LG&E/KU – Ghent Station

Phase II Air Quality Control Study

Draft System

March 29, 2011
Revision B – Issued For Client Review

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Building a world of difference.

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Tables

1.0 Introduction

As a part of the draft system analysis of the conceptual design process for Ghent, 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, 3, and 4 the major modifications and additions to the draft system being considered include new pulse jet fabric filter (PJFF) systems that will supplement the existing electrostatic precipitator (ESP) systems of each unit in the removal of particulate. For Unit 2 a new selective catalytic reduction (SCR) system for removing NO_x emissions as well as a new PJFF system would be added. For more detail on the AQC equipment modifications, additions, etc. discussed here for each Ghent unit refer to Section 5.0.

Following this introductory section for the Ghent 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 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 Ghent 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

2.0 Unit 1

2.1 Existing Draft System

2.1.1 Layout

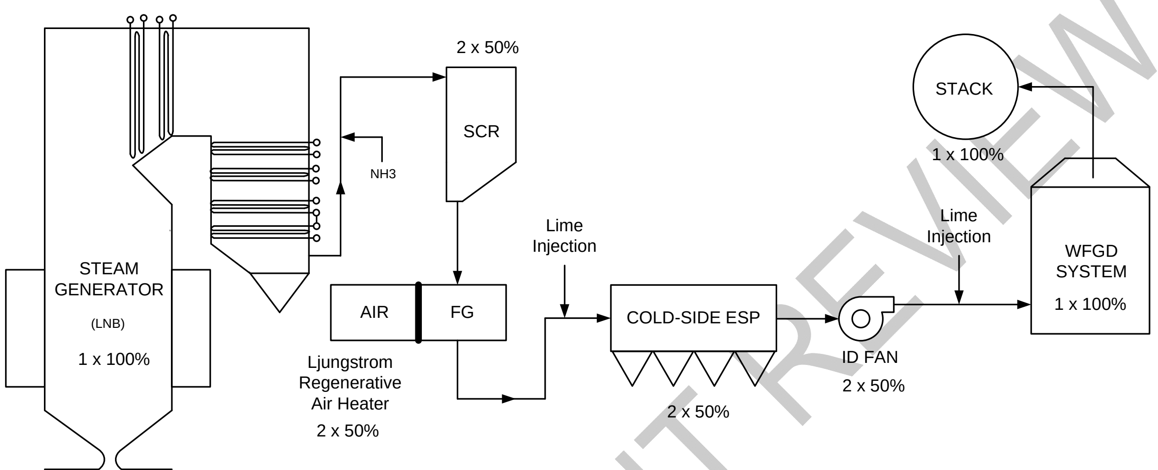

Figure 2-1
Ghent Unit 1 Existing Draft System

The flue gas draft system begins at the outlet of the boiler, or economizer (from this point forward in this draft system analysis section the flue gas draft system will be referred to as just the draft system). From there the flue gas travels directly to an SCR system for the removal of NO_x emissions then to two 50 percent capacity ljungstrom regenerative type air heaters. The air heaters transfer energy in the flue gas to the combustion air entering the boiler. Once through the air heaters, the flue gas travels into two 50 percent capacity cold-side electrostatic precipitator (CS-ESP) systems where particulate is removed. Two 50 percent capacity induced draft (ID) fans then draw the flue gas out of the CS-ESP systems and send it to the wet flue gas desulfurization (WFGD) system. The flue gas path is split between two trains of equipment from the boiler outlet up to this point. 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 stack. An illustration of the Unit 1 existing draft system based on this description is shown in Figure 2-1.

2.1.2 ID Fans

The existing draft fan system consists of two ID fans as previously discussed. The TECO-Westinghouse electric motors for each ID fan have a maximum operating nominal speed of 900 rpm. The nameplate horsepower rating of the ID fan motors is 9,000 horsepower with a service factor of 1.15. They operate at a nominal voltage of 4160 volts. Primary flow control of the ID fans is accomplished by the use of a variable frequency drive (VFD) system manufactured by ASI Robicon (Siemens) that allows for variable speed flow control. The input voltage to the VFD system is nominally 4160 volts. The ID fans are double inlet centrifugal fans with a maximum nominal speed capability of 900 rpm with the VFD system. The current ID fans, ABB Garden City Fan model 138 AF 6472, were installed in 1992 with two-speed capability (720/900 rpm). They were then modified around 2004 with blade tips, more powerful motors, and a VFD system.

2.1.3 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 and 2-2.

Table 2-1
Unit 1 Boiler Characteristics at MCR

Boiler total heat input	5,300 MBtu/hr (based on the Unit 3 net plant output of 476,000 kW and heat rate of 11,131 Btu/kWh – worst case across Ghent units)
Boiler excess air	18.2 % or 3.00% oxygen – wet basis (estimated)
Loss On Ignition (LOI)	2.0 % (estimated)
Ambient conditions	
Dry bulb temperature	74 ^{o}F
Relative humidity	60 %
Barometric pressure	29.09 inHg

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

SCR leakage	2 % (estimated)
Air heater leakage	10 % (estimated)
CS-ESP leakage	5 % (estimated)
Flue gas temperatures	
Boiler outlet	757 ^{o}F
SCR system outlet	757 ^{o}F
Air heater outlet	347 ^{o}F
CS-ESP outlet	308 ^{o}F
ID fan outlet	~325 ^{o}F (calculated)
WFGD outlet	~130 ^{o}F (calculated)
Draft system operating pressures *	
Furnace pressure	-0.5 inches of water gauge (inwg)
Boiler outlet	-3.2 inwg
SCR outlet	-13.2 inwg
Air heater outlet	-22.4 inwg
CS-ESP outlet	-25.7 inwg
ID fan outlet	6.1 inwg
Wet scrubber outlet	1.7 inwg
Stack outlet	0.0 inwg
Draft system differential pressures *	
Boiler	2.7 inches of water (inw)
SCR system	10.0 inw
Air heater	9.2 inw
CS-ESP	3.3 inw
WFGD	4.4 inw
Stack	1.7 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 draft system characteristics listed in Tables 2-1 and 2-2, the estimated performance requirements of the existing ID fans are shown as the MCR point in Figure 2-2.

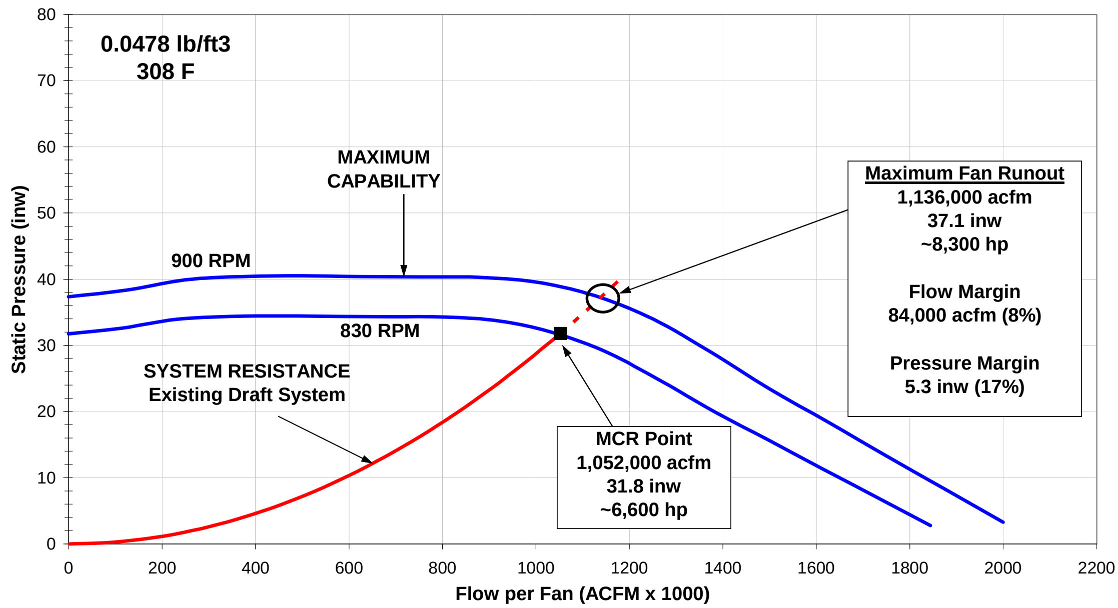

Figure 2-2
Unit 1 Existing ID Fan Performance with Existing Draft System

It should be noted that the Maximum Capability performance curve shown in Figure 2-2 is an estimate of the Ghent Unit 1 ID fan performance capabilities. Since no performance curve is available representing the increased performance due to the addition of blade tips from the 2004 modifications, B&V estimated the performance based on the original ID fans curves from 1992 and the effective blade length extension provided by the blade tips. The actual ID fan maximum capability may vary.

Based on the MCR point shown in Figure 2-2, it appears that the ID fans operate at approximately 830 rpm and have flow and pressure margins of approximately 8 and 17 percent, respectively. These margins are below the ranges of flow and pressure margins that are typically recommended by Black & Veatch for fans in either new or retrofit applications. The recommended Black & Veatch Test Block fan sizing philosophy, outlined at the beginning of this section, would typically result in flow margins in the range of 20 to 30 percent and pressure margins in the range of 35 to 45 percent.

With the expected installation of a PJFF system, the existing ID fans do not appear to have sufficient margin to overcome the additional system resistance, and provide for margin as well. Conversely, it appears that the unit is not experiencing any issues with the existing ID fans. Therefore, the existing Unit 1 ID fans could be retained and supported with a set of new booster fans.

Lastly, the existing draft system equipment and ductwork transient design pressures are listed in Table 2-3. 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 1. These may need to be determined during detailed design depending on their location in the draft system.

Table 2-3
Unit 1 Existing Draft System Equipment and Ductwork Transient Design Pressures

Furnace/Boiler	+13 / -7 inwg
Boiler Outlet Duct	+13 / -7 inwg
SCR Inlet Duct	+Unknown * / -35 inwg
SCR	+Unknown * / -35 inwg
SCR Outlet Duct	+Unknown * / -35 inwg
Air Heater Inlet Duct	Unknown *
Air Heater	Unknown *
Air Heater Outlet to CS-ESP Inlet	+Unknown * / -35 inwg
CS-ESP	+10 / -35 inwg
CS-ESP Outlet to ID Fan Inlet	+Unknown * / -35 inwg
ID Fan	Unknown (typically more conservative than connecting duct)
ID Fan Outlet to WFGD Inlet	Unknown *
WFGD	+33 / -Unknown * inwg
WFGD Outlet to Stack Inlet	+2 / -Unknown * inwg

* 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

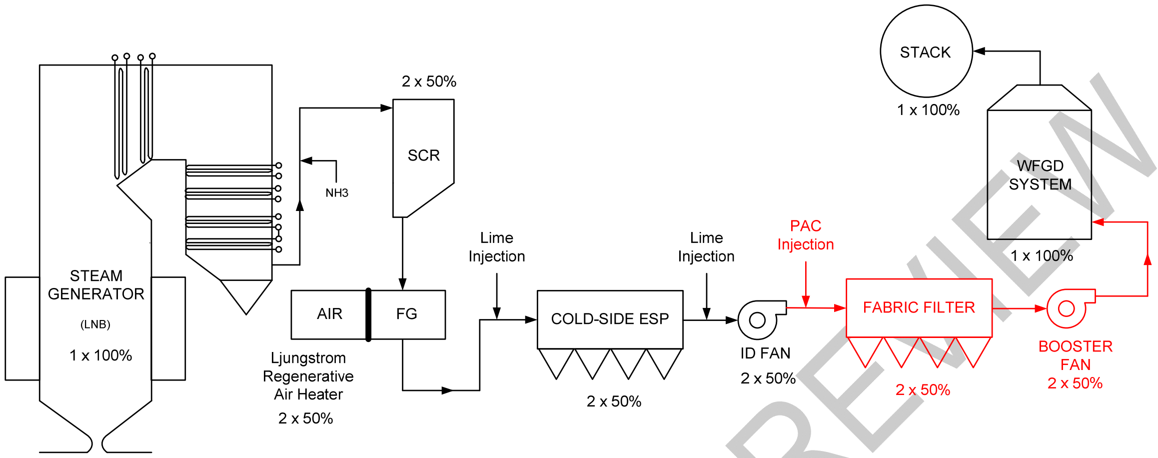

Figure 2-3
Unit 1 Future Draft System

Based on the additions to the Unit 1 draft system previously discussed and the expectation that the existing ID fans will be supported by a set of new booster fans, the flue gas would be redirected through the draft system as follows. Once the flue gas is through the ID fans it would enter the new PJFF system allowing for the removal of particulate. The proposed new booster fans would then draw the flue gas out of the PJFF system and send it to the WFGD system. The flue gas path would remain split between two trains of equipment from the boiler outlet up to this point. An illustration of the Unit 1 future draft system based on this description is shown in Figure 2-3.

2.2.2 Draft System Characteristics

The major performance characteristics of the Unit 1 future draft system at MCR are as follows in Table 2-4. Note that the items in bold in Table 2-4 are new.

Table 2-4 Unit 1 Future Draft System Characteristics at MCR	
SCR system leakage	2 %
Air heater leakage	10 % (estimated)
CS-ESP leakage	5%
PJFF system leakage	**3 %**
Flue gas temperatures	
Boiler outlet	757 ^{o}F
SCR system outlet	757 ^{o}F
Air heater outlet	347 ^{o}F
CS-ESP outlet	308 ^{o}F
ID fan outlet	~325 ^{o}F (calculated)
PJFF outlet	**~325 ^{o}F** (calculated)
Booster fan outlet	**~335 ^{o}F** (calculated)
Wet scrubber outlet	~130 ^{o}F (calculated)
Draft system differential pressures	
Boiler	2.7 inw
SCR	10.0 inw
Air heater	9.2 inw
CS-ESP	3.3 inw
ID fan to PJFF inlet	**1.0 inw**
PJFF	**6.0 inw**
Booster fan outlet to WFGD inlet	**1.0 inw**
WFGD	4.4 inw
Stack	1.7 inw

2.2.3 Analysis of Existing ID Fans with Future Draft System

To further demonstrate the affect the additional draft system resistance of the PJFF, shown in Table 2-4, has on the existing ID fans and that new booster fans should be installed, a new system resistance curve is shown in Figure 2-4. The MCR point of this new system resistance curve in Figure 2-4 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. Since the unit is not experiencing any issues with the existing ID fans, Black & Veatch has elected to provide this additional fan capacity through the use of booster fans downstream of the PJFF system.

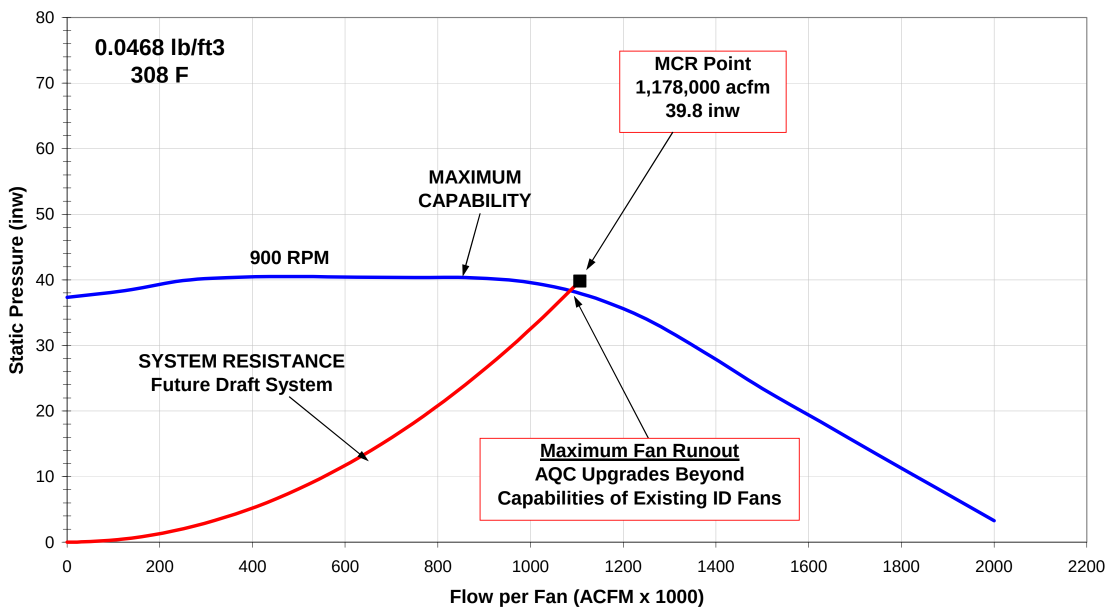

Figure 2-4
Unit 1 Existing ID Fan Performance with Future Draft System

New booster fans would be placed downstream of the PJFF in order to operate the PJFF system under negative draft pressures. This would also require that the booster fans overcome the resistance of the existing WFGD system. With this in mind, the performance requirements of the existing ID fans would change to that which is estimated and shown in Figure 2-5.

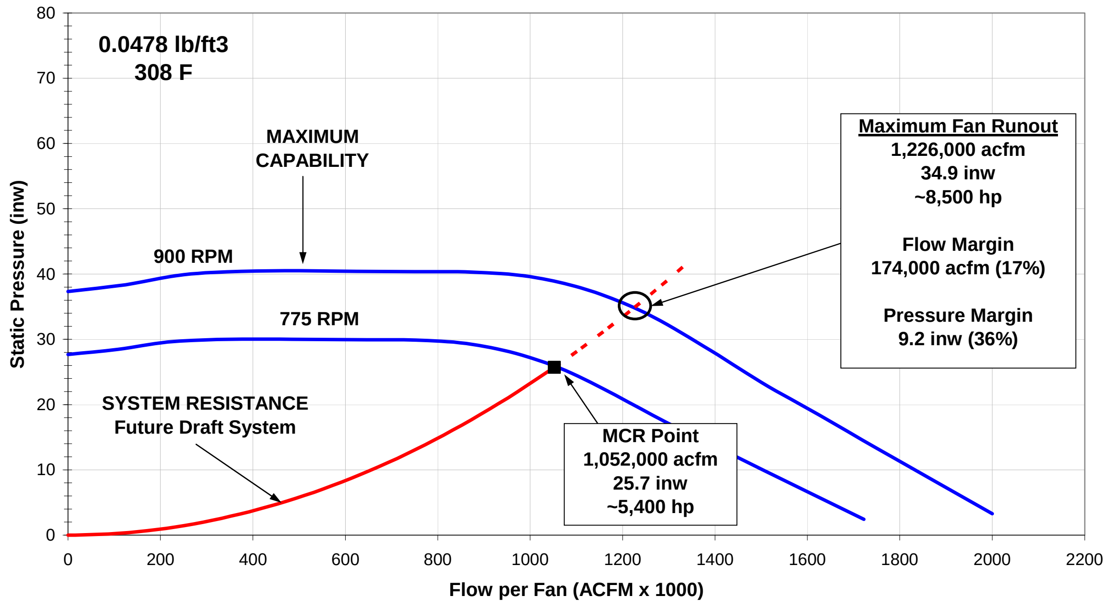

Figure 2-5
Unit 1 Existing ID Fan Performance with Future Draft System and New Booster Fans

2.2.4 New Booster Fan Design Conditions

Based on the layout of the future draft system in Figure 2-3 and the future draft system characteristics in Table 2-4, the estimated performance requirements of the new booster fans at MCR are shown in Table 2-5. Also in Table 2-5 are the recommended Test Block conditions developed using the standard Black & Veatch fan sizing philosophy previously outlined. Note the flow and pressure margins of 25 and 47 percent, respectively.

Additionally, Black & Veatch has assumed that LG&E/KU would prefer centrifugal type fans with variable speed capability to match the existing ID fans. The variable speed capability would be through the use of VFD systems.

Table 2-5
Unit 1 New Booster Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	------	900
Inlet Temperature (°F)	325	350
Inlet Density (lb/ft^3)	0.0491	0.0473
Flow per Fan (acfm) *	1,054,000	1,318,000
Inlet Pressure (inwg)	-7.0	-9.4
Outlet Pressure (inwg)	7.1	11.3
Static Pressure Rise (inw)	14.1	20.7
Shaft Power Required (HP) **	2,800	5,100
Efficiency (%) **	85	85
Number of Fans	2	2
Flow Margin (%)	---------	25
Pressure Margin (%)	---------	47

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

Lastly, due to the similarity in unit size and recommended fan arrangements between Units 1 and 2, consideration should be given to installing the same booster fans and drive system for both Units 1 and 2. This will be discussed later with Unit 2 in more detail.

2.2.5 Operating and Transient Design Pressures

With a pressure margin of 47 percent listed in Table 2-5, the new booster fans would be expected to operate in the future draft system with the Test Block pressures listed in Table 2-6. The normal operating, or MCR, pressures have been shown in Table 2-6 as well for reference. The normal operating, or MCR, pressures upstream of the existing ID fans are not shown since they are not expected to change with the addition of a PJFF system downstream.

Table 2-6
Unit 1 Future Flue Gas Draft System Pressures at MCR and New Booster Fan Test Block

	MCR Pressure (inwg)	Booster Fan Test Block Pressure (inwg)
ID Fan Outlet	0.0	0.0
PJFF Inlet	-1.0	-1.4
PJFF Outlet	-7.0	-9.4
Booster Fan Outlet	7.1	11.3
Wet scrubber Inlet	6.1	9.9
Wet scrubber Outlet	1.7	3.5

With the future draft system Test Block operating pressures defined in Table 2-6, the future draft system potential minimum transient design pressure requirements can be determined and are shown in Table 2-7. 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 -9.4 inwg (see Table 2-6) when the booster fans are operating at Test Block conditions. The calculated negative transient design pressure in this case would be 44 percent higher or -13.5 inwg. Since this pressure is lower than the NFPA 85 minimum of -35 inwg that will be discussed later, -35 inwg would be the minimum transient design pressure. The positive transient design pressure would be +35 inwg (see Table 2-7).

The transient design pressures in Table 2-7 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. Since National Fire Protection Association (NFPA) 85 requires that new flue gas ductwork and equipment between the boiler outlet and the ID fan inlet (it should be implied that this would include booster fans as well) be designed for transient pressures of ± 35 inwg, 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 2-7 are new or potential modifications.

Table 2-7
Unit 1 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 / -35 inwg ***
Air Heater Outlet to CS-ESP Inlet	**+35 *** / -35 inwg
CS-ESP	**+35 *** / -35 inwg
CS-ESP Outlet to ID Fan Inlet	**+35 *** / -35 inwg
ID Fan	Unknown (typically more conservative than connecting duct)
ID Fan Outlet to PJFF Inlet	**+35 / -35 inwg ***
PJFF Inlet Duct	**+35 / -35 inwg**
PJFF	**+35 / -35 inwg**
PJFF Outlet to Booster Fan Inlet	**+35 / -35 inwg**
New Booster Fan	(Determined by Manufacturer)
Booster Fan Outlet Duct	**+33** / -10 inwg **
Wet Scrubber Inlet Duct	+33 / -10 inwg **
WFGD	+33 / -10 inwg **
Wet Scrubber Outlet to Stack Inlet	± 10 inwg **

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

** Estimated – Ductwork and equipment downstream of the new booster fans 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 booster fan outlet through the wet 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.

The AQC equipment additions and changes to all of the Ghent units will likely be considered major alterations or extensions to the existing facilities per the NFPA 85 code - Section 1.3 (2007 Edition). The code, in this instance, would imply that the boiler and flue gas ductwork from the boiler outlet (economizer outlet) to the ID fan inlet 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 <u>a reasonable degree of safety</u> can be provided without upgrading to the full extent of the code.

With the addition of the proposed Ghent 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."

The design process of the recently installed Unit1 1 SCR system would have required an analysis of the boiler transient design pressures as previously discussed, and possibly boiler stiffening. Since the Unit 1 SCR system is in place without the boiler being stiffened to the new NFPA 85 design pressures, it is expected that the new PJFF system could be installed without the addition of cost prohibitive boiler stiffening and stiffening of other existing equipment. However, further research during detailed design would be required to confirm this.

3.0 Unit 2

3.1 Existing Draft System

3.1.1 Layout

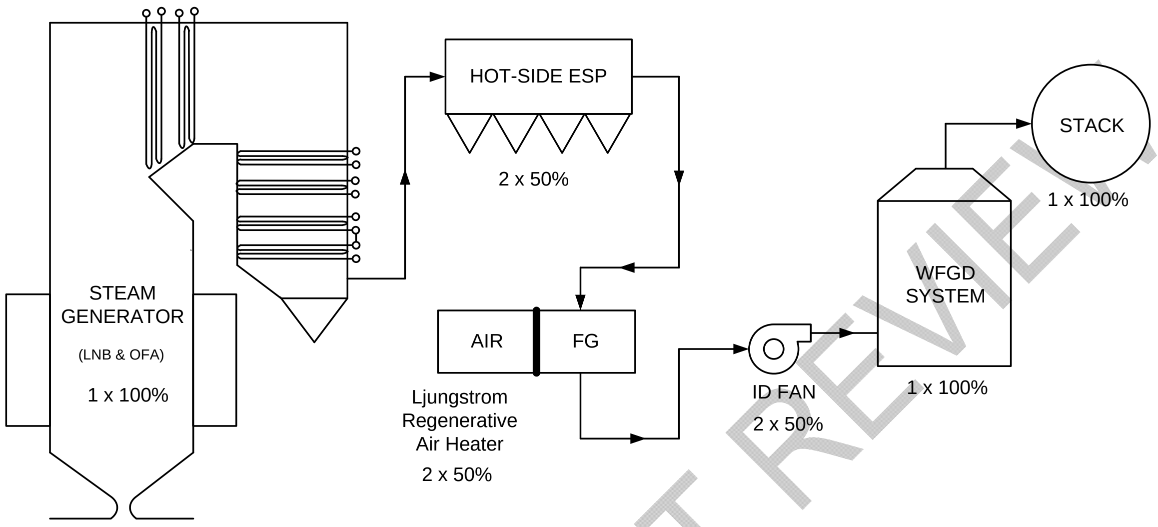

Figure 3-1
Unit 2 Existing Draft System

The draft system begins at the outlet of the boiler, or economizer. From there the flue gas travels directly to two 50 percent capacity hot-side ESPs (HS-ESP) where particulate is removed. Two 50 percent capacity ljungstrom regenerative type air heaters then transfer a large amount of energy in the flue gas to the combustion air entering the boiler. Once through the air heaters, two 50 percent capacity ID fans then draw the flue gas out of the air heaters and send it to the wet scrubber. The flue gas path is split between two trains of equipment from the boiler outlet up to this point. Once the majority of the sulfur dioxide in the flue gas is removed by the wet scrubber, the flue gas then exits to the atmosphere through the stack. An illustration of the Unit 2 existing draft system based on this description is shown in Figure 3-1.

3.1.2 ID Fans

The existing draft fan system consists of two ID fans as previously discussed. The TECO-Westinghouse electric motors for each ID fan have a maximum operating nominal speed of 900 rpm. The nameplate horsepower rating of the ID fan motors is 12,500 horsepower with a service factor of 1.15. They operate at a voltage of 6600 volts. Primary flow control of the ID fans is accomplished by the use of a VFD system manufactured by ASI Robicon (Siemens) that allows for variable speed flow control. The input voltage to the VFD system is nominally 4160 volts. The ID fans, Howden model L5N.3938, are double inlet centrifugal fans with a maximum nominal speed capability of 900 rpm with the VFD system.

3.1.3 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 and 3-2.

Table 3-1
Unit 2 Boiler Characteristics at MCR

Boiler total heat input	5,300 MBtu/hr (based on the Unit 3 net plant output of 476,000 kW and heat rate of 11,131 Btu/kWh – worst case across Ghent units)
Boiler excess air	21.8 % or 3.50% oxygen – wet basis (estimated)
Loss On Ignition (LOI)	2 % (estimated)
Ambient conditions	
Dry bulb temperature	74 ^{o}F
Relative humidity	60 %
Barometric pressure	29.09 inHg

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

HS-ESP leakage	5 % (estimated)
Air heater leakage	10 % (estimated)
Flue gas temperatures	
Boiler outlet	659 ^{o}F
HS-ESP outlet	586 ^{o}F
Air heater outlet	281 ^{o}F
ID fan outlet	~300 ^{o}F (calculated)
Wet scrubber outlet	~130 ^{o}F (calculated)
Draft system operating pressures	
Furnace pressure	-0.5 inwg
Boiler outlet	-5.1 inwg
HS-ESP outlet	-10.8 inwg
Air heater outlet	-18.6 inwg
ID fan outlet	11.4 inwg
Wet scrubber outlet	1.5 inwg
Stack outlet	0.0 inwg
Draft system differential pressures	
Boiler	4.6 inw
HS-ESP	5.7 inw
Air heater	7.8 inw
Wet scrubber	9.9 inw
Stack	1.5 inw

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

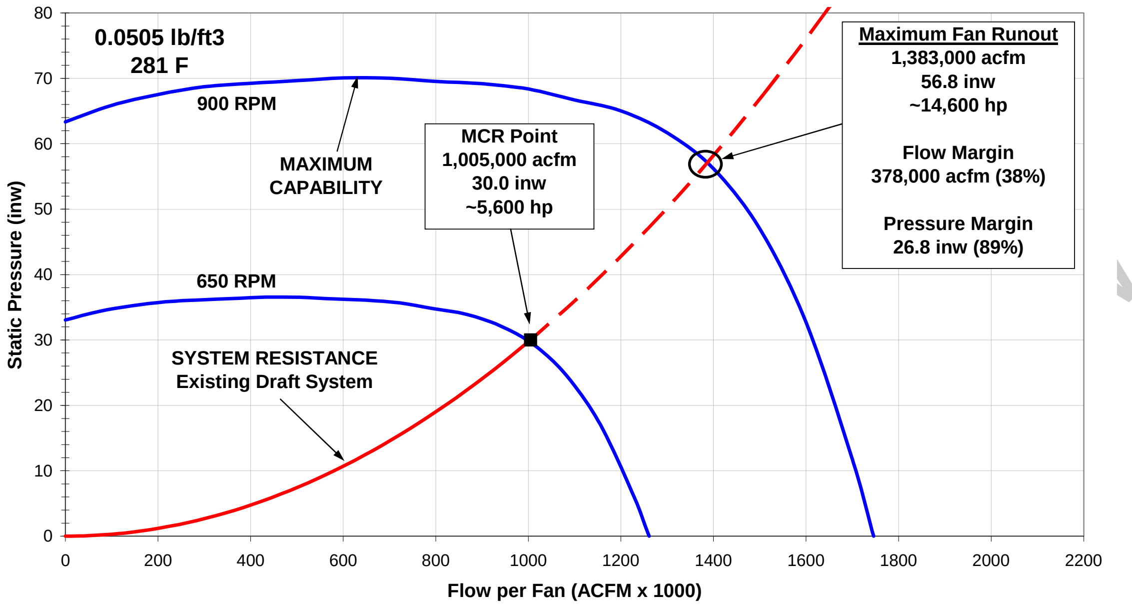

Figure 3-2
Unit 2 Existing ID Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 3-2, it appears that the ID fans operate at approximately 650 rpm and have flow and pressure margins of approximately 38 and 89 percent, respectively. Unlike the Unit 1 existing ID fan margins, these are well 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 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. However, the location of the existing ID fans is less than ideal due to the significantly limited amount of space. Inlet and outlet ductwork for the HS-ESP as well as ID fan is in this area. Placing the ID fans downstream of a new PJFF system (it is recommended that PJFF systems be under negative pressure) would require space that does not appear to exist for the additional ductwork that would be required in the ID fan area. Retaining the existing ID fans as the sole provider of flue gas draft pressure does not appear feasible from a physical space limitation standpoint. However, the possibility does exist for the existing ID fans to be relocated where new inlet and outlet ductwork could more easily be positioned to allow the PJFF system to be upstream of these ID fans. Black & Veatch would expect this to be reviewed more in detailed design, though, due to the specific unknowns that are involved at this point. Therefore, a set of new booster fans is recommended to support the ID fans if a PJFF system is installed in the future.

Lastly, the existing draft system equipment and ductwork transient design pressures are listed in Table 3-3. 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 2. These may need to be determined during detailed design depending on their location in the draft system.

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

Furnace/Boiler	+26.5 / -26.5 inwg
Boiler Outlet to HS-ESP Inlet	+10 / -30 inwg
HS-ESP	+10 / -30 inwg
HS-ESP Outlet to Air Heater Inlet	+10 / -30 inwg
Air Heater	Unknown *
Air Heater Outlet to ID Fan Inlet	+10 / -30 inwg
ID Fan	Unknown (typically more conservative than connecting duct)
ID Fan Outlet to WFGD Inlet	+6 / -6 inwg **
WFGD	+6 / -6 inwg **
WFGD Outlet to Stack Inlet	+6 / -6 inwg

* The design pressures of the air heaters and upstream flue gas duct would not be affected by the installation of a PJFF system. However, if an SCR system is installed in the future, these design pressures would need to be confirmed to allow the SCR system installer to apply the proper amount of stiffening to existing equipment if required.

** These design pressures listed by LG&E/KU are lower than the operating pressures listed in Table 3-2. LG&E/KU would need to reevaluate these design pressures if a PJFF system is installed

3.2 Existing Draft System

3.2.1 Layout

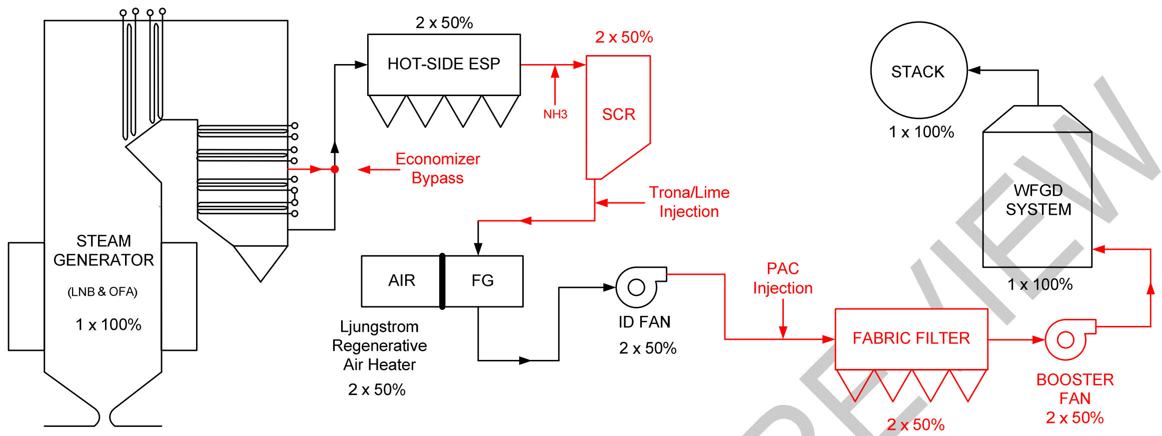

Figure 3-3
Unit 2 Future Draft System

Based on the additions to the Unit 2 draft system previously discussed and the expectation that the existing ID fans will be supported by a set of new booster fans, the flue gas would be redirected through the draft system as follows. At the outlet of the HS-ESP the flue gas would travel to the new SCR system allowing for the removal of NOx emissions before entering the air heaters. Additionally, as the flue gas travels through the boiler, a portion of it may bypass all, or part of, the economizer. The economizer bypass would allow a minimum flue gas temperature entering the SCR to be maintained. Once the flue gas is through the ID fans it would enter the new PJFF system allowing for the removal of particulate. The proposed new booster fans would then draw the flue gas out of the PJFF system and send it to the WFGD system. The flue gas path would remain split between two trains of equipment from the boiler outlet up to this point. An illustration of the Unit 2 future draft system based on this description is shown in Figure 3-3.

3.2.2 Draft System Characteristics

The major performance characteristics of the Unit 2 future draft system at MCR are as follows in Table 3-4. Note that the items in bold in Table 3-4 are new.

Table 3-4
Unit 2 Future Draft System Characteristics at MCR

SCR system leakage	**2 %**
HS-ESP leakage	5 % (estimated)
Air heater leakage	10 % (estimated)
PJFF system leakage	**3 %**
Flue gas temperatures	
Boiler outlet	659 ^{o}F
HS-ESP outlet	586 ^{o}F
SCR outlet	**586 ^{o}F ***
Air heater outlet	281 ^{o}F
ID fan outlet	~300 ^{o}F (calculated)
PJFF outlet	~300 ^{o}F (calculated)
New Booster fan outlet	~310 ^{o}F (calculated)
Wet scrubber outlet	~130 ^{o}F (calculated)
* This temperature is below expected minimum ammonia injection temperatures. Usage of an economizer bypass system is expected at all loads with the HS-ESP in service	
Draft system differential pressures	
Boiler	4.5 inw
HS-ESP	5.7 inw
SCR	**10.0 inw**
Air heater	7.8 inw
ID fan outlet to PJFF inlet	**1.0 inw**
PJFF	**6.0 inw**
Booster fan outlet to WFGD inlet	**1.0 inw**
WFGD	9.9 inw
Stack	1.5 inw

3.2.3 Analysis of Existing ID Fans with Future Draft System

There is the potential, from a performance perspective, that the existing ID fans could provide the only motive force to move the flue gas through the draft system. However, new ductwork would need to be arranged to locate the ID fans downstream of the PJFF system as it is highly recommended to operate a PJFF under negative draft pressure. As previously mentioned, though, significant cost is expected to implement this ductwork, if possible. Nevertheless, with SCR and PJFF system additions upstream, the existing ID fans in their existing configuration would have margins of approximately 12 percent on flow and 26 percent on pressure as shown in Figure 3-4 by the "Maximum Capability" curve and the "Maximum Fan Runout" box. These margins would be below the typically recommended Black & Veatch margins, but may be adequate to warrant the reuse of the existing ID fans for Unit 2 depending on LG&E/KU's comfort level with these margins. Although the estimated horsepower requirement at "Maximum Fan Runout" listed in Figure 3-4 is beyond the existing Unit 2 ID fan motor nameplate horsepower of 12,500 hp, the service factor of 1.15 could be utilized to attain this horsepower.

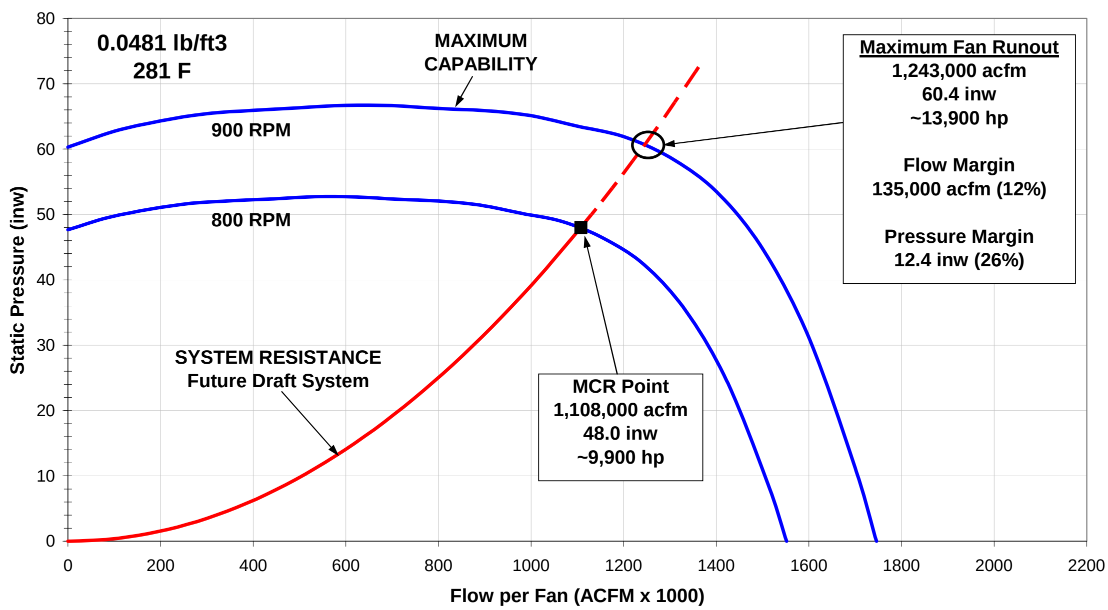

Figure 3-4
Unit 2 Existing ID Fan Performance with Future Draft System

Black & Veatch, however, recommends the use of booster fans at this time to compensate for the draft losses of the new PJFF system. Furthermore, in order to maintain the recommended negative draft pressures at the PJFF, the booster fans would also be designed to compensate for the existing WFGD draft resistance. The existing ID fans have sufficient margin to allow the operation of Unit 2 with an SCR system while the new PJFF system and booster fans are erected. Once the PJFF is in operation, the capacity required of the existing ID fans would decrease. The estimated performance of the existing ID fans with booster fans downstream of a new PJFF system is shown in Figure 4-5. Note that the outlet pressure of the existing ID fans is expected to be reduced to approximately atmospheric pressure, or 0.0 inwg. This will allow the PJFF system to be under negative draft pressures as previously discussed.

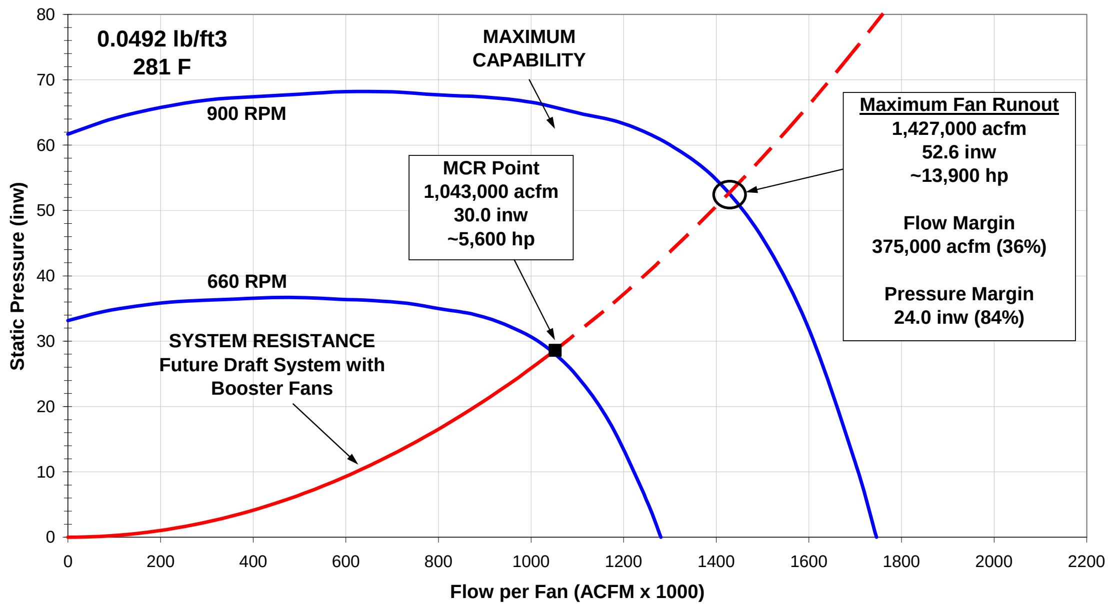

Figure 3-5
Unit 2 Existing ID Fan Performance with Future Draft System and New Booster Fans

3.2.4 New Booster Fan Design Conditions

Based on the layout of the future draft system in Figure 3-3 and the future draft system characteristics in Table 3-4, the estimated performance requirements of the new booster fans at MCR are shown in Table 3-5. Also in Table 3-5 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy. Note the flow and pressure margins of 25 and 49 percent, respectively.

Additionally, Black & Veatch has assumed that LG&E/KU would prefer centrifugal type fans with variable speed capability to match the existing ID fans. The variable speed capability would be through the use of VFD systems.

Table 3-5
<u>Unit 2 New Booster Fan</u> MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	---------	900
Inlet Temperature (°F)	300	325
Inlet Density (lb/ft^3)	0.0508	0.0488
Flow per Fan (acfm) *	1,050,000	1,316,000
Inlet Pressure (inwg)	-7.0	-9.9
Outlet Pressure (inwg)	12.4	19.0
Static Pressure Rise (inw)	19.4	28.9
Shaft Power Required (HP) **	3,800	7,100
Efficiency (%) **	85	85
Number of Fans	2	2
Flow Margin (%)	---------	25
Pressure Margin (%)	---------	49

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

Note that due to the same draft system additions and same relative plant size of Unit 1 with Unit 2, it would likely be advantageous to obtain booster fans with similar capabilities. Monetary savings are expected with this approach in the engineering time and construction of these booster fans. Therefore, it would be recommended that booster fans for Unit 1 be of the same performance capabilities as Unit 2. The booster fans on Unit 1 would be oversized, but with the VFD systems in place very little, if any, operating efficiency losses are expected. If this approach is taken the booster fan performance requirements of Unit 1 can be replaced with the same requirements as Unit 2.

3.2.5 Operating and Transient Design Pressures

With a pressure margin of 49 percent listed in Table 3-5, the new booster fans would be expected to operate in the future draft system with the Test Block pressures listed in Table 3-6. The normal operating, or MCR, pressures have been shown in Table 3-6 as well for reference. Also shown is Table 3-7 listing the new operational requirements of the existing ID fans, which differ from Table 3-2, and their maximum capabilities. Note that the items in bold in Tables 3-6 and 3-8 are new.

Table 3-6
Unit 2 Future Flue Gas Draft System Pressures at MCR and New Booster Fan Test Block

	MCR Pressure (inwg)	Booster Fan Test Block Pressure (inwg)
ID Fan Outlet	0.0	0.0
PJFF Inlet	-1.0	-1.4
PJFF Outlet	-7.0	-9.9
Booster Fan Outlet	12.4	19.0
Wet scrubber Inlet	11.4	17.6
Wet scrubber Outlet	1.5	3.2

Table 3-7
Unit 2 Future Flue Gas Draft System Pressures at MCR and ID Fan Maximum Capability

	MCR Pressure (inwg)	ID Fan Maximum Capability (Test Block) Pressure (inwg)
Furnace/Boiler	-0.5	-0.5
Boiler/Economizer Outlet	-5.1	-9.4
HS-ESP Outlet	-10.8	-19.9
SCR Outlet	-20.8	-38.3
Air Heater Outlet	-28.6	-52.6
ID Fan Outlet	0.0	0.0

With the future draft system Test Block operating pressures defined in Tables 3-6 and 3-7, the future draft system potential minimum transient design pressure requirements can be determined and are shown in Table 3-8. The Black & Veatch philosophy for calculating the minimum required transient design pressures is the same method discussed for Unit 1. Note that the items in bold in Table 3-8 are new or potential modifications.

The calculated transient design pressures in Table 3-8 are based on the individual capabilities of each set of ID and booster fans and not the draft system as a whole. This is only an initial look at the potential transient design pressures that may be needed if either set of fans were allowed to operate a full capacity. There are many different events that could cause the ID and booster fan combination to react in many different ways. Reviewing the potential draft system pressures that could result from these different events is not the purpose of this study. This review would take place during detailed design to more accurately determine a worst case scenario where the capabilities of the draft system as a whole would be analyzed.

The transient design pressures in Table 3-8 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.

Table 3-8
Unit 2 Future Flue Gas Draft System Potential Transient Design Pressure Requirements

Furnace/Boiler	**+35 / -35 inwg ***
Boiler Outlet to HS-ESP Inlet	**+35 / -35 inwg ***
HS-ESP	**+35 / -35 inwg ***
HS-ESP Outlet Duct	**+35 / -35 inwg ***
SCR Inlet Duct	**+35 / -35 inwg**
SCR	**+35 / -55 inwg ***
SCR Outlet Duct	**+35 / -55 inwg ***
Air Heater Inlet Duct	**+35 / -55 inwg ***
Air Heater	**+35 / -76 inwg ***
Air Heater Outlet to ID Fan Inlet	**+35 / -76 inwg ***
ID Fan	Unknown (typically more conservative than connecting duct)
ID Fan Outlet Duct	**+35 / -35 inwg ***
PJFF Inlet Duct	**+35 / -35 inwg**
PJFF	**+35 / -35 inwg**
PJFF Outlet to Booster Fan Inlet	**+35 / -35 inwg**
Booster Fan	(Determined by Manufacturer)
Booster Fan Outlet Duct	**+28 *** / **-6** ** inwg
Wet Scrubber Inlet Duct	**+28 *** / -6 inwg
WFGD	**+28 *** / -6 inwg
Wet Scrubber Outlet to Stack Inlet	+6 / -6 inwg

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

** The negative transient design pressure of the WFGD system is expected to be matched.

As mentioned earlier in the Unit 1 discussions, the AQC equipment additions and changes to all of the Ghent units will likely be considered major alterations or extensions to the existing facilities per the NFPA 85 code - Section 1.3 (2007 Edition). The code, in this instance, would imply that the boiler and flue gas ductwork from the boiler outlet (economizer outlet) to the ID/booster fan inlet be designed for transient pressures of ± 35 inwg at a minimum per Section 6.5. 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. For calculated transient design pressures over ± 35 inwg the calculated pressure is used. Further research is needed during detailed design to determine whether the remaining portions of the existing Unit 2 boiler and draft system meets this criteria or if they would require stiffening.

3.2.6 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. However, LG&E/KU has stated that the existing Ghent SCR systems on Units 1, 3, and 4 consist of catalysts that have minimum ammonia injection temperatures of 644^{o}F. It is unknown whether this catalyst type or if catalysts with lower minimum temperatures would be used. Nevertheless, based on the Ghent Unit 2 draft system temperatures listed in Table 3-4, the operation of an economizer bypass is expected at all loads to maintain this minimum ammonia injection temperature.

A gas-side economizer bypass, as shown in Figure 3-3, has been determined to be a plausible solution. 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 HS-ESP inlet 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 electrostatic precipitators and 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 3-4 since their use is expected to be limited, if needed, at unit MCR. These ducts could be combined into one duct or remain separate entering the HS-ESP inlet duct. Issues with limited mixing time are not expected since the flue gas must pass through the HS-ESP system before entering the SCR system. However, carbon steel material temperature limitations in the existing HS-ESP inlet ductwork may become a concern if excessive amounts of flue gas bypass the economizer.

Alternatively, these economizer bypass ducts could bypass the HS-ESP and enter directly into the SCR system inlet as well. However, roughly the same amount of flue gas would need to flow through the economizer bypass to maintain SCR inlet temperatures. Bypass ducts in this orientation would increase in length and cost and mixing times may become a concern. The ductwork material in the main flue gas path would not experience as high of an overall flue gas temperature, though, and carbon steel temperature limitations in the main flue gas path would not be as much of a concern.

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 that 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 older air heaters that were not designed for SCR operation. Black & Veatch recommends that the air heaters incorporate the proper modifications 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 modifications typically include, but are not limited to, the following:

- Replacement of baskets with enamel coated baskets.
- Reduction of the number of basket layers to two layers.
- Installation of higher energy and/or multimedia (steam or compressed air / high pressure water) sootblowers with improved controls.

4.0 Units 3 and 4

4.1 Existing Draft System

4.1.1 Layout

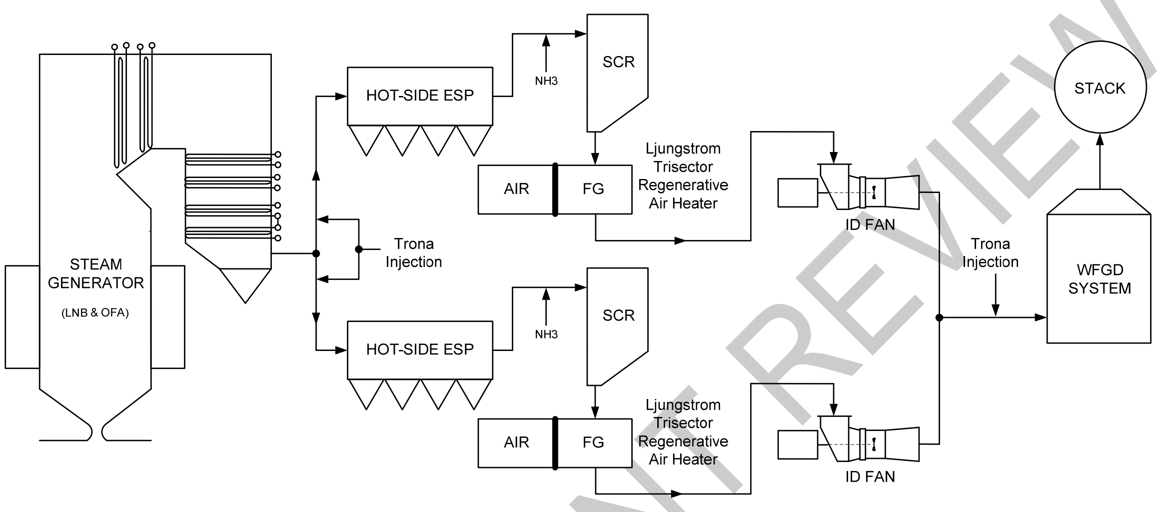

Figure 4-1
Units 3 and 4 Existing Draft Systems

Each draft system of Units 3 and 4 begins at the outlet of the boiler, or economizer. As shown in Figure 4-1 the flue gas travels directly to two 50 percent capacity hot-side ESPs (HS-ESP) where particulate is removed. At the outlet of the HS-ESP system the flue gas travels to the SCR system allowing for the removal of NOx emissions before entering the air heaters. Two 50 percent capacity ljungstrom regenerative type air heaters then transfer a large amount of energy in the flue gas to the combustion air entering the boiler. Once through the air heaters, two 50 percent capacity ID fans then draw the flue gas out of the air heaters and send it to the wet scrubber. The flue gas path is split between two trains of equipment from the boiler outlet up to this point. Once the majority of the sulfur dioxide in the flue gas is removed by the wet scrubber, the flue gas then exits to the atmosphere through the stack.

4.1.2 ID Fans

Each draft fan system of Units 3 and 4 consists of two ID fans. The WEG electric motors for each ID fan are single-speed motors that operate nominally at 900 rpm. The nameplate horsepower rating of the ID fan motors is 13,600 horsepower with a service factor of 1.15. They operate at a nominal voltage of 13,800 volts. Primary, flow control for the ID fans is accomplished by the use of variable pitch fan blades. The ID fans are axial type fans from FlaktWoods, model PFTU-335-250-25.

4.1.3 Boiler and Draft System Characteristics

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

Table 4-1
Units 3 and 4 Boiler Characteristics at MCR

Boiler total heat input	5,300 MBtu/hr (based on the Unit 3 net plant output of 476,000 kW and heat rate of 11,131 Btu/kWh – worst case across Ghent units)
Boiler excess air	21.8 % or 3.50% oxygen – wet basis (estimated)
Loss On Ignition (LOI)	2 % (estimated)
Ambient conditions	
Dry bulb temperature	74 °F
Relative humidity	60 %
Barometric pressure	29.09 inHg

Table 4-2 Units 3 and 4 Existing Draft System Characteristics at MCR	
HS-ESP leakage	5 % (estimated)
SCR system leakage	2 % (estimated)
Air heater leakage	10 % (estimated)
Flue gas temperatures – Unit 3 // Unit 4	
Boiler outlet	731 ^{o}F // 798 ^{o}F
HS-ESP outlet	702 ^{o}F // 764 ^{o}F
SCR outlet	691 ^{o}F // 754 ^{o}F
Air heater outlet	316 ^{o}F // 305 ^{o}F
ID fan outlet	~340 ^{o}F // ~330 ^{o}F (calculated)
Wet scrubber outlet	~130 ^{o}F // ~130 ^{o}F (calculated)
Draft system operating pressures – Unit 3 // Unit 4	
Furnace pressure	-0.5 inwg // -0.5 inwg
Boiler outlet	-5.1 inwg // -4.5 inwg
HS-ESP outlet	-10.9 inwg // -10.8 inwg
SCR outlet	-20.9 inwg // -20.8 inwg
Air heater outlet	-36.1 inwg // -29.4 inwg
ID fan outlet	5.9 inwg // 14.6 inwg
Wet scrubber outlet	2.0 inwg // 1.6 inwg
Stack outlet	0.0 inwg // 0.0 inwg
Draft system differential pressures – Unit 3 // Unit 4	
Boiler	4.6 inw // 4.0 inw
HS-ESP	5.8 inw // 6.3 inw
SCR system	10.0 inw // 10.0 inw
Air heater	15.2 inw // 8.6 inw
Wet scrubber	3.9 inw // 13.0 inw
Stack	2.0 inw // 1.6 inw

Based on the layout of the existing draft system in Figure 4-1 and the boiler and the draft system characteristics listed in Tables 4-1 and 4-2, the estimated performance requirements of the Unit 3 existing ID fans are shown as the MCR point in Figure 4-2. The Unit 4 ID fans would be similar.

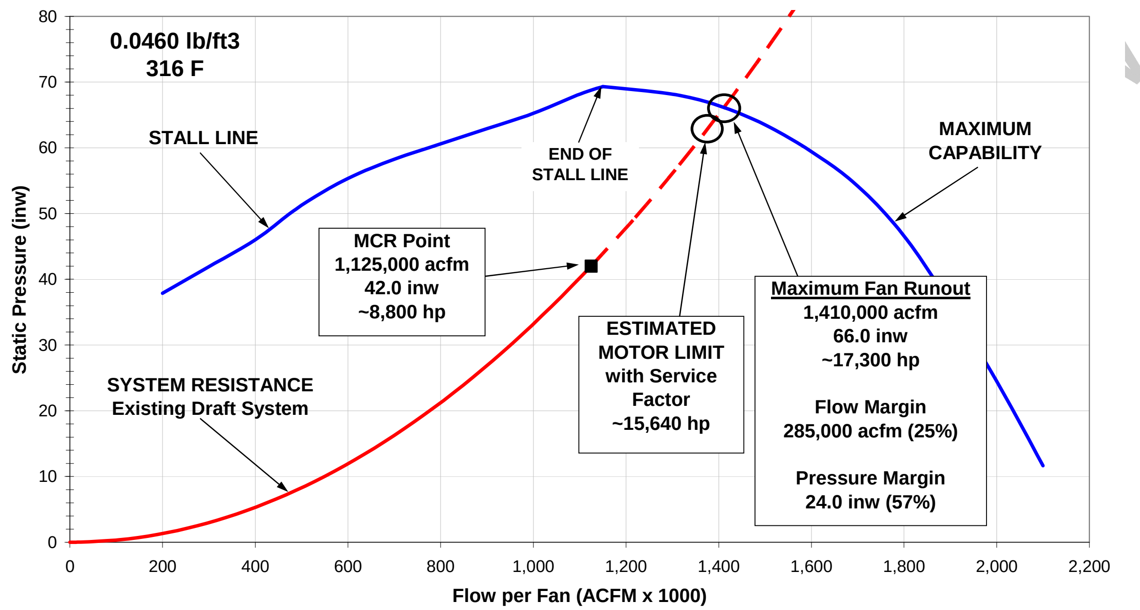

Figure 4-2
Unit 3 Existing ID Fan Performance with Existing Draft System

Based on the MCR point shown in Figure 4-2, it appears that the ID fans have flow and pressure margins of approximately 25 and 57 percent, respectively. These margins are beyond the ranges of flow and pressure margins that are typically recommended by Black & Veatch. From a performance perspective, it appears that they would be more than adequate to support the addition of a PJFF system that is discussed later. However, as shown in Figure 4-2, the motors are not designed to accommodate the full fan runout capacity at the specified flue gas density. If these ID fans are retained with the addition of a PJFF system, the installation of more powerful motors would be recommended to retain the maximum amount of margin.

From an operation and maintenance perspective, though, LG&E/KU has expressed interest in replacing these existing axial fans due to higher than expected maintenance and repair costs. Therefore, with the installation of a PJFF system, the installation of new ID fans of the centrifugal type is planned as well.

Lastly, the existing draft system equipment and ductwork transient design pressures for Units 3 and 4 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
Units 3 and 4 Existing Flue Gas Draft System Equipment and Ductwork Transient Design Pressures

Furnace/Boiler	+25 / -25 inwg
Boiler Outlet to HS-ESP Inlet	+25 / -40 inwg
HS-ESP	+30 / -30 inwg
HS-ESP Outlet Duct	+25 / -40 inwg
SCR Inlet Duct	Unknown *
SCR	Unknown *
SCR Outlet Duct	Unknown *
Air Heater Inlet Duct	+25 / -40 inwg
Air Heater	+35 / -35 inwg
Air Heater Outlet to ID Fan Inlet	+10 / -44 inwg
ID Fan	Unknown (typically more conservative than connecting duct)
ID Fan Outlet to Wet Scrubber Inlet	+44 / -6 inwg
Wet Scrubber	Unknown *
Wet Scrubber Outlet to Stack Inlet	+6 / -6 inwg

* These pressures will need to be determined during detailed design

4.2 Future Draft System

4.2.1 Layout

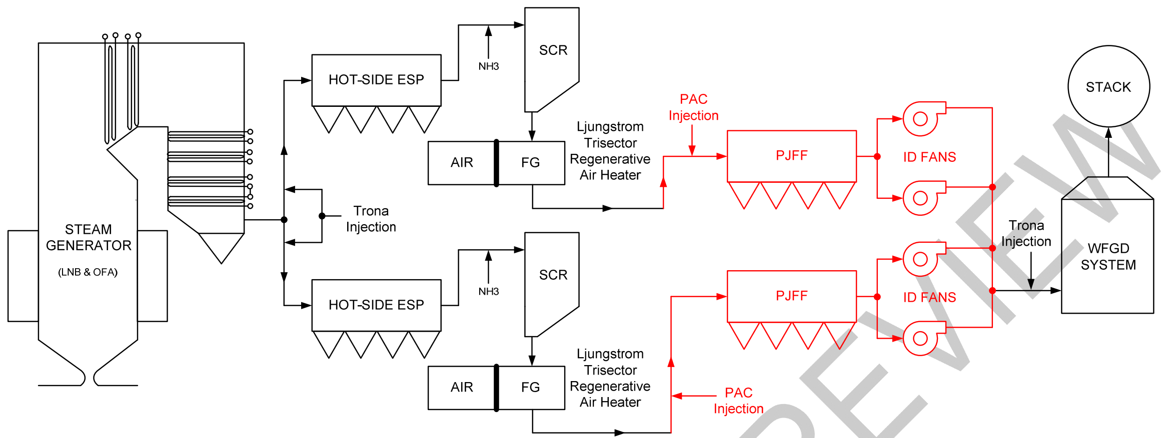

Figure 4-3
Units 3 and 4 Future Draft System

Based on the additions to the Units 3 and 4 draft systems previously discussed, the flue gas would be redirected through the draft system as follows. At the outlet of the existing air heaters the flue gas would travel to the new PJFF system allowing for the removal of particulate. New centrifugal type ID fans would then draw the flue gas out of the PJFF system and send it to the WFGD system. The flue gas path would remain split between two trains of equipment from the boiler outlet up to this point. An illustration of the Units 3 and 4 future draft systems based on this description is shown in Figure 4-3.

4.2.2 Draft System Characteristics

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

Table 4-4 Units 3 and 4 Future Draft System Characteristics at MCR	
SCR system leakage	2 % (estimated)
HS-ESP leakage	5 % (estimated)
Air heater leakage	10 % (estimated)
PJFF system leakage	**3 %**
Flue gas temperatures – Unit 3 // Unit 4	
Boiler outlet	731 °F // 798 °F
HS-ESP outlet	702 °F // 764 °F
SCR outlet	691 °F // 754 °F
Air heater outlet	316 °F // 305 °F
PJFF outlet	**316 °F // 305 °F**
ID fan outlet	**~345 °F // ~335 °F** (calculated)
Wet scrubber outlet	~130 °F // ~130 °F (calculated)
Draft system differential pressures	
Boiler	4.6 inw // 4.0 inw
HS-ESP	5.8 inw // 6.3 inw
SCR	10.0 inw // 10.0 inw
Air heater	15.2 inw // 8.6 inw
Air heater outlet to PJFF inlet	**1.0 inw // 1.0 inw**
PJFF	**6.0 inw // 6.0 inw**
ID fan outlet to WFGD inlet	**1.0 inw // 1.0 inw**
WFGD	3.9 inw // 13.0 inw
Stack	2.0 inw // 1.6 inw

4.2.3 Analysis of Existing ID Fans with Future Draft System

There is the potential, from a performance perspective, that the Unit 3 existing ID fans could provide the motive force to move the flue gas through the draft system. Ductwork would need to be arranged to locate the ID fans downstream of the PJFF system as it is highly recommended to operate a PJFF under negative draft pressure. With new PJFF system additions upstream, the existing ID fans would have margins of approximately 15 percent on flow and 32 percent on pressure as shown in Figure 4-4 by the "Maximum Capability" curve and the "Maximum Fan Runout" box. The Unit 4 ID fans would have similar margins. These margins would be a little below the typically recommended Black & Veatch margins, but adequate to warrant the reuse of the existing ID fans for Units 3 and 4. However, as previously discussed for Figure 4-2, the estimated horsepower requirement at "Maximum Fan Runout" listed in Figure 4-4 is beyond the existing ID fan motor nameplate horsepower of 13,600 hp with the service factor of 1.15 applied. If the margins listed in Figure 4-4 are to be attained, new more powerful ID fan motors would be needed.

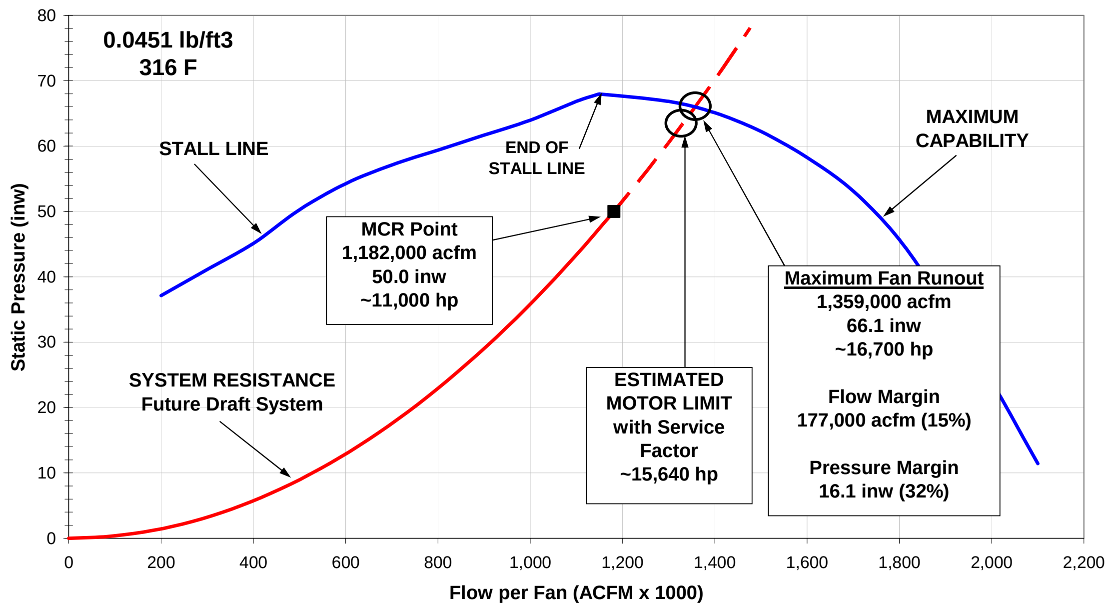

Figure 4-4
Unit 3 Existing ID Fan Performance with Future Draft System

Nevertheless, due to the maintenance and operational issues LG&E/KU experienced Black & Veatch plans on the replacement of the existing axial ID fans with centrifugal type fans at this time. Since single fan flow and pressure capabilities of centrifugal fans are not to the level of axial fans due to manufacturing limitations, Black & Veatch previously proposed a three centrifugal ID fan arrangement per unit. This arrangement, however, did not allow the flue gas path to continue to be split upstream of the ID fans with the common ID fan inlet duct. As shown in Figure 4-3, a four centrifugal ID fan arrangement is now planned on as directed by LG&E/KU which allows a split flue gas path through the ID fans permitting the biasing of flows between paths.

4.2.4 New Centrifugal ID Fan Design Conditions

Based on the layout of the future draft system in Figure 4-3 and the future draft system characteristics in Table 4-4, the estimated performance requirements of the new ID fans at MCR are shown in Table 4-5. Also in Table 4-5 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy. Note the flow and pressure margins of 24 and 38 percent, respectively, and the number of fans per unit.

Since the fan sizing of the new Unit 3 ID fans was a bit more conservative, it was chosen to represent the fan sizing for both Units 3 and 4. Additionally, due to the similarity between unit size and draft system layout, it would be recommended to purchase ID fans of the same performance. This philosophy of utilizing similar fan sizing between Units 3 and 4 is similar to that recommended for Units 1 and 2.

Additionally, Black & Veatch has assumed that LG&E/KU would prefer variable speed capability to match the existing flow control method of Units 1 and 2. The variable speed capability would be through the use of VFD systems.

Table 4-5
Units 3 and 4 New ID Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	---------	900
Inlet Temperature (°F)	316	341
Inlet Density (lb/ft^3)	0.0451	0.0418
Flow per Fan (acfm) *	591,000	735,000
Inlet Pressure (inwg)	-43.1	-58.7
Outlet Pressure (inwg)	6.9	10.2
Static Pressure Rise (inw)	50.0	68.9
Shaft Power Required (HP) **	5,600	9,500
Efficiency (%) **	84	84
Number of Fans per Unit	4	4
Flow Margin (%)	---------	24
Pressure Margin (%)	---------	38

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

4.2.5 Operating and Transient Design Pressures

With a pressure margin of 38 percent listed in Table 4-5, the new ID fans would be expected to operate the future draft system with the Test Block pressures listed in Table 4-6. The normal operating, or MCR, pressures have been shown in Table 4-6 as well for reference.

Table 4-6
Unit 3 Future Flue Gas Draft System Pressures at MCR and New ID Fan Test Block

	MCR Pressure (inwg)	Test Block Pressure (inwg)
Furnace/Boiler	-0.5	-0.5
Boiler/Economizer Outlet	-5.1	-6.1
HS-ESP Outlet	-10.9	-13.3
SCR Outlet	-20.9	-25.8
Air Heater Outlet	-36.1	-49.6
PJFF Inlet	-37.1	-50.9
PJFF Outlet	-43.1	-58.7
ID Fan Outlet	6.9	10.2
Wet Scrubber Inlet	5.9	8.8
Wet Scrubber Outlet	2.0	3.7

Table 4-7
Unit 4 Future Flue Gas Draft System Pressures at MCR and New ID Fan Test Block

	MCR Pressure (inwg)	Test Block Pressure (inwg)
Furnace/Boiler	-0.5	-0.5
Boiler/Economizer Outlet	-4.5	-5.3
HS-ESP Outlet	-10.8	-13.2
SCR Outlet	-20.8	-25.7
Air Heater Outlet	-29.4	-39.2
PJFF Inlet	-30.4	-40.5
PJFF Outlet	-36.4	-48.3
ID Fan Outlet	15.6	21.7
Wet Scrubber Inlet	14.6	20.4
Wet Scrubber Outlet	1.6	3.1

With the future draft system Test Block operating pressures defined in Tables 4-6 and 4-7, the future draft system potential minimum transient design pressure requirements can be determined and are shown in Tables 4-8 and 4-9. The Black & Veatch philosophy for calculating the minimum required transient design pressures is the same method discussed for Unit 1. Note that the items in bold in Tables 4-8 and 4-9 are new or potential modifications.

The transient design pressures in Tables 4-8 and 4-9 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.

Table 4-8
Unit 3 Future Flue Gas Draft System Potential Transient Design Pressure Requirements

Furnace/Boiler	**+35 / -35 inwg ***
Boiler Outlet to HS-ESP Inlet	**+35 *** / -40 inwg
HS-ESP	**+35 / -35 inwg ***
HS-ESP Outlet Duct	**+35 *** / -40 inwg
SCR Inlet Duct	**+35 / -35 inwg ***
SCR	**+35 / -38 inwg ***
SCR Outlet Duct	**+35 / -38 inwg ***
Air Heater Inlet Duct	**+35 *** / -40 inwg
Air Heater	+35 / **-72 *** inwg
Air Heater Outlet to PJFF Inlet	**+35 / -74 inwg ***
PJFF Inlet Duct	**+35 / -74 inwg**
PJFF	**+35 / -85 inwg**
PJFF Outlet to ID Fan Inlet	**+35 / -85 inwg**
ID Fan	(Determined by Manufacturer)
ID Fan Outlet Duct	**+44 / -6 inwg ****
Wet Scrubber Inlet Duct	+44 / -6 inwg
WFGD	**+44 / -6 inwg ****
Wet Scrubber Outlet to Stack Inlet	+6 / -6 inwg

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

** The transient design pressures of the existing ID fan outlet duct are expected to be matched if not already.

Table 4-9
Unit 4 Future Flue Gas Draft System Potential Transient Design Pressure Requirements

Furnace/Boiler	**+35 / -35 inwg ***
Boiler Outlet to HS-ESP Inlet	**+35 *** / -40 inwg
HS-ESP	**+35 / -35 inwg ***
HS-ESP Outlet Duct	**+35 *** / -40 inwg
SCR Inlet Duct	**+35 / -35 inwg ***
SCR	**+35 / -38 inwg ***
SCR Outlet Duct	**+35 / -38 inwg ***
Air Heater Inlet Duct	**+35 *** / -40 inwg
Air Heater	+35 / **-57 *** inwg
Air Heater Outlet to PJFF Inlet	**+35 / -59 inwg ***
PJFF Inlet Duct	**+35 / -59 inwg**
PJFF	**+35 / -70 inwg**
PJFF Outlet to ID Fan Inlet	**+35 / -70 inwg**
ID Fan	(Determined by Manufacturer)
ID Fan Outlet Duct	**+44 / -6 inwg ****
Wet Scrubber Inlet Duct	+44 / -6 inwg
WFGD	**+44 / -6 inwg ****
Wet Scrubber Outlet to Stack Inlet	+6 / -6 inwg

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

** The transient design pressures of the existing ID fan outlet duct are expected to be matched if not already.

As mentioned earlier in the Unit 1 discussions, the AQC equipment additions and changes to all of the Ghent units will likely be considered major alterations or extensions to the existing facilities per the NFPA 85 code - Section 1.3 (2007 Edition). The code, in this instance, would imply that the boiler and flue gas ductwork from the boiler outlet (economizer outlet) to the ID/booster fan inlet be designed for transient pressures of ± 35 inwg at a minimum per Section 6.5. 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. For calculated transient design pressures over ± 35 inwg the calculated pressure is used. Further research is needed during detailed design to determine whether the remaining portions of the existing Unit 2 boiler and draft system meets this criteria or if they would require stiffening.

5.0 Summary

The Unit 1 major modifications and additions to the draft system being considered include a new PJFF system. The Unit 2 major modifications and additions to the draft system being considered include a new SCR system and a new PJFF system. Units 3 and 4 would be similar to Unit 1. In order for the existing Ghent 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 Ghent draft systems. Unit 1 would be equipped with a new set of centrifugal booster fans with VFD systems for flow control to support the existing set of ID fans. The need for ductwork stiffening in some portions of the existing draft system is likely and boiler stiffening may be required as well. Unit 2 would be equipped with a new set of centrifugal booster fans with VFD systems for flow control to support the existing set of ID fans also. To support the operation of the Unit 2 SCR system at all loads an economizer bypass would be included with the SCR system. Air heater modifications would also take place to support the SCR installation. Similar to Unit 1, the need for ductwork stiffening in some portions of the existing draft system is likely and boiler stiffening may be required as well. For Unit 3, Black & Veatch would plan to install new centrifugal ID fans with VFD systems to match the flow control method in use for Units 1 and 2. These new ID fans would compensate for the increased draft losses since it is desired that the existing ID fan be replaced. However, it appears that the existing Unit 3 axial ID fans have adequate capacity to support the AQC upgrades provided that additional ductwork is arranged to allow these fans to be downstream. If LG&E/KU does retain the existing axial ID fans on Unit 3 for the AQC upgrades, higher horsepower motors would be recommended. Unit 4 is similar to Unit 3 and Black & Veatch has planned on installation of new centrifugal ID fans with VFD systems there as well. The existing Unit 4 ID fans could also support the AQC upgrades. Lastly, ductwork stiffening in some portions of the existing draft system of Units 3 and 4 would likely be needed and boiler stiffening may be needed also.