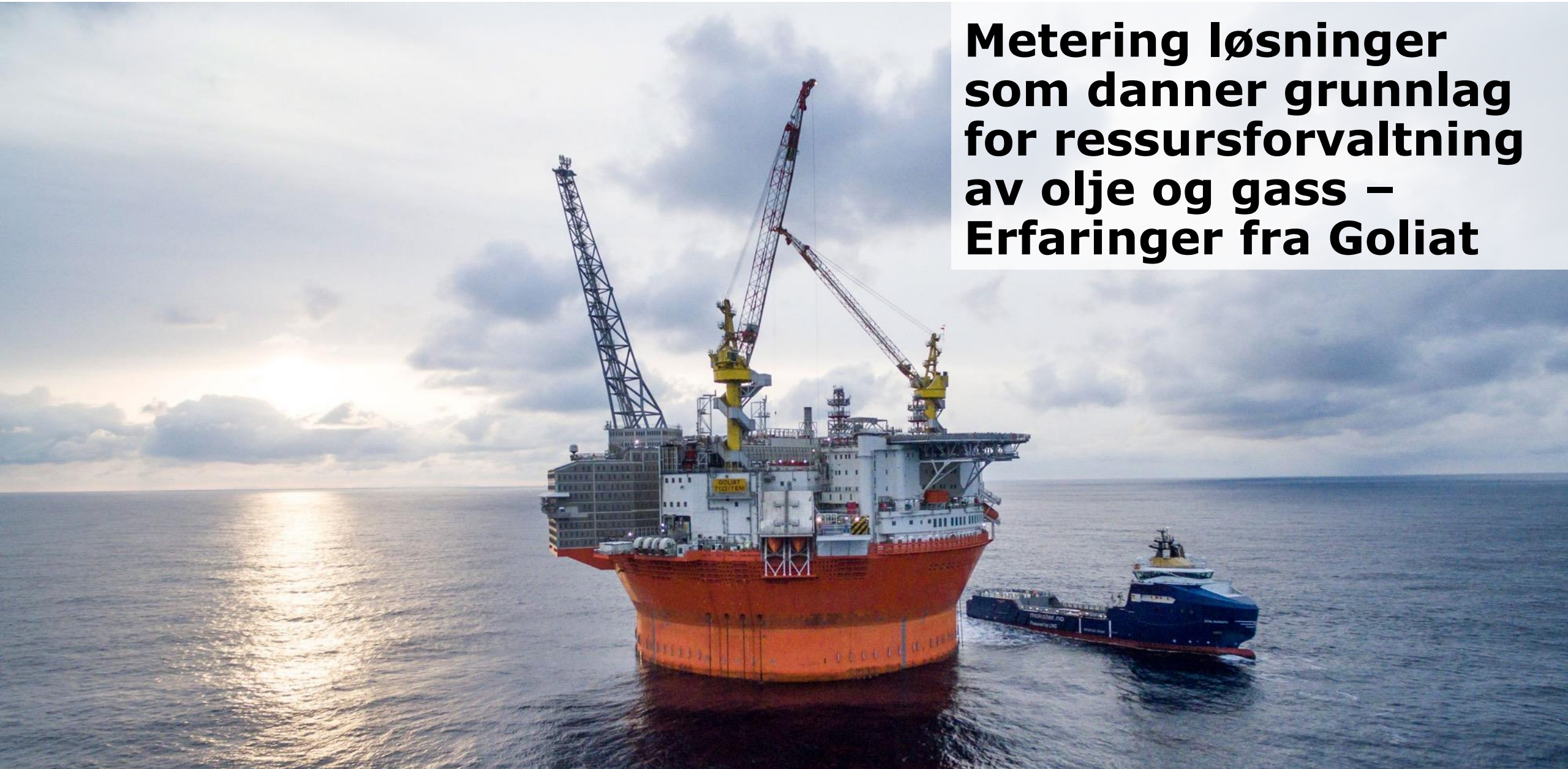
vår energi

Metering løsninger som danner grunnlag for ressursforvaltning av olje og gass – Erfaringer fra Goliat



Apr 6, 2018

Man må gjøre feil for å lære og derav bygge kompetanse

Kompetanse ???

vår energi

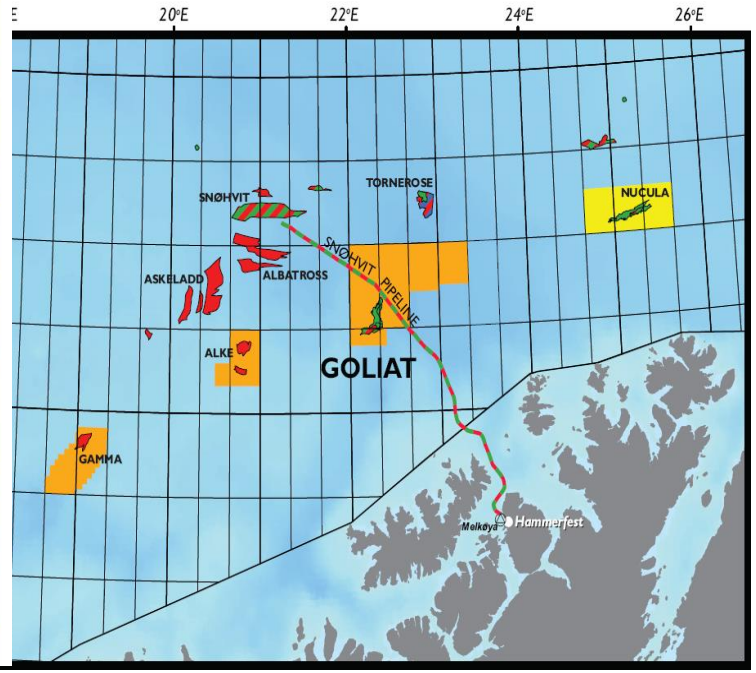
PL229 Goliat Lokalisering og eierskap

Lisens tildelt I 1997

- 85 km Nord Vest av Hammerfest
- 50 km Sør Øst av Snøhvit

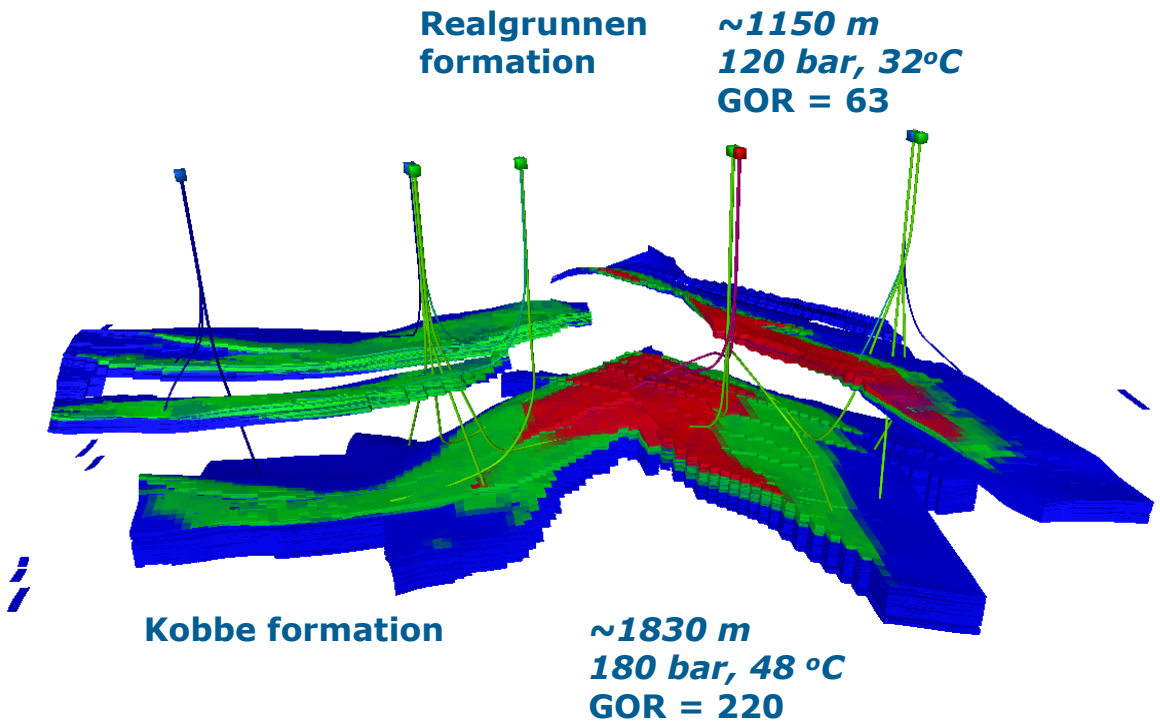
Eierskap

- Eni Norge AS (operatør) 65%
- Statoil Petroleum AS 35%



Reservoar karakteristikker for Goliat

Oppdaget I år 2000



Klargjøring for PUD

Pre-engineering by Chicago Bridge & Iron Company.
CB&I was a large engineering, procurement and construction (EPC) company with its administrative headquarters in the Woodlands, Texas. CB&I specialized in projects for oil and gas companies. CB&I employed more than 32000 people worldwide. In May 2018 the company merged into McDermott International.

Shallow Reservoir

- 1100-1850 meter below sea level
- Reservoir temperature: 32-48°C
- Reservoir pressure: 120-180 bara

Crude oil API gravity (@ 15°C)

- Realgrunnen: 32-34
- Kobbe: 42-45

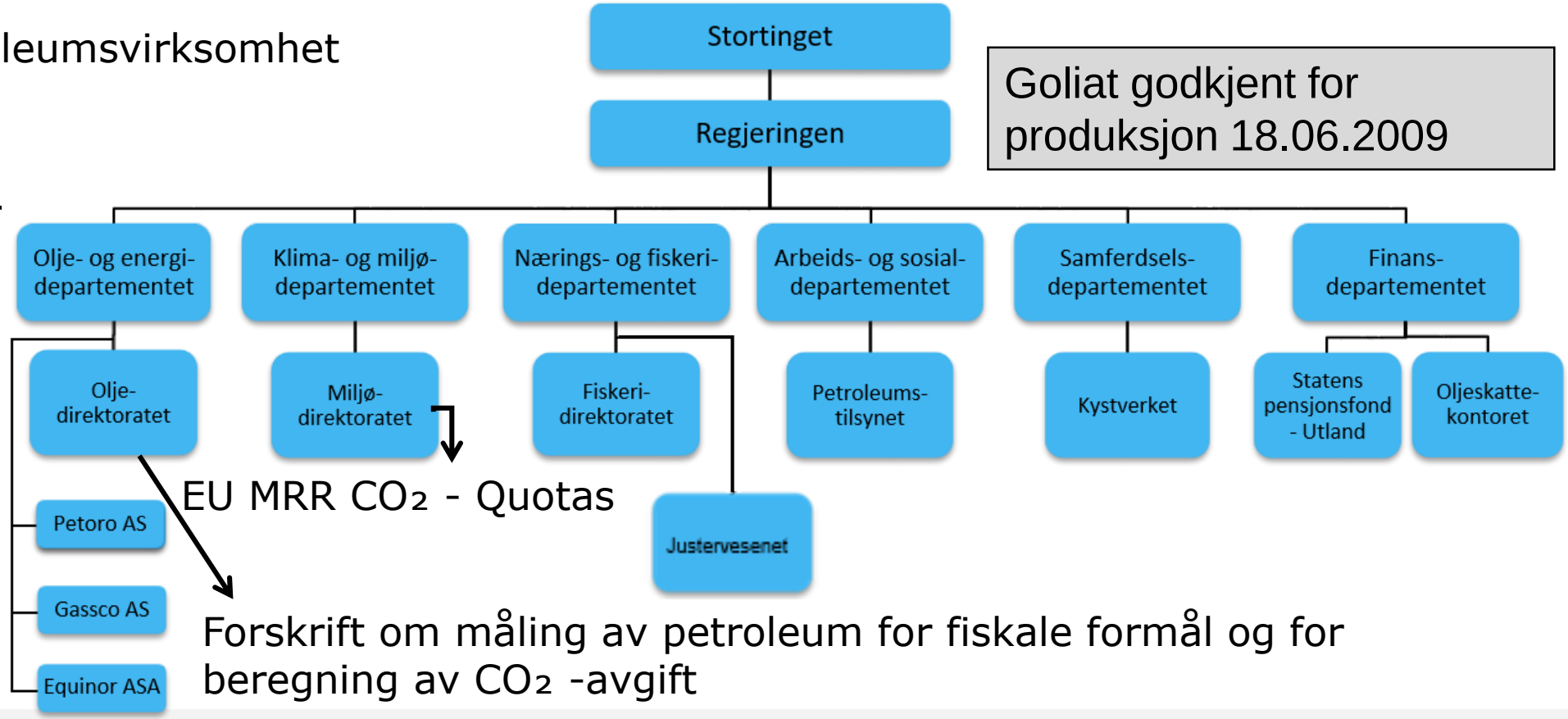
vår energi

Statlig organisering av petroleumsvirksomheten

Hovedmålet i petroleumspolitikken er å legge til rette for lønnsom produksjon av olje og gass i et langsiktig perspektiv. Verdiskapingen skal i størst mulig grad tilfalle det norske folk, forvaltningen skal skje innenfor forsvarlige rammer når det gjelder HMS og hensynet til det ytre miljø og sameksistens med andre næringer skal ivaretas

Forskrift til lov om petroleumsvirksomhet

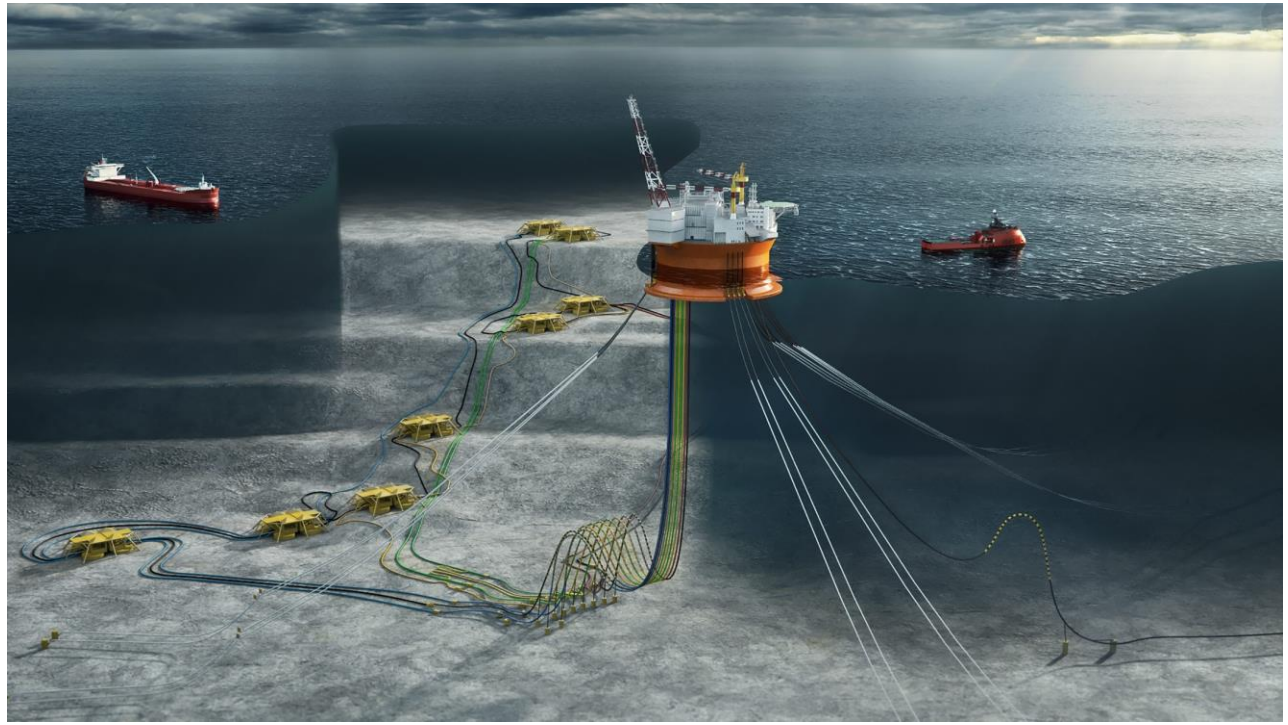
Oljedirektoratets hovedmål er å bidra til størst mulige verdier for samfunnet fra olje- og gassnæringen gjennom ei effektiv og forsvarlig ressursforvaltning. I dette arbeidet tar man hensyn til helse, miljø, tryggleik og til andre brukere av havet.



Goliat godkjent for produksjon 18.06.2009

vår energi

Engineering -> Start up



350-400 meter water depth

Detail engineering, construction, procurement, MC, etc. by *Hyundai Heavy Industries (*HHI) in Ulsan, South Korea.
HHI decided June 22, 2018 to temporarily shut down its *offshore* shipyard due to a lack of orders

Production start up 12 March 2016
dvs nesten 7 år etter godkjent PUD og 16 år etter oppdagelse.

vår energi

Goliat FPSO Design Basis

Main Topside Systems Process Capacities:

- Gas processing: 3.9 million Sm^3/day
- Oil production: 16 500 Sm^3/day (104 000 bbl/d)
- Produced Water: 12 000 Sm^3/day (76 000 bbl/d)
- Water injection (incl. PW): 20 000 Sm^3/day (126 000 bbl/d)

Oil Export Specifications:

- TVP: < 0.965 bara at 35° C
- Water in Oil: ≤ 0.3 vol % BS&W
- Max temperature: 50° C
- Max salt content: 150 ppm

Oil Storage capacity:

~ 1.036.000 bbl (95% filling grade)

107 meter in diameter and 75 meter tall

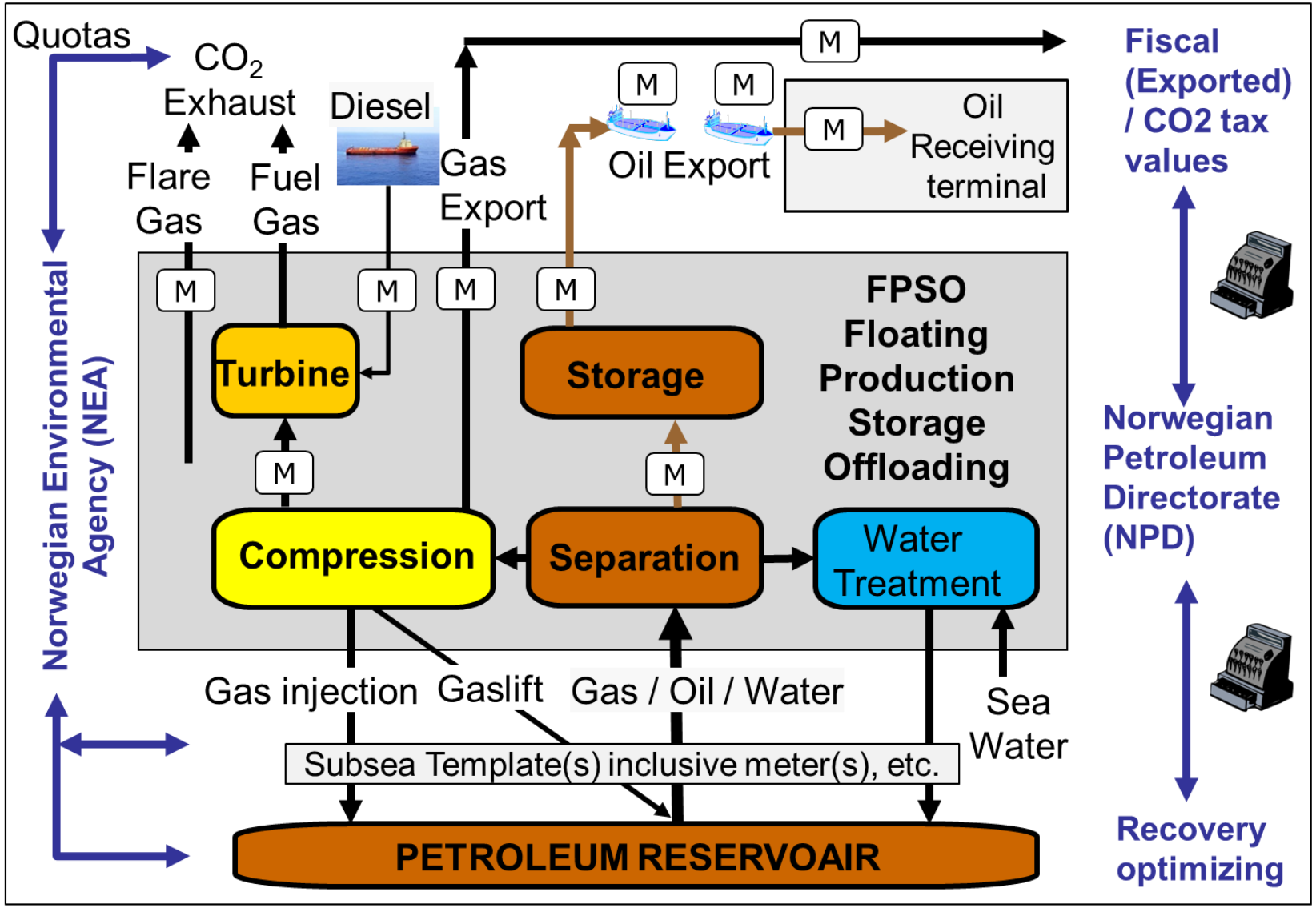
Flowlines

Production Loop:	12” ID
Gas Injection:	10” ID
Gas Lift:	6” ID
Sea Water Injection:	10” ID
Produced Water Injection:	10” ID

Reservoir	Type of well	No. of wells
Kobbe	Prod.	7
	WI	5
	GI	2
Realgrunnen Main/Central	Prod.	3
	WI	3
Realgrunnen South	Prod.	1
	WI	1
Total wells	(All types)	**22**

vår energi

Resource management, Norwegian Ministry of Petroleum and Energy



Metering / Måling?

Omfattende kompetanse krav!

- Styringssystem (QA)
  - Mål / krav
  - Data flyt
  - Usikkerhetsanalyser
  - Risikovurdering
  - Fysiske målinger
    - Mengde
    - Densitet
    - Trykk
    - Temperatur
    - Etc
  - Kalkulasjoner
  - Computere
  - Datakommunikasjon
  - Rapportering
- Kvaliteskontroll
- Forbedringsprosesser

vår energi

Reservoir management

The reservoir drainage is continuously optimized based on the observed reservoir response both on a field and a well level

- Pressure response
- Gas-to-oil ratio
- Watercut
- Recovery factor

Accurate rate allocation is essential for effective reservoir management

- Understanding the reservoir response
- Implementing correct production optimization actions

The overall mass balance is only as accurate as the input data

- Fiscal offloading data
- Cargo tank inventory level transmitters
- Oil production well multiphase flow meters
- Gas- and water injection well venturi flow meters
- Topside gas injection meter
- Topside gas lift meter
- Fuel and flare gas meters
- Separator flow measurements

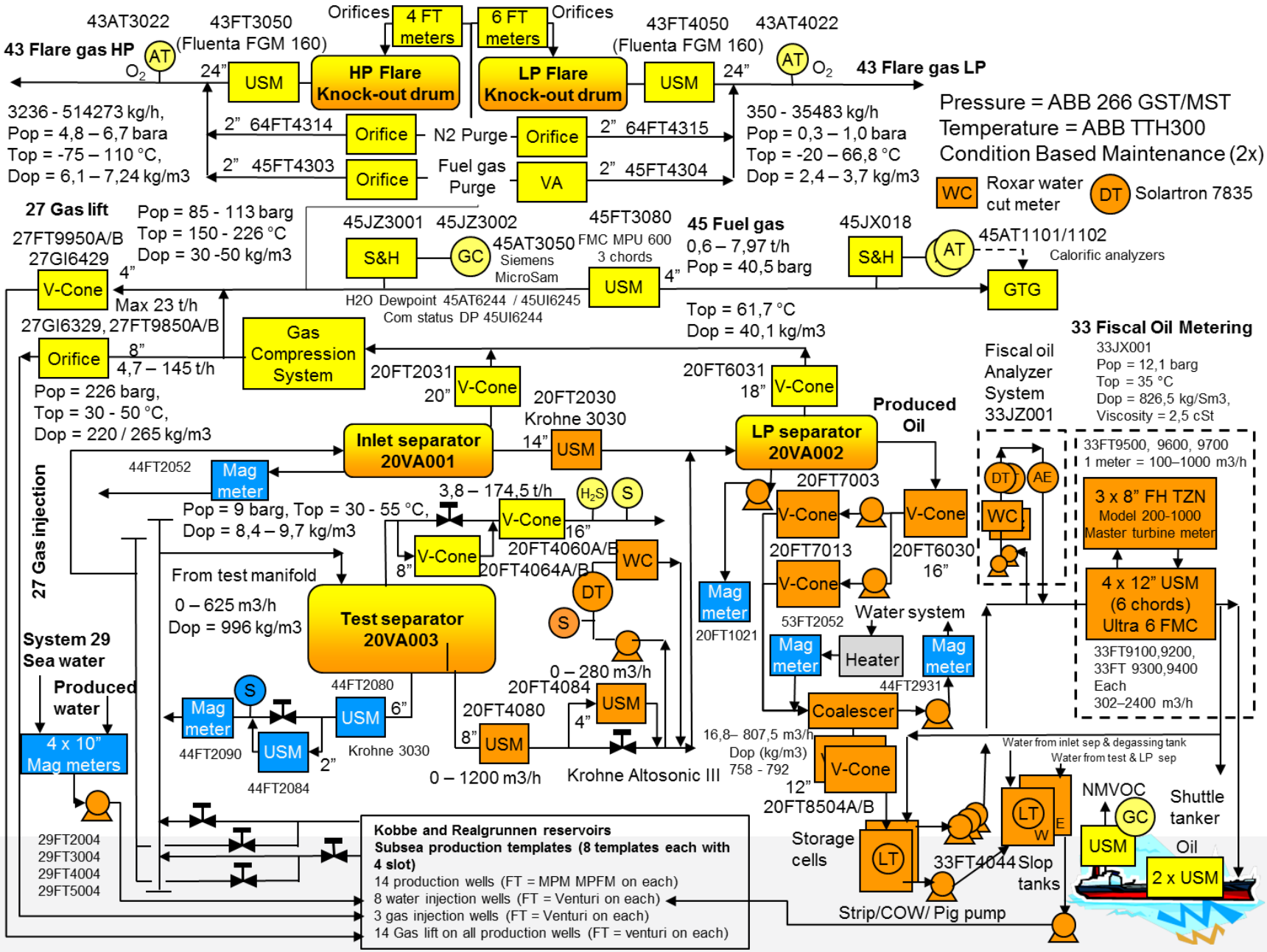
Dosing of production chemicals also require accurate flow rate measurements

- MEG, corrosion inhibitor, wax inhibitor, scale inhibitor

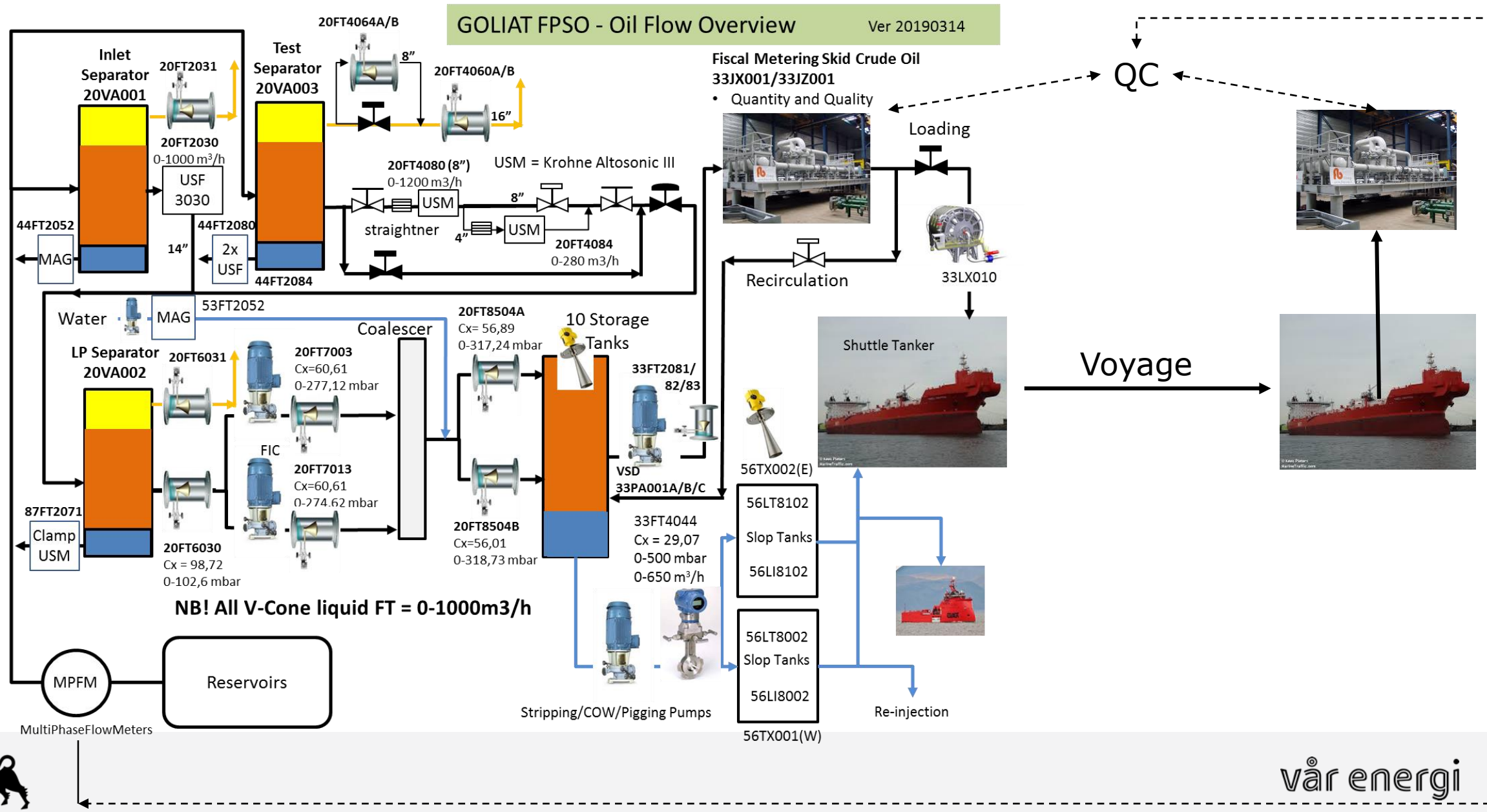
Common types of oilfield scale

- –$CaCO_3$ (calcite)
- –$BaSO_4$ (barite)
- –$CaSO_4.2H_2O$ (gypsum)
- –$FeCO_3$ (siderite)
- –FeS (several forms)
- –NaCl (salt)
- –$CaSO_4$ (anhydrite)

Eksempler på metering punkter på Goliat FPSO



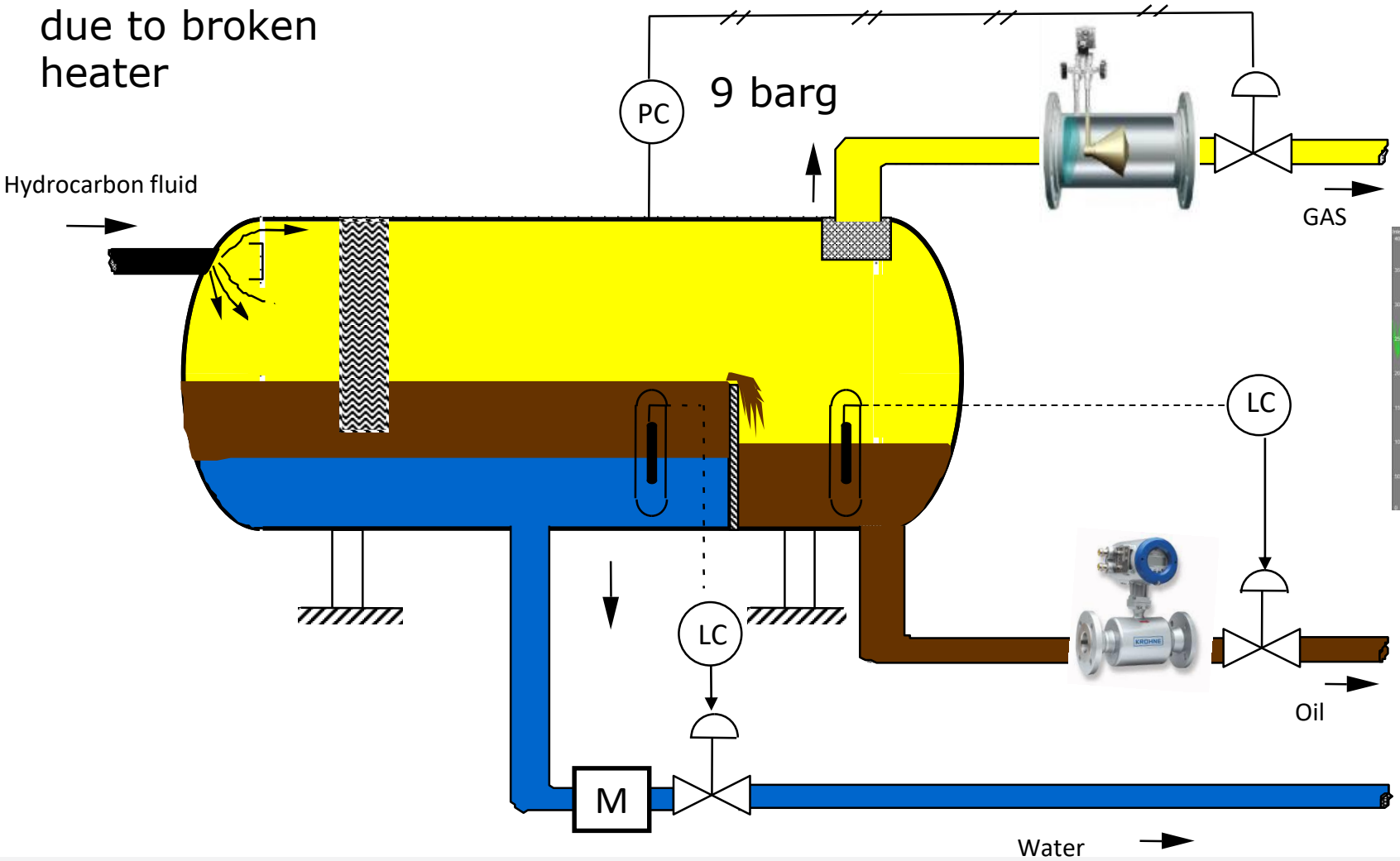
Goliat FPSO Oil Flow Overview

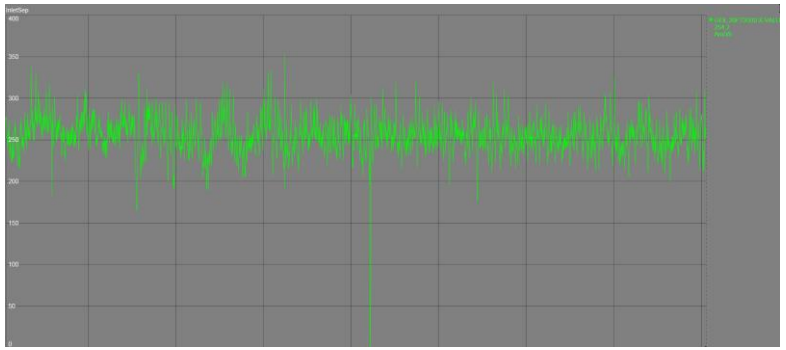


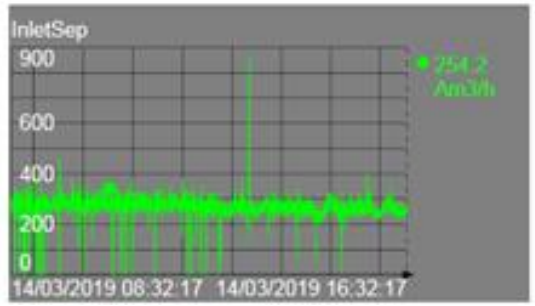
vår energi

Inlet separator

15 °C versus 55 °C due to broken heater







Oil Production

Tag no 20FE8504A

Oil Production

Producer

		On/ off	PL01	PL02	Oil Sm3/h
B-1	KP6				29.22
B-2	KP5				33.77
B-3	RMP3				32.14
B-4	RMP1				58.35
C-1	SMOP1				0.00
C-3	RCP1				36.82
C-4	RMP2				46.91
D-1	KP9				16.26
D-3	KP1				28.88
D-4	KP16				25.22
E-1	KP7				34.54
E-3	RSP1				18.15
E-4	KP4				43.04
	Total Vol Rate				446.83

PL-01 253.9 Sm3/h

PL-02 193.0 Sm3/h

Inlet

254.2 Am3/h

182.4 Sm3/h

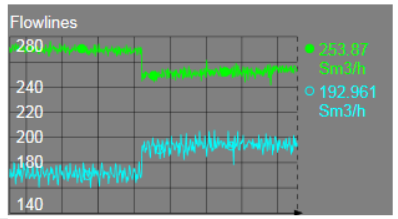
Test

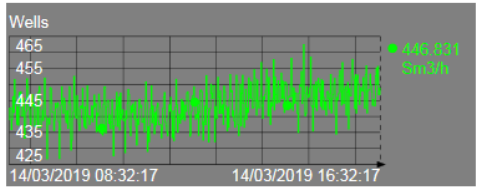
697.8 Am3/h

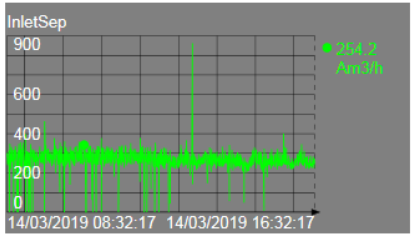
426.1 Sm3/h

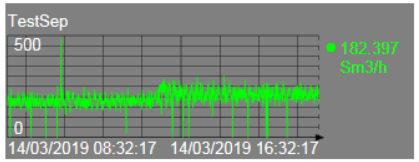
LP

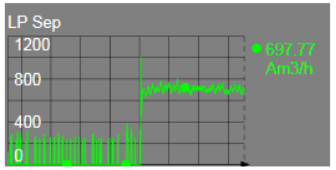
El Coalescer

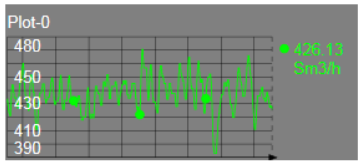










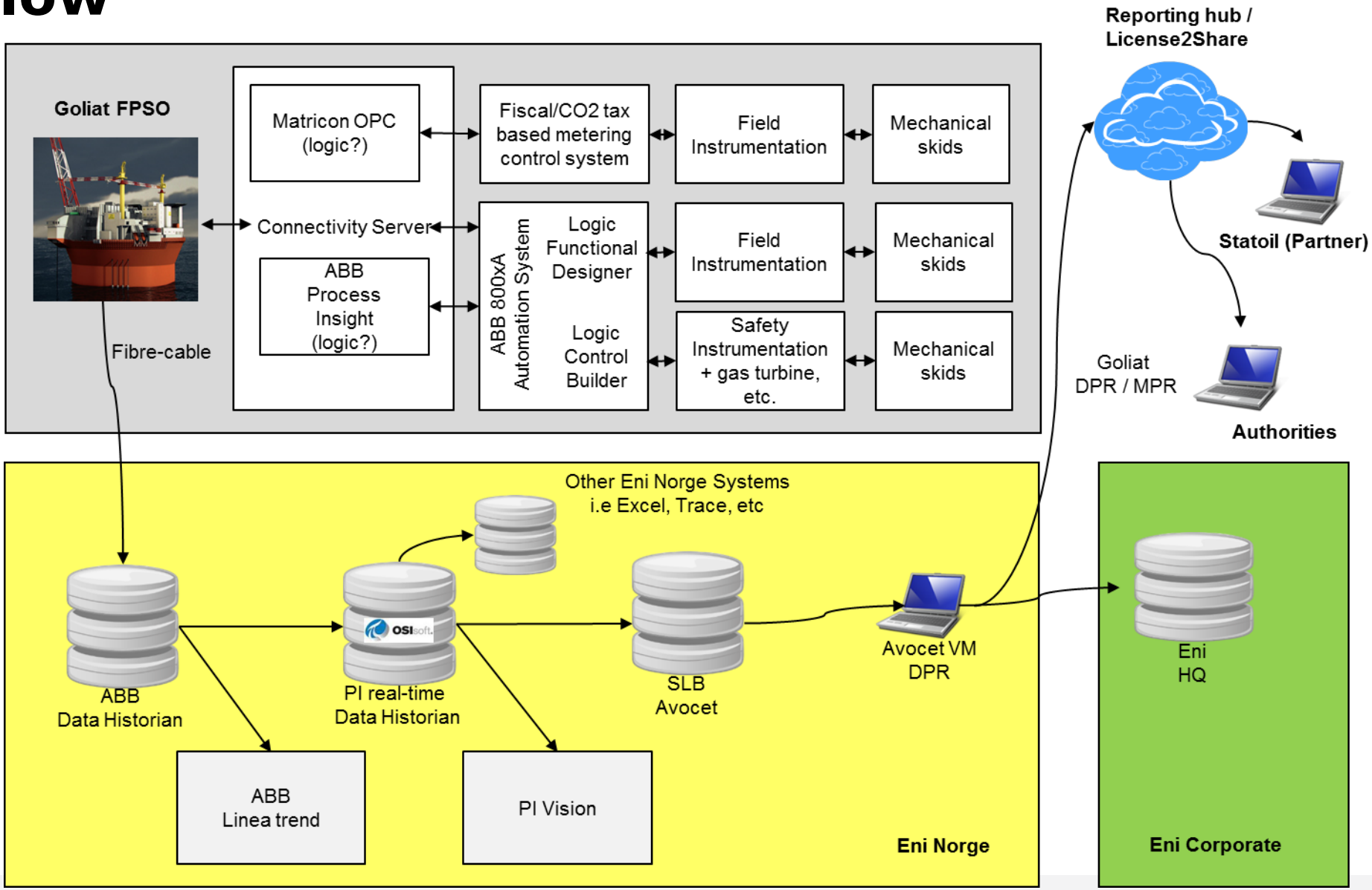


Previous Day

Wells	10652.8 Sm3
PL01	6518.0 Sm3
PL02	4134.2 Sm3
Inlet	6472.2 Am3
Test	4237.0 Sm3
LP	815.8 Am3
Coalescer	10515.8 m3
Tank Diff	9764.0 m3
Tank Dip	10233.8 m3

vår energi

Dataflow

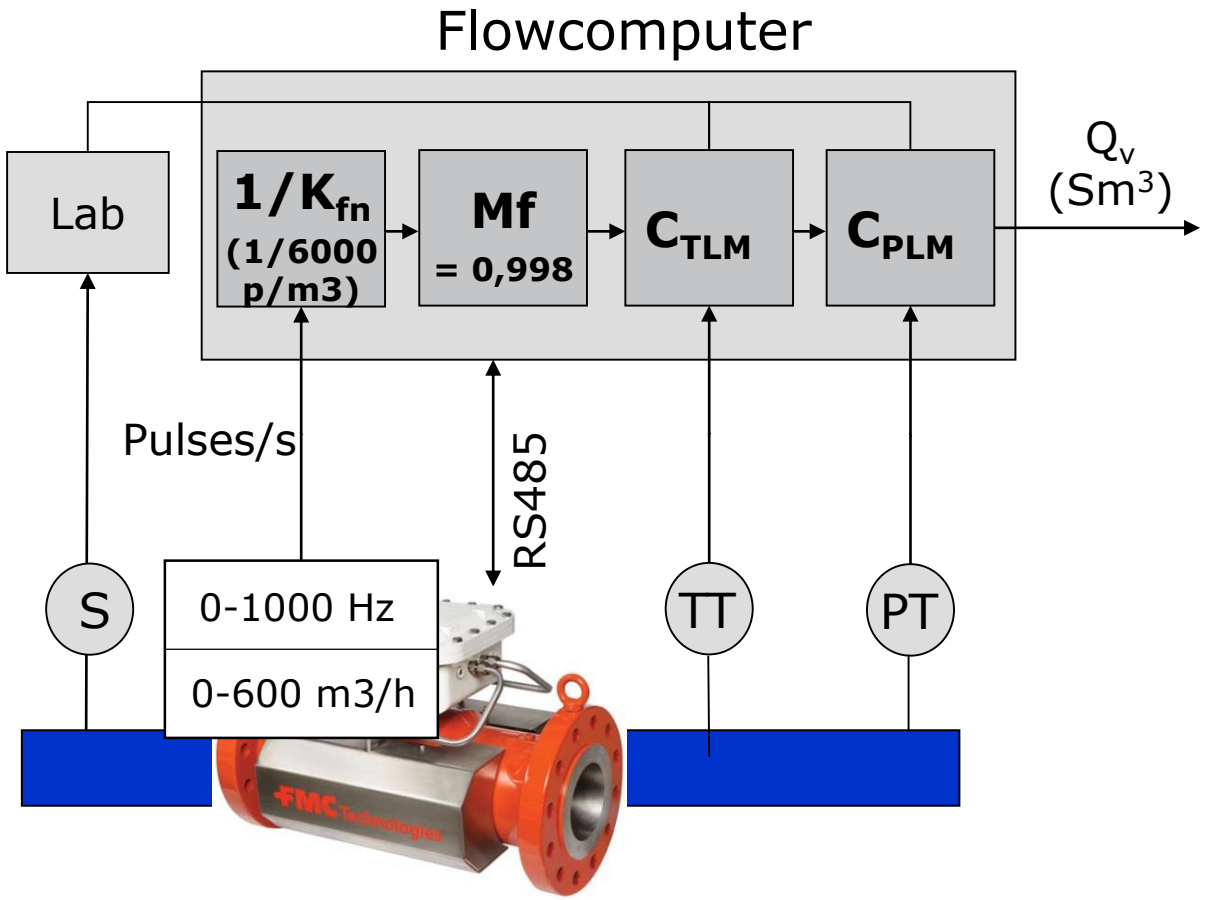

Goliat FPSO
Matricon OPC (logic?)
Fiscal/CO2 tax based metering control system
Field Instrumentation
Mechanical skids
Connectivity Server
ABB Process Insight (logic?)
ABB 800xA Automation System
Logic Functional Designer
Logic Control Builder
Field Instrumentation
Mechanical skids
Safety Instrumentation + gas turbine, etc.
Mechanical skids
Fibre-cable
Reporting hub / License2Share
Statoil (Partner)
Goliat DPR / MPR
Authorities
Other Eni Norge Systems i.e Excel, Trace, etc
ABB Data Historian
PI real-time Data Historian
SLB Avocet
Avocet VM DPR
Eni HQ
ABB Linea trend
PI Vision
Eni Norge
Eni Corporate

Dataflow

Mf = K_{fn}/K_{ft}

K_{fn}=Kfactor nominell
K_{ft}=Kfactor true

Output = 1 puls / 0,166 litre



V-Cone meter

Tag no 20FE8504A

Goliat Development Project

GOLIAT

COMPANY RETURN CODE:

Accepted	1 ☐
Accepted with comments incorporated - revise and Resubmit	2 ☐
Not Accepted - Revise and resubmit	3 ☐
Issued for Information	4 ☐
Interface information as clouded is accepted and frozen	5 ☐

Signed: ..... Date: .....

Rev	Date	Description	Prepared	Verified	Approved
C01	26.05.2014	Issued for Information	ANMO	JUSO	PBCH

eni norge | HYUNDAI HEAVY INDUSTRIES CO.,LTD. | ABB | ABB AS

Document Title: Calibration Certificates V-Cone Flow Meters

Document Number: 229A-HHI-EJ301-J-VB-2207 C01

PO No. : WE104MA3AB01 | Tag no: See Page 2

Supplier Doc. No		Sup. Rev.	Proj. Code	Orig. Code	PO Pkg ref.	Disc Code	Doc. type	Seq. no	Rev
508-CAL									

McCrometer, Inc.
V-Cone - Calibration Report

Serial Number:	11-5577	Meter Inside Diameter(inch):	12.094
Calibration Date:	06-06-2012	Cone Outside Diameter(inch):	8.968
Report Date:	06-06-2012	Beta Ratio:	0.6709
Model Number:	VW12-136-PED	Average Cd:	0.8150
Description:	Null		
Sold To:	Null		

	Temp °F	Time sec	Weight LBS	Actual Rate GPM	ΔP inWC	Reynolds /1000	Cd
1	84.0	31.078	10017.00	2327.75	45.399	721.95	0.8251
2	84.0	30.651	7629.00	1797.52	27.381	557.50	0.8204
3	84.0	30.427	5712.00	1355.75	15.666	420.49	0.8181
4	84.0	30.876	3903.00	912.91	7.145	283.14	0.8157
5	84.0	31.757	2920.00	664.04	3.853	205.95	0.8079
6	84.0	30.705	1825.00	429.24	1.631	133.13	0.8027
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

CALIBRATION 874 ☒ REVIEWED ☐ WITNESSED BY: LAA DATE: 25/10-12

REVIEWED & WITNESSED on behalf of 1856 25 OKT. 2012

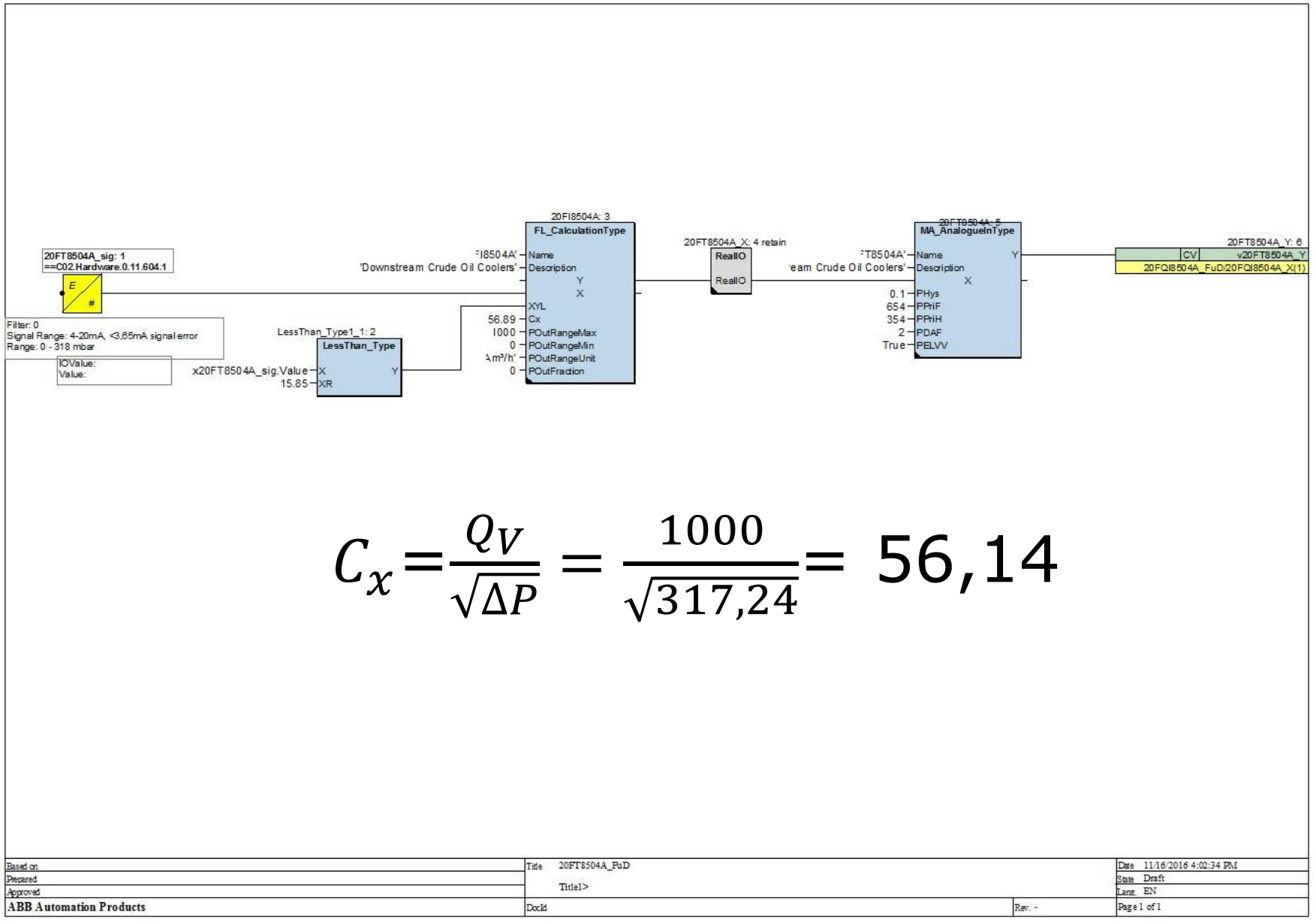
Certified By:	P. Hobbs	Certification Date:	6-6-12
Calibration Fluid:	WATER	Record Filename:	11-5577

This calibration was performed on a gravimetric flow stand, traceable to the National Institute of Standards and Technology, USA. The flow measurement uncertainty of the facility is estimated to be +/-0.15% of reading based on the cumulative uncertainties of time, weight and temperature measurements combined with other systematic uncertainties.

McCrometer, Inc.
3255 W. Stetson Avenue, Hemet, CA 92545-7799
Phone: (951) 652-6811 Fax: (951) 652-3078
e-mail: info@mccrometer.com Web Site: http://www.mccrometer.com
Hours: 8 a.m. - 4:30 p.m. PST, Monday-Friday

vår energi

Functional designer



$$C_x = \frac{Q_V}{\sqrt{\Delta P}} = \frac{1000}{\sqrt{317{,}24}} = 56{,}14$$

Functional designer

1.3 Function block schematics

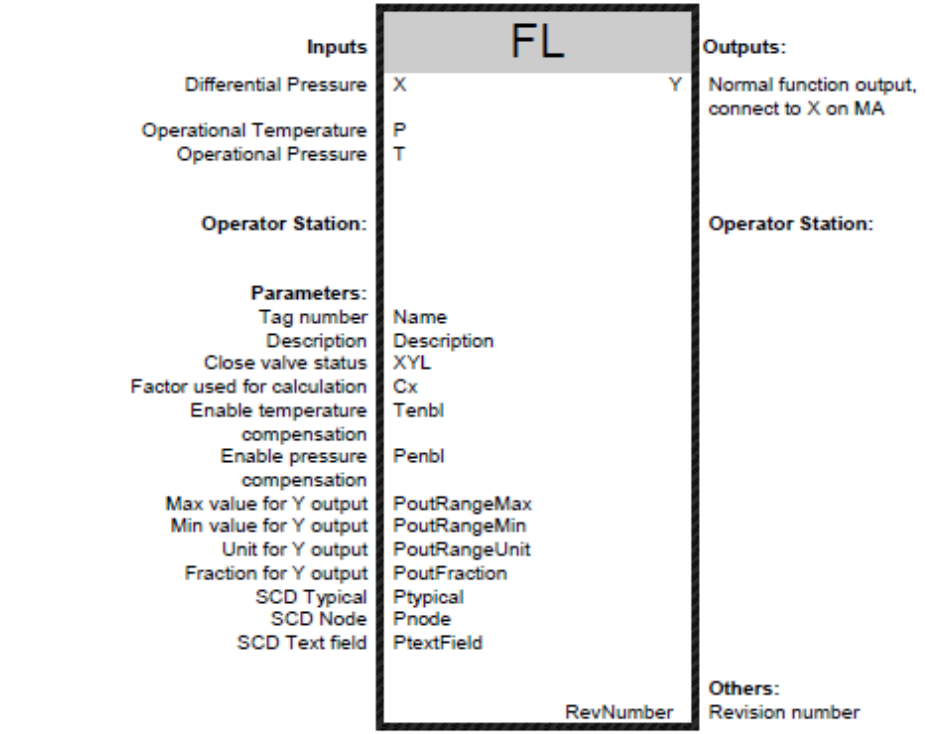


Table 1.2 FB Schematic

Function block intended for execution of simple signal as well as control variable processing. Flow (Sm^3/h) of gas/liquid is calculated based on differential pressure with optional gas density compensation for operational temperature and pressure .

Algorithm:

$Y = Cx * \sqrt{X * (P + 1.01325)/(T + 273.15)}$

Where:

Cx = Measuring constant given by the pressure drop across the actual orifice plate.

X = Diff. pressure transmitter signal (mbar).

T = Temperature (degC).

P = Pressure (barg).

vår energi

V-Cone meter

Tag no 20FE8504A

$$Q_{\frac{m^3}{h}} = 3600 * \frac{\pi}{4} * \sqrt{\frac{2}{\rho} * \frac{{D_m}^2 * \beta^2}{\sqrt{1-\beta^4}}} * \sqrt{\Delta P_{Pa}} * C_d$$

$$C^* = 1.1107 \times \frac{{D_{(m)}}^2 \times \beta^2}{\sqrt{1-\beta^4}} \times C_d \qquad \beta = \sqrt{1 - \frac{d_{mm}}{D_{mm}}}$$

$$Q_{\frac{m^3}{h}} = 3600 * C^* * \sqrt{\frac{\Delta P_{Pa}}{\rho}} \qquad d_{mm} = D_{mm}\sqrt{1-\beta^2}$$

$$Q_{\frac{m^3}{h}} = C_x * \sqrt{\Delta P_{mbar}}$$

$$C_x = \frac{Q_V}{\sqrt{\Delta P}} = \frac{1000}{\sqrt{317{,}24}} = 56{,}14$$

V-Cone® Application Sizing

Serial #	11-5577	Fluid	HYDROCARBON LIQUID		
Tag	20FE8504A	Fluid State	LIQUID		
P.O. Ref.		End User			
Model	VW12-136-PED	Market		Mark/App Code	
		Application			

Description	
Note	

C_d	0.8150		q	max. Flowrate	1000	m3/H	McCrometer Eng.	RuPe
P_f	3.3	barG	Re	max. Reynolds	6.137e+05			
T_f	35	°C	V	max. Velocity	3.748	ms		
ρ	762.2	kg/m3 ⇐	ΔP	max. Dp	317.24	mbar		
μ	1.430	cP ⇐	ΔP	min. Dp	1.6185	mbar		
G			D	Meter I.D.	12.094	in		
Z			d	Cone O.D.	8.9680	in		
Y			β	Beta Ratio	0.6709			
k				Turn Down	14			
C_P								
Mw	158.9	⇐						
P_b								
T_b								
Z_b								
P_{atm}	14.696	psi						
P_c								
T_c								
F_a	1.000							
aPE	D 6.7e-06	d 6.7e-06						
P_v								
P_{loss}	146.4	mbar						

⇐ Entered value.

	Re	Cd	Velocity ms	Gas. Exp. Y	ΔP mbar	Flowrate m3/H
1	6.137e+05	0.8150	3.748		317.24	1000.0
2	5.504e+05	0.8150	3.362		255.15	896.83
3	4.871e+05	0.8150	2.975		199.82	793.65
4	4.238e+05	0.8150	2.588		151.24	690.48
5	3.605e+05	0.8150	2.201		109.42	587.30
6	2.971e+05	0.8150	1.815		74.353	484.13
7	2.338e+05	0.8150	1.428		46.039	380.95
8	1.705e+05	0.8150	1.041		24.478	277.78
9	1.072e+05	0.8150	0.6545		9.6713	174.60
10	4.384e+04	0.8150	0.2677		1.6185	71.429

Table based on one flow condition (P, T , Z , k ...) V40 Version 2.0

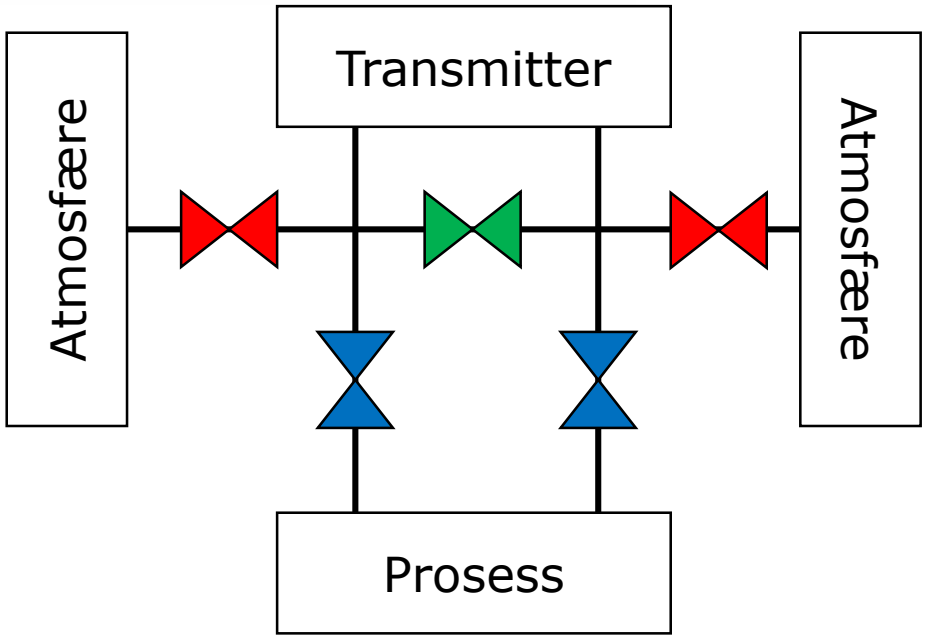
Record Start Date	11/28/2011
Print Date	09-23-2012

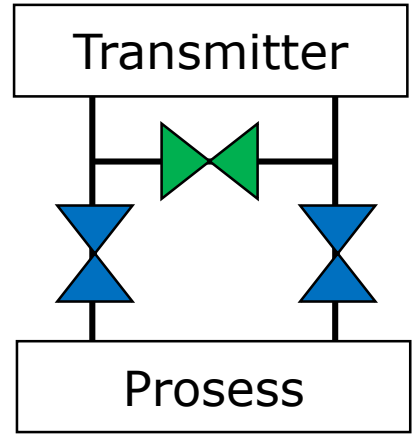
McCROMETER

vår energi

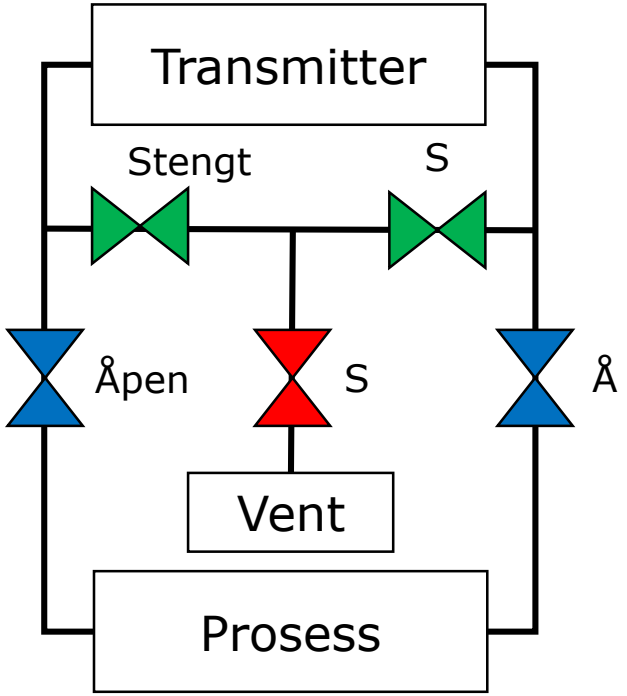
Instrument tubing, valve manifolds, etc.

Isolering
Vent / Test
Utlikning

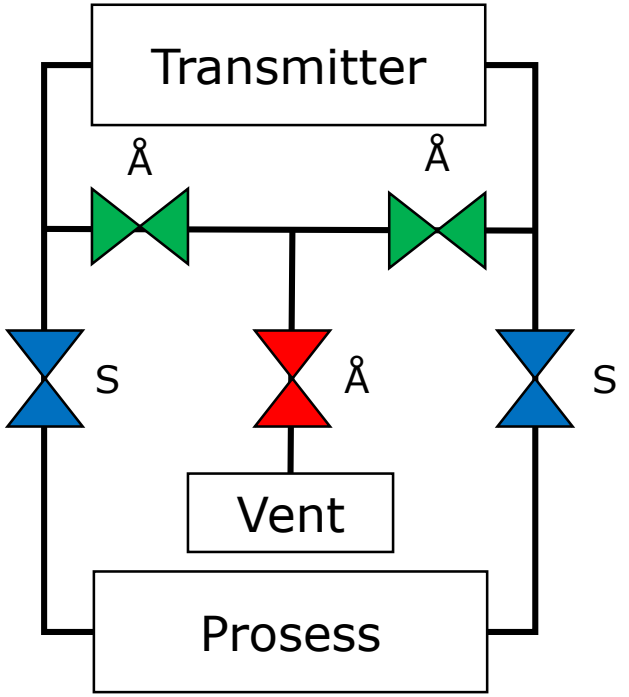




Normal operasjon

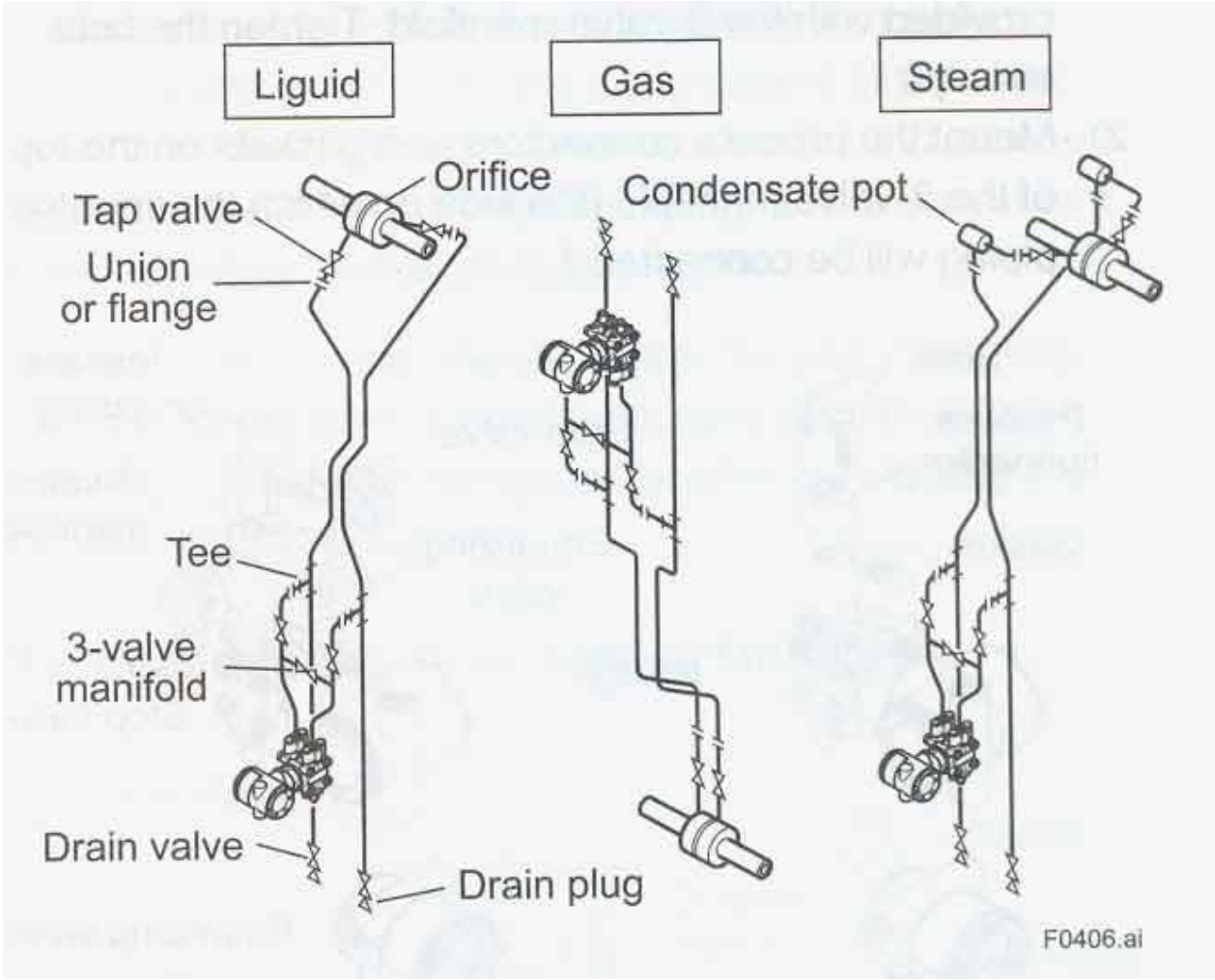


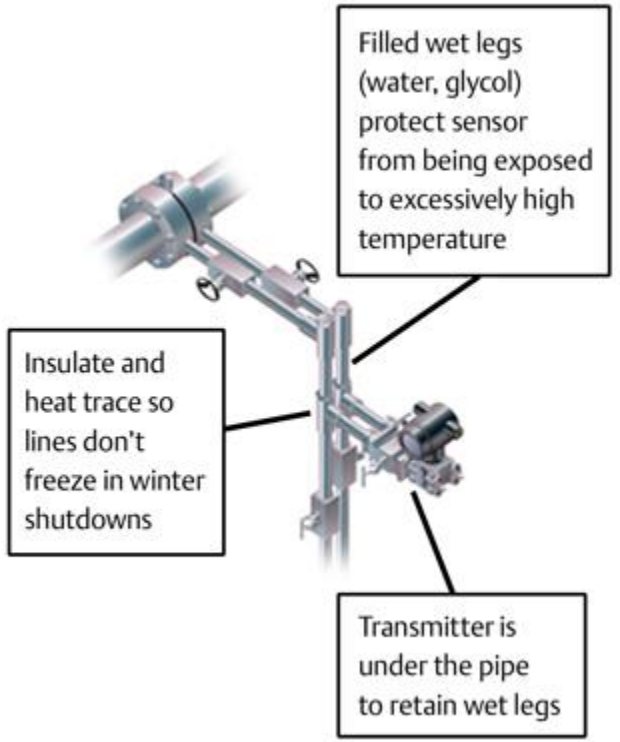
Ikke i operasjon



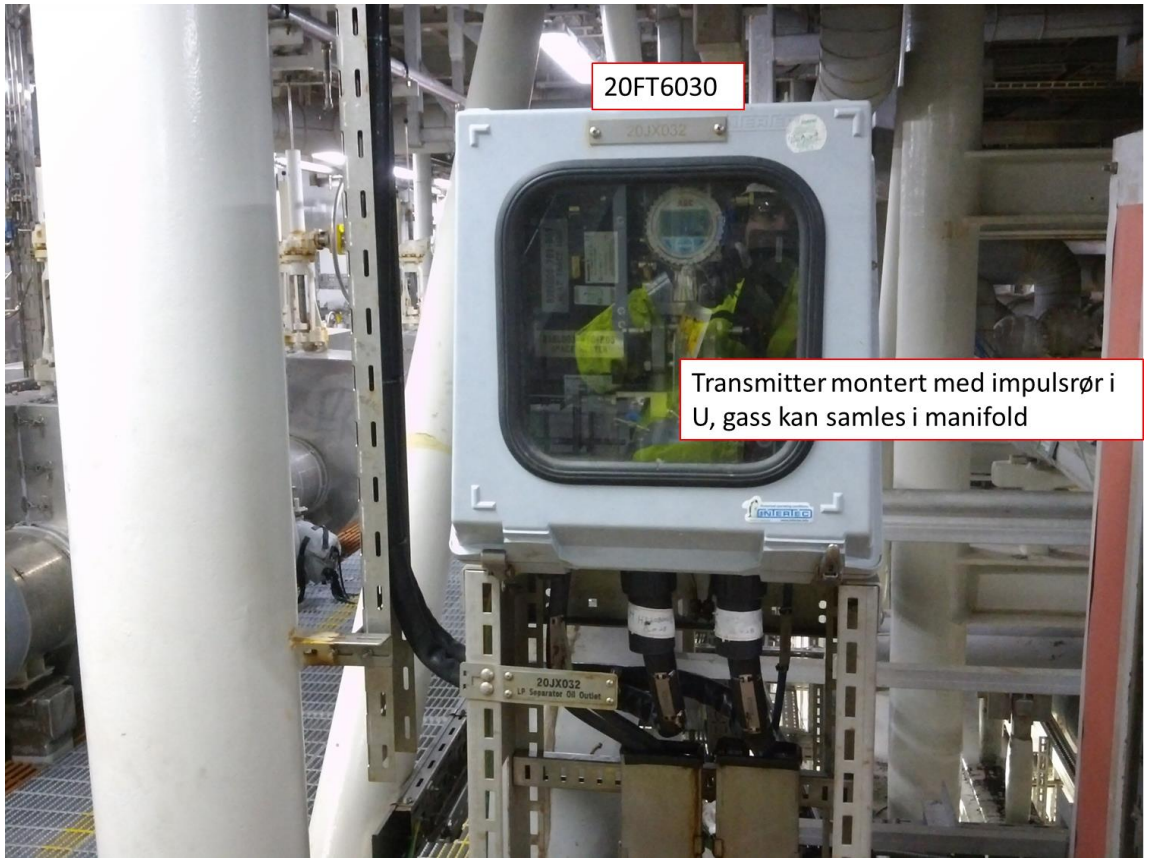
vår energi

Impulse tubes + valve manifolds, general recommendations

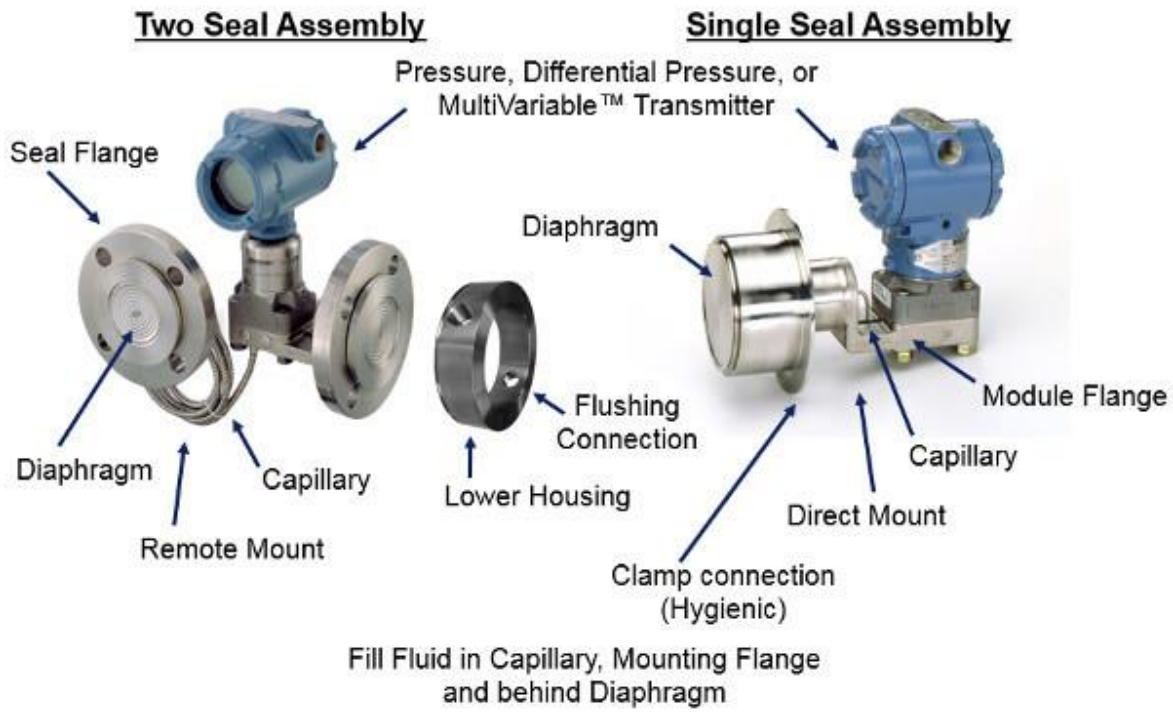




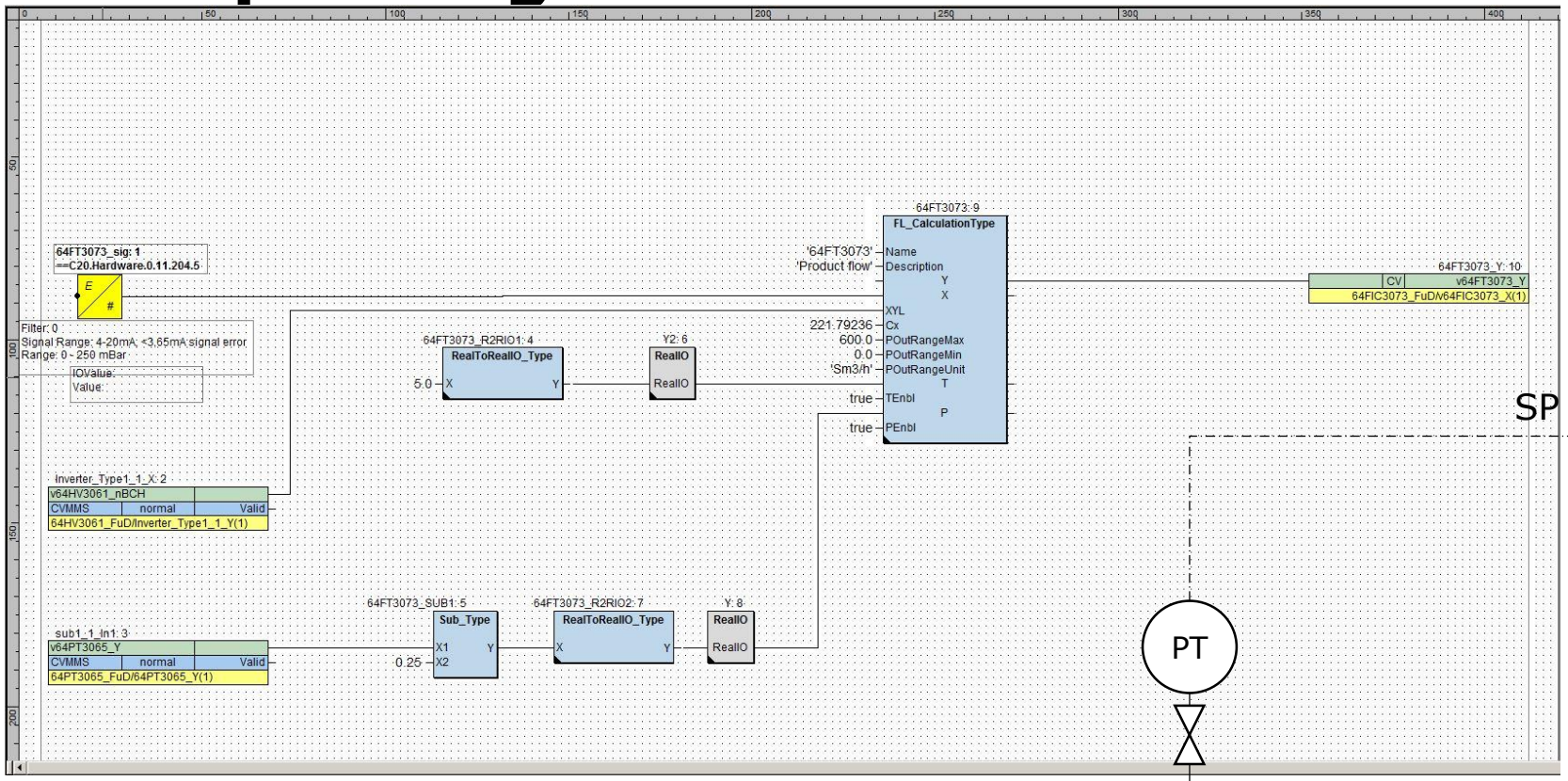
Oil Production, oil out of LP separator, Tag 20FT6030

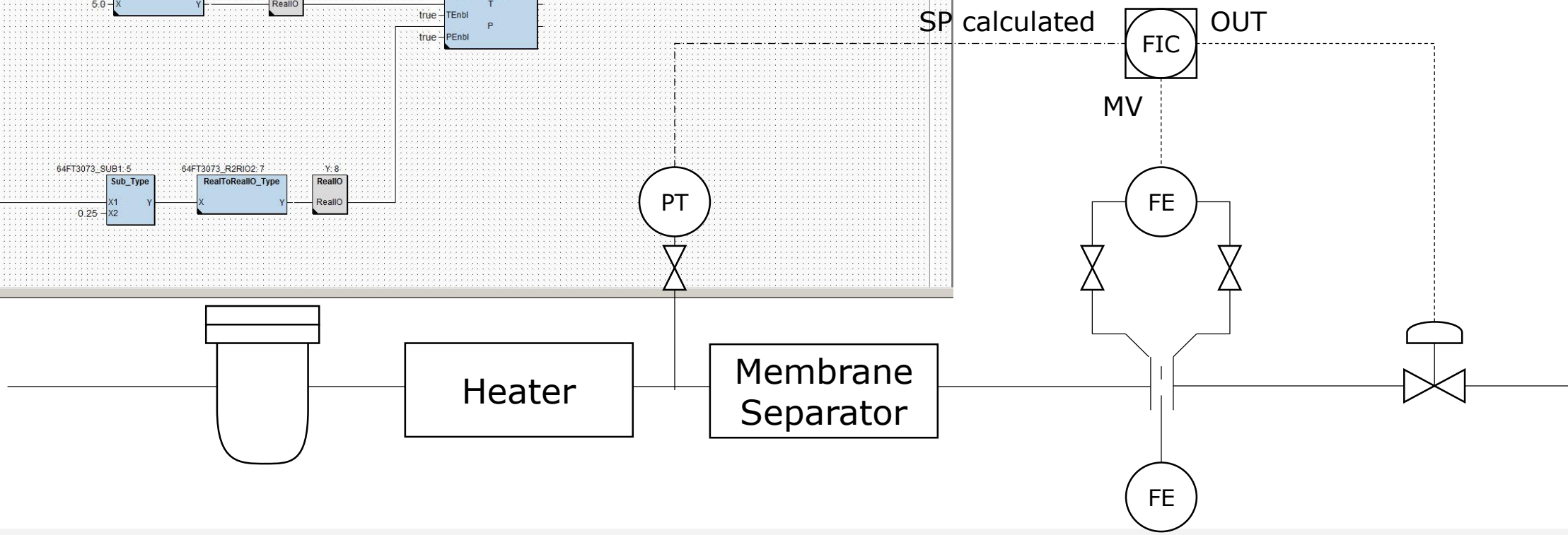


Pressure transmitters with remote seal



Simplified gas flow measurement based upon DP





Simplified gas flow measurement based upon DP

$$Q_S = C_x * \sqrt{\frac{\Delta P}{\rho_s}}$$

Po = Absolute pressure, Paa / bara
To = Absolute temperature, Kelvin

$$Q_S = C_x * \sqrt{\frac{\Delta P * P_0}{T_o}}$$

Calculate Cx factor when Q_{vst} ,ΔP, ρ_o, P_o and T_o are;
Q_{vst} = 750 Sm3/hr @ ΔP = 250 mbar, P_o = 9,31325 bara and T_o = 318,15 K (= 45 °C)

$$C_x = \frac{Q_s}{\sqrt{\frac{\Delta P * P_0}{T_o}}} = \frac{750}{\sqrt{\frac{250 * 9{,}31325}{318{,}15}}} = 277{,}24045$$

Simplified gas flow measurement based upon DP

ABB Power and productivity for a better world™

Calculation Report

Generated by SolveDP V1.80.35

Customer:	–	ABB LSU Name/Ref:	ABB Norway
Customer Ref:	–	ABB FF Ref:	TBA
Project Name:	Goliat	Calculation:	(for info) 04/07/2018 23:14:13
Tag No(s):	64-FE-3073	Calculated By:	Rachael Gorman
Item 1	**FPD150 Orifice Plate for Flow Measurement**		

Input data

Fluid:	Mixture
Operating Pressure:	8,3 bar [G]
Operating Temperature:	45 °C
Operating Density:	9,9279 kg/m³
Z Factor:	1
Operating Viscosity:	1,866E-05 Pa.s
Isentropic Index:	1,398
Design Pressure:	(none specified)
Design Temperature (max):	(none specified)
Design Temperature (min):	(none specified)
Meter Max Flow:	750 Sm³/h
Maximum Flow:	675 Sm³/h
Normal Flow:	600 Sm³/h
Minimum Flow:	187,5 Sm³/h
Pipe N.B. & Schedule:	2" / 10S
Pipe ID:	54,8 mm
Pipe OD:	60.3 mm
Pipe Wall Thickness:	2,75 mm
Pipe Material:	316 / 316L Stainless Steel
Element Material:	316 / 316L Stainless Steel
Plate Thickness:	3 mm

Calculated Results (ISO 5167:2003)

Plate Type & Tappings:	Concentric square edged - Flange taps
DP @ meter max:	250 mbar
DP @ maximum:	201.75 mbar
DP @ normal:	158,94 mbar
DP @ minimum:	15.285 mbar
Permanent Pressure Loss @ meter max:	185.35 mbar
Pipe ID @ 45 °C:	54,8226 mm
Flow Velocity @ meter max:	10.58 m/s
Beta:	0,4906
Co-efficient of Discharge:	0,6055
Expansibility Factor:	0,9929
Reynolds Number @ meter max:	308,640
Reynolds Number @ normal:	246,910
Minimum Plate Thickness:	0,4 mm
Bore at Operating Temperature:	26.9 mm
Machined Bore:	**26.89 mm**

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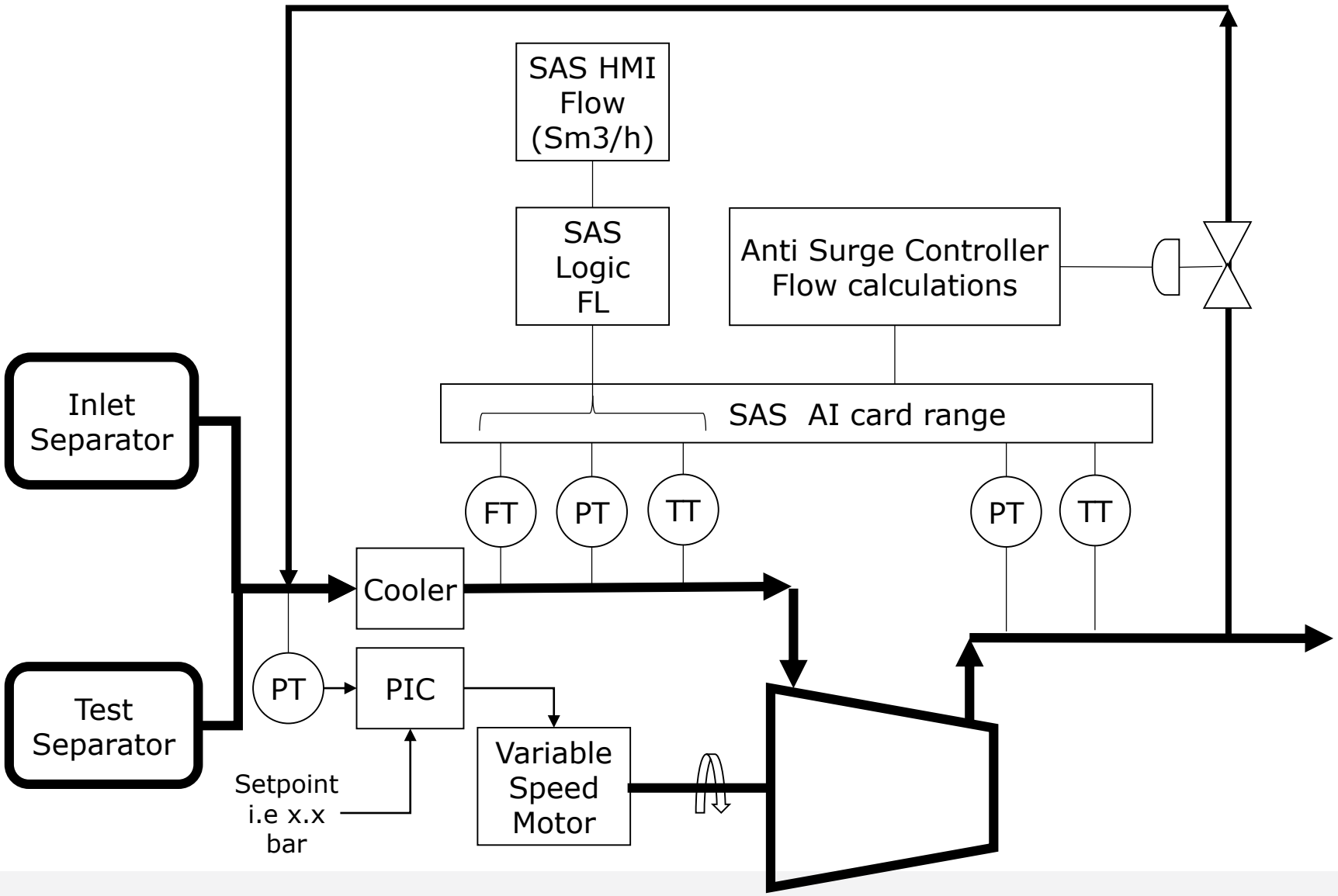
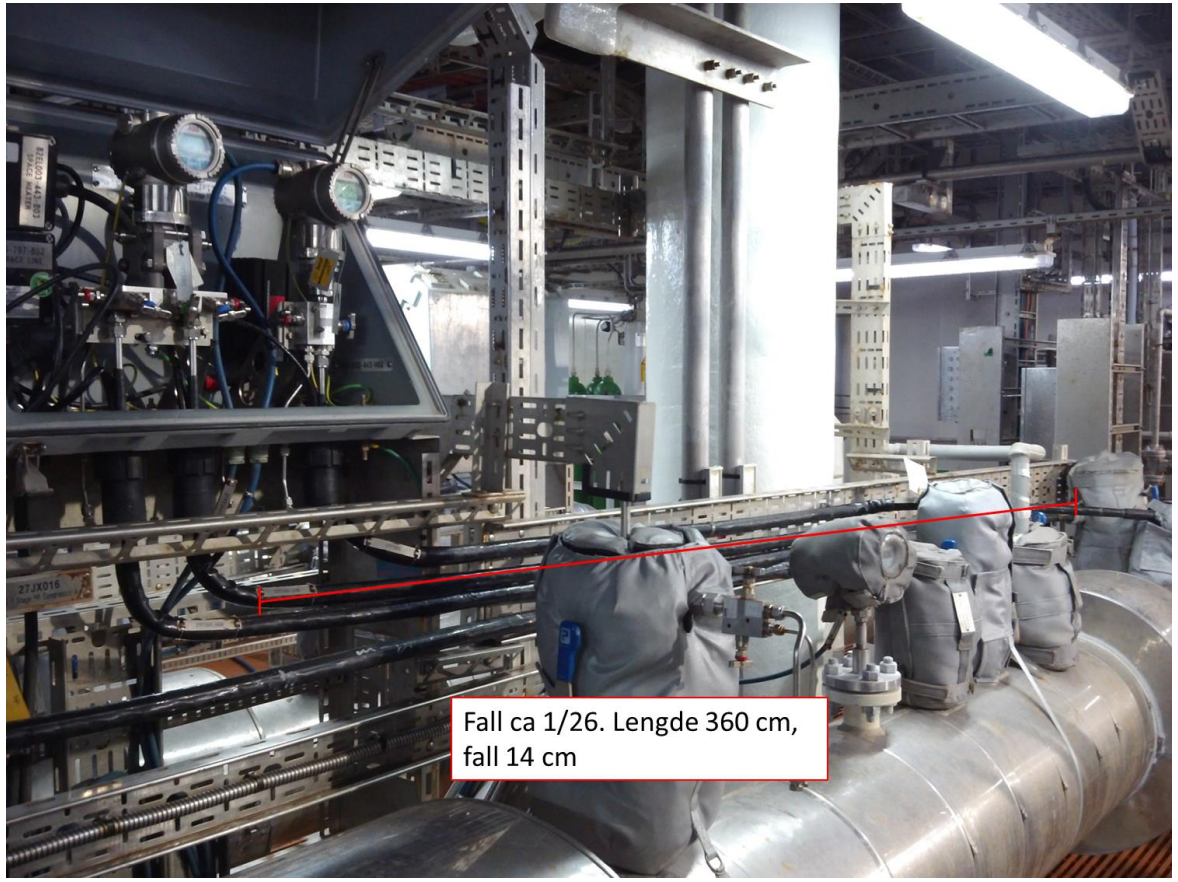
Anti Surge Control



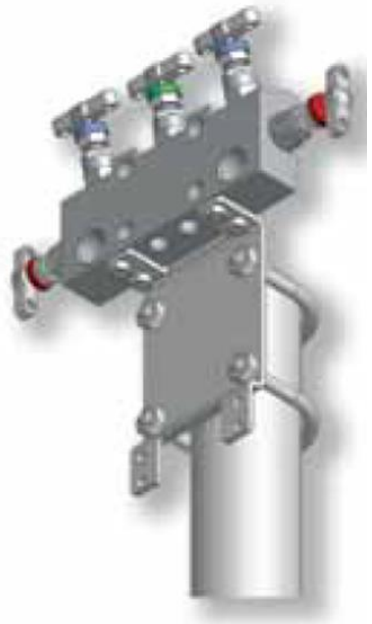
1st Stage HP Compressor A



Instrument valve manifolds + Block heater

Raychem® self-regulating electric tracer lowers heat output as the bundle gets warmer.
- High-temperature tracers are used to maintain process temperatures up to 250°F (121°C)
- High and low temperature tracing models available.
- Features include ATEX, FM®, and CSA® approved tracer for use in hazardous areas.

Fluoropolymer tracer jacket with tinned copper braided shield



ıe manifold to provide efficient conduction heating, with a self-
ıpplied with a cable length of 1m.

Attribute	Value
Material	Aluminium, sea water resistant
Size	90 x 40 x 30 mm
Voltage	110V - 265V
Rating	50W
Type of Protection	IP68, NEMA 4X
Explosion Proof	II 2 GD EEx d IIC T4
Certificate Number (PTB)	02 ATEX 1116X

MESC	Description	Part Number
609870.050.1	Electrical Heater	CONTACT PARKER*

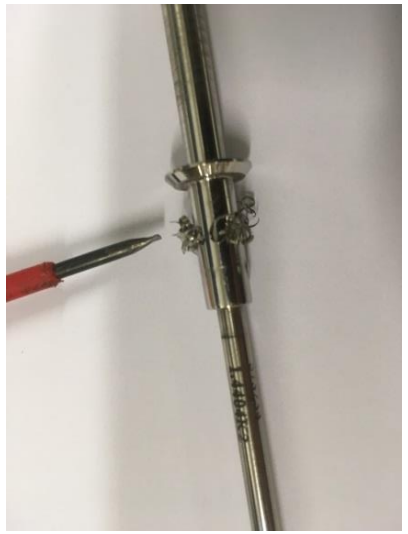
* **Note:** Heating requirements can vary depending on service. To contact the division, please telephone 00 44 1271 313131, or email: ipde_technical@parker.com

Variable Area (VA) Meters

DK37 M8

H250 M9

H250 M40R



Måling av kjemikalier, eks MEG
Luft / gass – kompressorer, etc

1, Kalibrert på annet medium enn de måler på
2, Manglende trykk og temperatur kompensering

Kan korrigeres for ved hjelp av software faktorer

Volume rate of flow

$$\rho_v = \frac{\alpha}{\rho_m} * D_S * \sqrt{g * m_S * \rho_m * \left(1 - \frac{\rho_m}{\rho_S}\right)}$$

V_S: Volume of float
A: Annular gap area
A_S: Cross-sectional area of float at the reading line
m_S: Mass of float
ρ_S: Density of float
ρ_m: Density of liquid product
c_W: Drag coefficient
v: Flow velocity of liquid product
D_k: Inside diameter of cone at reading line
D_S: Diameter of float at reading line

Volume Flowrate

$$K_F = \sqrt{\frac{(\rho_{f1} - \rho_2) \cdot \rho_1}{(\rho_{f1} - \rho_1) \cdot \rho_2}}$$

K_F = Correction Factor
ρ_{f1} = Density of the float being used
ρ_1 = Density of the calibration liquid
ρ_2 = Density of the new liquid

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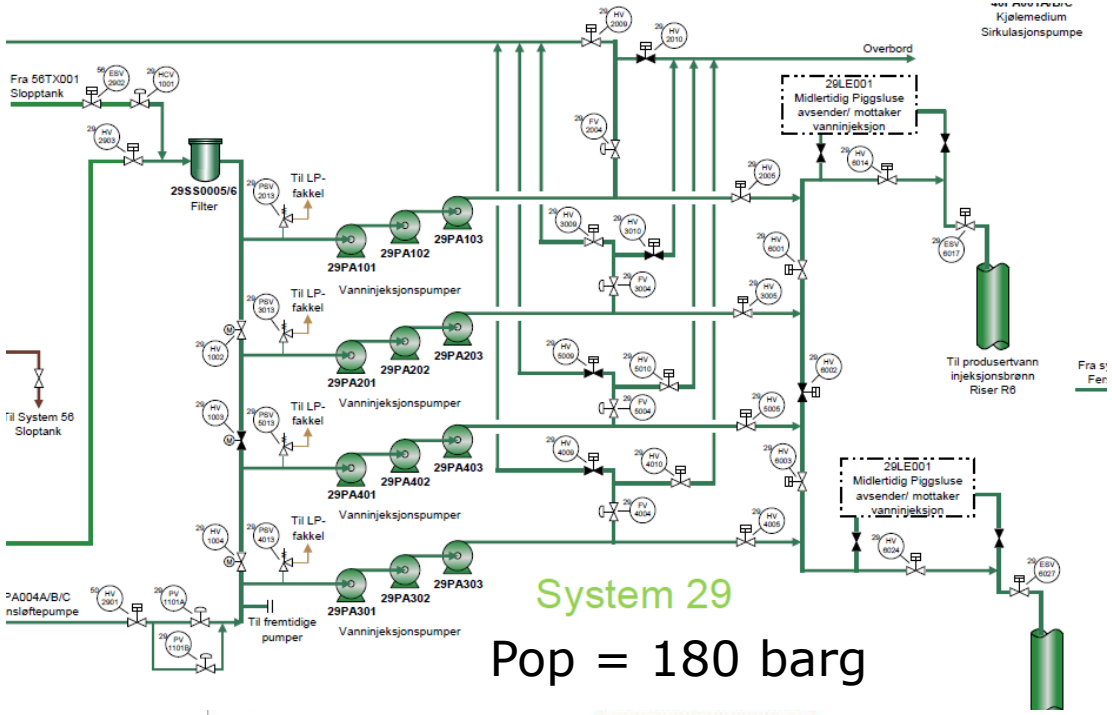
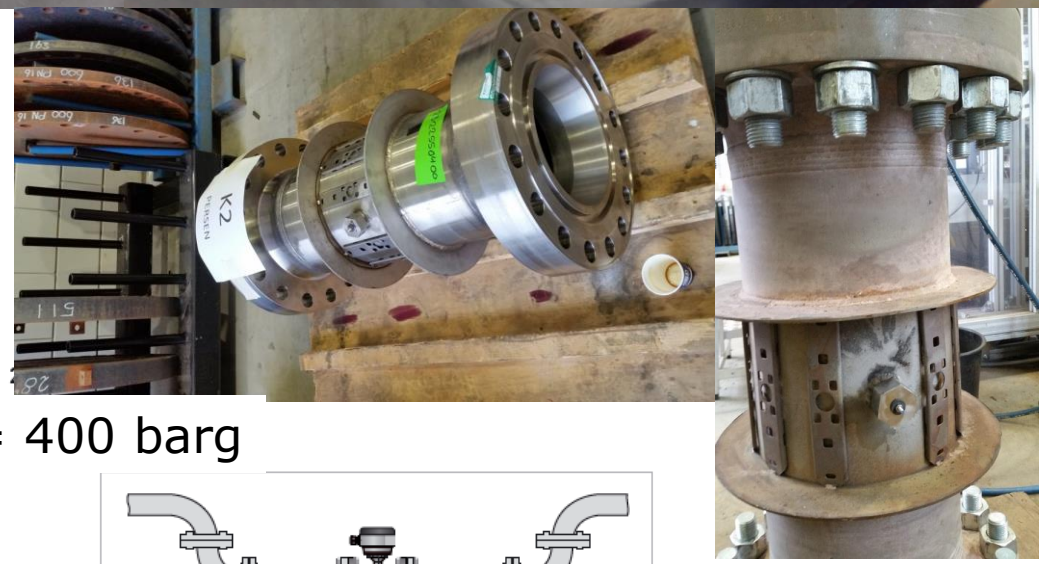
Mag Meters, - High pressure

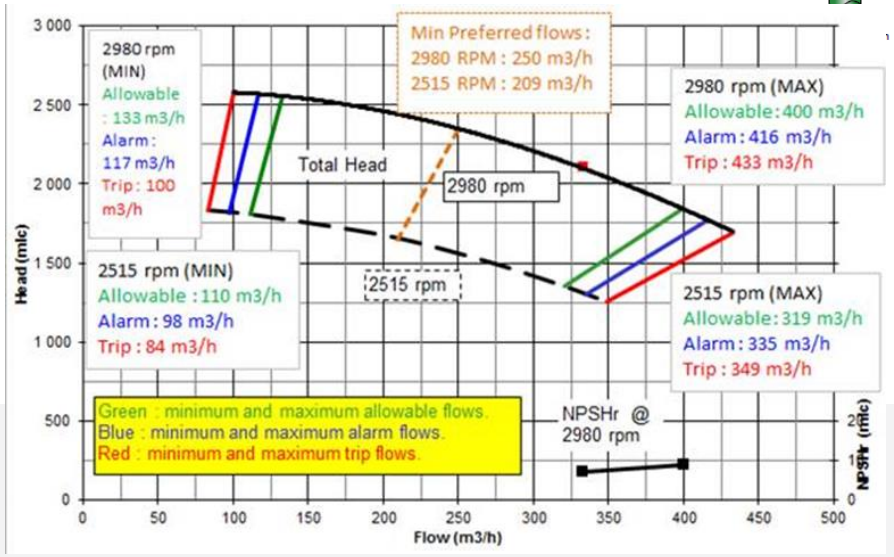


System 29

Pop = 180 barg



Ptest = 400 barg



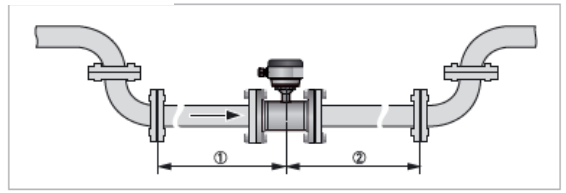


Figure 2-3: Recommended inlet and outlet sections

① ≥ 5 DN

② ≥ 2 DN

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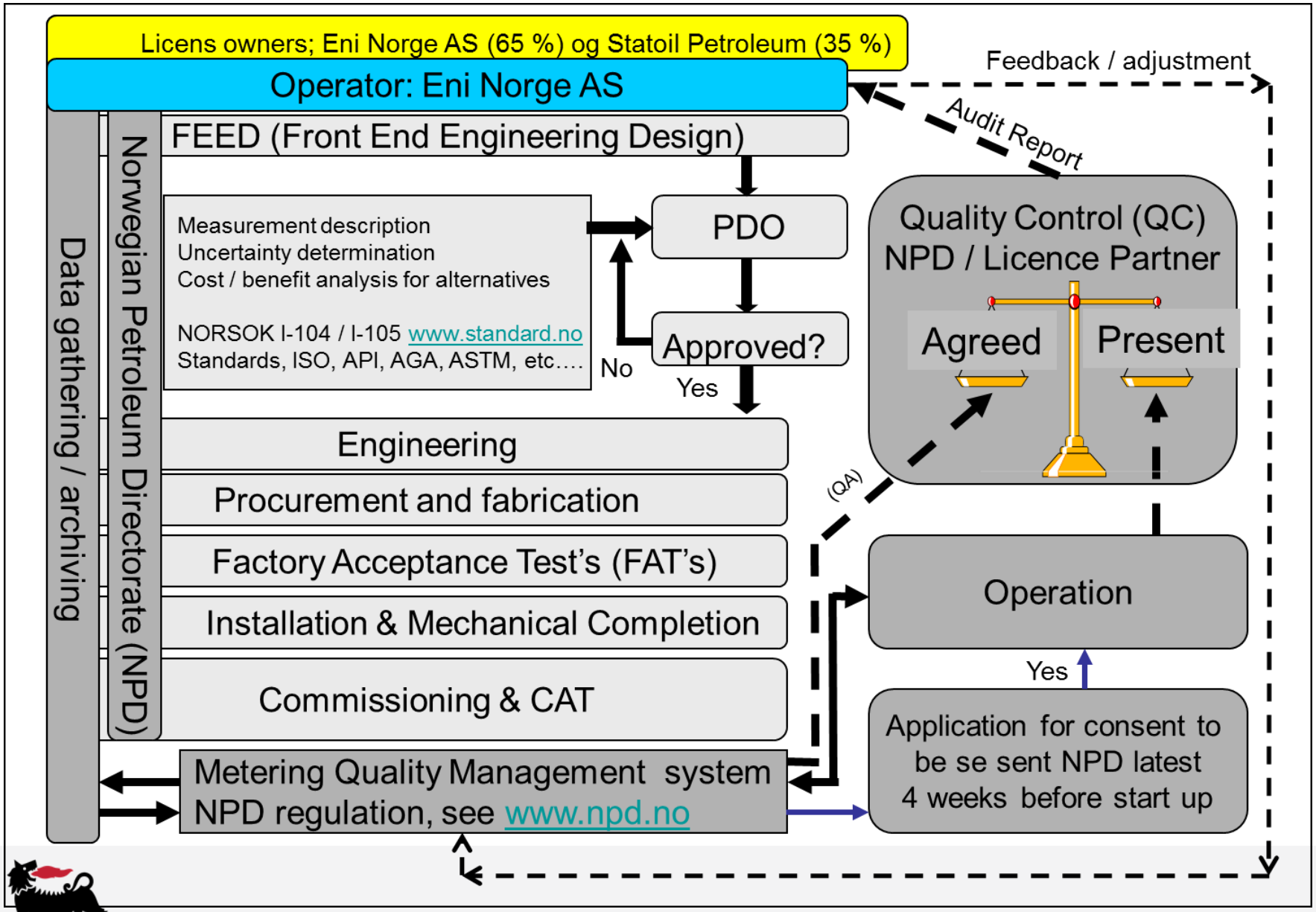
Hvilken lærdom kan vi trekke ut av Goliat utbyggingen!

- At det er behov for riktig kompetanse til enhver tid
- At det i slike prosjekt som Goliat er for sent å lære i en hekstisk hverdag, ref. at man må gjøre feil for å lære.
- Behov for gode kvalitetssikringssystemer, kvalitetskontroller og kontinuerlige proaktive forbedringer

Metering lifecycle concept



Goliat

License awarded in 1997

Discovered in year 2000

Approved for production 18.06.2009

Production start up 12 March 2016

Hvorfor omtalt som et skandale prosjekt?
Manglende kompetanse

Kompetanse hva er det?

- Modnet / erfarings oppbygd teoretisk og praktisk kunnskap

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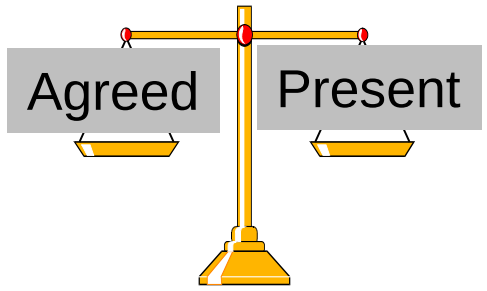
Measurement uncertainty requirements ref TR3032



Instrument	Instrument uncertainty within calibrated span at installation point (Note 1)	Instrument uncertainty within calibrated span (Note 2)
Flow measurement - liquid petroleum	+/- 2,0 % of measured value	+/- 0,5 % of measured value
Flow measurement – Natural Gas	+/- 3,0 % of measured value	+/- 1,0 % of measured value
Flow measurements - liquid water	+/- 2,0 % of measured value	+/- 0,5 % of measured value
Flow measurements - steam	+/- 2,0% of measured value	+/- 1 % of measured value
Flow measurements - air	+/- 3,0 % of measured value	+/- 1 % of measured value
Flow measurements – chemicals	+/- 2,0 % of measured value	+/- 0,5% of measured value
Temperature – inline	+/- 0,5 % of measured value	+/- 0,3 % of measured value

Konklusjon

- QA / QC system fra A til Å
- Kompetanse krav og oppfølging fra A til Å
  - Oljedirektoratets måleforskrift
  - Petroleumstilsynet
    - Aktivitetsforskriften
      - §21
- Lær av EU sin MRR forordning
  - https://ec.europa.eu/clima/sites/clima/files/ets/monitoring/docs/quick_guide_operators_en.pdf

- Er det behov for instrument guide lines i regi av NFOGM / Norsk Olje og Gass ?

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