COAL-BIOMASS COFIRING

PRACTICAL CONSIDERATIONS

Larry Felix
Southern Research Institute

DOE Cooperative Agreement No. DE-FC26-00NT40895

Southern Research Institute

Why Biomass Cofiring?

- Cofiring Helps to Reduce SO_2 and NO_X Emissions Legislatively Targeted for Reduction
- Renewable Energy may be Mandated at a percentage of a Utilities Energy Output
- U.S. Tax Advantages for the Production of Energy from Renewable Fuels
- Climate Protection – Global Warming

US Consensus

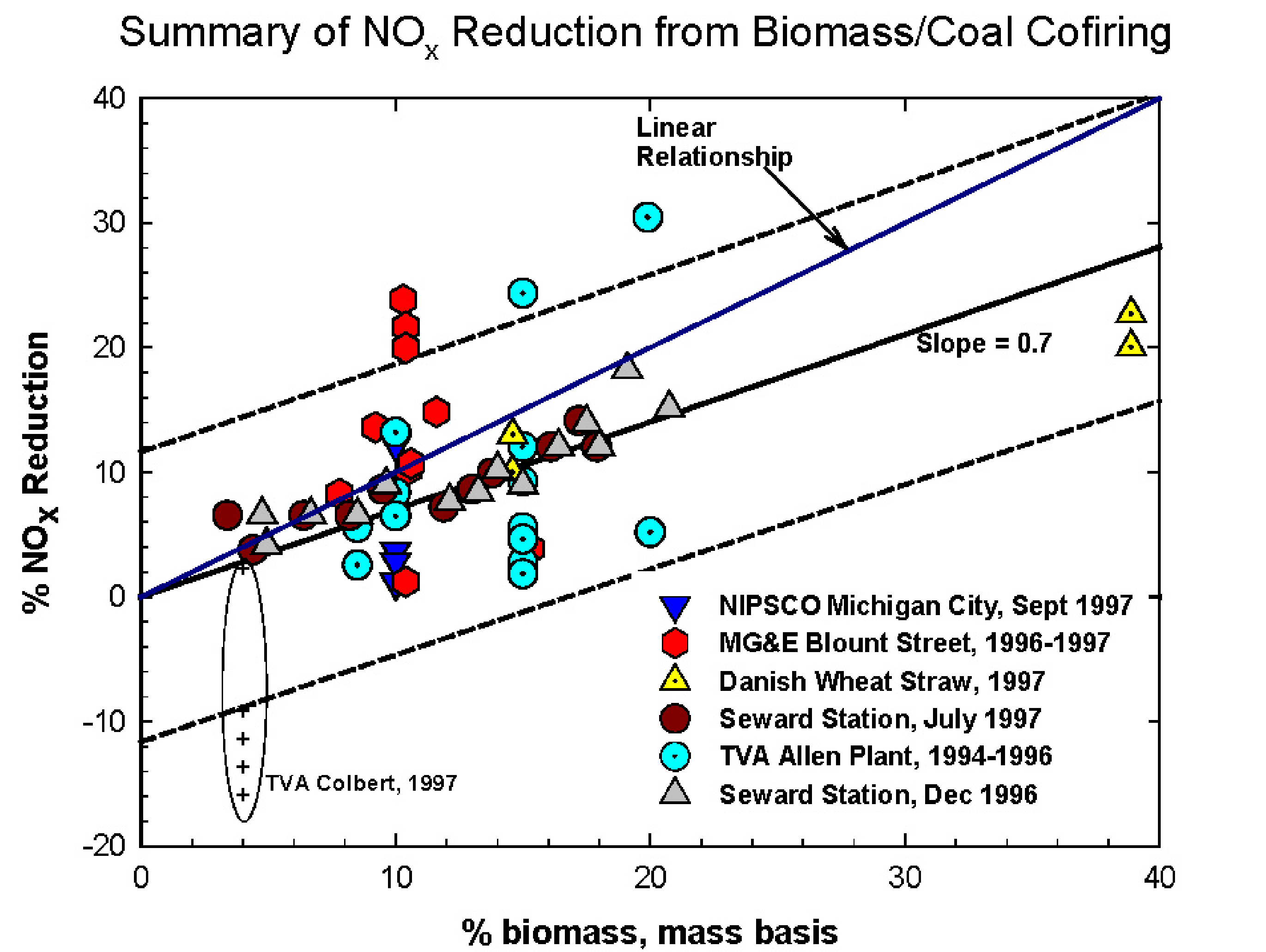
"The addition of biomass has been shown to reduce NO_X emissions in most commercial facilities, usually beyond the reductions expected because of a lower overall fuel-bound nitrogen content. The high volatiles content of biomass can effectively establish a fuel-rich zone early in the flame that can reduce NO_X emissions. Adding biomass can reduce flame temperatures, leading to lower levels of thermal NO_X. The high moisture content of some biomass may also be effective for NO_X reduction at full-scale."[1]

[1] Dayton, David, *A Summary of NO_X Emissions Reduction from Biomass Cofiring*, DOE Contract DE-AC36-99-GO10337, NREL/TP-510-32260, National Renewable Energy Laboratory, Golden CO, May, 2002, p.3

Full-Scale Experience in the US

Plant	Biomass	%	NO_X Result	Reference
Hammond	Wood	13	No effect	Boylan, et al., 1992
Kraft	Wood	0-30	Reduced > fuel N	Boylan, et al., 1994
Greenidge Station	Dry wood	10	No effect	Prinzing et al, 1996
Greenidge Station	Wet wood	10	Reduced	Prinzing et al, 1996
Madison Gas & Electric	Switchgrass	14	No to slight effect	Ragland et al, 1996
Allen Fossil Plant	Wood	0-20	Reduced > fuel N	Tillman et al, 1996
Sandia Pilot	Wood, switchgrass	0-66	Reduced ∝ to fuel N	Baxter and Robinson, 1999
Seward, Allen, Michigan City	Wood	0-20	Reduced < fuel N on average	Tillman, Plasynski, and Hughes, 1999
Gadsden	Switchgrass	10	No effect	Boylan, 2001
Colbert	Wood	1-5	Up to 16% Increase	Dayton, 2002

US Results – Mass Basis (Dayton – NREL, May 2002)

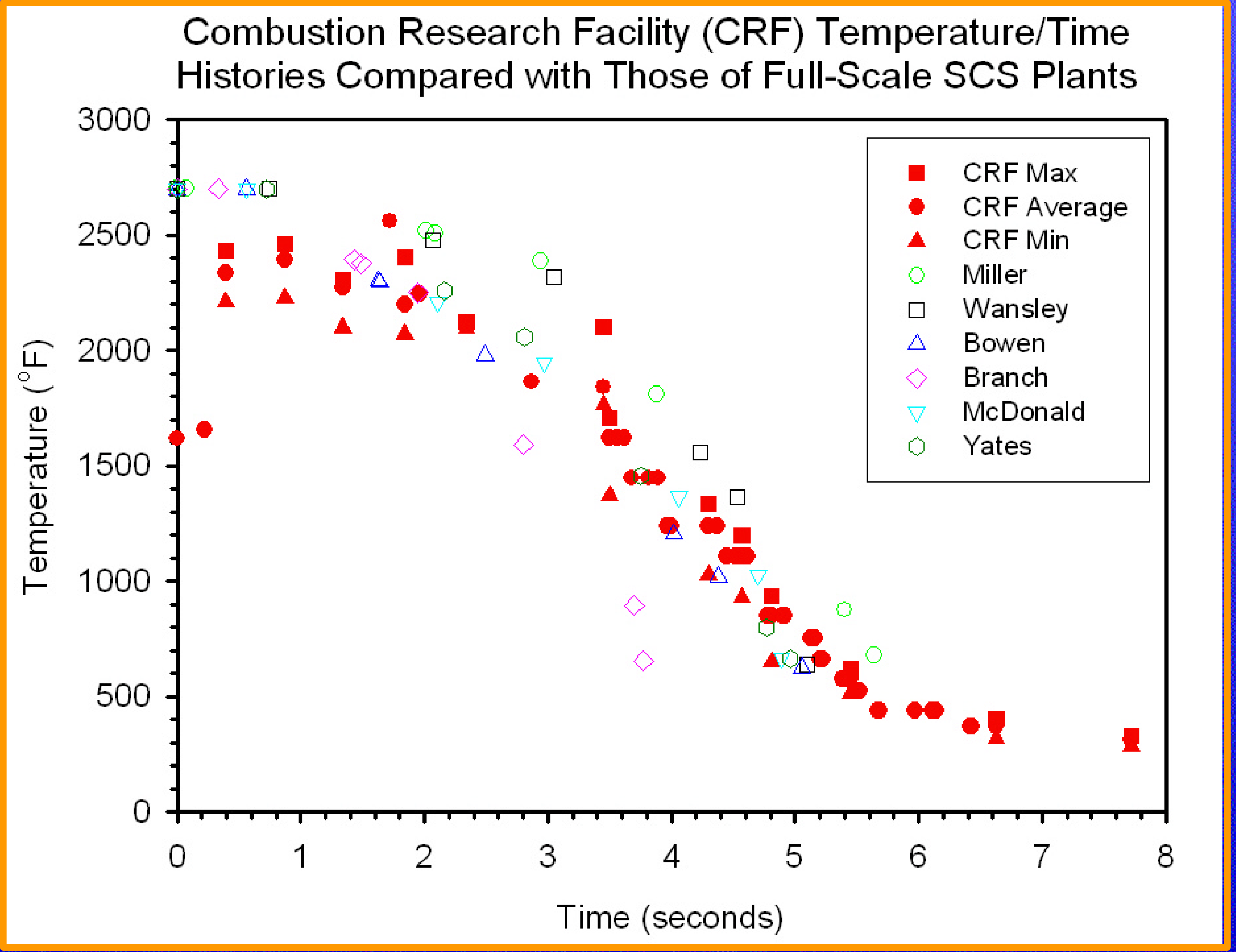


A summary of NOx reduction from a number of biomass/coal cofiring full-scale and pilot-scale demonstration tests, based on the mass input of biomass. Dashed lines are 95% prediction limits that encompass the range of variability in the measured data.

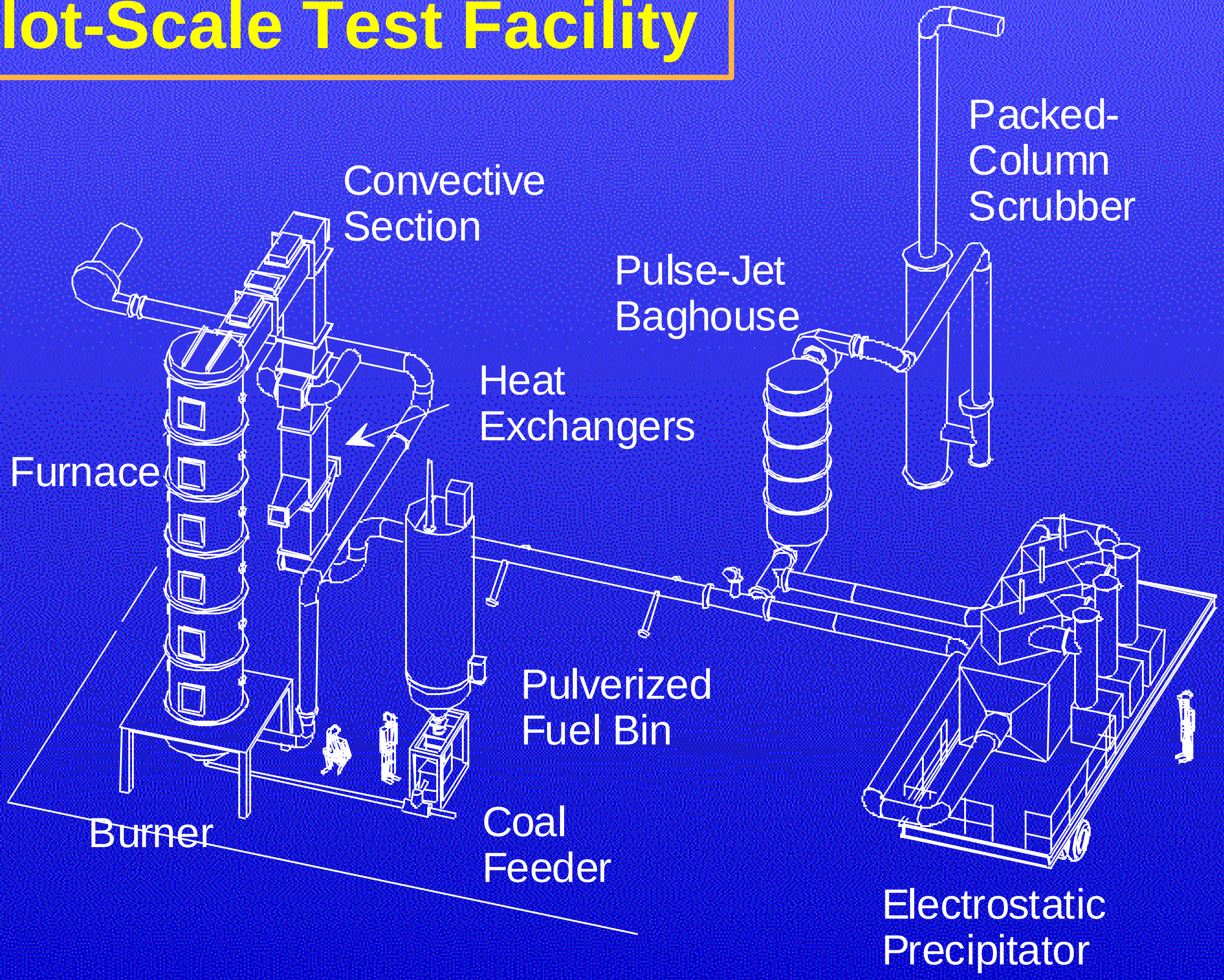
At the Pilot Scale

Combustion Research Facility

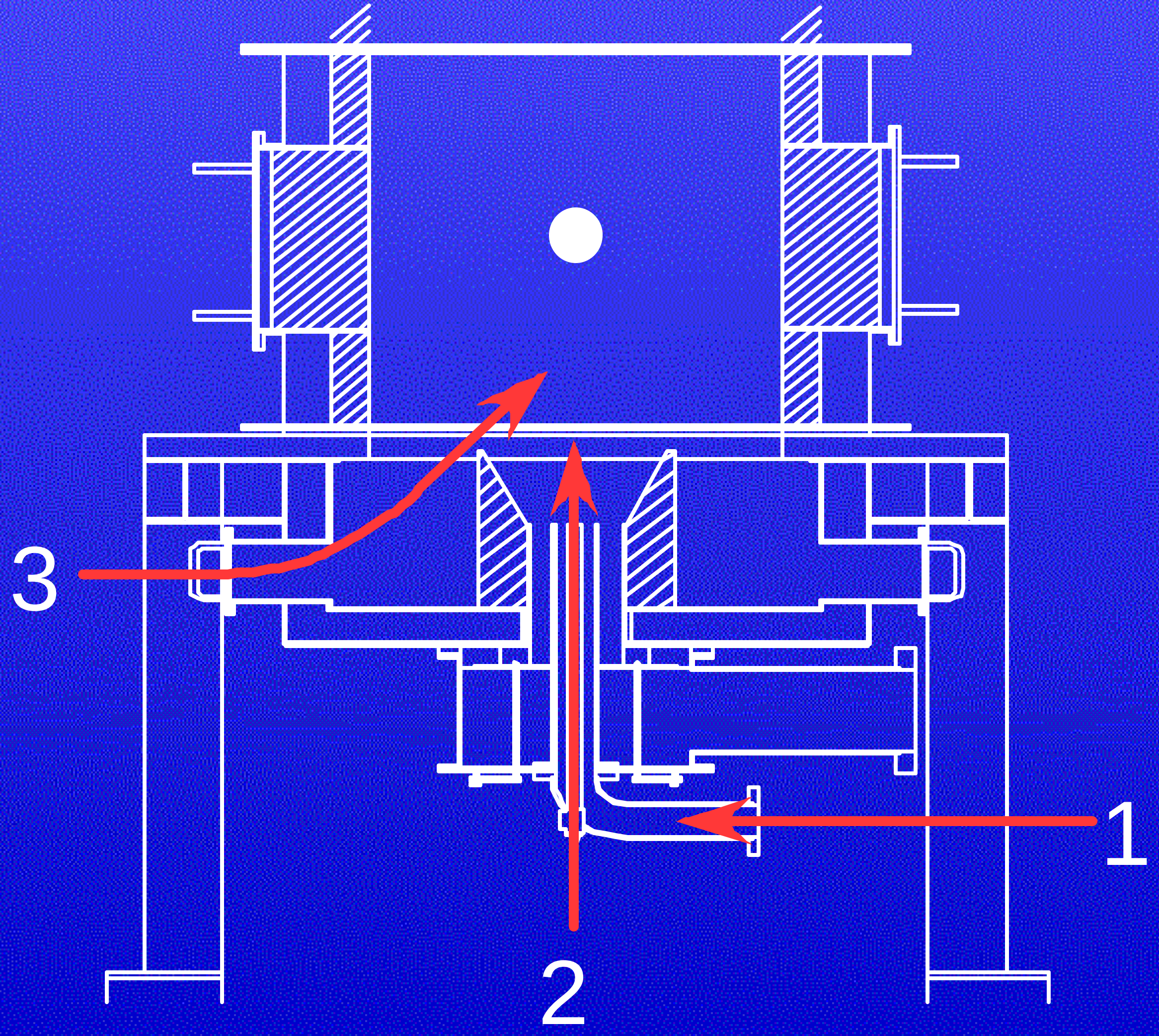
- All testing conducted at the SRI/SCS 6.0 MMBtu/hr Combustion Research Facility (at 3.5 MMBtu/hr)
- Continuous measurement and logging of ~ 200 pertinent process parameters
- In-situ testing for mass emissions, particle size, char, pyrometry, ash resistivity, gases (O_2 at furnace exit and at CEM location, CO, CO_2, SO_2, NO_X, NH_3, H_2O, HCl).
- On-site wet chemical flue gas and ash analyses, CHN (for carbon in ash), fuel heat value measurement
- Instrumented CE-Raymond Model 352 Deep Bowl mill

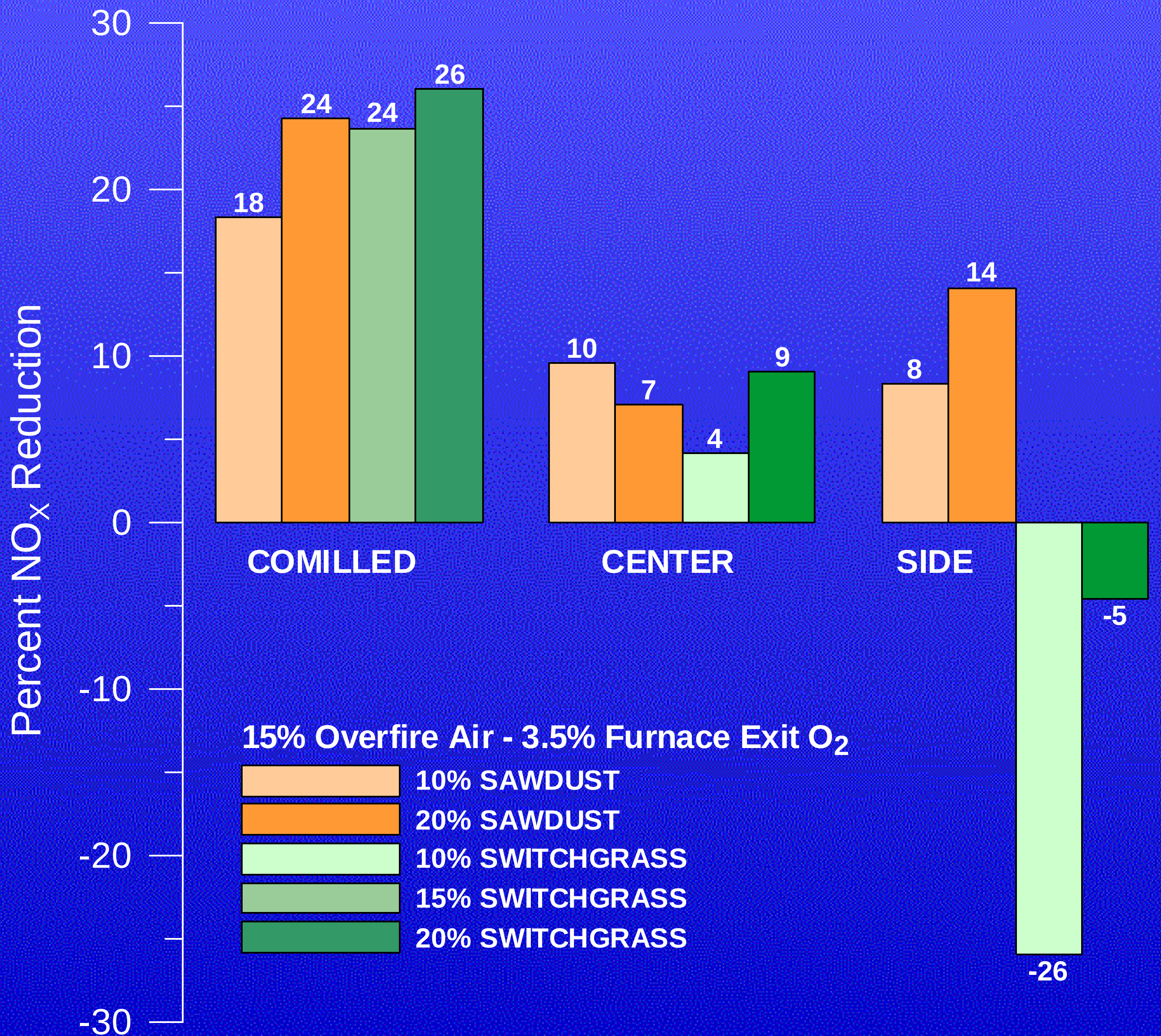

Combustion Research Facility (CRF) Temperature/Time Histories Compared with Those of Full-Scale SCS Plants
Temperature (^{o}F)
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
Time (seconds)
CRF Max
CRF Average
CRF Min
Miller
Wansley
Bowen
Branch
McDonald
Yates

Pilot-Scale Test Facility



Locations for Biomass Injection





Percent NOx Reduction
30
20
10
0
-10
-20
-30
18
24
24
26
10
7
4
9
8
14
-26
-5
COMILLED
CENTER
SIDE
15% Overfire Air - 3.5% Furnace Exit O2
10% SAWDUST
20% SAWDUST
10% SWITCHGRASS
15% SWITCHGRASS
20% SWITCHGRASS

Milling Coal and Biomass

SRI / SCS

CE-Raymond
Model 352
Deep Bowl Mill

Analyses of Fuels

ANALYSIS	COAL	BIOMASS	
PROXIMATE (As Received)	Eastern hv bit. Pratt Seam	Switchgrass Field Chopped	Sawdust Red Oak
MOISTURE, %	2.64	15.18	3.11
ASH, %	16.08	29.53	0.52
VOLATILE, %	33.14	47.69	82.45
FIXED CARBON, %	48.14	7.60	13.92
SULFUR, %	1.47	0.21	0.01
HEAT VALUE, Btu/lb	12760	5891	8017
ULTIMATE (Dry)			
CARBON, %	69.53	36.59	48.97
HYDROGEN, %	4.64	3.50	6.09
NITROGEN, %	1.60	1.59	0.15
SULFUR, %	1.51	0.25	0.01
ASH, %	16.52	34.82	0.54
OXYGEN, % (DIFF)	6.20	23.25	44.24
CHLORINE, %	0.01	0.10	0.01

MILLING COAL AND BIOMASS-1

MILLING RATES	UNIT	COAL Pratt Seam	SAWDUST 10%	 20%	SWITCHGRASS 15%	 20%
Net Coal Added to Bins	lb/h	1052.0	626.5	652.8	358.8	265.5
Coal Burned	lb/h	0.0	278.6	126.2	311.3	309.5
Fuel Heat Value	Btu/lb	12760	12323	12085	12089	11911
Mill Output	lb/hr	1052.0	905.1	779.0	670.0	574.9
Mill Rejects	lb/h	30.0	25.2	24.4	19.0	15.1

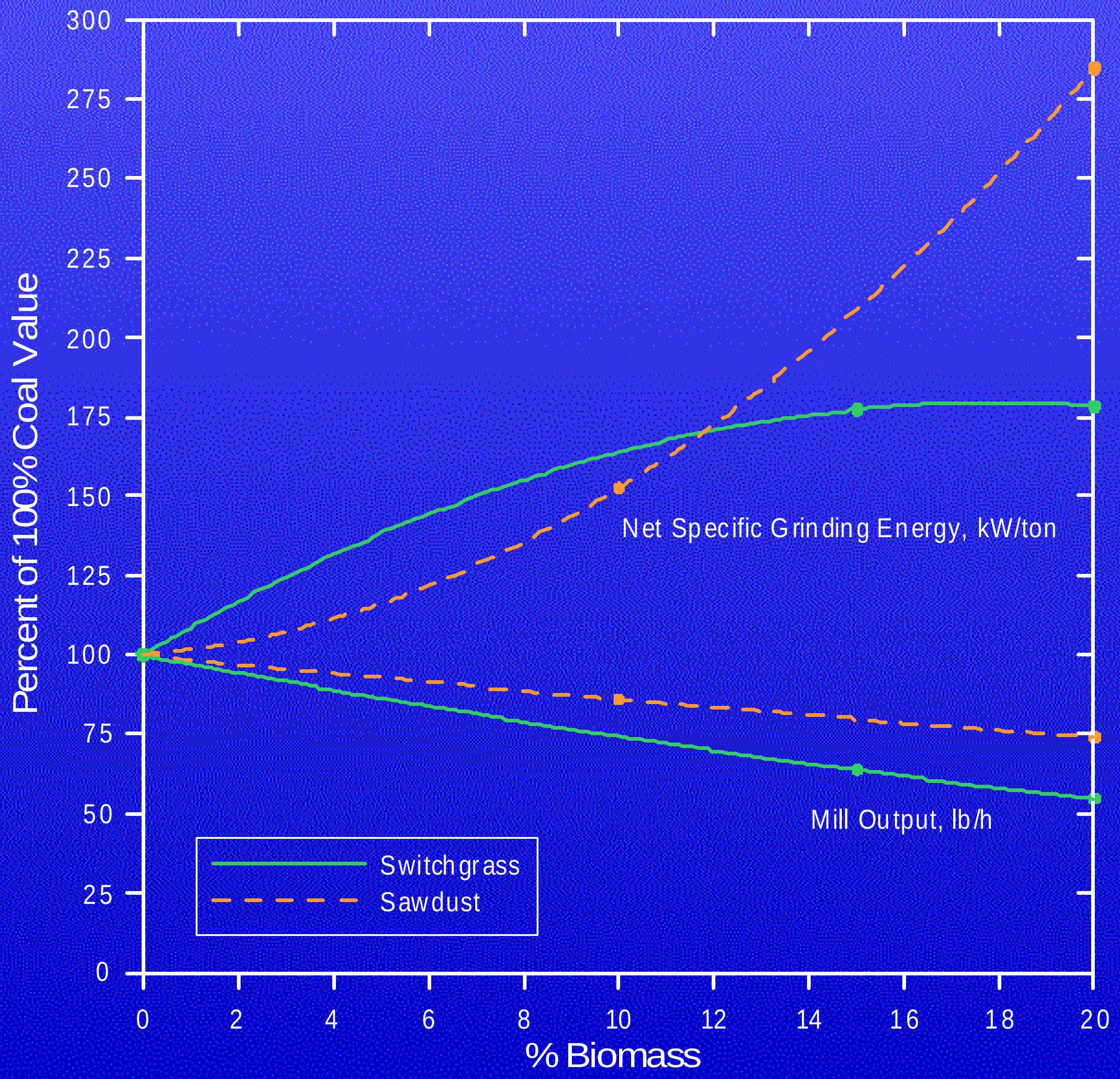
MILLING COAL AND BIOMASS - 2

AVERAGES	UNIT	COAL Pratt Seam	SAWDUST 10%	SAWDUST 20%	SWITCHGRASS 15%	SWITCHGRASS 20%
Mill Current	Amps	43.2	45.5	51.2	44.1	43.0
Drying Natural Gas	scfh	112.0	100.2	63.5	66.0	82.1
Mill Inlet Temperature	°F	185.2	179.9	172.6	161.8	176.3
Mill Outlet Temperature	°F	145.0	145.1	145.0	135.1	145.0
Mill Exit Gas Flow	ACFM	2259	2260	2261	2260	2259
Mill Exit Gas Flow	SCFM	1965	1961	1959	1989	1952
ΔP at Mill Inlet	in. H2O	-0.25	-0.25	-0.24	-0.25	-0.25
O_2 at Mill Inlet	%	16.9	17.2	18.2	11.7	12.7
Mill Spring Pressure, West	lbs	1259	2358	3614	2163	2057
Mill Spring Pressure, East	lbs	3786	5665	8006	5048	4842
Journal Lift, West	in.	0.16	0.18	0.18	0.17	0.20
Journal Lift, East	in.	0.16	0.18	0.18	0.17	0.18
Hardgrove Grindability	no unit	49.0	N/A	N/A	N/A	N/A

MILLING COAL AND BIOMASS - 3

CALCULATED ENERGY USAGE	UNIT	COAL Pratt Seam	SAWDUST 10%	SAWDUST 20%	SWITCHGRASS 15%	SWITCHGRASS 20%
Fuel Heat Value	Btu/lb	12760	12323	12085	12089	11911
Mill Output	MBtu/hr	13.4	11.2	9.4	8.1	6.8
Specific Grinding Energy, gross	kW/ton	24.7	30.2	39.8	39.7	45.0
Specific Grinding Energy, net	kW/ton	3.79	5.78	10.81	6.73	6.76
Specific Drying Energy	Btu/lb	113.0	117.4	86.2	105.4	151.9
Specific Grinding Energy, gross	kWh/MBtu	0.97	1.23	1.65	1.64	1.89
Specific Grinding Energy, net	kWh/MBtu	0.15	0.23	0.45	0.28	0.28
Specific Drying Energy	Btu/MBtu	8857	9530	7133	8715	12752
Hardgrove Grindability	no unit	49.0	N/A	N/A	N/A	N/A

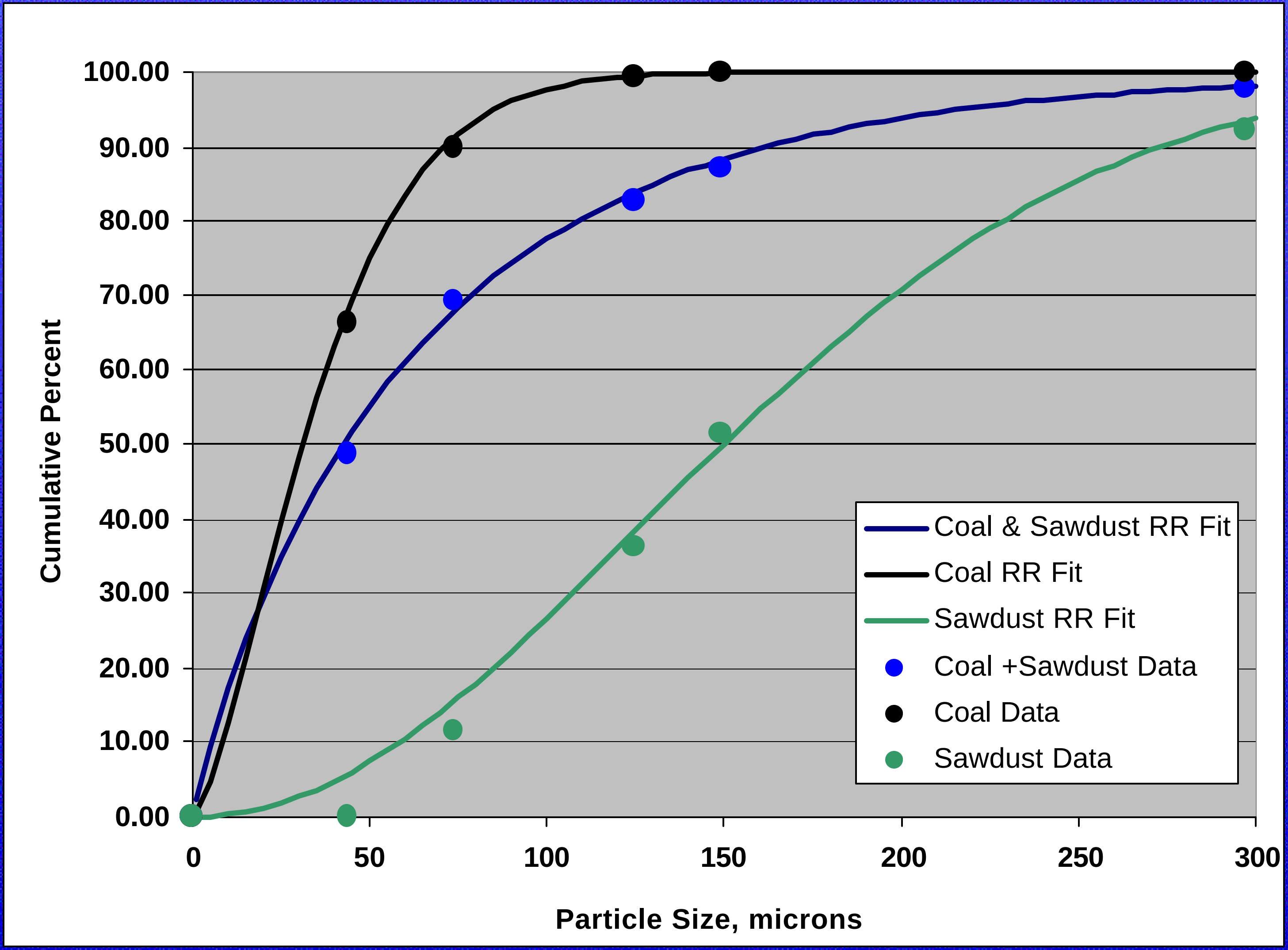
Biomass Comilled with HV Bituminous Coal



Southern Research Institute

Size Distributions

80% Pratt Seam Coal - 20% Sawdust

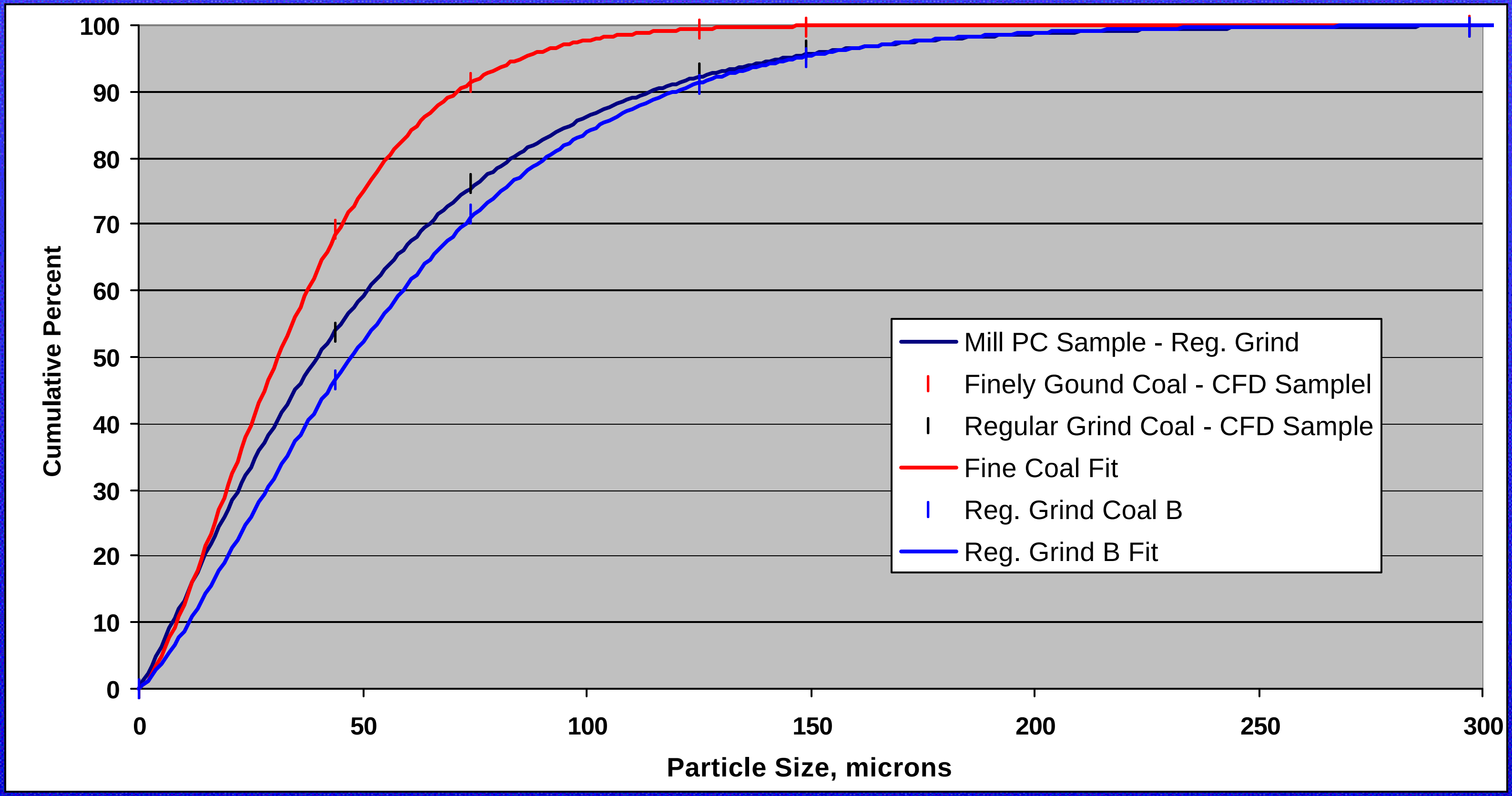


Southern Research Institute

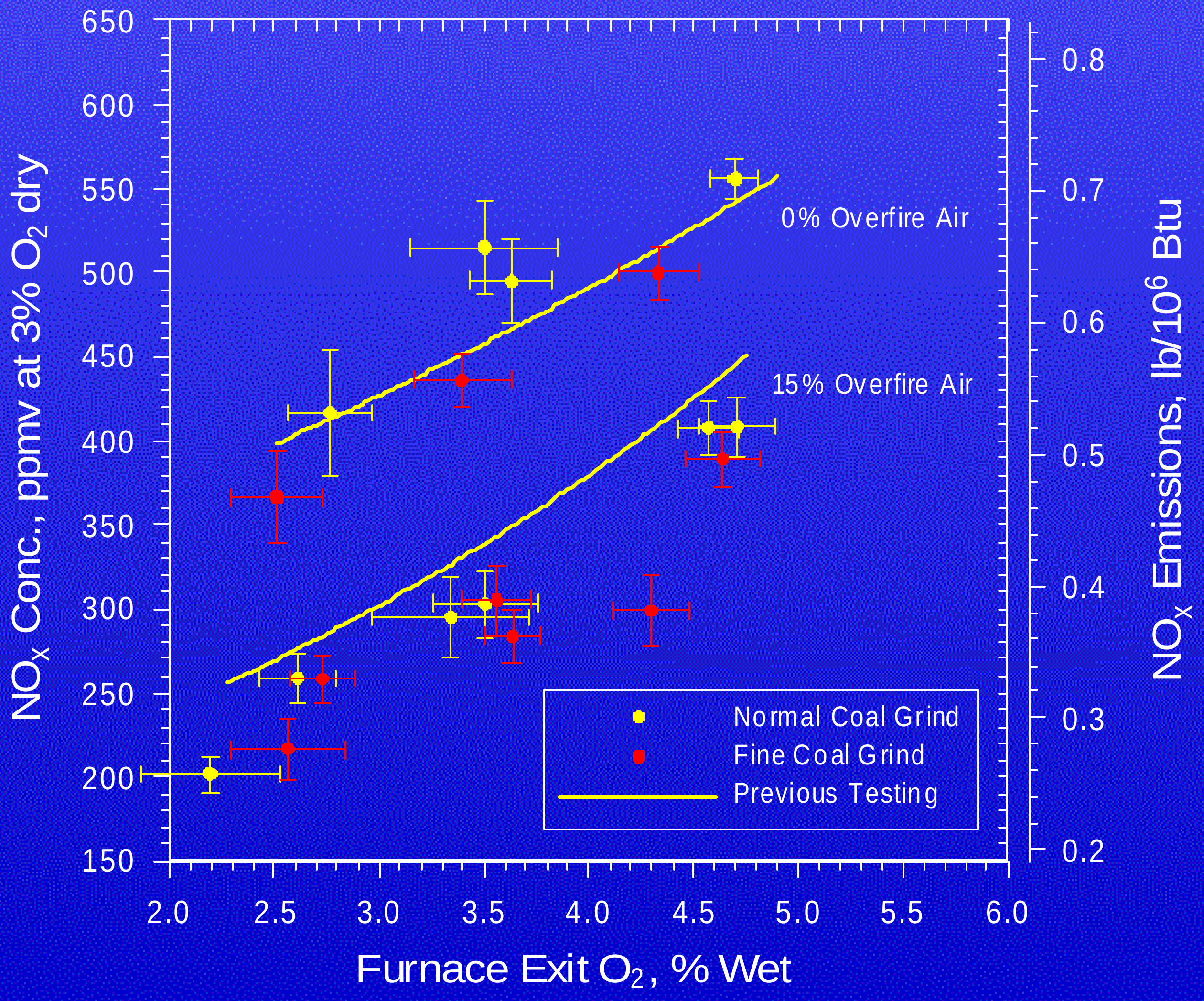
Is it the Biomass
OR
Does Coal Particle Size Affect NO_X and/or UBC Emissions?

Southern Research Institute

Regular Grind (70% < 200 mesh) and Fine Grind Coal

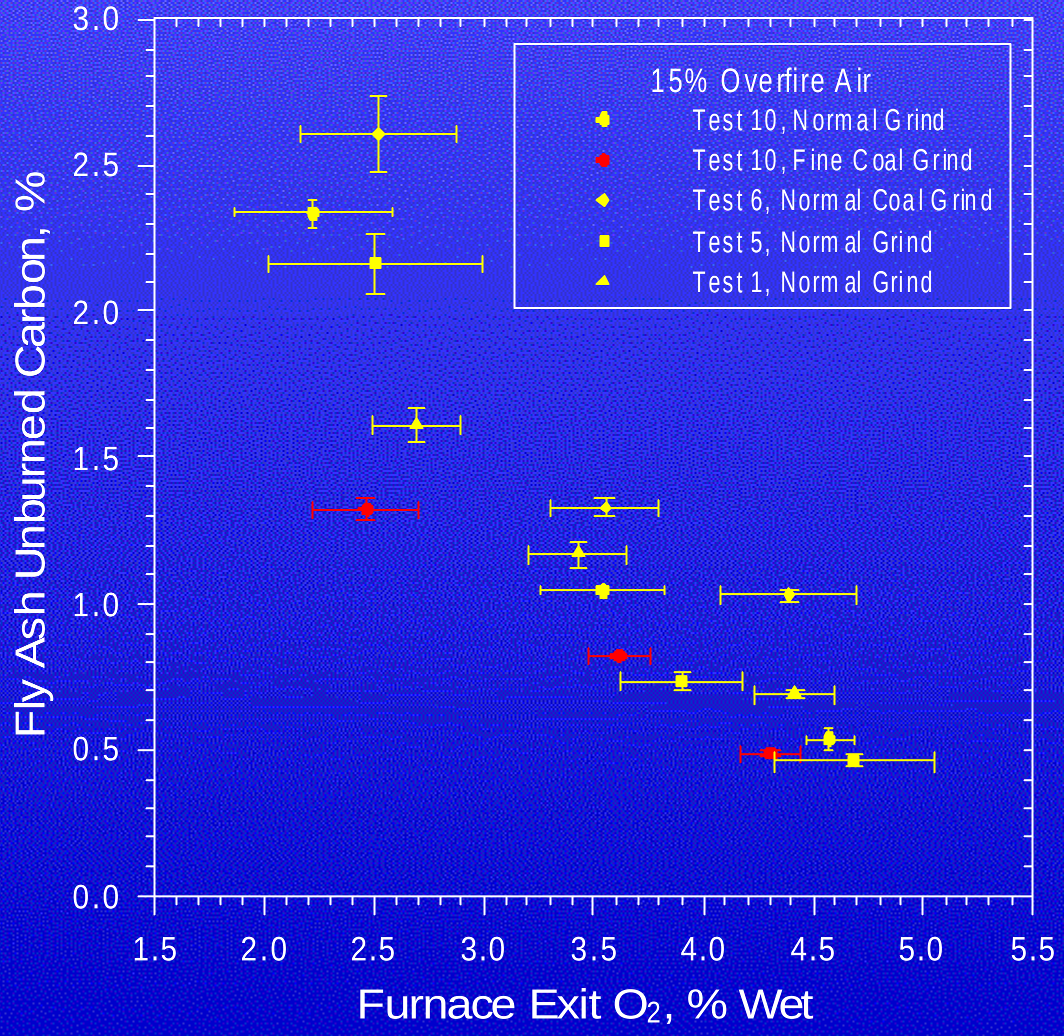


Pratt Seam Coal - Baseline Injection Configuration
Effect of Normal and Fine Coal Grind
NO_X Performance in the Pilot-Scale Combustor
Dependence on Furnace Exit Oxygen



Southern Research Institute

Pratt Seam Coal - Comilling Configuration
Effect of Normal and Fine Coal Grind
Unburned Carbon Performance
in the Pilot-Scale Combustor



With Comilling, NO_X and UBC Emissions are Apparently Unaffected by More Finely Ground Coal ~90% <200 mesh