CanmetENERGY

Leadership in ecoInnovation

On the Performance of an Advanced Pilot-Scale CO_2 Capture and Compression Unit (CO_2CCU)

Kourosh E. Zanganeh, Ahmed Shafeen, and Carlos Salvador

Zero Emission Technologies (ZET) Group
Clean Electric Power Generation
CanmetENERGY, Natural Resources Canada

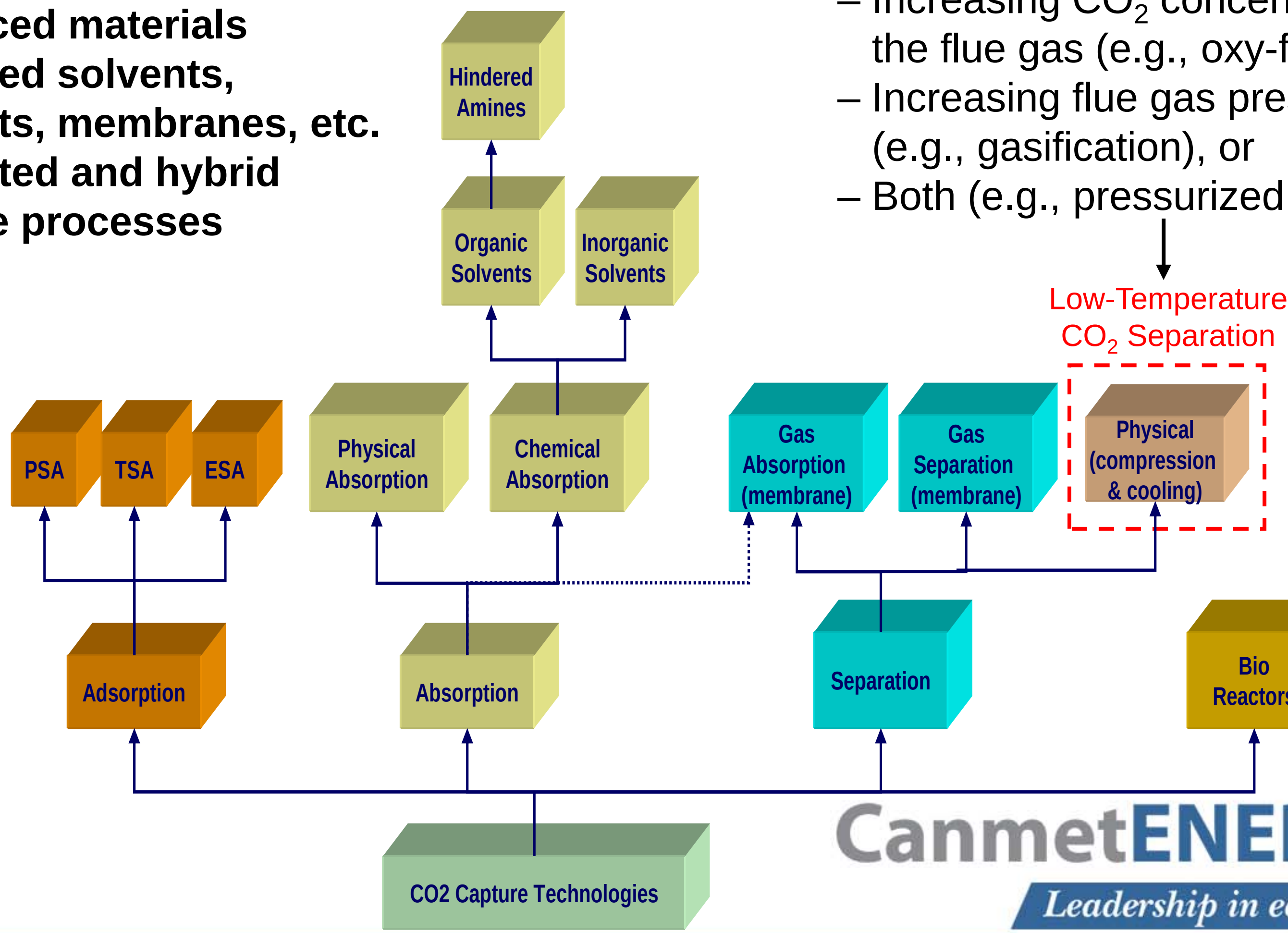
1st International Oxyfuel Combustion Conference
(Cottbus, Germany)

CO_2 Capture Process Options

Challenge: How to reduce the *cost* of CO_2 capture and compression?

- **Advanced materials**
- **Improved solvents, sorbents, membranes, etc.**
- **Integrated and hybrid capture processes**

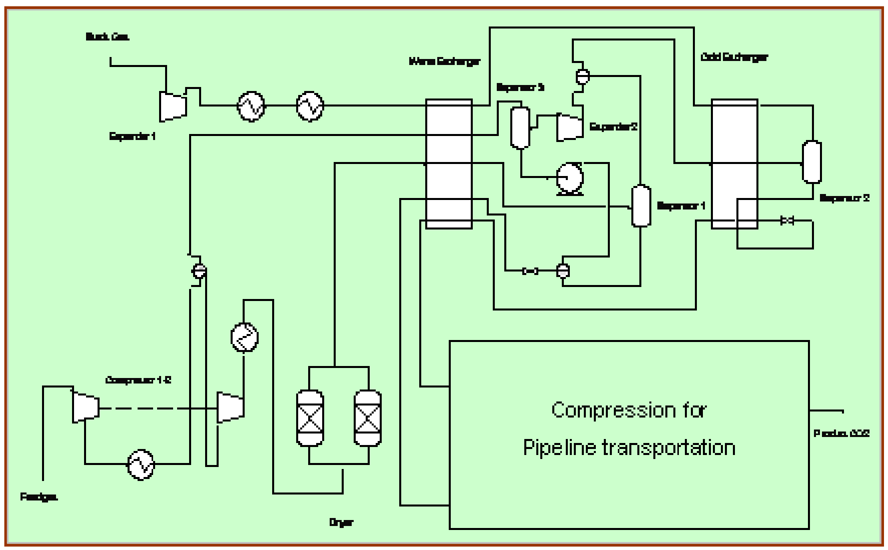
- Facilitate CO_2 capture by
  - Increasing CO_2 concentration in the flue gas (e.g., oxy-fuel)
  - Increasing flue gas pressure (e.g., gasification), or
  - Both (e.g., pressurized oxy-fuel)

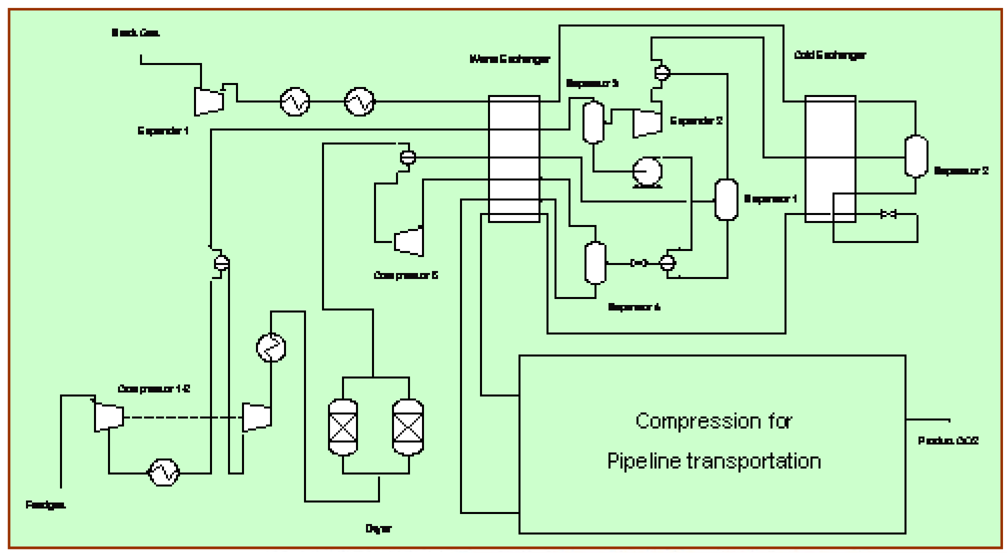


CanmetENERGY
Leadership in ecoInnovation

Development of CanmetENERGY's CO_2CCU

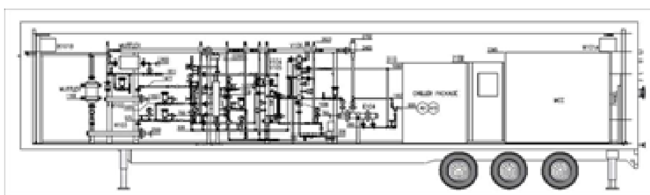
- An efficient low-temp. separation process was developed for capture of CO_2 from oxy-fuel combustion and other flue gas streams
- Design objectives were set to maximize the CO_2 *recovery* rate, at or above a given *purity* level, while minimizing the *energy* demand over a range of *feed gas compositions:*
  - CO_2 mole fraction in the inlet flue gas stream > 50%
  - CO_2 product purity > 95%



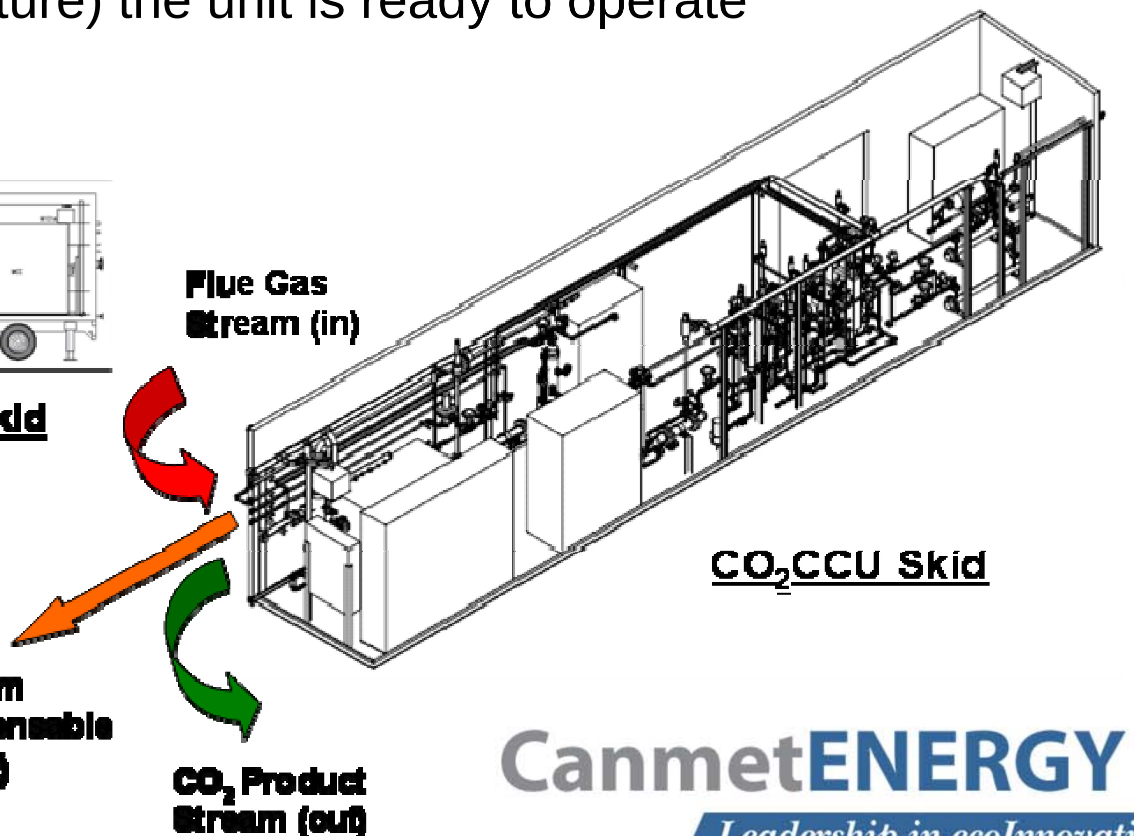


Implementation of CO_2CCU

- Trailer-mounted modular unit
- Onboard independent control system to operate and control the unit
- Transportable and suitable for field testing and demonstrations
- Once connected to the appropriate power source and feed gas stream (for CO_2 capture) the unit is ready to operate



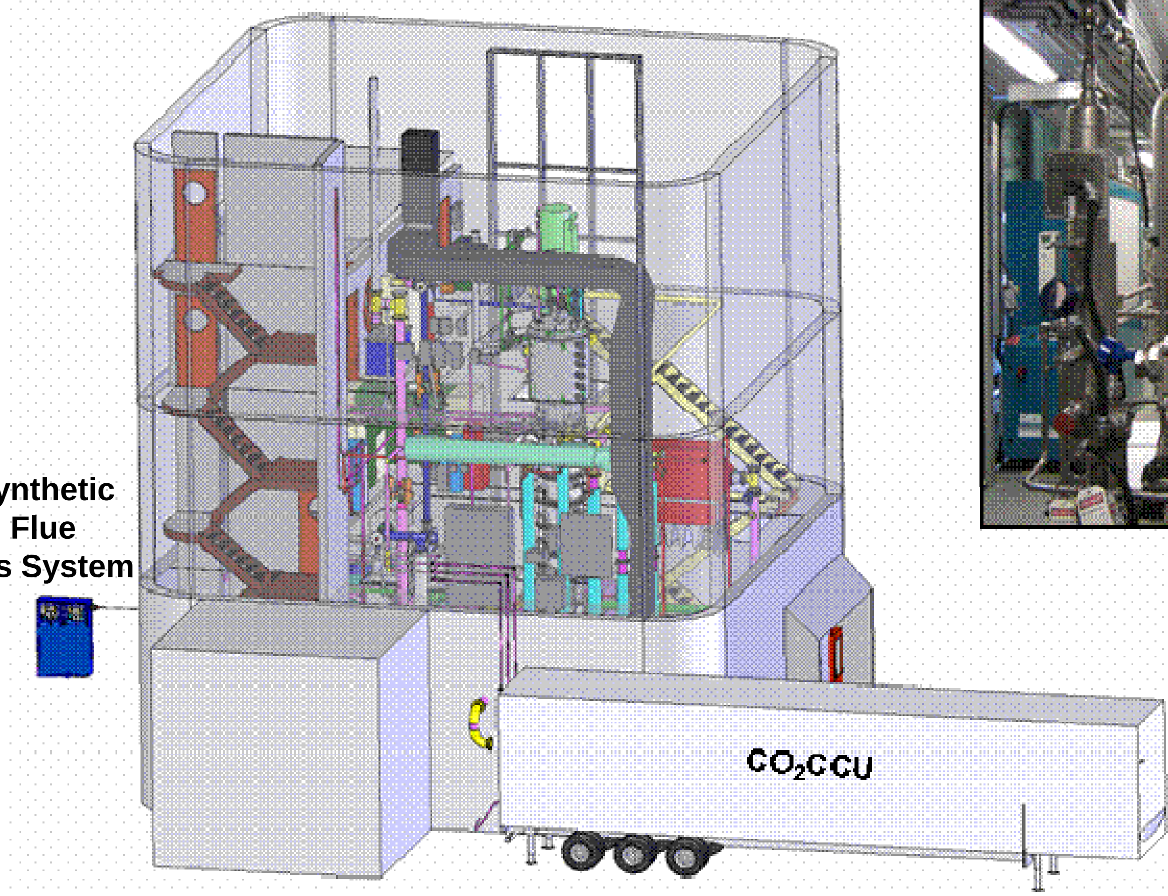
Trailer Mounted CO_2CCU Skid



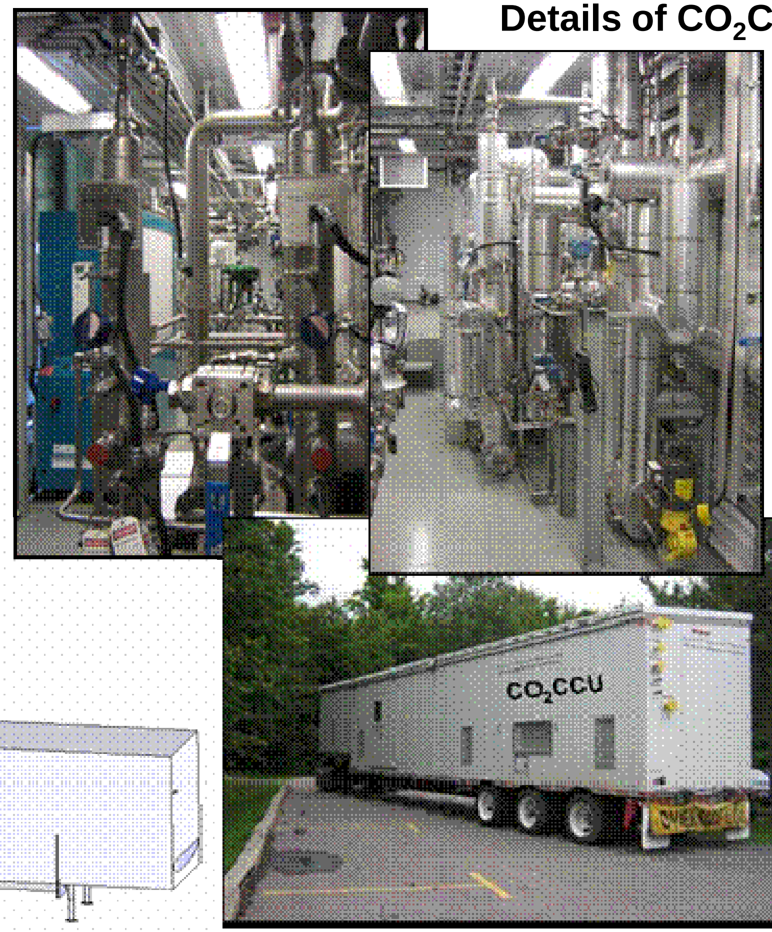
Implementation of CO_2CCU – System Integration

0.3 MW_{th} Oxy-fuel Vertical Combustor Research Facility (VCRF); operational since 1994.

Synthetic Flue Gas System



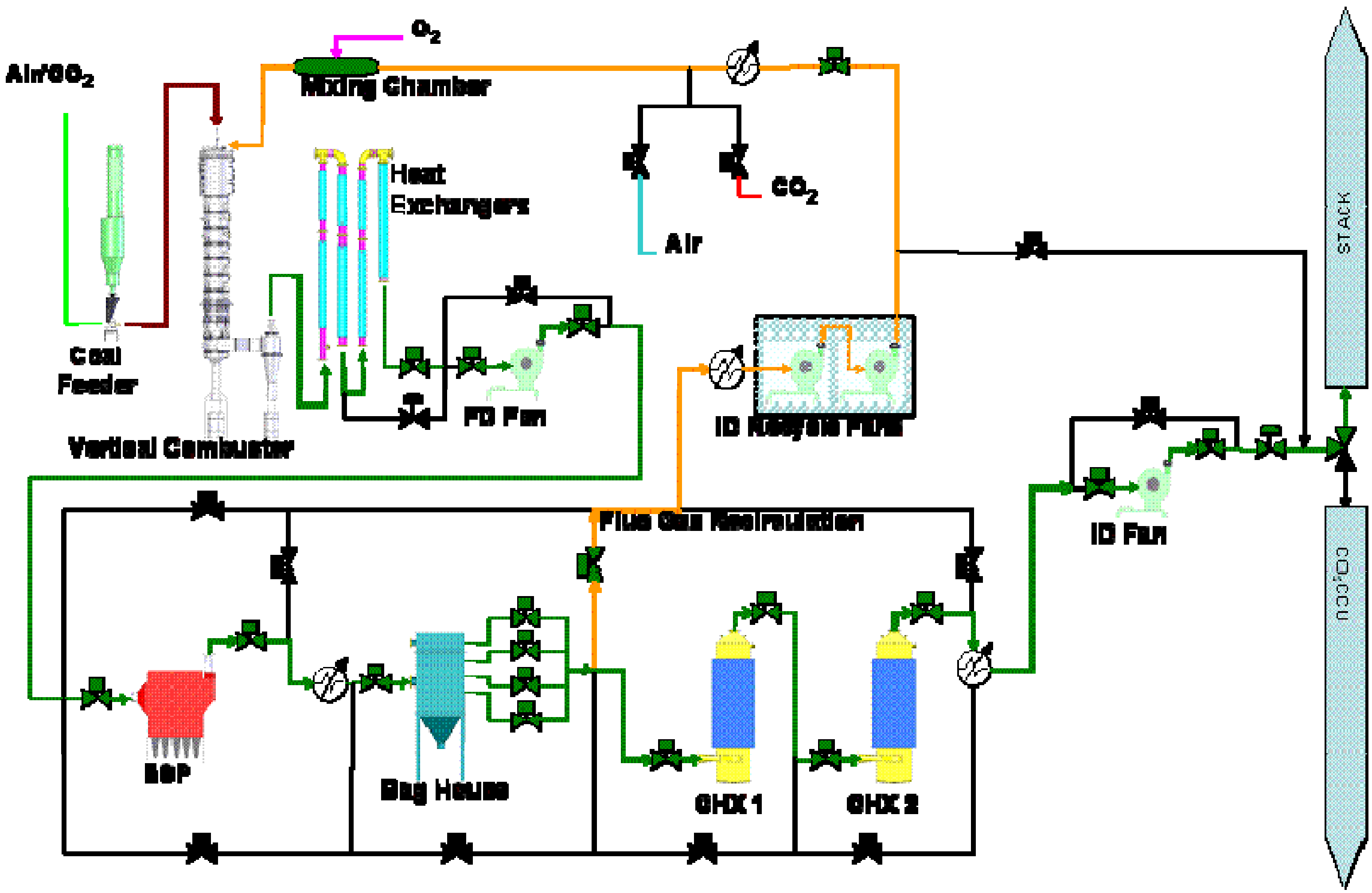
Details of CO_2CCU



CanmetENERGY

Leadership in ecoInnovation

Integrated VCRF-CO_2CCU Process Flow Diagram



Note: Hg IS REMOVED USING AN ACTIVATED CARBON FILTER, WITH A BYPASS OPTION.

Sample Simulated Compositions of Inlet & Outlet Streams (HYSYS™)

CO2 Recovery Rate ~ 75%

	Feedgas-1		Feedgas-2	
	Wet Basis	Dry Basis	Wet Basis	Dry Basis
	% vol	% vol	% vol	% vol
CO_2	74.34	75.68	50.00	51.68
O_2	6.14	6.25	2.42	2.50
Argon	2.41	2.45	2.03	2.10
N_2	14.98	15.25	42.02	43.43
H_2O	1.77	0.00	3.25	0.00
SO_2	0.32	0.33	0.23	0.24
NO	0.04	0.04	0.05	0.05

Feedgas-1 Outlet Streams			Feedgas-2 Outlet Streams		
Composition	Product	Vent	Composition	Product	Vent
Flow (kg/hr)	89.1	29.8	Flow (kg/hr)	51.4	66.6
Temp (deg C)	43	25	Temp (deg C)	43	25
Press (bar)	110	1	Press (bar)	110	1
Composition	[% vol]	[% vol]	Composition	[% vol]	[% vol]
CO_2	95.8	24.24	CO_2	95.51	29.17
O_2	1.13	19.35	O_2	0.26	3.65
Argon	0.6	7.19	Argon	0.32	3.01
N_2	2.01	49.11	N_2	3.2	64.1
H_2O	0	0	H_2O	0	0
SO_2	0.45	0	SO_2	0.69	0
NO	0.01	0.11	NO	0.01	0.06

Minimum Flow	80 kg/h
Maximum Flow	160 kg/h

Lead Chamber Process:

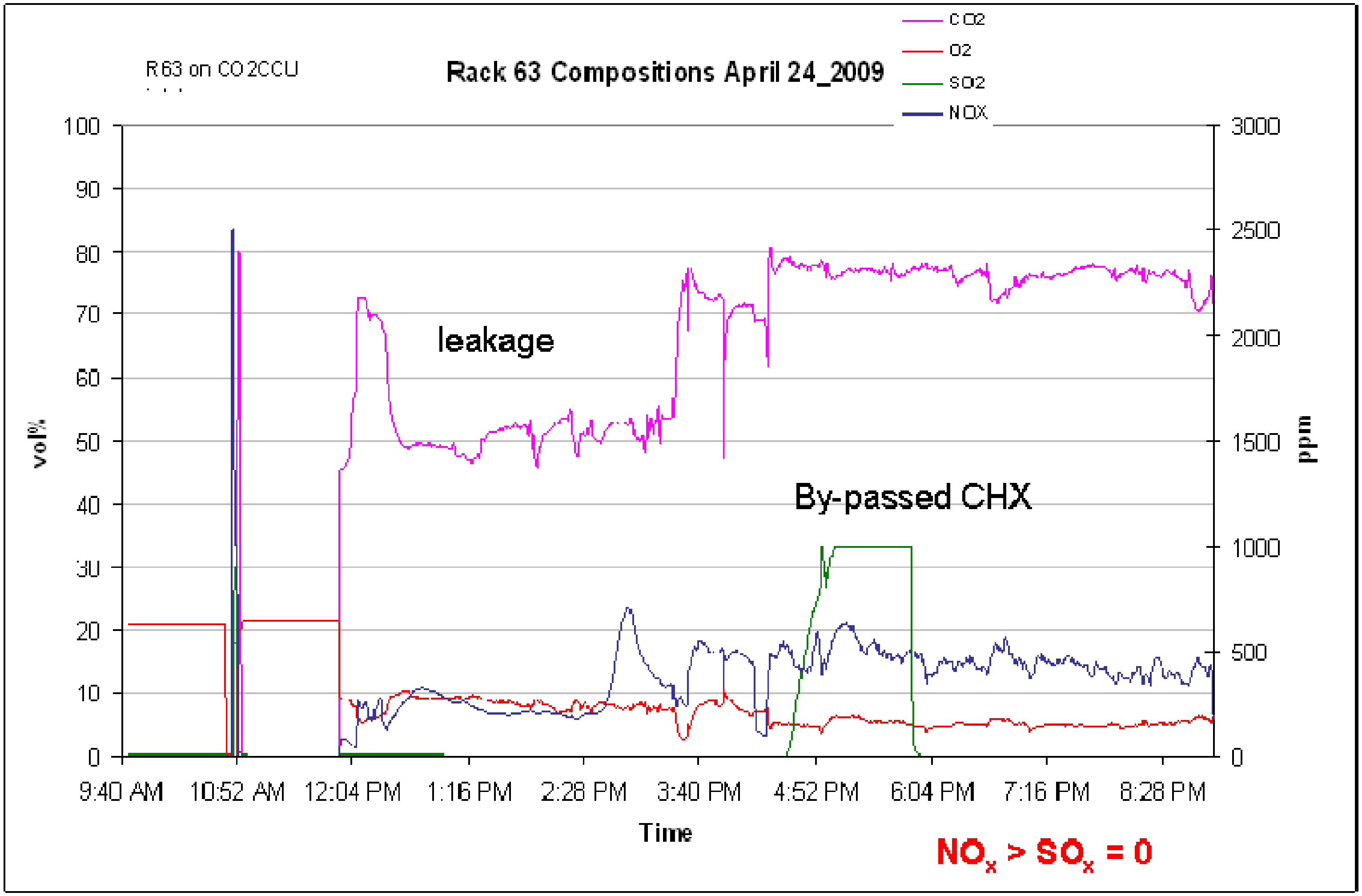
$$NO_2 + SO_2 + H_2O = NO + H_2SO_4$$

$$2\,NO_2 + H_2O = HNO_2 + HNO_3$$

$$3\,HNO_2 = HNO_3 + 2\,NO + H_2O$$

CanmetENERGY
Leadership in ecoInnovation

Test Results with Oxy-Coal Flue Gas

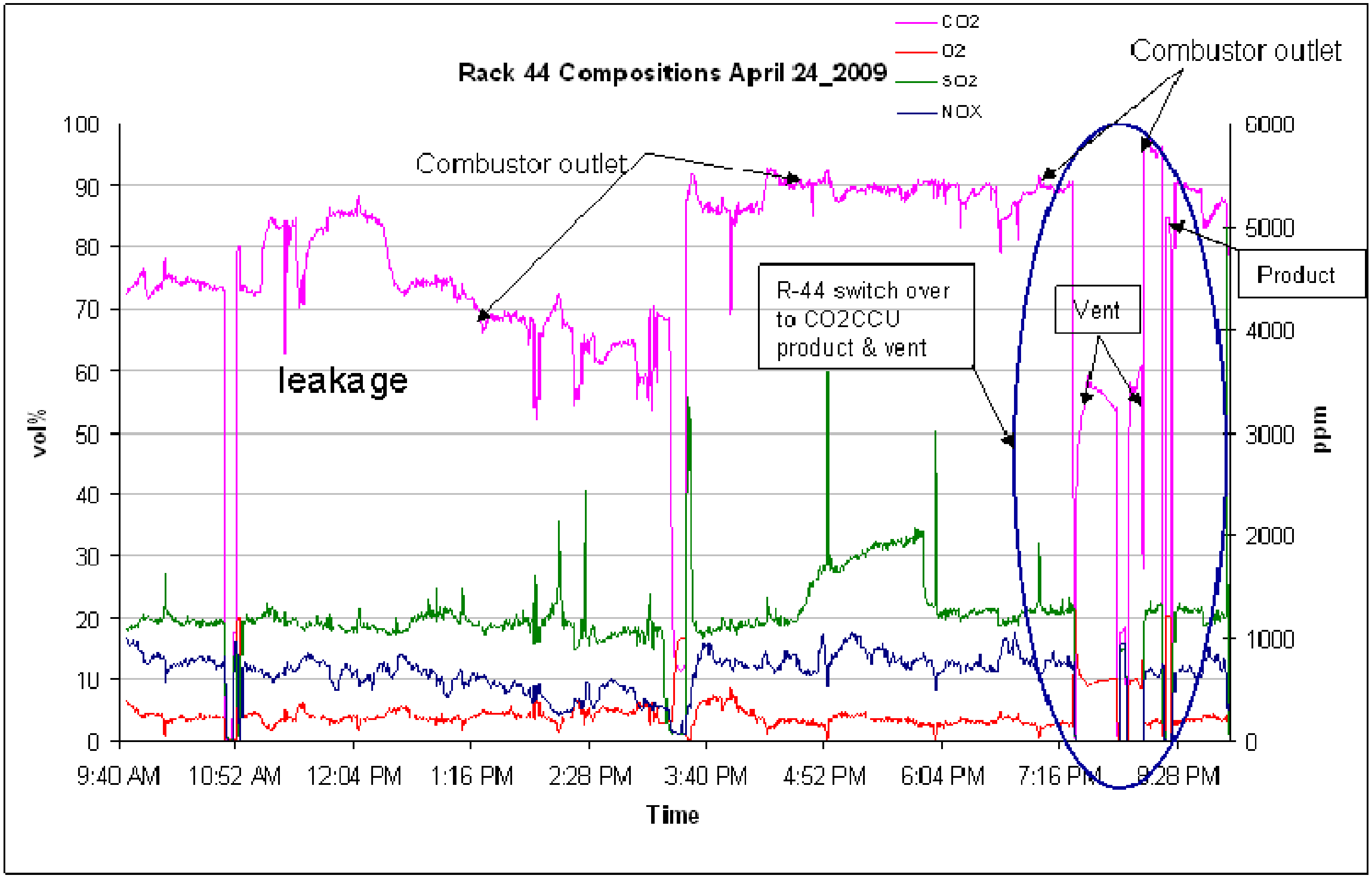


Inlet stream to CO_2CCU

CanmetENERGY

Leadership in ecoInnovation

Test Results with Oxy-Coal Flue Gas

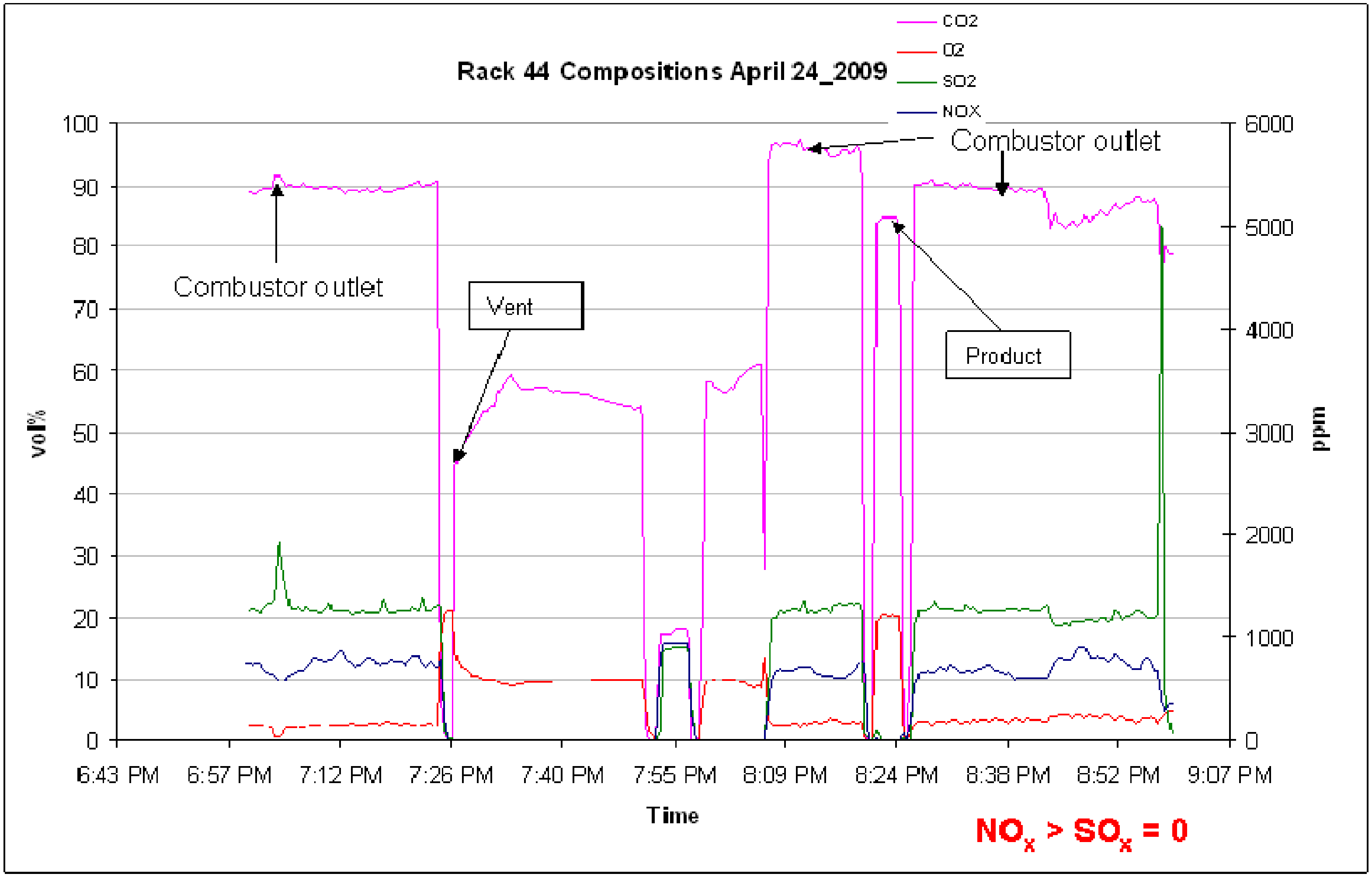


Combustor Outlet, Product and Vent Streams

CanmetENERGY

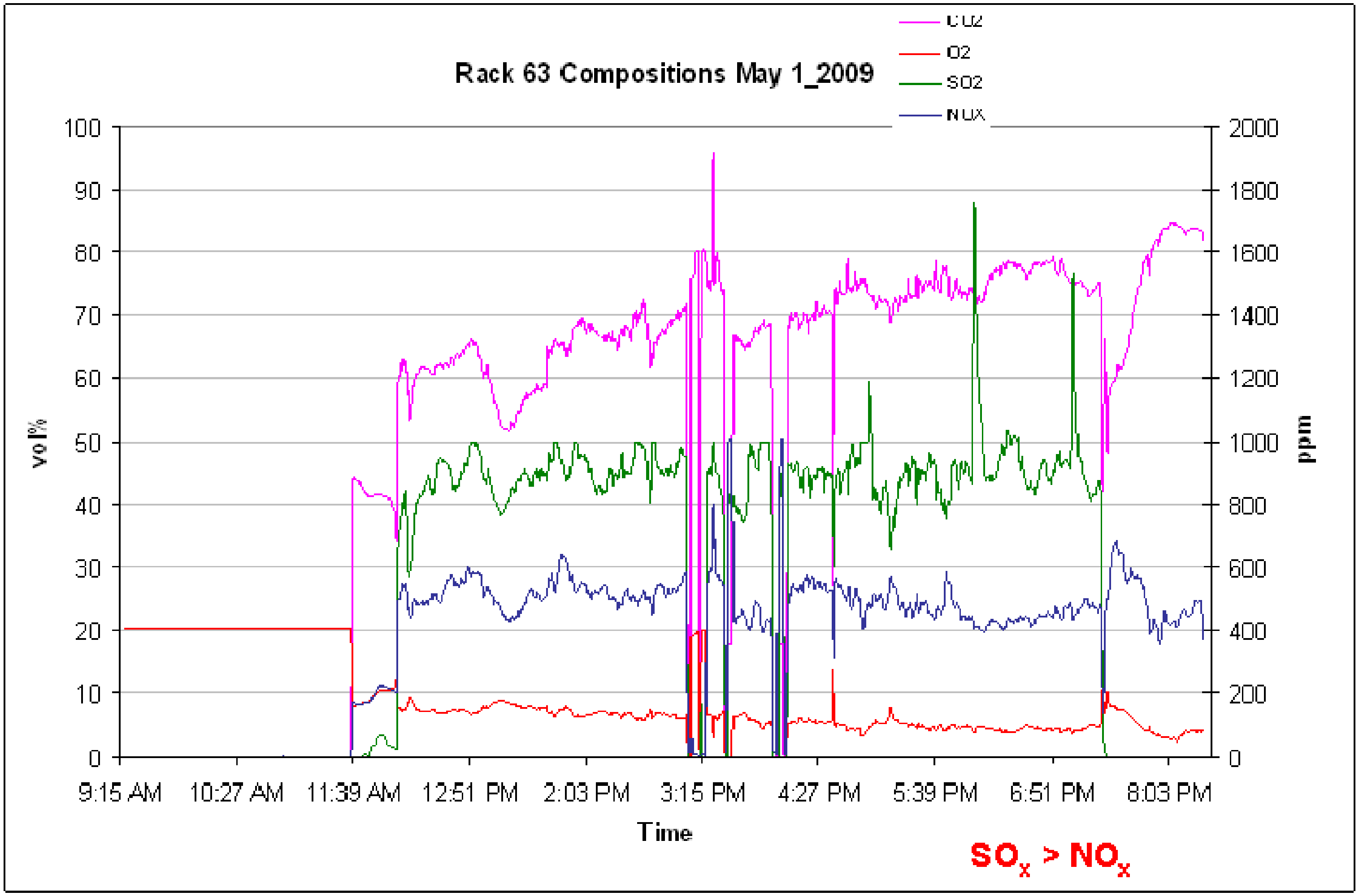
Leadership in ecoInnovation

Test Results with Oxy-Coal Flue Gas



Combustor Outlet, Product and Vent Streams

Test Results with Oxy-Coal Flue Gas

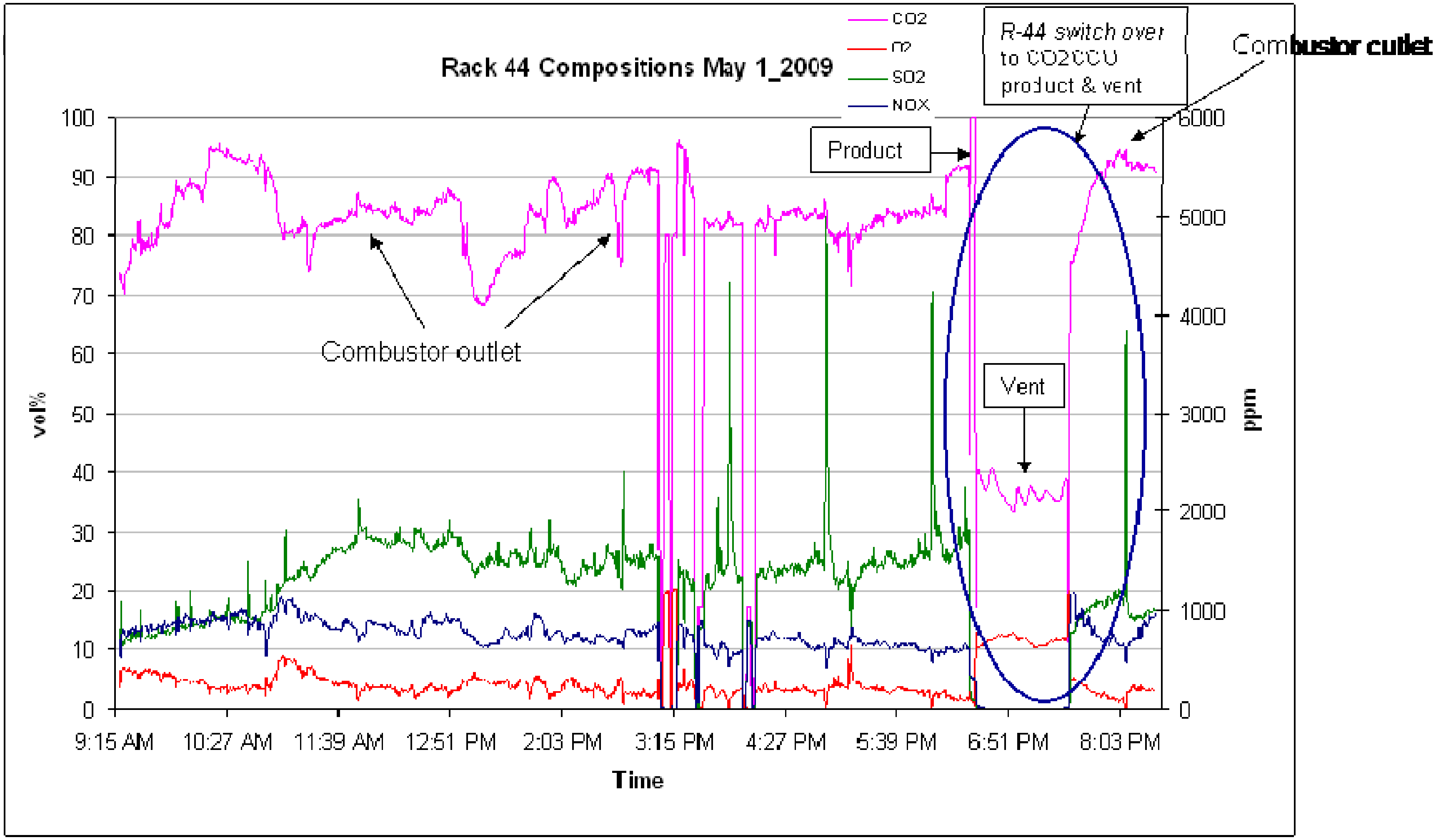


Inlet stream to CO_2CCU

CanmetENERGY

Leadership in ecoInnovation

Test Results with Oxy-Coal Flue Gas

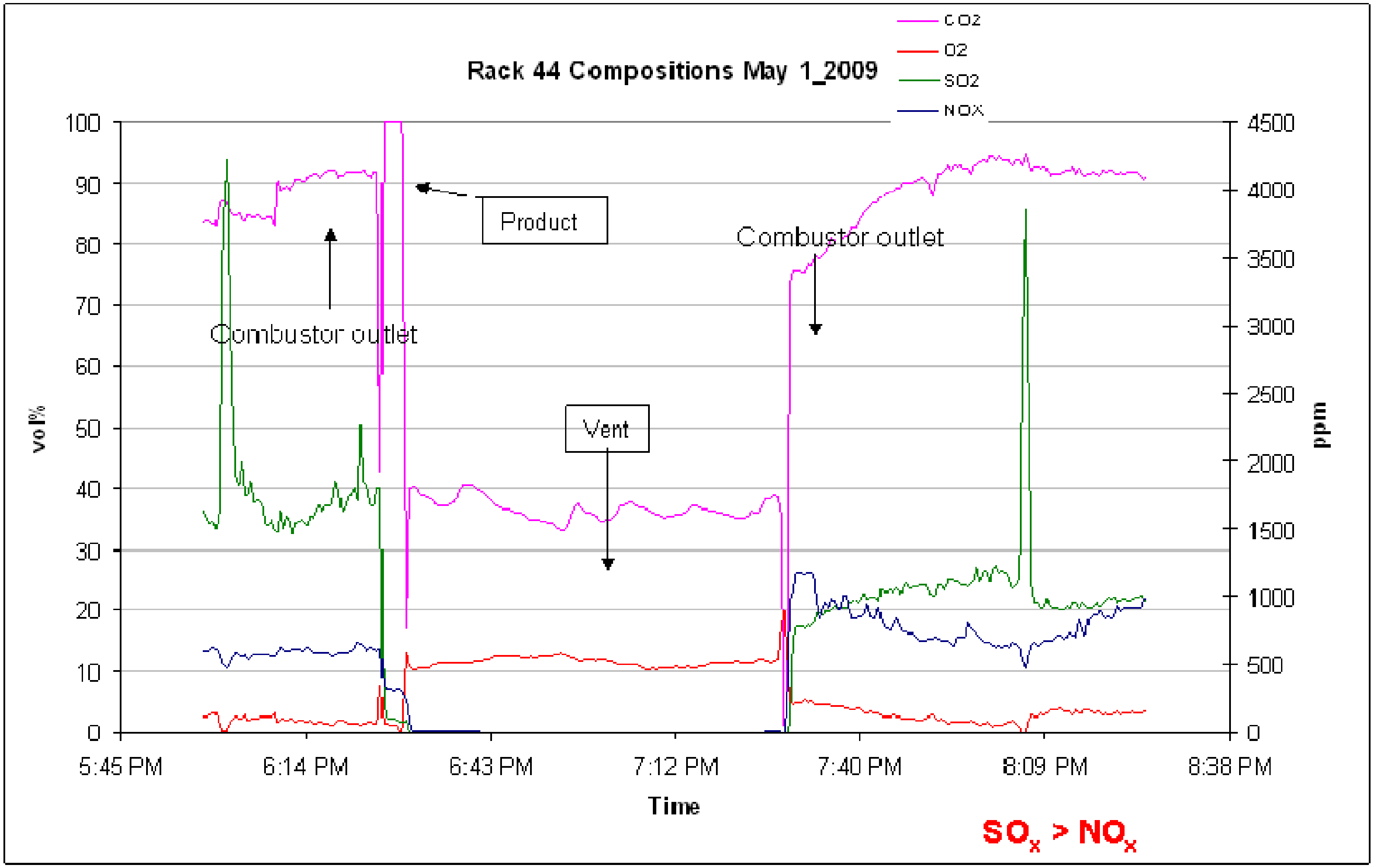


Combustor Outlet, Product and Vent Streams

CanmetENERGY

Leadership in ecoInnovation

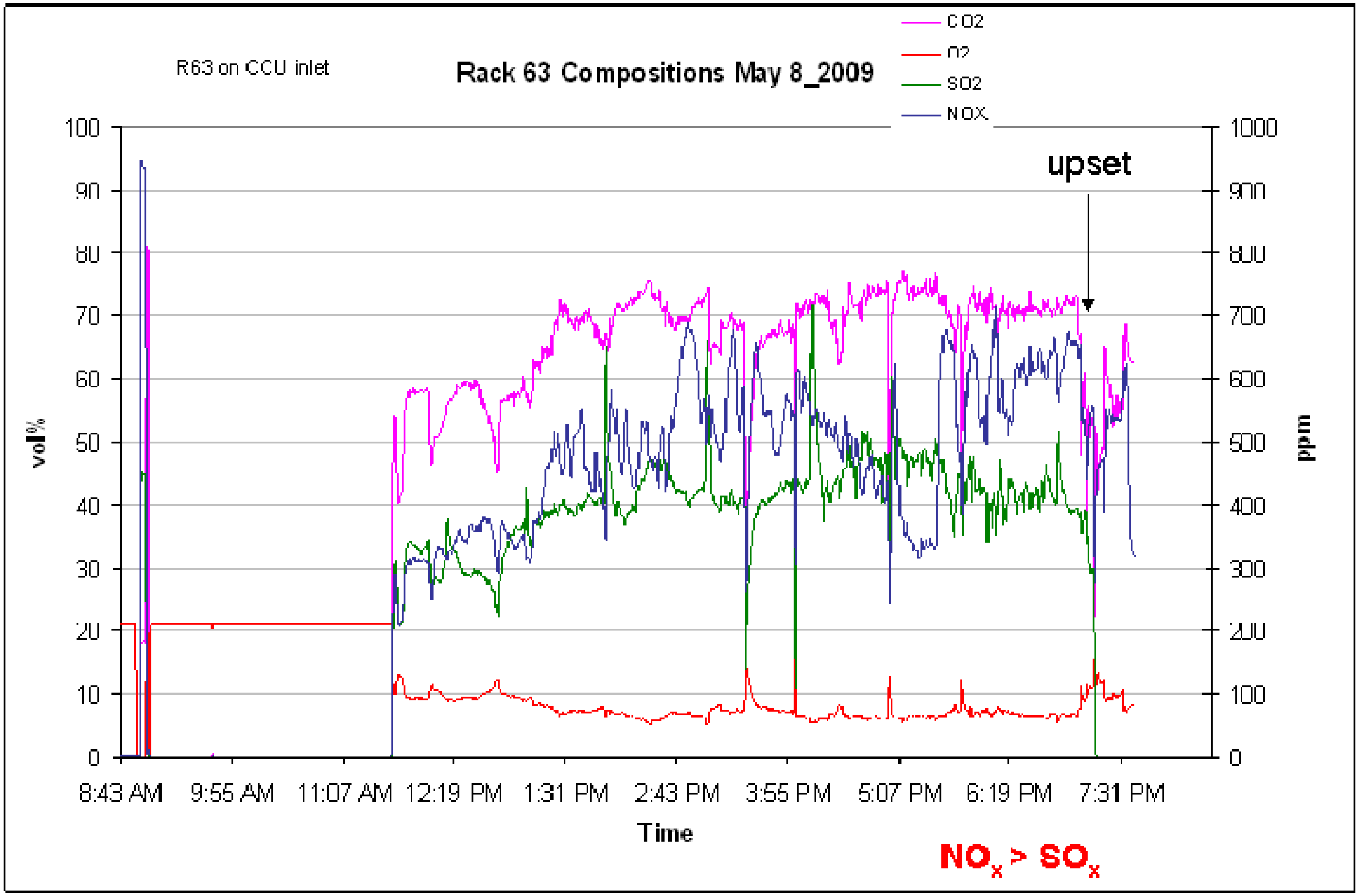
Test Results with Oxy-Coal Flue Gas



Combustor Outlet, Product and Vent Streams

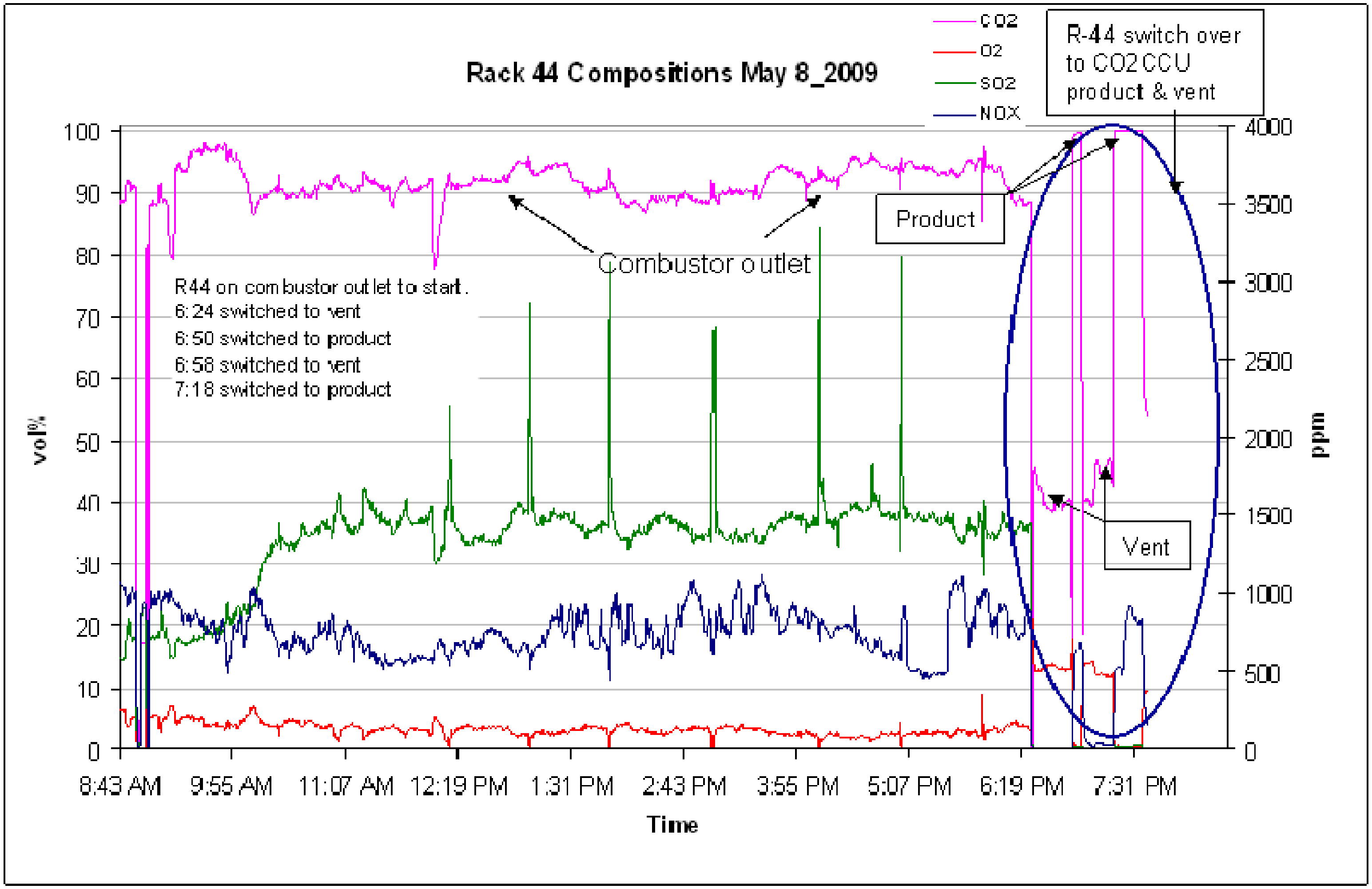
CanmetENERGY
Leadership in ecoInnovation

Test Results with Oxy-Coal Flue Gas



Inlet stream to CO_2CCU

Test Results with Oxy-Coal Flue Gas

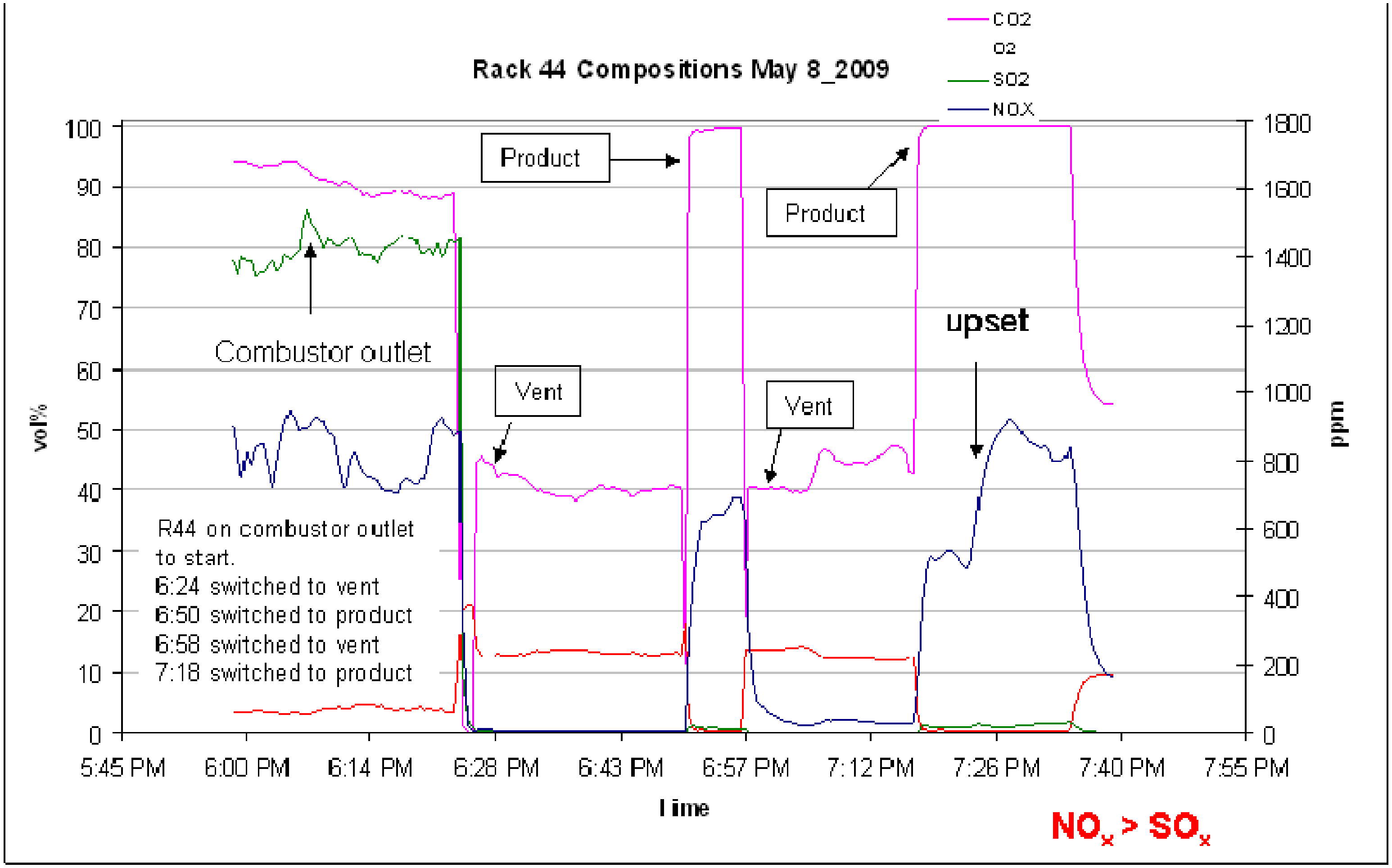


Combustor Outlet, Product and Vent Streams

CanmetENERGY

Leadership in ecoInnovation

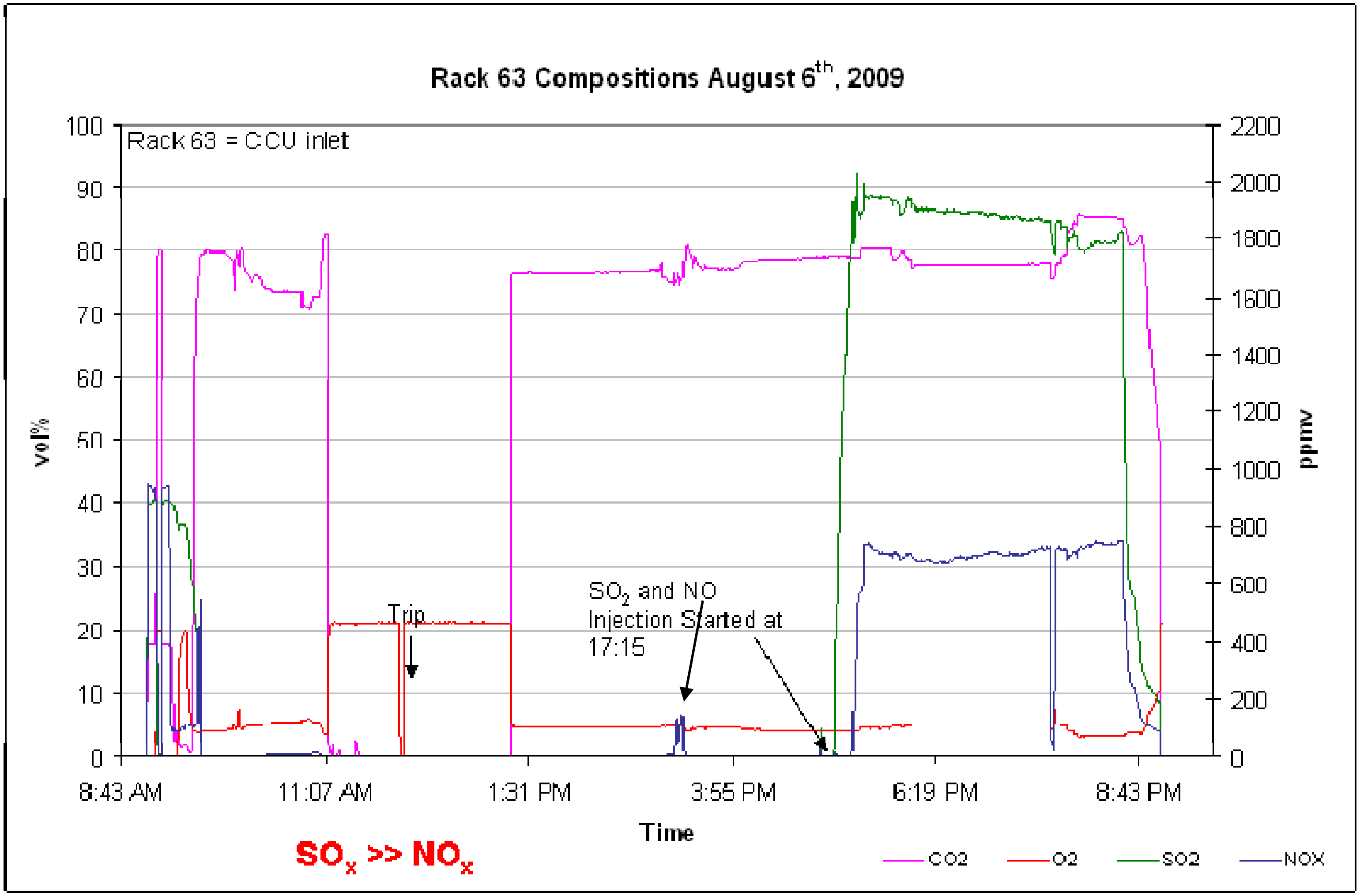
Test Results with Oxy-Coal Flue Gas



Combustor Outlet, Product and Vent Streams

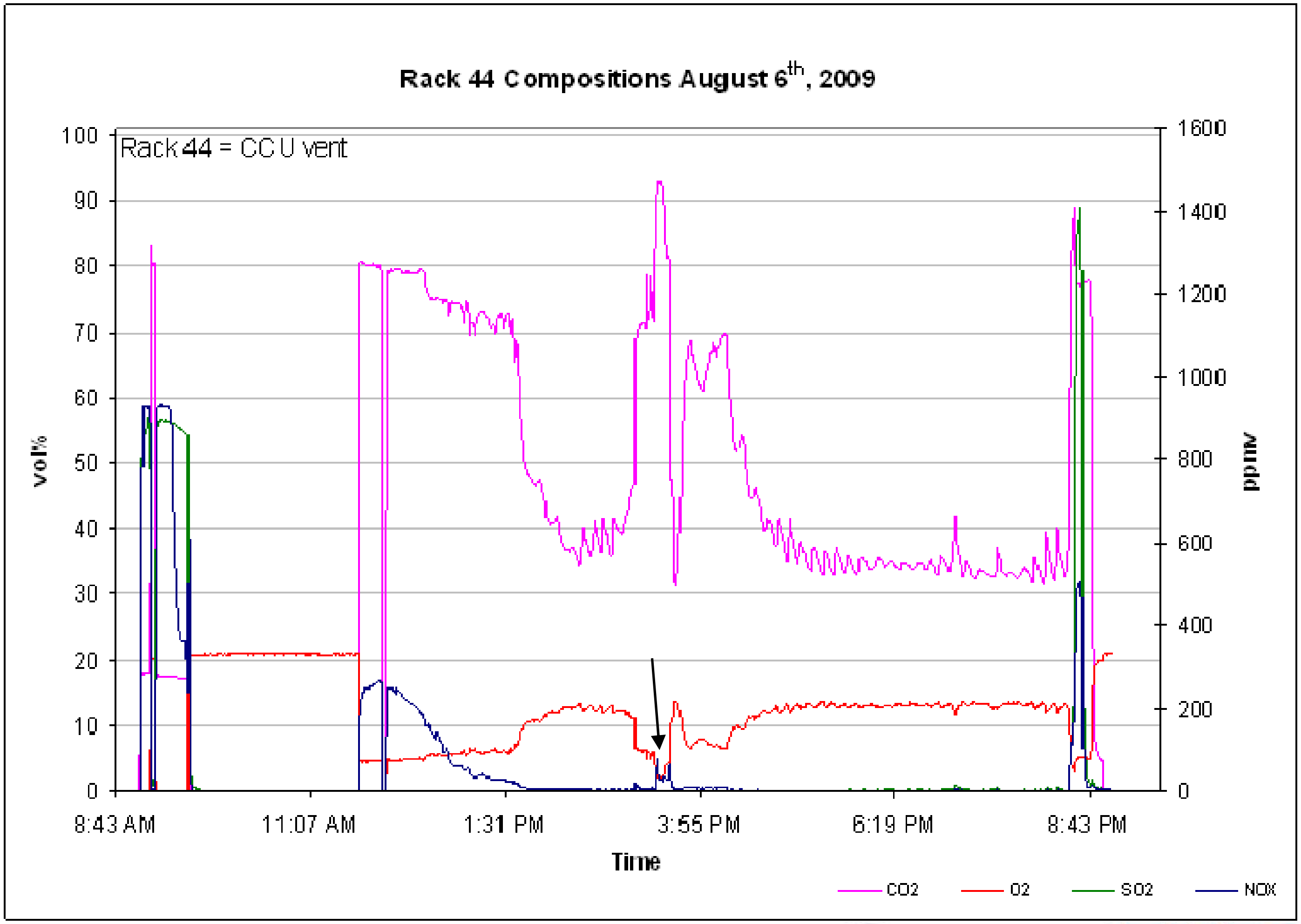
CanmetENERGY
Leadership in ecoInnovation

Test Results with Synthetic Flue Gas



Inlet stream to CO_2CCU

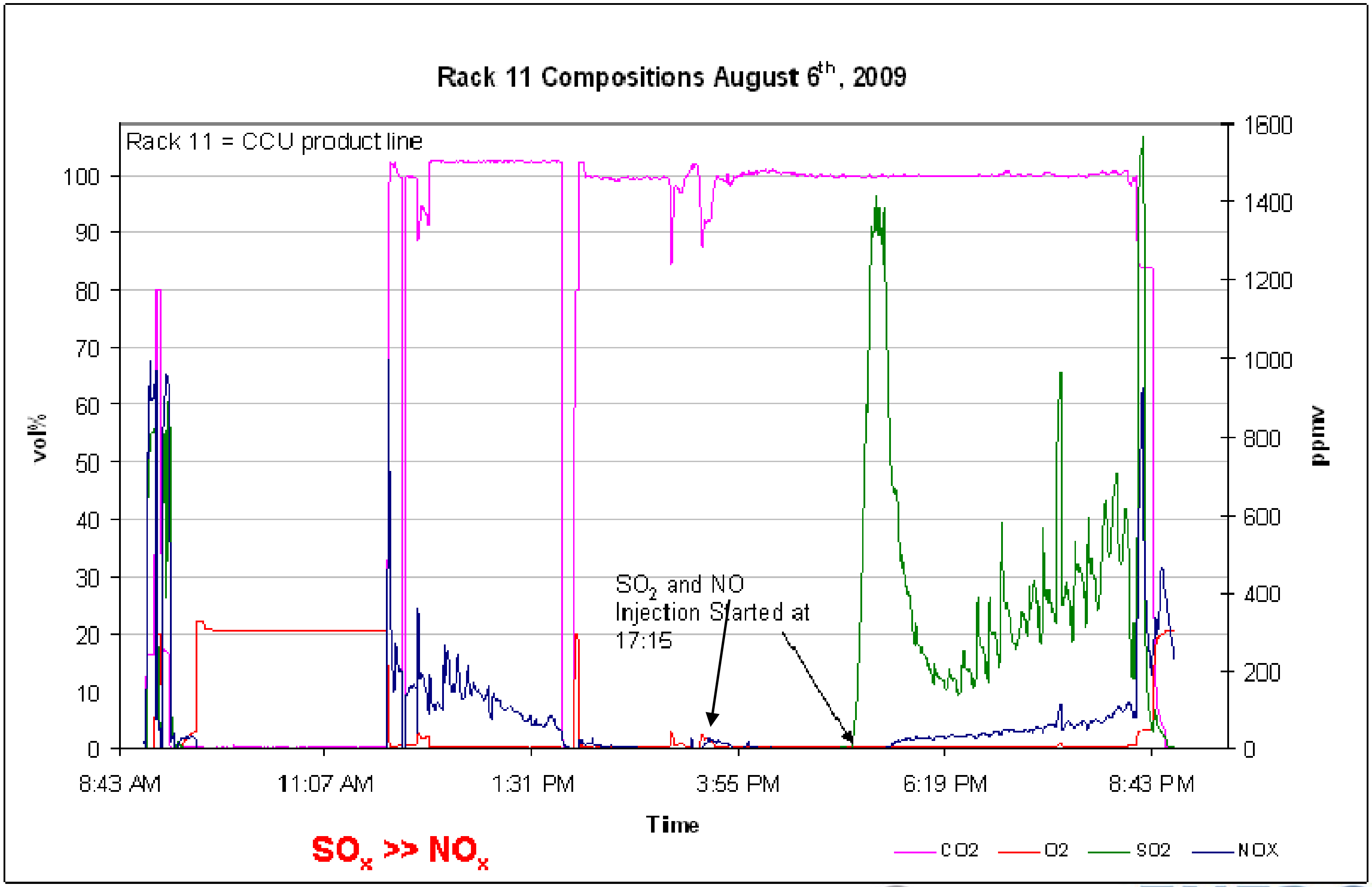
Test Results with Synthetic Flue Gas - CO_2CCU Vent Stream



CanmetENERGY

Leadership in ecoInnovation

Test Results with Synthetic Flue Gas - CO_2CCU Product Stream

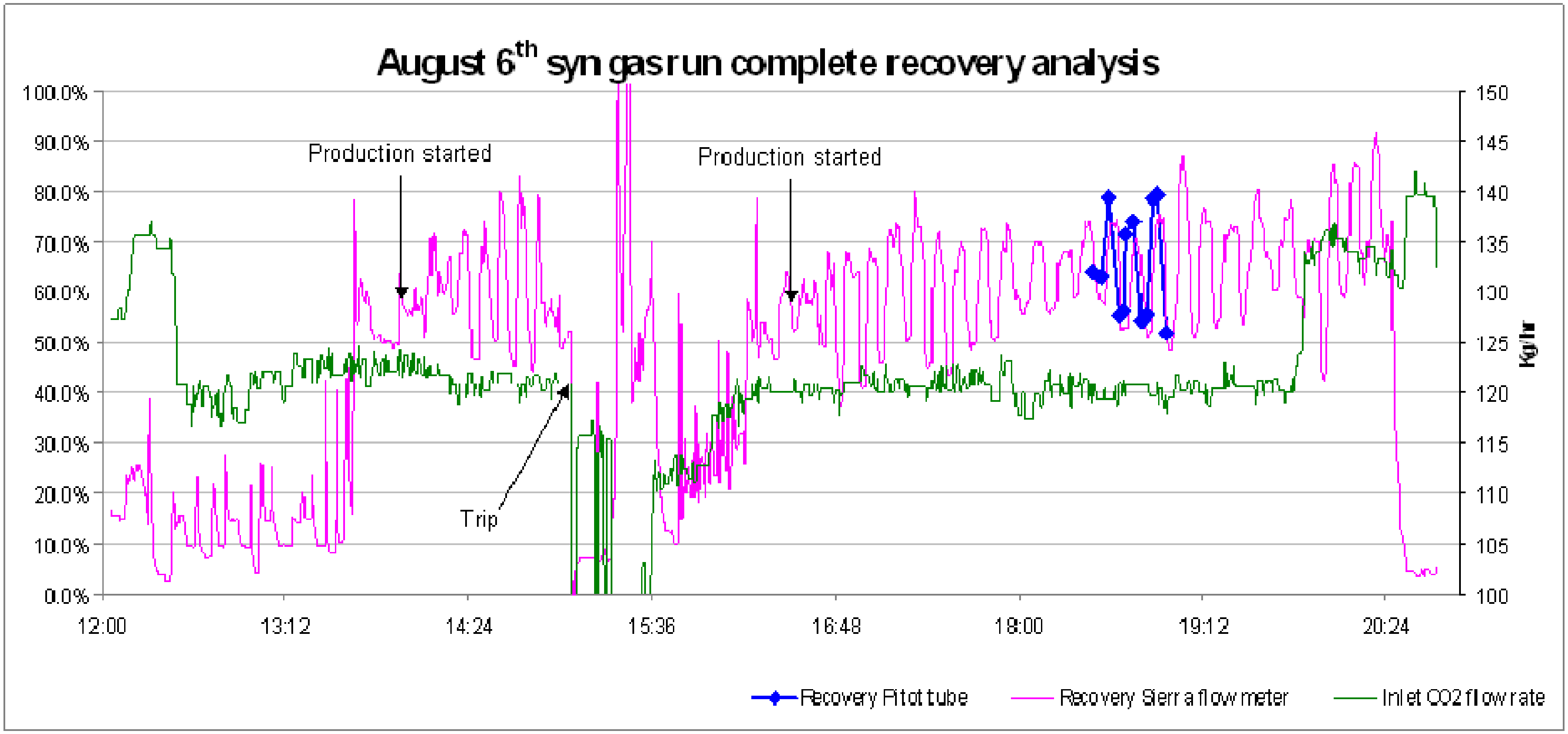


SO_x >> NO_x

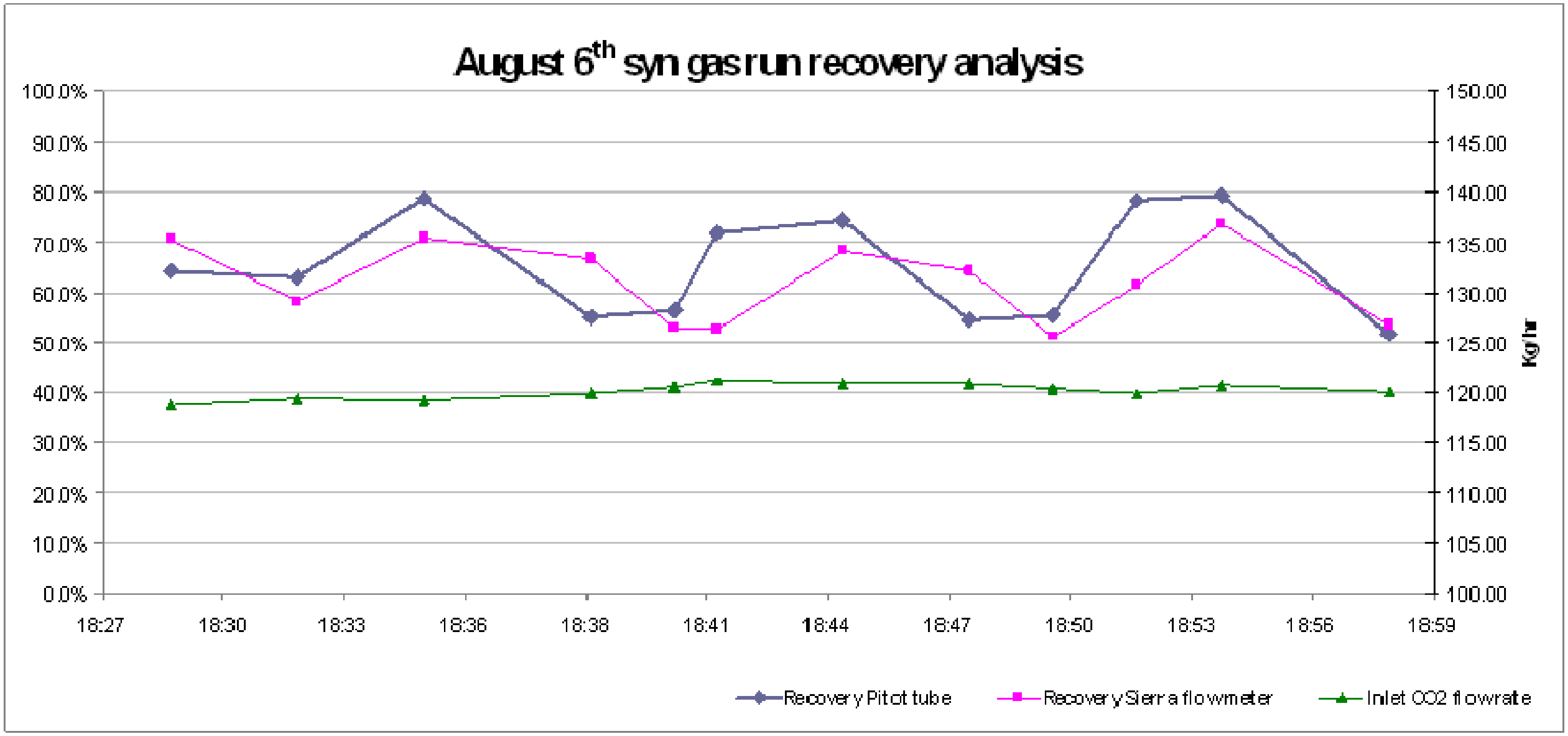
CanmetENERGY

Leadership in ecoInnovation

CO_2 Recovery Analysis



CO_2 Recovery Analysis



Inlet CO_2 ~ 77%; Ave. Recovery rate ~ 68% (at $T > T_{design} + 15\ ^{o}C$); Purity ~ 99%

CanmetENERGY

Leadership in ecoInnovation

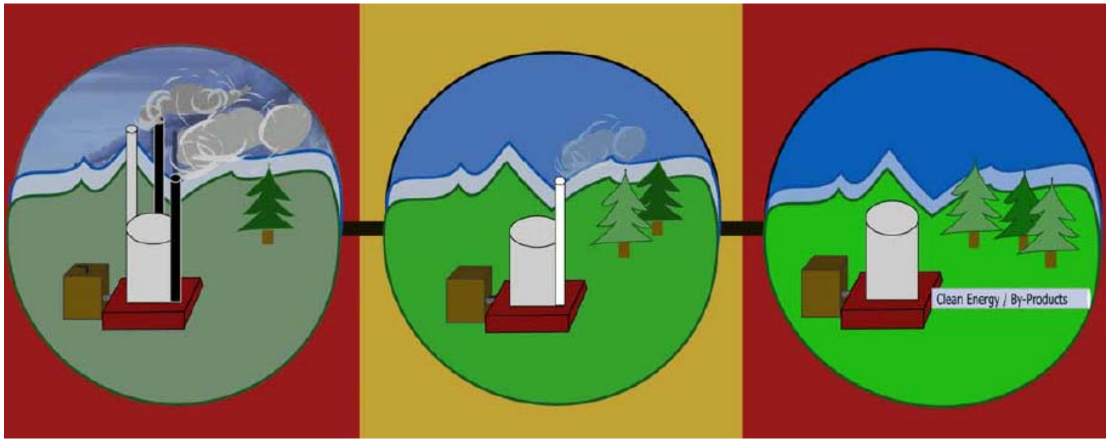
Concluding Remarks

- Testing with both synthetic and oxy-coal flue gas is in progress:
  - Performance analysis
  - Impact of impurities
  - Product and vent streams samples analysis using GC
- The unit has already achieved its performance bench marks
- CO_2 product purity >95%
- CO_2 product recovery rates close to model estimates
- Easy to scale up for commercial applications (scale up is easier than scale down)

CanmetENERGY

Leadership in ecoInnovation

Acknowledgment: *This work was supported by the PERD (Program of Energy Research and Development) and the CanmetENERGY CO_2 R&D Consortium. The authors gratefully acknowledge the support provided by these programs.*



Questions?

CanmetENERGY

Leadership in ecoInnovation