Supersonic Ejector for Capturing Dry-Gas Seal Vent Gases

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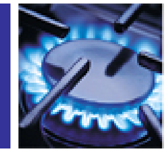
Outline




1. Motivation and Challenges.
2. Why *Supersonic* Ejector.
3. Development of the Device.
4. Results of Testing of Two-Stage System.
5. Implementation at Compressor Station.
6. Conclusions.

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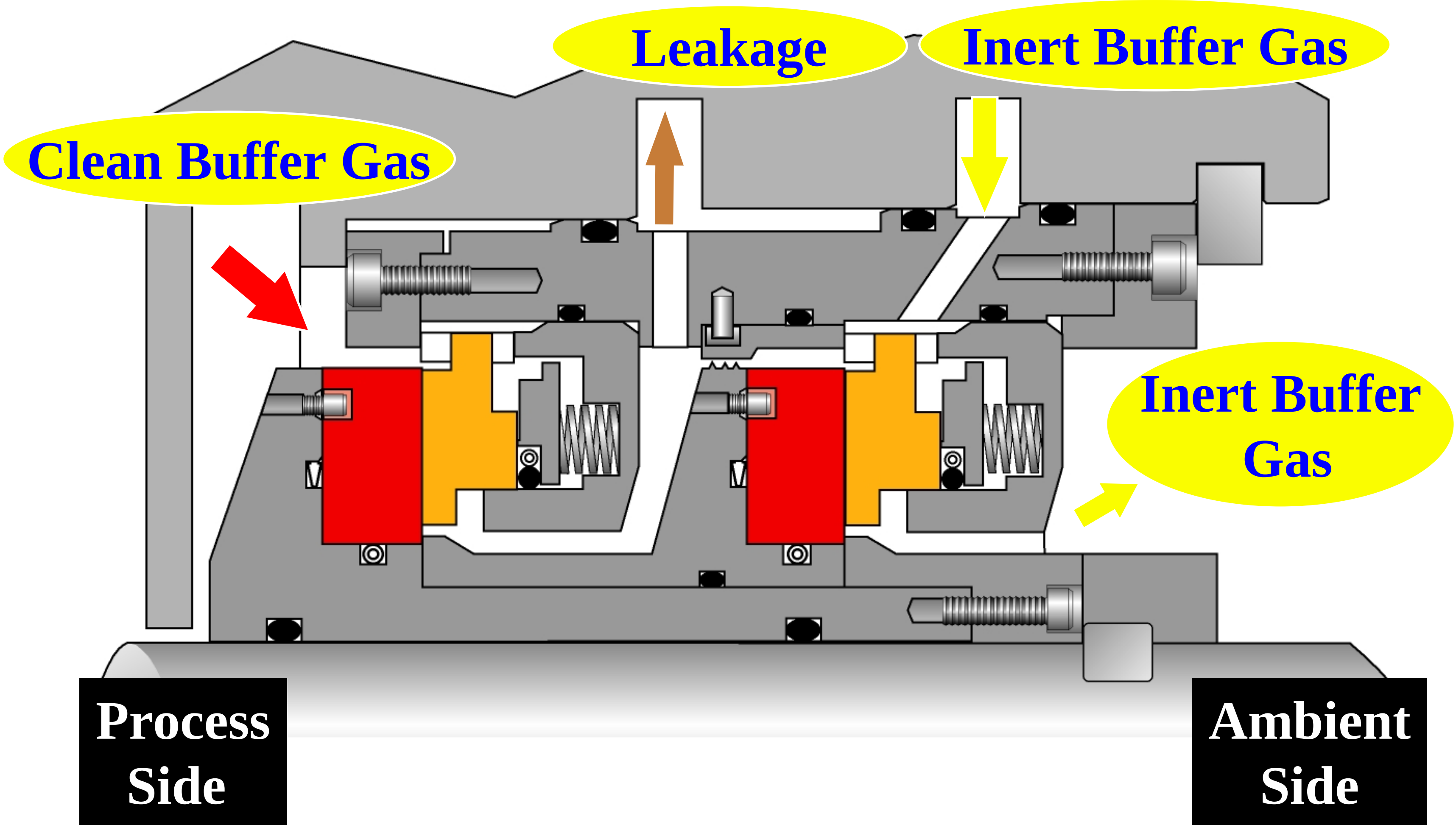
Typical Primary and Secondary Dry-Seal



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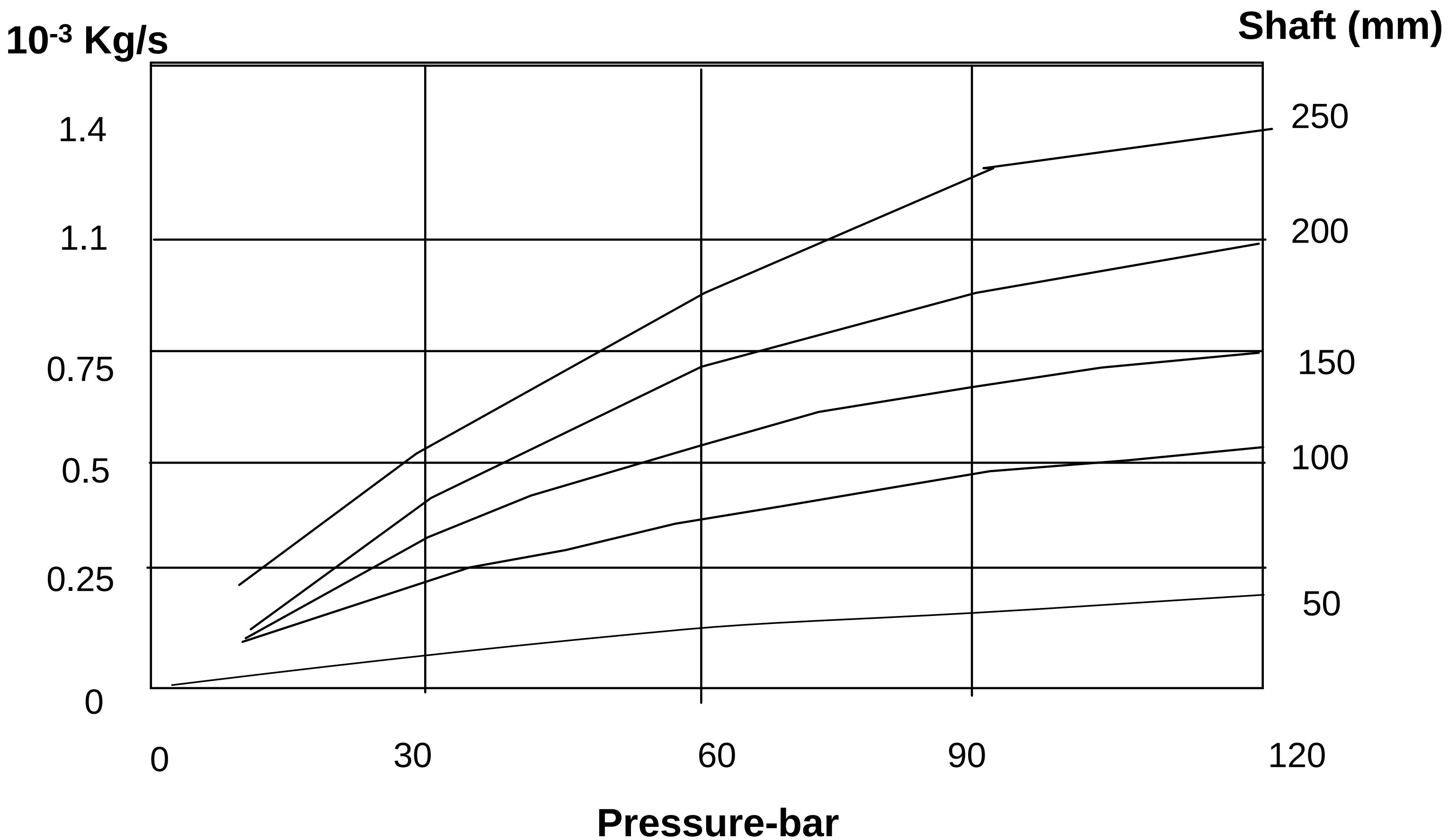
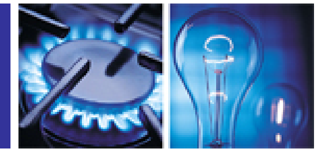
Primary Seal Leakage Rate

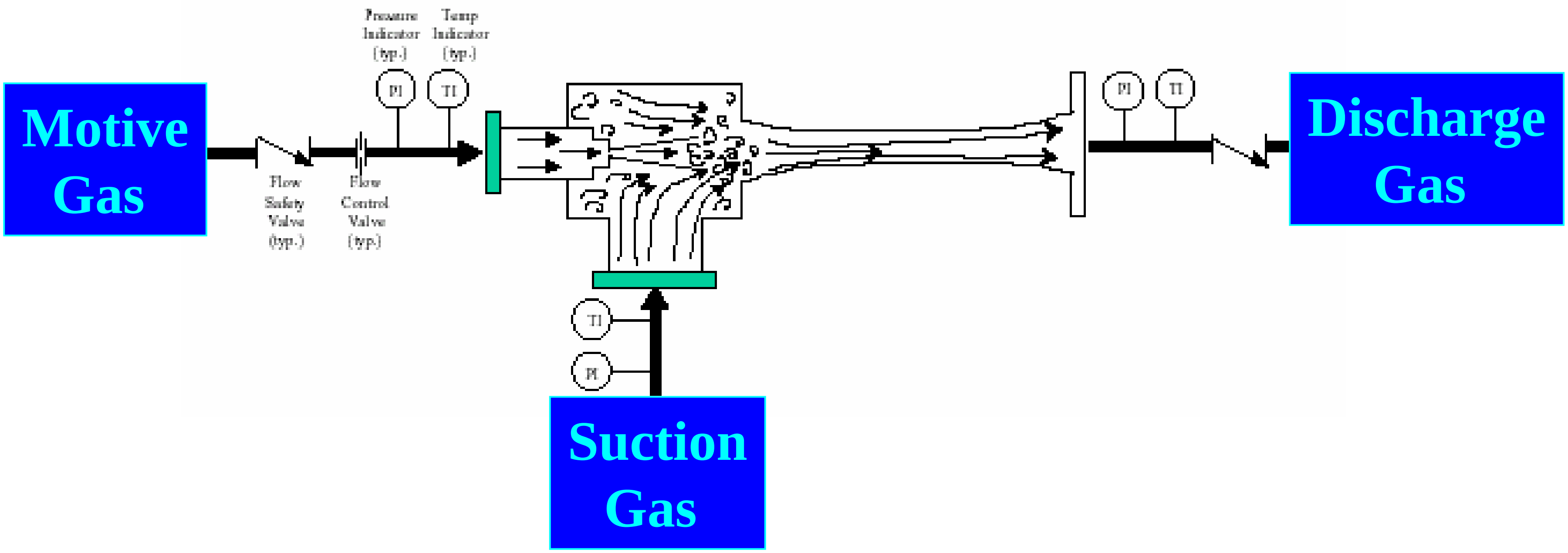


Why Capture Dry Gas Seal Vent?



Seal gas leakage	2.0-8.0	m3/hr
~average	5.0	m3/hr
	1.55	MMScf/y
# of TransCanada units	348	
x 348 @ 50% utilization	269	MMScf/y
Tonnes of natural gas	0.0440	lbs/cf
	5,369	tonnes
conversion to CO2-E	21	
CO2-E	113	ktonnes/year
CO2 Emissions trading	$15	per tonne of CO2-E
Gas value	$6	per MCF
CO2-E value	$1,691,237	
Value of Gas	$1,614,216	
Total	$3,305,453	
Annual saving per unit:	**$9,498**	

Concept of Ejector



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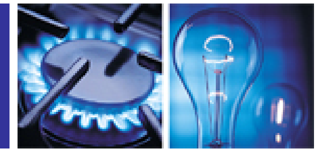
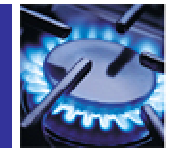
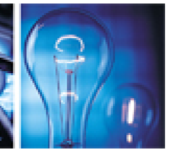
Why Ejector?



- Motive gas is available (fuel gas upstream of regulator).
- Discharge gas from the Ejector can be burned in the GG.
- Auxiliary boilers are not always employed in compressor station, and typically operate intermittently (on/off).
- Some stations do not have boilers (warm climate regions).
- No moving parts.
- Low cost.

Why *Supersonic* Ejector?

- Low suction pressure 300-550 kPa-a.
- Hence high expansion ratio of motive/suction pressure (~ 14).
- Discharge pressure 2500–3400 kPa-a.
- Hence compression ratio up to 8.
- Low suction flow (5-15 m^3/hr).

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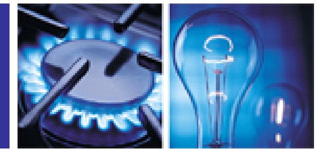
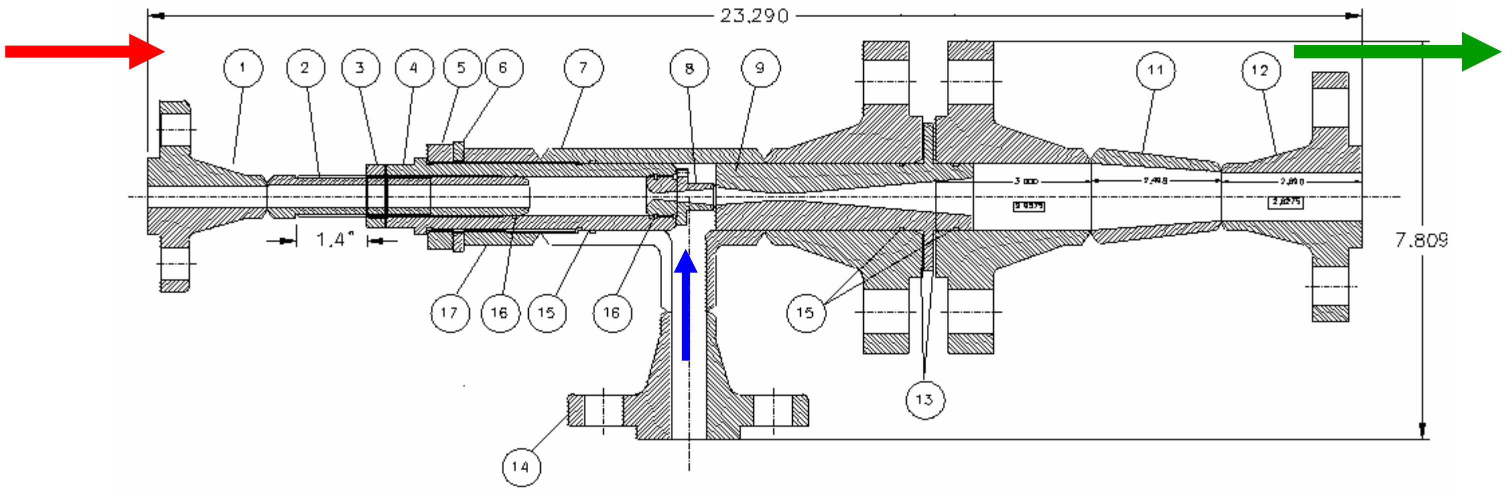
Development of the SSE



- ❑ Two-stage supersonic ejectors:
  - The first stage is highly supersonic (nozzle exit Mach number ≈ 2.54),
  - The second stage is moderately supersonic (nozzle exit Mach number ≈ 1.72).
- ❑ Extensive testing to arrive at optimum design.
- ❑ Final configuration gave
  - expansion pressure ratio (motive/suction) of the order of 14.0
  - compression pressure ratio (discharge/suction) of around 8.1

1st Stage Design



Nozzle Diameter	mm	1.6
Nozzle Exit	mm	2.8
Half Angle	deg	1
Diffuser Inlet Diamter	mm	4
Half Angle	deg	4.7
Diffuser Throat Diameter	mm	3.5
Diffuser Throat Length	mm	8
Diffuser Exit Diameter	mm	18
Diffuser Exit Half Angle	deg	5

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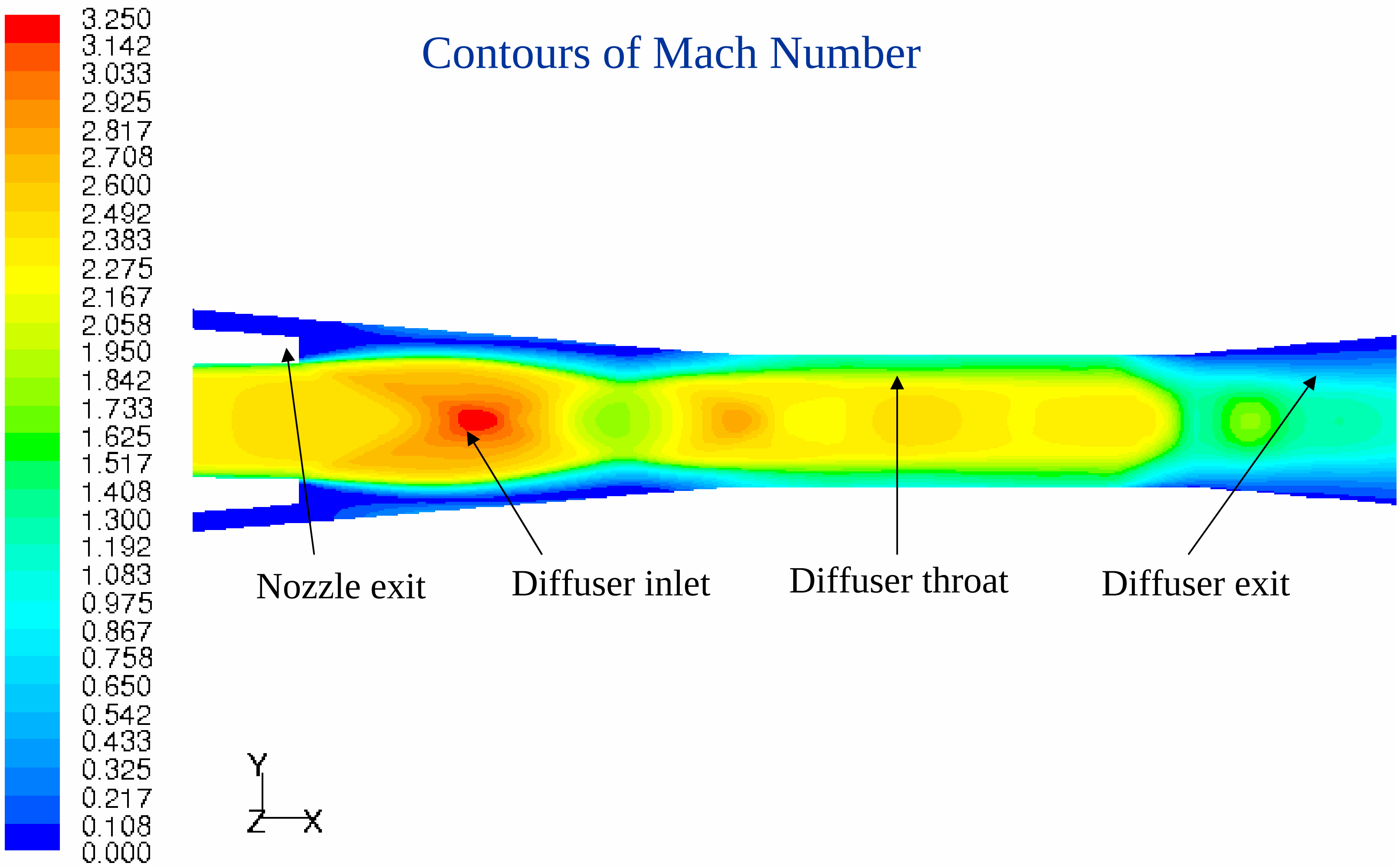
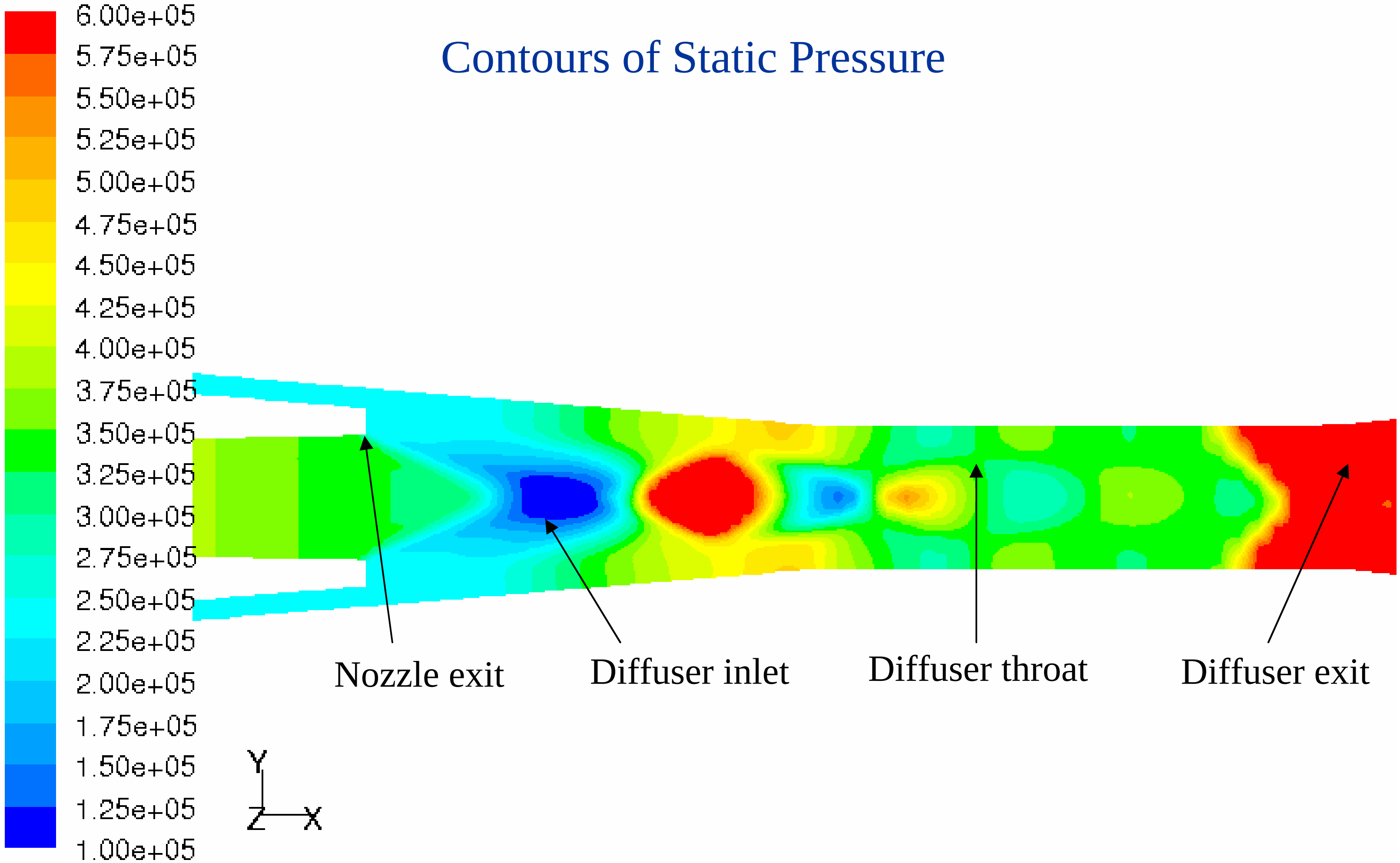
1st Stage (CFD Results)



1st Stage (CFD Results)



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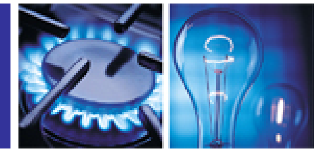
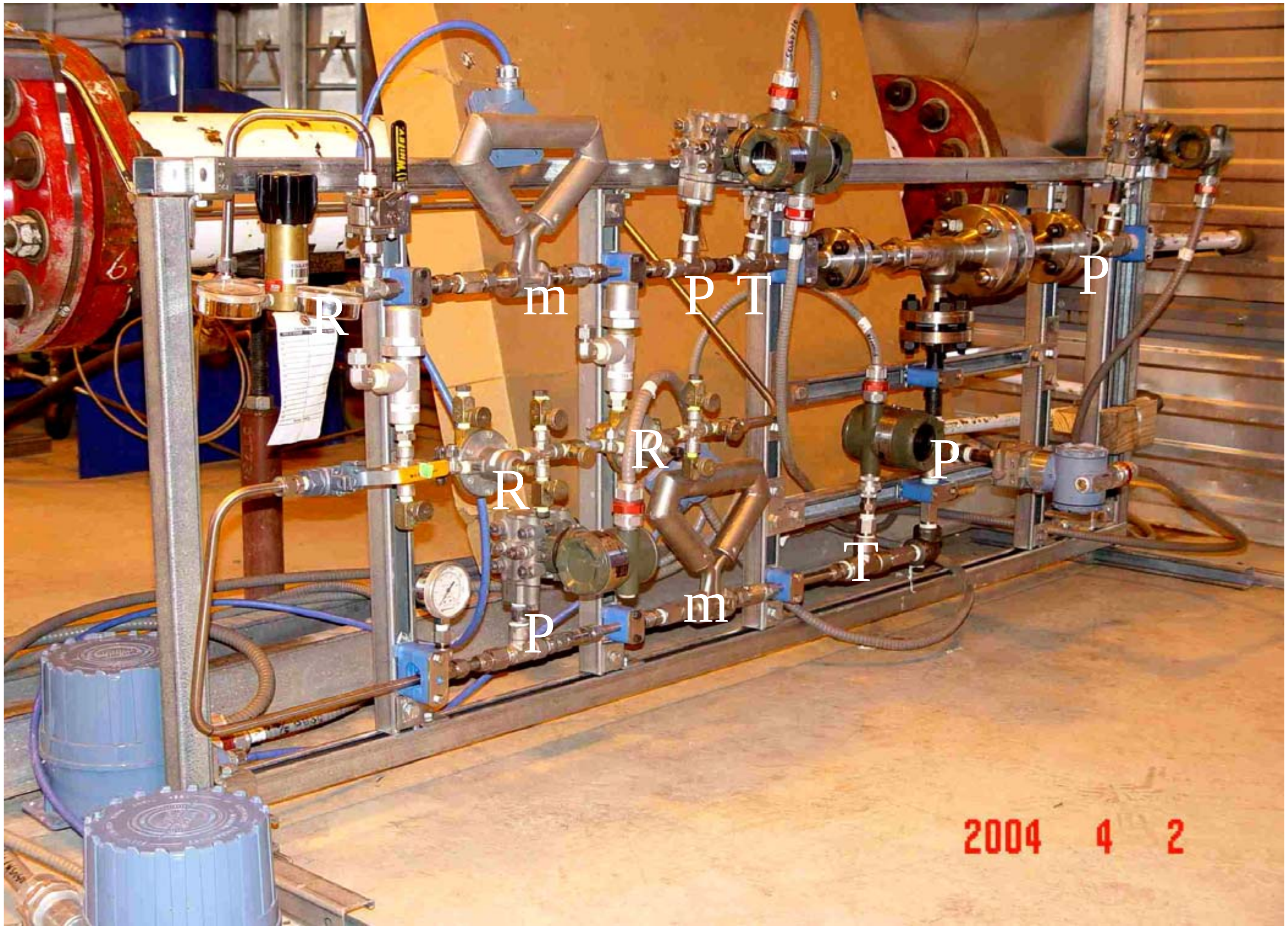
Bench Testing at Compressor Station in Alberta





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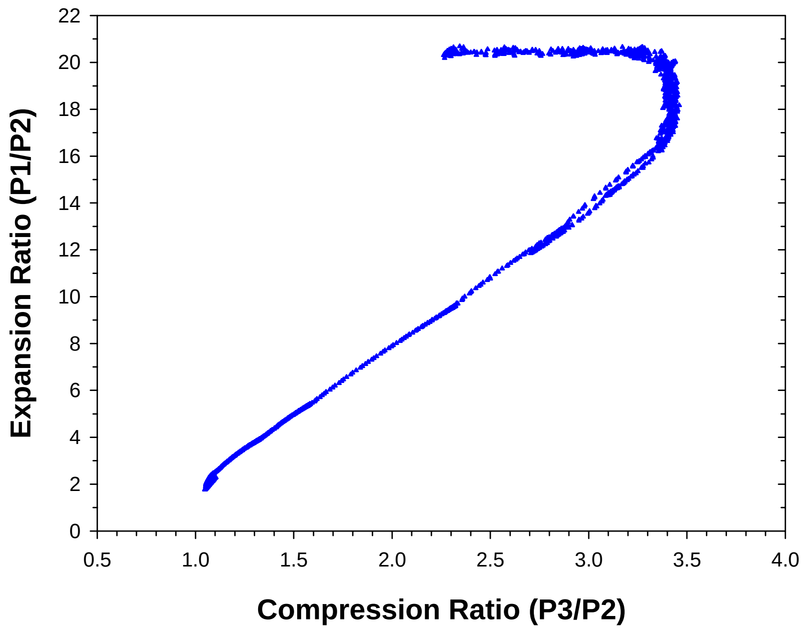
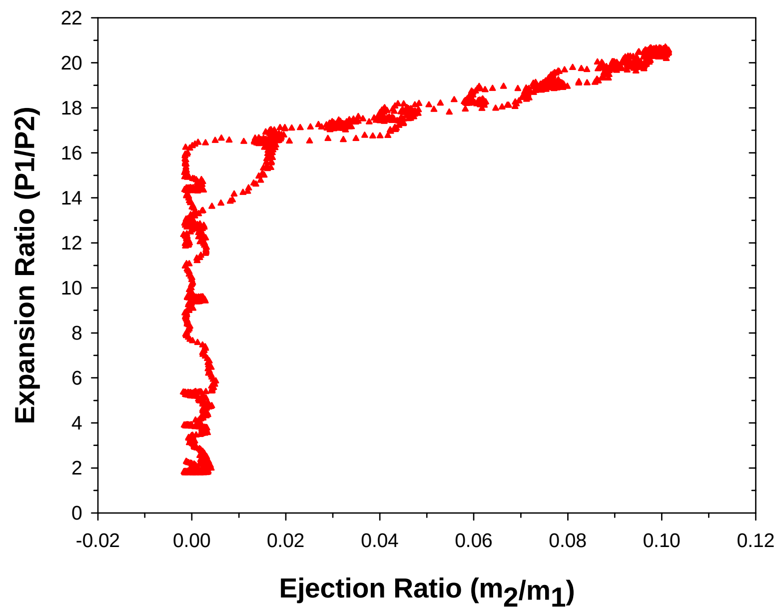
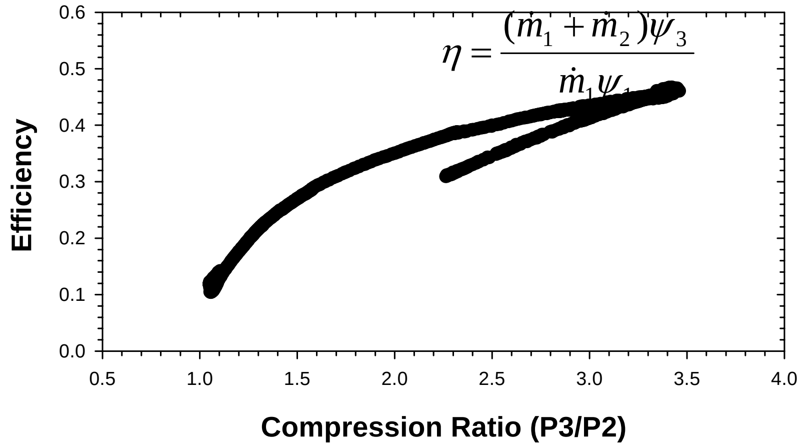
1.6x2.8 mm Nozzle @ 20.5 mm position

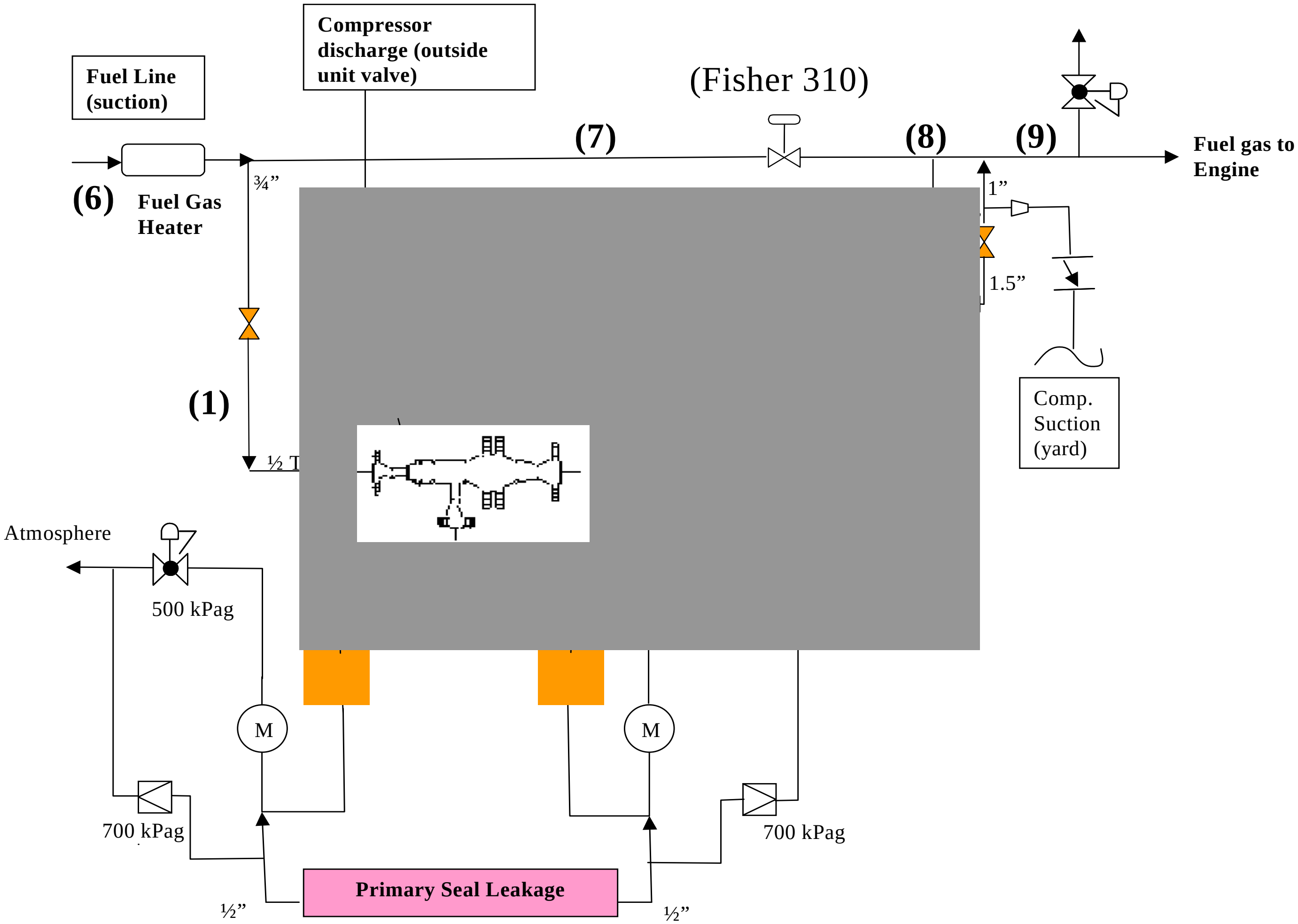






$$\eta = \frac{(\dot{m}_1 + \dot{m}_2)\psi_3}{\dot{m}_1 \psi_1}$$

P&ID for Supersonic Gas Ejector Skid



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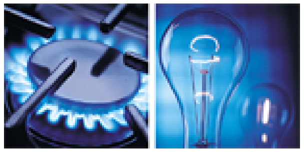
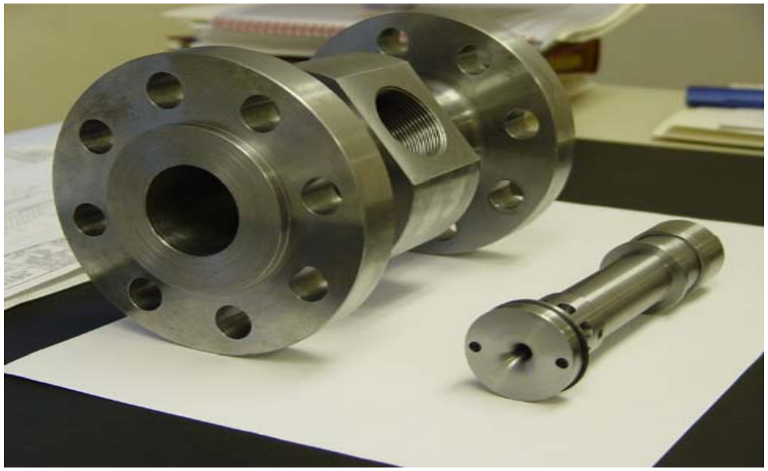
2nd Stage Ejector Nozzles and Internals





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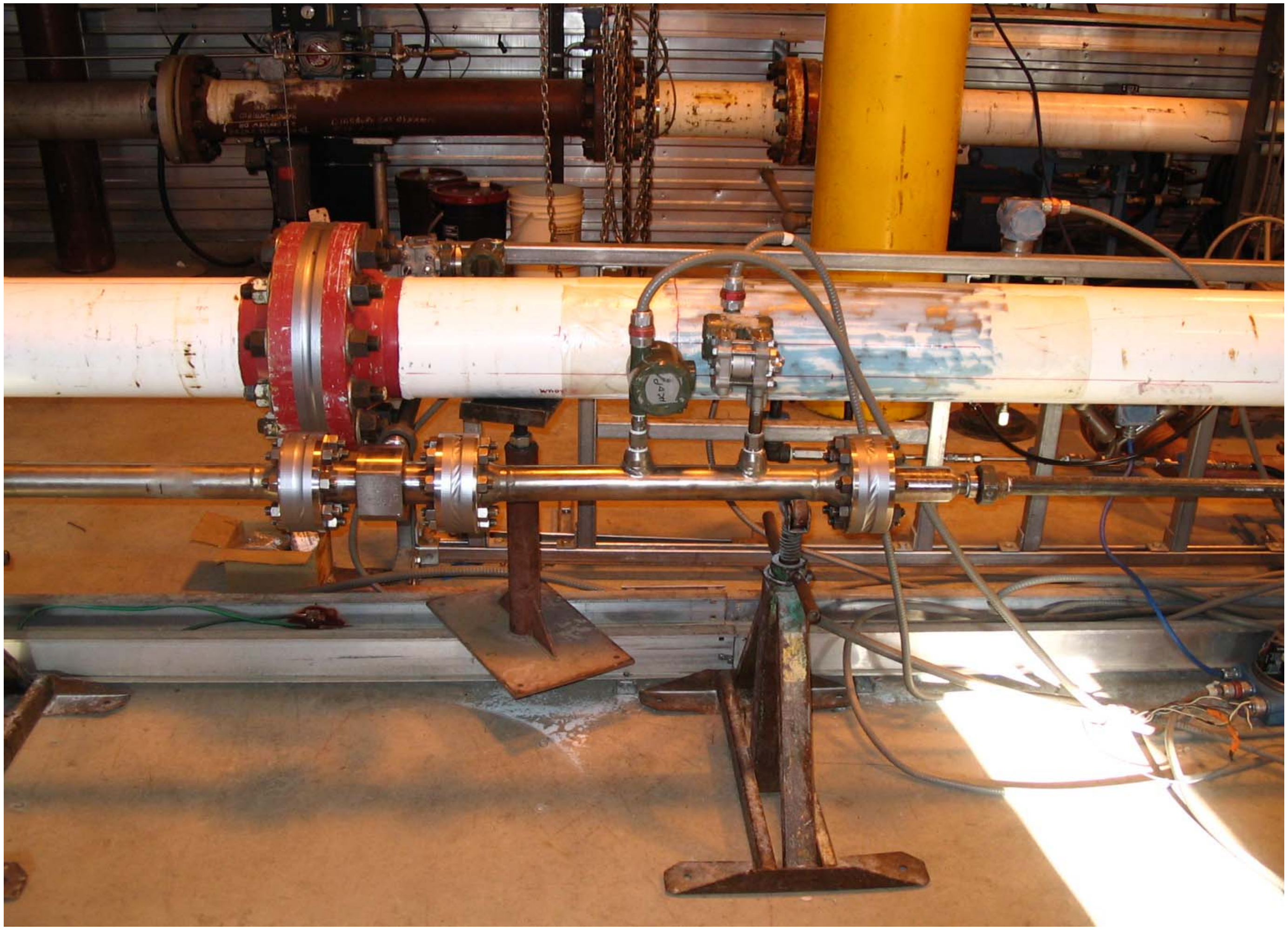
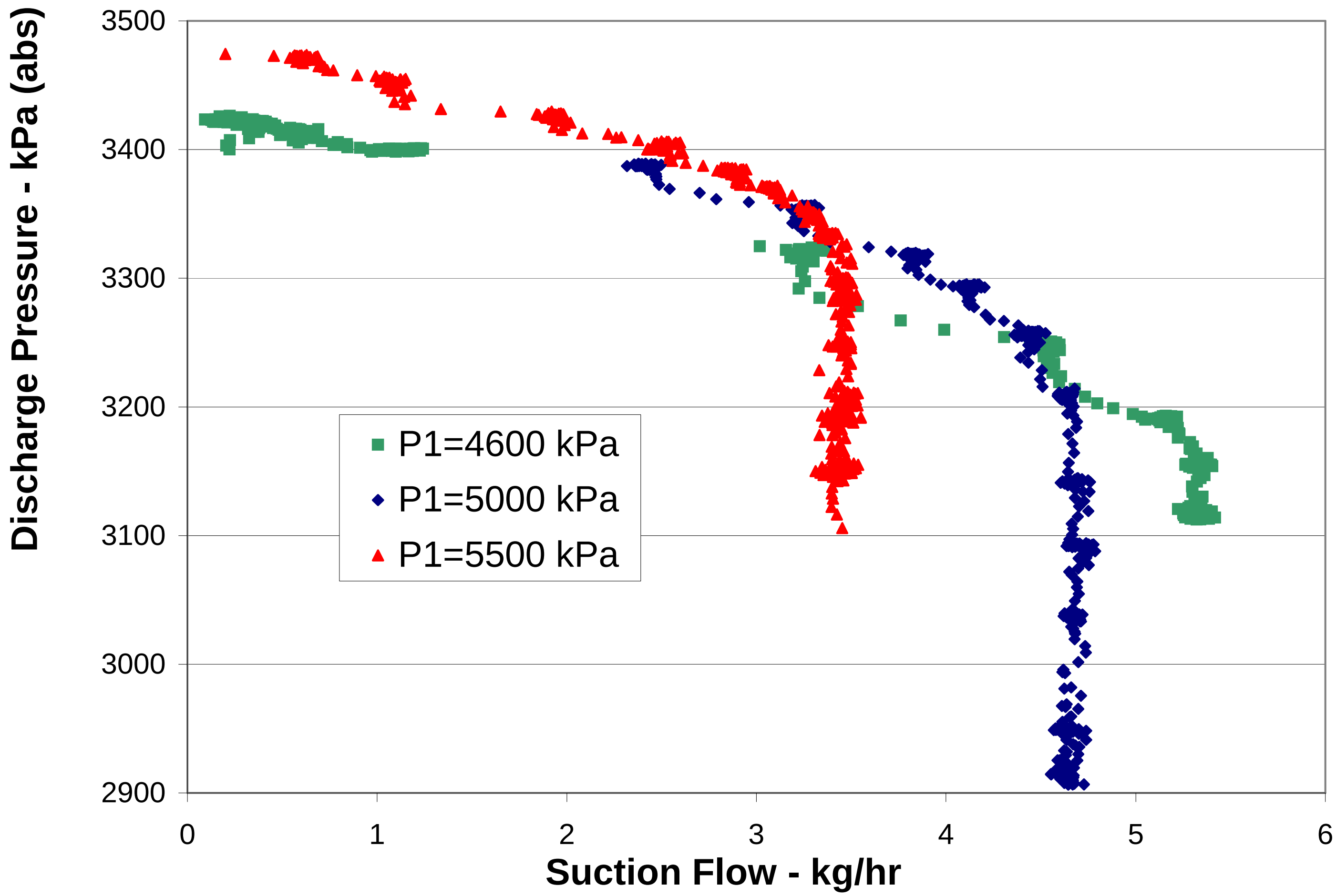
Test bench at Didsbury Compressor Station



Test Results of the Two-Stage SSE System



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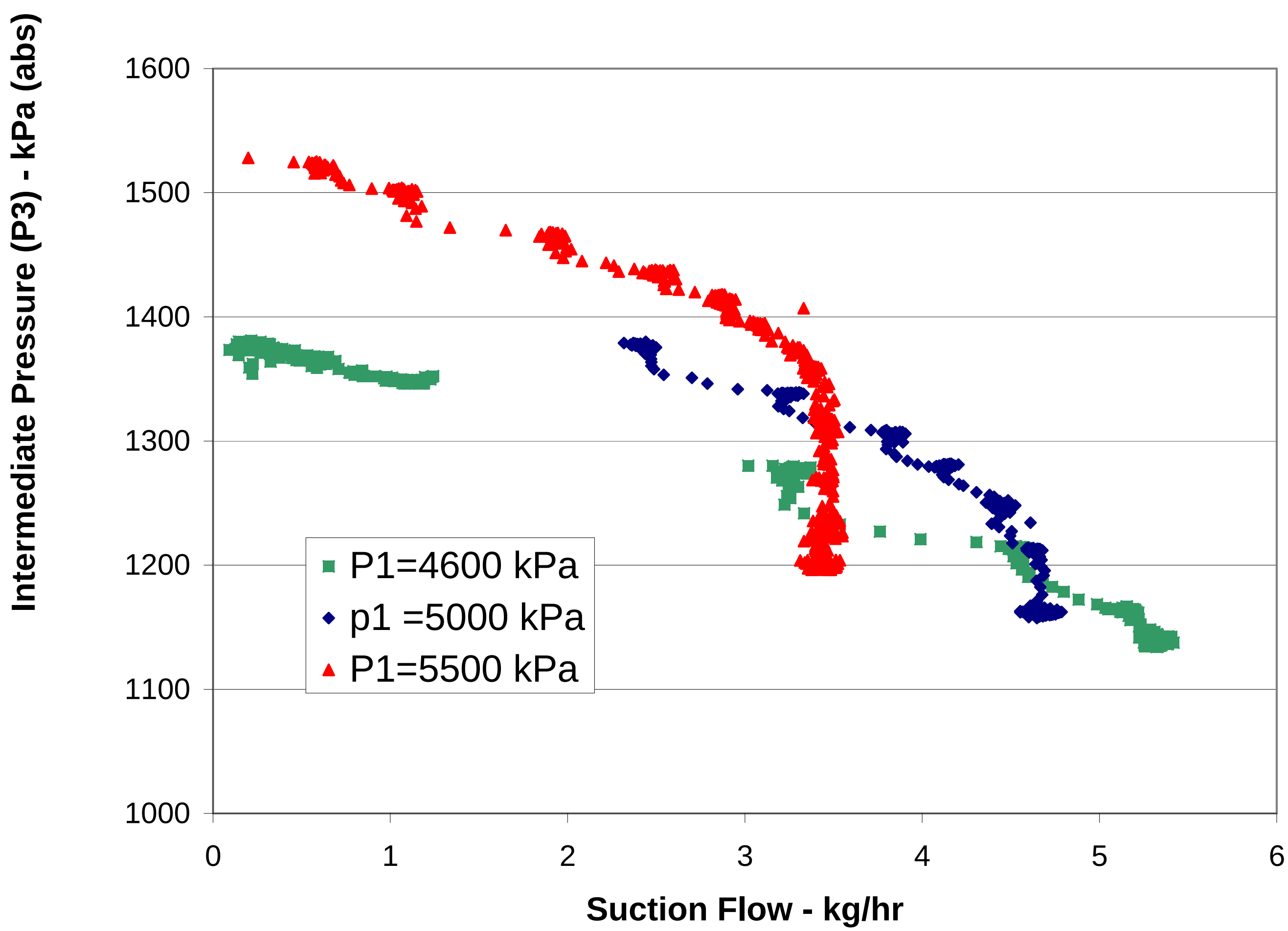
Test Results of the Two-Stage SSE System



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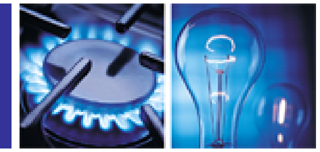
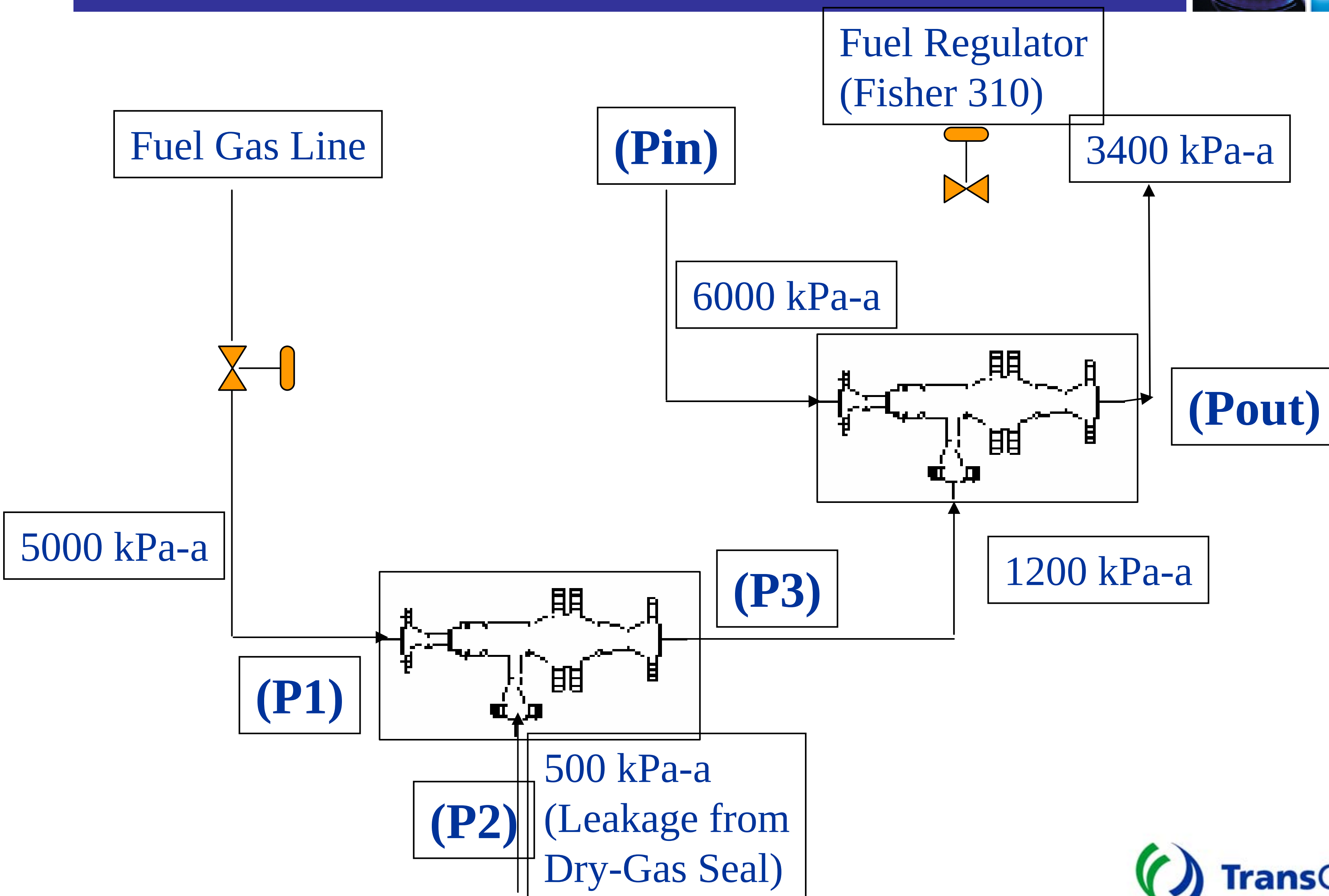
P&ID Schematic of the 2-stage Ejector system





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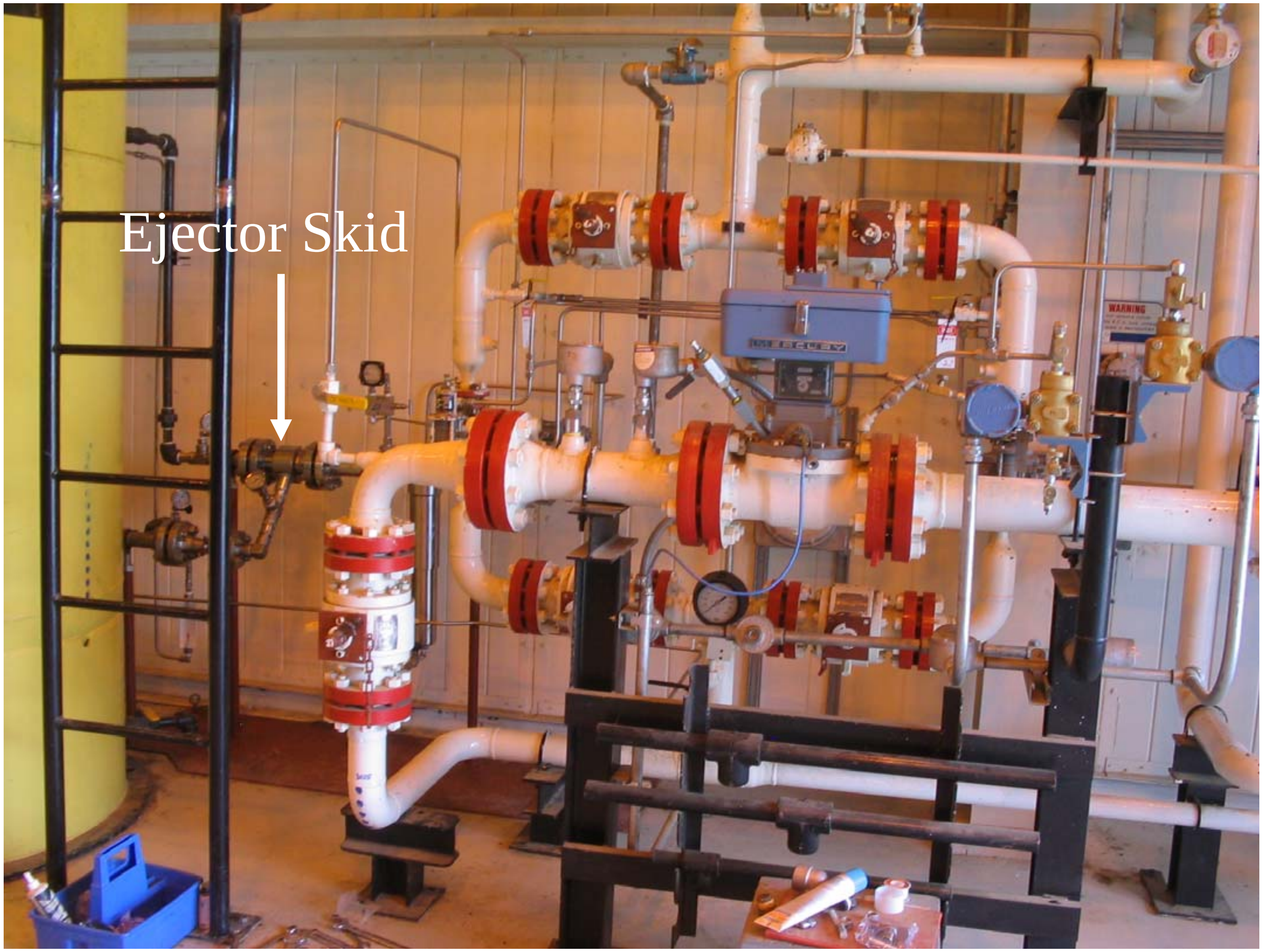
Fuel Gas System to Gas Turbine



Project Team After Installation

TransCanada Compressor Station in Alberta

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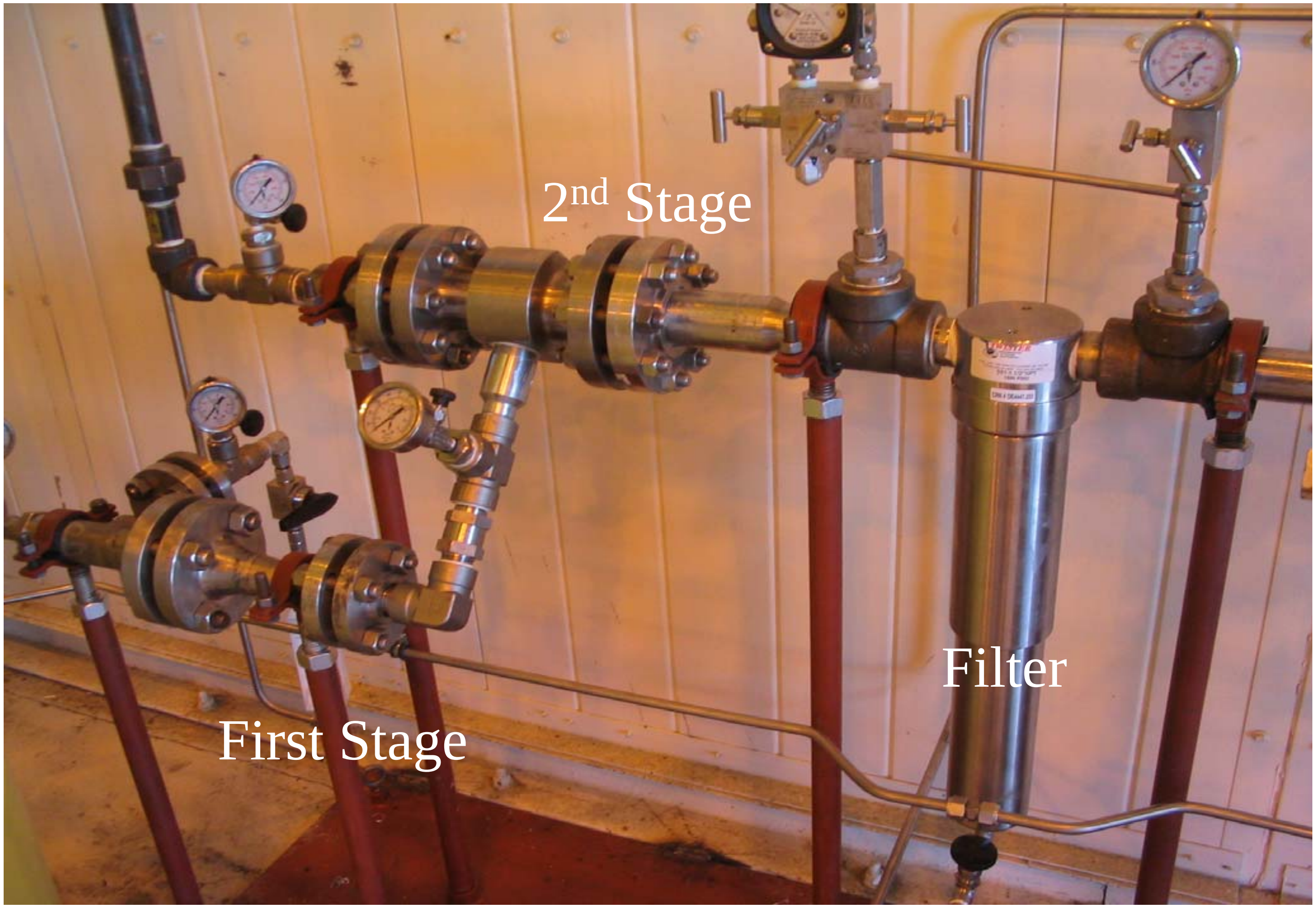
Gas-Gas Ejector Skid



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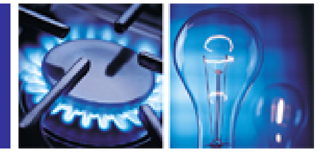
Field Test data collected from Pilot Project



Location # (Refer to Fig. 11)	P (kPa-a)	T (^{o}C)	Mass Flow (kg/s)	Mass Flow (kg/hr)
1	5090	35.9	0.01770	63.720
DE Seal	506	10.0	0.001607	5.785
NDE Seal	512	10.0	0.001607	5.785
Total Seal Leakage	509	10.0	0.003214	11.570
N1	509	-113.0	0.01770	63.720
2	509	10.0	0.00286	10.285
Vent to Amb	509	10.0	0.00036	1.285
3	1190	12.7	0.021	74.005
4	5990	35.0	0.463	1668.240
N2	1190	-68.0	0.463	1668.240
5	2990	8.2	0.484	1742.245
6	5140	10.0	1.177	4237.500
7	5090	35.9	0.693	2495.255
8	2900	23.0	0.693	2495.255
9	2690	18.4	1.177	4237.500

Collected After Successful Commissioning of the Supersonic Ejector (Data Collected on June 23, 2007).

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Continued – Filed Test Data

Location # (Refer to Fig. 11)	P (kPa-a)	T (^oC)	Mass Flow (kg/s)	Mass Flow (kg/hr)
1	5800	35.9	0.02017	72.612
DE Seal	512	10.0	0.00214	7.704
NDE Seal	517	10.0	0.001696	6.106
Total Seal Leakage	515	10.0	0.003836	13.810
N1	515	-113.0	0.02017	72.612
2	515	10.0	0.00250	9.000
Vent to Amb	515	10.0	0.00134	4.810
3	1400	12.7	0.023	81.612
4	6540	35.0	0.506	1820.880
N2	1400	-68.0	0.506	1820.880
5	3160	8.2	0.528	1902.492
6	5850	10.0	1.177	4237.500
7	5800	35.9	0.649	2335.008
8	3100	23.0	0.649	2335.008
9	2690	18.4	1.177	4237.500

Collected After Successful Commissioning of the Supersonic Ejector (Data Collected on July 20, 2007).

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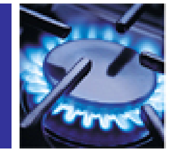
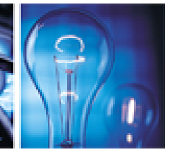
Net Savings





Ejector 2nd stage motive flow	0.4634	kg/s
Motive gas extra power needed	9,300	W
Motive gas turbine extra fuel needed	31,000	W
Fuel heating value	39	MJ/m3
Fuel heating value	52,000,000	J/kg
Fuel gas burned	0.000596154	kg/s
GHG CO2 from above burning	0.00155	kg/s
GHG CO2 from above burning	48.8808	tonnes/year
Captured Dry-seal vent gas	9	kg/hr
Captured Dry-seal vent gas	0.0025	kg/s
Heat Energy Equivalent	130,000	W
GHG CO2-E of the captured gas	0.0525	kg/s
GHG CO2-E of the captured gas	1,656	tonnes/year
Net Heat Energy Saving	**99,000**	W
Net GHG CO2-E	**1,607**	tonnes/year

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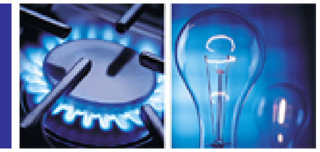
Conclusions



- It is possible to achieve a very high expansion ratio (14-18 20 times) with a supersonic nozzle. The challenge is always in the recompression of the expanded gas through a supersonic diffuser.

- For the application of a supersonic ejector for the purpose of capturing the vent gas from the primary dry-gas seal, a two-stage ejector was developed:
  - Expansion of the motive gas in the first stage ejector nozzle is easy.
  - However, recompression to a pressure equal to the fuel gas pressure was the challenge, and that necessitated the second stage to boost the gas pressure to an adequate level.

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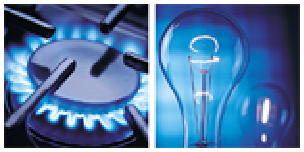
Conclusions



- Implementation design concept and analysis indicated that the above implementation plan, which attended to operational and functional details of both the primary and secondary seals, as well as the adjacent magnetic bearing chamber, is achievable.

- The S.S. ejector system was installed and commissioned successfully on an 24 MW GT unit in one of TransCanada’s compressor stations in Alberta, and is currently accumulating hours of operation:
  - Reducing 1600 tonnes/year of CO2-E of GHG.
  - Saving of 99 kW of Heat Energy.

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Benefits

- ✓ 100% recovery of vented methane gas
- ✓ 100% capture of greenhouse gas emissions
- ✓ No moving parts
- ✓ No seal, no shaft, no packing
- ✓ Maintenance free operation
- ✓ Zero operating cost
- ✓ Use is not limited to compressors only
- ✓ Can be used wherever there is low pressure, low flow rate vent stream and a high pressure stream
- ✓ Small footprint
- ✓ Pay back period 1-2 years

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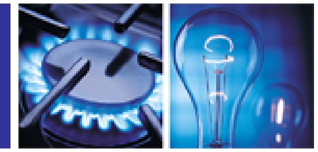
Global Pipeline Honorable Mention Award



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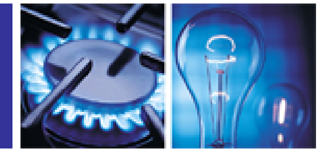

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