Natural Gas STAR
Production Technology Transfer Workshop

"Centrifugal Compressor Wet Seal"
"Seal Oil Degassing & Recovery"

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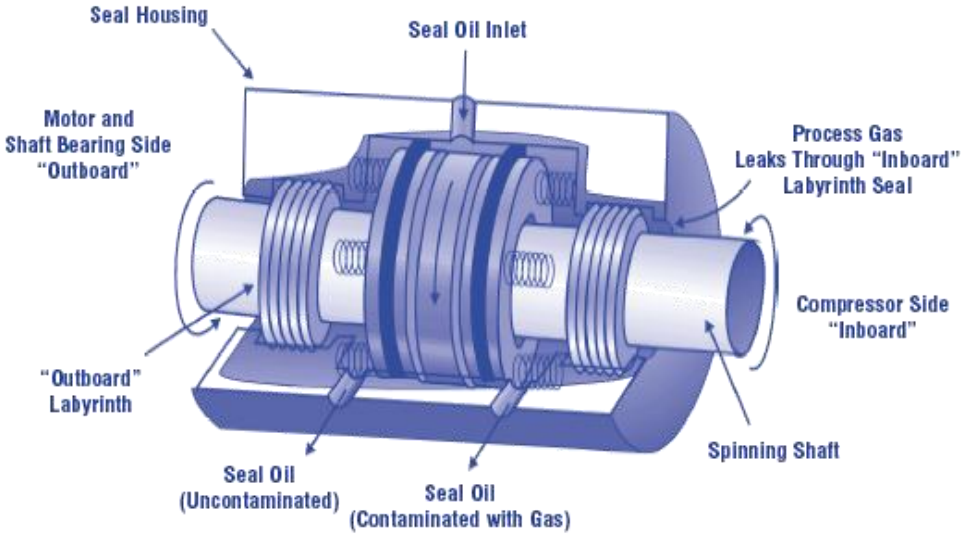
bp

NaturalGas
EPA POLLUTION PREVENTER

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 vents methane to the atmosphere
- **Wet seals leak little gas at the seal face**
- **Most emissions are from seal oil degassing**
- **Seal oil degassing may vent 40 to 200 scf/minute**
- **One Natural Gas STAR Partner reported emissions as high as 75,000 scf/day**

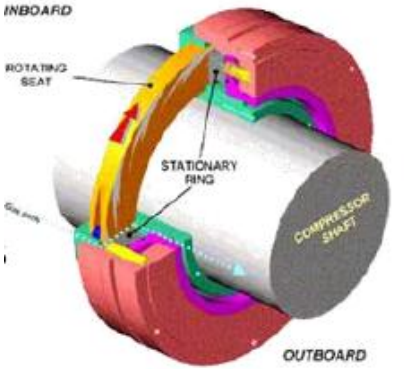
Source: PEMEX



Traditional Solution: Retrofitting/Installing Dry Seals

- **Dry seals:**
  - 0.4 to 2.8 scf/ minute leak rate
  - Significantly less than wet seals
- **Very cost-effective option for new compressors**
- **Significant capital costs and downtime for retrofitting compressors**
  - See *Lessons Learned* for more info
- **Alternative exists for more cost-effective seal oil degassing and vapor recovery retrofit with less downtime**

Dry seals keep gas from escaping while rotating with the shaft



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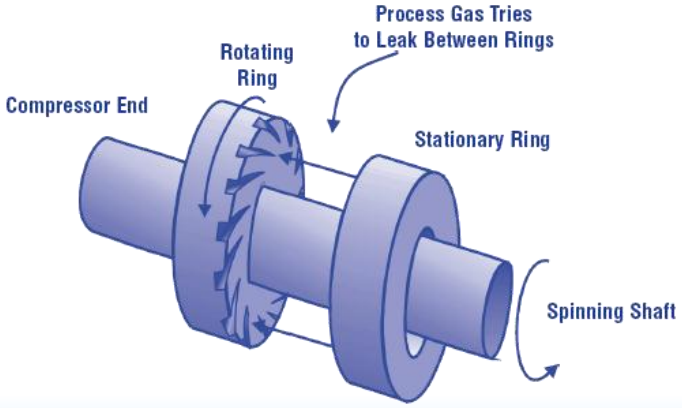
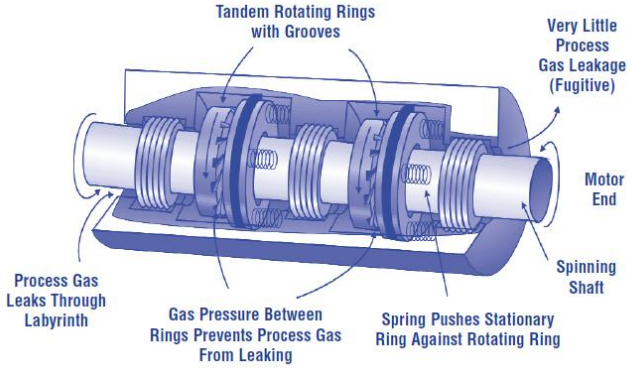
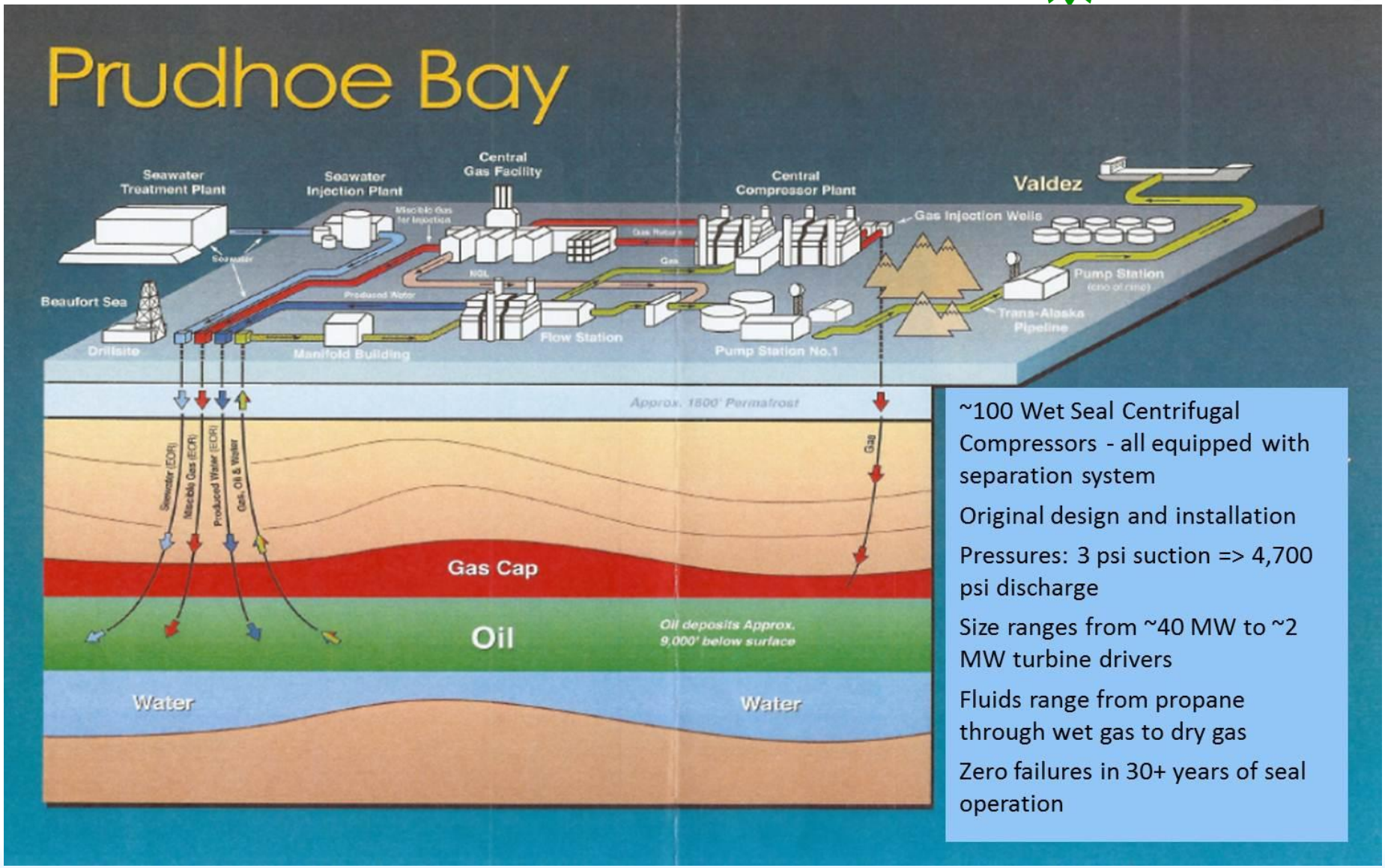




Alternative Solution – Seal-oil/Gas Separation and Recovery/Use

- **Simple process of separating seal-oil and entrained gas with the gas routed to recovery and/or use.**
  - Recovery system that separates gas from the exiting seal-oil before routing to the degassing tank
  - Recovered gas sent to various outlets: flare purge, low pressure fuel, turbine fuel ~273 psig (18.6 Bar), compressor suction
  - Systems lead to lower emissions from degassing tank vent (more details on following slides)
- **BP has wet seal gas recovery systems on ~ 100 centrifugal compressors at its North Slope facilities**
  - BP's initial results show recovery of >99% of seal oil gas that would be otherwise vented to atmosphere from degassing tank
  - BP and Natural Gas STAR collaborated on a detailed study of the alternative wet seal emission mitigation opportunity.

BP's North Slope Experience



~100 Wet Seal Centrifugal Compressors - all equipped with separation system

Original design and installation

Pressures: 3 psi suction => 4,700 psi discharge

Size ranges from ~40 MW to ~2 MW turbine drivers

Fluids range from propane through wet gas to dry gas

Zero failures in 30+ years of seal operation

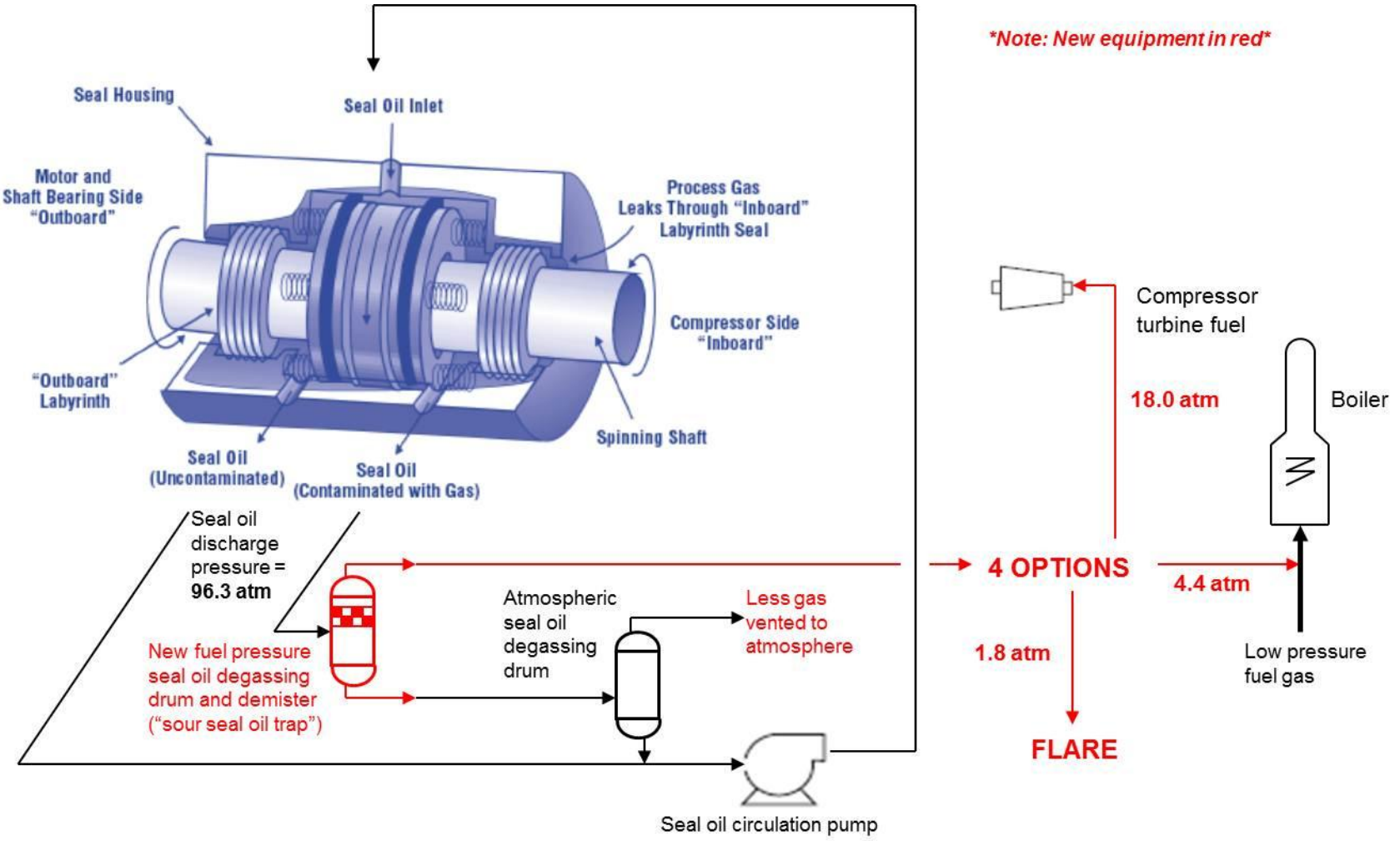
Central Gas Facility (CGF)

- **World's largest gas processing plant (max feed of 246 MMcm/day)**
- **Processes all gas from Prudhoe Bay gathering & boosting stations (except local fuel)**
- **Products:**
  - Residue gas
  - Natural gas liquids (blended with oil and delivered to TAPS)
  - Miscible injectant (used for EOR purposes)
- **11 compressors (totaling over 500,000 HP)**
  - Three boosters
  - Two refrigerant
  - Two MI
  - Four tandems
- **Seal oil vapor recovery lines to flare purge**

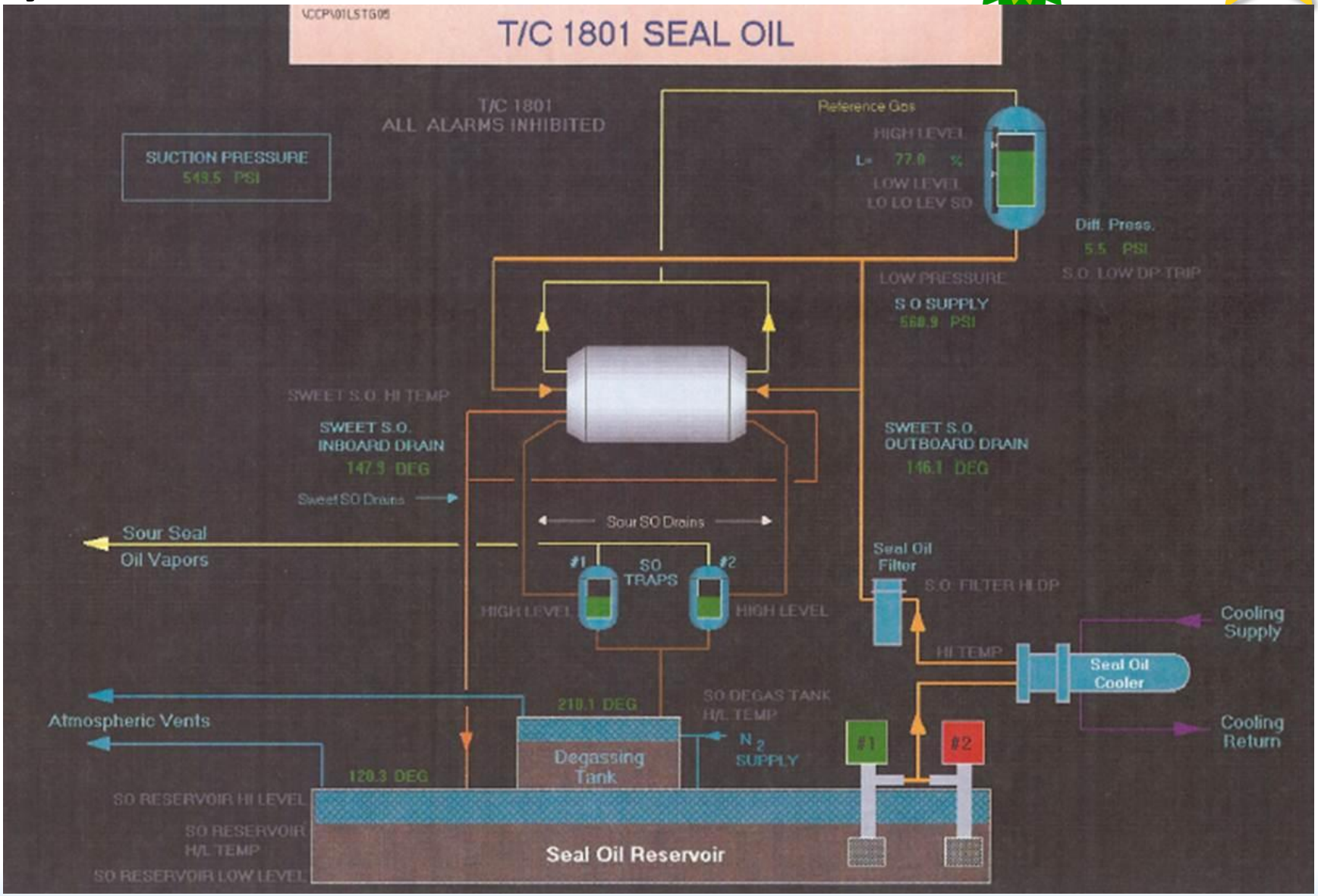
Central Compressor Plant (CCP)

- **World's largest compressor station (~238 MMcm/day capacity)**
- **Receives residue gas from CGF, compresses to higher pressures, and sends to gas injection wellpads (~200 MMcm/day at 3,600 to 4,000 psig)**
- **15 compressors (totaling 537,000 HP)**
  - Nine low pressure (1st stage) compressors in parallel
  - Four high pressure (2nd stage) compressors in parallel
  - Two tandem compressors (1st and 2nd stages) in parallel
- **Seal oil vapor recovery lines sent to flare or fuel gas (for compressor turbines, heaters, and blanket gas)**

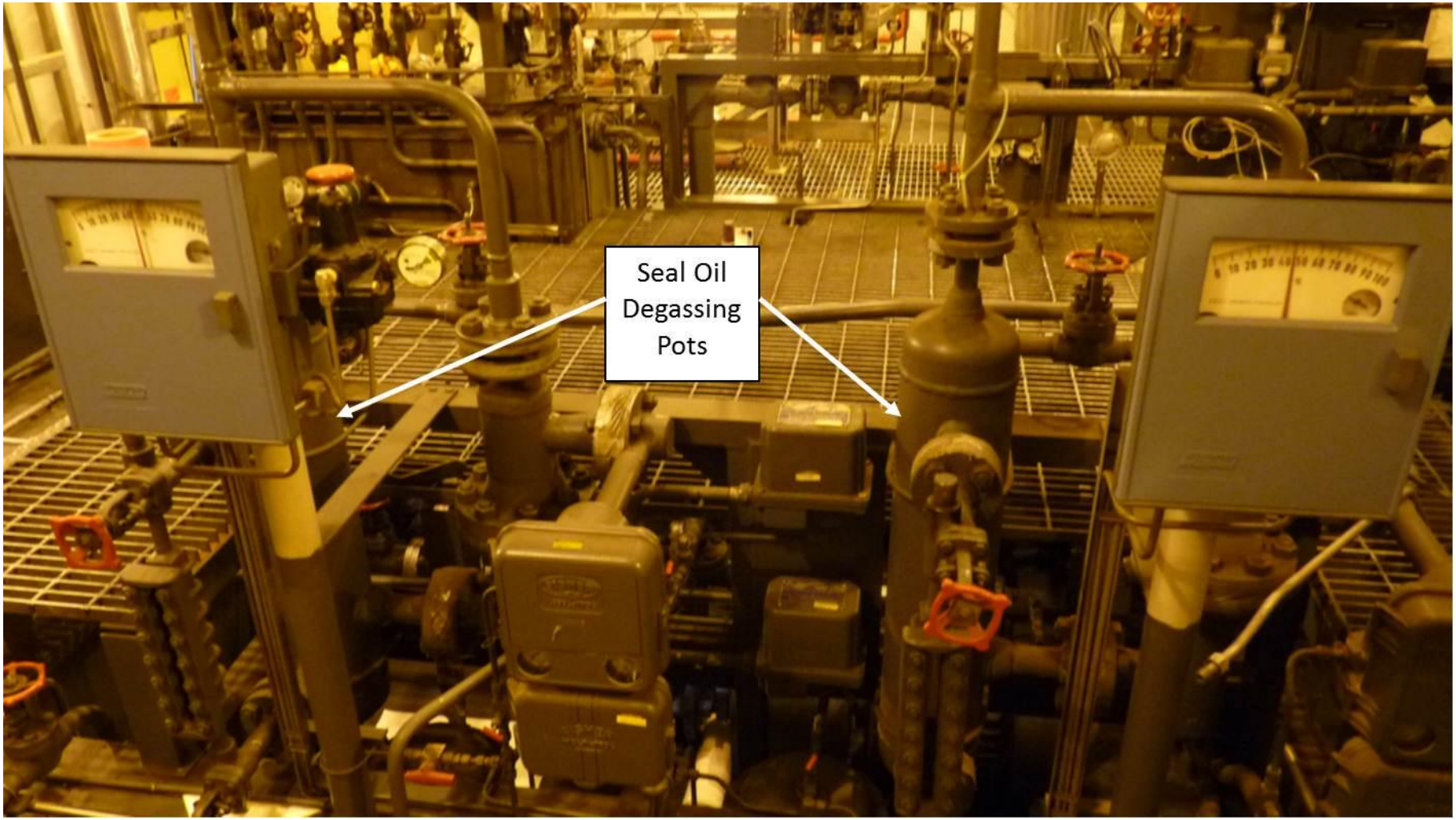
Sour Seal Oil Vapor Recovery System



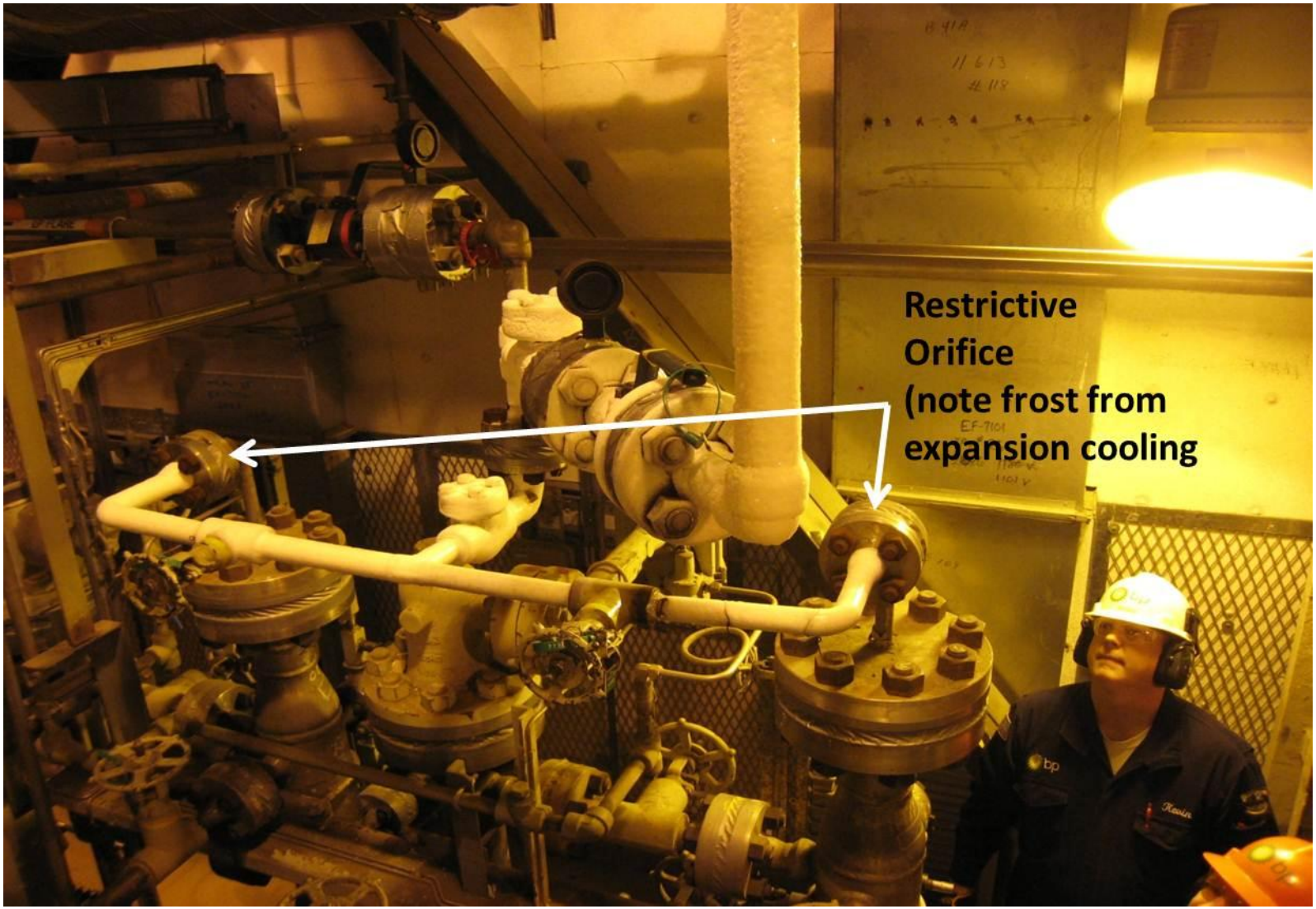
Seal-Oil/Gas Separation and Recovery System: CCP



Seal Oil Degassing Separators



Seal Oil Degassing Separator/System

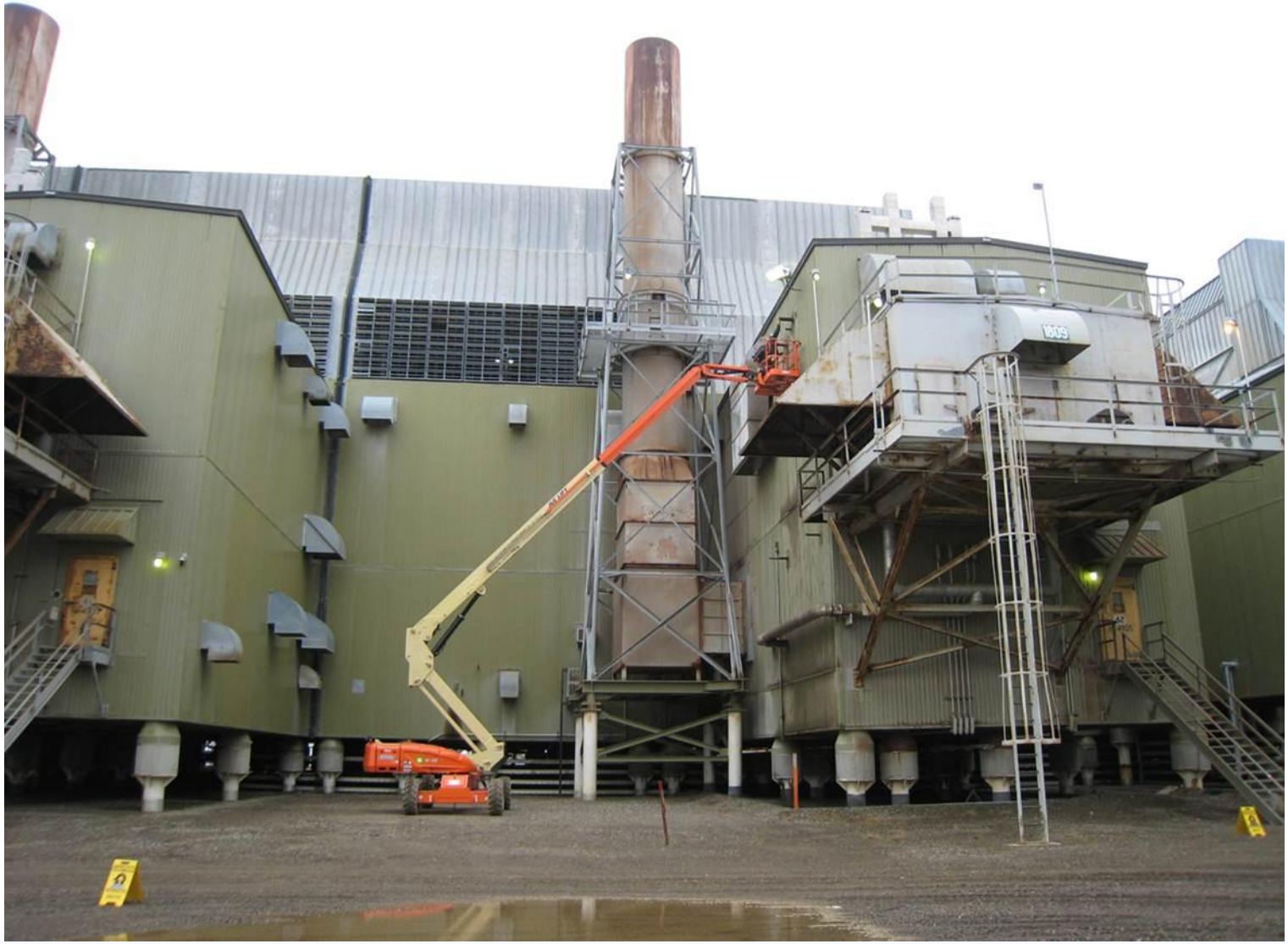


Early Results:
BP Measurements at CCP

- **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**

CCP Compressor Vent Measurement



FLIR Camera Verification

Benefits

- **Benefits of approach**
  - Simple, broadly flexible, and reliable
  - Less expensive capital costs compared to dry seal retrofit ($250,000 - $1 million – dry seal retrofit)
  - Less down-time compared to dry seal retrofit
  - Eliminates most emissions & recovers gas for use/sales
  - Positive cash flow after less than a month
- **Investment includes cost of:**
  - Intermediate degassing drum ("sour seal oil trap")
  - New piping
  - Gas demister/filter
  - Pressure regulator for fuel gas line

PROJECT SUMMARY: CAPTURE AND USE OF SEAL OIL DEGASSING EMISSIONS			
Operating Requirements	▪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

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

CONCLUSIONS

- **Centrifugal compressor oil film (wet) seals have been utilized since the early 1970's**
- **These seal systems, including the degassing function, when designed, operated and monitored properly are an effective sealing system and greatly minimize emissions**
- **Wet seals with degassing systems installed originally with compressors can perform effectively with very low emissions and high reliability**
- **Retrofit degassing systems should be able to meet the same low emissions and high reliability operation**