Appendix J

Air Heater Heat Loss to Stack Calculations

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 04/18/94 **Milliken Unit 2 with Ljungstrom Air Heater**

Fuel Bituminous Coal Source

Fuel Unit 100 lbs

Fuel, O2, and Air per Unit of Fuel / Flue Gas (F.G.) Composition Moles per Fuel Unit (AF)

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divisor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	72.20	12	6.02	1	6.02	6.02				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.24	12	0.02							
5	H2	4.88	2	2.44	0.5	1.22				2.44	
6	S	1.62	32	0.05	1	0.05	0.05				
7	O2 (deduct)	5.97	32	0.19	1	-0.19					
8	N2	1.44	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	7.00	18	0.39		0.00				0.39	
11	Ash	6.65				0.00					
12	Sum	100.00		9.16		7.10					
	O2 and Air, Moles for Total Air = 149.1 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.10					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					3.49		3.49			
15	O2 (total) supplied = lines 13 + 14					10.59					
16	N2 supplied = 3.76 x O2, line 15					39.86			39.86		
17	Air (dry) supplied = O2 + N2					50.45					
18	H2O in air = moles dry air x A/(B - A)*					1.06				1.06	
19	Air (wet) supplied = lines 17 + 18					51.51					
20	Flue gas constituents = lines 1 to 18, total						6.07	3.49	39.91	3.89	0.00

LINE	Fuel Analysis as Fired (AF), % by Wt or Vol		Moles C/100 lb fuel	
a	C	72.4		
	H2	4.9	C in fuel	6.04
b	S	1.6	C in refuse	0.02
	O2	6.0	C in CO2+CO	6.02
	N2	1.4	C in CO2	6.02
	H2O	7.0	C in CO	0.00
	Ash	6.7		
		100.0		

LINE		
c	CO2 12.5 O2 7 CO 0 N2 80.5	
d	Total air (T.A.) assigned or by ORSAT	149.1 %
e	Lines f, g, h For Gaseous Fuels	
f	Wt fuel unit = sum(moles each x mol. wt) lb	
g	Mol. wt of fuel = line f/100	
h	Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft	
i	Fuel Heat Value 12,959 Btu/lb /cu ft	
j	Combustible in refuse, % "C"	3.43 %
	Carbon unburned, lb/100 lb fuel	
k	= % ash in fuel x %"C"/(100-%"C")	0.2 %
l	Exit temp of fuel gas, t2	264 F
m	Dry-bulb (ambient) temp, t'1	80 F
n	Wet-bulb temp	F
o	Rel humid. (psychrometric chart)	60 %
p	B*, barometric pressure, in. Hg	30.00
q	Sat. press. H2O at amb temp, in. Hg	1.032
r	A*, press. H2O in air, lines (o x q), in. Hg	0.619
s	Total Moles: Wet Flue Gas 53.36; Dry Flue Gas 49.47	

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

	Flue gas constituents	CO2 + SO2		O2	N2	H2O	CO	Total
22		9.42	10.02	7.12	6.96	8.10	6.98	
23	Mcp, mean, t2 to t'1	10,430	93	4,571	51,131		0	66,226
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)					1,584		1,584
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					4,217		4,217
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					52,985		52,985
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18							125,012
28	Total in wet flue gas							3,330
29	Due to carbon in refuse = line k x 14,100							0
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							128,342
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							1,295,900
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							9.90 %
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 04/19/94 **Milliken Unit 2 with Ljungstrom Air Heater**

Fuel Bituminous Coal

Source

Fuel Unit 100 lbs

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divesor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	Flue Gas (F.G.) Composition Moles per Fuel Unit (AF) CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	72.07	12	6.01	1	6.01	6.01				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.34	12	0.03							
5	H2	4.88	2	2.44	0.5	1.22				2.44	
6	S	1.71	32	0.05	1	0.05	0.05				
7	O2 (deduct)	5.96	32	0.19	1	-0.19					
8	N2	1.42	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	7.00	18	0.39		0.00				0.39	
11	Ash	6.61				0.00					
12	Sum	100.00		9.16		7.09					
	O2 and Air, Moles for Total Air = 150.2 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.09					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					3.56		3.56			
15	O2 (total) supplied = lines 13 + 14					10.65					
16	N2 supplied = 3.76 x O2, line 15					40.10			40.10		
17	Air (dry) supplied = O2 + N2					50.75					
18	H2O in air = moles dry air x A/(B - A)*					1.07				1.07	
19	Air (wet) supplied = lines 17 + 18					51.82					
20	Flue gas constituents = lines 1 to 18, total						6.06	3.56	40.15	3.90	0.00

Fuel Anal.as Fired (AF), % by Wt or Vol	
C	72.4
H2	4.9
S	1.7
O2	6.0
N2	1.4
H2O	7.0
Ash	6.6
	100.0

Moles C/100 lb fuel

C in fuel	6.03
C in refuse	0.03
C in CO2+CO	6.01
C in CO2	6.01
C in CO	0.00

CO2 12.4 O2 7.1 CO 0 N2 80.5

Total air (T.A.) assigned or by ORSAT		150.2	%
Lines f, g, h For Gaseous Fuels			
Wt fuel unit = sum(moles each x mol. wt) lb			
Mol. wt of fuel = line f/100			
Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft			
Fuel Heat Value	12,978 Btu/lb	/cu ft	
Combustible in refuse, % "C"		4.85	%
Carbon unburned, lb/100 lb fuel = % ash in fuel x %"C"/(100-%"C")		0.3	%
Exit temp of fuel gas, t2		266	F
Dry-bulb (ambient) temp, t'1		80	F
Wet-bulb temp			F
Rel humid. (psychrometric chart)		60	%
B*, barometric pressure, in. Hg		30.00	
Sat. press. H2O at amb temp, in. Hg		1.032	
A*, press. H2O in air, lines (o x q), in. Hg		0.619	

Total Moles	Wet Flue Gas 53.67	Dry Flue Gas 49.77

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

	Flue gas constituents	CO2 + SO2		O2	N2	H2O	CO	Total
22		9.43	10.02	7.12	6.96	8.10	6.98	
23	Mcp, mean, t2 to t'1	10,530	100	4,715	52,001		0	67,345
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)					1,611		1,611
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					4,263		4,263
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					52,985		52,985
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18							126,205
28	Total in wet flue gas							4,752
29	Due to carbon in refuse = line k x 14,100							0
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							130,957
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							1,297,800
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							10.09 %
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							

Combustion Calculations -- Molal Basis

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divisor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	Flue Gas (F.G.) Composition Moles per Fuel Unit (AF): CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	72.13	12	6.01	1	6.01	6.01				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.27	12	0.02							
5	H2	4.87	2	2.44	0.5	1.22				2.44	
6	S	1.70	32	0.05	1	0.05	0.05				
7	O2 (deduct)	5.99	32	0.19	1	-0.19					
8	N2	1.33	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	7.00	18	0.39		0.00				0.39	
11	Ash	6.71				0.00					
12	Sum	100.00		9.15		7.10					
	O2 and Air, Moles for Total Air = 150.2 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.10					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					3.56		3.56			
15	O2 (total) supplied = lines 13 + 14					10.65					
16	N2 supplied = 3.76 x O2, line 15					40.11			40.11		
17	Air (dry) supplied = O2 + N2					50.76					
18	H2O in air = moles dry air x A/(B - A)*					1.07				1.07	
19	Air (wet) supplied = lines 17 + 18					51.83					
20	Flue gas constituents = lines 1 to 18, total						6.06	3.56	40.15	3.90	0.00

Conditions -- Assigned or Observed and Miscellaneous

Date 04/20/94 **Milliken Unit 2 with Ljungstrom Air Heater**

Fuel Bituminous Coal

Source

Fuel Unit 100 lbs

Fuel Anal.as Fired (AF), % by Wt or Vol

C	72.4
H2	4.9
S	1.7
O2	6.0
N2	1.3
H2O	7.0
Ash	6.7
	100.0

Moles C/100 lb fuel

C in fuel	6.03
C in refuse	0.02
C in CO2+CO	6.01
C in CO2	6.01
C in CO	0.00

CO2 12.4 O2 7.1 CO 0 N2 80.5

Total air (T.A.) assigned or by ORSAT	150.2	%
Lines f, g, h For Gaseous Fuels		
Wt fuel unit = sum(moles each x mol. wt) lb		
Mol. wt of fuel = line f/100		
Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft		
Fuel Heat Value 12,973 Btu/lb /cu ft		
Combustible in refuse, % "C"	3.84	%
Carbon unburned, lb/100 lb fuel = % ash in fuel x %"C"/(100-%"C")	0.3	%
Exit temp of fuel gas, t2	258	F
Dry-bulb (ambient) temp, t'1	80	F
Wet-bulb temp		F
Rel humid. (psychrometric chart)	60	%
B*, barometric pressure, in. Hg	30.00	
Sat. press. H2O at amb temp, in. Hg	1.032	
A*, press. H2O in air, lines (o x q), in. Hg	0.619	

Total Moles	Wet Flue Gas	Dry Flue Gas
	53.67	49.78

*Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

LINE		CO2 + SO2		O2	N2	H2O	CO	Total
22	Flue gas constituents							
23	Mcp, mean, t2 to t'1	9.41	10.01	7.12	6.96	8.09	6.98	
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)	10,067	95	4,510	49,749		0	64,420
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					1,541		1,541
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					4,070		4,070
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18					52,891		52,891
28	Total in wet flue gas							122,923
29	Due to carbon in refuse = line k x 14,100							3,775
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							0
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							126,698
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							1,297,300
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							9.77 %

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 10/17/95 **Milliken Unit 2 with Heat Pipe**

Fuel Bituminous Coal Source

Fuel Unit 100 lbs

Fuel, O2, and Air per Unit of Fuel | Flue Gas (F.G.) Composition Moles per Fuel Unit (AF)

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divisor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	73.31	12	6.11	1	6.11	6.11				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.18	12	0.02							
5	H2	4.78	2	2.39	0.5	1.20				2.39	
6	S	1.72	32	0.05	1	0.05	0.05				
7	O2 (deduct)	4.99	32	0.16	1	-0.16					
8	N2	1.46	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	7.00	18	0.39		0.00				0.39	
11	Ash	6.56				0.00					
12	Sum	100.00		9.16		7.20					
	O2 and Air, Moles for Total Air = 136.8 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.20					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					2.65		2.65			
15	O2 (total) supplied = lines 13 + 14					9.85					
16	N2 supplied = 3.76 x O2, line 15					37.08			37.08		
17	Air (dry) supplied = O2 + N2					46.93					
18	H2O in air = moles dry air x A/(B - A)*					0.99				0.99	
19	Air (wet) supplied = lines 17 + 18					47.92					
20	Flue gas constituents = lines 1 to 18, total						6.16	2.65	37.13	3.77	0.00

LINE			
a	Fuel Analysis Fired (AF), % by Wt or Vol		
	C 73.5	Moles C/100 lb fuel	
	H2 4.8	C in fuel	6.12
	S 1.7	C in refuse	0.02
	O2 5.0	C in CO2+CO	6.11
	N2 1.5	C in CO2	6.11
	H2O 7.0	C in CO	0.00
	Ash 6.6		
	100.0		
b			
c	CO2 13.3 O2 5.75 CO 0 N2 81		
d	Total air (T.A.) assigned or by ORSAT	136.8 %	
e	Lines f, g, h For Gaseous Fuels		
f	Wt fuel unit = sum(moles each x mol. wt) lb		
g	Mol. wt of fuel = line f/100		
h	Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft		
i	Fuel Heat Value	13,029 Btu/lb /cu ft	
j	Combustible in refuse, % "C"	2.72 %	
	Carbon unburned, lb/100 lb fuel		
k	= % ash in fuel x %"C"/(100-%"C")	0.2 %	
l	Exit temp of fuel gas, t2	289 F	
m	Dry-bulb (ambient) temp, t'1	80 F	
n	Wet-bulb temp	F	
o	Rel humid. (psychrometric chart)	60 %	
p	B*, barometric pressure, in. Hg	30.00	
q	Sat. press. H2O at amb temp, in. Hg	1.032	
r	A*, press. H2O in air, lines (o x q), in. Hg	0.619	
s	Total Moles: Wet Flue Gas 49.71; Dry Flue Gas 45.94		

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

		CO2 + SO2		O2	N2	H2O	CO	Total
22	Flue gas constituents							
23	Mcp, mean, t2 to t'1	9.48	10.07	7.14	6.97	8.11	6.99	
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)	12,097	113	3,952	54,097		0	70,259
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					1,677		1,677
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					4,713		4,713
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18					52,021		52,021
28	Total in wet flue gas							128,670
29	Due to carbon in refuse = line k x 14,100							2,585
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							0
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							131,255
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							1,302,900
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							10.07 %

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 10/18/95 **Milliken Unit 2 with Heat Pipe**

Fuel Bituminous Coal Source

Fuel Unit 100 lbs

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divisor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	CO2 + SO2	O2	N2	H2O	CO
	Fuel, O2, and Air per Unit of Fuel						Flue Gas (F.G.) Composition Moles per Fuel Unit (AF)				
1	C to CO2	73.49	12	6.12	1	6.12	6.12				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.20	12	0.02							
5	H2	4.84	2	2.42	0.5	1.21				2.42	
6	S	1.76	32	0.06	1	0.06	0.06				
7	O2 (deduct)	5.31	32	0.17	1	-0.17					
8	N2	1.49	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	6.30	18	0.35		0.00				0.35	
11	Ash	6.62				0.00					
12	Sum	100.00		9.18		7.22					
	O2 and Air, Moles for Total Air = 137.2 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.22					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					2.69		2.69			
15	O2 (total) supplied = lines 13 + 14					9.91					
16	N2 supplied = 3.76 x O2, line 15					37.30			37.30		
17	Air (dry) supplied = O2 + N2					47.21					
18	H2O in air = moles dry air x A/(B - A)*					1.00				1.00	
19	Air (wet) supplied = lines 17 + 18					48.21					
20	Flue gas constituents = lines 1 to 18, total						6.18	2.69	37.36	3.76	0.00

LINE			
a	Fuel Anal.as Fired (AF), % by Wt or Vol		
	C 73.7	Moles C/100 lb fuel	
	H2 4.8	C in fuel	6.14
b	S 1.8	C in refuse	0.02
	O2 5.3	C in CO2+CO	6.12
	N2 1.5	C in CO2	6.12
	H2O 6.3	C in CO	0.00
	Ash 6.6		
	100.0		
c	CO2 13.2 O2 5.8 CO 0 N2 81		
d	Total air (T.A.) assigned or by ORSAT	137.2 %	
e	Lines f, g, h For Gaseous Fuels		
f	Wt fuel unit = sum(moles each x mol. wt) lb		
g	Mol. wt of fuel = line f/100		
h	Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft		
i	Fuel Heat Value 13,137 Btu/lb	/cu ft	
j	Combustible in refuse, % "C"	2.89 %	
	Carbon unburned, lb/100 lb fuel		
k	= % ash in fuel x %"C"/(100-%"C")	0.2 %	
l	Exit temp of fuel gas, t2	294 F	
m	Dry-bulb (ambient) temp, t'1	80 F	
n	Wet-bulb temp	F	
o	Rel humid. (psychrometric chart)	60 %	
p	B*, barometric pressure, in. Hg	30.00	
q	Sat. press. H2O at amb temp, in. Hg	1.032	
r	A*, press. H2O in air, lines (o x q), in. Hg	0.619	
s	Total Moles: Wet Flue Gas 49.98; Dry Flue Gas 46.22		

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

	Flue gas constituents	CO2 + SO2		O2	N2	H2O	CO	Total
22								
23	Mcp, mean, t2 to t'1	9.49	10.07	7.14	6.97	8.12	6.99	
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)	12,432	119	4,108	55,741		0	72,399
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					1,729		1,729
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					4,808		4,808
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18					51,808		51,808
28	Total in wet flue gas							130,743
29	Due to carbon in refuse = line k x 14,100							2,776
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							0
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							133,519
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							1,313,700
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							10.16 %

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 05/14/96 **Milliken Unit 2 with Heat Pipe**

Fuel Bituminous Coal

Source

Fuel Unit 100 lbs

Fuel Anal.as Fired (AF), % by Wt or Vol

C	73.6
H2	4.9
S	1.9
O2	4.3
N2	1.5
H2O	6.4
Ash	7.4
	100.0

Moles C/100 lb fuel

C in fuel	6.13
C in refuse	0.02
C in CO2+CO	6.12
C in CO2	6.12
C in CO	0.00

CO2 14.5 O2 4.35 CO 0 N2 81.2

Total air (T.A.) assigned or by ORSAT		125.5	%
Lines f, g, h For Gaseous Fuels			
Wt fuel unit = sum(moles each x mol. wt) lb			
Mol. wt of fuel = line f/100			
Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft			
Fuel Heat Value	13,094 Btu/lb	/cu ft	
Combustible in refuse, % "C"		2.89	%
Carbon unburned, lb/100 lb fuel			
= % ash in fuel x %"C"/(100-%"C")		0.2	%
Exit temp of fuel gas, t2		288	F
Dry-bulb (ambient) temp, t'1		80	F
Wet-bulb temp			F
Rel humid. (psychrometric chart)		60	%
B*, barometric pressure, in. Hg		30.00	
Sat. press. H2O at amb temp, in. Hg		1.032	
A*, press. H2O in air, lines (o x q), in. Hg		0.619	

Total Moles	Wet Flue Gas	Dry Flue Gas
	46.03	42.33

Fuel, O2, and Air per Unit of Fuel / Flue Gas (F.G.) Composition Moles per Fuel Unit (AF)

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divesor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	73.38	12	6.12	1	6.12	6.12				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.22	12	0.02							
5	H2	4.86	2	2.43	0.5	1.22				2.43	
6	S	1.87	32	0.06	1	0.06	0.06				
7	O2 (deduct)	4.32	32	0.14	1	-0.14					
8	N2	1.53	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	6.43	18	0.36		0.00				0.36	
11	Ash	7.39				0.00					
12	Sum	100.00		9.17		7.25					
	O2 and Air, Moles for Total Air = 125.5 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.25					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					1.85		1.85			
15	O2 (total) supplied = lines 13 + 14					9.10					
16	N2 supplied = 3.76 x O2, line 15					34.25			34.25		
17	Air (dry) supplied = O2 + N2					43.35					
18	H2O in air = moles dry air x A/(B - A)*					0.91				0.91	
19	Air (wet) supplied = lines 17 + 18					44.27					
20	Flue gas constituents = lines 1 to 18, total						6.17	1.85	34.31	3.70	0.00

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

	Flue gas constituents	CO2 + SO2		O2	N2	H2O	CO	Total
22		9.47	10.06	7.14	6.97	8.11	6.99	
23	Mcp, mean, t2 to t'1	12,049	122	2,742	49,745		0	64,658
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)					1,542		1,542
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					4,704		4,704
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					52,177		52,177
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18							123,081
28	Total in wet flue gas							3,101
29	Due to carbon in refuse = line k x 14,100							0
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							126,182
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							1,309,400
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							9.64 %
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 05/15/96 **Milliken Unit 2 with Heat Pipe**

Fuel Bituminous Coal

Source

Fuel Unit 100 lbs

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divesor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	Flue Gas (F.G.) Composition Moles per Fuel Unit (AF) CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	72.16	12	6.01	1	6.01	6.01				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.15	12	0.01							
5	H2	4.70	2	2.35	0.5	1.18				2.35	
6	S	1.88	32	0.06	1	0.06	0.06				
7	O2 (deduct)	3.99	32	0.12	1	-0.12					
8	N2	1.49	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	7.94	18	0.44		0.00				0.44	
11	Ash	7.69				0.00					
12	Sum	100.00		9.05		7.12					
	O2 and Air, Moles for Total Air = 127.3 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.12					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					1.95		1.95			
15	O2 (total) supplied = lines 13 + 14					9.07					
16	N2 supplied = 3.76 x O2, line 15					34.14			34.14		
17	Air (dry) supplied = O2 + N2					43.21					
18	H2O in air = moles dry air x A/(B - A)*					0.91				0.91	
19	Air (wet) supplied = lines 17 + 18					44.12					
20	Flue gas constituents = lines 1 to 18, total						6.07	1.95	34.19	3.70	0.00

LINE		
	Fuel Analysis Fired (AF), % by Wt or Vol	a
	C 72.3	
	H2 4.7	
	S 1.9	
	O2 4.0	
	N2 1.5	
	H2O 7.9	
	Ash 7.7	
	100.0	
	Moles C/100 lb fuel: C in fuel 6.03; C in refuse 0.01; C in CO2+CO 6.01; C in CO2 6.01; C in CO 0.00	b
	CO2 14.3 O2 4.6 CO 0 N2 81.15	c
	Total air (T.A.) assigned or by ORSAT 127.3 %	d
	Lines f, g, h For Gaseous Fuels	e
	Wt fuel unit = sum(moles each x mol. wt) lb	f
	Mol. wt of fuel = line f/100	g
	Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft	h
	Fuel Heat Value 12,809 Btu/lb /cu ft	i
	Combustible in refuse, % "C" 1.89 %	j
	Carbon unburned, lb/100 lb fuel = % ash in fuel x %"C"/(100-%"C") 0.1 %	k
	Exit temp of fuel gas, t2 290 F	l
	Dry-bulb (ambient) temp, t'1 80 F	m
	Wet-bulb temp F	n
	Rel humid. (psychrometric chart) 60 %	o
	B*, barometric pressure, in. Hg 30.00	p
	Sat. press. H2O at amb temp, in. Hg 1.032	q
	A*, press. H2O in air, lines (o x q), in. Hg 0.619	r
	Total Moles: Wet Flue Gas 45.92; Dry Flue Gas 42.21	s

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

	Flue gas constituents	CO2 + SO2		O2	N2	H2O	CO	Total
22		9.48	10.07	7.14	6.97	8.12	6.99	
23	Mcp, mean, t2 to t'1	11,968	124	2,920	50,061		0	65,073
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)					1,552		1,552
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					4,757		4,757
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					52,250		52,250
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18							123,631
28	Total in wet flue gas							2,089
29	Due to carbon in refuse = line k x 14,100							0
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							125,720
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							1,280,900
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							9.81 %
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							

Combustion Calculations -- Molal Basis

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divesor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	Flue Gas (F.G.) Composition Moles per Fuel Unit (AF) CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	70.39	12	5.87	1	5.87	5.87				
2	C to CO	0.00	12	0.00	0.5	0.00					0.00
3	CO to CO2		28		0.5						
4	C unburned line k	0.14	12	0.01							
5	H2	4.84	2	2.42	0.5	1.21				2.42	
6	S	2.90	32	0.09	1	0.09	0.09				
7	O2 (deduct)	4.19	32	0.13	1	-0.13					
8	N2	1.38	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	5.90	18	0.33		0.00				0.33	
11	Ash	10.26				0.00					
12	Sum	100.00		8.90		7.04					
	O2 and Air, Moles for Total Air = 127.3 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					7.04					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					1.92		1.92			
15	O2 (total) supplied = lines 13 + 14					8.96					
16	N2 supplied = 3.76 x O2, line 15					33.72			33.72		
17	Air (dry) supplied = O2 + N2					42.68					
18	H2O in air = moles dry air x A/(B - A)*					0.90				0.90	
19	Air (wet) supplied = lines 17 + 18					43.58					
20	Flue gas constituents = lines 1 to 18, total						5.96	1.92	33.77	3.65	0.00

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

	Flue gas constituents	CO2 + SO2		O2	N2	H2O	CO	Total
22		9.48	10.07	7.14	6.97	8.12	6.99	
23	Mcp, mean, t2 to t'1	11,791	193	2,913	49,921		0	64,818
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)					1,548		1,548
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					4,728		4,728
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					51,438		51,438
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18							122,532
28	Total in wet flue gas							2,009
29	Due to carbon in refuse = line k x 14,100							0
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							124,542
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							1,262,900
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							9.86 %
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							

Conditions -- Assigned or Observed and Miscellaneous

Date 11/07/96 **Milliken Unit 2 with Heat Pipe**

Fuel Bituminous Coal
Source

Fuel Unit 100 lbs

Fuel Anal.as Fired (AF), % by Wt or Vol

C	70.5
H2	4.8
S	2.9
O2	4.2
N2	1.4
H2O	5.9
Ash	10.3
	100.0

Moles C/100 lb fuel

C in fuel	5.88
C in refuse	0.01
C in CO2+CO	5.87
C in CO2	5.87
C in CO	0.00

CO2 14.3 O2 4.6 CO 0 N2 81.14

LINE			
a			
b			
c			
d	Total air (T.A.) assigned or by ORSAT	127.3	%
e	Lines f, g, h For Gaseous Fuels		
f	Wt fuel unit = sum(moles each x mol. wt) lb		
g	Mol. wt of fuel = line f/100		
h	Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft		
i	Fuel Heat Value 12,629 Btu/lb /cu ft		
j	Combustible in refuse, % "C"	1.37	%
	Carbon unburned, lb/100 lb fuel		
k	= % ash in fuel x %"C"/(100-%"C")	0.1	%
l	Exit temp of fuel gas, t2	292	F
m	Dry-bulb (ambient) temp, t'1	80	F
n	Wet-bulb temp		F
o	Rel humid. (psychrometric chart)	60	%
p	B*, barometric pressure, in. Hg	30.00	
q	Sat. press. H2O at amb temp, in. Hg	1.032	
r	A*, press. H2O in air, lines (o x q), in. Hg	0.619	
s	Total Moles: Wet Flue Gas 45.30; Dry Flue Gas 41.65		

Combustion Calculations -- Molal Basis

Conditions -- Assigned or Observed and Miscellaneous

Date 11/08/96 **Milliken Unit 2 with Heat Pipe**

Fuel Bituminous Coal

Source

Fuel Unit 100 lbs

LINE	Fuel Constituent	Per Fuel Unit, lb	Mol. Wt Divisor	Moles Fuel Constituent	O2 Multiplier	O2 Moles Theo Reqd	Flue Gas (F.G.) Composition Moles per Fuel Unit (AF) CO2 + SO2	O2	N2	H2O	CO
1	C to CO2	68.99	12	5.75	1	5.75	5.75				0.00
2	C to CO	0.00	12	0.00	0.5	0.00					
3	CO to CO2		28		0.5						
4	C unburned line k	0.34	12	0.03							
5	H2	4.69	2	2.35	0.5	1.17				2.35	
6	S	2.81	32	0.09	1	0.09	0.09				
7	O2 (deduct)	3.92	32	0.12	1	-0.12					
8	N2	1.34	28	0.05		0.00			0.05		
9	CO2		44			0.00					
10	H2O	7.58	18	0.42		0.00				0.42	
11	Ash	10.33				0.00					
12	Sum	100.00		8.80		6.89					
	O2 and Air, Moles for Total Air = 130 % (see Line d at right)										
13	O2 (theo) reqd = O2, line 12					6.89					
14	O2 (excess) = (T.A. - 100)/100 x O2, line 12					2.06		2.06			
15	O2 (total) supplied = lines 13 + 14					8.95					
16	N2 supplied = 3.76 x O2, line 15					33.69			33.69		
17	Air (dry) supplied = O2 + N2					42.64					
18	H2O in air = moles dry air x A/(B - A)*					0.90				0.90	
19	Air (wet) supplied = lines 17 + 18					43.54					
20	Flue gas constituents = lines 1 to 18, total						5.84	2.06	33.74	3.66	0.00

LINE		
a	Fuel Analysis Fired (AF), % by Wt or Vol	
b	C 69.3 / H2 4.7 / S 2.8 / O2 3.9 / N2 1.3 / H2O 7.6 / Ash 10.3 / 100.0	Moles C/100 lb fuel: C in fuel 5.78; C in refuse 0.03; C in CO2+CO 5.75; C in CO2 5.75; C in CO 0.00
c	CO2 14 O2 4.935 CO 0 N2 81.09	
d	Total air (T.A.) assigned or by ORSAT	130 %
e	Lines f, g, h For Gaseous Fuels	
f	Wt fuel unit = sum(moles each x mol. wt) lb	
g	Mol. wt of fuel = line f/100	
h	Density of fuel @ 80 F & 30in. = line g/394 lb/cu ft	
i	Fuel Heat Value	12,306 Btu/lb /cu ft
j	Combustible in refuse, % "C"	3.19 %
k	Carbon unburned, lb/100 lb fuel = % ash in fuel x %"C"/(100-%"C")	0.3 %
l	Exit temp of fuel gas, t2	280.5 F
m	Dry-bulb (ambient) temp, t'1	80 F
n	Wet-bulb temp	F
o	Rel humid. (psychrometric chart)	60 %
p	B*, barometric pressure, in. Hg	30.00
q	Sat. press. H2O at amb temp, in. Hg	1.032
r	A*, press. H2O in air, lines (o x q), in. Hg	0.619
s	Total Moles	Wet Flue Gas 45.30 / Dry Flue Gas 41.64

21 *Note -- for air at 80 F and 60% relative humidity, A/(B - A) = 0.0212 is often used as standard.

Determination of Flue Gas and Combustible Losses in Btu per Fuel Unit (AF)

		CO2 + SO2		O2	N2	H2O	CO	Total
22	Flue gas constituents	9.46	10.05	7.13	6.97	8.11	6.99	
23	Mcp, mean, t2 to t'1	10,901	177	2,951	47,135		0	61,164
24	In dry flue gas = moles each, line 20 x Mcp x (t2 - t'1)					1,461		1,461
25	In H2O in air = moles H2O, line 18 x Mcp x (t2 - t'1)					4,497		4,497
26	In sens heat, H2O in fuel = moles, lines (5 + 10) x Mcp x (t2 - t'1)					51,782		51,782
27	In latent heat, H2O in fuel = moles, lines (5 + 10) x 1040 x 18							118,904
28	Total in wet flue gas							4,799
29	Due to carbon in refuse = line k x 14,100							0
30	Due to unburned CO in flue gas = moles C to CO x 12 x 9,755							123,703
31	Total flue gas losses + unburned combustible = lines 28 + 29 + 30							1,230,600
32	Heat value of fuel unit = 100 x line i for solid and liquid fuels							10.05 %
33	Stack and combustible loss, % of heat input = 100 x line 31/line 32							