LG&E/KU – E.W. Brown Station

Phase II Air Quality Control Study

Draft System

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Revision B – Issued For Client Review

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1.0 Introduction

As a part of the draft system analysis during the conceptual design process for the E.W. Brown station, the flue gas draft system requires evaluation to determine if modifications or replacements of the existing fans and other draft system components will be required. This is due to the installation of additional draft system equipment to control, or enhance the control of, certain flue gas emissions. For Units 1 and 2 the major modifications and additions to the draft system being considered include new selective catalytic reduction (SCR) systems for removing NO_x emissions as well as new pulse jet fabric filter (PJFF) systems that will replace the existing electrostatic precipitator (ESP) systems of each unit in the removal of particulate. For Unit 3 only a new PJFF system would be added to replace the existing ESP system. An SCR system for Unit 3 has already been designed and is currently being installed by others and is not a part of this study work.

Following this introductory section for the Brown draft systems, the draft system of each unit will be analyzed individually based on the draft system additions and changes previously discussed. First, there will be an overview of the layout of each existing draft system, existing boiler and draft system characteristics, existing fans, and design pressures. Next, an overview of the future draft system layout and expected operating characteristics will be discussed. The existing fans will be evaluated first against the future draft system performance requirements. Then, if new fans may be needed, the required maximum continuous rating (MCR) performance requirements will be presented for the new fans. A recommended Test Block fan performance will be indicated as well. The analysis of each unit will also include a look at estimates of the recommended draft system design pressures. Other draft system components that may be need to be considered for reliable draft system operation will conclude the unit discussion.

For the sizing of any new fans for the Brown site, the standard Black & Veatch fan sizing philosophy for developing Test Block conditions as additional margin on MCR conditions is recommended and has been utilized. At MCR design conditions, the fan operating conditions are the conditions expected when the equipment is new and the gas flow path is in a clean condition. This situation can not be maintained throughout the plant life; some equipment will suffer performance degradation compared to the new condition due to normal wear, leakage, etc., and the gas flow path will not remain clean. To account for this degradation, a fan's Test Block condition is developed and used to establish the maximum capability of the fan. Test block conditions are selected so that the fans are sized to accommodate degradation and abnormal operating conditions. This design philosophy provides fans that will allow continued full-load operation of the unit with typical, abnormal, or worn operating conditions and includes the application of the following items to the required MCR conditions:

- 10 percent margin on flue gas flow exiting the boiler
- 50 percent margin on leakages throughout the draft system
- 50 percent margin on air heater differential pressure
- 25^{o}F temperature increase at the fan inlet
- Adjustments of draft system pressure drops to correspond with increased Test Block flow rates
- 1.0 inch of water (inw) control allowance

The application of these items typically results in flow margins in the range of 20 to 30 percent and pressure margins in the range of 35 to 45 percent. If the flow and/or pressure margins for the Test Block conditions fall outside of these ranges the items listed above are typically adjusted appropriately.

2.0 Unit 1

2.1 Existing Draft System

2.1.1 Layout

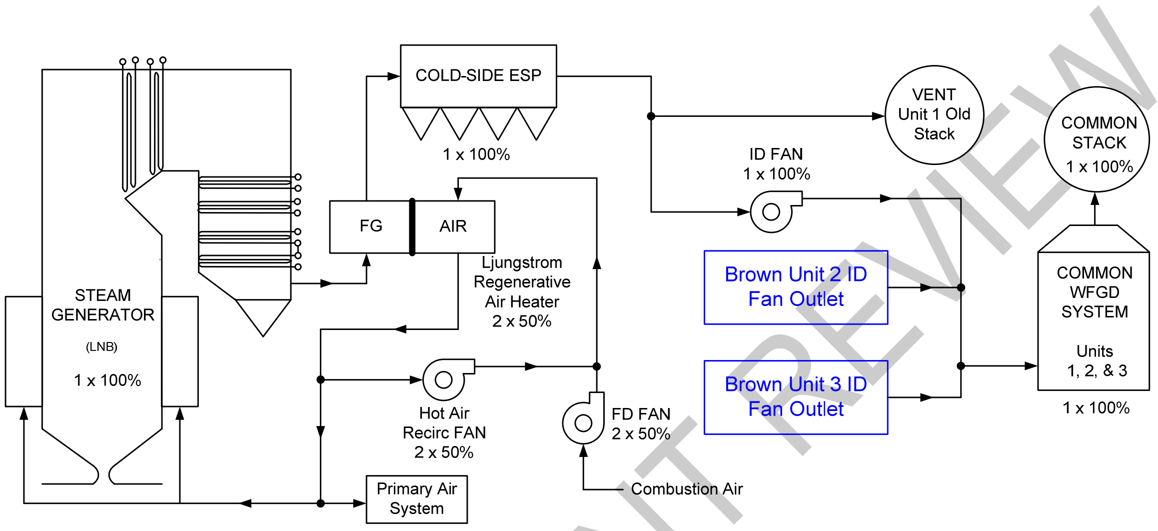

Figure 2-1
Brown Unit 1 Existing Draft System

The combustion air draft system begins at the inlet of the two 50 percent capacity forced draft (FD) fans. From there the combustion air travels directly into the ljungstrom regenerative air heaters extracting energy from the flue gas. Once through the air heaters, the combustion air travels to the furnace portion of the boiler and the primary air system in parallel. Additionally, operating in parallel is a hot air recirculation fan that extracts combustion air from the hot-side of the air heater and injects it back into the cold-side allowing for the preheating of combustion air.

The flue gas draft system begins at the outlet of the boiler, or economizer. From there the flue gas travels directly to two 50 percent capacity ljungstrom regenerative type air heaters transferring energy in the flue gas to the combustion air entering the boiler. Once through the air heaters, the flue gas travels into one 100 percent capacity cold-side electrostatic precipitator (CS-ESP) system where particulate is removed. One 100 percent capacity induced draft (ID) fan then draws the flue gas out of the CS-ESP system and sends it to a wet flue gas desulfurization (WFGD) system common to all Brown units. Once the majority of the sulfur dioxide in the flue gas is removed by the WFGD system, the flue gas then exits to the atmosphere through the common stack. Also included in the flue gas draft system is a vent to the old Unit 1 stack used as a separate vent per NFPA 85 code in the event of unit trips or other situations where exhausting the flue gas into the common WFGD system is not possible. This vent is located in the ductwork between the CS-ESP and ID fan. An illustration of the Unit 1 existing draft system based on this description is shown in Figure 2-1.

2.1.2 FD Fans

The existing combustion air draft system consists of two FD fans as previously discussed. The electric motors for each FD fan have a maximum operating nominal speed of 1200 rpm. The nameplate horsepower rating of the FD fan motors is 350 horsepower. The service factor of the motors is unknown. They operate at a nominal voltage of 2400 volts. Primary flow control of the FD fans is accomplished by the use of fluid drives in between the fans and motors allowing for variable speed flow control. The FD fans are double inlet centrifugal fans with a maximum speed capability of 1157 rpm due to the fluid drives. The FD fans are a Westinghouse Sturtevant design, model 125 TV DES 12.

2.1.3 Air Preheat System and Air Heaters

The existing combustion air draft system also consists of an air preheat system and two air heaters. The air preheat system preheats the incoming combustion air before entering the air heaters through the use of hot air recirculation fans. These recirculation fans intake hot combustion air exiting the air heaters and recirculate it back to the air inlet of the air heaters. This also serves to increase the average cold end temperature (ACET) of the air heaters minimizing acid gas condensation at the air heater flue gas outlet. The regenerative air heaters are a typical ljungstrom bisector vertical shaft design and transfer energy in the flue gas stream to the combustion air stream through the use of a rotating mass.

2.1.4 ID Fans

The existing flue gas draft fan system consists of one ID fan as previously discussed. Its TECO-Westinghouse electric motor has a maximum operating nominal speed of 900 rpm. The nameplate horsepower rating of the ID fan motor is 5,000 horsepower with a service factor of 1.15. It operates at a nominal voltage of 12,400 volts. Primary flow control of the ID fan is accomplished by the use of inlet vanes. The ID fan is a double inlet centrifugal fan with a maximum nominal speed capability of 900 rpm. The ID fan is a TLT-Babcock design model 2118AZ/1819.

2.1.5 Boiler and Draft System Characteristics

Currently, the major performance characteristics of the Unit 1 boiler and existing draft system at MCR are as follows in Tables 2-1, 2-2, and 2-3.

Table 2-1
Unit 1 Boiler Characteristics at MCR

Boiler total heat input	1,000 MBtu/hr (based on the net plant output of 102,000 kW and net heat rate of 9,802 Btu/kWh – Phase 1 design basis, May 2010)
Boiler excess air	34.3 % or 5.00% oxygen – wet basis (Phase 1 design basis, May 2010)
Loss On Ignition (LOI)	11.0 % (plant data 2008-2010)
Ambient conditions	
Dry bulb temperature	74 ^{o}F
Relative humidity	60 %
Barometric pressure	28.97 inHg

Table 2-2
Unit 1 Existing Combustion Air Draft System Characteristics at MCR

Air heater leakage	12 % (Babcock Power leakage data – 2006)
Combustion air temperatures	
FD fan inlet	74 °F
FD fan outlet	~80 °F (calculated)
Air heater outlet	~450 °F (estimated)
Windbox inlet	~450 °F (estimated)
Furnace inlet	~450 °F (estimated)
Draft system operating pressures *	
FD fan inlet	0.0 inches of water gauge (inwg)
FD fan outlet	11.0 inwg
Air heater outlet	6.0 inwg
Duct to windbox inlet	5.0 inwg
Furnace inlet	0.0 inwg
Draft system differential pressures *	
Air heater	5.0 inches of water (inw)
Ducts to windbox	1.0 inw
Windbox	5.0 inw

* Note that throughout this document gauge draft pressures will be listed with units of “inwg” and differential draft pressures with units of “inw”. This is similar to the difference between the units of “psig” and “psi”

Based on the layout of the existing draft system in Figure 2-1 and the boiler and the combustion air draft system characteristics listed in Tables 2-1 and 2-2, the estimated performance requirements of the existing FD fans are shown as the MCR point in Figure 2-2.

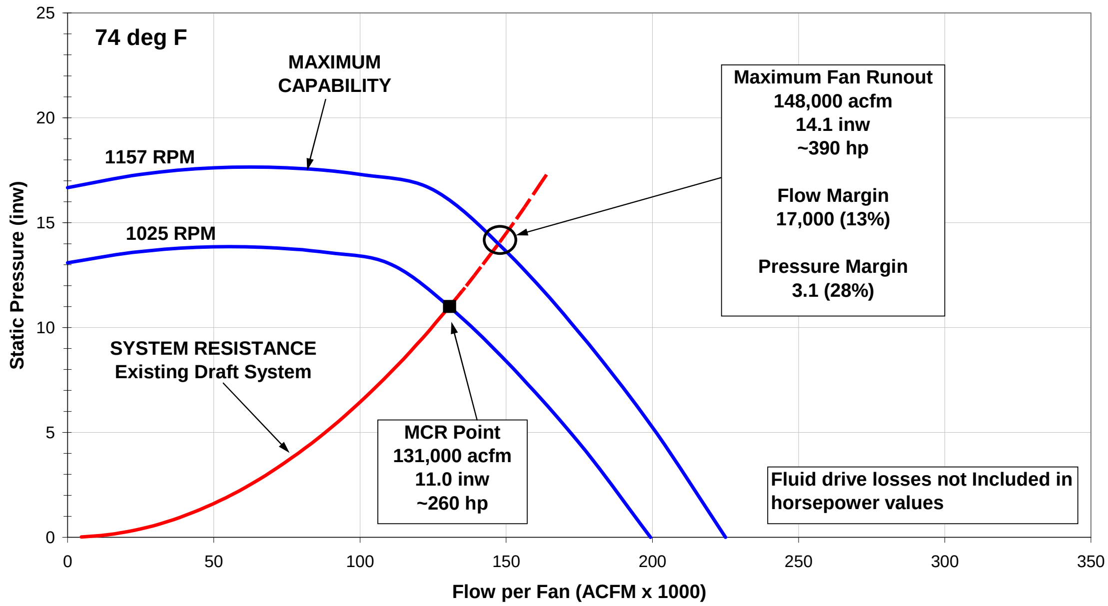

Figure 2-2
Unit 1 Existing FD Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 2-2, it appears that the FD fans have a flow and pressure margin of approximately 13 and 28 percent, respectively. These are adequate compared to the ranges of flow and pressure margins that are typically recommended by Black & Veatch.

With the expected installation of an SCR system, however, the existing FD fans would likely need to be abandoned in-place. Due to the close quarters in the Unit 1 boiler building around the boiler economizer outlet and air heaters and equipment congestion immediately north of the boiler building, a new SCR system would likely need be located outside and to the northeast from the boiler building. Additionally, routing SCR outlet ductwork back into the Unit 1 boiler building into the air heater gas inlets would be extremely difficult. Therefore, Black & Veatch recommends that a new single air heater be installed for Unit 1 in the vicinity of the new SCR system to minimize ductwork routing and interfacing with flue gas ductwork inside the Unit 1 boiler building. This also means that Black & Veatch would recommend that the existing FD fans be abandoned along with the existing air heaters. A new single FD fan would be installed matching the single air heater. A new air preheat system would need to be installed as well.

Table 2-3
Unit 1 Existing Flue Gas Draft System Characteristics at MCR

Air heater leakage	12 % (Babcock Power leakage data – 2006)
CS-ESP leakage	4 % (Babcock Power leakage data – 2006)
Flue gas temperatures	
Boiler outlet	650 ^{o}F
Air heater outlet	350 ^{o}F
CS-ESP outlet	340 ^{o}F
ID fan outlet	~360 ^{o}F (calculated)
WFGD outlet	~130 ^{o}F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inwg
Boiler outlet	-8.0 inwg
Air heater outlet	-14.0 inwg
CS-ESP outlet	-18.0 inwg
ID fan outlet	13.0 inwg
Common wet scrubber inlet	11.0 inwg
Common wet scrubber outlet	1.0 inwg
Common stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	7.5 inw
Air heater	6.0 inw
CS-ESP	4.0 inw
Duct to common wet scrubber	2.0 inw
WFGD	10.0 inw
Stack	1.0 inw

Based on the layout of the existing draft system in Figure 2-1 and the boiler and the flue gas draft system characteristics listed in Tables 2-1 and 2-3, the estimated performance requirements of the existing ID fan is shown as the MCR point in Figure 2-3.

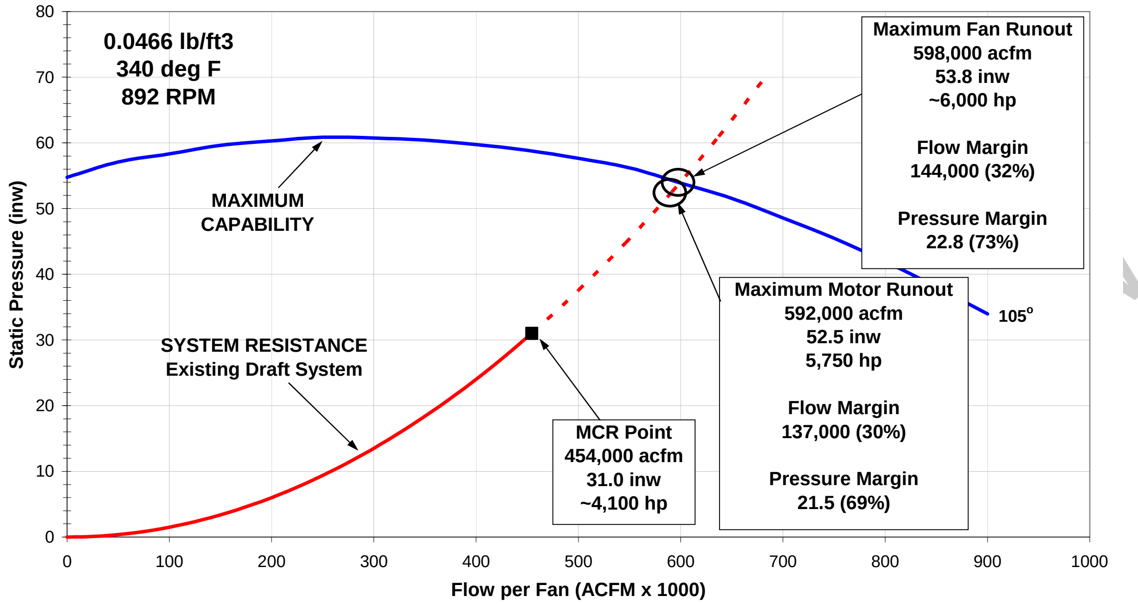

Figure 2-3
Unit 1 Existing ID Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 2-3, it appears that the ID fan has a flow and pressure margin of approximately 32 and 74 percent, respectively. However, since the estimated horsepower at the "Maximum Fan Runout" point is beyond the motor capabilities with the 1.15 service factor (5,750 hp) the flow and pressure margins are reduced to approximately 30 and 69 percent, respectively. This is shown by the "Maximum Motor Runout" box in Figure 2-3. These margins are at or above the ranges of flow and pressure margins that are typically recommended by Black & Veatch.

With the expected installation of SCR and PJFF systems, the existing ID fan appears to have sufficient margin to overcome the additional system resistance, and provide for margin as well. It appears the unit is not experiencing any issues with these fans as well. Therefore, based on their performance attributes, they could be retained without the need for additional fan capacity. Additionally, the location of the existing ID fan north of the Unit 1 boiler building should allow for its reuse in the proposed new draft system that will be discussed later. Adding ductwork to place the ID fan downstream of a new PJFF system (it is recommended that PJFF systems be under negative pressure) would be possible within the given site space constraints since the new PJFF and the other new major equipment would be placed to the northeast of the Unit 1 boiler building. Retaining the existing ID fan as the sole provider of flue gas draft pressure appears feasible from a performance and physical space standpoint.

Lastly, the existing draft system equipment and ductwork transient design pressures are listed in Table 2-4. These will be used in determining the amount of stiffening that would be required, if any, in support of the proposed AQC upgrades. These design pressures are unknown for some of the equipment and portions of ductwork of Unit 1. These may need to be determined during detailed design depending on their location in the draft system.

Table 2-4
Unit 1 Existing Draft System Equipment and Ductwork Transient Design Pressures

FD Fan	Unknown
FD Fan Outlet to Air Heater Air Inlet	Unknown
Air Heater (Air-Side)	Unknown
Air Heater Outlet to Windbox	Unknown *
Furnace/Boiler	Unknown *
Boiler Outlet to Air Heater Outlet	Unknown *
Air Heater	Unknown *
Air Heater Outlet to CS-ESP Inlet	Unknown *
CS-ESP	+15 / -22 inwg
CS-ESP Outlet to ID Fan Inlet	Unknown *
ID Fan	+112 / -112 inwg
ID Fan Outlet Duct	Unknown
Common WFGD Inlet Duct	Unknown
Common WFGD	Unknown
Common WFGD Outlet to Stack Inlet	Unknown

* Due to potential NFPA 85 requirements, these design pressures would need to be confirmed if stiffening is required in existing components.

2.2 Future Draft System

2.2.1 Layout

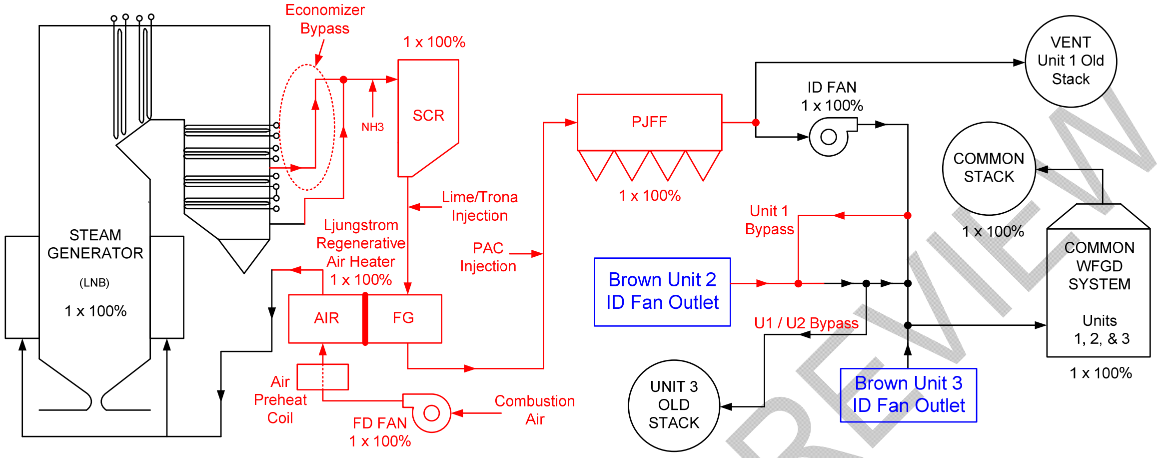

Figure 2-4
Unit 1 Future Draft System

Based on the additions to the Unit 1 draft system previously discussed and the expectation that the existing FD fans and air heaters would be replaced, the combustion air would be redirected through the draft system as follows. The combustion air would enter a new single FD fan that would force the combustion air through the new air preheat coil and new single air heater. Combustion air would then travel to the existing combustion air draft system. The hot water air preheat coil would utilize deaerator water to preheat the incoming combustion air maintaining a minimum ACET and air heater flue gas outlet temperature minimizing acid gas condensation. The new single air heater would be similar in design and operation to the existing air heaters. All new combustion air draft system components discussed here would be placed outside to the northeast of the Unit 1 boiler building in close proximity to the new SCR system. An illustration of the Unit 1 future combustion air draft system based on these descriptions is shown in Figure 2-4.

On the flue gas side of the draft system the flue gas would be redirected through the draft system as follows with the expectation that the existing ID fan would remain in service. At the boiler outlet flue gas would be redirected outside the boiler building to the new SCR system bypassing the existing air heaters. Additionally, as the flue gas travels through the boiler, a portion of it may bypass all, or part of, the economizer through a gas-side economizer bypass. The economizer bypass would allow a minimum flue gas temperature entering the SCR to be maintained. After the SCR system the flue gas would then travel through the new air heater and new PJFF system before being drawn into the existing ID fan. The existing CS-ESP system would be abandoned in place. However, all existing ductwork downstream of the existing CS-ESP system would likely need to be retained allowing the existing vent to the old Unit 1 stack to remain in service. This would be in addition to the cross-connect duct to Unit 2 ID fan outlet ductwork that will be discussed next. An illustration of the Unit 1 future flue gas draft system based on these descriptions is also shown in Figure 2-4.

Furthermore, LG&E/KU has expressed interest in including a means to bypass Unit 1 in the event that the common WFGD system would be offline. This is conceptually shown in Figure 2-4 ("Unit 1 Bypass") and physically shown Figure 2-5 by the new cross-connect duct in the upper right corner. Black & Veatch has arranged this bypass to discharge into Unit 2 ID fan outlet ductwork in order to minimize the amount of ductwork that would be needed to include this capability.

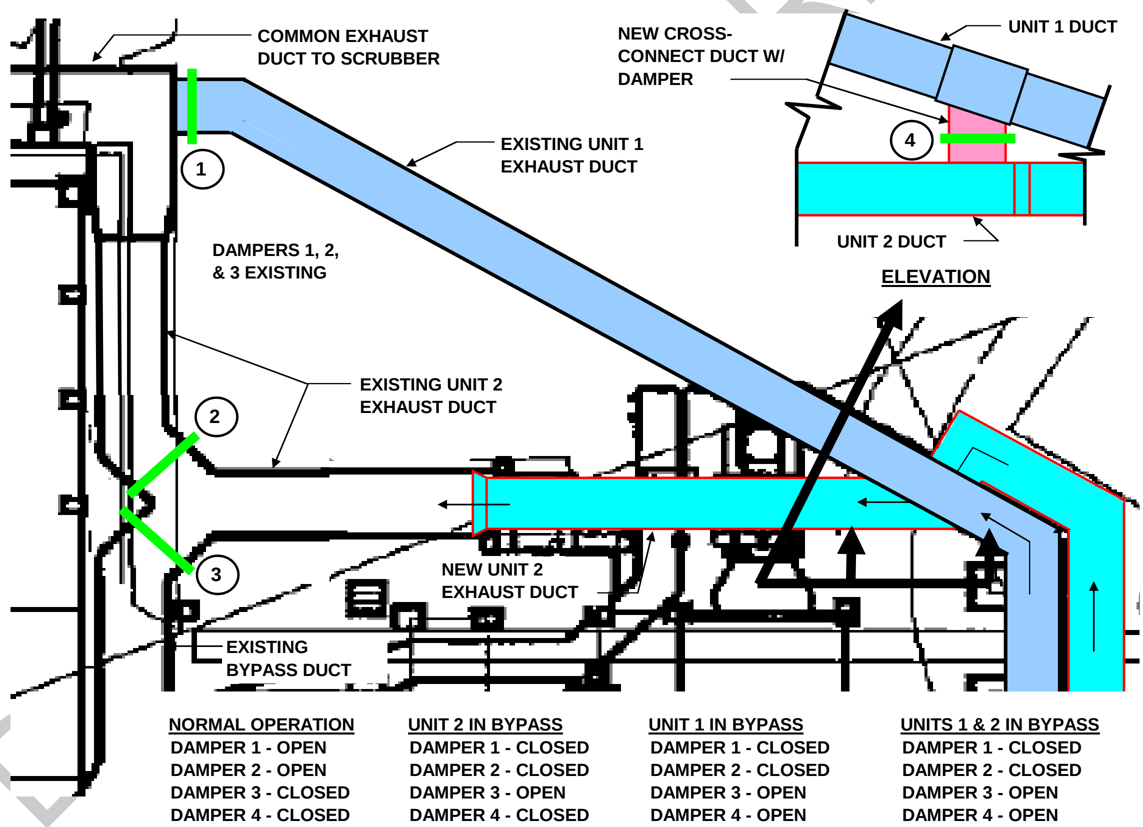

Figure 2-5
Unit 1 and 2 Future Bypass System

One concern with this Unit 1 bypass arrangement is that the ductwork downstream of the new cross-connect duct, shown in Figure 2-5, may not allow Units 1 and 2 to bypass the common WFGD system at the same time with both at full load. Relatively high velocities and pressure losses would be the result in this run of duct to the bypass stack if both Units were to operate at full load. A larger concern, though, centers on the venting ability of Unit 2 during unit trips, required per NFPA 85 code, since the Unit 2 ID fan outlet ductwork is also used for this purpose. If Unit 2 were to trip with Unit 1 exhausting flue gas through this duct as well there is the possibility that Unit 2 may not be able to properly vent if control of the Unit 2 ID fan were lost during this trip as well. This concern could possibly be mitigated with controls, however, B&V recommends that the need for and operation of the proposed cross-connect duct shown in Figure 2-5 be extensively reviewed during detailed design. This is especially the case if there is a desire that the vent to the old Unit 1 stack be abandoned.

2.2.2 Combustion Air Draft System Characteristics

Based on the layout discussion, the major performance characteristics of the Unit 1 future draft system at MCR are as follows in Table 2-5. Note that the items in bold in Table 2-5 are new.

Table 2-5
Unit 1 Future Combustion Air Draft System Characteristics at MCR

Air heater leakage	**6 %**
Combustion air temperatures	
FD fan inlet	74 °F
FD fan outlet	~80 °F (calculated)
Air preheat coil outlet	**~100 °F** (estimated)
Air heater outlet	**461 °F** (Table 2-7)
Windbox inlet	461 °F (Table 2-7)
Furnace inlet	461 °F (Table 2-7)
Draft system operating pressures *	
FD fan silencer inlet	**0.0 inwg**
FD fan inlet	**-1.0 inwg**
FD fan outlet	**12.0 inwg**
Air preheat coil outlet	**11.0 inwg**
Air heater outlet	**7.0 inwg**
Existing duct to windbox inlet	5.0 inwg
Furnace inlet	0.0 inwg
Draft system differential pressures *	
FD fan silencer	**1.0 inw**
Air preheat coil	**1.0 inw**
Air heater	**4.0 inw**
Ducts to windbox	**2.0 inw**
Windbox	5.0 inw

Note the air preheat coil outlet and air heater outlet temperatures. These temperatures are estimates based on Black & Veatch experience and an air heater budgetary quote. Black & Veatch recommends that LG&E/KU determine the exact temperatures that would be needed at MCR during detailed design to properly operate the existing combustion air system. Additionally, the system operating pressures and pressure differentials are based on Black & Veatch experience and the existing FD fan curves supplied by LG&E/KU. Again, Black & Veatch recommends that a more detailed review of the combustion air draft system be conducted to determine the exact values that should be used at MCR plant load.

2.2.3 New FD Fan Design Conditions

Based on the layout of the future draft system in Figure 2-4 and the future combustion air draft system characteristics in Table 2-5, the estimated performance requirements of the new single FD fan at MCR are shown in Table 2-6. Also in Table 2-6 are the recommended Test Block conditions developed using the standard Black & Veatch fan sizing philosophy previously outlined. Note the flow and pressure margins of 19 and 39 percent, respectively. The flow margin of 19 percent is slightly below the range of flow margins that typically results from Black & Veatch fan sizing. This is due to a fewer number of components that the FD fan would be forcing combustion air through that have the potential for leakage as compared to the ID fan. Additionally, the air heater pluggage margin was reduced to 25 percent from 50 percent and the 1.0 inw control allowance was not used in an effort create a reasonable pressure margin.

Black & Veatch has assumed that LG&E/KU would prefer only one centrifugal type fan with a single-speed motor to match the arrangement philosophy of the flue gas draft system with its single existing ID fan. However, Black & Veatch plans to utilize one of the existing 2400 volt two-speed Unit 2 ID fan motors (600/900 rpm, 800/2,500 hp) as the driver for the new Unit 1 FD fan. The reuse of existing 2400 volt electrical equipment to power the new FD fan would be possible with this arrangement, especially with the capability of starting up the FD fan at the low-speed of 600 rpm of these motors compared to the high-speed of 900 rpm. Additionally, this will allow the use of more existing equipment at the Brown site. Flow control would be accomplished with inlet vanes.

Lastly, note that the FD fan inlet temperature in Table 2-6 is different than that shown in Table 2-5. The temperature in Table 2-5 has been included to represent the design basis for the EW Brown site and is likely an annual average type of temperature. The MCR temperature shown in Table 2-6 is recommended by Black & Veatch for design purposes. Furthermore, the Test Block temperature in Table 2-6 is another 25 degrees F higher based on the Black & Veatch fan sizing philosophy previously discussed.

Table 2-6
Unit 1 New FD Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	85	110
Inlet Density (lb/ft^3)	0.0699	0.0668
Flow per Fan (acfm)	257,000	305,000
Inlet Pressure (inwg)	-1.0	-1.3
Outlet Pressure (inwg)	12.0	16.8
Static Pressure Rise (inw)	13.0	18.1
Shaft Power Required (HP) *	700	1,000
Efficiency (%) *	70	85
Number of Fans	1	1
Flow Margin (%)	---------	19
Pressure Margin (%)	---------	39

* Estimated – assumes single-speed operation with inlet vanes. Black & Veatch plans to use the existing Unit 2 two-speed 600/900 rpm 800/2,500 hp ID fan motors to drive the new Unit 1 FD fan.

2.2.4 New Air Heaters and Air Preheat System Design Conditions

Based on the layout of the future draft system in Figure 2-4 and the future combustion air draft system characteristics in Table 2-5, the estimated performance of the new single air heater for conceptual design purposes is listed in Table 2-7. The values in Table 2-7 would need to be confirmed during detailed design.

Table 2-7
Unit 1 New Air Heater Design Conditions at MCR

Type	Regenerative Ljungstrom Bisector
Shaft Orientation	Vertical
Flows (lb/hr)	
Entering Air *	1,076,000
Entering Gas (based on combustion calculations)	1,112,000
Leaving Air (based on combustion calculations)	1,011,000
Leaving Gas *	1,177,000
Temperatures (deg F)	
Entering Air	100
Entering Gas	650
Leaving Air *	461
Leaving Gas w/o Leakage *	342
Leaving Gas w/ Leakage	330
ACET *	221
Draft Pressures (inwg)	
Entering Air	11.0
Entering Gas	-18.0
Leaving Air *	8.0
Leaving Gas *	-22.6
Pressure Differentials (inw)	
Air *	3.0
Gas *	4.6 (6.0 maximum specified)
Air – Gas (cold end) *	34.5
Leakages	
Air – Gas (lb/hr) *	65,000
Percent (%) *	5.9

* Determined by Air Preheater Company

The values in Table 2-7 would be used in sizing the proposed new single air heater. However, note that the pressure differentials do not match up with Table 2-5. Black & Veatch chose to utilize the more conservative pressure differential estimates in Table 2-5 in sizing the FD fan due to the new SCR system that would have the potential to increase these differentials. Also note the parameters in Table 2-7 that have been provided by The Air Preheater Company. Again, as with the values in Table 2-5, the values in Table 2-7 would need to be finalized during detailed design to properly size the new air heater.

For the air preheat system Black & Veatch chose to use hot water as the heating medium which would be extracted from the deaerator. This was chosen instead of the existing philosophy of hot air recirculation to minimize additional equipment in the location of the SCR and PJFF system and to match the air preheat system philosophy on Unit 2. The new hot water pumps (two 100 percent capacity pumps), piping, valves, switchgear, power feeds, and control and instrumentation that would be needed are expected to require a minimum amount of additional space. The exact performance requirements of the new hot water air preheat coil to maintain a minimum ACET and to minimize acid gas condensation on the flue gas side would be determined during detailed design. However, for conceptual design purposes it has been assumed that this equipment would maintain the air heater air inlet temperature at approximately 100 degrees F to maintain an air heater flue gas outlet temperature of 330 degrees F as shown in Table 2-7. Black & Veatch has chosen an air heater gas outlet temperature of 330 degrees F to stay above an acid gas condensation temperature estimated to be in the range of 300 to 315 degrees F. Additionally, based on previous Black & Veatch experience the hot water pumps have been sized for conceptual design purposes to meet a flow rate of 400 gpm at a total developed head (TDH) of 200 ft. This sizing equates to a maximum power consumption of 22.5 kW per pump which includes pump and motor inefficiencies.

2.2.5 Flue Gas Draft System Characteristics

The major performance characteristics of the Unit 1 future flue gas draft system at MCR are as follows in Table 2-8. Note that the items in bold in Table 2-8 are new.

Table 2-8 Unit 1 Future Flue Gas Draft System Characteristics at MCR	
SCR system leakage	**2 %**
Air heater leakage	**6 %**
PJFF system leakage	**3 %**
Flue gas temperatures	
Boiler outlet	650 ^{o}F
SCR system outlet	**650 ^{o}F**
Air heater outlet	**330 ^{o}F**
PJFF outlet	**330 ^{o}F**
ID fan outlet	~355 ^{o}F (calculated)
Wet scrubber outlet	~130 ^{o}F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inwg
Boiler outlet	-8.0 inwg
SCR system outlet	**-18.0 inwg**
Air heater outlet	**-24.0 inwg**
PJFF outlet	**-30.0 inwg**
ID fan inlet	**-31.0 inwg**
ID fan outlet	13.0 inwg
Common wet scrubber inlet	11.0 inwg
Common wet scrubber outlet	1.0 inwg
Common stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	7.5 inw
SCR system	**10.0 inw**
Air heater	**6.0 inw**
PJFF system	**6.0 inw**
PJFF outlet duct to ID fan	**1.0 inw**
Duct to common wet scrubber	2.0 inw
WFGD	10.0 inw
Stack	1.0 inw

Note that the flue gas draft system operating parameters estimated in Table 2-8 are based on Black & Veatch experience. Black & Veatch recommends that a more detailed review of the future flue gas draft system be conducted to determine the exact values that should be used at MCR plant load for detailed design.

2.2.6 Analysis of Existing ID Fans with Future Draft System

To demonstrate the affect the additional draft system resistance of the new SCR and PJFF systems would have on the existing ID fan a new system resistance curve is shown in Figure 2-6. The existing ID fan in its existing configuration would have margins of approximately 13 percent on flow and 28 percent on pressure as shown in Figure 2-6 by the "Maximum Capability" curve and the "Maximum Fan Runout" box. These margins would be below the typically recommended Black & Veatch margins, but Black & Veatch believes they are adequate to warrant the reuse of the existing ID fan. Additionally, although the estimated horsepower requirement at "Maximum Fan Runout" listed in Figure 2-6 is beyond the existing ID fan motor nameplate horsepower of 5,000 hp, the service factor of 1.15 could be utilized to attain this fan capability. The existing Unit 1 ID fan will be retained with the future flue gas draft system as the only means to overcome the future flue gas draft system resistance.

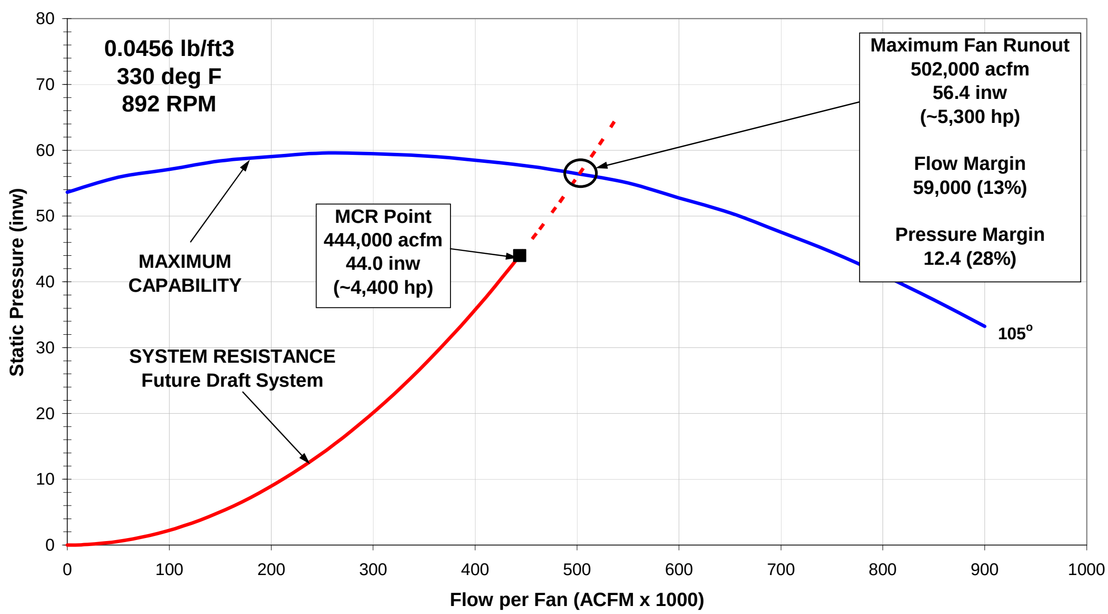

Figure 2-6
Unit 1 Existing ID Fan Performance with Future Draft System

2.2.7 Operating and Transient Design Pressures

With the determination of the existing ID fan's ability to provide the necessary capability to support the proposed new flue gas draft system additions, the maximum draft system pressures that the ID fan is capable of must be determined. This will allow the draft system design, or transient, pressures to be determined to properly design the new ductwork and draft system components preventing exposure to permanent deformation or buckling. This also applies to the new FD fan and combustion air draft system. Based on the new FD fan and existing ID fan's maximum capability in the future draft system, these maximum pressures are listed in Tables 2-9 and 2-10. The normal operating, or MCR, pressures have been shown in Tables 2-9 and 2-10 as well for reference.

Table 2-9
Unit 1 Future Combustion Air Draft System Pressures at MCR and New FD Fan Test Block

	MCR Pressure (inwg)	**Test Block Pressure (inwg)**
Atmosphere	0.0	0.0
Silencer Outlet	**-1.0**	**-1.3**
FD Fan Outlet	**12.0**	**16.8**
Air Preheat Coil Outlet	**11.0**	**15.5**
Air Heater Outlet	**7.0**	**9.0**
Existing Duct to Windbox Inlet	5.0	6.4
Furnace Inlet	0.0	0.0

Table 2-10 Unit 1 Future <u>Flue Gas</u> Draft System Pressures at MCR and Existing ID Fan Maximum Capability		
	MCR Pressure (inwg)	**Maximum Fan Runout Pressure (inwg)**
Furnace/Boiler	-0.5	-0.5
Boiler/Economizer Outlet	-8.0	-9.1
SCR Outlet	**-18.0**	**-20.5**
Air Heater Outlet	**-24.0**	**-32.5**
PJFF Outlet	**-30.0**	**-39.4**
ID Fan Inlet	**-31.0**	**-40.5**
ID Fan Outlet	13.0	15.9
Common Wet Scrubber Inlet	11.0	13.6
Common Wet Scrubber Outlet	1.0	2.1
Common Stack Outlet	0.0	0.0

With the future draft system Test Block operating pressures defined in Table 2-9 for the new FD fan and Maximum Fan Runout defined in Table 2-10 for the existing ID fan, the future draft system potential minimum transient design pressure requirements can be determined and are shown in Table 2-11. The Black & Veatch philosophy for calculating the minimum required transient design pressures is based on the draft system being designed to 66 percent of its yield stress for maximum continuous operating (Test Block) pressures and 95 percent for short durations, or transient conditions. This results in a 44 percent increase in the allowable stress throughout the draft system for short durations without resulting in permanent deformation or buckling of any structural components. For example, the PJFF outlet is expected to be exposed to a negative draft pressure of -39.4 inwg (see Table 2-10) when the ID fan would be operating at Maximum Fan Runout conditions. The calculated negative transient design pressure in this case would be 44 percent higher or -56.7 inwg. Since this pressure is higher than the NFPA 85 minimum of -35 inwg that will be discussed later, -57 inwg would be the minimum transient design pressure. The positive transient design pressure would be +35 inwg (see Table 2-11).

The transient design pressures in Table 2-11 may initially be used in determining the amount of stiffening of existing and new equipment that would be required, if any, in support of the proposed AQC upgrades. Note that the National Fire Protection

Association (NFPA) 85 requires, with potential exceptions, that new flue gas ductwork and equipment between the FD fan outlet and the ID fan inlet (it should be implied that this would include booster fans as well), including the boiler, be designed for transient pressures of ± 35 inwg for existing facilities with major alterations or extensions as well as new facilities. The calculated transient design pressures below ± 35 inwg are disregarded and the ± 35 inwg is used as the design transient pressure for that draft system component or section of ductwork. This is similar to the example previously described. For calculated transient design pressures over ± 35 inwg the calculated pressure is used. Note that the items in bold in Table 2-11 are new or potential modifications.

Table 2-11
Unit 1 Future Flue Gas Draft System Potential Transient Design Pressure Requirements

FD Fan Silencer	**± 10 inwg ****
FD Fan Silencer Outlet to FD Fan Inlet	**± 10 inwg ****
FD Fan	**Determined by Manufacturer**
FD Fan Outlet to Air Heater Air Inlet	**+35 / -35 inwg**
Air Heater (Air-Side)	**+35 / -35 inwg**
Air Heater Outlet to Existing Air Inlet	**+35 / -35 inwg**
Existing Air Inlet to Windbox	**+35 / -35 inwg ***
Furnace/Boiler	**+35 / -35 inwg ***
Boiler Outlet Duct	**+35 / -35 inwg ***
SCR Inlet Duct	**+35 / -35 inwg**
SCR	**+35 / -35 inwg**
SCR Outlet to Air Heater Gas Inlet	**+35 / -35 inwg**
Air Heater (Gas-Side)	**+35 / -47 inwg**
Air Heater Outlet to PJFF Inlet	**+35 / -47 inwg**
PJFF	**+35 / -57 inwg**
PJFF Outlet to ID Fan Inlet	**+35 / -59 inwg**
ID Fan	+112 / -112 inwg
ID Fan Outlet to Common WFGD Scrubber Inlet	Unknown
Common WFGD Scrubber	Unknown
Common WFGD Scrubber Outlet to Stack Inlet	Unknown

* Further research is needed to determine whether this would be required.

** Estimated – Ductwork and equipment downstream of the ID fan up to the stack inlet was assumed to have a minimum transient design pressure rating of +10/-10 inwg, typical of ductwork in that section of a draft system. If the actual design pressures in this section are different, stiffening would likely not be required except for the minimum positive design pressure greater than +10 inwg from the ID fan outlet through the WFGD scrubber. Existing design pressures already higher than +10 inwg should be retained. NFPA 85 does not specifically call out a minimum design pressure requirement for ductwork downstream of ID/Booster fans. **This philosophy also applies to any ductwork and equipment upstream of FD fans.**

The AQC equipment additions and changes to all of the Brown units will likely be considered major alterations or extensions to the existing facilities per the NFPA 85 code - Section 1.3 (2011 Edition). The code, in this instance, would imply that the combustion air and flue gas ductwork from the FD fan outlet to the ID fan inlet, including the boiler, be designed for transient pressures of ± 35 inwg at a minimum per Section 6.5. Further research is needed to determine whether the remaining portions of the existing Unit 1 boiler and draft system meet this criteria or if they would require stiffening. This further research would be required during detailed design.

The code however acknowledges that an exception could be taken if the expense for modifying the existing boiler framing system would be disproportionate to the amount of increased protection as long as a reasonable degree of safety can be provided. The "burden" for proving to the authority having jurisdiction (AHJ) whether a reasonable degree of safety can be provided would fall to the User or their Engineer. In Section 1.4.3 NFPA 85 permits the AHJ to deviate from these requirements if deemed impractical to upgrade the existing facility to meet the latest code requirements and provided that a reasonable degree of safety can be provided without upgrading to the full extent of the code.

With the addition of the proposed Brown AQC equipment for this study, this may be an instance where consideration should be given for deviating from these requirements. The basis for this line of reasoning is supported by the explanatory language in the Annex material. Section A.1.4 of NFPA 85 states that:

> "Users of equipment covered by this code should adopt those features that they consider applicable and practicable for existing installations. Physical limitations could cause disproportionate effort or expense with little increase in protection. In such cases, the authority having jurisdiction should be satisfied that reasonable protection is provided.
>
> In existing units, any condition that represents a serious combustion system hazard should be mitigated by application of appropriate safeguards."

Other than the potential boiler stiffening that may be required per NFPA 85 code, stiffening associated with the remaining sections of the existing combustion air and flue gas draft systems is not expected. Portions of the existing combustion air draft system downstream of new ductwork from the new air heater are expected to continue to operate at similar pressures. The existing flue gas draft system downstream of the boiler economizer outlet will be bypassed from the economizer outlet up to the inlet of the existing ID fan. However, a large portion of the existing flue gas ductwork would remain in operation due the Unit 1 vent to the old Unit 1 stack that would still be needed. This ductwork, though, is relatively new and is expected to have been designed to handle the increased capacity of the recently installed existing ID fan. Stiffening costs associated with any existing portions of the draft system are not expected.

The other part of the NFPA 85 compliance equation involves the use of a dedicated unit vent due to the common WFGD system. As previously discussed during the layout discussion of the future draft system, this would require that the existing vent to the old Unit 1 stack on top of the Unit 1 boiler building remain in service. Therefore, portions of the existing ductwork between the existing CS-ESP system and the ID fan would need to remain in service as well.

2.2.8 Additional Items

It is expected that the economizer bypass previously mentioned during the layout discussion would be needed to maintain flue gas temperatures entering the SCR when they are approximately 615^{o}F and lower. This is based on SCR catalyst that Black & Veatch would typically procure for high sulfur eastern bituminous fuels. It is unknown whether this catalyst type or if catalysts with different minimum temperatures would be used. Nevertheless, based on the Brown Unit 1 draft system temperatures listed in Table 2-8, the operation of an economizer bypass is not expected at MCR, but at loads relatively close to MCR and below to maintain this minimum ammonia injection temperature. The exact loads where the economizer bypass would be in operation would be determined during detailed design.

A gas-side economizer bypass, as shown in Figure 2-4, has been determined to be a plausible solution, especially if the existing flue gas ductwork immediately exiting the existing air heaters up to the CS-ESP is partially demolished. Typically these bypasses are each equipped with modulating dampers and expansion joints and consist of multiple, relatively small ducts to avoid structural steel and other obstructions. Economizer backpressure dampers in the main flue gas path may also be required. These ducts would exit the boiler backpass above the economizer and then inject the higher temperature flue gas into the economizer outlet duct at the first possible location to keep duct runs and costs to a minimum. The economizer bypass ductwork and dampers would bypass flue gas around the economizer in the boiler to increase the overall temperature of the flue gas entering the new SCR system. The proper reaction temperatures entering the SCR system would be maintained by the modulating dampers in the economizer bypass ducts. Should the pressure drop across the economizer decrease to a point that does not allow a suitable amount of flue gas to bypass the economizer, usually at low loads, backpressure dampers in the main flue gas path would be modulated to correct this. Additional pressure drop associated with these economizer backpressure dampers has not been added to Table 2-8 since their use is not expected at unit MCR. These ducts could be combined into one duct or remain separate entering the economizer outlet duct. Issues with limited mixing time are not expected since the flue gas must pass through a long duct run before entering the SCR system. Additionally, Black & Veatch recommends that the bypass duct be constructed out of materials that can withstand the flue gas temperatures exiting the boiler backpass prior to the economizer. Carbon steel material temperature limitations in the new economizer outlet ductwork may also become a concern if excessive amounts of flue gas bypass the economizer.

The most effective way of setting up the economizer bypass ductwork would be determined during detailed design. If designed and installed properly, gas-side bypasses are effective but require that the dampers, in a hot and particulate intensive environment, be properly maintained.

Other means of maintaining a minimum SCR flue gas inlet temperature consist of water-side economizer bypasses and water-side economizer recirculation systems. These systems can be effective as well but also have their own disadvantages. The most appropriate SCR catalyst with its own specific minimum temperature, as well as the most effective means of maintaining the minimum inlet temperature, would be further evaluated during detailed design.

Concerns of ammonium bisulfate (ABS) and other deposits are also important when considering SCR systems for NOx control. These deposits are caused by reactions between acid gases and excess ammonia (ammonia slip) from the SCR system. They form in the air heaters as the flue gas cools, typically in difficult to clean areas of air heaters. Black & Veatch recommends that the new single air heater incorporate the proper additions at the time of the SCR system installation which will require a separate study to be performed by the air heater manufacturer during detailed design. These air heater additions typically include, but are not limited to, the following:

- Installation of baskets with an enamel coating.
- Installation of only two basket layers.
- Installation of high energy and/or multimedia (steam or compressed air / high pressure water) sootblowers with controls that allow even cleaning of all basket areas.

3.0 Unit 2

3.1 Existing Draft System

3.1.1 Layout

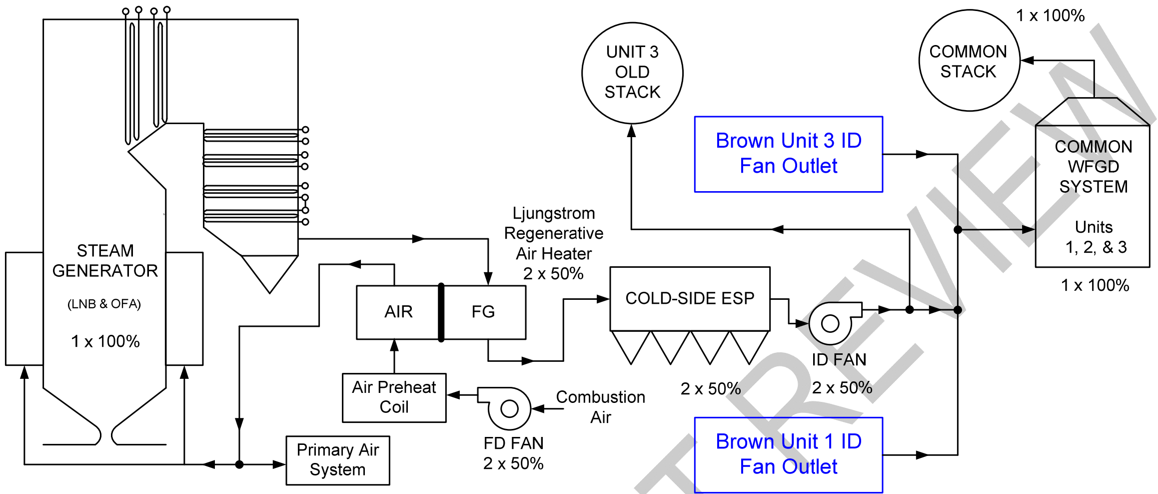

Figure 3-1
Unit 2 Existing Draft System

The combustion air draft system begins at the inlet of the two 50 percent capacity FD fans. From there the combustion air travels directly into the hot water air preheat coils preheating the combustion air. Next, the combustion air enters the two 50 percent capacity ljungstrom regenerative air heaters extracting energy from the flue gas. Once through the air heaters, the combustion air travels to the furnace portion of the boiler and the primary air system in parallel.

The flue gas draft system begins at the outlet of the boiler, or economizer. From there the flue gas travels directly to two 50 percent capacity ljungstrom regenerative type air heaters transferring energy in the flue gas to the combustion air entering the boiler. Once through the air heaters, the flue gas travels into a two 50 percent capacity CS-ESP system where particulate is removed. Two 50 percent capacity ID fans then draw the flue gas out of the CS-ESP system and send it to a WFGD system common to all Brown units. Once the majority of the sulfur dioxide in the flue gas is removed by the WFGD system, the flue gas then exits to the atmosphere through the common stack. Also included in the flue gas draft system is a vent to the old Unit 3 stack used as a separate vent in the event that the common WFGD system is not in operation, for unit trips, or other situations where exhausting the flue gas into the common WFGD system is not possible. An illustration of the Unit 2 existing draft system based on this description is shown in Figure 3-1.

3.1.2 FD Fans

The existing combustion air draft system consists of two FD fans as previously discussed. The electric motors for each FD fan have a maximum operating nominal speed of 1200 rpm. The nameplate horsepower rating of the FD fan motors is approximately 1,400 horsepower. The service factor of the motors is unknown. They operate at a nominal voltage of 2400 volts. Primary flow control of the FD fans is accomplished by the use of fluid drives in between the fans and motors allowing for variable speed flow control. The FD fans are double inlet centrifugal fans with a maximum speed capability of 1160 rpm due to the fluid drives. The FD fans are a Westinghouse Sturtevant design, model 2382. These FD fans were originally designed to service Unit 2 as a forced draft unit. Unit 2 is now a balanced draft unit.

3.1.3 Air Preheat System and Air Heaters

The existing combustion air draft system also consists of an air preheat system and two air heaters. The air preheat system preheats the incoming combustion air before entering the air heaters through the use of coils in the air heater inlet ductwork. These coils utilize hot water from the deaerator as the heating medium. Preheating the combustion air serves to increase the average cold end temperature (ACET) of the air heaters minimizing acid gas condensation at the air heater flue gas outlet. The regenerative air heaters are a typical ljungstrom bisector vertical shaft design and transfer energy in the flue gas stream to the combustion air stream through the use of a rotating mass.

3.1.4 ID Fans

The existing flue gas draft fan system consists of two ID fans as previously discussed. The TECO-Westinghouse two-speed pole amplitude modulation (PAM) electric motors are designed to operate nominally at 600 rpm at low-speed and 900 rpm at high-speed. The nameplate horsepower ratings of the motors are 800 at low-speed and 2,500 at high-speed with a service factor of 1.15. They operate at a nominal voltage of 2400 volts. Primary flow control of the ID fans is accomplished by the use of inlet vanes. The ID fans are a TLT-Babcock double inlet centrifugal design, model 1904AZ/1633/0.

3.1.5 Boiler and Draft System Characteristics

Currently, the major performance characteristics of the Unit 2 boiler and existing draft system at MCR are as follows in Tables 3-1, 3-2, and 3-3.

Table 3-1
Unit 2 Boiler Characteristics at MCR

Boiler total heat input	1,665 MBtu/hr (based on the net plant output of 102,000 kW and net heat rate of 9,802 Btu/kWh – Phase 1 design basis, May 2010)
Boiler excess air	18.2 % or 3.00% oxygen – wet basis (Phase 1 design basis, May 2010)
Loss On Ignition (LOI)	7.0 % (plant data 2008-2010)
Ambient conditions	
Dry bulb temperature	74 ^{o}F
Relative humidity	60 %
Barometric pressure	28.97 inHg

Table 3-2
Unit 2 Existing Combustion Air Draft System Characteristics at MCR

Air heater leakage	12 % (Babcock Power leakage data – 2006)
Combustion air temperatures	
FD fan inlet	74 °F
FD fan outlet	~80 °F (calculated)
Air heater outlet	~550 °F (estimated)
Windbox inlet	~550 °F (estimated)
Furnace inlet	~550 °F (estimated)
Draft system operating pressures *	
FD fan inlet	0.0 inwg
FD fan outlet	12.0 inwg
Air preheat coil outlet	11.0 inwg
Air heater outlet	6.0 inwg
Duct to windbox inlet	5.0 inwg
Furnace inlet	0.0 inwg
Draft system differential pressures *	
Air heater	5.0 inw
Ducts to windbox	1.0 inw
Windbox	5.0 inw

Based on the layout of the existing draft system in Figure 3-1 and the boiler and the combustion air draft system characteristics listed in Tables 3-1 and 3-2, the estimated performance requirements of the existing FD fans are shown as the MCR point in Figure 3-2.

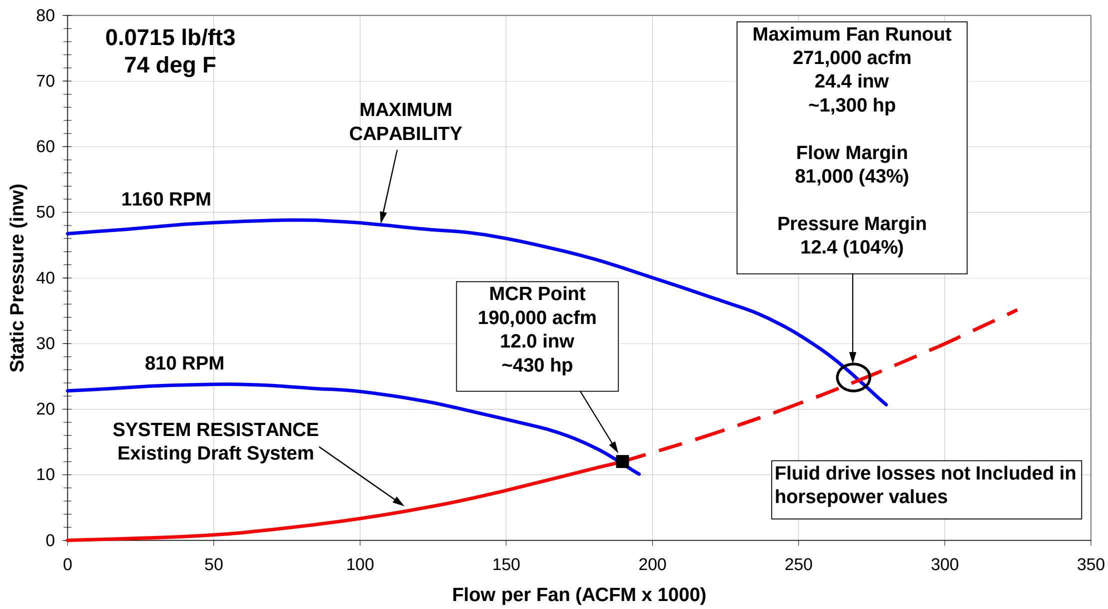

Figure 3-2
Unit 2 Existing FD Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 3-2, it appears that the FD fans have a flow and pressure margin of approximately 53 and 133 percent, respectively. These are well above the ranges of flow and pressure margins that are typically recommended by Black & Veatch.

With the expected installation of an SCR system, however, the existing FD fans would likely need to be abandoned in-place. Due to the equipment congestion immediately north of the boiler building, a new SCR system would likely need be located outside and to the northeast from the boiler building. Additionally, Black & Veatch recommends that a new air heater system be installed for Unit 2 in the vicinity of the new SCR system to minimize ductwork routing and interfacing with flue gas ductwork inside the Unit 2 boiler building. To match the Unit 1 future draft system layout, Black & Veatch is proposing the use of a single new air heater to replace the existing two. This also means that Black & Veatch would recommend that the existing FD fans be abandoned along with the existing air heaters. A new single FD fan would be installed matching the single air heater. A new air preheat system would need to be installed as well.

Table 3-3
Unit 2 Existing Flue Gas Draft System Characteristics at MCR

Air heater leakage	9 % (Babcock Power leakage data – 2006)
CS-ESP leakage	2 % (Babcock Power leakage data – 2006)
Flue gas temperatures	
Boiler outlet	730 °F
Air heater outlet	330 °F
CS-ESP outlet	320 °F
ID fan outlet	~335 °F (calculated)
WFGD outlet	~130 °F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inwg
Boiler outlet	-3.7 inwg
Air heater outlet	-8.0 inwg
CS-ESP outlet	-12.0 inwg
ID fan outlet	13.0 inwg
Common wet scrubber inlet	11.0 inwg
Common wet scrubber outlet	1.0 inwg
Common stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	3.2 inw
Air heater	4.3 inw
CS-ESP	4.0 inw
Duct to common wet scrubber	2.0 inw
WFGD	10.0 inw
Stack	1.0 inw

Based on the layout of the existing draft system in Figure 3-1 and the boiler and the flue gas draft system characteristics listed in Tables 3-1 and 3-3, the estimated performance requirements of the existing ID fans is shown as the MCR point in Figure 3-3.

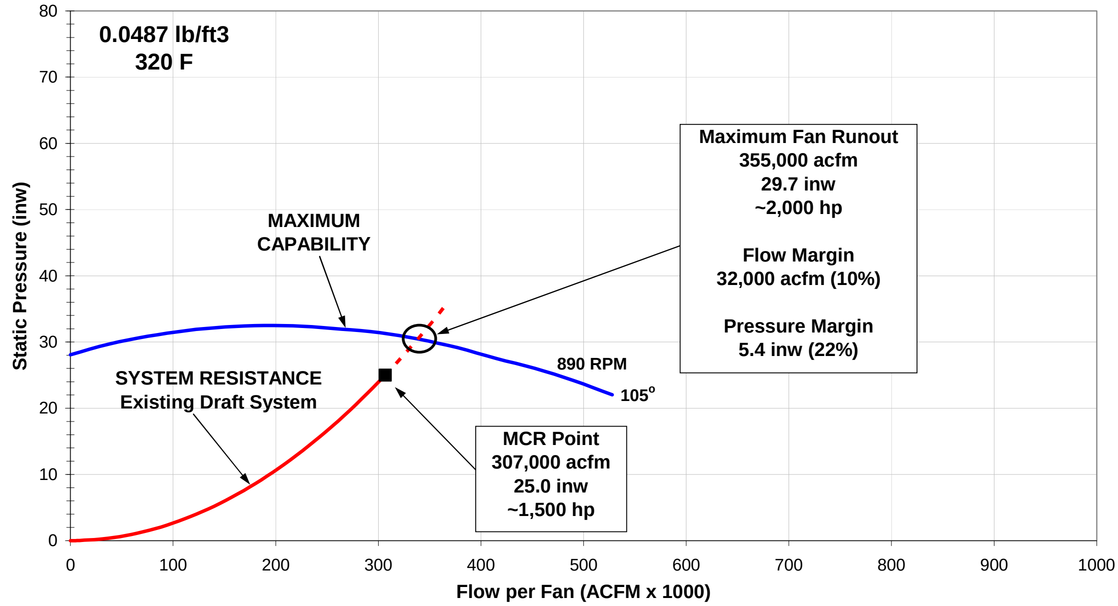

Figure 3-3
Unit 2 Existing ID Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 3-3, it appears that the ID fans have flow and pressure margins of approximately 10 and 22 percent, respectively, as shown by the "Maximum Capability" curve and the "Maximum Fan Runout" box. These margins are below the typically recommended ranges of Black & Veatch flow and pressure margins.

With the expected installation of SCR and PJFF systems, the existing ID fans would not have sufficient margin to overcome the additional system resistance, and provide for margin as well. Additionally, it would be relatively difficult, if possible, to construct new ductwork that would allow these fans to be tied into new major pieces of draft system equipment due the equipment congestion surrounding their location. Therefore, Black & Veatch recommends that the existing Unit 2 ID fans be abandoned in place and replaced with a new single ID fan to match the Unit 1 flue gas draft system layout.

Lastly, the existing draft system equipment and ductwork transient design pressures are listed in Table 3-4. These will be used in determining the amount of stiffening that would be required, if any, in support of the proposed AQC upgrades. These design pressures are unknown for some of the equipment and portions of ductwork of Unit 2. These may need to be determined during detailed design depending on their location in the draft system.

Table 3-4
Unit 2 Existing Draft System Equipment and Ductwork Transient Design Pressures

FD Fan	Unknown
FD Fan Outlet to Air Heater Air Inlet	Unknown
Air Heater (Air-Side)	Unknown
Air Heater Outlet to Windbox	Unknown *
Furnace/Boiler	Unknown *
Boiler Outlet to Air Heater Outlet	Unknown *
Air Heater (Gas-Side)	Unknown
Air Heater Outlet to CS-ESP Inlet	+25 / -18 inwg
CS-ESP	+25 / -18 inwg
CS-ESP Outlet to ID Fan Inlet	+25 / -18 inwg
ID Fan	+112 / -112 inwg
ID Fan Outlet Duct	Unknown *
Common WFGD Inlet Duct	Unknown
Common WFGD	Unknown
Common WFGD Outlet to Stack Inlet	Unknown

* Due to potential NFPA 85 requirements, these design pressures would need to be confirmed if stiffening is required in existing components.

3.2 Future Draft System

3.2.1 *Layout*

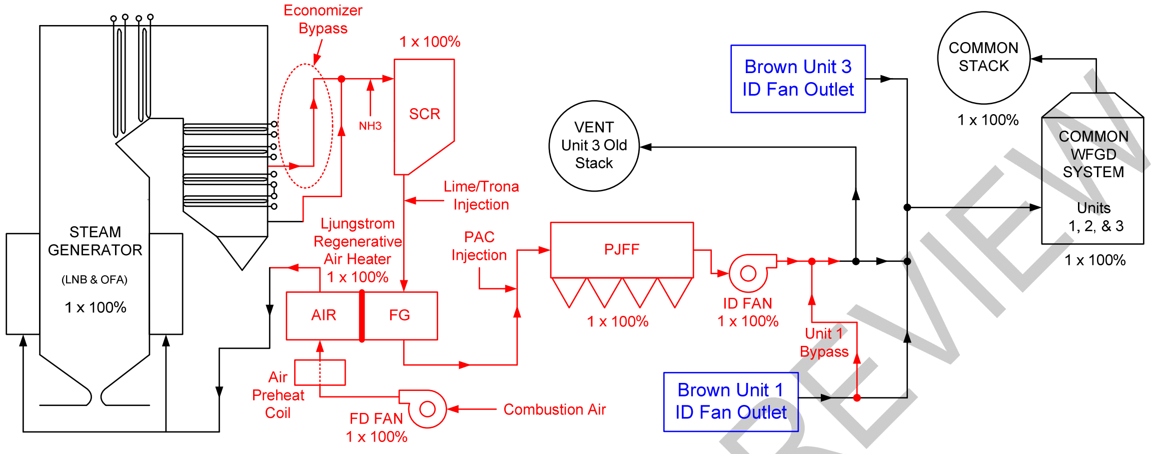

Figure 3-4
Unit 2 Future Draft System

Based on the additions to the Unit 2 draft system previously discussed and the expectation that the existing FD fans and air heaters would be replaced, the combustion air would be redirected through the draft system as follows. The combustion air would enter a new single FD fan that would force the combustion air through the new air preheat coil and new single air heater. Combustion air would then travel to the existing combustion air draft system. The hot water air preheat coil would utilize the existing hot water air preheat system that uses deaerator water to preheat the incoming combustion air maintaining a minimum ACET and air heater flue gas outlet temperature minimizing acid gas condensation. The new single air heater would be similar in design and operation to the existing air heaters. All new combustion air draft system components discussed here would be placed outside to the northeast of the Unit 2 boiler building in close proximity to the new SCR system. An illustration of the Unit 2 future combustion air draft system based on these descriptions is shown in Figure 3-4.

On the flue gas side of the draft system the flue gas would be redirected through the draft system as follows with the expectation that the existing ID fans would be replaced with a new single ID fan. At the boiler outlet flue gas would be redirected outside and to the northeast of the boiler building to the new SCR system bypassing the existing air heaters. Additionally, as the flue gas travels through the boiler, a portion of it may bypass all, or part of, the economizer through a gas-side economizer bypass. The economizer bypass would allow a minimum flue gas temperature entering the SCR to be maintained. After the SCR system the flue gas would then travel through the new air heater and new PJFF system before being drawn into the new ID fan. The new ID fan would then send the flue gas through a section of new duct before entering the existing exhaust duct where the flue gas can be directed to the common WFGD system or the old Unit 3 stack. The existing CS-ESP system and existing ID fans would be abandoned in place. An illustration of the Unit 2 future flue gas draft system based on these descriptions is also shown in Figure 3-4 (in red).

Furthermore, as discussed earlier LG&E/KU has expressed interest in including a means to bypass Unit 1 in the event that the common WFGD system would be offline. This is conceptually shown in Figure 3-4 and physically shown Figure 2-5. Black & Veatch has arranged this bypass to discharge into Unit 2 ID fan outlet ductwork in order to minimize the amount of ductwork that would be needed to include this capability. One concern with this arrangement is that the ductwork downstream of the new cross-connect duct, shown in Figure 2-5, may not allow Units 1 and 2 to bypass the common WFGD system at the same time with both at full load. Relatively high velocities and pressure losses would be the result in this run of duct to the bypass stack if both Units were to operate at full load. A larger concern, though, centers on the venting ability of Unit 2 during unit trips that is required per NFPA 85 code. If Unit 2 were to trip with Unit 1 exhausting flue gas through this duct as well there is the possibility that Unit 2 may not be able to properly vent if control of the Unit 2 ID fan were lost during this trip as well. This concern could possibly be mitigated with controls, however, B&V recommends that the need for and operation of the proposed cross-connect duct shown in Figure 2-5 be extensively reviewed during detailed design.

3.2.2 Combustion Air Draft System Characteristics

Based on the layout discussion, the major performance characteristics of the Unit 2 future draft system at MCR are as follows in Table 3-5. Note that the items in bold in Table 3-5 are new.

Table 3-5
Unit 2 Future Combustion Air Draft System Characteristics at MCR

Air heater leakage	**6 %**
Combustion air temperatures	
FD fan inlet	74 °F
FD fan outlet	~80 °F (calculated)
Air preheat coil outlet	**~100 °F** (estimated)
Air heater outlet	**560 °F** (Table 2-7)
Windbox inlet	560 °F (Table 2-7)
Furnace inlet	560 °F (Table 2-7)
Draft system operating pressures *	
FD fan silencer inlet	**0.0 inwg**
FD fan inlet	**-1.0 inwg**
FD fan outlet	**13.0 inwg**
Air preheat coil outlet	**12.0 inwg**
Air heater outlet	**8.0 inwg**
Existing duct to windbox inlet	5.0 inwg
Furnace inlet	0.0 inwg
Draft system differential pressures *	
FD fan silencer	**1.0 inw**
Air preheat coil	**1.0 inw**
Air heater	**4.0 inw**
Ducts to windbox	**3.0 inw**
Windbox	5.0 inw

Note the air preheat coil outlet and air heater outlet temperatures. These temperatures are estimates based on Black & Veatch experience and an air heater budgetary quote. Black & Veatch recommends that LG&E/KU determine the exact temperatures that would be needed at MCR during detailed design to properly operate the existing combustion air system. Additionally, the system operating pressures and pressure differentials are based on Black & Veatch experience and the existing FD fan curves supplied by LG&E/KU. Again, Black & Veatch recommends that a more detailed review of the combustion air draft system be conducted to determine the exact values that should be used at MCR plant load.

3.2.3 New FD Fan Design Conditions

Based on the layout of the future draft system in Figure 3-4 and the future combustion air draft system characteristics in Table 3-5, the estimated performance requirements of the new single FD fan at MCR are shown in Table 3-6. Also in Table 3-6 are the recommended Test Block conditions developed using the standard Black & Veatch fan sizing philosophy previously outlined. Note the flow and pressure margins of 19 and 38 percent, respectively. The flow margin of 19 percent is slightly below the range of flow margins that typically results from Black & Veatch fan sizing. This is due to a fewer number of components that the FD fan would be forcing combustion air through that have the potential for leakage as compared to the ID fan. Additionally, the air heater pluggage margin was reduced to 25 percent from 50 percent and the 1.0 inw control allowance was not used in an effort create a reasonable pressure margin.

Due to Unit 2's similar size to Unit 1, Black & Veatch has assumed that LG&E/KU would prefer only one centrifugal type fan with a single-speed motor to match the arrangement philosophy of the Unit 1 draft system with its single equipment train. Again, as with the Unit 1 new FD fan, Black & Veatch plans to utilize one of the existing 2400 volt two-speed Unit 2 ID fan motors (600/900 rpm, 800/2,500 hp) as the driver for the new Unit 2 FD fan. The reuse of existing 2400 volt electrical equipment to power the new FD fan would be possible with this arrangement, especially with the capability of starting up the FD fan at the low-speed of 600 rpm of these motors compared to the high-speed of 900 rpm. Additionally, this will allow the use of more existing equipment at the Brown site. Flow control would be accomplished with inlet vanes.

Lastly, note that the FD fan inlet temperature in Table 3-6 is different than that shown in Table 3-5. The temperature in Table 3-5 has been included to represent the design basis for the EW Brown site and is likely an annual average type of temperature. The MCR temperature shown in Table 3-6 is recommended by Black & Veatch for design purposes. Furthermore, the Test Block temperature in Table 3-6 is another 25 degrees F higher based on the Black & Veatch fan sizing philosophy previously discussed.

Table 3-6
Unit 2 New FD Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	85	110
Inlet Density (lb/ft^3)	0.0699	0.0668
Flow per Fan (acfm)	377,000	448,000
Inlet Pressure (inwg)	-1.0	-1.3
Outlet Pressure (inwg)	13.0	18.0
Static Pressure Rise (inw)	14.0	19.3
Shaft Power Required (HP) *	1,200	1,600
Efficiency (%) *	70	85
Number of Fans	1	1
Flow Margin (%)	---------	19
Pressure Margin (%)	---------	38

* Estimated – assumes single-speed operation with inlet vanes. Black & Veatch plans to use the existing Unit 2 two-speed 600/900 rpm 800/2,500 hp ID fan motors to drive the new Unit 2 FD fan.

3.2.4 New Air Heaters and Air Preheat System Design Conditions

Based on the layout of the future draft system in Figure 3-4 and the future combustion air draft system characteristics in Table 3-5, the estimated performance of the new single air heater for conceptual design purposes is listed in Table 3-7. The values in Table 3-7 would need to be confirmed during detailed design.

Table 3-7
Unit 1 New Air Heater Design Conditions at MCR

Type	Regenerative Ljungstrom Bisector
Shaft Orientation	Vertical
Flows (lb/hr)	
Entering Air *	1,575,000
Entering Gas (based on combustion calculations)	1,646,000
Leaving Air (based on combustion calculations)	1,483,000
Leaving Gas *	1,738,000
Temperatures (deg F)	
Entering Air	100
Entering Gas	730
Leaving Air *	560
Leaving Gas w/o Leakage *	342
Leaving Gas w/ Leakage	330
ACET *	221
Draft Pressures (inwg)	
Entering Air	12.0
Entering Gas	-13.7
Leaving Air *	9.2
Leaving Gas *	-18.0
Pressure Differentials (inw)	
Air *	2.8
Gas *	4.3 (6.0 maximum specified)
Air – Gas (cold end) *	32.3
Leakages	
Air – Gas (lb/hr) *	92,000
Percent (%) *	5.6

* Determined by The Air Preheater Company

The values in Table 3-7 would be used in sizing the proposed new single air heater. However, note that the pressure differentials do not match up with Table 3-5. Black & Veatch chose to utilize the more conservative pressure differential estimates in

Table 3-5 in sizing the FD fan due to the new SCR system that would have the potential to increase these differentials. Also note the parameters in Table 3-7 that have been provided by The Air Preheater Company. Again, as with the values in Table 3-5, the values in Table 3-7 would need to be finalized during detailed design to properly size the new air heater.

For the air preheat system Black & Veatch chose to use hot water as the heating medium which would be extracted from the deaerator. This was chosen to match the existing philosophy of hot water air preheating for Unit 2. For the existing air preheat system to operate with the new draft system, though, new pumps may be needed due to the additional distance that the new air preheat coil would be away from the Unit 2 boiler. New piping, valves, switchgear, power feeds, and control and instrumentation are expected to be required as well. The exact performance requirements of the new hot water air preheat coil to maintain a minimum ACET and to minimize acid gas condensation on the flue gas side would be determined during detailed design. However, for conceptual design purposes it has been assumed that this equipment would maintain the air heater air inlet temperature at approximately 100 degrees F to maintain an air heater flue gas outlet temperature of 330 degrees F as shown in Table 3-7. Black & Veatch has chosen an air heater gas outlet temperature of 330 degrees F to stay above an acid gas condensation temperature estimated to be in the range of 300 to 315 degrees F. A determination of whether or not the existing pumps could be reused would also be done during detailed design, however, for conceptual design purposes Black & Veatch has assumed that the pumps would be replaced. Based on previous experience the hot water pumps have been sized to meet a flow rate of 800 gpm at a total developed head (TDH) of 200 ft. This sizing equates to a maximum power consumption of 44.1 kW per pump which includes pump and motor inefficiencies.

3.2.5 Flue Gas Draft System Characteristics

The major performance characteristics of the Unit 2 future flue gas draft system at MCR are as follows in Table 3-8. Note that the items in bold in Table 3-8 are new.

Table 3-8 Unit 2 Future Flue Gas Draft System Characteristics at MCR	
SCR system leakage	**2 %**
Air heater leakage	**6 %**
PJFF system leakage	**3 %**
Flue gas temperatures	
Boiler outlet	730 ^{o}F
SCR system outlet	**730 ^{o}F**
Air heater outlet	**330 ^{o}F**
PJFF outlet	**330 ^{o}F**
ID fan outlet	~355 ^{o}F (calculated)
Wet scrubber outlet	~130 ^{o}F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inwg
Boiler outlet	-3.7 inwg
SCR system outlet	**-13.7 inwg**
Air heater outlet	**-19.7 inwg**
PJFF outlet	**-25.7 inwg**
ID fan outlet	**13.0 inwg**
Common wet scrubber inlet	11.0 inwg
Common wet scrubber outlet	1.0 inwg
Common stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	3.2 inw
SCR system	**10.0 inw**
Air heater	**6.0 inw**
PJFF system	**6.0 inw**
Duct to common wet scrubber	2.0 inw
WFGD	10.0 inw
Stack	1.0 inw

Note that the flue gas draft system operating parameters estimated in Table 3-8 are based on Black & Veatch experience. Black & Veatch recommends that a more detailed review of the future flue gas draft system be conducted to determine the exact values that should be used at MCR plant load for detailed design.

3.2.6 Analysis of Existing ID Fans with Future Draft System

To further demonstrate the affect the additional draft system resistance of the SCR and PJFF systems, shown in Table 3-8, have on the existing ID fans and that a new ID fan should be installed, a new system resistance curve is shown in Figure 3-5. The MCR point of this new system resistance curve in Figure 3-5 is clearly outside the capabilities of the existing ID fans. Additional fan capacity would be required to reach the new draft system MCR point and to provide additional margin.

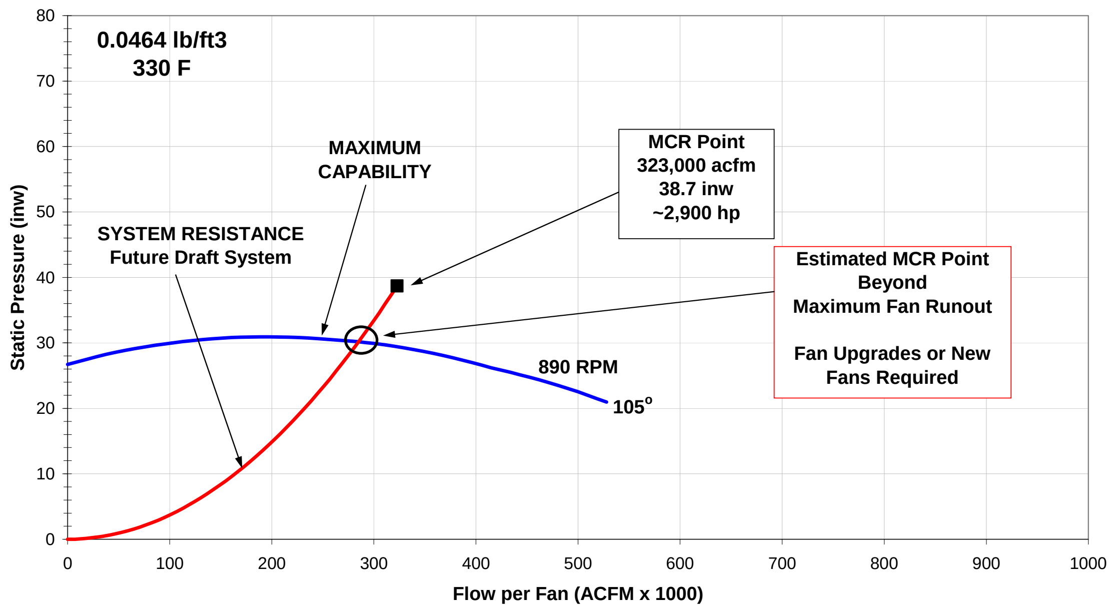

Figure 3-5
Unit 2 Existing ID Fan Performance with Future Draft System

3.2.7 New ID Fan Design Conditions

Based on the layout of the future draft system in Figure 3-4 and the future flue gas draft system characteristics in Table 3-8, the estimated performance requirements of the new single ID fan at MCR is shown in Table 3-9. Also in Table 3-9 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy. Note the flow and pressure margins of 23 and 40 percent, respectively.

Black & Veatch has assumed that LG&E/KU would prefer only one centrifugal type fan with a single-speed motor to match the arrangement philosophy of the Unit 1 draft system with its single train of single-speed FD and ID fans. Flow control would be accomplished with inlet vanes.

Table 3-9
Unit 2 New ID Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	330	355
Inlet Density (lb/ft^3)	0.0464	0.0438
Flow per Fan (acfm) *	646,000	793,000
Inlet Pressure (inwg)	-25.7	-35.6
Outlet Pressure (inwg)	13.0	18.5
Static Pressure Rise (inw)	38.7	54.1
Shaft Power Required (HP) **	5,600	7,900
Efficiency (%) **	70	85
Number of Fans	1	1
Flow Margin (%)	---------	23
Pressure Margin (%)	---------	40

*Per fan basis with both fans in operation
**Estimated – assumes variable speed operation

3.2.8 Operating and Transient Design Pressures

With a pressure margin of 38 percent listed in Table 3-6, the new FD fan would be expected to operate the future combustion air draft system with the Test Block pressures listed in Table 3-10. The normal operating, or MCR, pressures have been shown in Table 3-10 as well for reference. Note that the items in bold in Table 3-10 are new.

With a pressure margin of 40 percent listed in Table 3-9, the new ID fan would be expected to operate in the future flue gas draft system with the Test Block pressures listed in Table 3-11. The normal operating, or MCR, pressures have been shown in Table 3-11 as well for reference. Note that the items in bold in Table 3-11 are new.

Table 3-10
Unit 2 Future Combustion Air Draft System Pressures at MCR and New FD Fan Test Block

	MCR Pressure (inwg)	Test Block Pressure (inwg)
Atmosphere	0.0	0.0
Silencer Outlet	**-1.0**	**-1.3**
FD Fan Outlet	**13.0**	**18.0**
Air Preheat Coil Outlet	**12.0**	**16.8**
Air Heater Outlet	**8.0**	**10.3**
Existing Duct to Windbox Inlet	5.0	6.4
Furnace Inlet	0.0	0.0

Table 3-11
Unit 2 Future Flue Gas Draft System Pressures at MCR and New ID Fan Maximum Capability

	MCR Pressure (inwg)	Test Block Pressure (inwg)
Furnace/Boiler	-0.5	-0.5
Boiler/Economizer Outlet	-3.7	-4.4
SCR Outlet	**-13.7**	**-16.7**
Air Heater Outlet	**-19.7**	**-27.8**
PJFF Outlet	**-25.7**	**-35.6**
ID Fan Outlet	13.0	18.5
Common Wet Scrubber Inlet	11.0	15.8
Common Wet Scrubber Outlet	1.0	2.3
Common Stack Outlet	0.0	0.0

With the future draft system Test Block operating pressures defined in Tables 3-10 and 3-11 for the new FD fan and new ID fan, the future draft system potential minimum transient design pressure requirements can be determined and are shown in Table 3-12. The same Black & Veatch philosophy for calculating the minimum required transient design pressures that was discussed previously is utilized here as well. The transient design pressures in Table 3-12 may initially be used in determining the amount of stiffening of existing and new equipment that would be required, if any, in support of the proposed AQC upgrades. Note that the items in bold in Table 3-12 are new or potential modifications.

Table 3-12
Unit 2 Future Flue Gas Draft System Potential Transient Design Pressure Requirements

FD Fan Silencer	**± 10 inwg ****
FD Fan Silencer Outlet to FD Fan Inlet	**± 10 inwg ****
FD Fan	**Determined by Manufacturer**
FD Fan Outlet to Air Heater Air Inlet	**+35 / -35 inwg**
Air Heater (Air-Side)	**+35 / -35 inwg**
Air Heater Outlet to Existing Air Inlet	**+35 / -35 inwg**
Existing Air Inlet to Windbox	**+35 / -35 inwg ***
Furnace/Boiler	**+35 / -35 inwg ***
Boiler Outlet Duct	**+35 / -35 inwg ***
SCR Inlet Duct	**+35 / -35 inwg**
SCR	**+35 / -35 inwg**
SCR Outlet to Air Heater Gas Inlet	**+35 / -35 inwg**
Air Heater (Gas-Side)	**+35 / -41 inwg**
Air Heater Outlet to PJFF Inlet	**+35 / -41 inwg**
PJFF	**+35 / -52 inwg**
PJFF Outlet to ID Fan Inlet	**+35 / -52 inwg**
ID Fan	**Determined by Manufacturer**
ID Fan Outlet to Existing Common WFGD Scrubber Inlet Duct	**+27 / -10 inwg ****
Common WFGD Scrubber Inlet Duct	Unknown
Common WFGD Scrubber	Unknown
Common WFGD Scrubber Outlet to Stack Inlet	Unknown

* Further research is needed to determine whether this would be required.

** Estimated – Ductwork and equipment downstream of the ID fan up to the stack inlet was assumed to have a minimum transient design pressure rating of +10/-10 inwg, typical of ductwork in that section of a draft system. If the actual design pressures in this section are different, stiffening would likely not be required except for the minimum positive design pressure greater than +10 inwg from the ID fan outlet through the WFGD scrubber. Existing design pressures already higher than +10 inwg should be retained. NFPA 85 does not specifically call out a minimum design pressure requirement for ductwork downstream of ID/Booster fans. **This philosophy also applies to any ductwork and equipment upstream of FD fans.**

Other than the potential boiler stiffening that may be required per NFPA 85 code, stiffening associated with the remaining sections of the existing combustion air and flue gas draft systems is not expected. Portions of the existing combustion air draft system downstream of new ductwork from the new air heater are expected to continue to operate at similar pressures. The existing flue gas draft system downstream of the boiler economizer outlet will be completely replaced except for the ductwork to the common WFGD system that would remain and operate under similar pressures. Stiffening costs associated with any existing portions of the draft system are not expected.

The other part of the NFPA 85 compliance equation involves the use of a dedicated unit vent due to the common WFGD system. As previously discussed during the layout discussion of the future draft system, the ductwork associated with this vent would not require any manipulation for the future draft system and would remain in service.

3.2.9 Additional Items

It is expected that the economizer bypass previously mentioned during the layout discussion would be needed to maintain flue gas temperatures entering the SCR when they are approximately 615°F and lower. This is based on SCR catalyst that Black & Veatch would typically procure for high sulfur eastern bituminous fuels. It is unknown whether this catalyst type or if catalysts with different minimum temperatures would be used. Nevertheless, based on the Brown Unit 2 draft system temperatures listed in Table 3-8, the operation of an economizer bypass is not expected at MCR, but at loads below MCR to maintain this minimum ammonia injection temperature. The exact loads where the economizer bypass would be in operation would be determined during detailed design.

A gas-side economizer bypass, as shown in Figure 3-4, has been determined to be a plausible solution, especially if the existing flue gas ductwork immediately exiting the existing air heaters up to the CS-ESP is partially demolished. Typically these bypasses are each equipped with modulating dampers and expansion joints and consist of multiple, relatively small ducts to avoid structural steel and other obstructions. Economizer backpressure dampers in the main flue gas path may also be required. These ducts would exit the boiler backpass above the economizer and then inject the higher temperature flue gas into the economizer outlet duct at the first possible location to keep duct runs and costs to a minimum. The economizer bypass ductwork and dampers would bypass flue gas around the economizer in the boiler to increase the overall temperature of the flue gas entering the new SCR system. The proper reaction temperatures entering the SCR system would be maintained by the modulating dampers in the economizer bypass ducts. Should the pressure drop across the economizer decrease to a point that does not allow a suitable amount of flue gas to bypass the economizer, usually at low loads, backpressure dampers in the main flue gas path would be modulated to correct this. Additional pressure drop associated with these economizer backpressure dampers has not been added to Table 3-8 since their use is not expected at unit MCR. These ducts could be combined into one duct or remain separate entering the economizer outlet duct. Issues with limited mixing time are not expected since the flue gas must pass through a long duct run before entering the SCR system. Additionally, Black & Veatch recommends that the bypass duct be constructed out of materials that can withstand the flue gas temperatures exiting the boiler backpass prior to the economizer. Carbon steel material temperature limitations in the new economizer outlet ductwork may also become a concern if excessive amounts of flue gas bypass the economizer.

The most effective way of setting up the economizer bypass ductwork would be determined during detailed design. If designed and installed properly, gas-side bypasses are effective but require that the dampers, in a hot and particulate intensive environment, be properly maintained.

Other means of maintaining a minimum SCR flue gas inlet temperature consist of water-side economizer bypasses and water-side economizer recirculation systems. These systems can be effective as well but also have their own disadvantages. The most appropriate SCR catalyst with its own specific minimum temperature, as well as the most effective means of maintaining the minimum inlet temperature, would be further evaluated during detailed design.

Concerns of ammonium bisulfate (ABS) and other deposits are also important when considering SCR systems for NOx control. These deposits are caused by reactions between acid gases and excess ammonia (ammonia slip) from the SCR system. They form in the air heaters as the flue gas cools, typically in difficult to clean areas of air heaters. Black & Veatch recommends that the new single air heater incorporate the proper additions at the time of the SCR system installation which will require a separate study to be performed by the air heater manufacturer during detailed design. These air heater additions typically include, but are not limited to, the following:

- Installation of baskets with an enamel coating.
- Installation of only two basket layers.
- Installation of high energy and/or multimedia (steam or compressed air / high pressure water) sootblowers with controls that allow even cleaning of all basket areas.

4.0 Unit 3

4.1 Existing Draft System

4.1.1 Layout

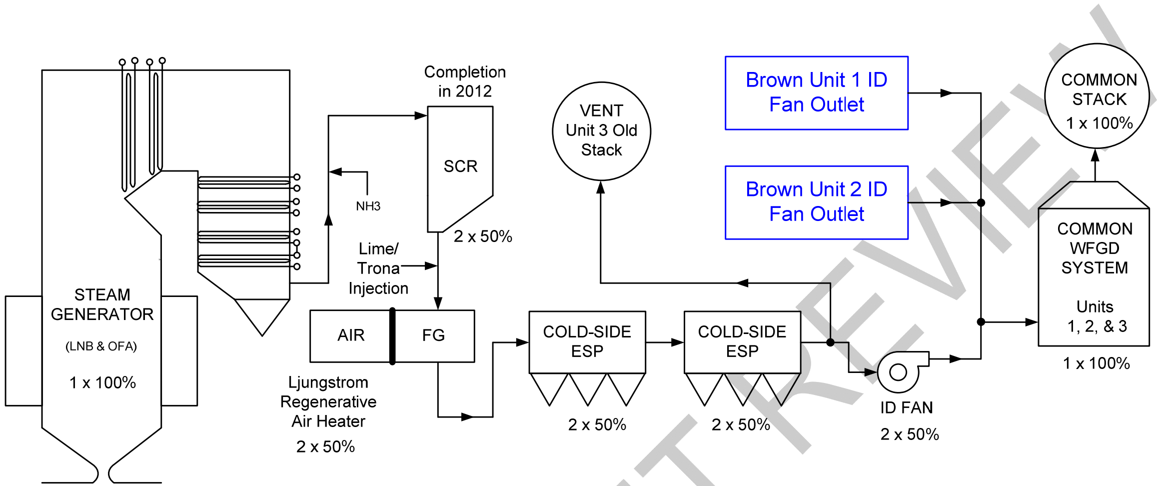

Figure 4-1
Unit 3 Existing Draft System

The Units 3 flue gas draft system begins at the outlet of the boiler, or economizer. As shown in Figure 4-1 the flue gas travels directly to and SCR system with two 50 percent capacity modules removing NOx emissions. This system is scheduled for completion in 2012 by others and is not a part of this study work. Next, the flue gas enters two 50 percent capacity ljungstrom regenerative type air heaters that transfer a large amount of energy in the flue gas to the combustion air entering the boiler. Once through the air heaters, flue gas is then drawn through two sets of two 50 percent capacity CS-ESP systems by two 50 percent capacity ID fans. The flue gas is then sent to the WFGD scrubber common to all Brown units. Once the majority of the sulfur dioxide in the flue gas is removed by the common WFGD scrubber, the flue gas then exits to the atmosphere through the common stack. Also included in the flue gas draft system is a vent, per NFPA 85 code, to the old Unit 3 stack used as a separate vent in the event of unit trips or other situations where exhausting the flue gas into the common WFGD system is not possible. An illustration of the Unit 3 existing flue gas draft system based on these descriptions is shown in Figure 4-1.

Unlike Units 1 and 2, the Unit 3 combustion air draft system would not require any modifications for the proposed AQC upgrades and will, therefore, not be discussed here.

4.1.2 ID Fans

The existing flue gas draft fan system consists of two ID fans as previously discussed. The TECO-Westinghouse two-speed PAM electric motors are designed to operate nominally at 720 rpm at low-speed and 900 rpm at high-speed. The nameplate horsepower ratings of the motors are 6,300 at low-speed and 10,750 at high-speed with a service factor of 1.15. They are rated for a voltage of 12,470 volts. Primary flow control of the ID fans is accomplished by the use of inlet vanes. The ID fans are a TLT-Babcock double inlet centrifugal design, model 1904AZ/2327.

4.1.3 Boiler and Draft System Characteristics

Currently, the major performance characteristics of the Unit 3 boiler and existing flue gas draft system at MCR are as follows in Tables 4-1 and 4-2.

Table 4-1
Unit 3 Boiler Characteristics at MCR

Boiler total heat input	4,120 MBtu/hr (based on net plant output of 433,000 kW and heat rate of 9,516 Btu/kWh)
Boiler excess air	16.8 % (2.8 % oxygen, wet basis)
Loss On Ignition (LOI)	7.0 % (plant data 2008-2010)
Ambient conditions	
Dry bulb temperature	74 ^{o}F
Relative humidity	60 %
Barometric pressure	28.97 inHg

Table 4-2
Unit 3 Existing Flue Gas Draft System Characteristics at MCR

Air heater leakage	6 % (Babcock Power leakage data – 2006)
CS-ESP leakage	12 % (Babcock Power leakage data – 2006)
Flue gas temperatures	
Boiler outlet	730 ^{o}F
Air heater outlet	340 ^{o}F
CS-ESP outlet	330 ^{o}F
ID fan outlet	~350 ^{o}F (calculated)
WFGD outlet	~130 ^{o}F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inwg
Boiler outlet	-5.0 inwg
Air heater outlet	-18.0 inwg
CS-ESP outlet	-19.0 inwg
ID fan outlet	12.0 inwg
Common wet scrubber inlet	11.0 inwg
Common wet scrubber outlet	1.0 inwg
Common stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	4.5 inw
Air heater	13.0 inw
CS-ESP	1.0 inw
Duct to common wet scrubber	1.0 inw
WFGD	10.0 inw
Stack	1.0 inw

Based on the layout of the existing draft system in Figure 4-1 and the boiler and the flue gas draft system characteristics listed in Tables 4-1 and 4-2, the estimated performance requirements of the existing ID fans is shown as the MCR point in Figure 4-2.

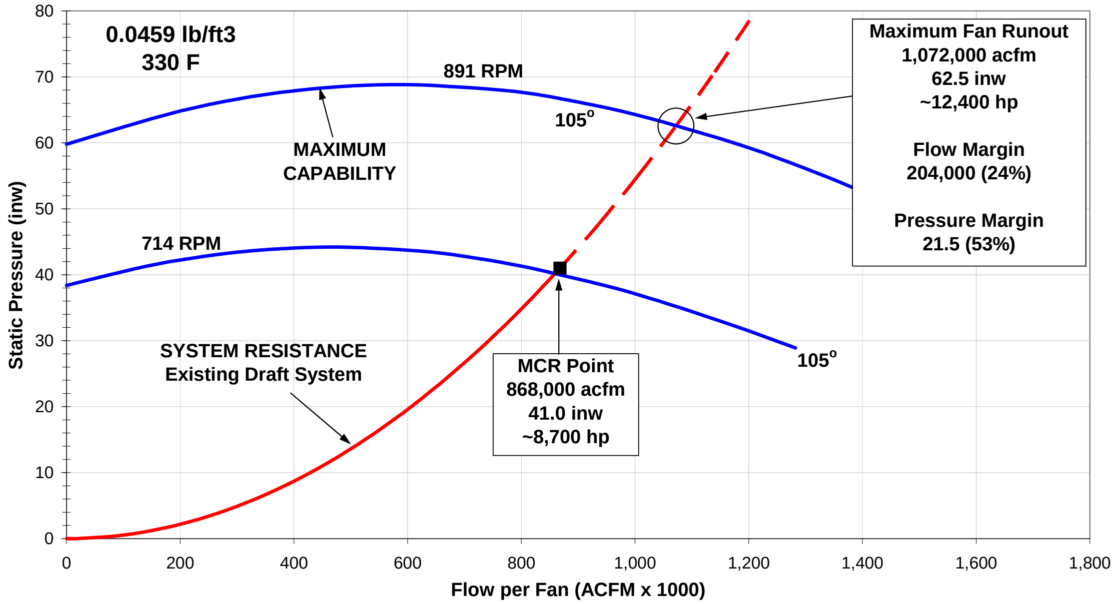

Figure 4-2
Unit 3 Existing ID Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 4-2, it appears that the ID fans have flow and pressure margins of approximately 24 and 53 percent, respectively. These margins are at or above the ranges of flow and pressure margins that are typically recommended by Black & Veatch. Additionally, although the estimated horsepower requirement at "Maximum Fan Runout" listed in Figure 4-2 is beyond the existing ID fan motor nameplate horsepower of 10,750 hp, the service factor of 1.15 could be utilized to attain this fan capability. Also shown in Figure 4-2 are the performance curves for the two speeds that the ID fans are capable of and based on the MCR point previously discussed it is expected that the ID fans would need operate at high-speed once the SCR is in place in 2012.

With the expected installation of a PJFF system to replace the existing CS-ESP systems, the existing ID fans appear to have sufficient margin to overcome the additional system resistance, and provide for margin as well. Additionally, it appears the unit is not experiencing any issues with these fans. Therefore, based on their performance attributes, they could be retained without the need for additional fan capacity. Also, the location of the existing ID fans southwest of the Unit 3 boiler building should allow for their reuse in the proposed new draft system that will be discussed later. Adding ductwork to place the ID fans downstream of a new PJFF system (it is recommended that PJFF systems be under negative pressure) would be possible within the given site space constraints since the new PJFF and the other new major equipment would be placed to the west of these Unit 3 existing ID fans. Retaining the existing ID fans as the sole provider of flue gas draft pressure appears feasible from a performance and physical space standpoint.

Lastly, the existing draft system equipment and ductwork transient design pressures are listed in Table 4-3. These will be used in determining the amount of stiffening that would be required, if any, in support of the proposed AQC upgrades. These design pressures are unknown for some of the equipment and portions of ductwork of Unit 3. These may need to be determined during detailed design depending on their location in the draft system.

Table 4-3
Unit 3 Existing Draft System Equipment and Ductwork Transient Design Pressures

Furnace/Boiler	Unknown *
Boiler Outlet to Air Heater Outlet	Unknown *
Air Heater	Unknown *
Air Heater Outlet to CS-ESP Inlet	Unknown *
CS-ESP	+15 / -27 inwg
CS-ESP Outlet to ID Fan Inlet	Unknown *
ID Fan	+133 / -133 inwg
ID Fan Outlet Duct	Unknown
Common WFGD Inlet Duct	Unknown
Common WFGD	Unknown
Common WFGD Outlet to Stack Inlet	Unknown

* Due to potential NFPA 85 requirements, these design pressures would need to be confirmed if stiffening is required in existing components.

4.2 Future Draft System

4.2.1 Layout

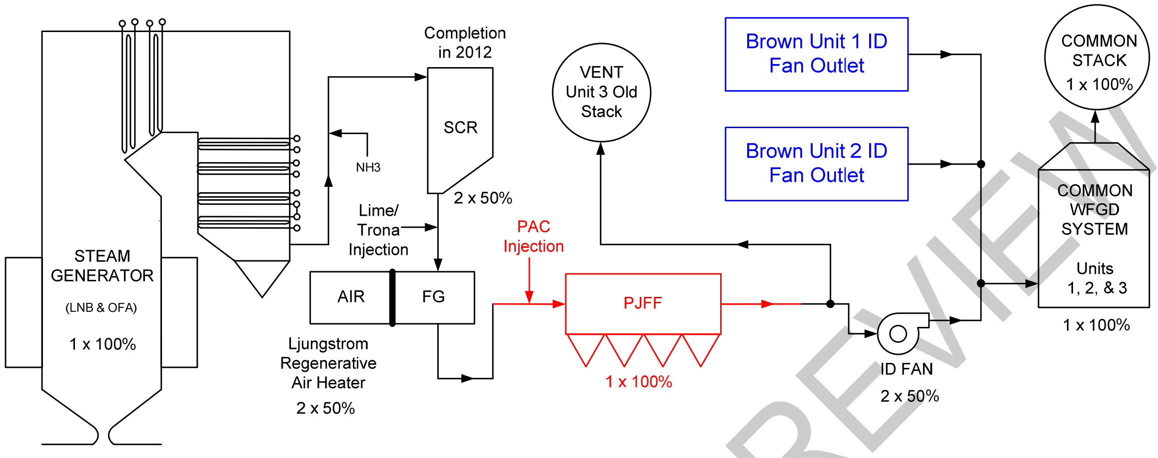

Figure 4-3
Unit 3 Future Draft System

Based on the additions to the Unit 3 flue gas draft systems previously discussed, the flue gas would be redirected through the draft system as follows with the expectation that the existing ID fans would remain in service. At the air heater outlets flue gas would be redirected outside the boiler building to the new PJFF system before being drawn into the existing ID fans. Both existing CS-ESP systems would be bypassed and abandoned in place. However, a portion of the existing ductwork downstream of the existing CS-ESP systems would need to be retained per NFPA 85 code allowing the existing vent to the old Unit 3 stack to remain in service. As previously mentioned no changes would need to be made to the combustion air draft system for Unit 3. An illustration of the Unit 1 future flue gas draft system based on these descriptions is also shown in Figure 4-3.

4.2.2 Flue Gas Draft System Characteristics

The major performance characteristics of the Unit 3 future flue gas draft system at MCR is as follows in Table 4-4. Note that the items in bold in Table 4-4 are new.

Table 4-4 Unit 3 Future Flue Gas Draft System Characteristics at MCR	
SCR system leakage	**2 % (2012 Completion – By Others)**
Air heater leakage	6 %
PJFF system leakage	**3 %**
Flue gas temperatures	
Boiler outlet	730 °F
SCR system outlet	**730 °F (2012 Completion – By Others)**
Air heater outlet	340 °F
PJFF outlet	**340 °F**
ID fan outlet	~370 °F (calculated)
Wet scrubber outlet	~130 °F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inwg
Boiler outlet	-5.0 inwg
SCR system outlet	**-15.0 inwg (2012 Completion – By Others)**
Air heater outlet	-28.0 inwg
PJFF inlet	**-29.0 inwg**
PJFF outlet	**-35.0 inwg**
ID fan outlet	12.0 inwg
Common wet scrubber inlet	11.0 inwg
Common wet scrubber outlet	1.0 inwg
Common stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	4.5 inw
SCR system	**10.0 inw (2012 Completion – By Others)**
Air heater	13.0 inw
Air Heater to PJFF Ductwork	**1.0 inw**
PJFF system	**6.0 inw**
Duct to common wet scrubber	1.0 inw
WFGD	10.0 inw
Stack	1.0 inw

Note that the flue gas draft system operating parameters estimated in Table 4-4 are based on Black & Veatch experience. Black & Veatch recommends that a more detailed review of the future flue gas draft system be conducted to determine the exact values that should be used at MCR plant load for detailed design.

4.2.3 Analysis of Existing ID Fans with Future Draft System

To demonstrate the affect the additional draft system resistance of the new SCR and PJFF systems would have on the existing ID fans a new system resistance curve is shown in Figure 4-4. The existing ID fans in their existing configuration would have margins of approximately 16 percent on flow and 35 percent on pressure as shown in Figure 4-4 by the "Maximum Capability" curve and the "Maximum Fan Runout" box. These margins would be below the typically recommended Black & Veatch margins, but Black & Veatch believes they are sufficient to warrant the reuse of the existing ID fans. Additionally, although the estimated horsepower requirement at "Maximum Fan Runout" listed in Figure 4-4 is beyond the existing ID fan motor nameplate horsepower of 10,750 hp, the service factor of 1.15 could be utilized to attain this fan capability. The existing Unit 2 ID fans will be retained with the future flue gas draft system as the only means to overcome the future flue gas draft system resistance.

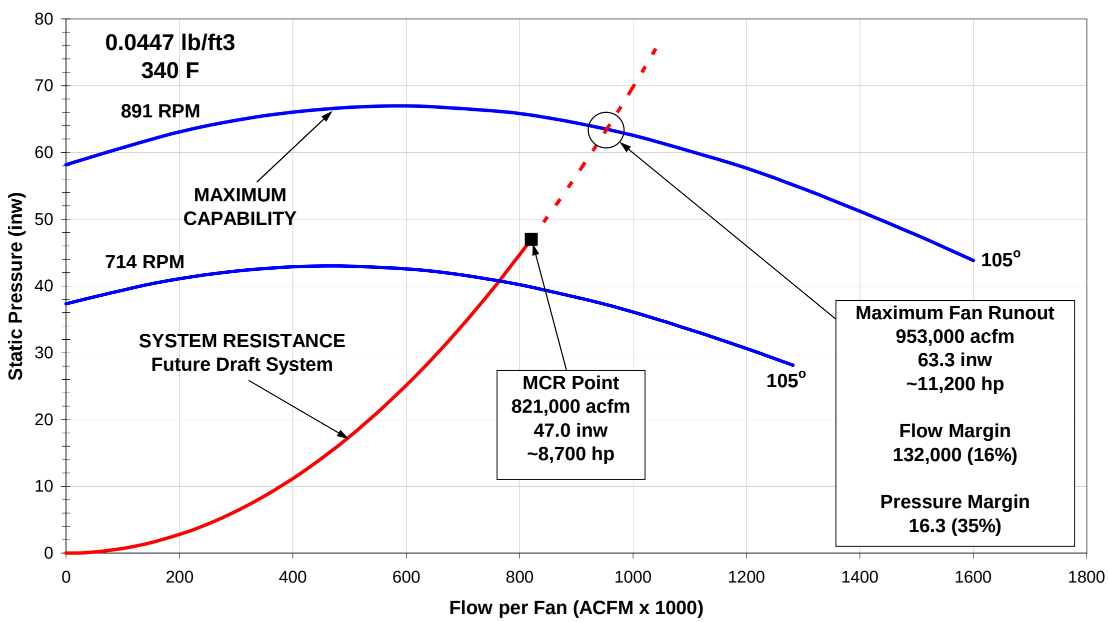

Figure 4-4
Unit 3 Existing ID Fan Performance with Future Draft System

Also shown in Figure 4-4 are the performance curves for the two speeds that the ID fans are capable of and based on the MCR point shown it is expected that the ID fans would need operate at high-speed once the PJFF system is in place.

4.2.4 Operating and Transient Design Pressures

With the determination of the existing ID fan's ability to provide the necessary capability to support the proposed new flue gas draft system additions, the maximum draft system pressures that the ID fan is capable of must be determined. This will allow the draft system design, or transient, pressures to be determined to properly design the new ductwork and draft system components preventing exposure to permanent deformation or buckling. Based on the existing ID fan's maximum capability in the future draft system, these maximum ("Maximum Fan Runout") pressures are listed in Table 4-5. The normal operating, or MCR, pressures have been shown in Table 4-5 as well for reference.

Table 4-5
Unit 3 Future Flue Gas Draft System Pressures at MCR and Existing ID Fan Maximum Capability

	MCR Pressure (inwg)	Maximum Fan Runout Pressure (inwg)
Furnace/Boiler	-0.5	-0.5
Boiler/Economizer Outlet	-5.0	-5.8
SCR Outlet	**-15.0**	**-17.6**
Air Heater Outlet	-28.0	-39.9
PJFF Inlet	**-29.0**	**-41.1**
PJFF Outlet	**-35.0**	**-48.2**
ID Fan Outlet	12.0	15.1
Common Wet Scrubber Inlet	11.0	14.0
Common Wet Scrubber Outlet	1.0	2.2
Common Stack Outlet	0.0	0.0

With the future draft system Maximum Fan Runout defined in Table 4-5 for the existing ID fans, the future flue gas draft system potential minimum transient design pressure requirements can be determined and are shown in Table 4-6. The same Black & Veatch philosophy for calculating the minimum required transient design pressures that was discussed previously is utilized here as well. The transient design pressures in Table

4-6 may initially be used in determining the amount of stiffening of existing and new equipment that would be required, if any, in support of the proposed AQC upgrades. Note that the items in bold in Table 4-6 are new or potential modifications.

Table 4-6
Unit 3 Future Flue Gas Draft System Potential Transient Design Pressure Requirements

Furnace/Boiler	**+35 / -35 inwg ***
Boiler Outlet Duct	**+35 / -35 inwg ***
SCR Inlet Duct	**+35 / -35 inwg ****
SCR	**+35 / -35 inwg ****
SCR Outlet Duct	**+35 / -35 inwg ****
Air Heater Inlet Duct	**+35 / -35 inwg *****
Air Heater	**+35 / -58 inwg *****
Air Heater Outlet Duct	**+35 / -60 inwg *****
PJFF Inlet Duct	**+35 / -60 inwg *****
PJFF	**+35 / -70 inwg**
PJFF Outlet to ID Fan Inlet	**+35 / -70 inwg**
ID Fan	+133 / -133 inwg
ID Fan Outlet to Common WFGD Scrubber Inlet	Unknown
Common WFGD Scrubber	Unknown
Common WFGD Scrubber Outlet to Stack Inlet	Unknown

* Further research is needed to determine whether this would be required.

** Black & Veatch has assumed that the new SCR system being installed by others would be designed for transient pressures of +35/-35 inwg.

*** These transient design pressures are expected to be needed with the PJFF system installation.

The design process of the recently installed Unit 3 SCR system would have required an analysis of the boiler transient design pressures per NFPA 85 code as previously discussed, and possibly boiler stiffening. The Unit 3 SCR system installation is already in progress and it is expected that the unit transient design pressure analyses have been completed. Under this assumption the new PJFF system could be installed without additional boiler stiffening costs as these would have been associated with the SCR system, if needed. However, further research during detailed design would be required to confirm this. Stiffening costs associated with the remaining sections of the existing draft system are not expected. Portions of the existing draft system upstream of new ductwork to the new PJFF system are expected to have been recently stiffened in support of the SCR system installation. Portions of the existing draft system downstream of the new PJFF system include the recently installed existing ID fans and common WFGD system and this equipment is expected to have incorporated the ID fan capacity into their design.

Lastly, the other part of the NFPA 85 compliance equation involves the use of a dedicated unit vent due to the common WFGD system. As previously discussed during the layout discussion of the future draft system, this would require that the existing vent on the south side of the old Unit 3 stack remain in service. Therefore, portions of the existing ductwork between the existing CS-ESP systems and the ID fans would need to remain in service as well.

5.0 Summary

The Unit 1 major modifications and additions to the draft system being considered include a new SCR system and a new PJFF system. The Unit 2 major modifications and additions to the draft system being considered include the same as that of Unit 1. Unit 3 would only include a new PJFF system since an SCR system installation is already in progress. In order for the existing Brown draft systems to support the installation of this additional draft system equipment to control, or enhance the control of, certain flue gas emissions, significant upgrades would be required.

To support the installation of the AQC equipment being considered, Black & Veatch has identified various improvements to the Brown draft systems. Unit 1 would include extensive modifications to the combustion air and flue gas draft systems due to the congestion in the boiler building preventing installation of an SCR system immediately downstream of the boiler. The combustion air draft system would be equipped with a new single-speed centrifugal FD fan with inlet vanes for flow control, a new bisector regenerative air heater, a new hot water air preheat coil, and a new hot water air preheat system in close proximity to the new SCR system. The new FD fan would be driven by one of the existing Unit 2 ID fan motors. The existing FD fans, air heaters, and air preheat system would be abandoned. The flue gas draft system would utilize the recently installed existing single-speed centrifugal ID fan and the recently installed vent to the old Unit 1 stack. The need for stiffening of remaining portions of the existing draft system is not expected due to the extensive amount of ductwork and equipment being replaced and the recent draft system upgrades incorporated for the common WFGD installation. However, boiler stiffening may be required.

Since the Unit 2 draft system additions are similar to Unit 1, Unit 2 would be similarly equipped except that a new single-speed centrifugal ID fan would be installed as well abandoning the existing ID fans. As with Unit 1, the new FD fan would be driven by one of the existing Unit 2 ID fan motors. Similar to Unit 1, the need for stiffening of remaining portions of the existing draft system is not expected due to the extensive amount of ductwork and equipment being replaced. However, boiler stiffening may be required.

For Unit 3, Black & Veatch would plan to utilize the existing two-speed centrifugal ID fans with inlet vanes for flow control since they have sufficient capacity to support the new SCR (by others) and new PJFF systems. No changes to the existing combustion air system would be needed. Also, stiffening of remaining portions of the existing draft system of Unit 3 is not expected due to the recent SCR system and common WFGD system installations. The need for boiler stiffening is not expected as well since the analysis to determine whether this would be needed or not is already assumed to have been completed for the Unit 3 SCR system design.