Virginia City Hybrid Energy Center
Response to Data Request
Bruce Buckheit, Member, Virginia Air Pollution Control Board

Question (Page No. 11):

For SO_2 control – evaluate CFB and SDA performance capability (see below) to determine whether it is consistent with "best achievable levels" and the extent to which the device meets removal levels achieved elsewhere, document performance level that can be expected to be achieved.

Response:

The emission limits for the VCHEC facility have been set to assure the lowest overall impact on the environment. Changes to any one of the limits for SO_2, CO, NO_X and VOC will affect the others. ***Over controlling any one emission will have the effect of increasing others.***

With respect to SO_2, Figure 1 shows percent sulfur capture versus corresponding limestone flow for two representative fuel sulfur contents over a range with an upper limit of 2.28 percent. Changes in limestone flow affect other operating variables such as boiler efficiency and uncontrolled NO_X. Figure 2 shows the performance of the scrubber as a function of hydrated lime consumption and outlet SO_2 concentration. The range of CFB boiler sulfur capture is from 80% to 92% based the scrubber planned for this project. Cost effective total SO_2 control points to a range of 80% to 92% capture in the boiler and the remaining capture in the scrubber. Figure 3 shows that boiler efficiency increases with fuel sulfur content and decreases with increases SO_2 control efficiency. Some CFB boilers have operated at a higher sulfur capture on a short term basis. In such cases the uncontrolled NO_X (Figure 4) and hence the ammonia slip increased significantly.

During startup, the limestone in the boiler bed will not have been calcined and thus the calcium will not be available to react with the sulfur, thus removal rates will be very low until enough heat has been developed to start the reaction. The dry FGD will also not be functioning until the exit temperature of the boiler is high enough to evaporate the lime slurry that is injected. The proposed 24-hour SO_2 limit of 0.12 lbs./MMBtu (375.84 lbs/hour) does not exclude startup. The inclusion of startup periods puts severe constraints on the operation of to CFB boiler. The attached spreadsheet (Attachment 1) shows the expected startup fuel and emission requirements necessary to meet the current 24-hour average SO_2 limit. Any lower SO_2 24-hour emission limit, without excluding startup, will likely not be met. Note that in order to meet current limits; the facility was modified to burn more oil for a longer period. Modifications included larger burners, a higher capacity fuel oil system, and larger tanks.

Figure 4 shows that the uncontrolled NO_X emission rate increases with increasing SO_2 control (limestone injection). Figure 5 shows the impact of ammonia injection on NO_X emissions starting with the uncontrolled value and ending at the point where ammonia slip exceeds 10 ppm. Ammonia slip of 10 ppm is the operational limit for the power generation system required to avoid reduced performance and damage to system components.

Examples of other operating factors that affect NO_X and other emissions from the CFB boiler include the following:

1. Fuel volatile content: The uncontrolled NO_x emission level correlates well with fuel volatile content. The variation of uncontrolled NO_x with fuel volatile content is shown below.

Volatile Content (%, **as fired**)	Uncontrolled NO_x (lb/MMBtu)
17.0	0.132
19.6	0.145
22.1	0.157

2. Excess air level: The uncontrolled NO_x level increases with the excess air level. The variation of uncontrolled NO_x with excess air level is shown below.

Excess Air (%)	Uncontrolled NO_x (lb/MMBtu)
15.0	0.135
20.0	0.145
25.0	0.155

Note that the choice of the design excess air, 20 percent, minimizes uncontrolled NO_x formation to the extent possible while ensuring efficient fuel combustion, low CO and VOC emissions and efficient sulfur capture. Reducing the excess air level below 20 percent would result in inefficient fuel combustion and sulfur capture and would result in higher CO and VOC emissions.

3. Air staging: The uncontrolled NO_x emission level decreases as the extent of combustion air staging is increased, i.e. as the amount of secondary air is increased and the amount of primary air is decreased. The variation of uncontrolled NO_x with air staging is shown below.

% Primary Air (%)	Uncontrolled NO_x (lb/MMBtu)
45.0	0.120
50.0	0.145
55.0	0.170

Note that the choice of the design air staging level, 50% percent primary air, minimizes NO_x formation while ensuring efficient fuel combustion, low CO and VOC emissions and efficient sulfur capture. Reducing the primary air level below 50 percent would result in inefficient fuel combustion and sulfur capture and would result in higher CO and VOC emissions.

4. Furnace temperature: The uncontrolled NO_x emission level increases with furnace temperature. The variation of uncontrolled NO_x with furnace temperature is shown below.

Furnace Temperature (°F)	Uncontrolled NO_x (lb/MMBtu)
1625	0.135
1650	0.145
1675	0.155

Note that the choice of the design furnace temperature, 1650 °F, minimizes NO_x formation while ensuring efficient fuel combustion and low CO and VOC emissions. The selected design furnace temperature also ensures a sufficiently high gas temperature, necessary for the effectiveness of the selective non-catalytic NO_x reduction technology used for NO_x emission control. Reducing the furnace temperature would result in inefficient fuel combustion and higher CO and VOC emissions and would compromise the ability of the SNCR system to control the NO_x emission level across the operating load range of the boiler.

5. Sulfur capture level: The uncontrolled NO_x emission level increases as the rate of limestone feed to the furnace (for sulfur capture) is increased. The variation of uncontrolled NO_x with sulfur retention is shown below.

Sulfur Capture (%)	Uncontrolled NO_x (lb/MMBtu)
80.0	0.138
85.0	0.145
90.0	0.160

The choice of the design furnace sulfur retention level, 85 percent, is driven by a desire to minimize NO_x emissions while ensuring efficient limestone and hydrated lime use (used for sulfur capture in the furnace and scrubber respectively). Deviating from the design furnace sulfur retention level could result in excessive sorbent use and ash generation.

6. Boiler load: The uncontrolled NO_x emission level decreases as load is reduced down to approximately 60% load, aided by the decrease in furnace temperature (see 4 above). As load is further reduced below 60%, the uncontrolled NO_x emission level increases with decreasing load due to the increase in the excess air level below 60% load (see 2 above). The variation of uncontrolled NO_x with boiler load is shown below:

Boiler Load (% MCR)	Uncontrolled NO_x (lb/MMBtu)
100.0	0.145
70.0	0.130
60.0	0.125
50.0	0.130

The industry experience with CFB boilers has shown that the SNCR NO_X reduction process has an optimum operation temperature range. As the boiler load is reduced the reaction temperature decreases to levels outside the optimum range for NO_X emission control. The NO_X emissions at part load are higher due to lower SNCR control efficiencies. Because NO_X is already high, more limestone injection increases

uncontrolled NO_X which exacerbates NO_X emissions. Therefore, the ability to control SO_2 emissions at part load is limited due to the NO_X limit.

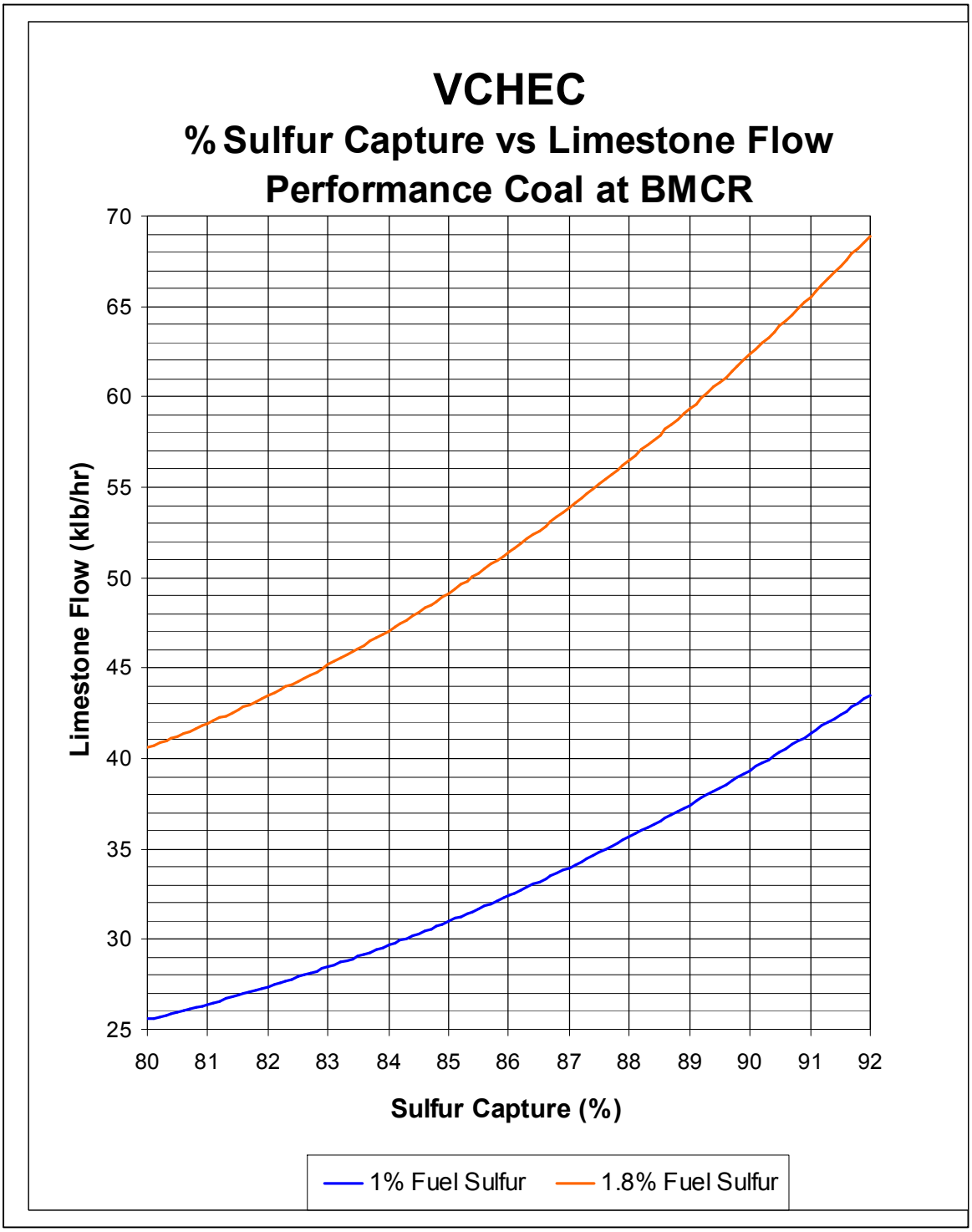
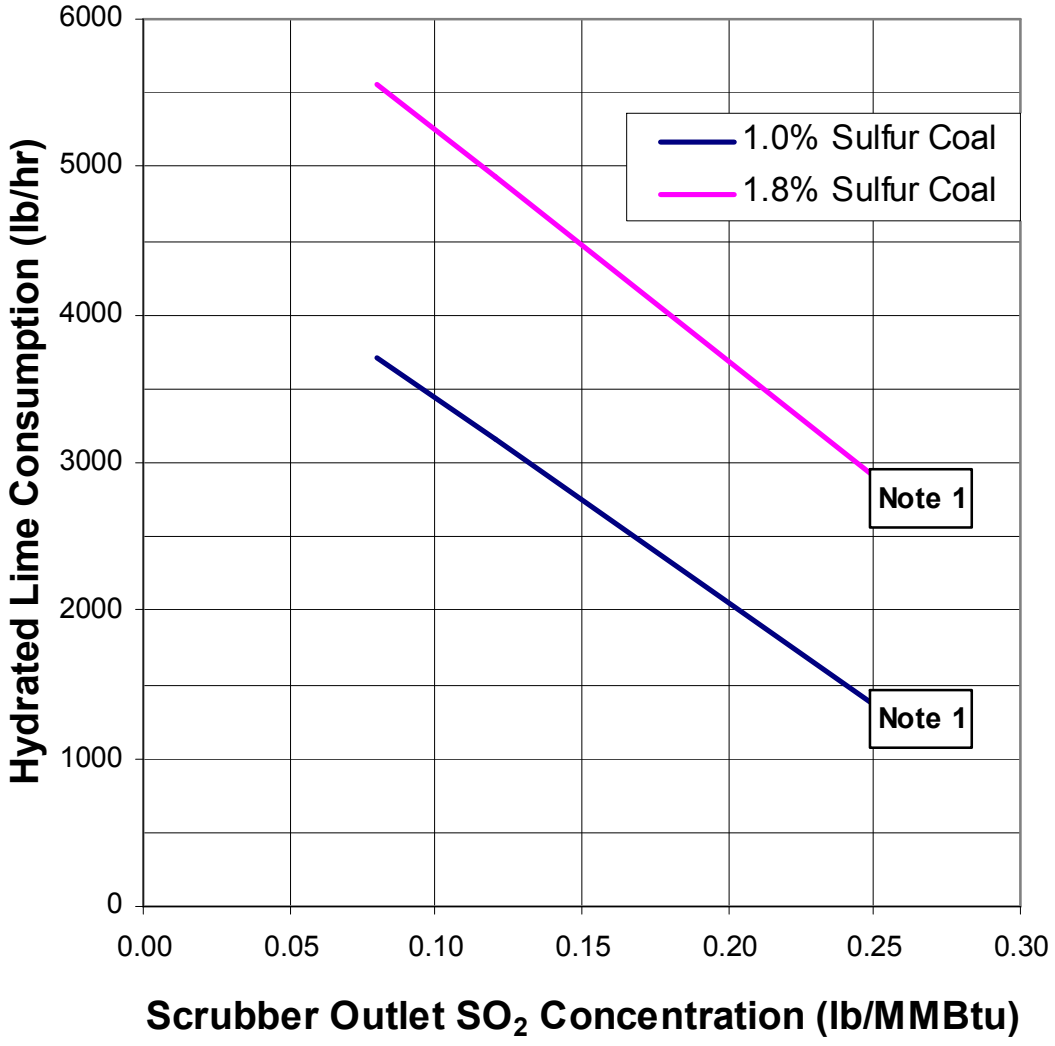

VCHEC
% Sulfur Capture vs Limestone Flow
Performance Coal at BMCR
Limestone Flow (klb/hr)
70
65
60
55
50
45
40
35
30
25
80
81
82
83
84
85
86
87
88
89
90
91
92
Sulfur Capture (%)
1% Fuel Sulfur
1.8% Fuel Sulfur

Figure 1

Figure 2 VCHEC
Scrubber Hydrated Lime Consumption vs. Outlet SO_2 Concentration and Fuel Sulfur Content at 85% Boiler Sulfur Removal



Note 1: When controlling the scrubber outlet SO2 to 0.25 lb/MMBtu, the scrubber outlet HCl and HF emissions will exceed the guaranteed values.

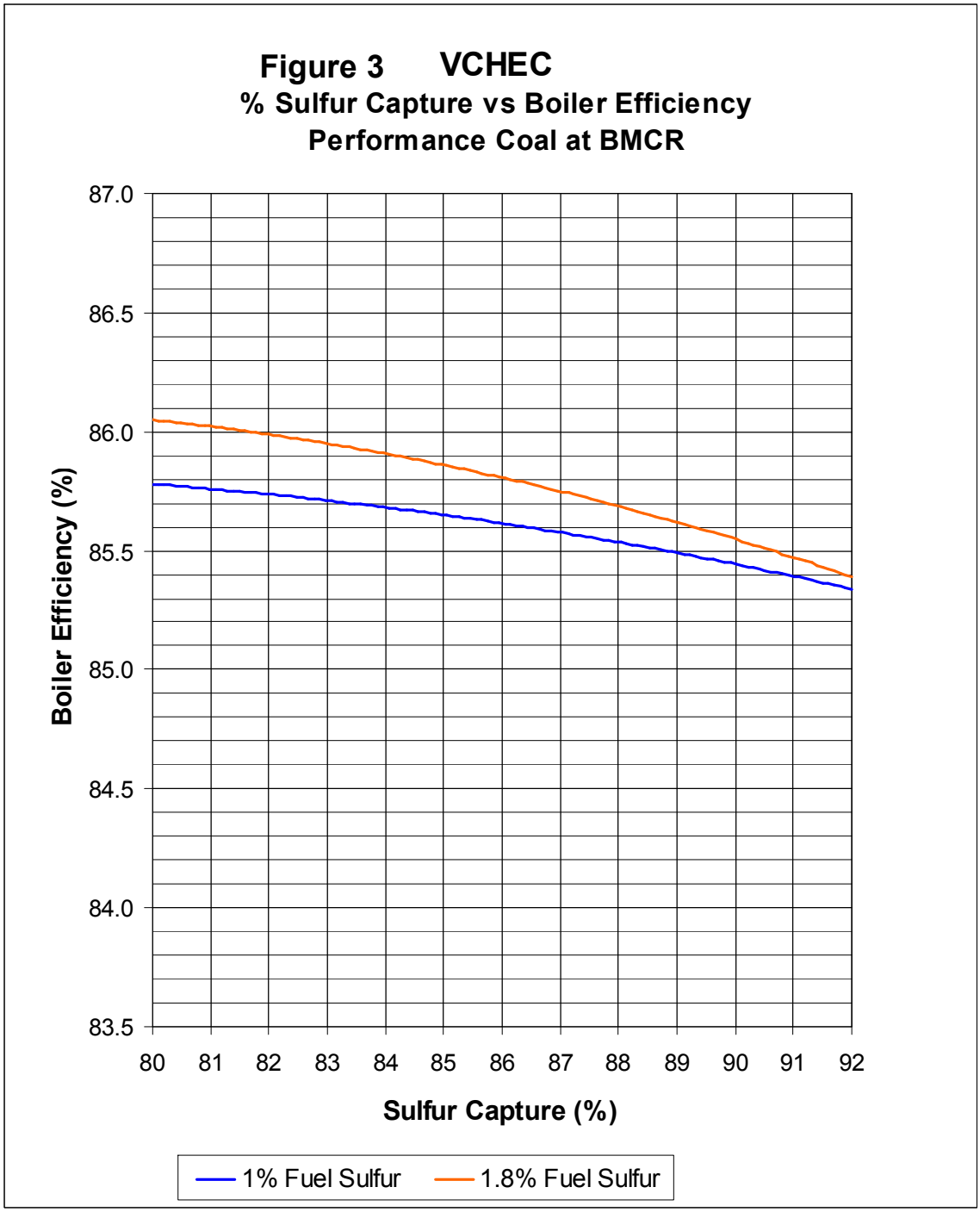


Figure 3 VCHEC
% Sulfur Capture vs Boiler Efficiency
Performance Coal at BMCR
Boiler Efficiency (%)
87.0
86.5
86.0
85.5
85.0
84.5
84.0
83.5
80
81
82
83
84
85
86
87
88
89
90
91
92
Sulfur Capture (%)
1% Fuel Sulfur
1.8% Fuel Sulfur

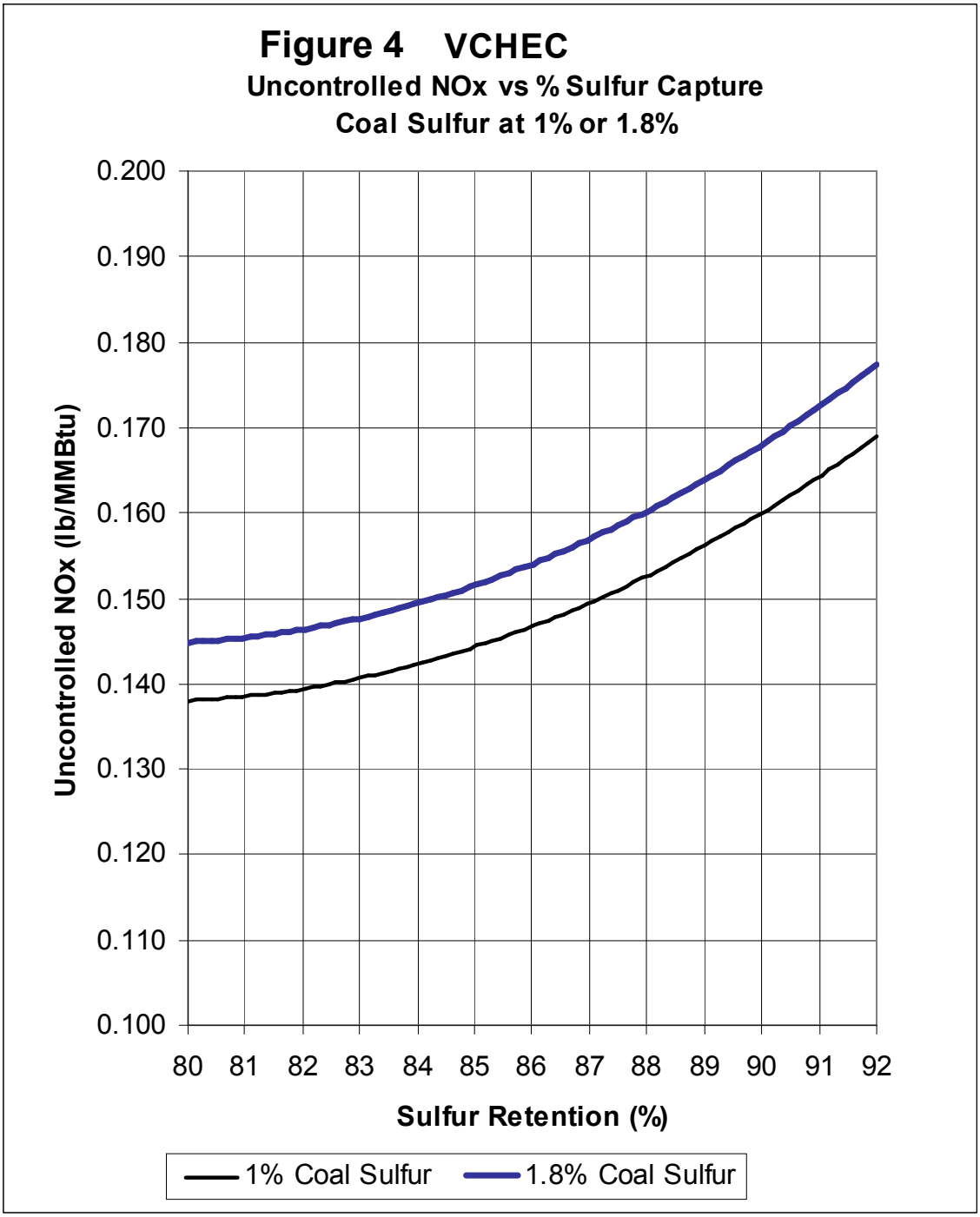


Figure 4 VCHEC
Uncontrolled NOx vs % Sulfur Capture
Coal Sulfur at 1% or 1.8%
Uncontrolled NOx (lb/MMBtu)
0.200
0.190
0.180
0.170
0.160
0.150
0.140
0.130
0.120
0.110
0.100
80 81 82 83 84 85 86 87 88 89 90 91 92
Sulfur Retention (%)
1% Coal Sulfur
1.8% Coal Sulfur

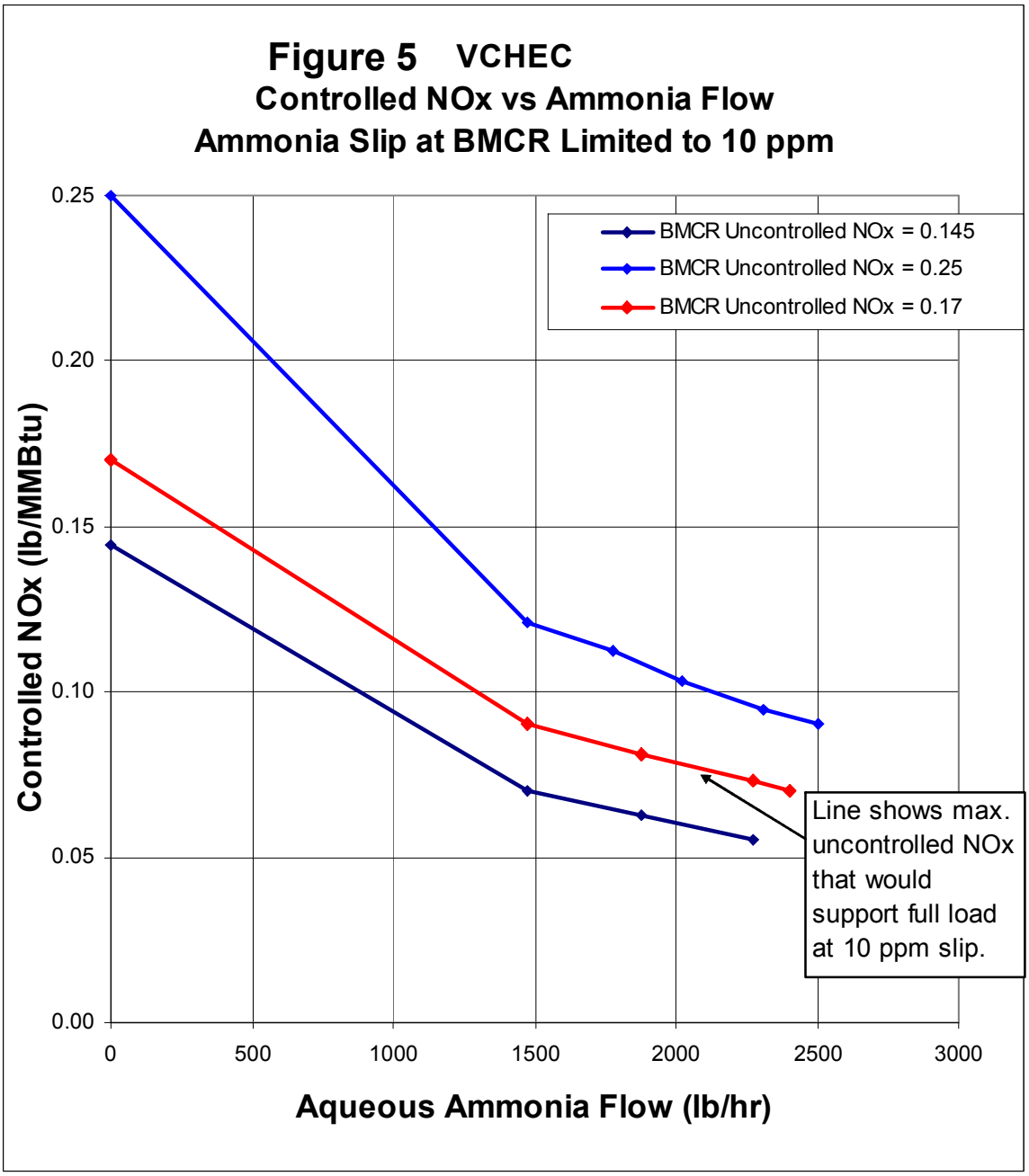


Figure 5 VCHEC
Controlled NOx vs Ammonia Flow
Ammonia Slip at BMCR Limited to 10 ppm
BMCR Uncontrolled NOx = 0.145
BMCR Uncontrolled NOx = 0.25
BMCR Uncontrolled NOx = 0.17
Controlled NOx (lb/MMBtu)
0.25
0.20
0.15
0.10
0.05
0.00
0
500
1000
1500
2000
2500
3000
Aqueous Ammonia Flow (lb/hr)
Line shows max. uncontrolled NOx that would support full load at 10 ppm slip.

ATTACHMENT 1

Predicted Start Up Emissions for ominion (orst Coal)

Boiler MCR Heat nput Worst Coal	MMBtu/hr	3041
Start Up Burner Capacit	% MCR	40.0
Start Up Burner Capacit	MMBtu/hr	1216
Start Up Burner urn own		4:1
Start Up Fuel		2
Start Up Fuel Sulfur Content	%	0.00
Start Up Fuel Heating alue	Btu/lb	19170
Start Up Fuel Uncontrolled SO2	lb/MMBtu	0.0000
Solid Fuel Sulfur Content	%	1.80
Solid Fuel Heating alue	Btu/lb	6794
Solid Fuel Uncontrolled SO2	lb/MMBtu	5.2988

Cold Start (Using Sand for Start Up)

ime	Start Up Fuel	Solid Fuel	otal	Load	Cumulative Heat	Bed emp	Uncontrolled SO2	Boiler Sulfur Retention	Scrubber Sulfur Retention	Sulfur ioxide	Sulfur ioxide	Cumulative Sulfur ioxide	Rolling verage Sulfur ioxide	NOx	NOx	CO	CO	OC	OC	M10 articulat e	M10 articulat e	Flue as Flow	Flue as Flow	Flue as emperature
Hr	MMBtu/hr	MMBtu/hr	MMBtu/hr	MCR Heat nput		F	lb/MMBtu	%	%	lb/MMBtu	lb/hr	lb	lb/MMBtu	lb/MMBtu	lb/hr	lb/MMBtu	lb/hr	lb/MMBtu	lb/hr	lb/MMBtu	lb/hr	lb/hr	% of full load	F
1.0	912	0	912	30.0	912.3	300	0.00	0.00	0.00	0.000	0	0	0.00	0.20	182	0.90	821	0.035	32	0.01	9.1	2155502	68	150
2.0	1186	0	1186	39.0	2098.2	409	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.52	617	0.020	24	0.01	11.9	2349207	74	160
3.0	1186	0	1186	39.0	3284.2	518	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.45	534	0.017	21	0.01	11.9	2349207	74	170
4.0	1186	0	1186	39.0	4470.2	627	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.42	498	0.016	19	0.01	11.9	2349207	74	179
5.0	1186	0	1186	39.0	5656.1	736	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.40	474	0.015	18	0.01	11.9	2349207	74	189
6.0	1186	0	1186	39.0	6842.1	844	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.39	463	0.015	18	0.01	11.9	2349207	74	199
7.0	1186	0	1186	39.0	8028.0	953	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.38	451	0.015	17	0.01	11.9	2349207	74	209
8.0	1186	0	1186	39.0	9214.0	1062	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.37	439	0.014	17	0.01	11.9	2349207	74	219
9.0	1186	0	1186	39.0	10400.0	1171	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.36	427	0.014	16	0.01	11.9	2349207	74	228
10.0	1186	0	1186	39.0	11585.9	1280	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.35	415	0.013	16	0.01	11.9	2349207	74	238
11.0	1186	0	1186	39.0	12771.9	1290	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.35	415	0.013	16	0.01	11.9	2349207	74	239
12.0	1186	0	1186	39.0	13957.9	1300	0.00	0.00	0.00	0.000	0	0	0.00	0.20	237	0.35	415	0.013	16	0.01	11.9	2349207	74	240
13.0	1186	152	1338	44.0	15295.9	1350	0.60	50.00	50.18	0.150	201	201	0.01	0.26	348	0.60	803	0.023	31	0.01	13.4	2359469	74	165
14.0	1216	304	1520	50.0	16816.3	1400	1.06	70.00	52.82	0.150	228	429	0.03	0.25	380	0.45	684	0.017	26	0.01	15.2	2391254	75	165
15.0	912	608	1520	50.0	18336.8	1425	2.12	77.00	69.23	0.150	228	657	0.04	0.24	365	0.40	608	0.015	23	0.01	15.2	2196549	69	165
16.0	608	912	1520	50.0	19857.2	1450	3.18	85.00	68.55	0.150	228	885	0.04	0.23	350	0.35	532	0.013	20	0.01	15.2	2001845	63	165
17.0	304	1216	1520	50.0	21377.7	1475	4.24	85.00	76.41	0.150	228	1113	0.05	0.21	319	0.30	456	0.012	18	0.01	15.2	1905060	60	165
18.0	0	1520	1520	50.0	22898.2	1500	5.30	85.00	84.90	0.120	182	1295	0.06	0.15	228	0.25	380	0.010	15	0.01	15.2	1905060	60	165

Cold Start (U	
ime	Comments
Hr	
1.0	Start Up Burners On
2.0	
3.0	
4.0	
5.0	
6.0	
7.0	
8.0	
9.0	
10.0	
11.0	
12.0	Steam Coil ir Heater n Service if Necessar to Raise Boiler bove 240 F, Start Limestone Feed
13.0	Scrubber Online Coal Feed Starts Limestone is Marginall ffective for Sulfur Capture in the Furnace
14.0	
15.0	
16.0	
17.0	
18.0	Start Up Burner Off, mmonia n ection is On