A Dual Fluid Bed Pilot Plant for Fuel Conversion and Co-firing Research

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Fluidized Bed Combustion Pilot Plant Research

CANMET Energy Technology Centre
Natural Resources Canada

1980s Mark II AFBC unit 40 cm x 40 cm

1990s CFBC unit 40 cm ID (coal)

1995-> BFB unit (1 m ID)
B: Bubbling & Biomass

Beyond-> Need for research beyond combustion

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Original CETC – CFBC Pilot Plant

- **Circulating Fluidized Bed Unit:**

  0.8 MW thermal capacity

  refractory lined, 0.4 m ID ~ 7 m high

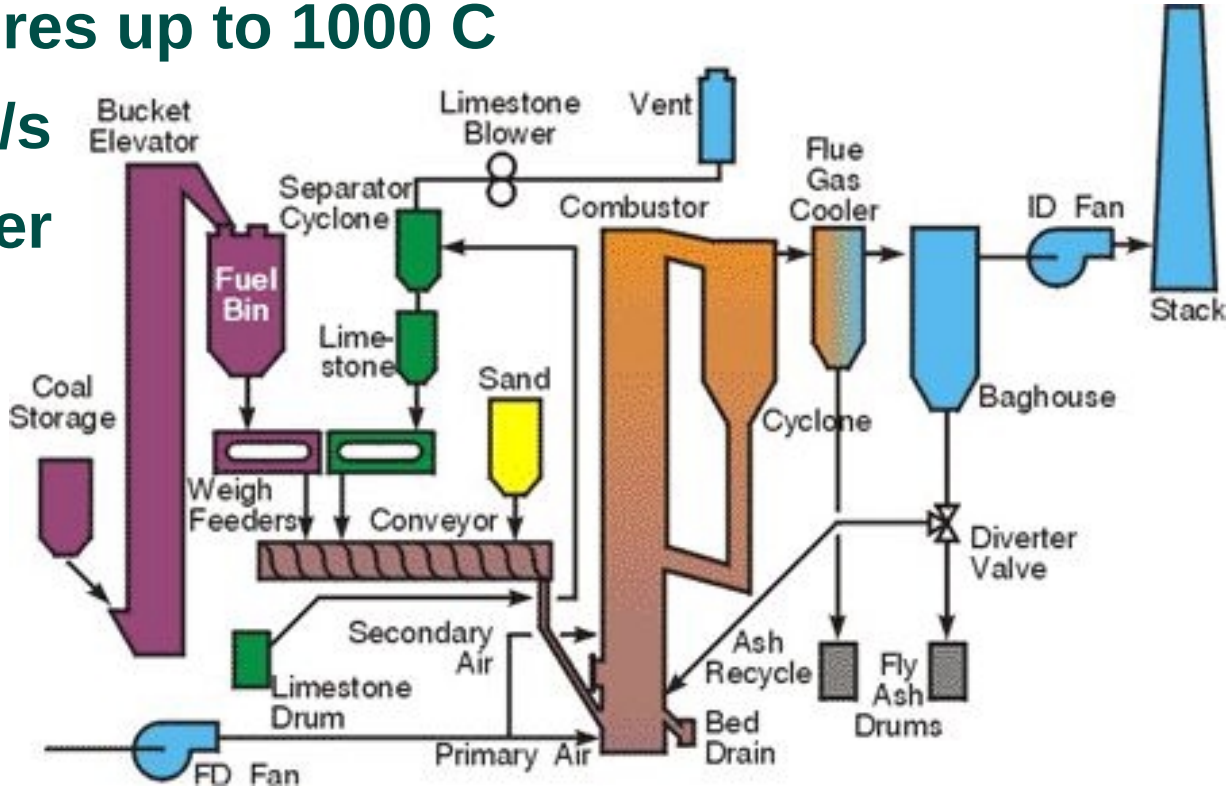
  operating temperatures up to 1000 C

  fluid. velocity to 8 m/s

  Automated NG burner

  Designed for coal:

  5 cm feed screw



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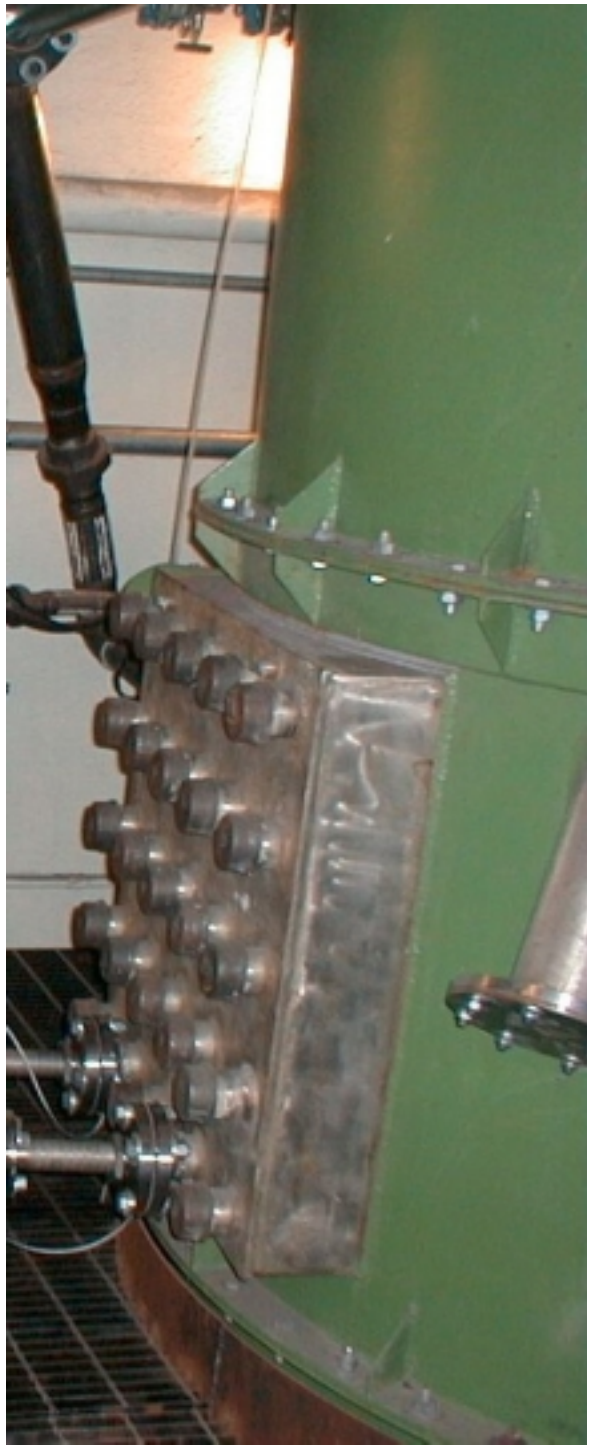
New BFB Pilot Plant

- 1 MW Bubbling Fluidized Bed Unit:
  refractory lined,
  1 m ID - 6 m high
  operating temperatures up to 1000 C
  fluidization velocity 1 – 3 m/s
  NG warm-up burner

Designed for biomass:

25 cm overbed feed port

15 cm underbed feed port



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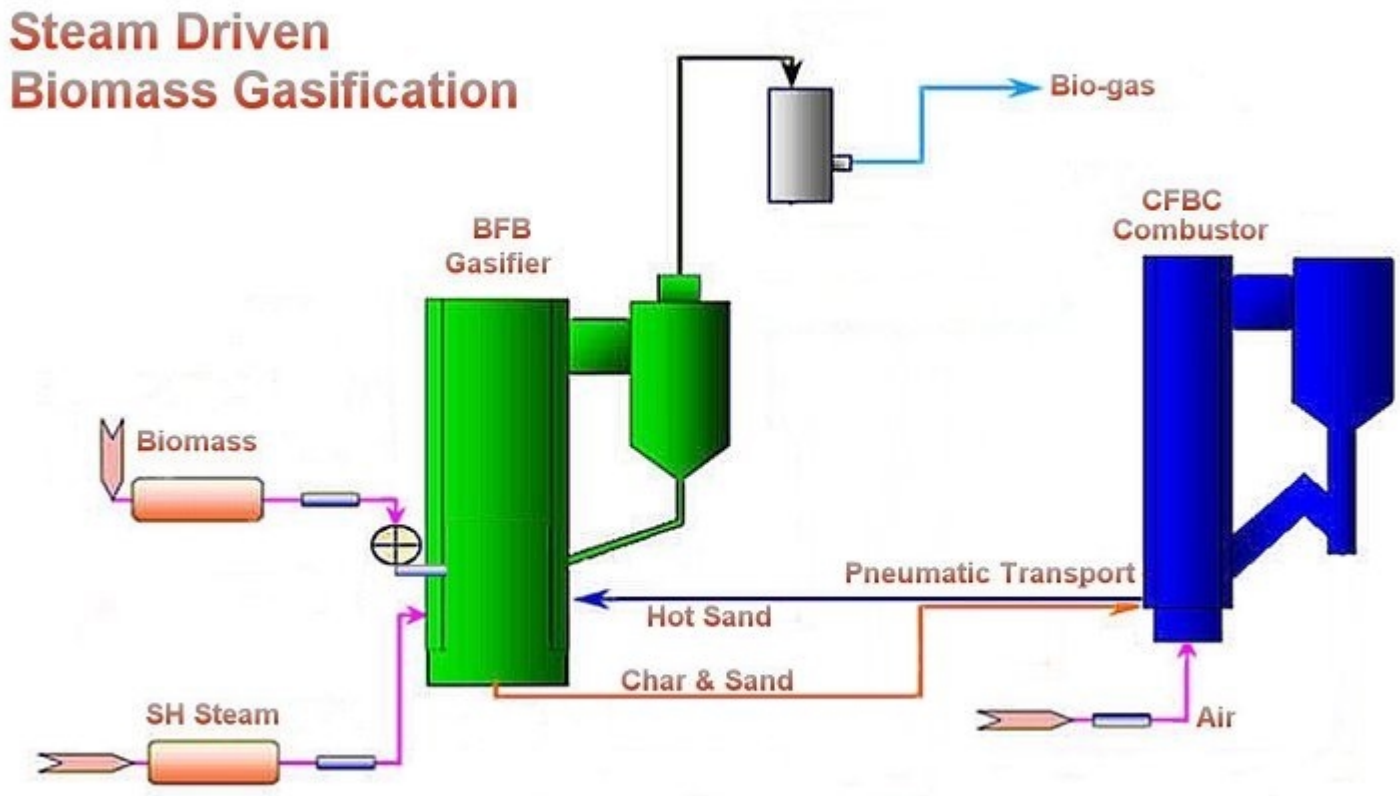
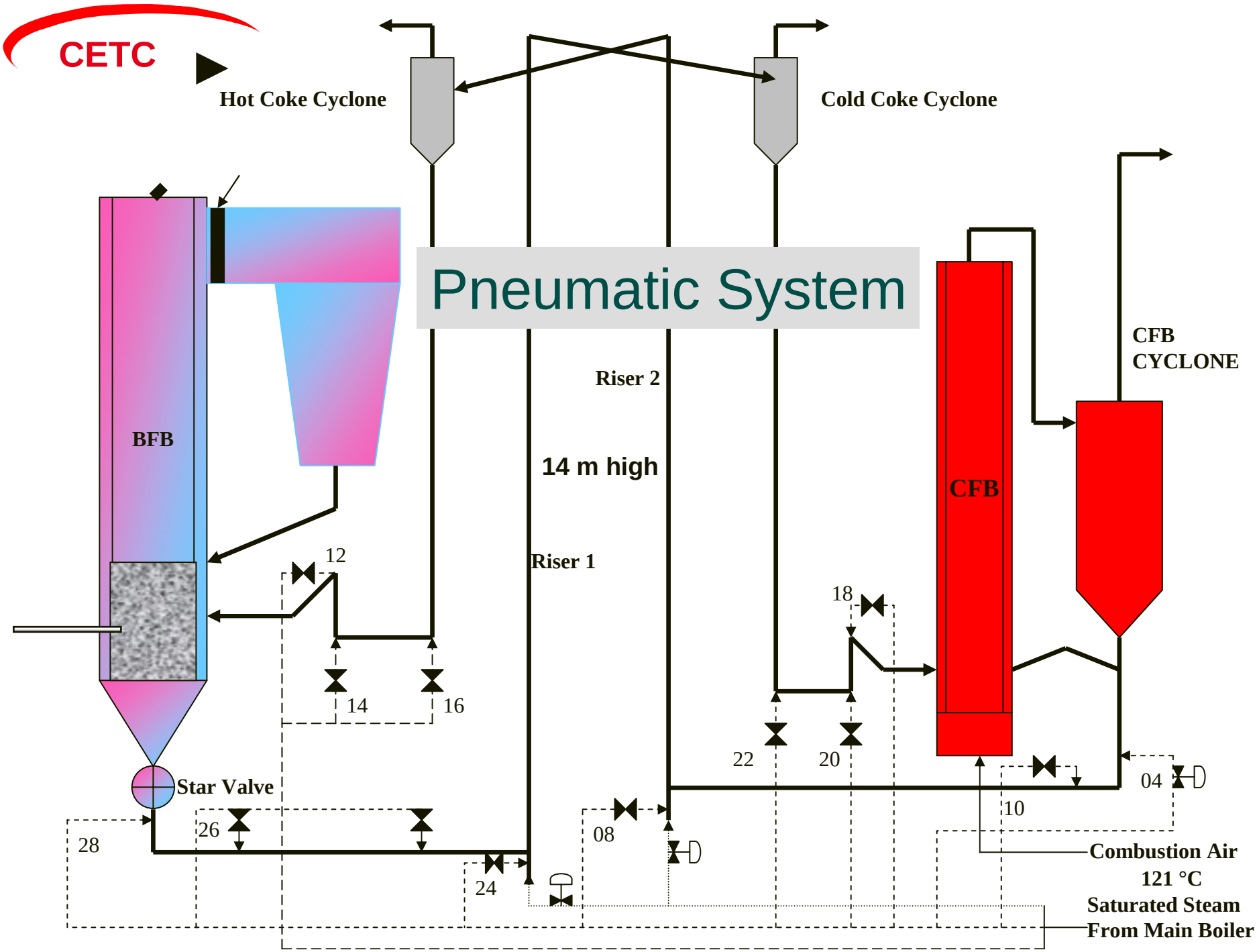
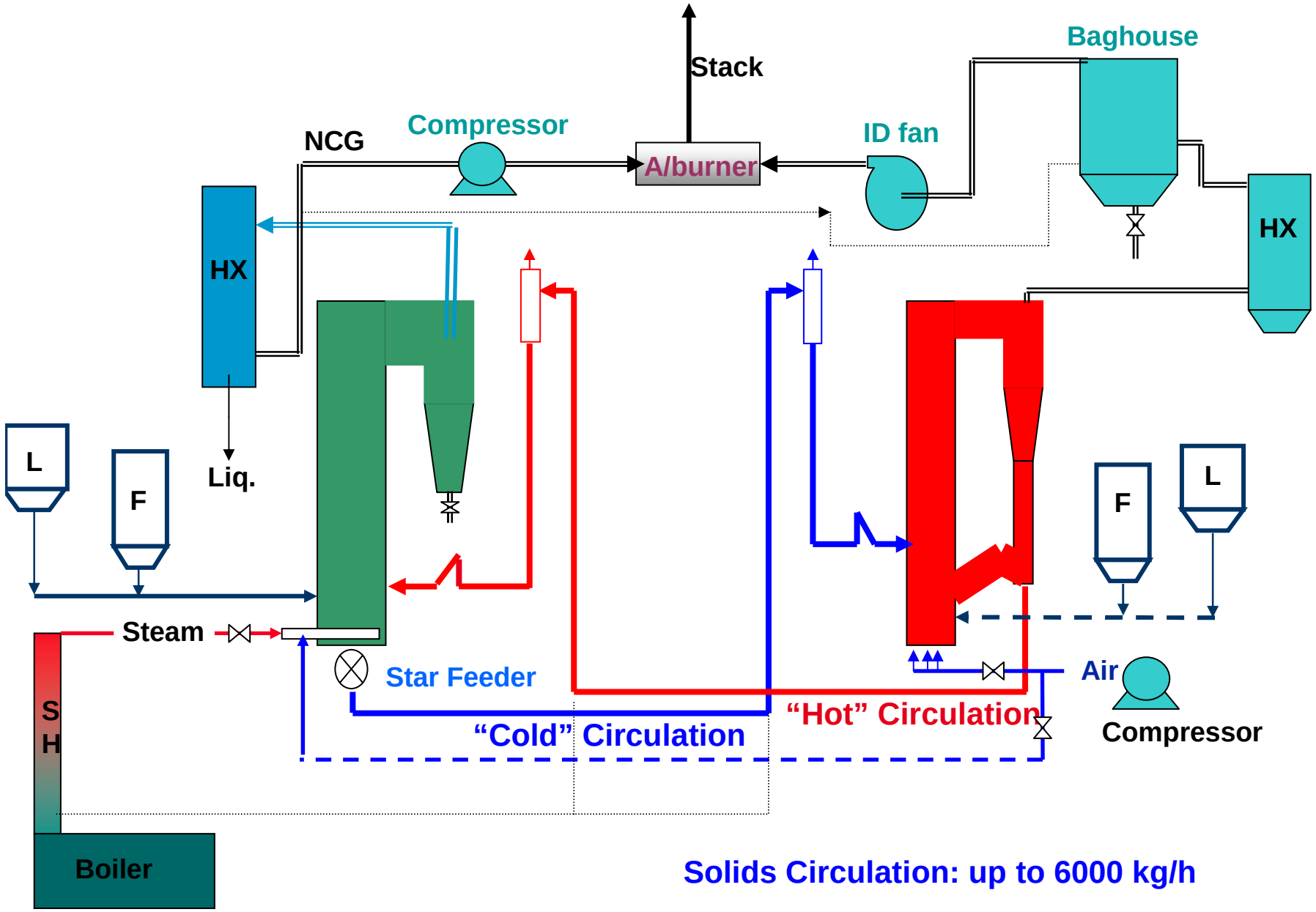
Biomass Gasification Concept:
- Wood Chips
- Black Liquor




CETC
Hot Coke Cyclone
Cold Coke Cyclone
Pneumatic System
BFB
Riser 2
14 m high
Riser 1
CFB
CFB
CYCLONE
12
14
16
18
22
20
04
10
08
24
26
28
Star Valve
Combustion Air
121 °C
Saturated Steam
From Main Boiler

CETC-O Dual Fluid Bed Pilot Plant



Solids Circulation: up to 6000 kg/h

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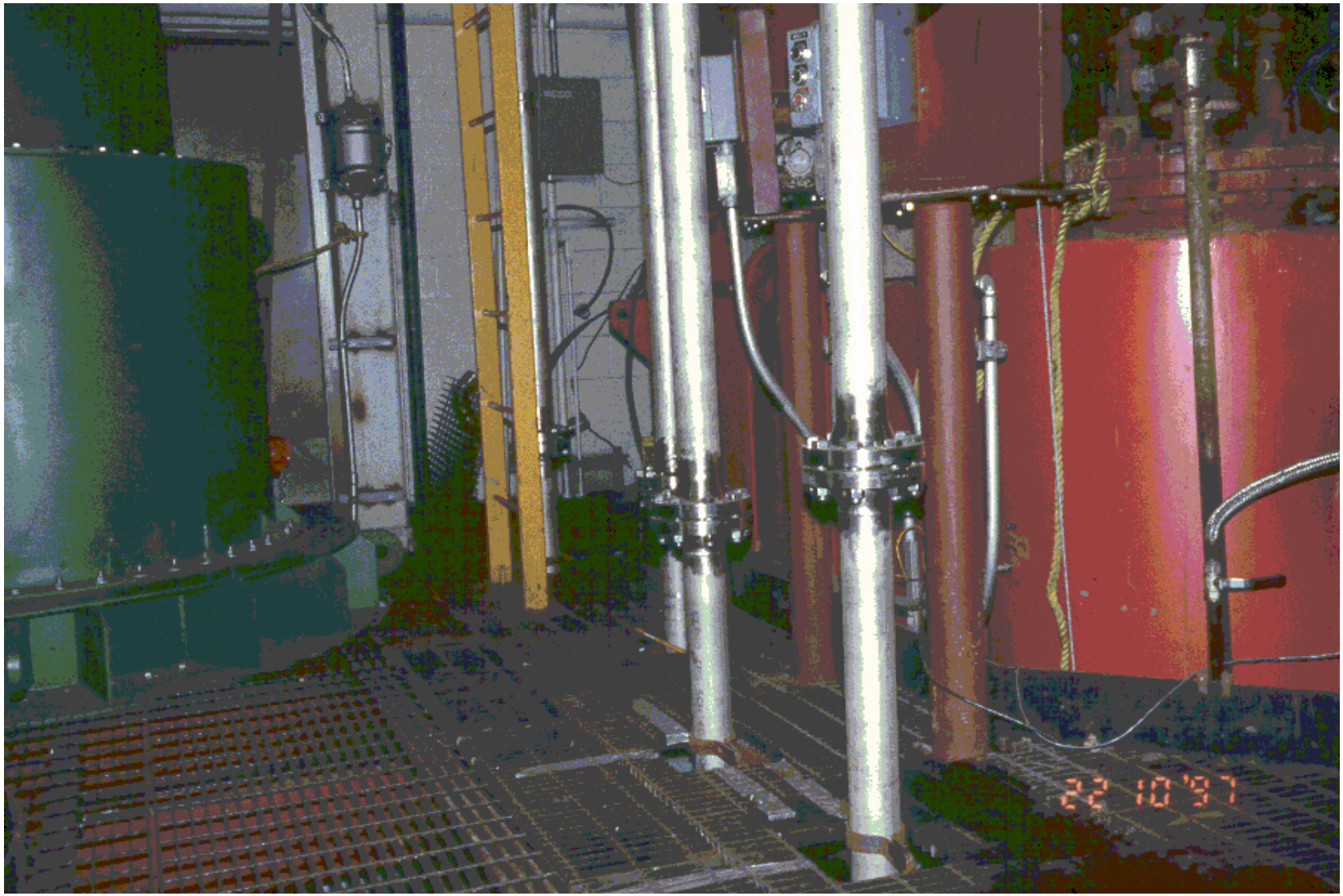
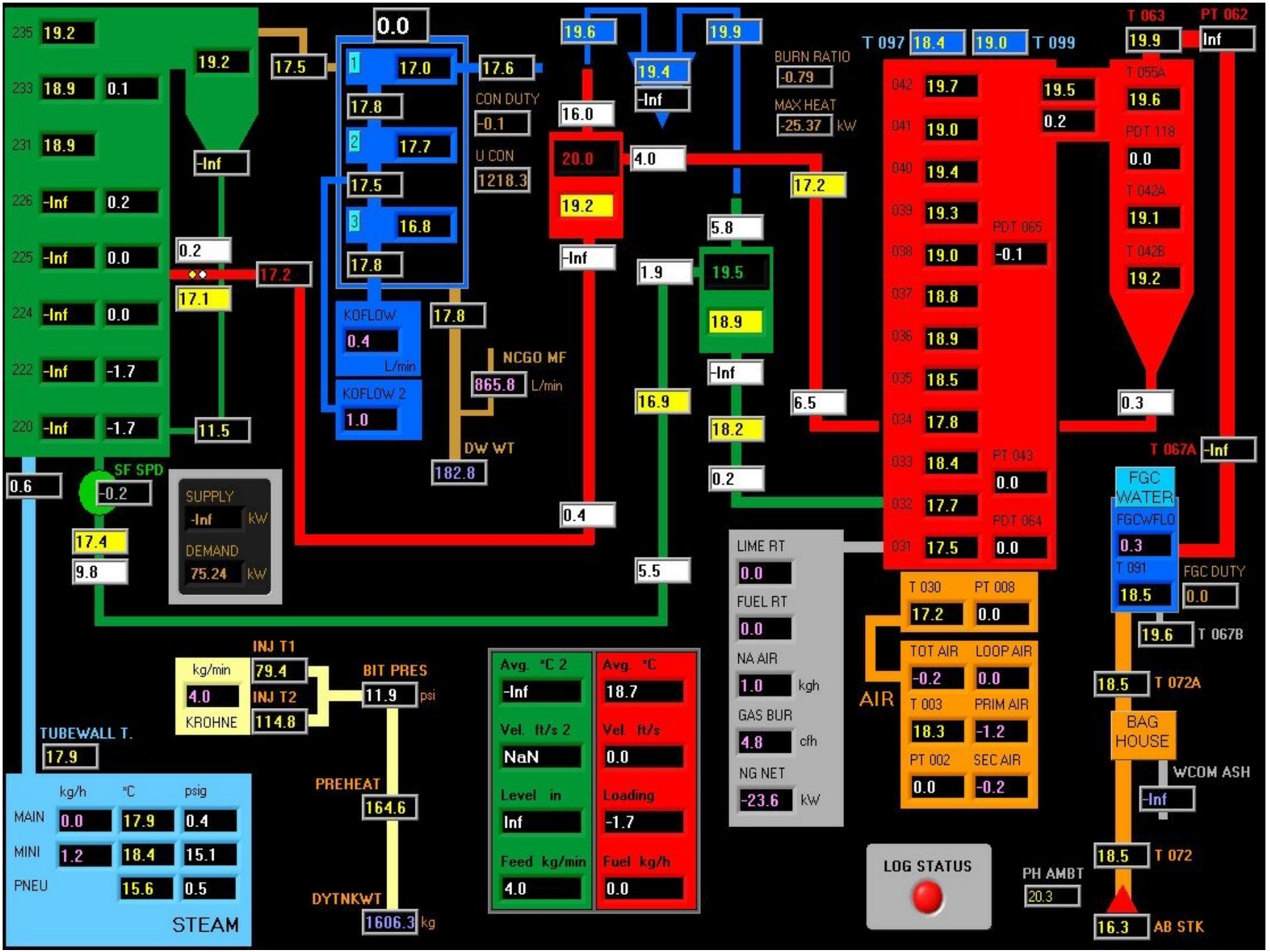
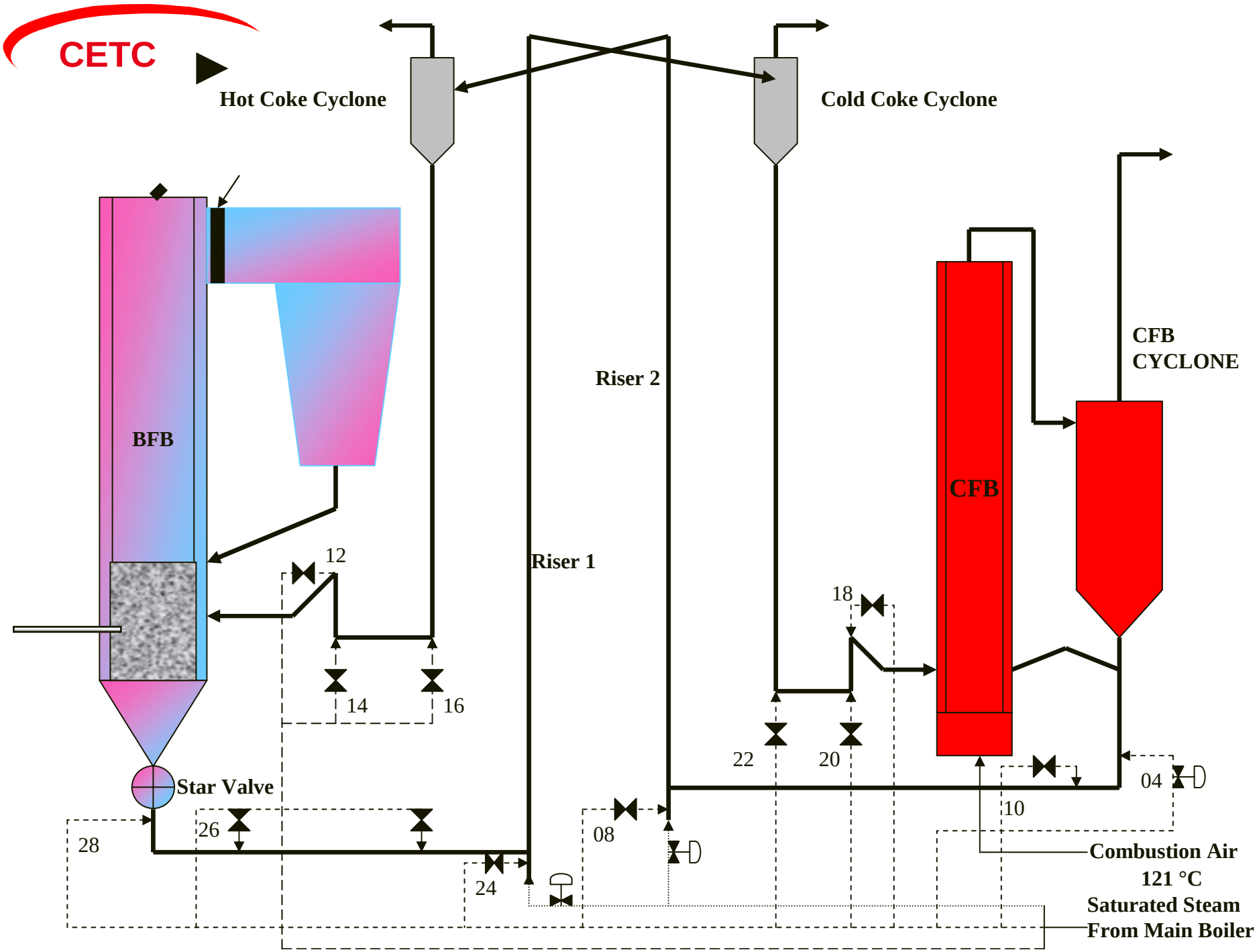
Dual Fluid Bed Pilot Plant

BFB Transport CFB




235 19.2
233 18.9 0.1
231 18.9
226 -Inf 0.2
225 -Inf 0.0
224 -Inf 0.0
222 -Inf -1.7
220 -Inf -1.7
19.2
-Inf
0.2
17.1
11.5
17.5
0.0
1 17.0
17.8
2 17.7
17.5
3 16.8
17.8
17.6
CON DUTY
-0.1
U CON
1218.3
KOFLOW
0.4
L/min
KOFLOW 2
1.0
17.8
NCGO MF
865.8 L/min
DW WT
182.8
19.6
19.9
19.4
-Inf
16.0
20.0
19.2
-Inf
4.0
17.2
5.8
19.5
18.9
-Inf
1.9
16.9
18.2
0.2
6.5
0.4
5.5
BURN RATIO
-0.79
MAX HEAT
-25.37 kW
T 097 18.4 19.0 T 099
042 19.7
041 19.0
040 19.4
039 19.3
038 19.0
037 18.8
036 18.9
035 18.5
034 17.8
033 18.4
032 17.7
031 17.5
19.5
0.2
PDT 065
-0.1
PT 043
0.0
PDT 064
0.0
T 063 19.9
PT 062 Inf
T 055A 19.6
PDT 118 0.0
T 042A 19.1
T 042B 19.2
0.3
T 067A -Inf
FGC WATER
FGCWFLO 0.3
T 091 18.5
FGC DUTY 0.0
19.6 T 067B
18.5 T 072A
BAG HOUSE
WCOM ASH
-Inf
18.5 T 072
16.3 AB STK
0.6
SF SPD
-0.2
17.4
9.8
SUPPLY
-Inf kW
DEMAND
75.24 kW
LIME RT
0.0
FUEL RT
0.0
NA AIR
1.0 kgh
GAS BUR
4.8 cfh
NG NET
-23.6 kW
AIR
T 030 17.2
PT 008 0.0
TOT AIR -0.2
LOOP AIR 0.0
T 003 18.3
PRIM AIR -1.2
PT 002 0.0
SEC AIR -0.2
INJ T1
kg/min
4.0
KROHNE
79.4
INJ T2
114.8
BIT PRES
11.9 psi
TUBEWALL T.
17.9
PREHEAT
164.6
DYTNKWT
1606.3 kg
Avg. °C 2
-Inf
Vel. ft/s 2
NaN
Level in
Inf
Feed kg/min
4.0
Avg. °C
18.7
Vel. ft/s
0.0
Loading
-1.7
Fuel kg/h
0.0
kg/h °C psig
MAIN 0.0 17.9 0.4
MINI 1.2 18.4 15.1
PNEU 15.6 0.5
STEAM
LOG STATUS
PH AMBT
20.3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Star Valve
Combustion Air
121 °C
Saturated Steam
From Main Boiler

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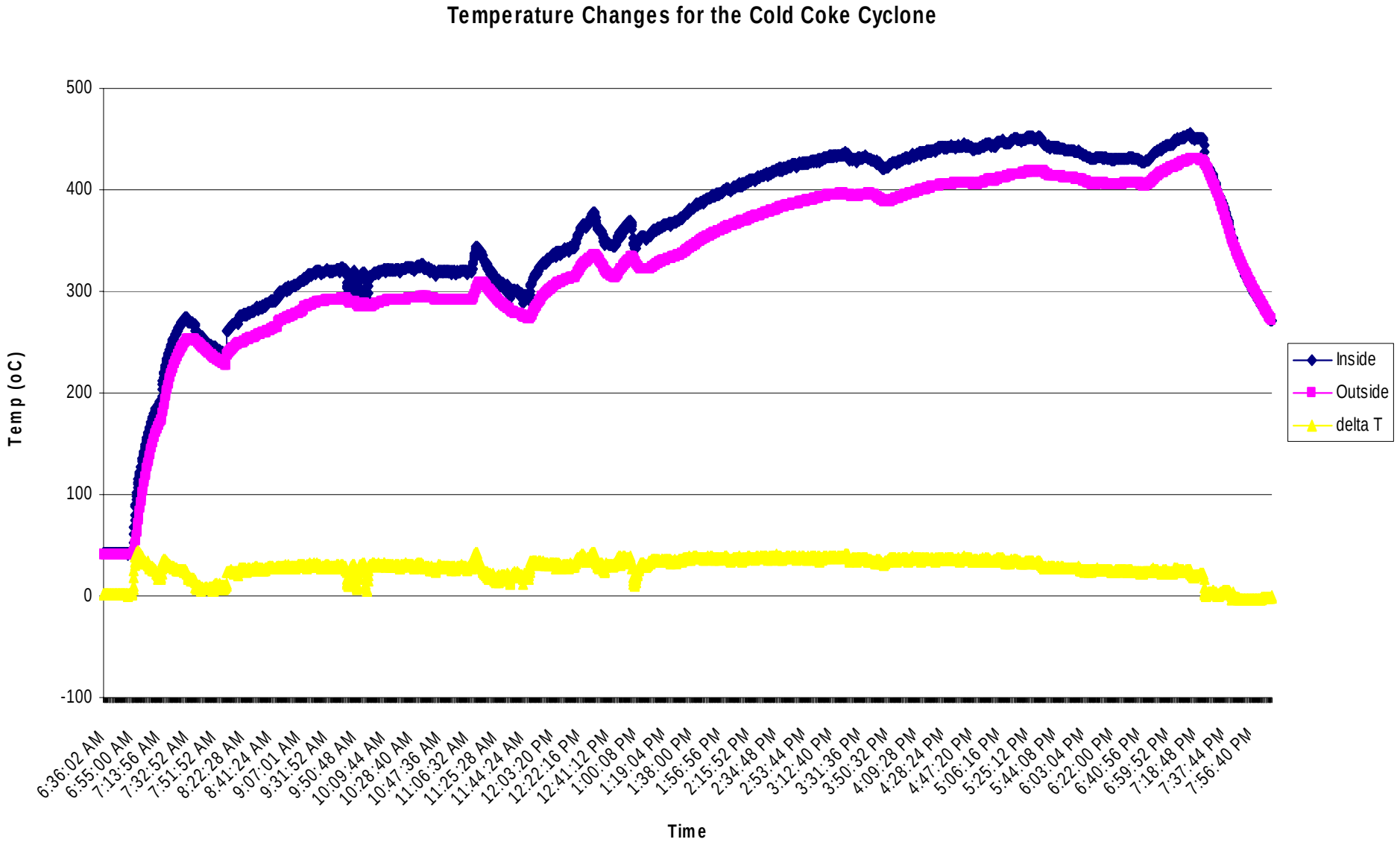
Transport – Monitor & Control Point



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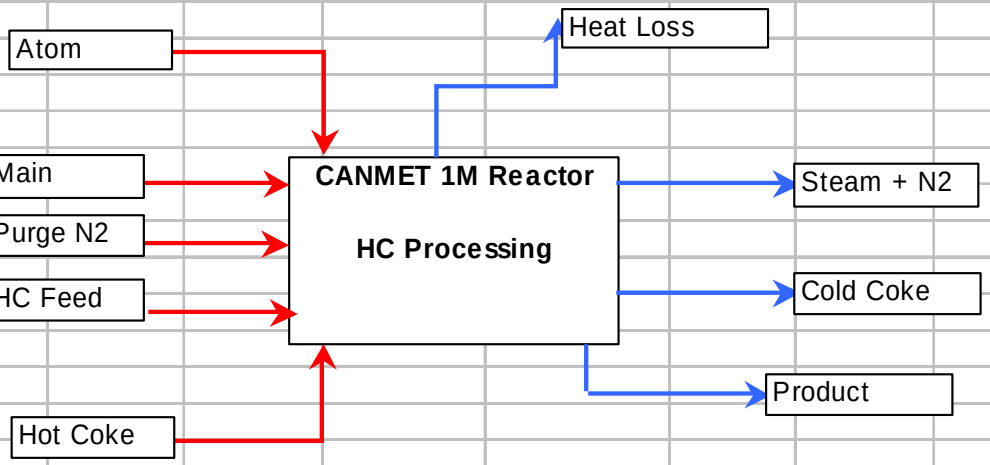
DUAL FLUID BED HEAT BALANCE



Heat In = Heat Out + Heat Loss

	Rate (kg/hour)	Temp. In (^oC)	Temp. Out (^oC)	Cp kJ/kg/K	Heat kJ/kg	Heat kJ/Hour	Heat kW
HEAT SINKS							
Main Steam	75	500	526	2.166	56.3	4224	1.2
Atom Steam	6.7	350	526	2.166	381.2	2554	0.7
Purge Steam	0	120	526	2.166	879.4	0	0.0
N_2 Purge	10	25	526	1.0416	521.8	5218	1.4
Bitumen Feed	318	319.7	526	1.735	892.9	283946	78.9
Total Heat Req'd					2732	295943	**82.2**
HEAT SOURCE							
Coke Circulation	5070.1	606	526	1.6	128	648973	**180.3**

Heat Required

Heat Input

Feed Rate (kg/min)	5.3
Star Feeder (RPM)	14.64

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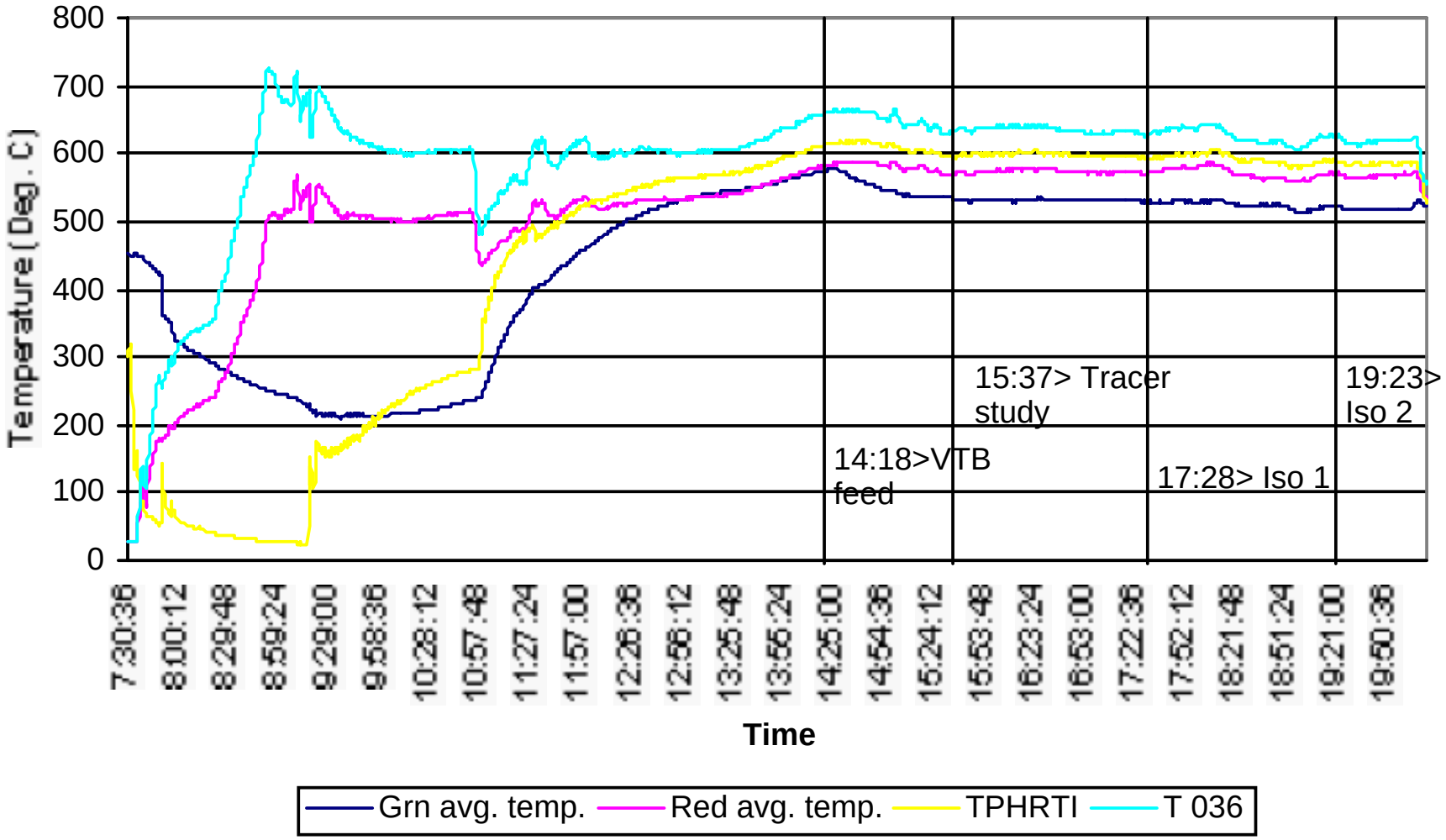
Temperature (Deg. C)
800
700
600
500
400
300
200
100
0
7:30:36
8:00:12
8:29:48
8:59:24
9:29:00
9:58:36
10:28:12
10:57:48
11:27:24
11:57:00
12:26:36
12:56:12
13:25:48
13:55:24
14:25:00
14:54:36
15:24:12
15:53:48
16:23:24
16:53:00
17:22:36
17:52:12
18:21:48
18:51:24
19:21:00
19:50:36
Time
14:18>VTB feed
15:37> Tracer study
17:28> Iso 1
19:23> Iso 2
Grn avg. temp.
Red avg. temp.
TPHRTI
T 036

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Dual Fluid Bed Operation

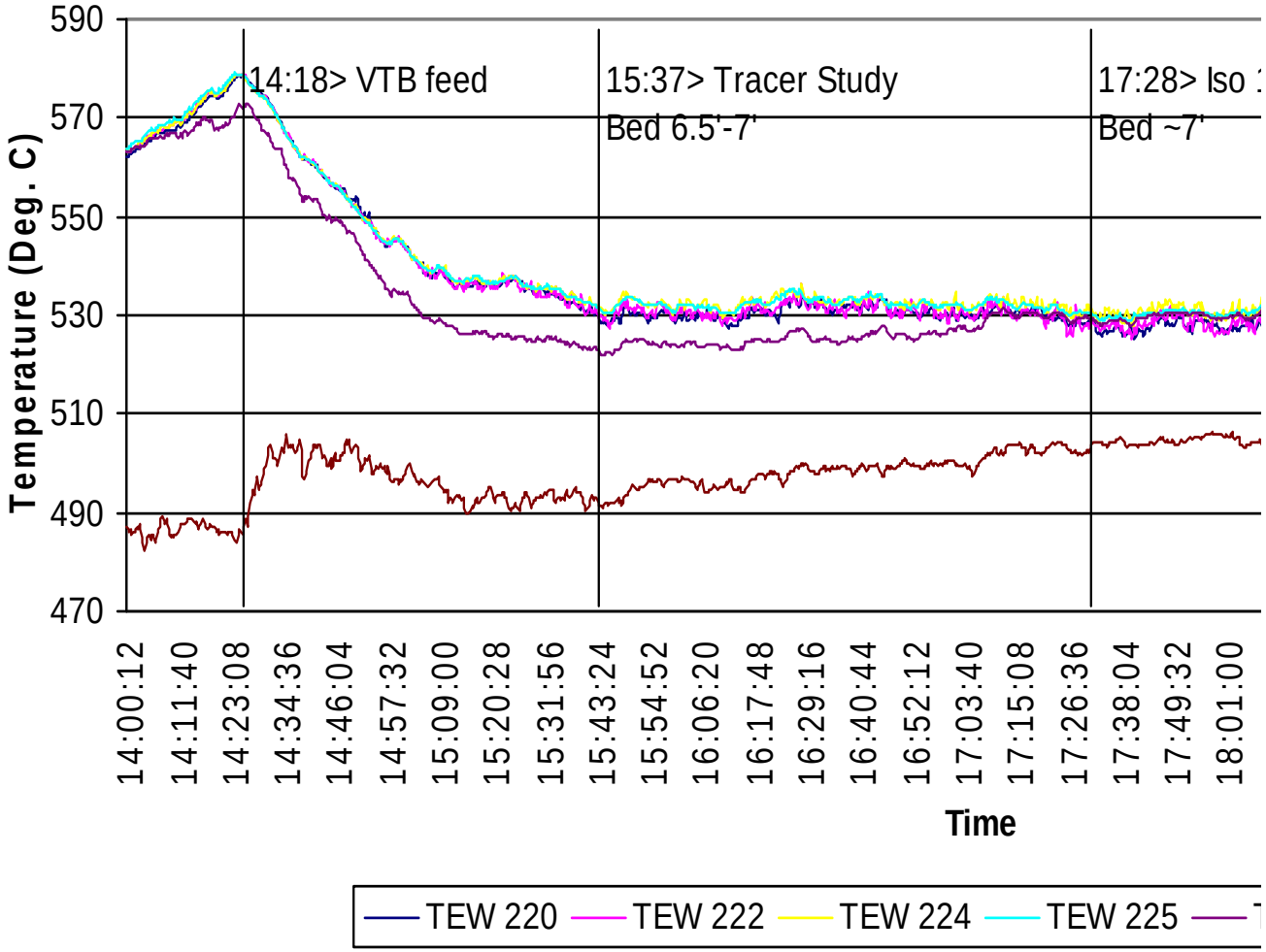
SS conditions:

BFB temperature: ± 2 °C

Circulation Rate: ± 80 kg/h

Fluidization Steam: ± 1 %

Bed height: ± 0.1 m



Co-Firing Biomass & Fluid Coke

Preparing biomass for co-firing involves "tuning" the fuel mix and “verifying” boiler operation so that there is little or no loss in total efficiency. Since biomass in general has significantly less sulfur than coke, there is an SO2 benefit and there may also be NOx reduction, but this has to be evaluated.

Investment levels are very site specific and are affected by the available biomass, determining handling, size reduction and drying facilities, and the type of burner modifications.

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Ash Issues

Ash deposition and boiler tube corrosion can be an issue for some co-firing arrangements, depending on the biomass, ash chemistry, and operating conditions. Biomass can contain considerable alkali and alkaline-earth elements and chlorine, which, when mixed with other gas components derived from coke such as sulphur compounds, promotes a different array of vapour and fine particulate deposition.

CONCERN: CFBC combustion of fluid coke is typically above 900 C. This is a potential problem for biomass ash agglomeration

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* RESULTS FOR SAMPLE **Industrial Pellet** / ACT010055 *
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SAMPLE COMMENT/DESCRIPTION: **Ground Wood Pellets**

PROXIMATE ANALYSIS (wt%)

	As Analyzed	Dry@105°C
Moisture	4.17	
Ash	3.31	3.45
Volatile	74.12	77.35
Fixed Carbon	18.40	19.20
ULTIMATE ANALYSIS (wt%)		
Carbon	48.55	50.66
Hydrogen	5.51	5.75
Nitrogen	0.26	0.27
Sulphur	<0.03	<0.03
Oxygen (Diff)	38.17	39.84
CALORIFIC ANALYSIS		
Cal/g	4614	4815
MJ/KG	19.32	20.16
BTU/LB	8305	8667

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Proximate-ultimate analyses of Syncrude coke

	As analyzed	Dry @105°C	Dry Ash free
Proximate analysis Wt %			
Moisture	0.48		
Ash	6.28	6.31	
Volatile	6.34	6.37	6.80
Fixed carbon	86.90	87.32	93.20
Ultimate analysis Wt %			
Carbon	80.92	81.31	86.79
Hydrogen	1.66	1.67	1.78
Nitrogen	1.88	1.89	2.02
Sulphur	7.09	7.12	7.60
Oxygen (by diff.)	1.69	1.70	1.81
Calorific analysis			
MJ/kg	30.61	30.75	32.82

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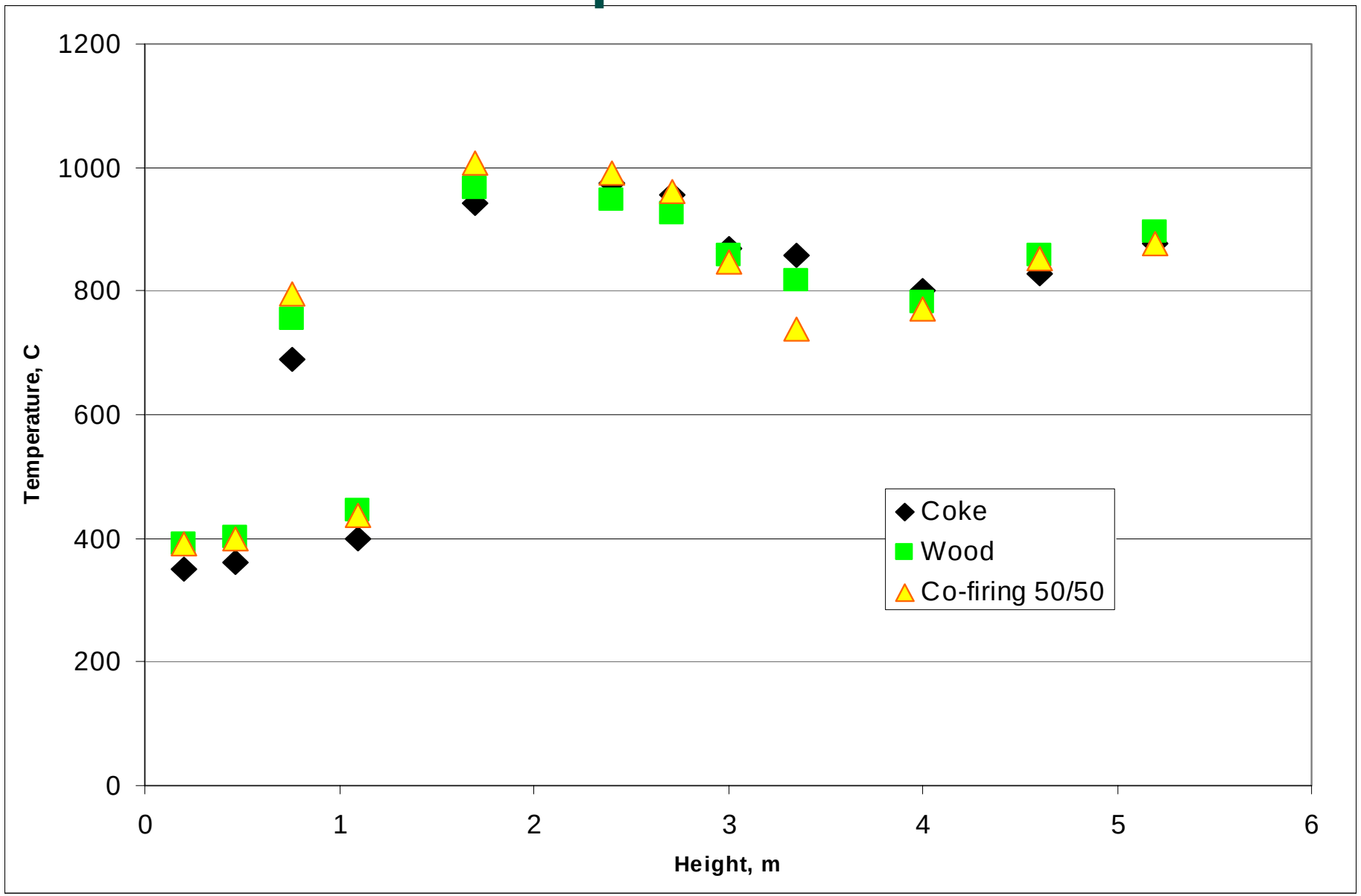
CFBC – Temperature Profiles



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CFBC – Co-firing Flue Gas

	Wood	Coke	Mix:50/50
Vel. m/s	5.4	4.0	5.2
O2, %	4.6	5.6	4.3
CO, ppm	150	260	380
SO2, ppm	30	285	150
NOx	NA	90	NA

Ash Analyses & further work continuing….