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C E T C CANMET ENERGY TECHNOLOGY CENTRE

CANMET T&I Oxyfuel FBC Project

CLEAN ENERGY TECHNOLOGIES

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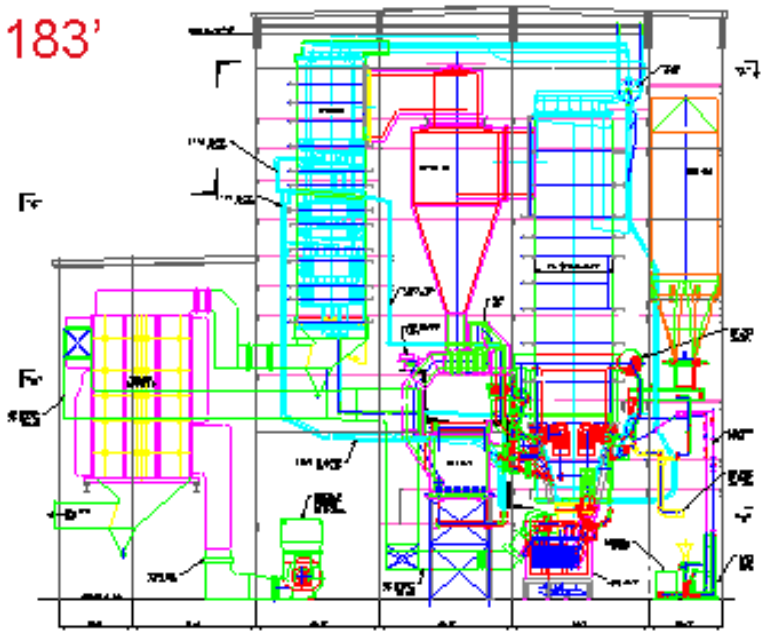
Canada

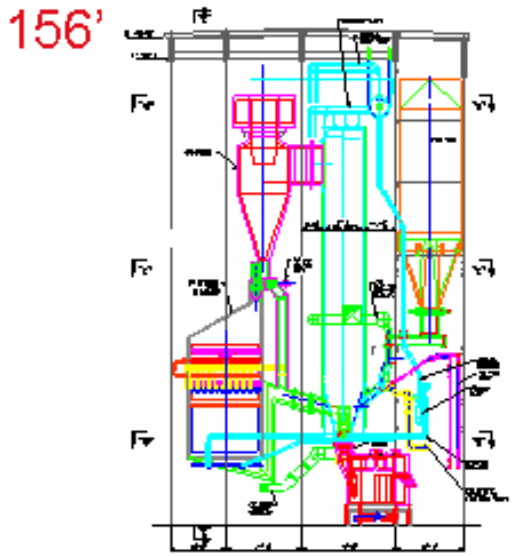
O_2 Fired FBC Systems

- Not a new concept, discussed in Yaverbaum's 1977 book and rejected on grounds of cost
- Makes sense if a pure stream of CO_2 is required
- This is of interest to CETC:
  - Need O_2 firing for the regeneration reaction in a CO_2 looping cycle.
- Some vendors are arguing that O_2 firing is better with CFBC technology than for PC technology because less CO_2 needs to be recycled because heat can be eliminated by means of better heat transfer and re-circulated solids.
- It offers the possibility of negative CO_2 if biomass is fired.

ALSTOM



Air Fired CFB



Oxygen Fired CFB

Current Status

- Explored by Zhejiang University
  - Bench-scale work
- CERCHAR (SNET–French Utility)
  - to carry out pilot plant work
- Being advocated by Alstom
  - Based on bench-scale work
  - Suggests no problems with sticky ash, agglomeration
- Oxy-fuel firing at CETC-Ottawa in Mini-CFBC
  - October-November, 2005
    - Coal and biomass (wood pellets at 20% by weight)
    - CO_2 used in the tests
  - Feb to May, 2006: Oxy-fuel firing with flue gas recirculation,

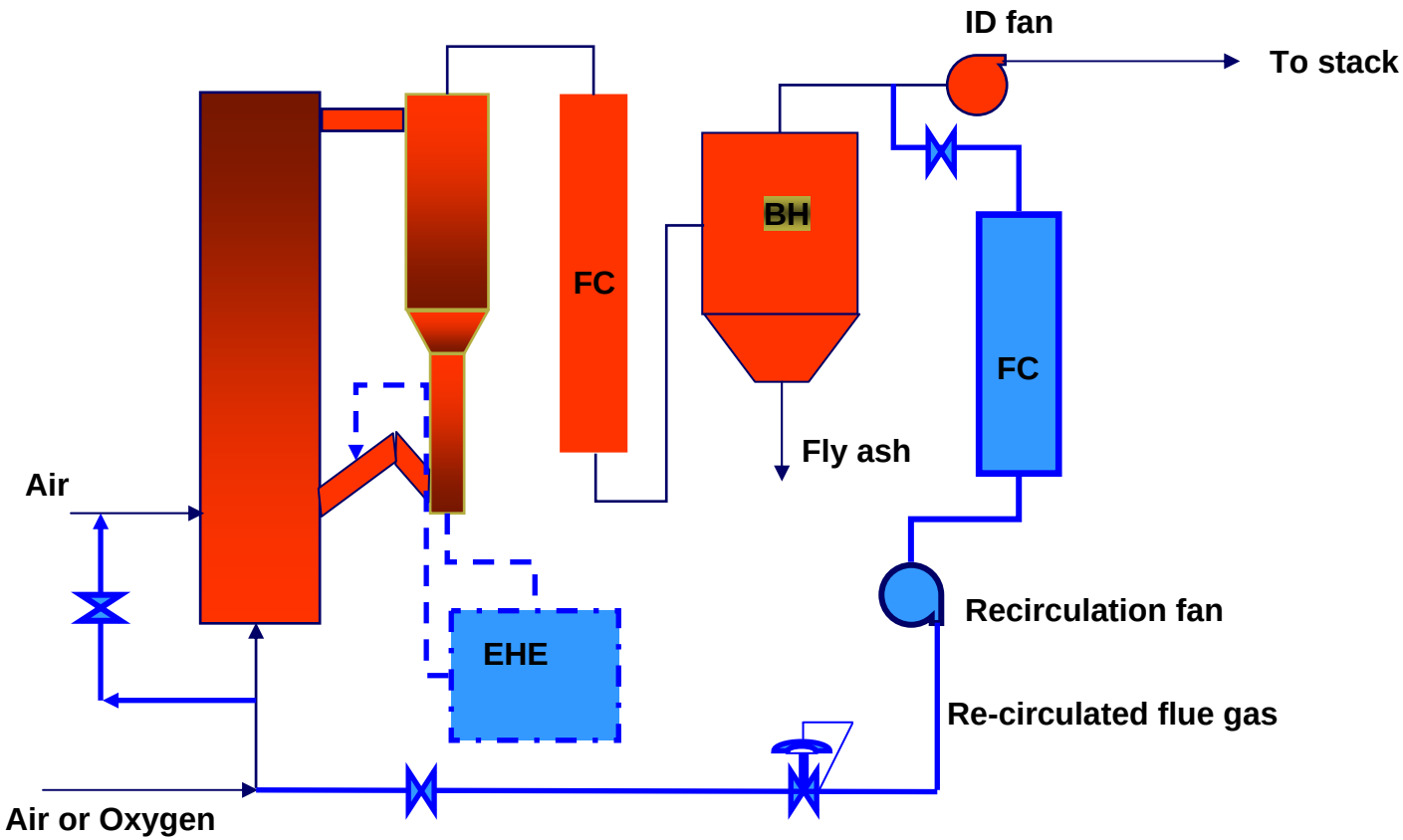
Opportunities at CETC

- Existing $8-10 million CFBC facility
  - Trained FBC personnel and minimal upgrading expenses for O_2 firing
- Existing experience on O_2 firing
- Current T&I funding for 3-year R&D program
- Commitment to bench-scale O_2 firing work to support CO_2 looping cycle
- Extensive ASPEN modeling support available

R&D plans

- Design of flue gas recirculation system under way
  - Rate: 0-800kg/h
  - With a flue gas cooler to condense water vapour
- Commisioning for CFBC O_2 firing in Dec. 2006
- Limited tests for financial year 2006/07
- More extensive program in the following two years, with possibility of obtaining more funds for new ideas

Modifications to CETC's 0.8MWt CFBC



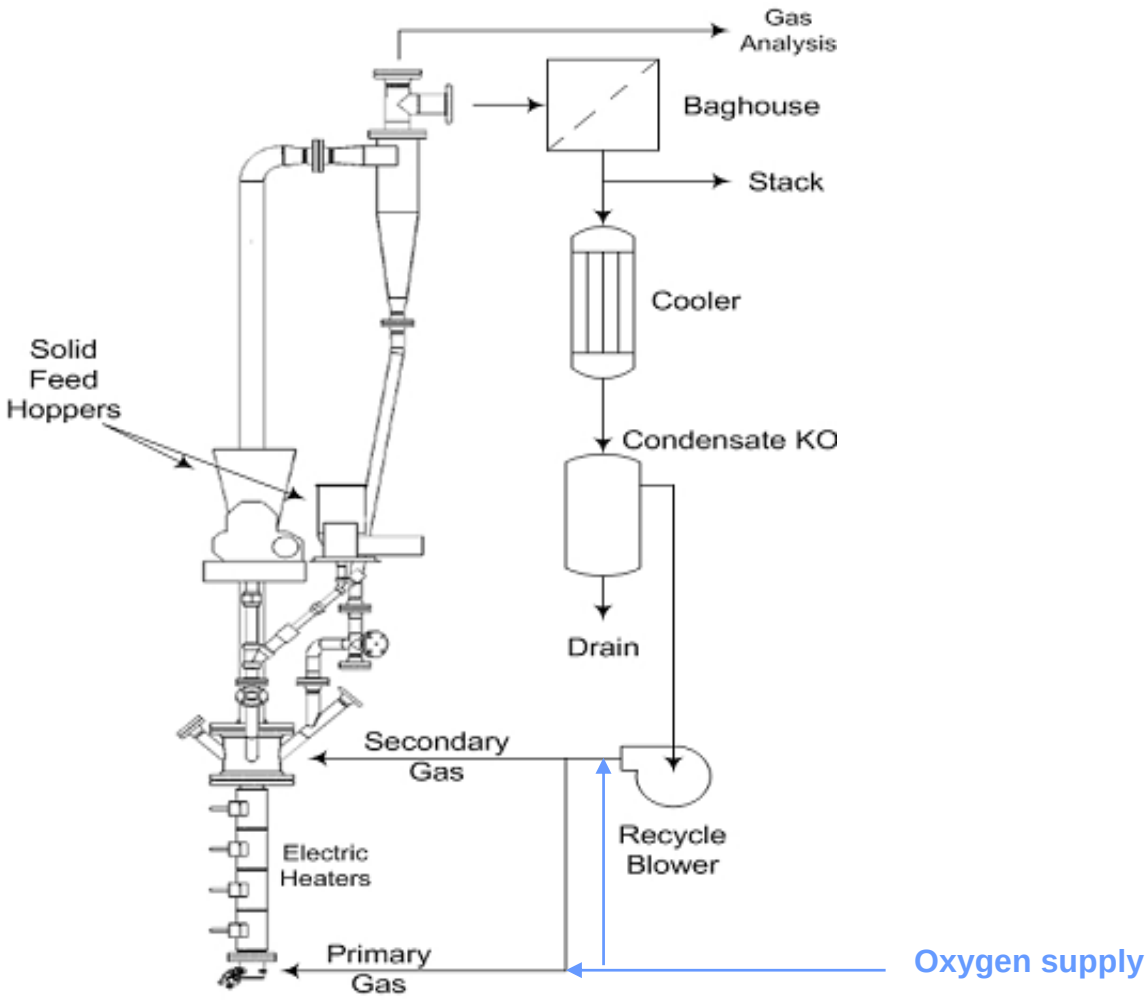
Research Directions

- Verify that agglomeration is not a problem with longer-term operation
- Verify emissions—SO_2, NO_x and N_2O
- Look at emissions of unburned hydrocarbons, PAHs, and PCDD/Fs for co-firing biomass
- Heat transfer in oxy-fuel firing environment
- External heat exchanger
  - Reduce flue gas recirculation rate
  - Increase mole fraction of oxygen in the primary and secondary gas streams up to 70%(?)

CANMET Mini CFB Unit

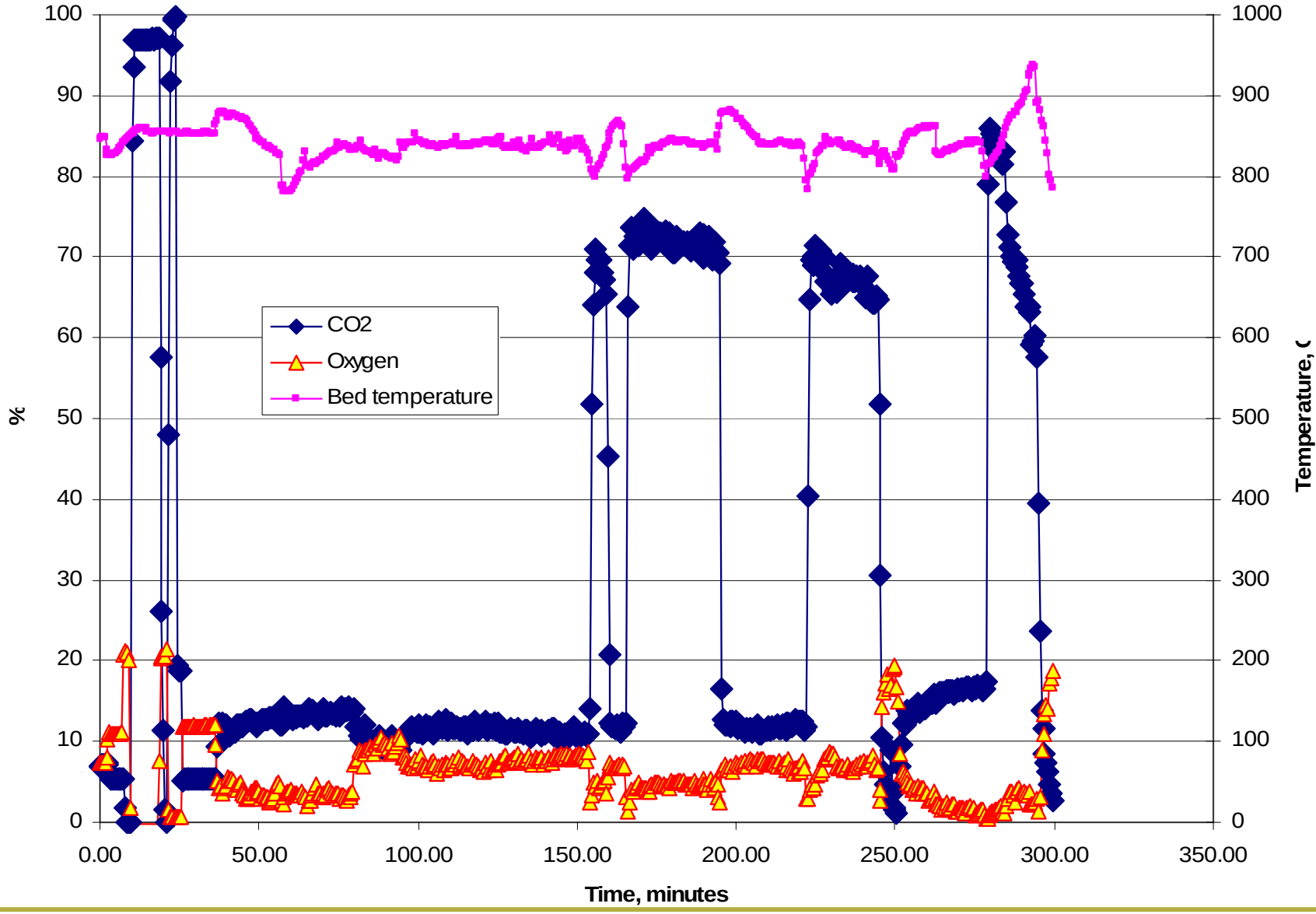
- Characteristics
  - 10 cm ID
  - 5 m in height
  - Can feed multiple fuel stocks
  - Online flue gas analysis
  - Equipped with a bag filter
  - Redesigned for oxy-fuel combustion with FGR
  - Commissioned for oxy-fuel combustion with bottled CO_2

Mini-CFBC for Oxy-fuel tests



Mini-CFBC Oxy-fuel tests, Oct.-Nov. 2005

- Oxygen and carbon dioxide used
- 35% oxygen in primary and secondary gas supply
- Transition was smooth both to and from oxy-fuel firing mode


100
90
80
70
60
50
40
30
20
10
0
%
1000
900
800
700
600
500
400
300
200
100
0
Temperature, C
CO2
Oxygen
Bed temperature
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
Time, minutes

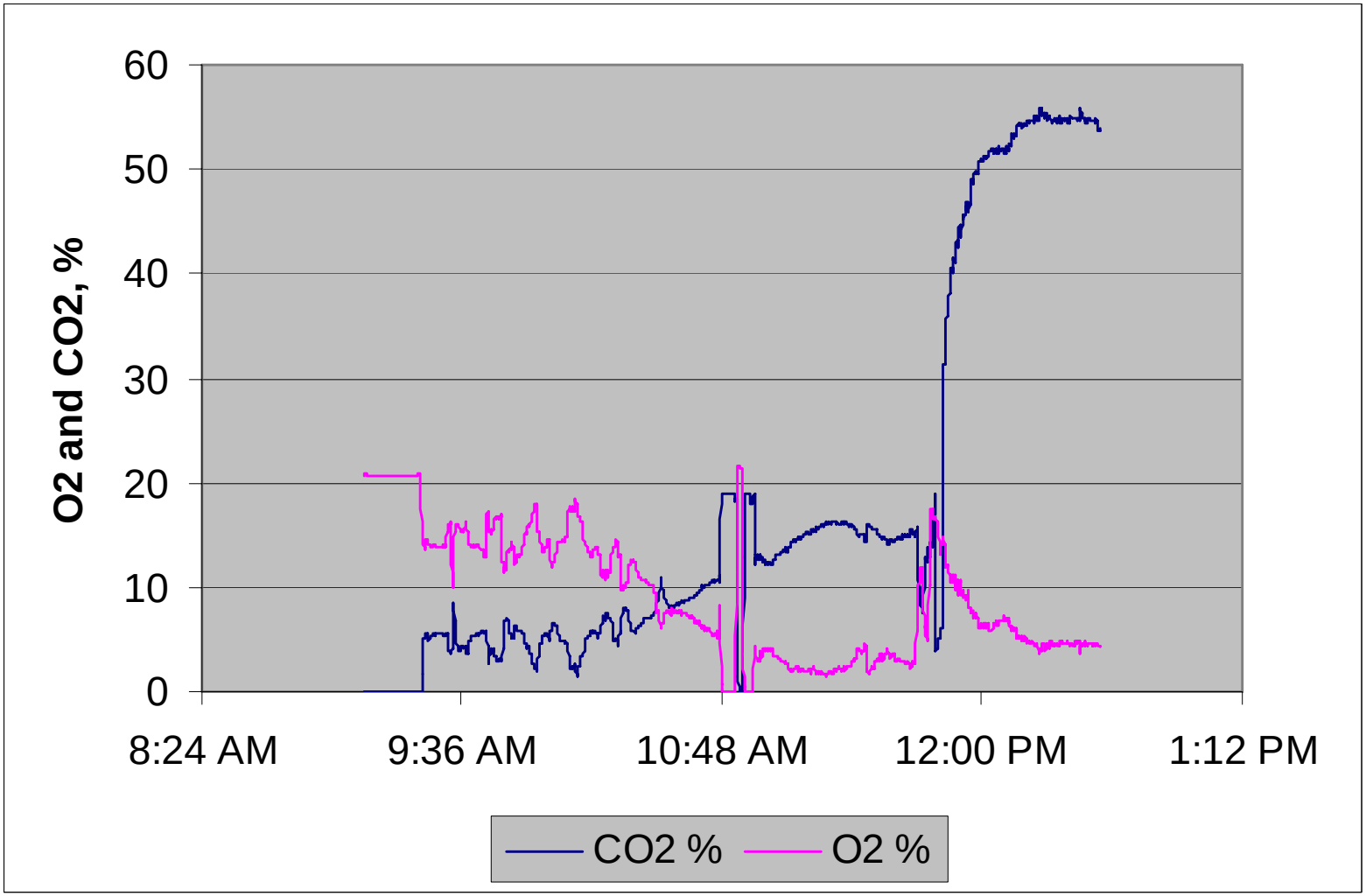
Mini-CFBC Oxy-fuel tests, Feb-May, 2006

- Flue gas re-circulation line installed including a cooler for condensing water vapour
- External Heat Exchanger for cooling Solids installed.
- Limited number of tests conducted with oxygen and recirculated flue gas.

Oxy-fuel Test Results

- Fuel: Eastern bituminous coal and Highvale coal
- Test started in air and switched to O_2/FGR
- Local O_2 concentration varied from 23 to 40%
- Global O_2 concentration was about 21%
- Flue gas CO_2 concentration reached 55%

Flue gas compositions, EB coal



Essential Findings

- CANMET's mini CFB allows smooth transition from air firing to oxy-fuel firing with flue gas recirculation
- Good control of bed and riser temperature under oxy-fuel firing
- Significant sources of leakage limited flue gas CO_2 concentration to 55%
- Input O_2 concentration was limited by the delivery capability

Future Work

- Eliminate all sources of leakages
- Increase O_2 delivery capability
- Continuing with the Retrofit of the 0.8MWth CFBC for oxy-fuel firing