Project Title:

CanmetENERGY CO_2 R&D Consortium

Technology Area:	**Technology Maturity:**
Oxy-Combustion and CO_2 Capture	Pilot-Scale Research

Primary Project Goal:

The CanmetENERGY CO_2 R&D Consortium (Consortium) is conducting oxy-fuel combustion research and development (R&D) using a 0.3 MWth (1 million Btu/h) modular pilot-scale facility. The Consortium has completed nine successive phases of R&D that include oxy-fuel combustion, advanced power cycles, integrated multi-pollutant control, and carbon dioxide (CO_2) capture and compression technologies.

Technical Goals

The technical goal of the Consortium is to develop advanced energy conversion technologies with near-zero emissions for improved efficiency and commercial competitiveness for capture of CO_2 and air pollutants resulting from combustion of fossil fuels. One emphasis of the Consortium research program is the oxy-fuel combustion technology. Since, combustion takes place in an oxygen (O_2)-enriched environment, the flue gas comprises mainly CO_2, water, and minor impurities. This CO_2-rich flue gas stream can then be purified, dried, and compressed for pipeline transport and use or permanent storage in geological formations. Oxy-fuel combustion also results in efficiency advances of high flame temperatures and reduced equipment sizes due to lower gas volume.

Technical Content:

The Consortium activities in the past have included experimental investigations using coal; coal slurry; bitumen and natural gas to study the characteristics of oxy-fuel combustion; advanced near-zero emissions Brayton and Rankine cycles; solid oxide fuel cell modeling; multi-pollutant capture research for integrated removal of fine particulates, nitrogen oxide (NO_X), sulfur oxide (SO_X), and mercury (Hg); advanced oxy-fuel combustion processes and co-firing with opportunity fuels such as petroleum coke; system components and prototype design and pilot-scale testing; and modeling and development of new CO_2 capture and compression processes.

The latest completed Phase 9 of the Consortium's program included the development of a CO_2 capture and compression unit. This unit is capable of separating and compressing CO_2 from combustion flue gas streams for pipeline transport and storage. Part of this work involved the development of a CO_2 high-pressure test cell for studying CO_2 phase change, generating vapor-liquid equilibrium (VLE) data, and studying the impact of impurities in the flue gas stream on the capture processes. This has important practical applications relating to the CO_2 pipeline, material selection, and commercial design of these systems. Other ongoing R&D activities include the modeling of advanced supercritical oxy-coal plants with CO_2 capture; cost analysis; the development and testing of multi-pollutant control strategies, as well as testing in oxy-steam mode; and optimization of a novel multi-function oxy-fuel/steam burner.

Figure 1 shows the major process components comprising the 0.3 MWth oxy-fuel Vertical Combustor Research Facility (VCRF) integrated with the CO_2 capture and compression unit (CO_2CCU). The overall pilot-scale research facility is used to develop pollutant control technologies that incorporate a fabric filter or ESP for particulate capture, condensing heat exchangers and/or SO_X scrubbing to remove acid gases and oxidized Hg from the flue gas combustion stream.

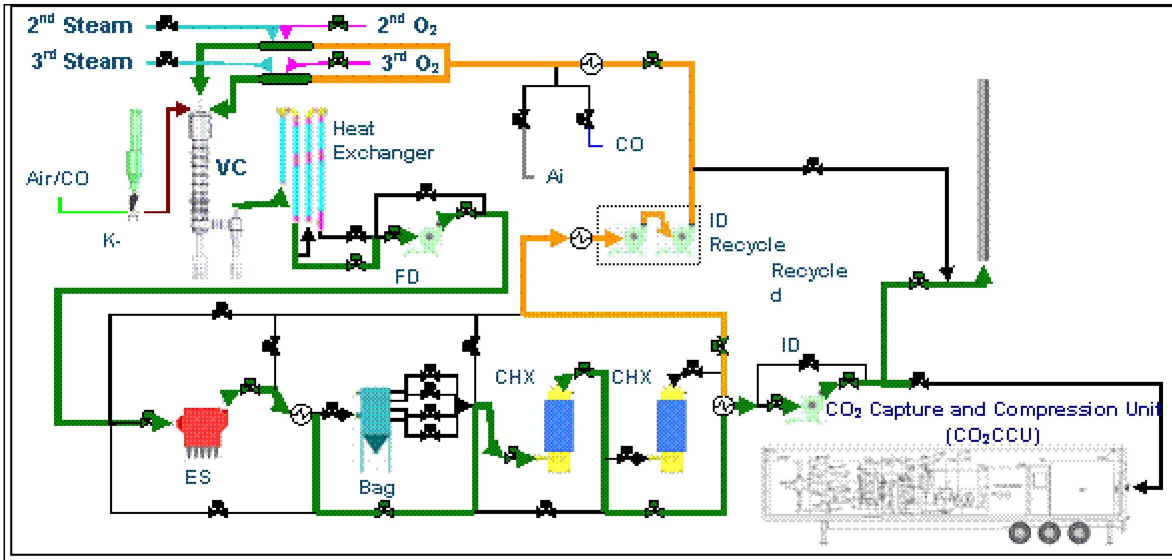

Figure 1: Schematic of the CanmetENERGY's Integrated Oxy-Fuel Vertical Combustor Research Facility

Figure 2 displays the pilot-scale CO_2CCU. The CO_2CCU is capable of processing CO_2 flue gas streams at a maximum rate of 160 Kg/hr with CO_2 concentrations of 50 percent or higher (in dry volume) to produce a CO_2 product stream with more than 95 percent purity.

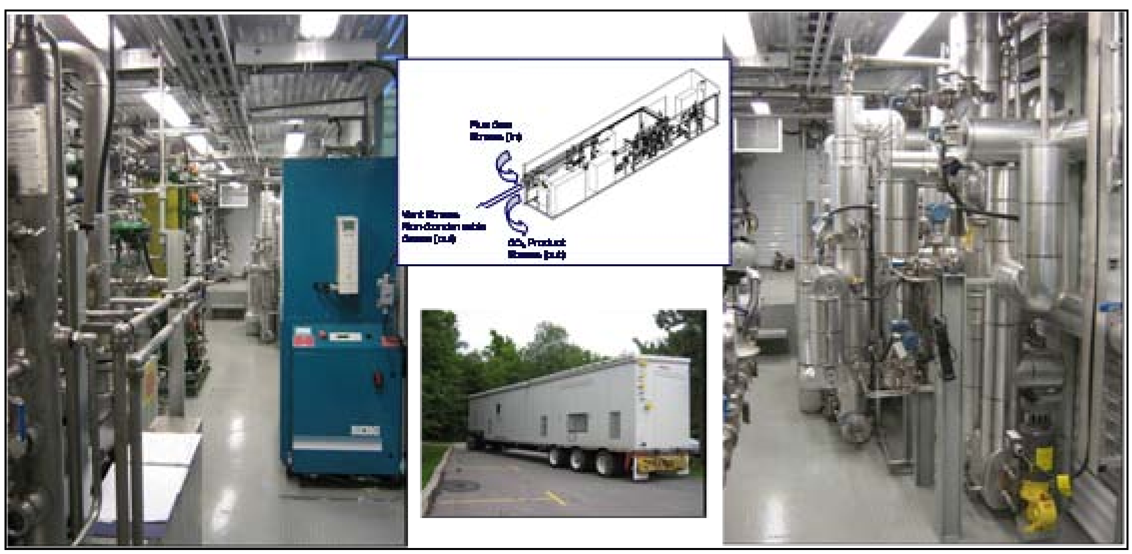

Figure 2: CanmetENERGY's CO_2 Capture and Compression Unit

The high-pressure CO_2 test cell and its high-pressure viewing chamber (HPVC) shown in Figure 3 were used to create supercritical CO_2 and study the CO_2 phase change in a controlled environment. The chamber can handle a maximum pressure of 200 atm and a temperature range of -60°C to 150°C. There are two gas and liquid sample ports located at different heights and optical windows with a CCD camera for observations inside the chamber to study the CO_2 liquid-gas interface.

Figure 3: CanmetENERGY's High-Pressure CO_2 Test Cell and Bench-Scale Facility

Technology Advantages:

- The program allows research to be carried out at a pilot scale small enough to reduce the overall R&D cost, while the experiments scale is sufficiently large enough to provide proof-of-concept before proceeding to a larger and more costly medium-scale pilot technology demonstration.

R&D Challenges:

- Integration and cycle development for O_2/FGR, O_2 combustion, and hydroxy-fuel combustion of fossil fuels in different advanced cycles.
- Improving the understanding of combustion, heat transfer, and emissions in oxy-fuel combustion.
- Development of environmental multi-pollutant controls for NO_X, SO_X, Hg, and particulates.
- Minimizing energy demand for O_2 production while keeping the O_2 purity high.
- Decreasing energy consumption for capture and compression of CO_2.

Results To Date/Accomplishments:

- Developed new, ultra-low NO_X oxy-combustion burner and tested the prototype burners in VCRF with sub-bituminous and lignite coals.
- Determined that FE^{3+} salts were capable of oxidizing Hg and achieved a 75% Hg oxidation with an optimal pH between 1 and 3 on bench-scale tests.
- Increased the computational fluid dynamic (CFD) tools for model simulation of oxy-combustion flame characteristics.
- Created a CO_2 capture and compression process simulator and implemented a pilot-scale CO_2 capture research facility that has enhanced the program's CO_2 research capabilities.
- Developed new advanced gas turbine and high-efficiency fuel cell-based power generation cycles.
- Developed models of advanced supercritical oxy-coal plants with CO_2 capture and cost models for

economic analysis. • Developed and tested multi-pollutant control strategies and processes. • Conducted testing in oxy-steam mode for pulverized coal and performed optimization of a novel multi-function oxy-fuel/steam burner.	
Next Steps: Phase 10 program work under consideration will include projects in areas related to the modeling and economic analysis of supercritical coal-fired plants with CO_2 capture; performance testing of an advanced CO_2 recovery module; development of global control strategies for the CO_2CCU; development of multi-pollutant control processes for removal of SO_X, NO_X, and Hg emissions using the CO_2CCU; testing of a novel hot sieving electrostatic precipitator; development of process models for advanced post-combustion capture of CO_2; development of models and optimization tools for mitigating greenhouse gas (GHG) emissions from oil sands and upgrading facilities; and oxy-firing of bio-based fuels with CO_2 capture.	
Available Reports/Technical Papers/Presentations: "Novel Oxy-Steam Burner for Zero-Emission Power Plants," 1st International Oxy-Fuel Combustion Conference, Cottbus, Germany, September 2009. "Performance of an Advanced Pilot-Scale CO_2 Capture and Compression Unit," 1st International Oxyfuel Combustion Conference, Cottbus, Germany, September 2009. "An Integrated Approach for Oxy-fuel Combustion with CO_2 Capture and Compression," 7th Annual Conference on CCS – May 5-8, 2008.	
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