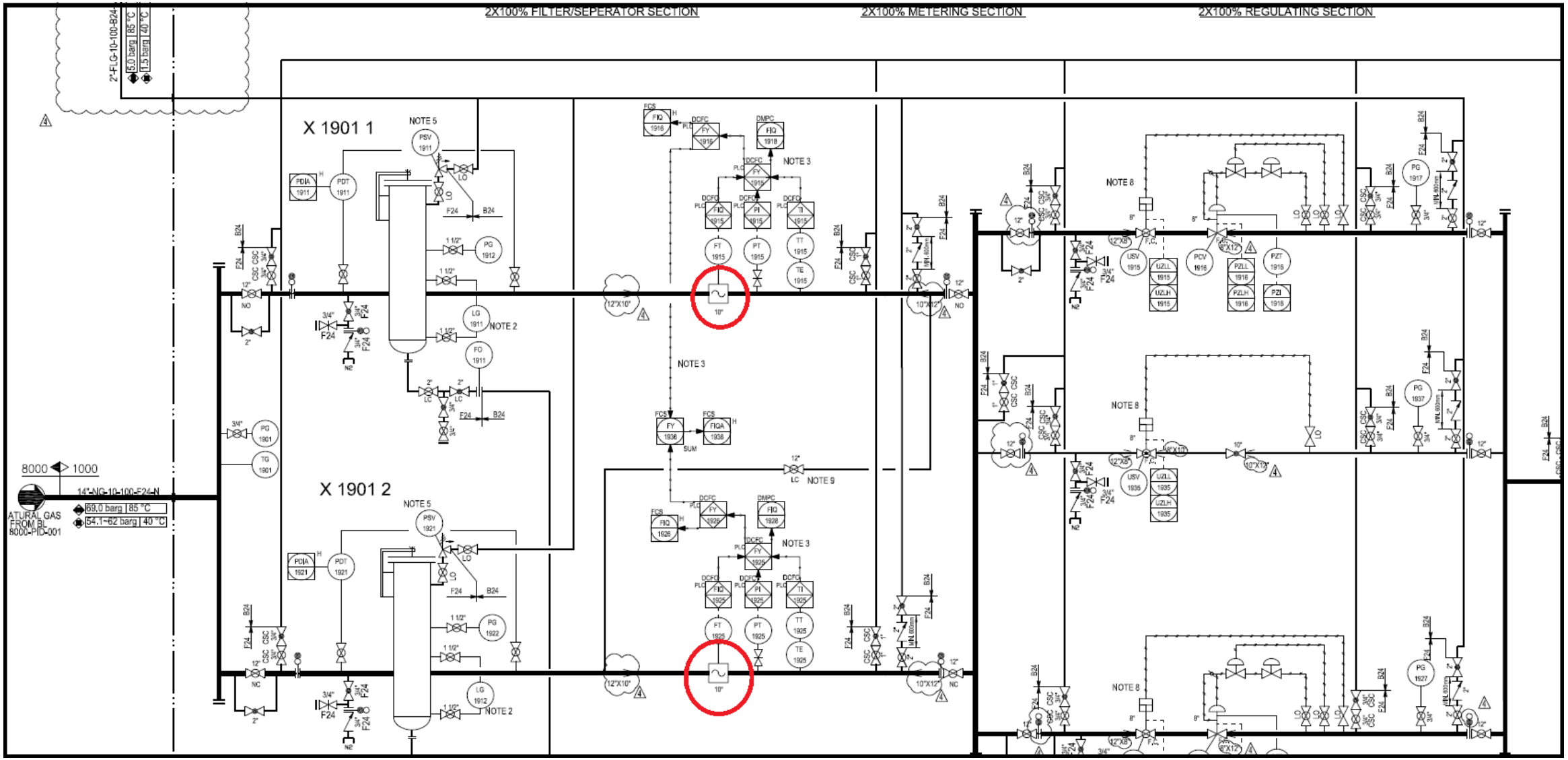
Selection Pattern

Application	Flowmeter Type
Gas station	Ultrasonic
Fuel system	Ultrasonic-Turbine-Vortex
Fluid with high amount of conductivity	Magnetic
Fluids with conductivity less than 5 us/m	Vortex
Low pressure gases	Venturi
High pressure steam services	Flow nozzle
High erosion present	Flow nozzle
Battery limit-Product	Coriolis
Process unit where controlling parameters is a high priority	Orifice

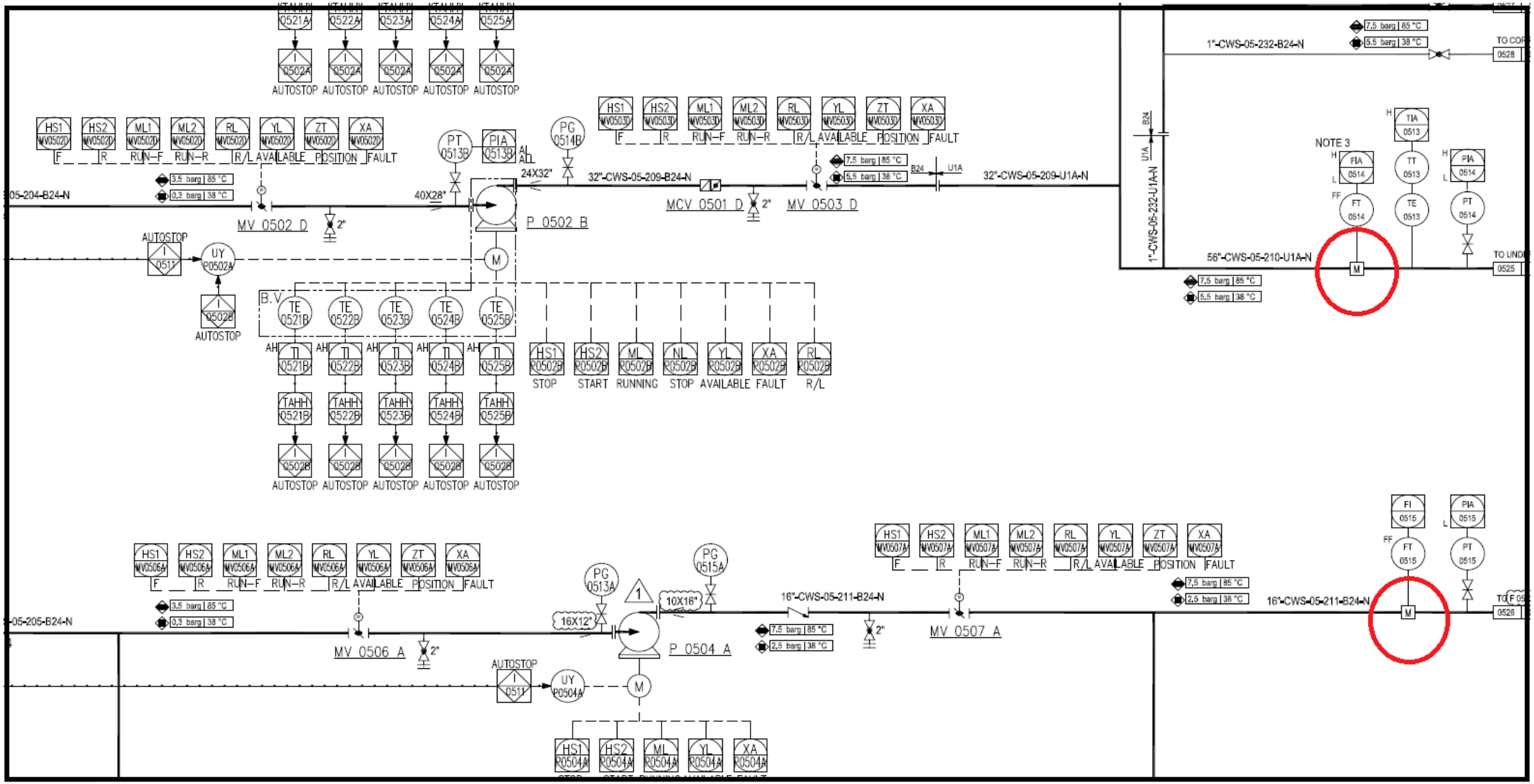
Examples


VENTURI
FLOW NOZZLE
ROTAMETER
TURBINE OR PROPELLER TYPE FLOW METER
ANNUBAR TYPE FLOW ELEMENT
AVERAGE PILOT TUBE OR ANNUBAR
POSITIVE DIS-PLACEMENT METER
VORTEX FLOWMETER
ULTRASONIC FLOWMETER
CORIOLIS FLOWMETER
MAGNETIC FLOWMETER

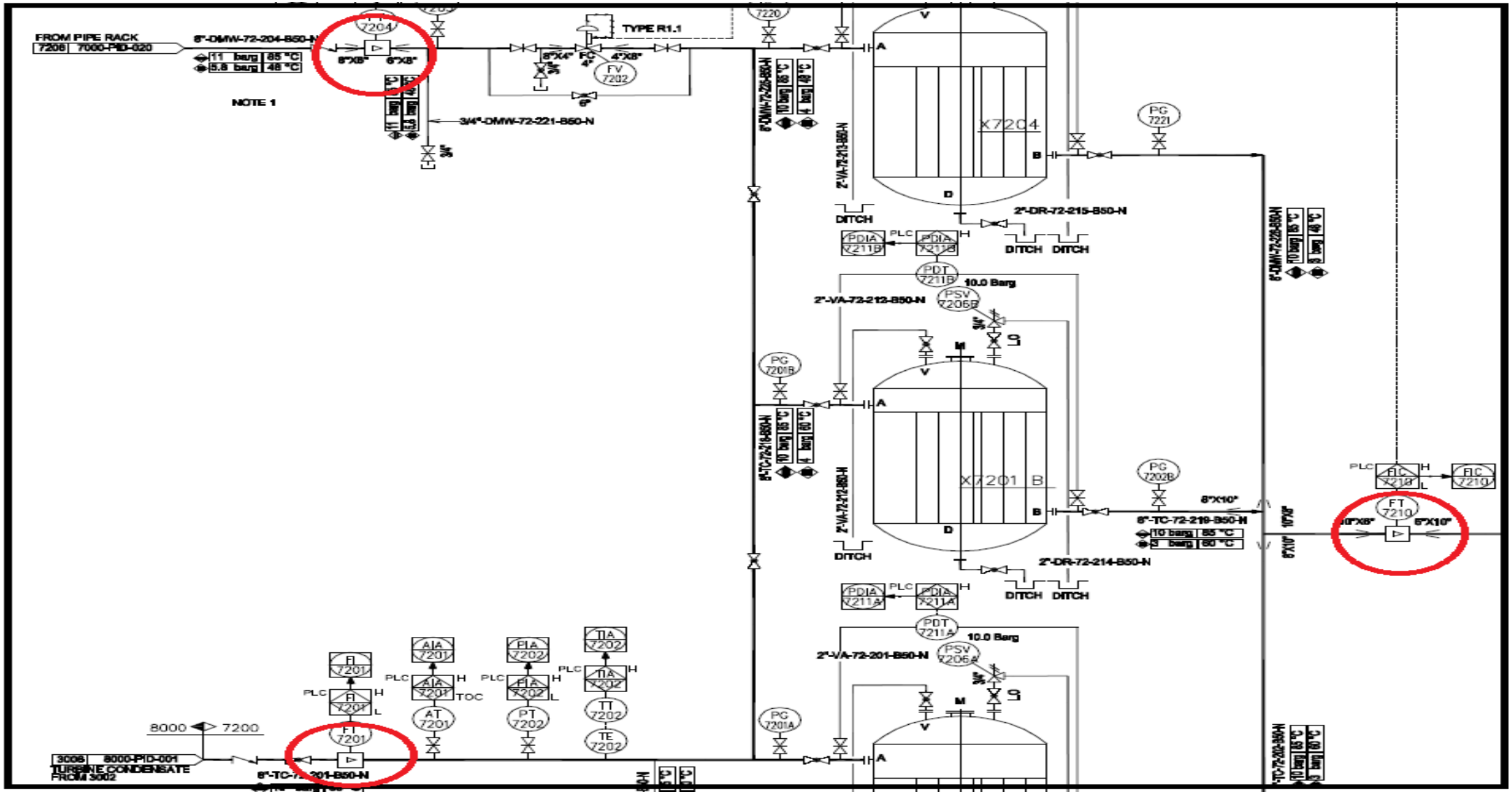
GAS STATION


2X100% FILTER/SEPERATOR SECTION
2X100% METERING SECTION
2X100% REGULATING SECTION
X 1901 1
X 1901 2
NOTE 5
NOTE 3
NOTE 2
NOTE 8
NOTE 9
8000
1000
14"-NG-10-100-F24-N
69,0 barg | 85 °C
54.1~62 barg | 40 °C
2"-FLG-10-100-B24
5,0 barg | 85 °C
1,5 barg | 40 °C

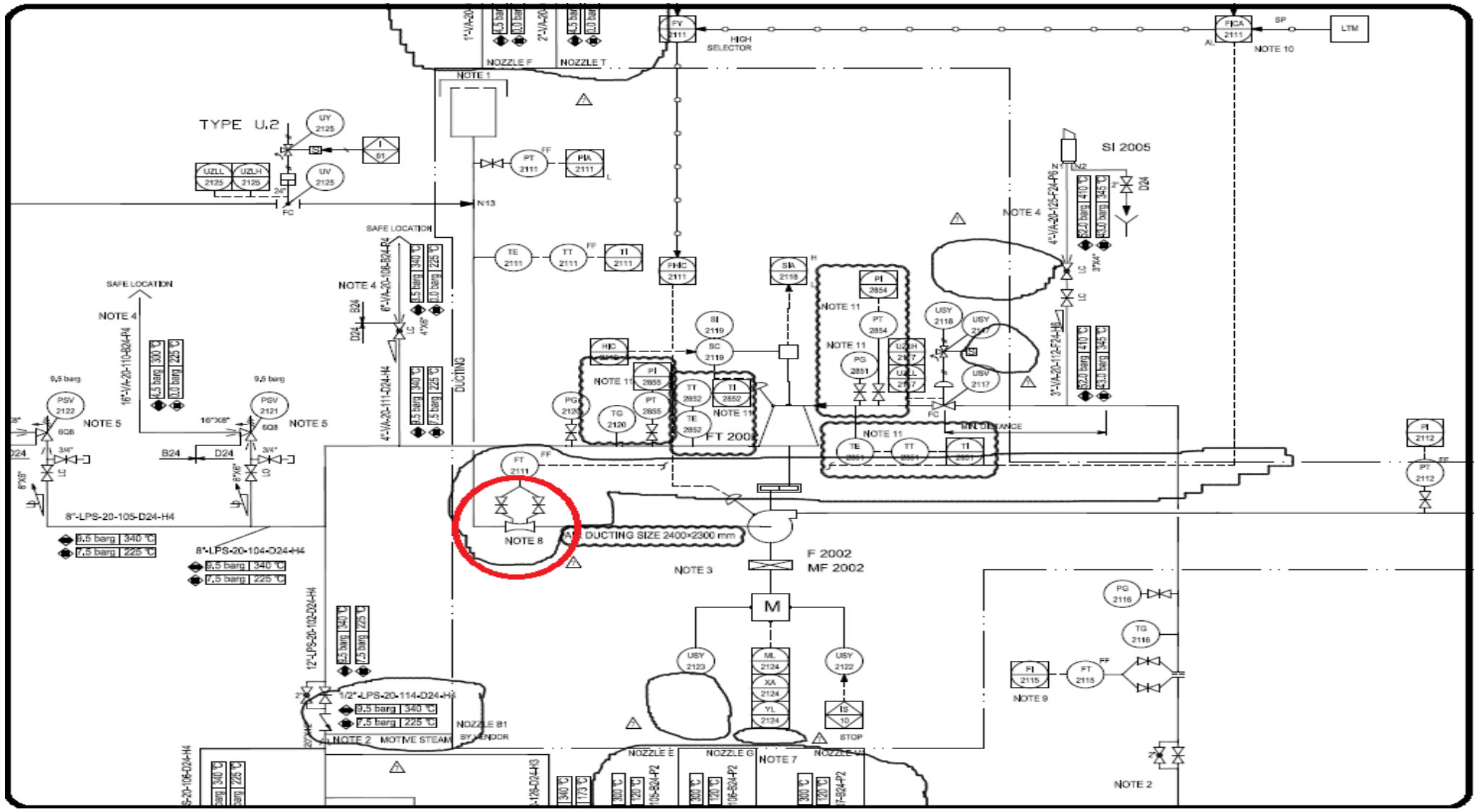
FLUID WITH HIGH AMOUNT OF CONDUCTIVITY- COOLING WATER SYSTEM



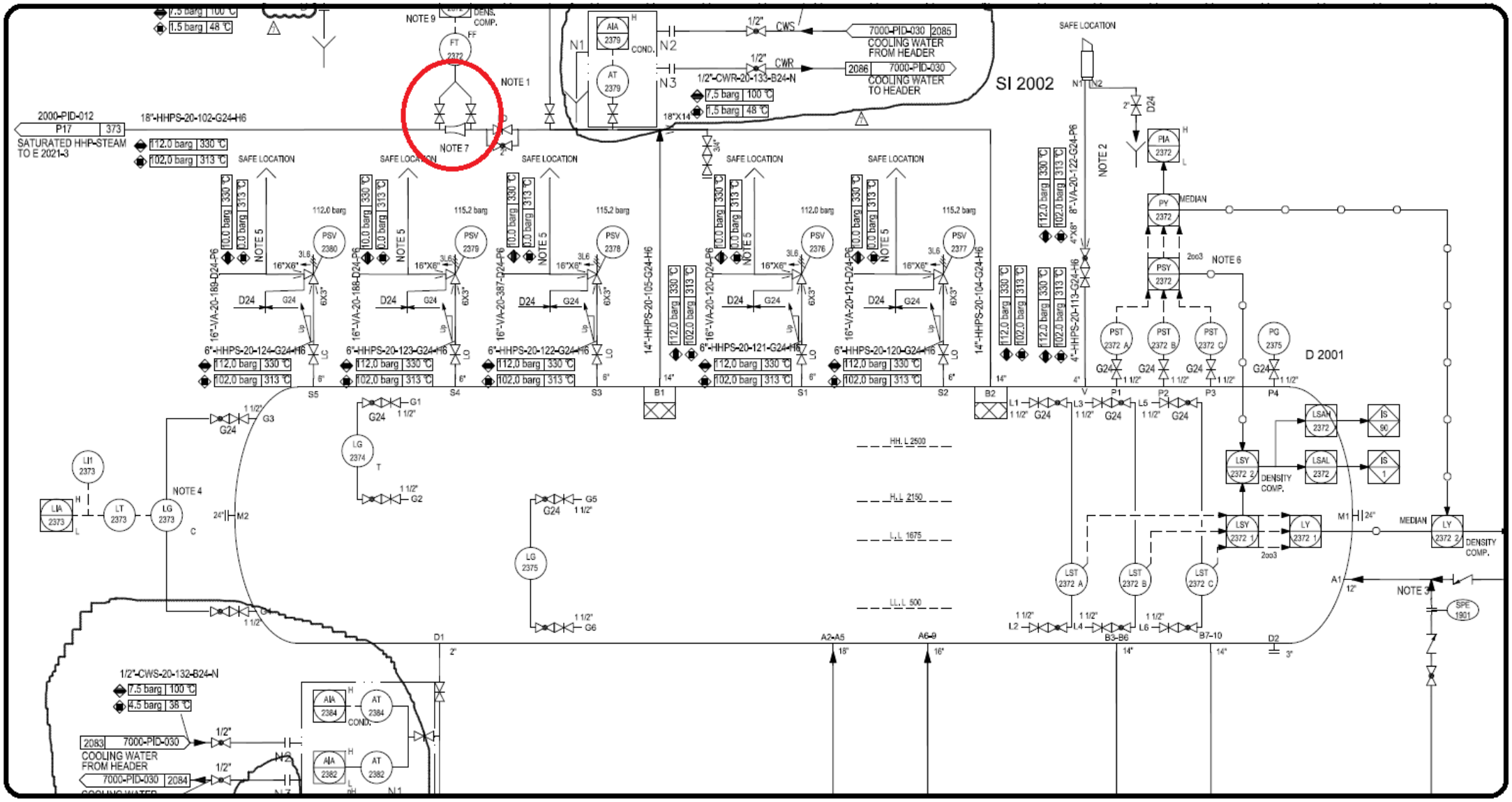
FLUIDS WITH CONDUCTIVITY LESS THAN 5 US/M-POLISHING UNIT



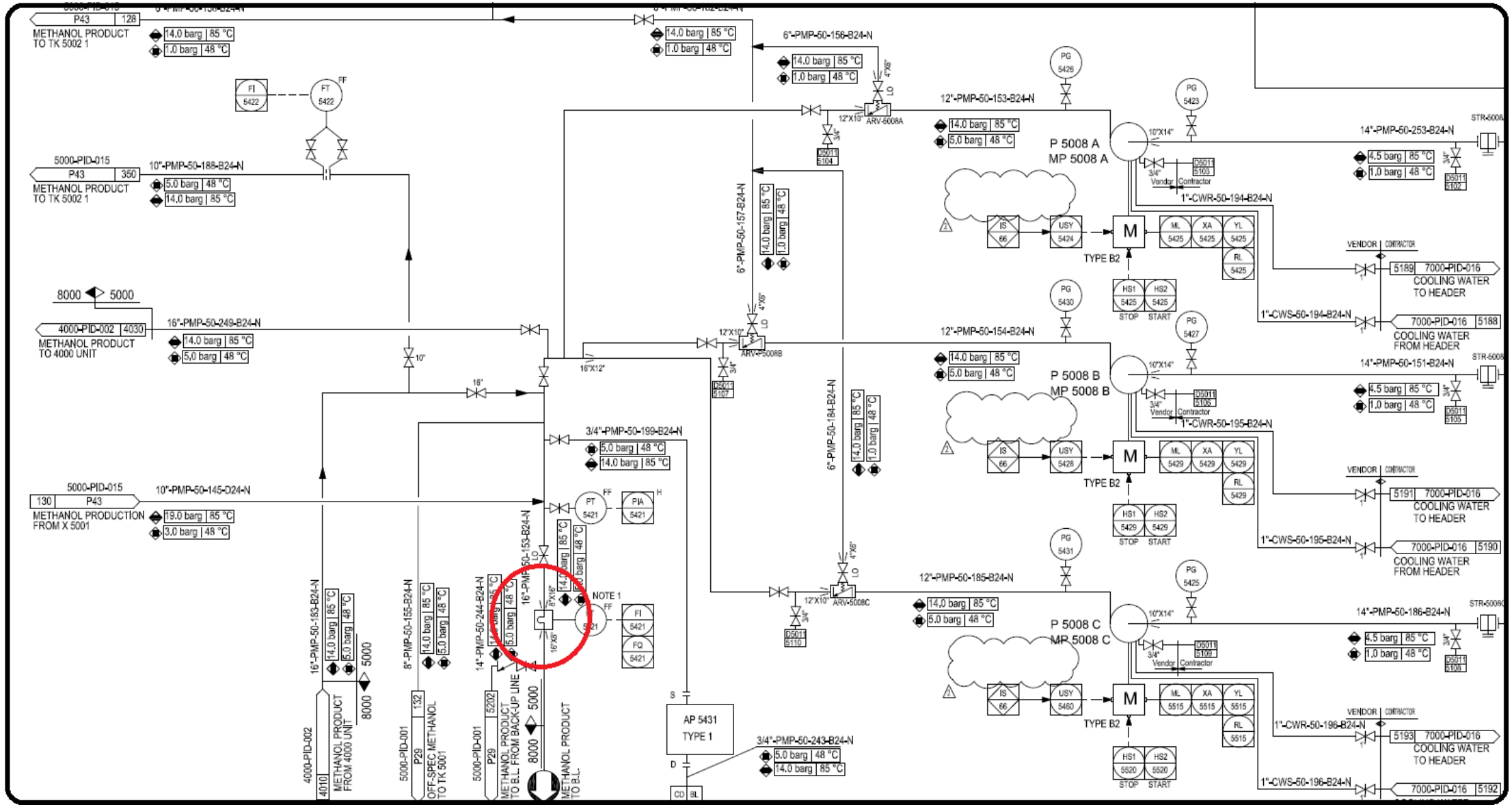
LOW PRESSURE GASES-COMBUSTION AIR



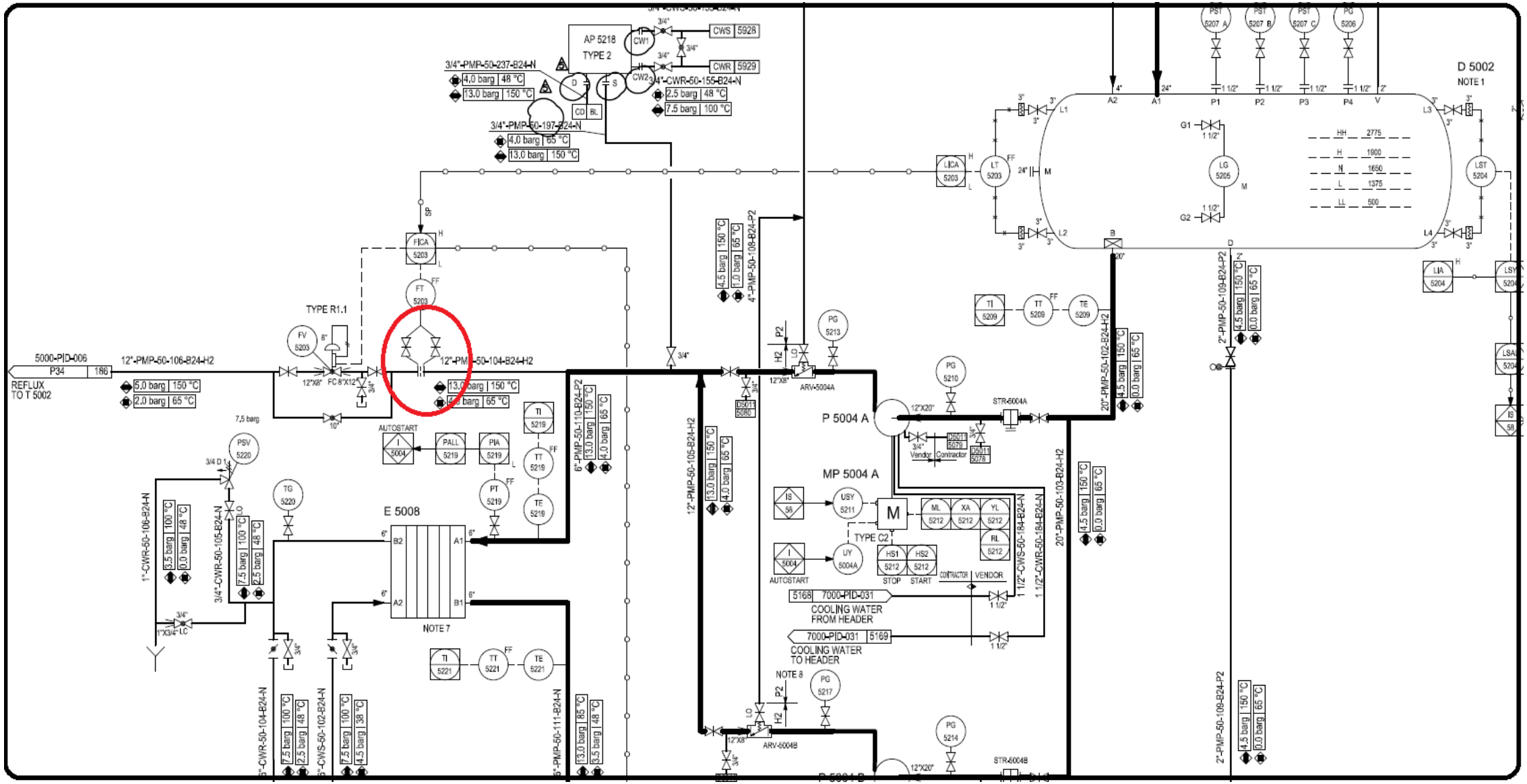
HIGH PRESSURE STEAM SERVICES-STEAM DRUMS

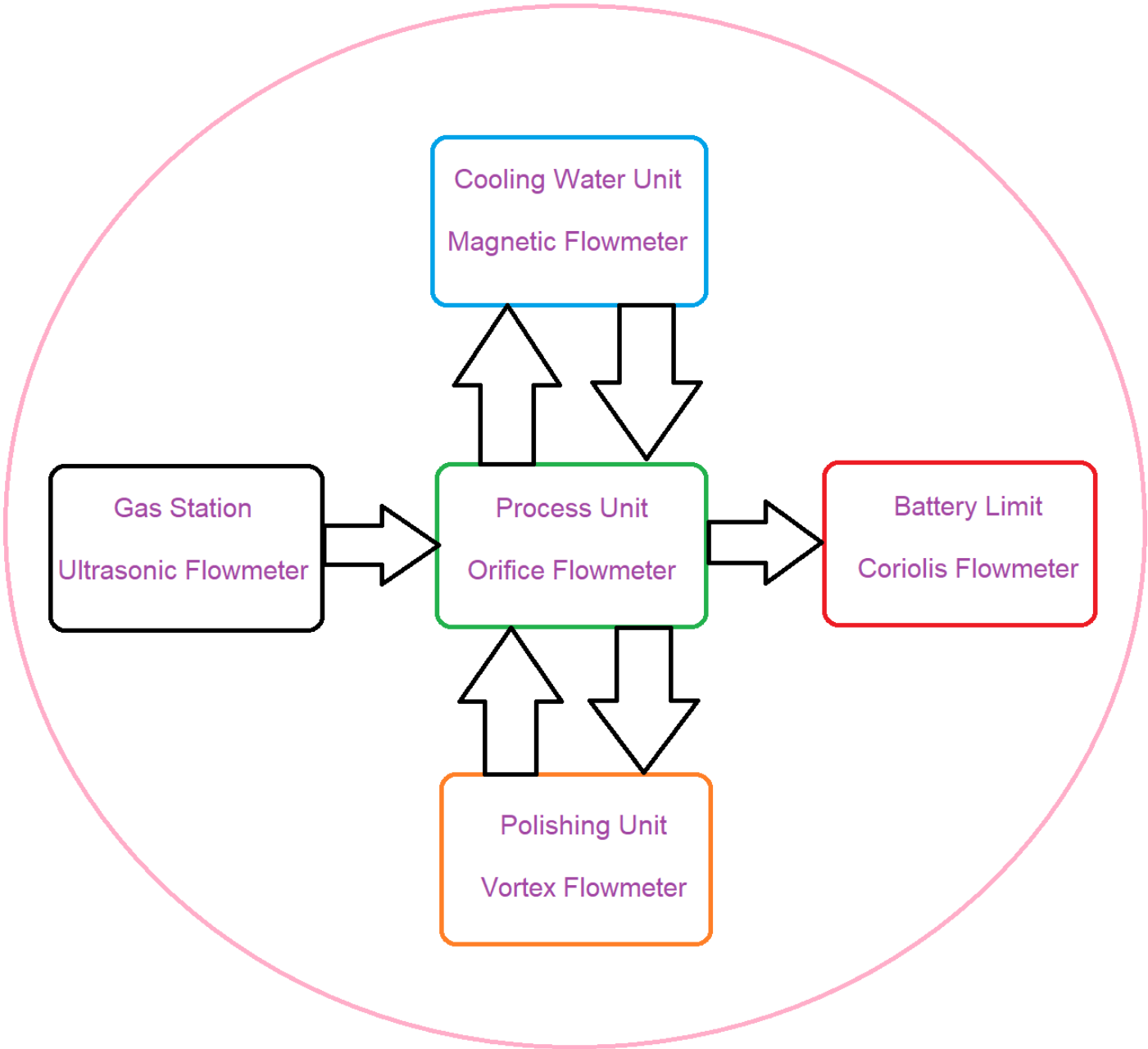


BATTERY LIMIT-PRODUCT



PROCESS UNIT WHERE CONTROLLING PARAMETERS IS A HIGH PRIORITY

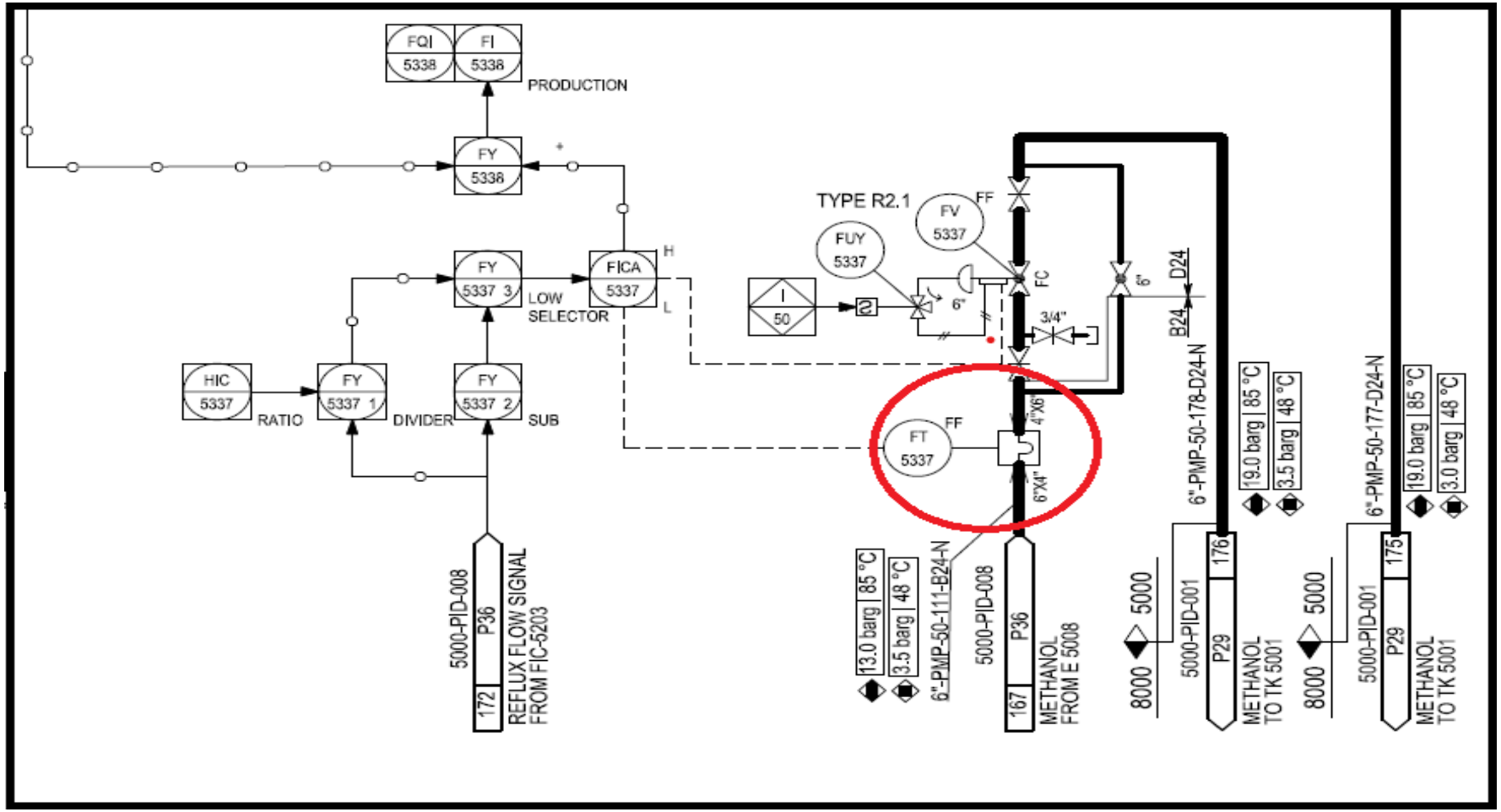



Cooling Water Unit
Magnetic Flowmeter
Gas Station
Ultrasonic Flowmeter
Process Unit
Orifice Flowmeter
Battery Limit
Coriolis Flowmeter
Polishing Unit
Vortex Flowmeter

FLOWMETER SIZING

EXAMPLE : METHANOL

EMERSON FLOWMETER SIZING



Flow Transmitter, Mass Coriolis

Sizing Flow	150000 kg/h
Minimum Flow	42003 kg/h
Normal Flow	126008 kg/h
Fluid Phase	Liquid
Sizing Pressure	3.5 bar g
Sizing Temperature	48 ℃
Sizing Density	766 kg/m3
Sizing Viscosity	0.40 cP
Sizing Moleweight	32.04 kg/kmol
Meter size	6"
Material	AISI 316
Flange: Size, Rating, Type	6", Class 150, RF
Max. Allowable Pressure Drop	<0.1 bar

Sizing Input

Measurement Type

- [x] Flow
- [ ] Density
- [ ] Viscosity

Select Technology

- (●) Coriolis
- ( ) Density
- ( ) Magnetic
- ( ) Viscosity
- ( ) Vortex

Equipment Selection

- (●) Coriolis Flow Meter (Includes Sensor and Transmitter)
- ( ) Sensor Only / MVDSolo

Application Requirements

- [ ] Hygienic (3A/EHEDG)
- [ ] Display All Sensors with no filters

PRODUCT FAMILY

ALL SENSORS

LINE SIZE

6 INCH (DN150)

Fluid Selection

FLUID STATE

LIQUID

FLUID SOURCE

DATABASE

PICK FROM FLUIDS DATABASE

METHANOL

Process Variables

OPERATING CONDITIONS

	MIN	NORMAL	MAX	FULL SCALE /DESIGN	UNITS
FLOW RATE	42003.000(	126008.00(	150000.00(		litres/hr
LINE PRESSURE	3.5000	3.5000	3.5000		bar-g
TEMPERATURE	48.0000	48.0000	48.0000		C
AMBIENT TEMP.	35.0000	35.0000	35.0000		C

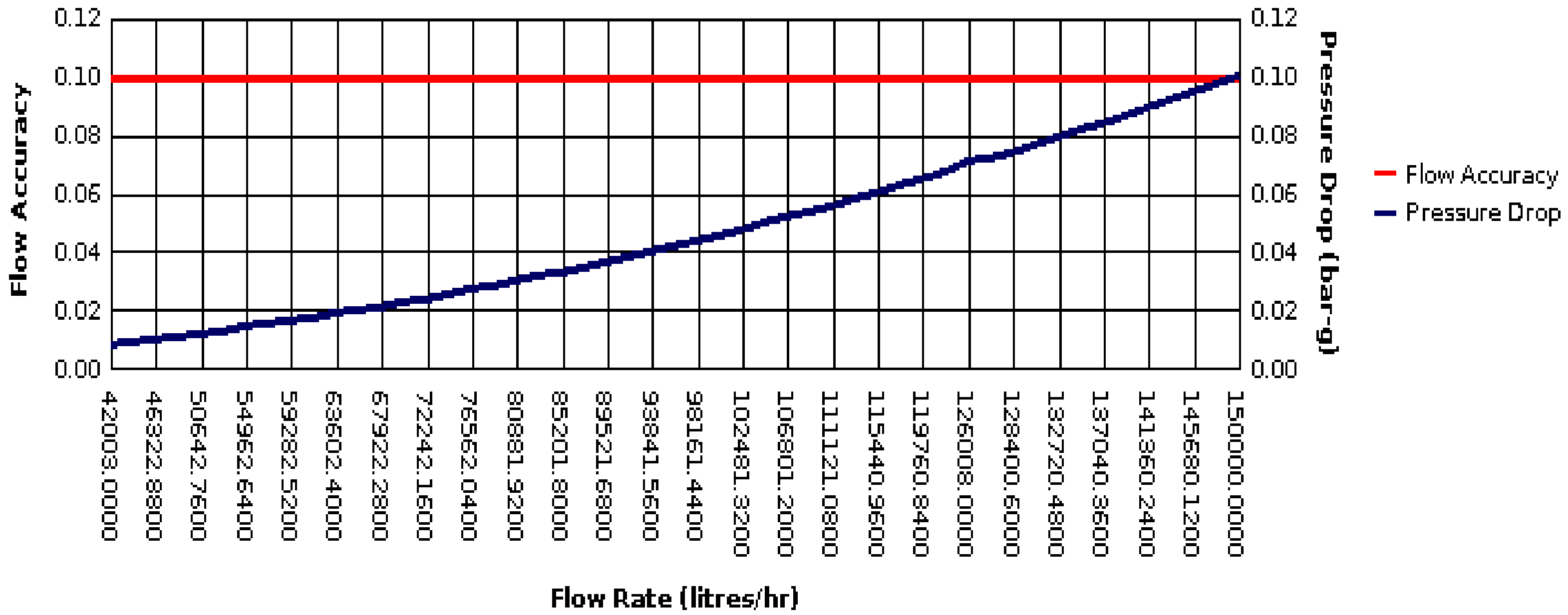
FLUID PROPERTIES

	MIN	NORMAL	MAX	UNITS
Density	765.6933	765.6933	765.6933	kg/m3
VISCOSITY	0.4044	0.4044	0.4044	cP
VAPOR PRESSURE	0.5081			bar-a
MAX FLOW ACCURACY	3.0000			% of Rate
MAX PRESSURE DROP	0.1000			bar-g

RESULT

MODEL NAME	COMPARE	MASS FLOW RATE ACCURACY			PRESSURE DROP (BAR)			TUBE VELOCITY (M/SEC)			DENSITY ACCURACY (KG/M3)	FLOW RATE REPEATABILITY	MODEL DESCRIPTION
		MIN	NORMAL	MAX	MIN	NORMAL	MAX	MIN	NORMAL	MAX			
CMFHC4M	☐	0.3098	0.1033	0.1	0.0003	0.0025	0.0035	0.3639	1.0916	1.2994	0.5000	0.05	MICRO MOTION ELITE CORIOLIS METER, 10-14 INCH (DN250-DN350), 316L STAINLESS STEEL
CMFHC3Y	☐	0.1976	0.1	0.1	0.0007	0.0055	0.0077	0.5685	1.7056	2.0304	0.5000	0.05	MICRO MOTION ELITE CORIOLIS METER, 8-10 INCH (DN200-DN250), SUPER DUPLEX STEEL, HIGH PRESSURE
CMFHC2G	☐	0.1	0.1	0.1	0.0022	0.0167	0.0233	0.9398	2.8195	3.3563	1.0000	0.05	MICRO MOTION ELITE CORIOLIS METER, 8 INCH (DN200), 316L STAINLESS STEEL
CMFHC3A	☐	0.1976	0.1	0.1	0.0007	0.0055	0.0077	0.5685	1.7056	2.0304	0.5000	0.05	MICRO MOTION ELITE CORIOLIS METER, 8-10 INCH (DN200-DN250) HIGH TEMPERATURE SENSOR; 316L STAINLESS STEEL, HIGH TEMPERATURE
CMFHC3G	☐	0.1976	0.1	0.1	0.0007	0.0055	0.0077	0.5685	1.7056	2.0304	1.0000	0.05	MICRO MOTION ELITE CORIOLIS METER, 10 INCH (DN250), 316L STAINLESS STEEL

FLOW RATE (LITRES/HR)	MASS FLOW ACCURACY	PRESSURE DROP (BAR)	VELOCITY (M/SEC)	REYNOLDS NUMBER
150000.0000	0.1	0.0077	2.0304	439455.5008
139200.3000	0.1	0.0066	1.8842	407815.5837
128400.6000	0.1	0.0057	1.7380	376175.6665
126008.0000	0.1	0.0055	1.7056	369166.0583
117600.9000	0.1	0.0048	1.5918	344535.7494
106801.2000	0.1	0.0040	1.4456	312895.8322
96001.5000	0.1	0.0033	1.2995	281255.9151
85201.8000	0.1	0.0026	1.1533	249615.9979
74402.1000	0.1116	0.0020	1.0071	217976.0808
63602.4000	0.1305	0.0015	0.8609	186336.1636
52802.7000	0.1572	0.0011	0.7147	154696.2465
42003.0000	0.1976	0.0007	0.5685	123056.3293

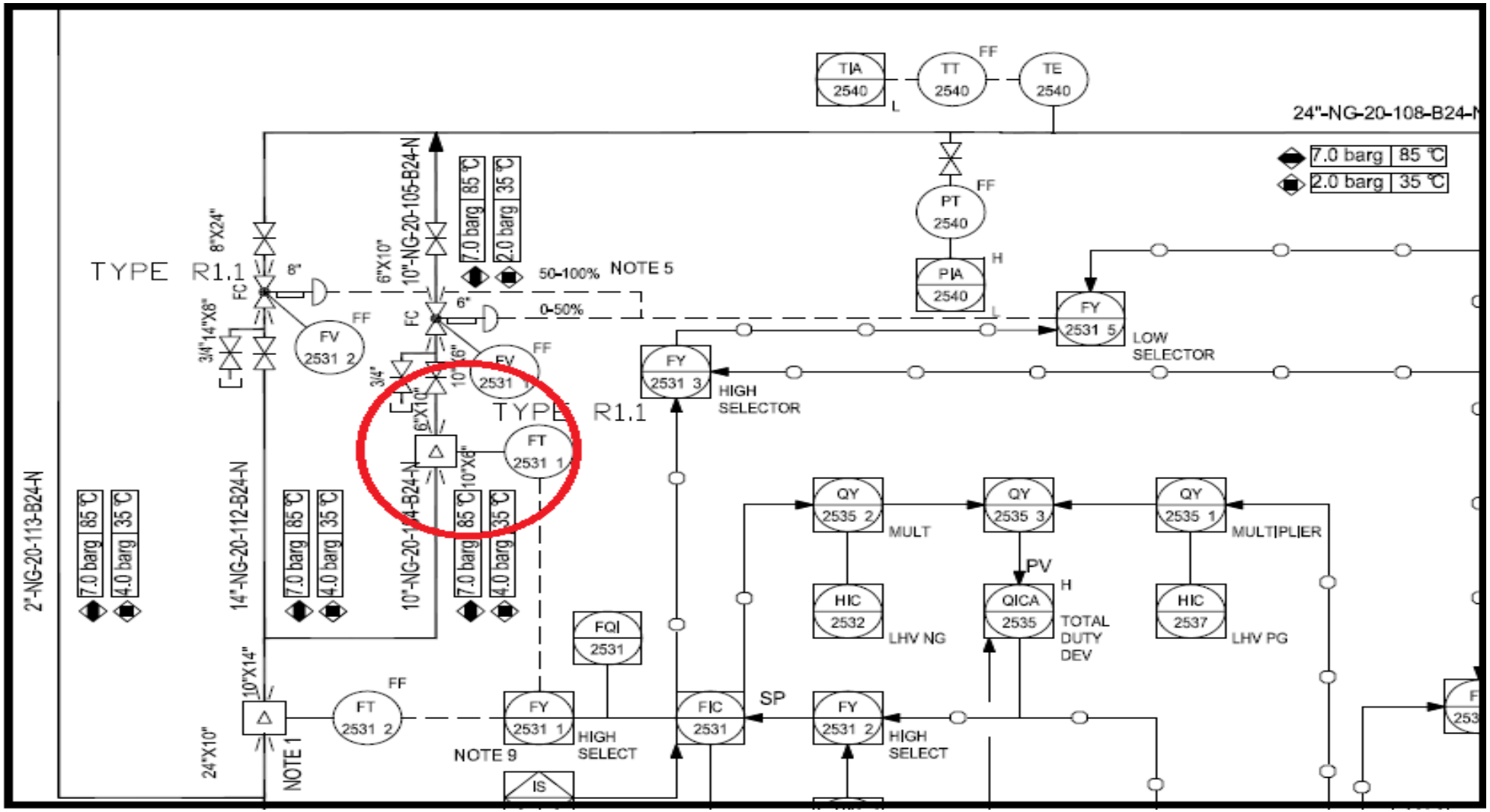


Flow Accuracy
Pressure Drop (bar-g)
Flow Rate (litres/hr)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
42003.0000
46322.8800
50642.7600
54962.6400
59282.5200
63602.4000
67922.2800
72242.1600
76562.0400
80881.9200
85201.8000
89521.6800
93841.5600
98161.4400
102481.3200
106801.2000
111121.0800
115440.9600
119760.8400
126008.0000
128400.6000
132720.4800
137040.3600
141360.2400
145680.1200
150000.0000
Flow Accuracy
Pressure Drop

FLOWMETER SIZING

EXAMPLE : NATURAL GAS

EMERSON FLOWMETER SIZING



Flow Transmitter, Vortex

Sizing Flow	10000 Nm3/h
Minimum Flow	2800 Nm3/h
Normal Flow	8400 Nm3/h
Fluid Phase	Gas
Sizing Pressure	4 bar g
Sizing Temperature	35 ℃
Sizing Density	3.30 kg/m3
Sizing Viscosity	0.012 cP
Sizing Compressibility	0.99
Sizing Cp/Cv Ratio	1.30
Sizing Moleweight	16.74
Meter size	6 "
Material	AISI 316
Flange: Size, Rating, Type	6", Class 150, RF
Located in 10" pipe	

Sizing Input

Measurement Type

- [x] Flow
- [ ] Density
- [ ] Viscosity

Select Technology

- ○ Coriolis
- ● Density
- ○ Magnetic
- ● Viscosity
- ● Vortex

Application Requirements

METER TYPE

- [x] Flanged/Wafer
- [x] Reducer
- [ ] Dual
- [ ] Quad

PROCESS LINE SIZE

10 INCH (DN250)

SCHEDULE

CUSTOM

PIPE ID

10.02 IN

Fluid Selection

FLUID STATE

GAS

FLUID SOURCE

DATABASE

PICK FROM FLUIDS DATABASE

METHANE

OPERATING CONDITIONS

	MIN	NORMAL	MAX	FULL SCALE /DESIGN	UNITS
FLOW RATE	2800.0000	8400.0000	10000.0000		Nm3/hr
LINE PRESSURE	4.0000	4.0000	4.0000		bar-g
TEMPERATURE	35.0000	35.0000	35.0000		C

FLUID PROPERTIES

	MIN	NORMAL	MAX	UNITS
Density	3.1638	3.1638	3.1638	kg/m3
VISCOSITY	0.0115	0.0115	0.0115	cP
PRESSUREATMOSPHERIC	1.01325348			bar-a

BASE REFERENCE CONDITIONS - GAS ONLY (FOR STANDARD/NORMAL UNIT CONVERSIONS)

PRESSURE	14.6960	psia
TEMPERATURE	15.5556	C
DENSITY	0.6785	kg/m3

Sensor Comparison

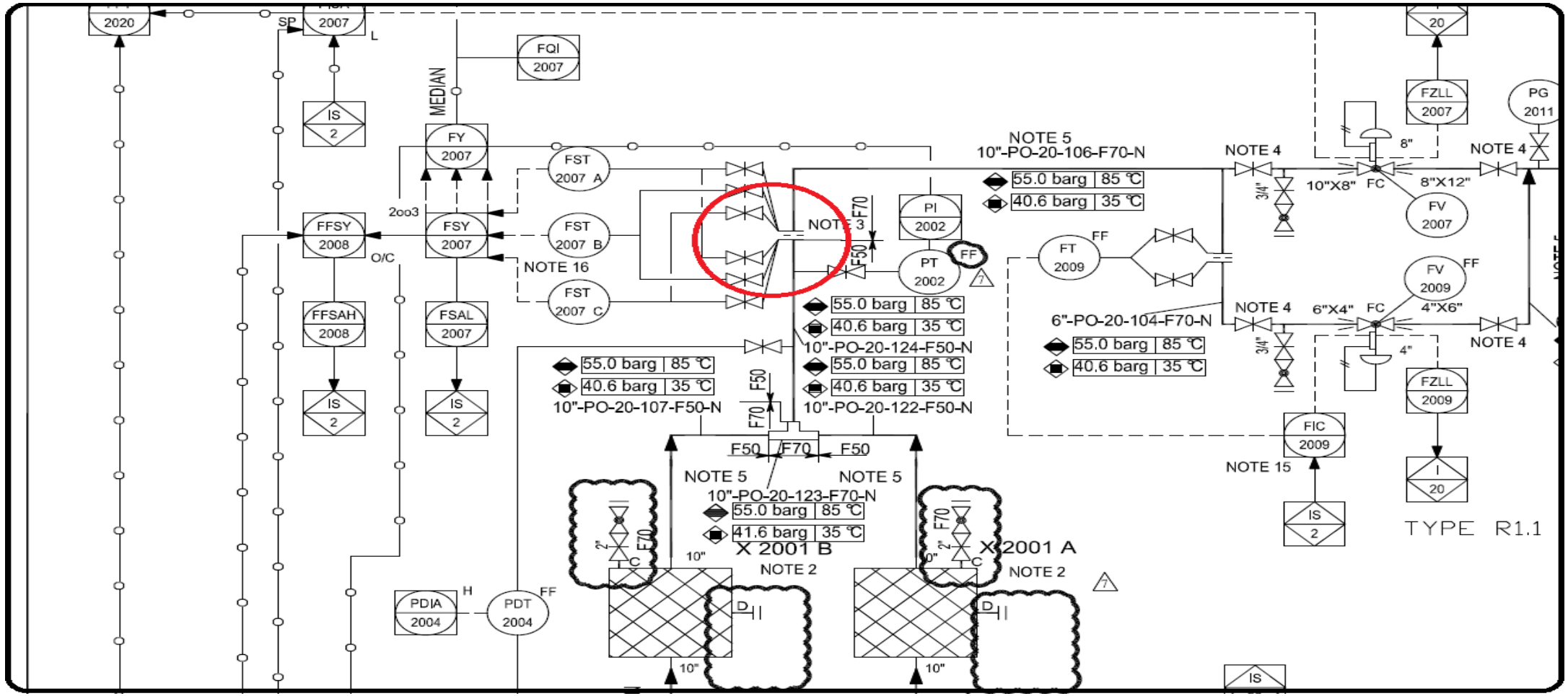
	Min	Normal	Max	Full Scale /Design
Flow Rate (Nm3/hr)	2800.0000	8400.0000	10000.0000	-
Line Pressure (bar-g)	4.0000	4.0000	4.0000	-
Temperature (C)	35.0000	35.0000	35.0000	-
Density (kg/m3)	3.1638	3.1638	3.1638	-
Viscosity (cP)	0.0115	0.0115	0.0115	-

Product Name	8600DF040	8800DF060	8600DF080
Product Description	Optimized for cost-effective general purpose flow metering and clean fluid applications including steam air water and nitrogen.	A gasket-free non-clog meter body that eliminates potential leak points. Isolated sensors offer flow and temperature sensor replacement without breaking the process seal.	Optimized for cost-effective general purpose flow metering and clean fluid applications including steam air water and nitrogen.
Flow Accuracy @ Minimum	1	1	1
Flow Accuracy @ Normal	1	1	1
Flow Accuracy @ Maximum	1	1	1
Pressure Drop @ Minimum (bar)	0.0157	0.0031	0.0010
Pressure Drop @ Normal (bar)	0.1413	0.0275	0.0090
Pressure Drop @ Maximum (bar)	0.2002	0.0390	0.0127
Velocity @ Minimum (m/sec)	20.3100	8.9495	5.1683
Velocity @ Normal (m/sec)	60.9301	26.8484	15.5048
Velocity @ Maximum (m/sec)	72.5359	31.9624	18.4581
Minimum Accurate Flow at 1% (Nm3/hr)	567.3041	1287.4489	2229.3744
Maximum Pressure rating (bar)	--	--	--
Temperature Limits (C)	--	--	--
Density Accuracy @ Normal (kg/m3)	--	--	--

FLOWMETER SIZING

EXAMPLE : PROCESS OXYGEN

EMERSON FLOWMETER SIZING



Orifice Plate Assembly

Sizing Flow	78000 Nm3/h
Minimum Flow	21923 Nm3/h
Normal Flow	65769 Nm3/h
Fluid Phase	Gas
Sizing Pressure	40 bar g
Sizing Temperature	35 ℃
Sizing Density	52.5 kg/m3
Sizing Viscosity	0.022 cP
Sizing Compressibility	0.98
Sizing Cp/Cv Ratio	1.39
Sizing Moleweight	32.01 kg/kmol
Sizing dP	2500 mmWG
Sizing Pipe ID, app.	257.5 (10", Sch.30) mm
Sizing d/D Ratio, app.	0.73
Material, Orifice Plate	Monel
Flange: Size, Rating, Type	10", Class 600, RF

Sizing Name

Enter your Sizing Information below

**This information is not included in any custom tagging requirements*

Sizing Name

EIEPD

Service

Process Oxygen

Project Name

Methanol-ASU

Fluid Selection

Fluid Type

Gas | Liquid | Steam | Natural Gas

Gas Type

Database | Custom

Fluids Database

Oxygen

- [ ] Fluid Plugs Or Clogs (High Viscosity, Slurry, Entrained Solids, Solidifies Etc.)
- [ ] Fluid Causes Wear And Erosion (Entrained Solids, Abrasive, Etc.)

Process Piping

Units Of Measurement

Inch | Millimeter

Pipe Cross-Section

Circular | Rectangular

Custom Pipe ID

Standard | Custom

Pipe Material

Stainless Steel (304, 316)

Nominal Pipe Size

10 inch

Pipe Schedule

STD

Pipe ID

10.020 inch

Wall Thickness

0.365 inch

Flow Direction

Horizontal

Primary Element Details

Rosemount 1495 Orifice Plate

Primary Element Material

316 Stainless Steel

Bore Configuration

Concentric Bore, Square Edge

Tap Type

Flange Tapping

Orifice Flange/Fitting Type

ASME B16.36 CL 600 RF

☐ Add A Model 1496 Orifice Flange Union

Calculation Standard

ISO-5167-2 (2003)

Solve For

Bore Size | Differential Pressure

Preferred DP	UOM	Condition
0.24	bar	at Full Scale Flow

Process Variables

Operating Conditions

	Min	Normal	Max	Full Scale / Design	Units
Flow	21923	65769	78000	78000	Nm3/hr
Pressure	40	40	40	47	bar-g
Temperature	35	35	35	85	C
Ambient Temperature	35	35	35		C
Atmospheric Pressure	14.696	psia			

Rosemount 485 Annubar Primary

Built with a patented design, the Rosemount 485 Annubar Primary Element is an averaging pitot tube that delivers reliable measurement accuracy over a wide flow range. This sensor maintains a small profile in the pipe to reduce permanent pressure loss and increase energy savings. This T-shaped sensor is capable of temperature, pressure and flow measurements via a single pipe penetration.

- Permanent Pressure Loss (PPL): Low
- Straight Run: Better
- Accuracy of Primary: ±0.75% of Rate
- Type of Installation: Insertion

Rosemount 1495 Orifice Plate

The Rosemount 1495 Orifice Plate Primary Element is engineered for reliable measurement performance. As the most common primary element used around the globe, this orifice plate offers a standard configuration with a square-edged concentric bore in both paddle and universal-type plates. This product is available in standard line sizes (2 - 24 in. or 50 - 600 mm) and is also suitable in high temperature and pressure applications.

- Permanent Pressure Loss (PPL): Medium
- Straight Run: Good
- Accuracy of Primary: ±0.5-1.667% of Rate
- Type of Installation: Flanged

Rosemount™ 405P Compact Orifice Plate

The Rosemount 405P Compact Orifice Plate Primary Element provides reliable and accurate flow measurements for closed loop control, general purpose monitoring and custody transfer applications. This easy-to-install, direct mount primary element is designed for gas, liquid and steam service. Available in a range of line sizes (0.5 – 12 in. or 15 - 300 mm), this product delivers reliable performance in harsh process conditions.

- Permanent Pressure Loss (PPL): Medium
- Straight Run: Good
- Accuracy of Primary: ±1.25-2.25% of Rate
- Type of Installation: Wafer

Sort By: Permanent Pressure Loss

Primary Element Technology	Operating Condition Notes	Calculated Minimum Flowrate (Nm3/hr)	Differential Pressure At Minimum Flow (bar)	Differential Pressure At Normal Flow (bar)	D S
 Rosemount 1495 Orifice Plate Standard Bore Bore Size = 7.250 inch (DP > Preferred DP)	Best Fit	2402.9993	0.021	0.186	
 Rosemount 1495 Orifice Plate Special Bore Bore Size = 7.371 inch (DP = Preferred DP)	Good	2510.5898	0.019	0.171	
 Rosemount 1495 Orifice Plate Standard Bore Bore Size = 7.375 inch (DP < Preferred DP)	Good	2514.6677	0.019	0.170	

Transmitter Connection

Mounting Style

- ○ Direct Mount
- ● Remote Mount

Manifold Style

Conventional

Transmitter Details

Communication Protocol

4-20mA HART®

Flow Calculations

- ● Fully Compensated Mass, Volumetric and Energy Flow
- ○ No Flow Calculations

Measurement Type

- ☑ Differential Pressure
- ☑ Static Pressure
- ☑ Process Temperature

Accuracy and Long Term Stability

- ○ Optimized for Flow (15 Year Stability, 14:1 Flow Turndown, 0.04% of Reading Accuracy)
- ● Industry Leading (15 Year Stability, 8:1 Flow Turndown, 0.04% of Span Accuracy)

Transmitter Capabilities

Warranty

- ○ 5 Year Limited Warranty
- ○ 3 Year Limited Warranty
- ● 18 Month Limited Warranty (Standard)

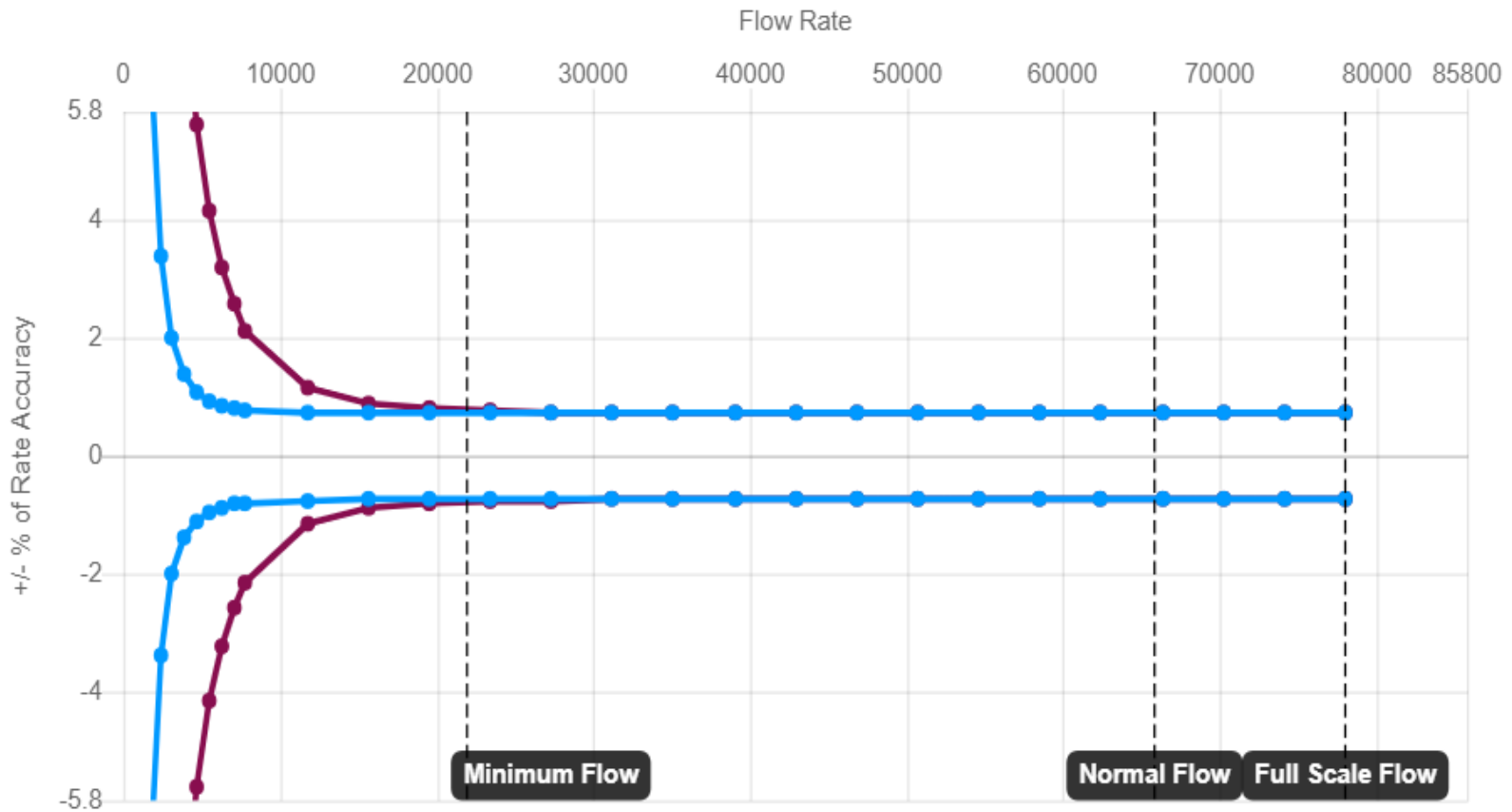
Display And Interface

- ○ No Display
- ● LCD Display
- ○ Remote Display and Interface

< PREVIOUS

NEXT >

Flow Accuracy

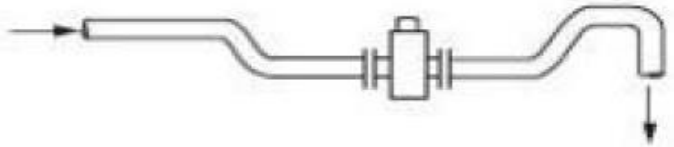


Rosemount™ 3051S MultiVariable™ Pressure Transmitter and 1495 Orifice Plate

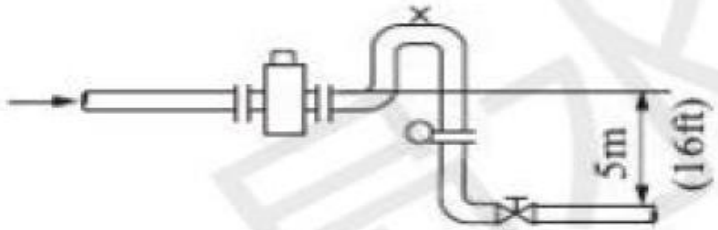
	Performance Class		Flow Accuracy at Normal Flow (% of Reading)	Flow Accuracy at 10% of Full Scale Flow (% of Reading)	Stability	Differential Pressure Range
○	Ultra for Flow		0 ± 0.729	0 ± 0.787	±0.15% of URL for 15 years	Range 2
●	Classic MV		0 ± 0.73	0 ± 2.129	±0.20% of URL for 15 years	Range 2

INSTALLATION
PIPING DESIGN CONSIDERATION
MAGNETIC FLOWMETER

b. For the opening emission pipe, the flwometer should be installed at the low pipe-line part.

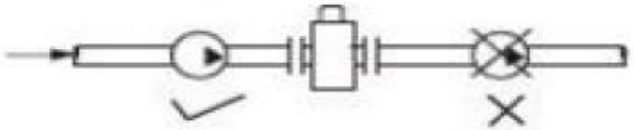


c. For pipe fall exceeding 5m, air valve (vacuum) should be installed at downstream flowmeter.

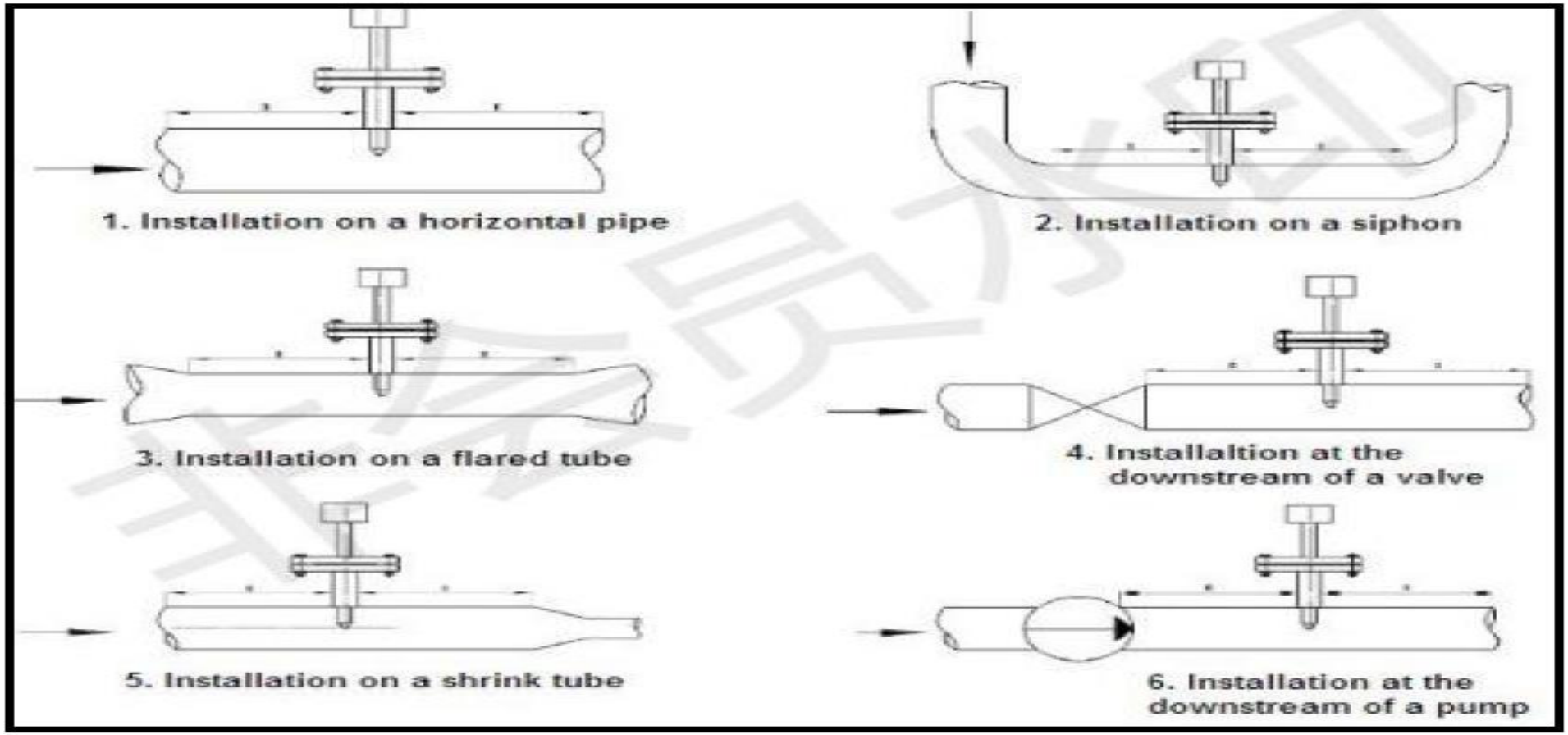


d. For the long pipeline, control valve is usually installed at downstream flowmeter.

e. The flowmeter could not be installed at the pumping side.

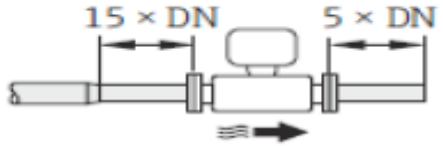


Pipe installation type	Installation diagram	Upstream part	Downstream pant
Horizontal pipe	1	10D	5D
Syphon	2	20D	5D
Flared tube	3	20D	10D
Downstream of valve	4	20D	5D
Shrink tube	5	10D	10D
Downstream of pump	6	30D	10D
Mixed liquid	7	30D	5D

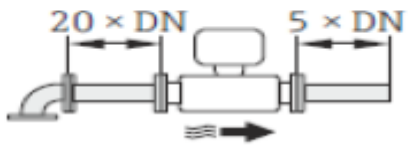


INSTALLATION
PIPING DESIGN CONSIDERATION
VORTEX FLOWMETER

1



2



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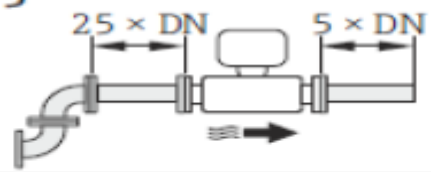

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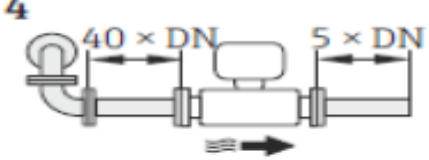

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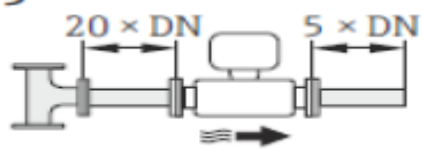

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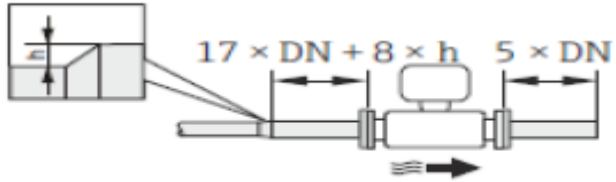

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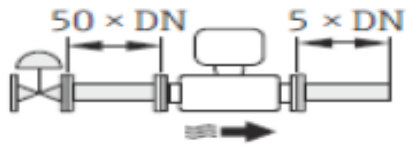
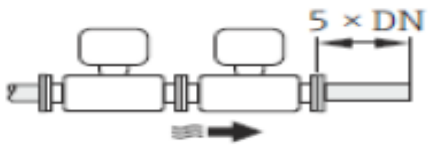
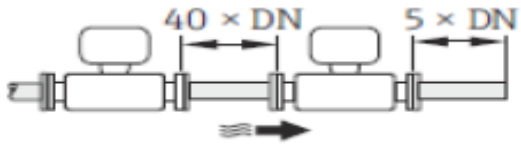


8 DN ≤ 25 (1"):



9 DN ≥ 40 (1½"):



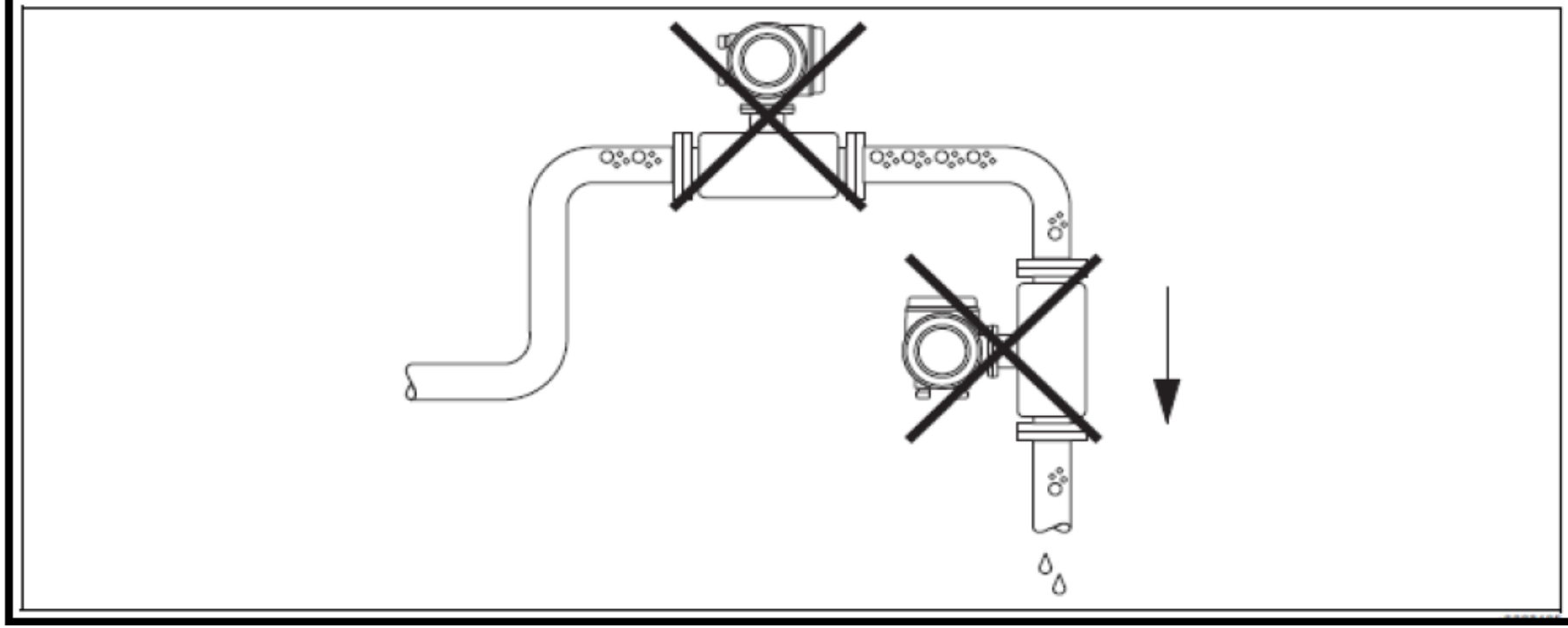
INSTALLATION
PIPING DESIGN CONSIDERATION
MASS FLOWMETER

Mass flowmeter

3.1 Installed on site

Entrained air or gas bubbles in the measuring tube can result in an increase in measuring errors
Avoid the following mounting locations in the pipe:

- Highest point of a pipeline. Risk of air accumulating.
- Directly upstream from a free pipe outlet in a vertical pipeline



PRE-COMMISSIONING AND START-UP

Standard Algorithms

Pressure, Temperature and Mole Weight Compensation of Flow

Where stated, pressure, temperature and mole weight compensation of flow is applied after square root extraction of flow signal with the following algorithm:

$$Q_{CVol} = Q_{RVol} \cdot \sqrt{\frac{Pa \cdot Td \cdot MWd}{Pd \cdot Ta \cdot MWa}} \quad \text{or} \quad Q_{CMass} = Q_{RMass} \cdot \sqrt{\frac{Pa \cdot Td \cdot MWa}{Pd \cdot Ta \cdot MWd}}$$

where

Q_{CVol} : Compensated flow [Nm^3/h]

Q_{RVol} : Uncompensated flow [Nm^3/h]

Q_{CMass} : Compensated flow [kg/h]

Q_{RMass} : Uncompensated flow [kg/h]

P_a : Actual Pressure [bar a]

T_a : Actual Temperature [K]

Mw_a : Actual Mole Weight [kg/kmole]

P_d : Sizing Pressure [bar a]

T_d : Sizing Temperature [K]

Mw_d : Sizing Mole Weight [kg/kmole]

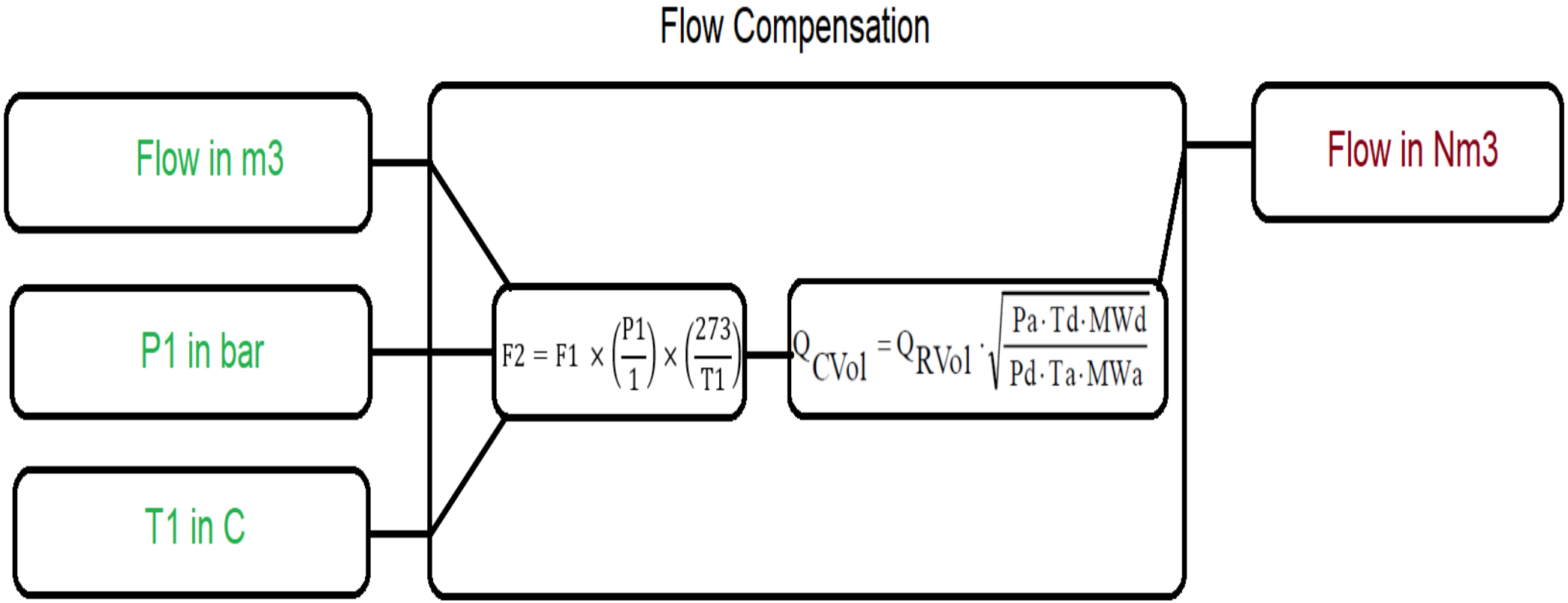
Gas and vapor flow measurements based on vortex meters are compensated by one of the following algorithms:

$$Q_{CVol} = Q_{RVol} \cdot \frac{Pa \cdot Td}{Pd \cdot Ta} \quad \text{or} \quad Q_{CMass} = Q_{RMass} \cdot \frac{Pa \cdot Td \cdot MWa}{Pd \cdot Ta \cdot MWd}$$

In case of failure of sensors used for compensation, then Pa, Ta or Mwa are to be replaced by Pd, Td or Mwd. If pressure, temperature and/or mole weight are not required, the factors must be removed in the above equation.

Flow compensation algorithms shall generally be configured with a plausibility check of compensating factors; i.e. if the factor values are outside predetermined limits, e.g. +/-15%, the limit factor shall be used for compensation, or in the case of sensor failure, the factors shall be set to the default (sizing) values. In both cases an alarm shall be initiated. Start-up flow loops with wide varying temperature and/or pressure shall be configured without limits.

OUR EXPERIENCE-MISTAKE
PLANT AIR FLOWMETER



VENDOR LIST

MASS FLOWMETER (CORIOLIS TYPE)

BOPP & REUTHER	GERMANY
EMERSON	UK/CHINA
ENDRESS & HAUSER	GERMANY/CHINA
HONEYWELL	W.EUROPE
KROHNE	GERMANY/CHINA
OVAL	JAPAN/CHINA
XI'AN DONGFENG MACHINERY&ELCTRONIC CO.,LTD	CHINA
BEIJING MAIN-LEND INSTRUMENT	CHINA

ULTRASONIC FLOWMETER

EMERSON	UK
FAURE HERMAN	FR
FUJI	JAPAN
INSTROMET	NETHERLAND
KROHNE	GERMANY