

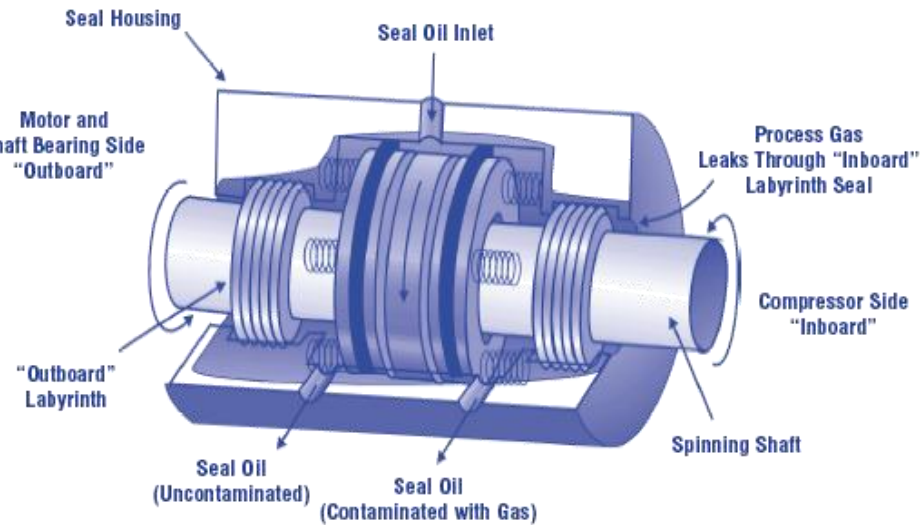
Centrifugal Compressor Wet Seals Seal Oil De-gassing & Control



Global Methane Initiative Workshop;
Washington DC; October 2012
Reid Smith BP,

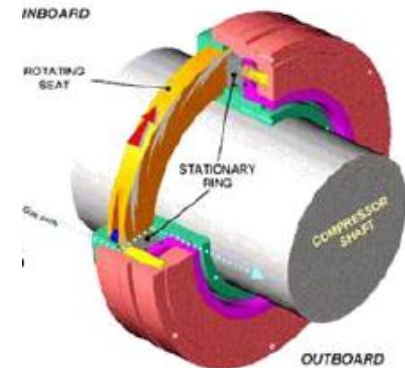
Centrifugal Compressor Wet Seals

- ⚡ High pressure seal oil circulates between rings around the compressor shaft
- ⚡ Oil absorbs the gas on the inboard side
 - ⚡ Little gas leaks through the oil seal
 - ⚡ Seal oil degassing typically vents methane to the atmosphere
 - ⚡ Seal oil degassing may vent 40 to 200 scf/minute



Traditional Solution: Retrofitting/Installing Dry Seals

- ⚡ Mechanical seal that keeps gas from escaping while rotating with the shaft.
- ⚡ 0.4 to 2.8 scf/min leak rate – significantly less than from wet seals
- ⚡ Cost-effective option for new compressors
- ⚡ Significant capital costs and downtime for retrofitting compressors



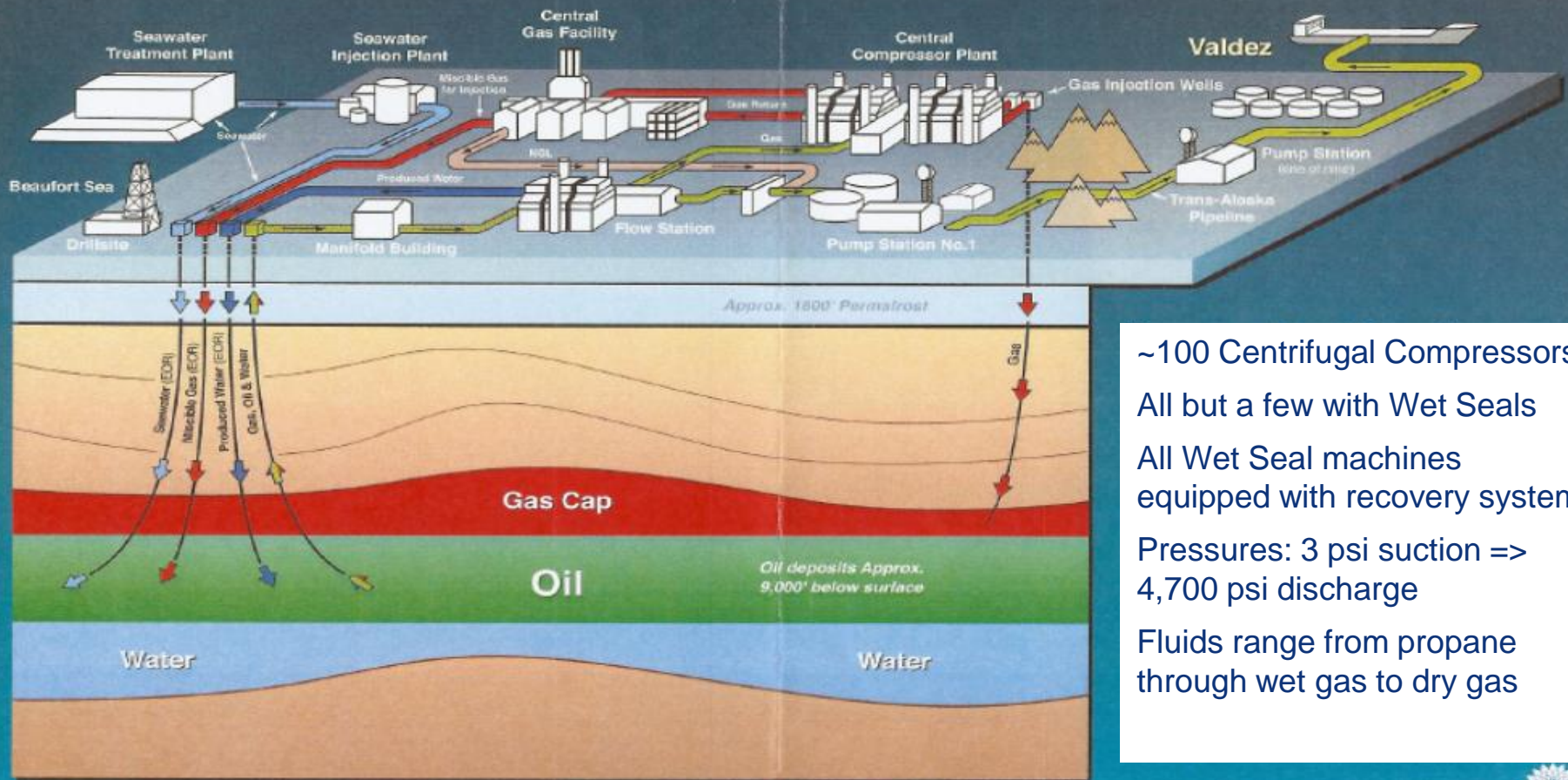
Source: PEMEX

Background of North Slope Study

- ⚡ Natural Gas STAR learned of anecdotal information on this potential mitigation opportunity a few years back
 - ⚡ Developed a theoretical example and presented to Natural Gas STAR Partners at workshops and in the Spring 2009 Newsletter
- ⚡ In taking measurements, BP identified wet seal gas recovery systems on centrifugal compressors at its North Slope facilities
 - ⚡ BP's initial results showed recovery of >99% of seal oil gas that would be otherwise vented to atmosphere from degassing tank
- ⚡ Led to BP and Natural Gas STAR collaboration on detailed measurement study of alternative wet seal capture mitigation opportunity
 - ⚡ Recovery system that separates gas from the sour seal oil before being sent to the degassing tank
 - ⚡ Recovered gas sent to various outlets: flare purge, low pressure fuel, turbine fuel ~273 psig (18.6 Bar), compressor suction
 - ⚡ System leads to lower emissions from degassing tank vent (more details on following slides)

Overview of North Slope Operations

Prudhoe Bay



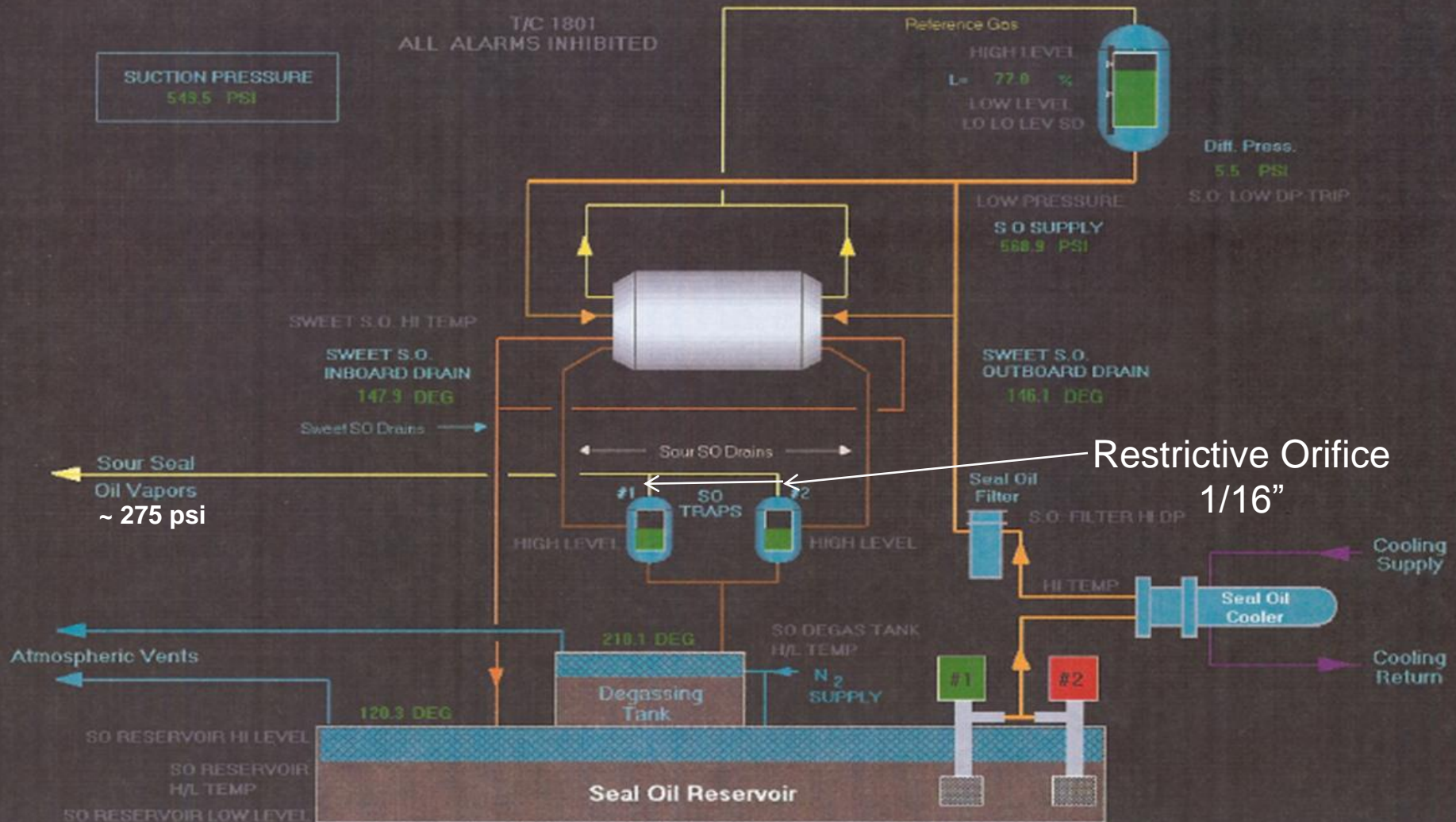
~100 Centrifugal Compressors
 All but a few with Wet Seals
 All Wet Seal machines equipped with recovery system
 Pressures: 3 psi suction => 4,700 psi discharge
 Fluids range from propane through wet gas to dry gas



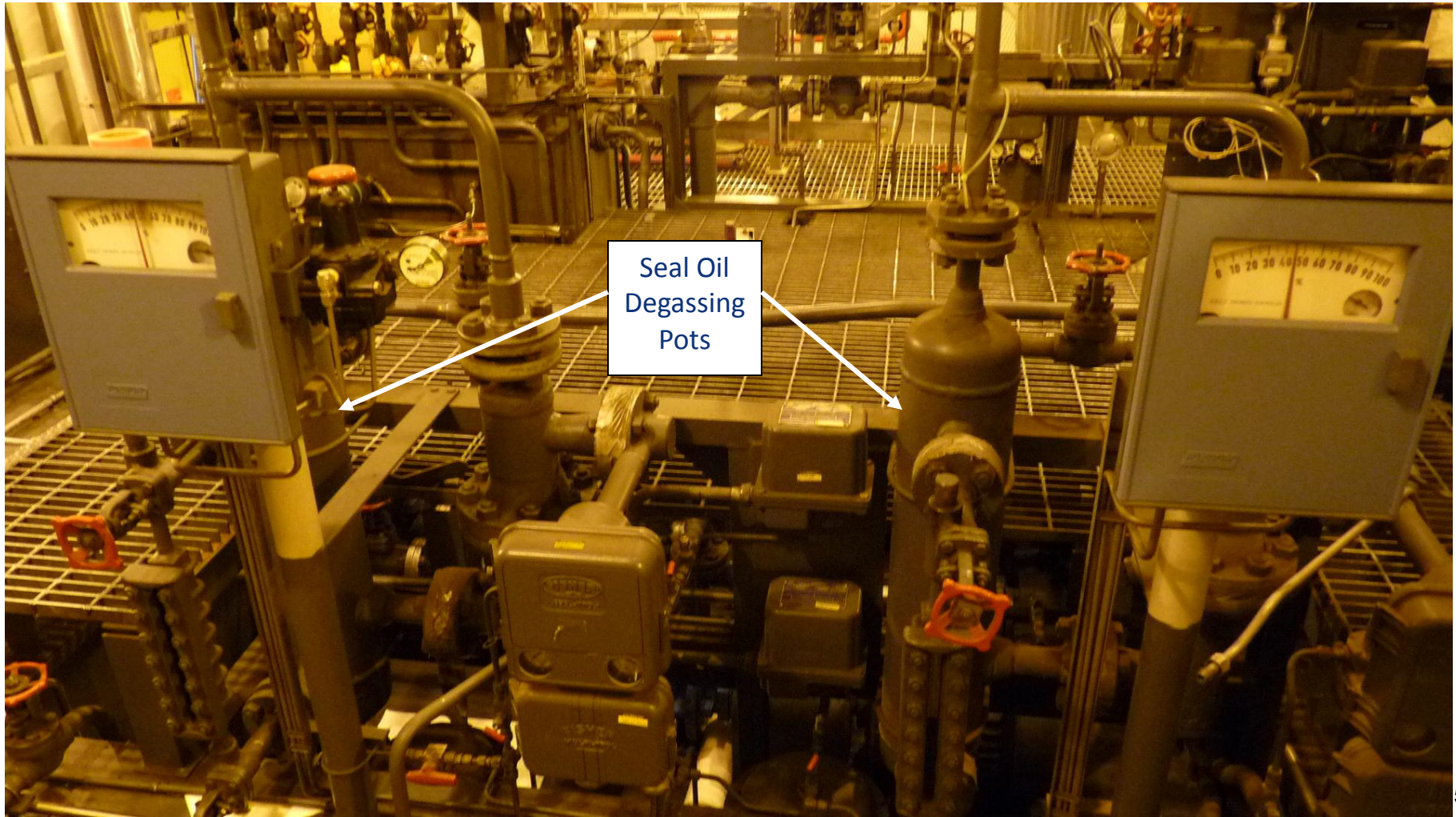
Sour Seal Oil Vapor Recovery System: CCP

VCCP01LSTG05

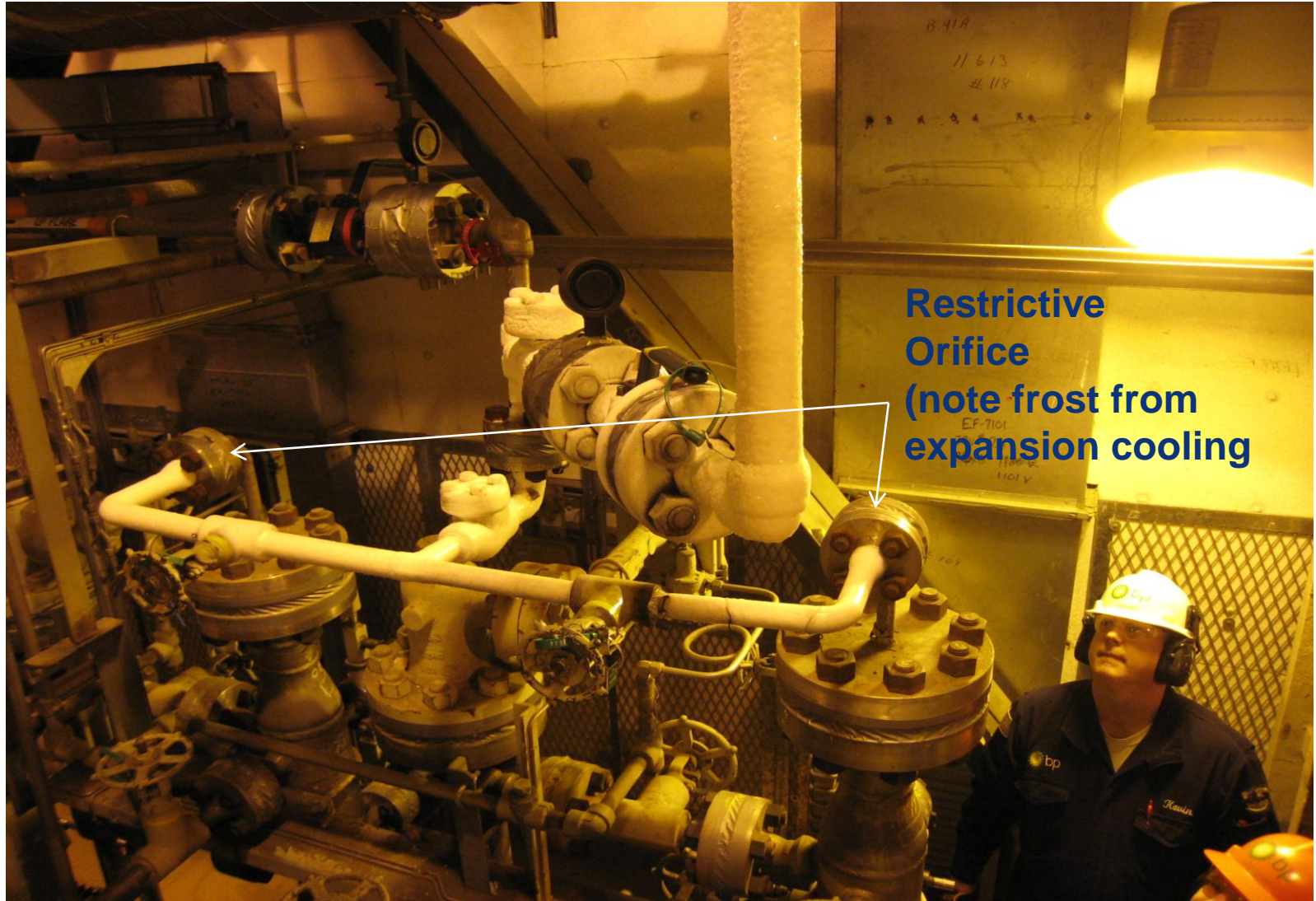
T/C 1801 SEAL OIL



Seal Oil Degassing Separators



Seal Oil Degassing Separator/System



Early Results: BP Measurements of CCP

- 🔥 Table shows initial measurements taken by BP from a low- and high-pressure compressor at CCP before study
- 🔥 Used nitrogen as “tracer gas” to calculate methane and total hydrocarbon flow-rates from vents
- 🔥 Recovered Gas: 0.92 MMSCFD LP; 3.7 MMSCFD HP Turbine Fuel

	High-Pressure Compressor	Low-Pressure Compressor
Nitrogen Purge Rate (SCF/Hr)	33	25
Vent Analysis (mole%)		
Nitrogen	43.846	86.734
Methane	37.872	6.93
Total Hydrocarbon + CO2	56.1540	13.2660
Total Methane Vent Flow (SCFM)	0.4751	0.0333
Total Vent Gas Flow (SCFM)	0.7044	0.0637
Number of Seals	2	2
Total Methane Vent Flow (SCFM/Seal)	0.2375	0.0166
Total Vent Gas Flow (SCFM/Seal)	0.3522	0.0319
“Average” Total Gas/Seal (Including Recovered) (SCFM)	108	108
Control Effectiveness	0.997	1.000

Preliminary results: Velocity Measurements

Table shows vane anemometer measurements taken prior to and during the study

Full results of study are not yet final, but initial results from CCP measurements show generally consistent flows with BP's results from before the study

CCP Velocity Readings - During Study												
Facility	Compressor Tag	Compressor description		# of Seals per Tank	Vent size in	1 Min Mean m/s	1 Min Mean m/s	1 Min Mean m/s	Vent Area ft2	fpm	scf/min	N2 Purge scf/min
CCP	K-18-1801	1st Stage Injection comp	Degassing Tank Vent	2	2	0.36	0.38	0.28	0.022	66.9	1.5	
			Seal Oil Reservoir Vent		4	0.35	0.34	0.37	0.087	69.5	6.1	
CCP	K-18-1809	2nd Stage Injection comp	Degassing Tank Vent	2	2	0.42	0.4	0.2	0.022	66.9	1.5	
			Seal Oil Reservoir Vent		4	0.6	0.57	0.81	0.087	129.9	11.3	
Velocity Readings - Prior to Study												
END	K-E3-1510/20/30A	Main A (1st, 2nd, 3rd stages)	Degassing Tank Vent	6	2	0.86	0.8	0.48	0.022	140.4	3.1	
END	K-E3-1510/20/30A	second vent	Degassing Tank Vent	6	6	0.87	0.52	0.71	0.196	137.8	27.1	
											30.1	
END	K-E3-1510/20/30B	Main B (1st, 2nd, 3rd stages)	Degassing Tank Vent	6	2	3.84	3.5	3.15	0.022	688.1	15.0	
END	K-E3-1510/20/30B	second vent	Degassing Tank Vent	6	6	2.68	2.14	4.67	0.196	622.5	122.3	
											137.3	
END	C-1501/02B	Booster B (1st & 2nd stages)	Degassing Tank Vent	2	2	0.64	0.42	0.67	0.022	113.5	2.5	
END	C-1501/02B	second vent	Degassing Tank Vent	2	2	0.54	0.39	0.46	0.021825	91.2	2.0	
											4.5	
LPC	K-52-1807	Reinjection Compressors	Degassing Tank Vent	2	2	0.82	0.91	0.83	0.022	167.9	3.7	
LPC	K-52-1808	Reinjection Compressors	Degassing Tank Vent		2	1.44	1.73	1.6	0.022	312.9	6.8	
LPC	K-42-1801	STV/IP Compressors	Degassing Tank Vent	2	2	0.82	0.93	1.06	0.022	184.3	4.0	
LPC	K-42-1801	Second vent	Degassing Tank Vent		4	0.96	0.58	0.52	0.087	135.1	11.8	
											15.8	
CCP	K-18-1801	1st Stage Injection comp	Degassing Tank Vent	2	2	0.3	0.33	0.32	0.022	62.3	1.4	
CCP	K-18-1802	1st Stage Injection comp	Degassing Tank Vent	2	2	0.54	0.56	0.45	0.022	101.7	2.2	
CCP	K-18-1803	1st Stage Injection comp	Degassing Tank Vent	2	2	0.45	0.15	0.19	0.022	51.8	1.1	
CCP	K-18-1804	1st Stage Injection comp	Degassing Tank Vent	2	2	0.05	0.17	0.06	0.022	18.4	0.4	
CCP	K-18-1805	1st Stage Injection comp	Degassing Tank Vent	2	2	2.65	2.67	2.52	0.022	514.3	11.2	
CCP	K-18-1806	1st Stage Injection comp	Degassing Tank Vent	2	2	0.38	0.74	0.56	0.022	110.2	2.4	
CCP	K-18-1807	1st Stage Injection comp	Degassing Tank Vent	2	2	0	0.04	0.22	0.022	17.1	0.4	
CCP	K-18-1808	1st Stage Injection comp	Degassing Tank Vent	2	2	0.2	0.09	0.09	0.022	24.9	0.5	
CCP	K-18-1813	1st Stage Injection comp	Degassing Tank Vent	2	2	0.54	0.64	0.65	0.022	120.0	2.6	
CCP	K-18-1809	2nd Stage Injection comp	Degassing Tank Vent	2	2	0.54	0.42	0.29	0.022	82.0	1.8	
CCP	K-18-1810	2nd Stage Injection comp	Degassing Tank Vent	2	2	1.17	0.46	0.34	0.022	129.2	2.8	
CCP	K-18-1811	2nd Stage Injection comp	Degassing Tank Vent	2	2	1.44	1.38	0.59	0.022	223.7	4.9	
CCP	K-18-1812	2nd Stage Injection comp	Degassing Tank Vent	2	2	0.38	0.43	0.4	0.022	79.4	1.7	
CGF	K-19-1802A/B	Booster #2	Degassing Tank Vent	2	3	0.26	0.31	0.93	0.049	98.4	4.8	
CGF	K-19-1802A/B	Second vent	Degassing Tank Vent		3	0.36	0.25	0.82	0.049	93.8	4.6	
											9.4	
CGF	K-19-1805	MI Compressor	Degassing Tank Vent	2	2	0.49	0.4	0.38	0.022	83.3	1.8	
CGF	K-19-1805	Second vent	Degassing Tank Vent		2	9.98	9.55	9.77	0.022	1922.1	42.0	
											43.8	

CCP Compressor Vent Measurement



FLIR Camera Verification



Applicability/Benefits

- 🔥 Investment includes cost of:
 - 💧 Intermediate degassing drum (“sour seal oil trap”)
 - 💧 New piping
 - 💧 Gas demister/filter
 - 💧 Pressure regulator for fuel gas line
- 🔥 Project summary:
 - 💧 Less expensive capital costs compared to dry seal retrofit (\$250,000 - \$1 million – dry seal retrofit)
 - 💧 Less down-time compared to dry seal retrofit
 - 💧 Prevents most seal oil gas emissions from venting to atmosphere while also improving site efficiency
 - 💧 Positive cash flow after less than a month

PROJECT SUMMARY: CAPTURE AND USE OF SEAL OIL DEGASSING EMISSIONS

Operating Requirements	<ul style="list-style-type: none"> ▪ Centrifugal compressor with seal oil system ▪ Nearby use for fuel gas or recycle ▪ New intermediate pressure flash drum, fuel filter, pressure regulator 		
Capital & Installation Costs	\$22,000 ¹		
Annual Labor & Maintenance Costs	Minimal		
Gas saved	~100 MMSCF/Year (2 seals @ 108 scf/min each)		
Gas Price per mscf	\$2.5	\$3.0	\$3.5
Value of Gas Saved	\$250,000	\$300,000	\$350,000
Payback Period in Months	1	<1	<1

¹Assuming a typical seal oil flow rate of 14.20 liters/minute (3.75 gallons/minute) (Source: EPA)



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