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GAGETOWN LOW NO_x/SO_x BURNER PROJECT TEST PROGRAM

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by

G.K. Lee* and R.J. Philp**

ABSTRACT

Canada, Denmark, Sweden and the United States are collaborating in a three-stage project, under the auspices of the International Energy Agency to develop and evaluate the performance of a low NO_x/SO_x burner for pulverized coal. Stage I, which involved small-scale burner tests with 45 coals from around the world, established that over 70% of the NO_x from pulverized coal flames was derived from the fuel nitrogen and that the conversion of fuel nitrogen to NO_x could be suppressed by proper air staging. In Stage II, the concept of air staging was translated into a prototype design for a NO_x coal burner and large-scale boiler simulator trials were conducted on four coals, two of which included sorbent injection to reduce SO_2 emissions. Stage III, now in progress, involves full-scale demonstration trials on low NO_x/SO_x burners installed in a front-wall-fired boiler in each country using the same general test procedures.

Under Stage III, five bituminous-coal fired boilers of different capacities are being evaluated for NO_x/SO_x reductions under closely controlled operational conditions to validate the trends observed in Stage II. One of the two Canadian boilers selected is the No. 2 Unit at the Central Heating Plant of Canadian Forces Base Gagetown. This Unit, rated at 20 MWt, supplies hot water for a district heating system.

This report gives a detailed outline of the test objectives, the general work plan and the measurement and sampling procedures that will be used during the field trials on Gagetown Unit No. 2

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Contents

1) TEST PLAN

The following tentative test plan is based on the availability of material and human resources, the test period that is available and the heating demand requirements.

1.1) Function Tests

Screen operation of burner and preliminary evaluation of performance.

Schedule: commence Jan. 15, 1987

1.1.1) Low NOx
Due to previous testing only minor tuning is expected. Critical parameters are carbon burnout and NOx.

1.1.2) Sorbent Injection
Assess SO_2 capture at a Ca/S of 2.5 using the same injection velocities as in previous testing.

1.2) Baseline Tests

Repetition of function tests, but with more extensive test procedure.

Scheduling: commence Feb. 1, 1988.

Test Matrix

	Test No.			
Parameter	1	2	3	4
sorbent injection	N	N	Y	Y
boiler load	1/2	Full	1/2	Full

N: No
Y: Yes
1/2: half load, lower burner only
Full: full load, both burners

1.3) Parametric Tests: Screening and Optimization

The objectives are to determine the limits of the parameters and the influence on boiler output. Only half load measurements required to ascertain effects will be made in the screening tests. Optimization tests at full load will cover a reduced range and testing will be more extensive.

1.3.1) Low NOx

Test Matrix

	Test No.				
Parameters	1	2	3	4	5
Sec/Tert Air	V	F	F	F	F
Swirl	F	V	F	F	F
Primary Air	F	F	V	F	F
Injection air	F	F	F	V	F
Core Air *	F	F	F	F	V

F: Fixed, Parameter at baseline (low NOx) operating conditions
V: Variable, 3-5 settings
*: if practical

1.3.2) Sorbent Injection

Test Matrix

	Test No.		
Parameters	1	2	3
Injection velocity	V	F	F
Ca/S	F	V	F
Sorbent type	L	L	H

V: variable
F: fixed
L: limestone
H: hydroxide

1.4) Long Term Test

The boiler will be operated for 2 days at full load. Limestone at a Ca/S ratio of 2.5 will be injected and optimized burner settings will be employed.

2) TEST SCHEDULE

It is estimated that 27 test days are required to complete the program, excluding those required for the function tests. The test sequence and schedule is shown in the attached figure.

3) TEST COAL: SPECIFICATIONS

V.M.: 33-35%
Ash : 8-12%
S : 2 1/2-3%

4) MEASUREMENTS

4.1) Log

4.1.1) Function Tests

Date:
Time:

Boiler Measurements:
Firing Configuration: Upper Burner, Y/N:
Lower Burner, Y/N:
MW Flow (0-25 MW):
Water Flow (0-100%):
Air Flow (0-100%):
Furnace draft, +100/-100 Pa =
Air Heater:
Gas Inlet Temp., °C =
Gas Outlet Temp., °C =
Air Inlet Temp., °C =
Air Outlet Temp., °C =
Flue Gas O_2, % =
Lower burner, oil flow, %:
secondary air flow, %:
tertiary air flow, %:
exhaustor, %:
Lower mill, primary air flow, %:
(No. 1) coal feeder, %:
pressure, inlet, +250/-1000 Pa:
outlet, 0/2.5 kPa:
motor amperes, A:

Test Schedule: Tentative

Test	Days 1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Parametric Screening																										
Sec/Tert.	------																									
Swirl		------																								
Core			------																							
Primary				------																						
Injection					------																					
Sorbent Injection Velocity						------																				
Ca/S							------																			
Baseline, Test Sequence No.1																										
Sorbent,Load																										
N,1/2								---																		
N,Full								---																		
Y,1/2									---																	
Y,Full									---																	
Parametric Optimization																										
Sec/Tert										----------																
Swirl											----------	----------														
Core													----------													
Primary														----------	----------											
Injection																----------										
Sorbent Injection velocity																	----------	----------								
Ca/S																			----------							
Baseline Test Sequence, No.2																										
Sorbent,Load																										
N,1/2																				---						
N,Full																					---					
Y,1/2																					---					
Y,Full																						---				
Long Term Test																										
Optimized condition																							--------	--------		
Parametric Optimization																										
Sorbent Type, Ca/S																									------	------

Upper burner, oil flow, %:
secondary air flow, %:
tertiary air flow, %:
exhaustor, %:
Upper mill, primary air flow, %:
(No. 2) coal feeder, %:
pressure, inlet, +250/-1000 Pa:
outlet, 0/2.5 kPa:
motor amperes, A:
I.D. Fan motor, A:
F.D. Fan motor, A:
Forced draft duct pressure, %:
Oxygen trim, %:
Air heater bypass, %:
Primary air, lower burner, %:
upper burner, %:
Secondary air, lower burner, %:
upper burner, %:
Coal/air temp, °C:
lower burner mill:
upper burner mill:
Water flow, Inlet, %:
Outlet, %:
temp., Inlet, °C:
Outlet, °C:
press., kPa guage:

<u>Burner</u>:

Settings	Lower	Upper
Secondary air swirler, mm.:		
Position, secondary air, mm.:		
tertiary air, mm.:		
core air, mm.:		

Flame Description:

<u>Sorbent Injection</u>:
Feed rate, % =
Time: Totalizer Count:
Time: Totalizer Count:
Air flow:

<u>E.C. Measurements</u>:
SO_2, ppm:
NO_x, ppm:
THC, ppm:
CO, ppm:
O_2, %:
CO_2, %:

Samples, check list:
Coal, Raw:
Pulverized:
Sorbent:
Fly Ash:

4.1.2) Baseline/Parametric Optimization Tests

Date:
Time:

Boiler Measurements:
Firing Configuration: Upper Burner, Y/N:
Lower Burner, Y/N:
MW Flow (0-25 MW):
Water Flow (0-100%):
Air Flow (0-100%):
Furnace draft, +100/-100 Pa =
Air Heater:
Gas Inlet Temp., °C =
Gas Outlet Temp., °C =
Air Inlet Temp., °C =
Air Outlet Temp., °C =
Flue Gas O_2, % =
Lower burner, oil flow, %:
secondary air flow, %:
tertiary air flow, %:
exhaustor, %:
Lower mill, primary air flow, %:
(No. 1) coal feeder, %:
pressure, inlet, +250/-1000 Pa:
outlet, 0/2.5 kPa:
motor amperes, A:
Upper burner, oil flow, %:
secondary air flow, %:
tertiary air flow, %:
exhaustor, %:
Upper mill, primary air flow, %:
(No. 2) coal feeder, %:
pressure, inlet, +250/-1000 Pa:
outlet, 0/2.5 kPa:
motor amperes, A:
I.D. Fan motor, A:
F.D. Fan motor, A:
Forced draft duct pressure, %:
Oxygen trim, %:
Air heater bypass, %:
Primary air, lower burner, %:
upper burner, %:
Secondary air, lower burner, %:
upper burner, %:

Coal/air temp, °C:
lower burner mill:
upper burner mill:
Water flow, Inlet, %:
Outlet, %:
temp., Inlet, °C:
Outlet, °C:
press., kPa guage:
Pressure drop, convective tube bank, " WC =
air preheater, " WC =
furnace/preheater outlet, " WC =
Soot blowing cycle:
Combustion air humidity, wet bulb, °C =
dry bult, °C =
relative humidity, % =
Furnace deposits, description:

<u>Burner</u>:

Settings	Lower	Upper

Secondary air swirler, mm.:
Position, secondary air, mm.:
tertiary air, mm.:
core air, mm.:
Pressure, tertiary air windbox,"WC =
Orifice and Venturi Measurements:
(1) Primary Air, Lower Burner (DP-127A):
pressure differential, " WC =
pressure at lower tap, " WC =
(2) Core, Secondary and Tertiary Air, Lower Burner (DP-129A)
pressure differential, " WC =
pressure at lower tap, " WC =
(3) Primary Air, Upper Burner (DP-128A):
pressure differential, " WC =
pressure at lower tap, " WC =
(4) Core, Secondary and Tertiary air, Upper Burner (DP-130A)
pressure differential, " WC =
pressure at lower tap, " WC =

Flame Description:

<u>Sorbent Injection</u>:
Feed rate, %:
Time: Totalizer Count:
Time: Totalizer Count:
Air flow:
Compressor: injection, A =
fluidizing, A =

<u>E.C. Measurements</u>:
SO_2, ppm:
NOx, ppm:
THC, ppm:
CO, ppm:
O_2, %:
CO_2, %:
Fly ash mass loading, kg/h:
Particle size distribution

<u>Ash mass balance</u>:
Ash from cyclone separators, kg:
Time, start:
finish:
Bottom ash, kg:
Time, start:
finish:

<u>Samples</u>, check list:
Coal, Raw:
Pulverized:
Sorbent:
Ash from cyclone separators:
Bottom ash:
Fly ash:

4.2) <u>Probe</u>

4.2.1) <u>Furnace Temperature</u>

4.2.1.1) <u>Suction Pyrometer</u>
O.D.: 2.5"
Length: 8' 4", maximum insertion

Procedure:
1) Tests:
1.1) Parametric Screening:
Injection air flow: one measurement at typical flow
1.2) Baseline test: full load, with and without limestone injection
1.3) Parametric Optimization:
Either for injection air or sorbent injection velocity tests, depending upon outcome of 1.2
2) Location of measurements:
2.1) L.1.1, L.2.1: at wall and every 1.5' to a maximum insertion of 6' in each port, 5 measurements/port
2.2) L.1.2, L.2.2: at 1.5' and 6', 2 measurements/port
2.3) R.1.2, R.2.2: at 1.5' and 4.5', 2 measurements/port

Port locations:
See attached figure
Port No.:
L.1.1: LHS, elevation no. 1 (lower), front
-port located on LHS of boiler (facing)
-approximately 9" below centre line of lower burner, and 10" from quarl exit
L.1.2: LHS, elevation no. 1 (lower), rear
-port located on LHS of boiler (facing)
-approximately 9" below centre line of lower burner, and 19" from rear wall
L.2.1: LHS, elevation no. 2, front
-port located on LHS of boiler (facing)
-approximately 28" above centre line of upper burner, and 10" from quarl exit
L.2.2: LHS, elevation no. 2, rear
-port located on LHS of boiler (facing)
-approximately 28" above centre line of upper burner, and 19" from rear wall
L.3: LHS, elevation no. 3, convection tube bank inlet
-port located on LHS of boiler (facing)
-approximately 44" from the first tube bank, and on the centre line, or port slightly above
L.4: LHS, elevation no. 4, outlet of convection tube bank
R.1.2: same as L.1.2, but located on RHS
R.2.2: same as L.2.2, but located on RHS
R.3: same as L.3, but located on RHS
R.4: same as L.4, but located on RHS
R.x.y: corresponding ports on the opposite side of the boiler

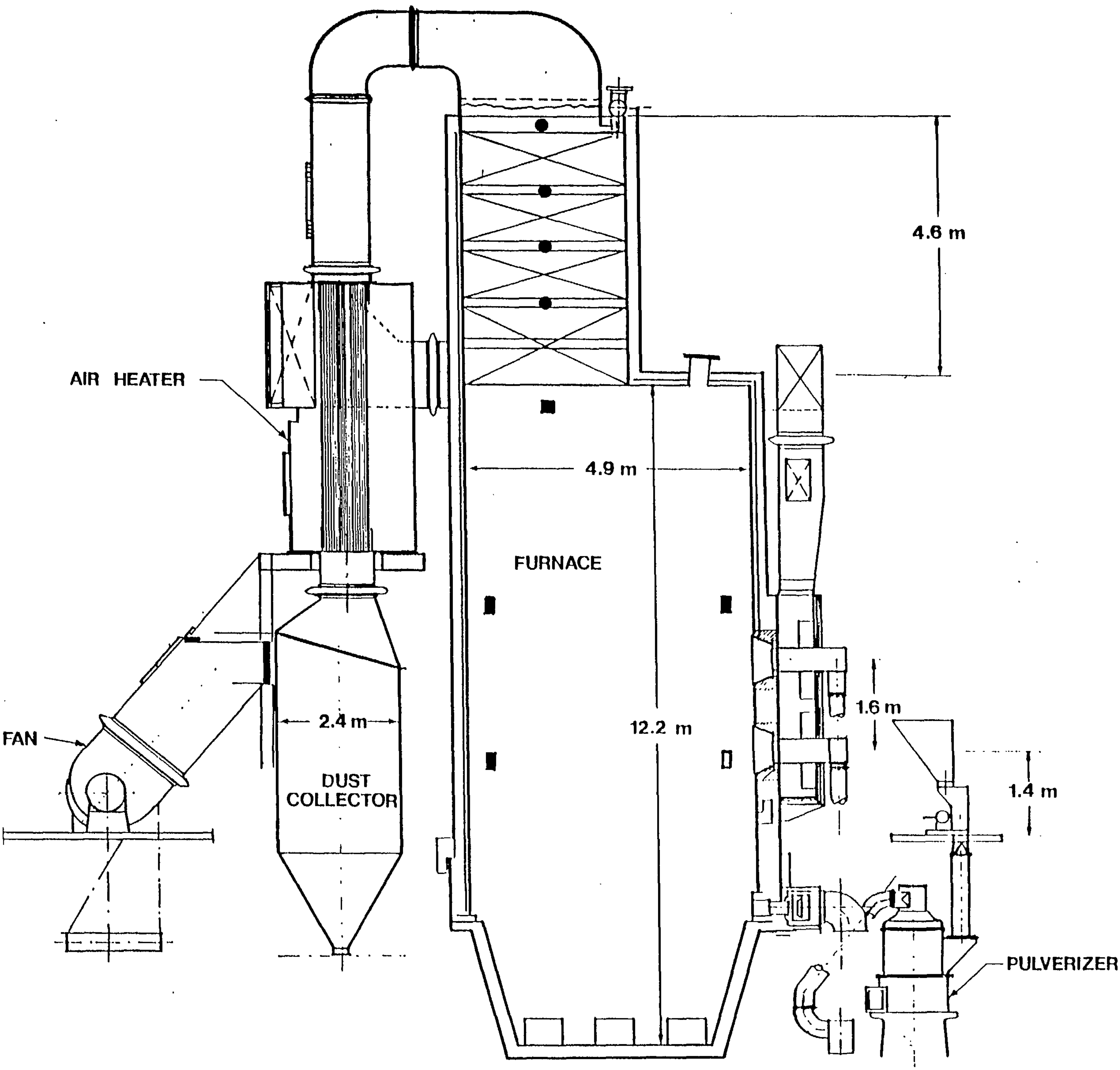
4.2.1.2) <u>Bare Thermocouple</u>

Bare thermocouples located at every 1.5' and supported by air cooled pipe to be used for measurements in ports L.3, L.4, R.3 and R.4.

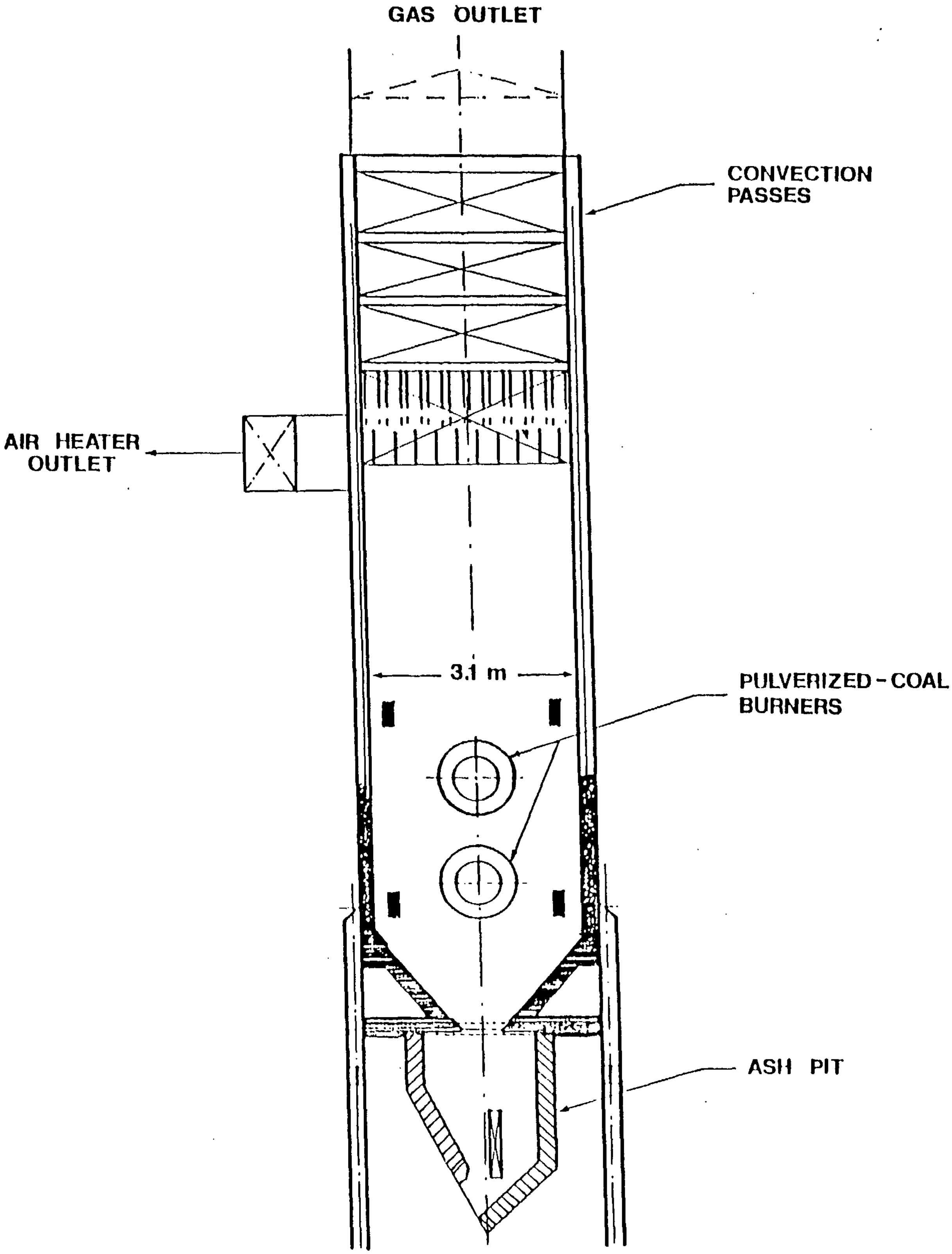
4.2.2) <u>Furnace Radiation</u>

Ellipsoidal Radiometer

Procedure:
1) Tests:
1.1) Baseline test: full load, with and without limestone injection
1.2) Parametric Optimization:
Either for injection air or sorbent injection velocity tests, depending upon outcome of 1.1
2) Location of measurements:
2.1) L.1.1, L.2.1: at wall
2.2) L.1.2, L.2.2, L.3: at wall



Side View: No.2 Generator – Gagetown CHP



Front View: No.2 Generator – Gagetown CHP

4.3) Stack Measurements

Flue gas will be monitored continously for SOx, NOx, CO, O_2, CO_2 and THC downstream of the I.D. fan. Particulates will also be sampled using standard isokinetic techniques so that loading may be determined. Laboratory particles size analysis will be conducted on the solids.

4.4) PRE-TEST

4.4.1) Calibrate orifice and venturi: lower burner air flows

4.4.2) Calibrate sorbent injection

TABLE 1 March 1987 Gagetown Tests prior to boiler cleaning

Test	P2	P7	P9	P10	P11
Date	Feb 28	Mar 2	Mar 3	Mar 4	Mar 4
Time: Start	15:12	12:55	14:20	10:22	13:16
End	16:55	14:28	15:45	11:48	15:00
Coal Type	Test	Test	Base	Base	Base
Boiler Output, MW	9.9	11.8	9.6	10	10
SO2, PPM	2163	986	827	281	181
NOx, PPM	492	391	347	276	261
Ca/S Mole Ratio	0	1.4	0	2.25	1.85
SO2 Absorption, %	0	50.7	0	59.	77.8
Calcium Efficiency	0	0.37	0	0.26	0.42
AH Outlet: Temp. C	282	288	260	272	271
O2, % (vol.)	6	3	2.9	2.4	2.7
Carbon in Bottom Ash, % (1)	7	2.2	6.8	4.9	5
Carbon in Fly Ash, % (1)	28.1	9.7	66.7	21.6	16
Coal Feedrate, kg/h	1608	1757	1271	1255	1236
Oil Flowrate, l/h	40	40	40	40	40
% of Total Energy Input	3.3	3.0	3.5	3.6	3.6
Limestone Feedrate, kg/h	0	223	0	98	96
Total Air, kg/h	20200	18500	15900	15300	15500
Dry Flue Gas, kg/h	21200	20400	16600	16000	16200
H2O in Flue Gas, kg/h	730	780	610	600	600
Boiler Efficiency, %	77.7	82.8	80.7	84.7	84.7
Dry Gas, H2 & H2O Loss, %	17.1	15.4	13.6	13.8	13.9
Unburned C in Ash Loss, %	4.4	1.0	4.9	0.7	0.5
Calcining Loss, %	0	0.8	0	0.4	0.4
Radiation Loss, %	0.8	0.8	0.8	0.8	0.8
Coal Analysis:					
C	68.64	72.09	81.02	81.73	80.93
H	4.42	4.6	5.1	5.12	5.09
N	1.23	1.39	1.62	1.61	1.66
O	7.55	6.46	6.04	5.98	6.43
S	3.15	2.91	1.28	1.06	1.26
Ash	10.93	9.64	3.31	3.02	3.13
Moisture	4.08	2.91	1.63	1.48	1.5
Calorific Value, MJ/kg	28.75	30.08	33.69	33.89	33.66

(1) 10% of input ash removed from ash pit

TABLE 2 March 1987 Gagetown Tests after boiler cleaning

Test	P13	P16a	P16b	P17	P19
Date	Mar 11	Mar 12	Mar 12	Mar 13	Mar 13
Time: Start	14:29	13:28	14:20	9:13	14:54
End	15:37	14:20	14:56	10:40	16:27
Coal Type	Base	Base	Base	Base	Base
Boiler Output, MW	10.7	10.5	10.5	17.4	17
SO2, PPM	764	227	276	784	357
NOx, PPM	364	420	417	400	363
Ca/S Mole Ratio	0	2.7	2.4	0	3.6
SO2 Absorption, %	0	65.7	73.7	0	54.5
Calcium Efficiency	0	0.24	0.31	0	0.15
AH Outlet: Temp. C	186	169	170	177	177
O2, % (vol.)	3	5.2	5.1	4.0	3.8
Carbon in Bottom Ash, % (1)	28.3	7.5	7.5	2	2
Carbon in Fly Ash, % (1)	71.6	22.5	22.5	61.2	21.8
Coal Feedrate, kg/h	1355	1310	1279	2148	2040
Oil Flowrate, l/h	40	40	40	65	65
% of Total Energy Input	3.3	3.5	3.6	3.4	3.6
Limestone Feedrate, kg/h	0	120	123	0	237
Total Air, kg/h	16900	17800	17700	28300	26700
Dry Flue Gas, kg/h	17700	18600	18400	29500	27800
H2O in Flue Gas, kg/h	640	610	600	1020	970
Boiler Efficiency, %	84.1	87.7	88.2	85.9	88.3
Dry Gas, H2 & H2O Loss, %	10.3	10.3	10.3	10.2	10.2
Unburned C in Ash Loss, %	4.8	1.2	0.7	3.0	0.7
Calcining Loss, %	0	0.5	0.5	0	0.6
Radiation Loss, %	0.8	0.8	0.8	0.8	0.8
Coal Analysis:					
C	81.32	79.26	80.66	81.38	81.47
H	5.04	4.94	4.96	5.04	5.09
N	1.58	1.69	1.5	1.67	1.65
O	6.55	6.50	6.8	6.26	6.14
S	1.14	1.03	1.24	1.16	0.99
Ash	2.46	4.44	2.72	2.52	2.80
Moisture	1.91	2.12	2.12	1.97	1.86
Calorific Value, MJ/kg	33.81	32.92	33.51	33.93	33.97

(1) 10% of input ash removed from ash pit