LG&E/KU – Ghent Station

Phase II Air Quality Control Study

Air Quality Control Validation Report

February 16, 2010
Revision C – Issued For Project Use

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Acronym List

AQC	Air Quality Control
As	Arsenic
Be	Beryllium
CAIR	Clean Air Interstate Rule
CATR	Clean Air Transport Rule
Cd	Cadmium
Co	Cobalt
Cr	Chromium
CS-ESP	Cold-side Electrostatic Precipitator
DCS	Distributed Control System
DOE	Department of Energy
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic Precipitator
H_2SO_4	Sulfuric Acid
HCl	Hydrogen Chloride
Hg	Mercury
ID	Induced Draft
inw	Inch of Water
LNB	Low NO_x Burners
LV	Low Voltage
MACT	Maximum Achievable Control Technology
MBtu	Million British Thermal Unit
MCC	Motor Control Center
Mn	Manganese
MSW	Municipal Solid Waste
MV	Medium Voltage
MWC	Medical Waste Combustors
NAAQS	National Ambient Air Quality Standard
NFPA	National Fire Protection Association
Ni	Nickel
NN	Neural Network
NO_x	Nitrogen Oxides
OFA	Overfire Air
PAC	Powdered Activated Carbon

Pb	Lead
PJFF	Pulse Jet Fabric Filter
PM	Particulate Matter
RAT	Reserve Auxiliary Transformer
RGFF	Reverse Gas Fabric Filters
SAM	Sulfuric Acid Mist
Sb	Antimony
SBS	Sodium Bisulfite
SCR	Selective Catalytic Reduction
Se	Selenium
SO_2	Sulfur Dioxide
SO_3	Sulfur Trioxide
tph	Tons per Hour
UAT	Unit Auxiliary Transformer
VFD	Variable Frequency Drives
WFGD	Wet Flue Gas Desulfurization

1.0 Introduction

Following the submittal of the Phase I report on July 8, 2010, Black & Veatch developed scope to further define facility technology options based on the Phase I report. The purpose of this Phase II air quality control (AQC) validation study is to build upon the previous fleet-wide, high-level air quality technology review and cost assessment conducted for six LG&E/KU facilities (Phase I) in order to develop a facility-specific project definition consisting of a conceptual design and a budgetary cost estimate for selected AQC technologies (Phase II) for the Ghent Generating Station. The following AQC technology options have been assessed in this report:

- PJFF on Units 1-4.
- Sorbent injection (trona/lime/SBS) injection on Unit 2.
- SCR on Unit 2.
- Powdered activated carbon (PAC) injection on Units 1-4.
- Feasibility of neural network (NN) on Units 1-4.

This validation study confirms the feasibility of installing the aforementioned AQC equipment at Ghent, and presents the supporting considerations, arrangements, and preliminary validating analyses of the AQC equipment that will be built upon in the next step of this project to complete the conceptual design and budgetary cost estimate.

2.0 Facility Description

2.1 Ghent- Units 1, 2, 3, and 4

The Ghent Station is located in Carroll County, approximately 9 miles northeast of Carrolton, Kentucky, on an approximately 1,670 acre site. Ghent Station includes four pulverized coal fired electric generating units with a gross total generating capacity of 2,107 MW. Ghent Station began commercial operations in 1973.

All four steam generators (boilers) fire high sulfur bituminous coal. Two of the boilers are manufactured by Combustion Engineering and two by Foster Wheeler. The Combustion Engineering boilers are tangential-fired, balanced draft forced circulation boilers, and Foster Wheeler boilers are balanced draft natural circulation boilers. Unit 1 has a gross capacity of 541 MW and is equipped with low NO_x burners (LNBs) and selective catalytic reduction (SCR) for nitrogen oxide (NO_x) control; cold-side dry electrostatic precipitator (ESP) for particulate matter (PM) control; wet flue gas desulfurization (WFGD) for sulfur dioxide (SO_2) control, and lime injection system for sulfuric acid (H_2SO_4) and/or sulfur trioxide (SO_3) control. Unit 2 has a gross capacity of 517 MW and is equipped with LNBs and overfire air (OFA) for NO_x control; hot-side dry ESP for PM control; and WFGD system for SO_2 control, and lime injection system for H_2SO_4/SO_3 control. Units 3 and 4 have a gross capacity of 523 MW and 526 MW, respectively, and are equipped with LNBs, OFA, and low-dust SCR for NO_x control; hot-side dry ESP for PM control; wet FGD system for SO_2 control, and trona injection system for H_2SO_4/SO_3 control.

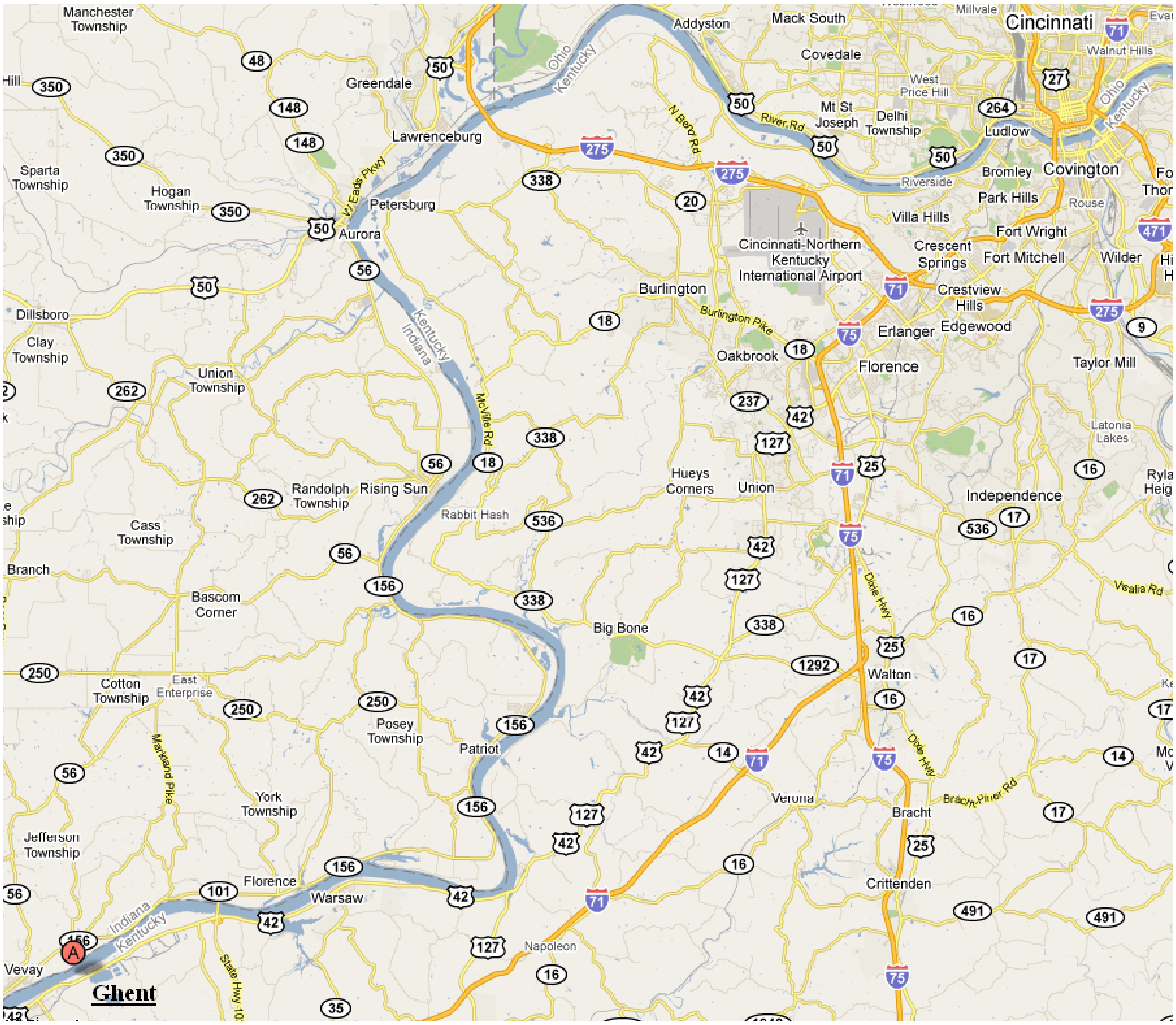
Gypsum, a scrubber by-product, produced at Ghent is stored in the on-site landfill. Fly ash and bottom ash is sluiced to on-site storage ponds. Black & Veatch is also involved in a separate study for the transportation of coal combustion products. Layouts developed for the alternative transport systems will be taken into account during the Phase II Air Quality Control Study. All four units are cooled using mechanical draft cooling towers.

Figures 2-1 and 2-2 illustrate the plant location and Table 2-1 summarizes the plant’s existing facilities.

NORTH

Figure 2-1. Ghent Power Plant Site

NORTH



SOUTH

Figure 2-2. Ghent and Surrounding Area Map

Table 2-1. Existing Ghent Plant Facilities	
Existing On Site Generation Units:	• Unit 1 - 541 gross MW (in-service date 1973) • Unit 2 - 517 gross MW (in-service date 1977) • Unit 3 - 523 gross MW (in-service date 1981) • Unit 4 - 526 gross MW (in-service date 1984)
Existing AQC Equipment:	• Unit 1 - LNBs, SCR, Cold-side Dry ESP, WFGD, Lime Injection System • Unit 2 - LNBs, OFA System, Hot-side Dry ESP, WFGD, Lime Injection System • Unit 3 - LNBs, OFA, Low -dust SCR, Hot-side Dry ESP, WFGD, Trona Injection System • Unit 4 - LNBs, OFA, Low -dust SCR, Hot-side Dry ESP, WFGD, Trona Injection System

3.0 Emission Target Basis

LG&E/KU provided a matrix of estimated requirements under current and future environmental regulations, as well as a summary implementation schedule of regulatory programs. Table 3-1 summarizes the future pollution emission targets provided by LG&E/KU for each unit.

The current regulatory drivers include the NO_2 and SO_2 National Ambient Air Quality Standard (NAAQS). On January 22, 2010, the Environmental Protection Agency (EPA) announced a new 1-hour NO_2 NAAQS of 100 ppb. The final rule for the new hourly NAAQS was published in the Federal Register on February 9, 2010, and the standard became effective on April 12, 2010. Likewise, on June 2, 2010, EPA strengthened the primary SO_2 NAAQS. EPA established a new 1-hour standard at a level of 75 ppb and revoked the existing 24-hour and annual standards.

The potential impact of future regulations is the primary driver for both the timing and extent of environmental controls planned at the LG&E/KU plants. Among the regulatory drivers are the Utility Maximum Achievable Control Technology (MACT), and the Clean Air Transport Rule (CATR) -- Clean Air Interstate Rule (CAIR) replacement to be proposed by the United States EPA by spring 2011 and summer 2011, respectively.

From this information, LG&E/KU developed specific pollutant emission limit targets with the intent that the limits would be applied to each unit individually to assess current compliance and the potential for additional AQC equipment. These regulatory drivers and their associated emission levels serve as the primary basis used by Black & Veatch to develop unit-by-unit AQC technology recommendations. For the purposes of this study, compliance options beyond the addition of new AQC technology (such as fuel switching, shutdown of existing emission units, development of new power generation, and emissions averaging scenarios) were not considered.

Table 3-1. Primary Design Emission Targets

Pollutant	Unit 1	Unit 2	Unit 3	Unit 4
NO_x	N/A[b]	0.041 lb/MBtu	N/A[b]	N/A[b]
SO_2	N/A[b]	N/A[b]	N/A[b]	N/A[b]
Sulfuric Acid Mist (SAM)	2-10 ppm[a] TBD	2-10 ppm[a] TBD	2-10 ppm[a] TBD	2-10 ppm[a] TBD
Mercury (Hg)	90% control or 0.012 lb/GWh	90% control or 0.012 lb/GWh	90% control or 0.012 lb/GWh	90% control or 0.012 lb/GWh
Hydrogen Chloride (HCl)	0.002 lb/MBtu	0.002 lb/MBtu	0.002 lb/MBtu	0.002 lb/MBtu
Particulate Matter (PM)[c],[d]	0.03[c] lb/MBtu	0.03[c] lb/MBtu	0.03[c] lb/MBtu	0.03[c] lb/MBtu
Arsenic (As) [e]	0.5×10^{-5} lb/MBtu	0.5×10^{-5} lb/MBtu	0.5×10^{-5} lb/MBtu	0.5×10^{-5} lb/MBtu
CO	0.10 lb/MBtu	0.10 lb/MBtu	0.10 lb/MBtu	0.10 lb/MBtu
Dioxin/Furan	15×10^{-18} lb/MBtu	15×10^{-18} lb/MBtu	15×10^{-18} lb/MBtu	15×10^{-18} lb/MBtu

Data from LG&E/KU Ghent Station kickoff meeting October 6, 2010 (Gary Revlett handouts and meeting notes) unless noted otherwise.

(a) Units provided in ppmvd at 3% O_2 as indicated in the draft H_2SO_4 BACT analysis dated September 30, 2010.

(b) Not applicable for this Phase II study.

(c) Emission rate target is higher than what can typically be achieved with chosen technology; a lower emission target may be possible.

(d) Particulate matter control limits for $PM_{2.5}$ or $PM_{condensable}$ have not been determined for this project.

(e) Particulate matter assumed to be the surrogate for emissions of certain non-mercury metallic HAP (i.e., antimony (Sb), beryllium (Be), cadmium (Cd), cobalt (Co), lead (Pb), manganese (Mn), and nickel (Ni)).

(f) Arsenic assumed to be the surrogate for non-mercury metallic HAP (i.e., arsenic (As), chromium (Cr), and selenium (Se)).

4.0 Site Visit Summary

The following section describes the existing site conditions and site visit observations for the Ghent Generating Station.

4.1 Site Visit Observations and AQC

The following observations are from the October 6-7, 2010 site visit and summarize the site and equipment constraints. The following excerpts are from the October 22, 2010, site visit meeting memo that focused specifically on installing the specified AQC equipment.

- Emissions of SO_2 should not be a problem for the Ghent units since the existing FGDs basically achieve +98% removal on the units and the air dispersion modeling shows that they require 96% removal on a plant average. Thus, no modification of the FGDs is required.
- Hg is an issue at Ghent. However, LG&E/KU hopes that with the addition of an SCR on Unit 2, acceptable Hg control may be achieved without additional modifications.
- The hot-side ESPs are currently being used either for ash scavenging or because the existing SCRs are the low-dust type. B&V noted that a change in catalyst could convert the SCRs to operate in high-dust conditions if the possibility of lower catalyst life is acceptable.
- The area and facilities for dry ash conversion and ash handling need to be considered with this study. LG&E/KU commented that B&V had previously completed an ash handling study and that the AQC study must be coordinated with the plans developed in the ash handling study.
- B&V may consider designing the Unit 2 SCR as high-dust units from the onset, allowing deletion of the existing ESPs at Unit 2 if warranted by congestion and construction difficulties.
- LG&E/KU would like to sell fly ash on an opportunistic basis, but is not necessarily tied to the existing ESPs. Saleable fly ash would require "scalping" of the fly ash upstream of PAC injection and require the retention and use of the existing ESPs.
- LG&E/KU prefers no new axial fans and prefers the existing axial fans, if re-used, be located downstream of the PJFFs.
- B&V to investigate a refined layout for Unit 3 PJFF that would reduce the ductwork runs indicated in the Phase I study.

- The courtyard area between Units 2 and 3 can be used for siting new equipment. The various maintenance shops on the south side of the courtyard could be relocated. There is no "sacred ground" onsite that must be avoided in locating new facilities. However, retention or re-establishment of the ground level breezeway and the overhead skyway between Units 2 and 3 is desirable.
- B&V believes it will likely not be feasible to reuse/upgrade the existing induced draft (ID) fans to avoid the addition of new booster or ID fans. Physical constraints on routing duct to and from the existing ID inlet fans is problematic. Locating the PJFFs to protect all of the existing ID fans is not practical in all cases, even for the axial fans at Units 3 and 4. The Unit 3 fans can be incorporated into the revised AQC system, but only in a location that may not be beneficial. B&V fan experts will review this, but new ID fans or booster fans are expected to be required for all units.
- Unit 1:
  - Sorbent injection will need to be relocated in the duct work to near the inlet of the PJFF. LG&E/KU questioned whether the PJFF vendors would be willing to offer SO3 guarantees based on sorbent injection. B&V noted that if the vendor is awarded both sorbent injection and the PJFF as a single package he will likely offer some guarantees, but the specific level will have to be negotiated.
  - Concern was expressed with the elevated PJFF for Unit 1 being located close to the Unit 2 cooling tower. B&V will investigate and provide opinions on the overall affect of the new structures on cooling tower performance and level of icing that could result.
  - If the impact to performance warrants it, it was discussed that a couple cells could be added to the east end of the tower to increase the overall tower capacity or allow impacted cells to be taken out of service.
  - Alternate arrangements at Unit 1 appear very limited at this time. LG&E/KU asked about relocating Unit 2's cooling tower to make more room for Unit 1 PJFF. The major issue with that approach is where to relocate the cooling tower. The potential of locating the new cooling tower towards the river or to the east of Unit 1's cooling tower was discussed. Any new construction towards the river, either relocating the Unit 2 cooling tower or the plant reagent piperack, would likely trigger permit concerns with the COE.

Building a new tower in the "rock pile" area (formerly the limestone storage area east of the plant) was also discussed. Routing of the underground circulating water lines potentially would be a major issue.

- Unit 2:
  - Because of the high level of congestion in the existing arrangement at Unit 2, plus the need to add a PJFF, B&V considered three alternatives for the SCR location at Unit 2. Two alternatives (Alternates 1 & 3) include split SCR's – two separate reactors, one for each ESP train, with the only difference between the alternatives being the location of the west side SCR.
  - Alternate 1 locates the west SCR in the area just west of the west ID fan and the east SCR above the tower support for the Unit 1 SCRs. The area west of the ID fans appears sufficiently open to allow construction of a tower support for the SCR. The advantage of this arrangement is the short runs of ductwork required, and the SCR reactor box location can be reached by a crane set up in the area located immediately south of the abandoned Unit 2 chimney.
  - Alternate 3 locates the west SCR along the west side of the Unit 2 boiler structure and the east SCR in the same location as Alternate 1. The approach suggested in the Phase 1 study of locating both split SCRs on the west side of the boiler structure would be problematic because of the difficulty of routing duct work from east side Unit 2 duct to the courtyard and back.
  - Alternate 2 is similar to that used for the Unit 1 SCR, with a combined SCR located above the ESPs. However, the area beneath the SCRs in Alternate 2 is very congested, making foundation design and installation extremely difficult. Moreover, the lack of nearby open area adjacent to the SCR locations will limit crane access and greatly complicate constructability. Assuming sufficient free area is found to accommodate the necessary foundations, Alternate 1 is more favorable to construction and the most likely option.
  - Low dust SCRs will be assumed for Unit 2 unless elimination of the existing ESPs is warranted for some other reason.

  - LG&E/KU has previous studies which propose locating the SCR modules in the courtyard on the west side of the Unit 2 boiler structure. LG&E/KU offered to provide these studies to B&V.
  - The Unit 2 PJFF is assumed to be located north of the existing ESPs and ductwork. A short temporary bypass ductwork can be installed between the air heater outlet duct and the ductwork to the scrubber inlet. This would allow the large section of ductwork located north of the bypass to be demolished and the PJFF installed in its place while Unit 2 is on line. The completed PJFF would be tied into the system during an outage. The new booster or ID fans for Unit 2 (not shown on the arrangement sketches) would tentatively be located at the west (downstream) end of the new PJFF.
- Unit 3:
  - The preliminary arrangement sketches show the PJFF location in the courtyard, requiring relocation of the maintenance shop. LG&E/KU has some ideas where the shop could be relocated. As currently configured, new booster or ID fans could be added south of the PJFF without impacting the existing tanks south of the shop.
  - The skyway connecting Units 2 and 3 would need to be temporarily removed while the PJFF is installed. The skyway would then be modified to route around the south side of the PJFF and reconnect to Unit 3. It may also be possible to modify the skyway to provide access from the turbine buildings to the PJFF. To avoid re-routing of the significant amount of interconnecting pipe located in the ground level breezeway between units, the PJFF would be designed to span over this piping and allow the breezeway structure to remain in place, if practical.
- Unit 4:
  - The most likely location for the new PJFF is between the existing Unit 4 ESP area and the Unit 3 cooling tower as shown on the sketch. This location avoids the large 96” diameter circulating water pipelines, the water well, and most of the underground utilities in the area.

- The ID fans currently being installed at Unit 4 would be difficult to incorporate into the proposed ductwork configuration running between the existing ductwork tie in and the new PJFF and back, as shown on the arrangement sketches. A more favorable configuration may be accomplished by locating the new ID fans near the PJFF. The new fans would be sized to replace the current ID fans. New ID fans in this location would allow relatively easy connection directly to the ductwork at the FGD inlet.
- LG&E/KU expressed general agreement with the arrangement as discussed for Unit 4. An alternate version of the Unit 4 arrangement sketch was developed to more closely depict the arrangement discussed.

5.0 Selected Air Quality Control Technology

The following sections present a general description of the AQC technologies considered for Ghent, as well as a unit by unit discussion of the key attributes of the technologies and special considerations for their application and arrangement at the affected units. Table 5-1 presents the selected AQC technologies that were considered in the validation process.

Table 5-1. AQC Technologies

	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**
NO_x Control	Existing SCR	New SCR	Existing SCR	Existing SCR
SO_2 Control	Existing WFGD	Existing WFGD	Existing WFGD	Existing WFGD
PM Control	New PJFF	New PJFF	New PJFF	New PJFF
HCl Control	Existing WFGD and Existing Sorbent Injection	Existing WFGD and New Sorbent Injection	Existing WFGD and Existing Sorbent Injection	Existing WFGD and Existing Sorbent Injection
CO Control	New NN	New NN	New NN	New NN
SO_3 Control	Existing Sorbent Injection	New Sorbent Injection	Existing Sorbent Injection	Existing Sorbent Injection
Hg Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Dioxin/Furan Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Fly Ash Sales	Existing CS-ESP	Existing HS-ESP	Existing HS-ESP	Existing HS-ESP

CS-ESP = Cold-Side Electrostatic Precipitator.
HS-ESP = Hot-Side Electrostatic Precipitator.

5.1 Technology Descriptions

The following sections provide a brief general description of the proposed AQC technologies.

5.1.1 Selective Catalytic Reduction System

In an SCR system, ammonia is injected into the flue gas stream just upstream of a catalytic reactor. The ammonia molecules in the presence of the catalyst dissociate a significant portion of the NO_x into nitrogen and water.

The aqueous ammonia is received and stored as a liquid. The ammonia is vaporized and subsequently injected into the flue gas by compressed air or steam as a carrier. Injection of the ammonia must occur at temperatures above 600° F to avoid chemical reactions that are significant and operationally harmful. Catalyst and other considerations limit the maximum SCR system operating temperature to 840° F. Therefore, the system is typically located between the economizer outlet and the air heater inlet. The SCR catalyst is housed in a reactor vessel, which is separate from the boiler. The conventional SCR catalysts are either homogeneous ceramic or metal substrate coated. The catalyst composition is vanadium-based, with titanium included to disperse the vanadium catalyst and tungsten added to minimize adverse SO_2 and SO_3 oxidation reactions. An economizer bypass may be required to maintain the reactor temperature during low load operation. This will reduce boiler efficiency at lower loads.

The SCR process is a complex system. The SCR requires precise NO_x-to-ammonia distribution in the presence of the active catalyst site to achieve current BACT levels. In the past, removal efficiencies were the measure of catalyst systems because of extremely high inlet NO_x levels. Current technology SCR systems do not use removal efficiency as a primary metric because the current generation of LNB/OFA systems limits the amount of NO_x available for removal. Essentially, as NO_x is removed through the initial layers of catalyst, the remaining layers have difficulty sustaining the reaction.

A number of alkali metals and trace elements (especially arsenic) poison the catalyst, significantly affecting reactivity and life. Other elements such as sodium, potassium, and zinc can also poison the catalyst by neutralizing the active catalyst sites. Poisoning of the catalyst does not occur instantaneously, but is a continual steady process that occurs over the life of the catalyst. As the catalyst becomes deactivated, ammonia slip emissions increase, approaching design values. As a result, catalyst in a SCR system is consumable, requiring periodic replacement at a frequency dependent on the level of catalyst poisoning. However, effective catalyst management plans can be implemented that significantly reduce catalyst replacement requirements.

There are two SCR system configurations that can be considered for application on pulverized coal boilers: high dust and tail end. A high dust application locates the SCR system before the particulate collection equipment, typically between the economizer outlet and the air heater inlet. A tail end application locates the catalyst downstream of the particulate and FGD control equipment.

The high dust application requires the SCR system to be located between the economizer outlet and the air heater inlet in order to achieve the required optimum SCR operating temperature of approximately 600° to 800° F. This system is subject to high levels of trace elements and other flue gas constituents that poison the catalyst, as previously noted. The tail end application of SCR would locate the catalyst downstream of the particulate control and FGD equipment. Less catalyst volume is needed for the tail end application, since the majority of the particulate and SO_2 (including the trace elements that poison the catalyst) have been removed. However, a major disadvantage of this alternative is a requirement for a gas-to-gas reheater and supplemental fuel firing to achieve sufficient flue gas operating temperatures downstream of the FGD operating at approximately 125° F. The required gas-to-gas reheater and supplemental firing necessary to raise the flue gas to the sufficient operating temperature are costly. The higher front end capital costs and annual operating cost for the tail end systems present higher overall costs compared to the high dust SCR option with no established emissions control efficiency advantage. Figure 5-1 shows a schematic diagram of SCR.

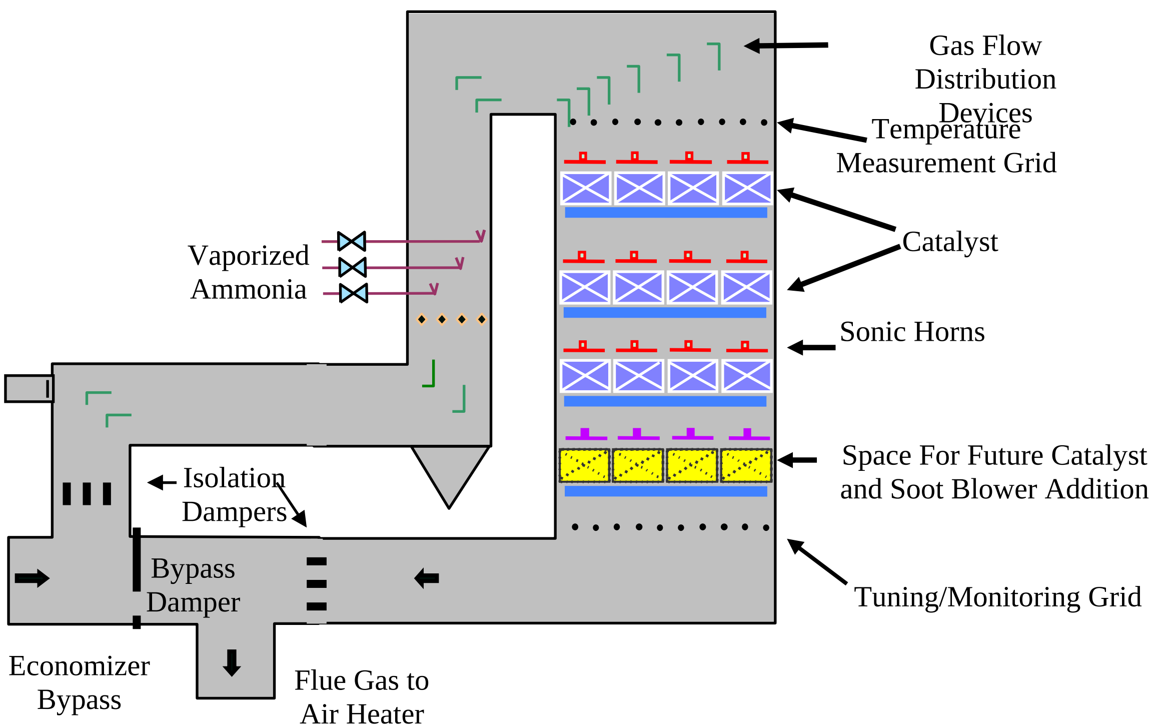


Figure 5-1. Schematic Diagram of a Typical SCR Reactor

5.1.2 Pulse Jet Fabric Filter

Pulse jet fabric filters (PJFFs) have been used for over 20 years on existing and new coal fired boilers and are media filters through which flue gas passes to remove the particulate. The success of FFs is predominately due to their ability to economically meet the low particulate emission limits for a wide range of particulate operations and fuel characteristics. Proper application of the PJFF technology can result in clear stacks (generally less than 5 percent opacity) for a full range of operations. In addition, the PJFF is relatively insensitive to ash loadings and various ash types, offering superb coal flexibility.

FFs are the current technology of choice when low outlet particulate emissions or Hg reduction is required for coal fired applications. FFs collect particle sizes ranging from submicron to 100 microns in diameter at high removal efficiencies. Provisions can be made for future addition of activated carbon injection to enhance gas phase elemental Hg removal from coal fired plants. Some types of fly ash filter cakes will also absorb some elemental Hg.

FFs are generally categorized by type of cleaning. The two predominant cleaning methods for utility applications are reverse gas and pulsejet. Initially, utility experience in the United States was almost exclusively with Reverse Gas Fabric Filters (RGFF). Although they are a very reliable and effective emissions control technology, RGFFs have a relatively large footprint, which is particularly difficult for implementation. PJFFs can be operated at higher flue gas velocities and, as a result, have a smaller footprint. The PJFF usually has a lower capital cost than a RGFF and matches the performance and reliability of a RGFF. As a result, only PJFFs will be considered further.

Cloth filter media is typically sewn into cylindrical tubes called bags. Each PJFF may contain thousands of these filter bags. The filter unit is typically divided into compartments that allow on-line maintenance or bag replacement after a compartment is isolated. The number of compartments is determined by maximum economic compartment size, total gas volume rate, air-to-cloth ratio, and cleaning system design. Extra compartments for maintenance or off-line cleaning not only increase cost, but also increase reliability. Each compartment includes at least one hopper for temporary storage of the collected fly ash. A cutaway view of a PJFF compartment is illustrated on Figure 5-2.

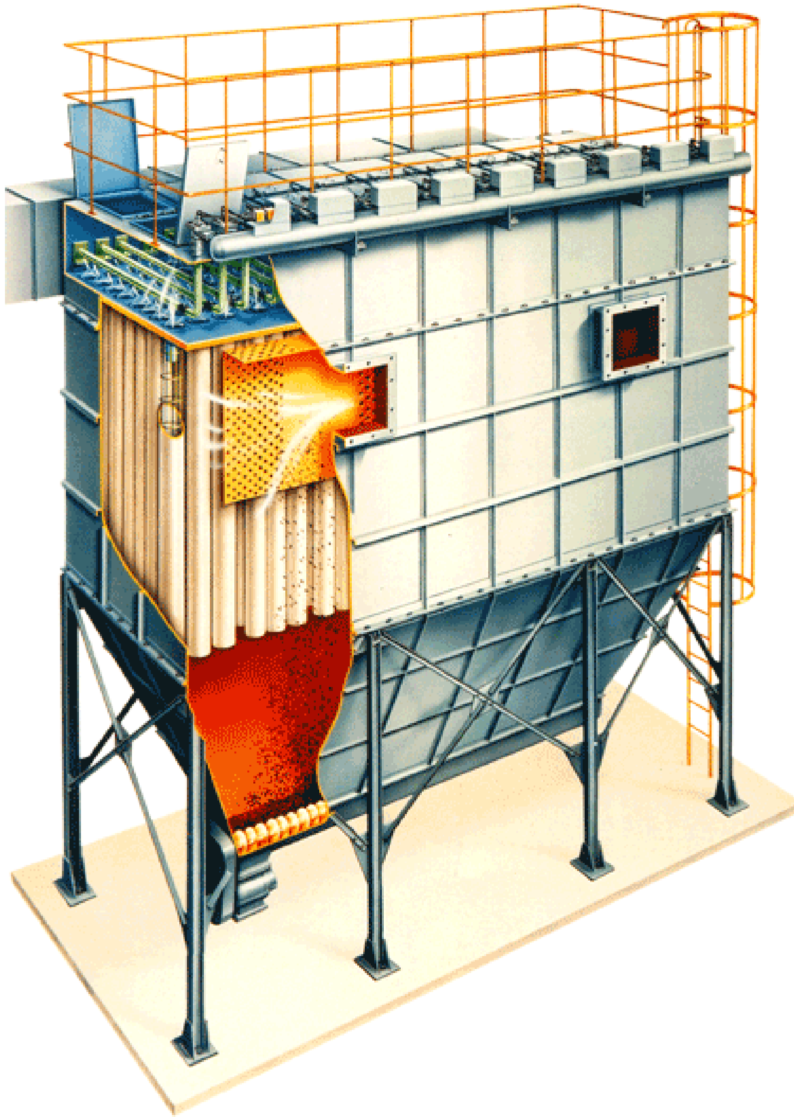


Figure 5-2. Pulse Jet Fabric Filter Compartment

Fabric bags vary in composition, length, and cross section (diameter or shape). Bag selection characteristics vary with cleaning technology, emissions limits, flue gas and ash characteristics, desired bag life, capital cost, air-to-cloth ratio, and pressure differential. Fabric bags are typically guaranteed for 3 years but frequently last 5 years or more.

In PJFFs, the flue gas typically enters the compartment hopper and passes from the outside of the bag to the inside, depositing particulate on the outside of the bag. To prevent the collapse of the bag, a metal cage is installed on the inside of the bag. The flue gas passes up through the center of the bag into the outlet plenum. The bags and cages are suspended from a tubesheet.

Cleaning is performed by initiating a downward pulse of air into the top of the bag. The pulse causes a ripple effect along the length of the bag. This dislodges the dust cake from the bag surface, and the dust falls into the hopper. This cleaning may occur with the compartment on line or off-line. Care must be taken during design to ensure that the upward velocity between bags is minimized so that particulate is not re-entrained during the cleaning process.

The PJFF cleans bags in sequential, usually staggered, rows. During on-line cleaning, part of the dust cake from the row that is being cleaned may be captured by the adjacent rows. Despite this apparent shortcoming, PJFFs have successfully implemented on-line cleaning on many large units.

The PJFF bags are typically made of felted materials that do not rely as heavily on the dust cake's filtering capability as woven fiberglass bags do. This allows the PJFF bags to be cleaned more vigorously. The felted materials also allow the PJFF to operate at a much higher cloth velocity, which significantly reduces the size of the unit and the space required for installation.

5.1.3 Powdered Activated Carbon Injection

With reported Hg removals of more than 90 percent for bituminous coal applications, PAC injection is an effective and mature technology in the control of Hg in Municipal Solid Waste (MSW) and Medical Waste Combustors (MWC). Its potential effectiveness on a wide range of coal fired power plant applications is gaining acceptance based on recent pilot and slipstream testing activities sponsored by the Department of Energy (DOE), EPA, Electric Power Research Institute (EPRI), and various research organizations and power generators. However, recent pilot scale test results indicate that the level of Hg control achieved with a PAC injection system is impacted by variables such as the type of fuel, the speciation of Hg in the fuel, operating temperature, fly ash properties, flue gas chloride content, and the mechanical collection device used in the removal of Hg.

PAC injection typically involves the use of a lignite based carbon compound that is injected into the flue gas upstream of a particulate control device as illustrated on Figure 5-3. Elemental and oxidized forms of Hg are adsorbed into the carbon and are collected with the fly ash in the particulate control device.

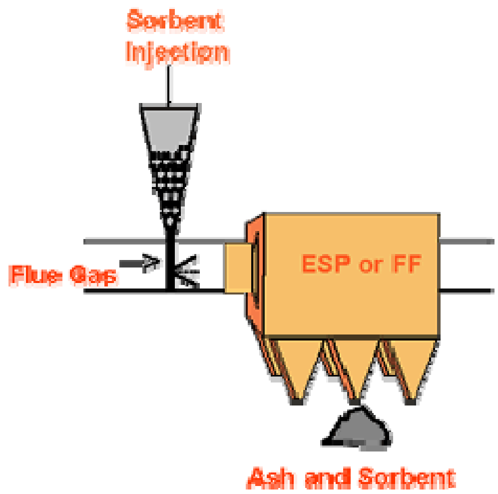


Figure 5-3. Activated Carbon Injection System

PAC injection is generally added upstream of either PJFFs or ESPs. For ESPs, the Hg species in the flue gas are removed as they pass through a dust cake of unreacted carbon products on the surface of the collecting plates. Additionally, a significantly higher carbon injection rate is required for PAC injection upstream of an ESP than is required for PAC injection upstream of a high air-to-cloth ratio PJFF or a PJFF that is located downstream of a SDA FGD system. Literature indicates that PAC injection upstream of a CS-ESP can reduce Hg emissions up to 60 percent for units that burn a sub-bituminous or lignite coal, and up to 80 percent for units that burn a bituminous coal. The addition of activated carbon does not directly affect the function of the ash handling system. The additional activated carbon in the fly ash does, however, affect the quality of the ash that is produced. For units that currently sell fly ash, this will negatively impact their continued ability to sell the ash.

Since the sale of fly ash depends on the carbon content of the ash, increasing the amount of carbon in the ash also makes it unsuitable for sale. To maintain the ash quality required for sale, the ash must either be removed upstream of the PAC injection system or the activated carbon should be injected into the flue gas so that it is not mixed with all the collected fly ash or is mixed with only a small portion of the total fly ash that is collected in the particulate control device. This can be accomplished by using a high air-to-cloth ratio PJFF downstream of CS-ESP.

Numerous testing efforts and studies have shown that most of the Hg resulting from the combustion of coal leaves the boiler in the form of elemental Hg, and that the level of chlorine in the coal has a major impact on the efficiency of Hg removal with PAC injection and the particulate removal system. Low chlorine coals, such as sub-bituminous and lignite coals, typically demonstrate relatively low Hg removal efficiency. Sub-bituminous and lignite coals produce very low levels (approximately 100 parts per million [ppm]) of HCl during combustion and; therefore, normal PAC injection would be anticipated to achieve very low elemental Hg removal.

The removal efficiency that is attained by halogenated PAC injection can be significantly increased by the use of PAC that has been pretreated with halogens, such as iodine or bromine. Recent testing results indicate that halogenated PAC injection upstream of a CS-ESP can reduce Hg emissions up to 80 percent for units that burn a sub-bituminous or lignite coal and up to 90 percent for units that burn a bituminous coal. Pretreated PAC is more expensive than untreated PAC: (approximately $5.00/lb of iodine, $1.00/lb of bromine, and $0.50/lb of PAC). However, less pretreated PAC is required to achieve significant removals, if such removal rates are dictated by more stringent Hg control regulations.

PAC can also be injected upstream of a PJFF located downstream of a semi-dry lime FGD. When a semi-dry lime FGD and a PJFF is injected with PAC upstream of the FGD, the activated carbon absorbs most of the oxidized Hg. This is a result of the additional residence time in the FGD and will basically allow greater contact between the Hg particles and the activated carbon. Because of the accumulated solids cake on the bags, the activated carbon is given another opportunity to interact with the Hg prior to disposal or recycle. Since the ash and reagent collected in the PJFF are already contaminated, the additional carbon collected in the PJFF will not affect ash sales or disposal. Recent literature indicates that PAC injection upstream of a semi-dry FGD and PJFF can reduce Hg emissions by 60 to 80 percent.

Halogenated PAC injection upstream of a semi-dry lime FGD and PJFF is basically similar in design to standard PAC, as described previously. Halogenated PAC includes halogens such as bromine or iodine. Literature indicates that halogenated sorbents require significantly lower injection rates (in some cases the difference is as much as a factor of 3) upstream of a semi-dry lime FGD and PJFF combination, as compared to an ESP, and can reduce Hg emissions of up to 95 percent.

5.1.4 Sorbent Injection

Injection of finely divided alkalis into the flue gas has been demonstrated for the removal of SO_3 from flue gases. Most commercial experience is from units firing high sulfur oil where trace metals, mainly vanadium, increase SO_2 oxidation. Magnesium-based compounds have been used successfully for decades to capture SO_3 in oil fired units. As coal fired units burning high sulfur bituminous coals have been retrofitted with SCR systems, interest in the injection of alkali compounds directly into the flue gas duct of a unit has increased. Sorbents such as SBS, trona, and hydrated lime have recently been used on large coal fired units, with reported results showing the achievement of high control efficiencies of SO_3 in high sulfur applications.

5.1.5 CO Reduction Technologies

Control of CO is divided into two basic categories, good combustion controls and neural networks.

5.1.5.1 Good Combustion Controls. As products of incomplete combustion, CO and VOC emissions are very effectively controlled by ensuring the complete and efficient combustion of the fuel in the boiler (i.e., good combustion controls). Typically, measures taken to minimize the formation of NO_x during combustion inhibit complete combustion, which increases the emissions of CO and VOC. High combustion temperatures, adequate excess air, and good air/fuel mixing during combustion minimize CO and VOC emissions. These parameters also increase NO_x generation, in accordance with the conflicting goals of optimum combustion to limit CO and VOC, but lower combustion temperatures to limit NO_x. The products of incomplete combustion are substantially different and often less pronounced when the unit is firing high sulfur bituminous coals, which is the rationale for the slightly higher BACT emissions limits found on units permitted to burn low sulfur PRB subbituminous coals. In addition, depending on the manufacturer, good combustion controls vary in terms of meeting CO emissions limits. Good combustion controls are an option to aid in reduction of CO but are assumed to currently be optimized. No further study of this option was considered in this report.

5.1.5.2 Neural Networks. Neural networks utilize a DCS based computer system that obtains plant data such as load, firing rate, burner position, air flow, CO emissions, etc. The computer system analyzes the impact of various combustion parameters on CO emissions. The system then provides feedback to the control system to improve operation for lower CO emissions. With this combustion system performance monitoring equipment in place, it is expected that sufficient information would be available to maintain the performance of each burner at optimum conditions to enable operations personnel to maintain the most economical balance of peak fuel efficiency and emissions of NO_x, and CO. In addition to burner performance these monitoring systems also allow continuous indication of pulverizer, classifier and fuel delivery system performance to provide early indication of impending component failures or maintenance requirements. This system is also used to improve heat rate and often provides operational cost savings along with CO control. It is commercially proven and has demonstrated CO reductions. However, CO emission reductions due to installation of NN vary from unit to unit based on each unit's specific equipment configuration and operation.

At this point, there are no proven and feasible post combustion AQC technologies for the control of CO emissions from coal-fired boilers of this size. DCS based computer furnace combustion monitoring systems, such as neural networks, may help reduce CO emissions by improving plant heat rate and optimizing the various combustion parameters responsible for the formation of CO. Improvising the coal mills and coal feed injection/air management and or burner modifications including the detuning of any existing NO_x combustion controls devices will help reduce the CO in combustion or pre-combustion stage. There are no arrangement fatal flaws or constraints associated with the installation of a NN at Ghent, although it cannot be validated at this point whether or not a NN can achieve the required CO target emission rate.

5.2 Unit by Unit Summary of AQC Selection

The following AQC control technologies comprise the selected technologies to control unit pollutant emissions to the targeted emission levels. As summarized on the following pages, the selected technologies are based on the known technology limitations, future expanding capability, arrangement or site fatal flaws, constructability challenges, unit off-line schedule requirements or site-specific considerations developed or understood during the AQC Technology Screening Workshop conducted on August 5-6, 2010, as well as information provided by LG&E/KU.

5.2.1 Ghent Unit 1

Table 5-2 identifies the selected AQC technologies for Ghent Unit 1. The key attributes of the technologies and special considerations for their application and arrangements are presented in a bulleted format for each technology.

Table 5-2. Unit 1– AQC Selection

AQC Equipment	Pollutant
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF	PM

New PAC Injection

- A PJFF is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the ID fans but upstream of new PJFF.
- PAC Injection can meet the new Hg compliance limit of 1 x 10^{-6} lb/MBtu or lower on a continuous basis and new dioxin/furan compliance limit of 15 x 10^{-18} lb/MBtu or lower on a continuous basis and hence is the most feasible control technology.
- Dioxin and Furan removal will be a co-benefit with targeted mercury emissions removal and additional PAC consumption beyond mercury removal will be required.
- The use of PAC system will slightly increase the truck traffic at the plant due to increased bulk deliveries.

New PJFF

- A PJFF can consistently achieve PM emissions of less than 0.03 lb/MBtu on a continuous basis and has the capability to expand in order to meet PM emissions lower than 0.03 lb/MBtu. Hence, a PJFF is the most feasible and expandable control technology considered for PM reduction, including future requirements.
- PJFF offers more direct benefits or co-benefits of removing future multi-pollutants like mercury and sulfuric acid using some form of injection upstream.
- The PJFF will increase pressure drop of the system. As such, the draft system needs to be investigated and new booster fans will be required. Additional auxiliary power requirement will need to be considered for new booster fans
- A new ash handling system will be required to collect ash from PJFF hoppers.
- Additional maintenance will be required for replacing bags and cages.
- The PJFF can be located downstream of the existing ID fans and upstream of the new booster fans and can possibly be installed as suggested in the high level layout drawings as shown in Appendix A.
- The PJFF for Unit 1 will be located on the south side of the existing Unit 2 cooling tower and west side of the existing Unit 1 scrubber module. The PJFF will be elevated above the ground level. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated.

5.2.2 Ghent Unit 2

Table 5-3 identifies the selected AQC technologies for Ghent Unit 2. The key attributes of the technologies and special considerations for their application and arrangements are presented in a bulleted format for each technology.

Table 5-3. Unit 2 – AQC Selection

AQC Equipment	Pollutant
New SCR	NO_x
New PAC Injection	Hg, Dioxin/Furan
New Trona/Lime/SBS Injection	SO_3
New stand-alone full size PJFF	PM

New SCR

- SCR can consistently achieve NO_x emissions of lower than 0.041 lb/MBtu on a continuous basis. Therefore, SCR is the most feasible and expandable control technology considered for NO_x reduction including future NO_x reduction requirements.
- The SCR will increase pressure drop of the system. However, the existing ID fans have the capability to handle additional pressure drop for the SCR system..
- Ammonia consumption increases with the addition of SCR. Detailed investigation or study will be required to confirm if a new ammonia storage facility is required or if the existing ammonia storage facility can be upgraded for accommodating Unit 2 ammonia supply.
- An SO_3 mitigation system like alkali injection and PJFF will be required.
- Existing air heater will be retained. Air heater basket modifications for acid resistance may be necessary after the installation of SCR.
- A new SCR can be located downstream of the existing HS-ESP and upstream of the existing air heater.
- A new SCR will be arranged as 2 x 50% reactors.
- Elevated cables and overhead lines may need to be relocated.

New PAC Injection

- A PJFF is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the ID fans but upstream of new PJFF.
- PAC Injection can meet the new Hg compliance limit of 1 x 10^{-6} lb/MBtu or lower on a continuous basis and new dioxin/furan compliance limit of 15 x 10^{-18} lb/MBtu or lower on a continuous basis and hence is the most feasible control technology.
- Dioxin and Furan removal will be a co-benefit with targeted mercury emissions removal and additional PAC consumption beyond mercury removal will be required.
- The use of PAC system will slightly increase the truck traffic at the plant due to increased bulk deliveries.

New PJFF

- A PJFF can consistently achieve PM emissions of less than 0.03 lb/MBtu on a continuous basis and has the capability to expand in order to meet PM emissions lower than 0.03 lb/MBtu. Hence, a PJFF is the most feasible and expandable control technology considered for PM reduction, including future requirements.
- PJFF offers more direct benefits or co-benefits of removing future multi-pollutants like mercury and sulfuric acid using some form of injection upstream.
- The PJFF will increase pressure drop of the system. As such, the draft system needs to be investigated and new booster fans will be required. Additional auxiliary power requirement will need to be considered for new booster fans.
- A new ash handling system will be required to collect ash from PJFF hoppers.
- Additional maintenance will be required for replacing bags and cages.
- The PJFF can be located downstream of the existing ID fans and upstream of the new booster fans and can possibly be installed as suggested in the high level layout drawings as shown in Appendix A.
- The PJFF for Unit 2 will be located on the north side of the existing Unit 2 hot-side ESP and east side of the existing Unit 2 scrubber modules. The PJFF will be elevated above the ground level. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated.

New SO_3 Control System (Reagent Injection)

A reagent injection system that injects trona, Lime or SBS into the flue gas to remove SO_3 would be necessary.

- A PJFF is recommended in conjunction with a reagent injection system.
- Trona/lime/SBS would be injected downstream of the SCR but upstream of the air heater.
- Reagent injection can reduce the sulfuric acid emissions on a continuous basis and mitigate the visible blue plume formation from the chimney which is often associated when burning high sulfur coal.
- The use of sorbent system will slightly increase the truck traffic at the plant.

5.2.3 Ghent Units 3 and 4

Table 5-4 identifies the selected AQC technologies for Units 3 and 4. The key attributes of the technologies and special considerations for their application and arrangements are presented in a bulleted format for each technology.

Table 5-4. Units 3 and 4 – AQC Technology Selection

AQC Equipment	Pollutant
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF	PM

New PAC Injection

- A PJFF is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the existing air heater but upstream of new PJFF.
- PAC Injection can meet the new Hg compliance limit of 1×10^{-6} lb/MBtu or lower on a continuous basis and new dioxin/furan compliance limit of 15×10^{-18} lb/MBtu or lower on a continuous basis and hence is the most feasible control technology.
- Dioxin and Furan removal will be a co-benefit with targeted mercury emissions removal and additional PAC consumption beyond mercury removal will be required.
- The use of PAC system will slightly increase the truck traffic at the plant due to increased bulk deliveries.

New PJFF

- A PJFF can consistently achieve PM emissions of less than 0.03 lb/MBtu on a continuous basis and has the capability to expand in order to meet PM emissions lower than 0.03 lb/MBtu. Hence, a PJFF is the most feasible and expandable control technology considered for PM reduction, including future requirements.
- PJFF offers more direct benefits or co-benefits of removing future multi-pollutants like mercury and sulfuric acid using some form of injection upstream.
- The PJFF will increase pressure drop of the system. As such, the draft system needs to be investigated and new ID fans will be required. The existing ID fans will be bypassed and abandoned in place. Additional auxiliary power requirement will need to be considered for the new ID fans
- A new ash handling system will be required to collect ash from PJFF hoppers.
- Additional maintenance will be required for replacing bags and cages.
- The PJFF can be located downstream of the existing air heater and upstream of the new ID fans and can possibly be installed as suggested in the high level layout drawings as shown in Appendix A.
- The PJFF for Unit 3 will be located on the east side of the Unit 3 boiler and west side of Unit 2 boiler. The PJFF will be elevated above the ground level. Existing structures which includes utility corridor walkway enclosure, maintenance shop, personnel skywalk, etc. will be investigated, evaluated, and, if necessary, relocated. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated. If practical, the utility walkway enclosure and personnel skywalk will be re-established upon completion of the PJFF.
- The PJFF for Unit 4 will be located on the north side of the Unit 4 WFGD and stack. Existing warehouse structure and foundation will be demolished. Above and under ground utilities will be investigated, evaluated, and, if necessary, relocated.

6.0 Validation Analyses

The following sections describe the analyses of various balance of plant systems necessary to validate the selected AQC equipment.

6.1 Draft System Analysis

As a part of the draft system analysis of the AQC validation process for Ghent, the flue gas draft fans need to be evaluated to determine if modifications, replacements, or additions to the existing fans will be required. This is due to the installation of additional draft system equipment to control certain flue gas emissions. For Units 1, 3, and 4 the modifications and additions to the draft system being considered include new PJFF systems that will supplement the existing ESPs of each unit in the removal of particulate. For Unit 2 draft system modifications and additions being considered are a new SCR system for removing NO_x emissions and a new PJFF system. For more detail on the AQC equipment modifications, additions, etc. for each Ghent unit refer to Section 5.0.

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. This philosophy includes the application of the following items to the required MCR conditions for new or modified fans:

- 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°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.

Additionally, following the preliminary analyses of the Ghent draft systems, there will be a discussion on draft system stiffening, or transient design pressure, requirements per NFPA 85.

6.1.1 Unit 1

Based on the additions to the Unit 1 draft system previously discussed and the flue gas flow through the draft system would change as follows. At the outlet of the existing ID fans the flue gas would travel to the new PJFF system allowing for the removal of finer particulate emissions before entering two new 50 percent capacity booster fans. The new booster fans, assumed to be equipped with variable speed control, would then send the flue gas to the WFGD system. An illustration of the Unit 1 future draft system based on these changes is shown in Figure 6-1.

With the expected installation of a PJFF system, the pressure demand on the draft fan system will be significantly higher than what the existing ID fans may deliver while still providing adequate margin. However, the efficient variable speed capabilities and recent major modifications are advantageous to operation and longevity of the existing ID fans. Therefore, it would be desirable to supplement the capabilities of the existing Unit 1 ID fans as opposed to replacing them. B&V proposes this be accomplished with two new 50 percent capacity centrifugal booster fans, also with variable speed control.

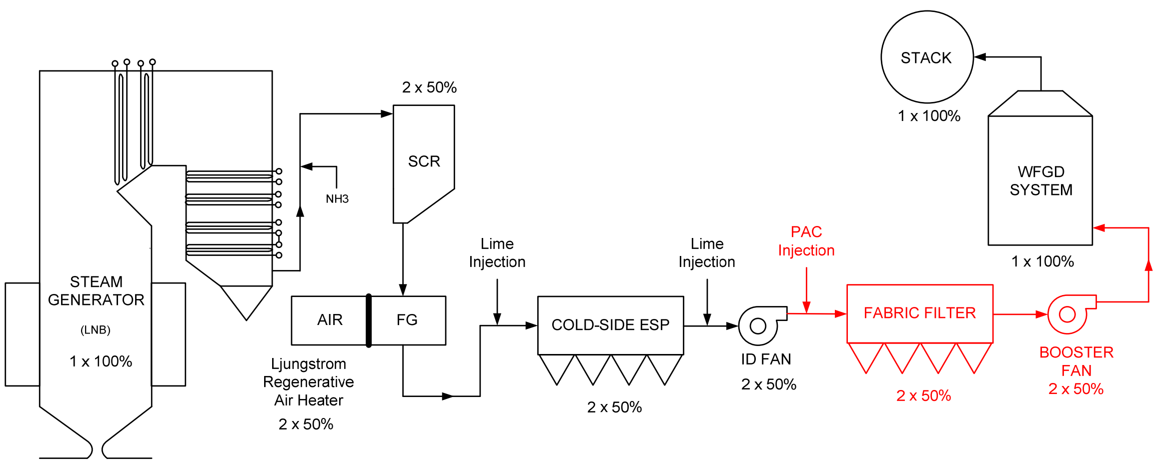


Figure 6-1. Unit 1 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 1 future draft system at MCR are as follows in Table 6-1. Note that the items in bold in Table 6-1 are new.

Table 6-1. Unit 1 Future Draft System Characteristics at MCR

SCR system leakage	2% (estimated)
Air heater leakage	10% (estimated)
ESP leakage	5% (estimated)
PJFF system leakage	**3%**
Flue gas temperatures	
Boiler outlet	729° F
SCR outlet	729° F
Air heater outlet	361° F
ESP outlet	358° F
PJFF outlet	**358° F**
ID fan outlet	~375° F (calculated)
Booster fan outlet	**~375° F (calculated)**
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	2.7 inw
SCR	10.0 inw
Air heater	9.2 inw
ESP	3.3 inw
PJFF	**8.0 inw**
WFGD	4.4 inw
Stack	1.7 inw

Based on the layout of the future draft system in Figure 6-1 and the future draft system characteristics in Table 6-1, the estimated performance requirements of the new booster fans at MCR are shown in Table 6-2. Also in Table 6-2 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 25 and 39 percent, respectively. To keep the booster fan Test Block pressure margin within the typical range of 35 to 45 percent the 1.0 inw control allowance was removed.

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

	MCR	Test Block
Fan Speed (rpm), maximum	------	900
Inlet Temperature (°F)	374	399
Inlet Density (lb/ft^3)	0.0461	0.0445
Flow per Fan (acfm) *	1,122,000	1,402,000
Inlet Pressure (inwg)	-8.0	-10.8
Outlet Pressure (inwg)	6.1	8.8
Static Pressure Rise (inw)	14.1	19.6
Shaft Power Required (HP) **	2,900	5,100
Efficiency (percent) **	85	85
Number of Fans	2	2
Flow Margin (percent)	---------	25
Pressure Margin (percent)	---------	39

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

6.1.2 Unit 2

Based on the additions to the Unit 2 draft system previously discussed the flue gas would be redirected through the draft system as follows. At the outlet of the hot-side ESP the flue gas would travel to the new SCR system allowing for the removal of NOx emissions before entering the air heaters. Once the flue gas is through the air heaters it would enter the existing ID fans. Between the existing ID fans and WFGD system would be the new PJFF system and new booster fans. The new booster fans, assumed to be equipped with variable speed control, would draw flue gas through the PJFF system and send it to the WFGD system. Additionally, the SCR system is expected to require an economizer bypass on the flue gas or water-side. An illustration of the Unit 2 future draft system based on this description is shown in Figure 6-2.

With the expected installation of both an SCR system and a PJFF system, the pressure demand on the draft fan system is expected to be significantly higher than what the existing ID fans may deliver while still providing adequate margin. However, the efficient variable speed capabilities and recent major modifications are advantageous to operation and longevity of the existing ID fans. Therefore, it would be desirable to supplement the capabilities of the existing Unit 2 ID fans as opposed to replacing them. B&V proposes this be accomplished with two new 50 percent capacity centrifugal booster fans as with Unit 1, also with variable speed control.

The economizer bypass for the SCR system is expected due to the relatively low flue gas temperatures currently exiting the economizer which are not expected to change significantly in the future. This is because a minimum SCR inlet temperature will need to be maintained for the proper reactions to take place in the reactor and at lower loads. When these temperatures decrease, additional energy may need to be injected into the flue gas stream which can be accomplished by using the economizer bypass. However, this economizer bypass may also be needed at full load as well due to the significant temperature drop occurring through the hot-side ESPs. B&V will conduct further analyses during conceptual design to determine the performance requirements of an economizer bypass to control flue gas temperatures entering the SCR system.

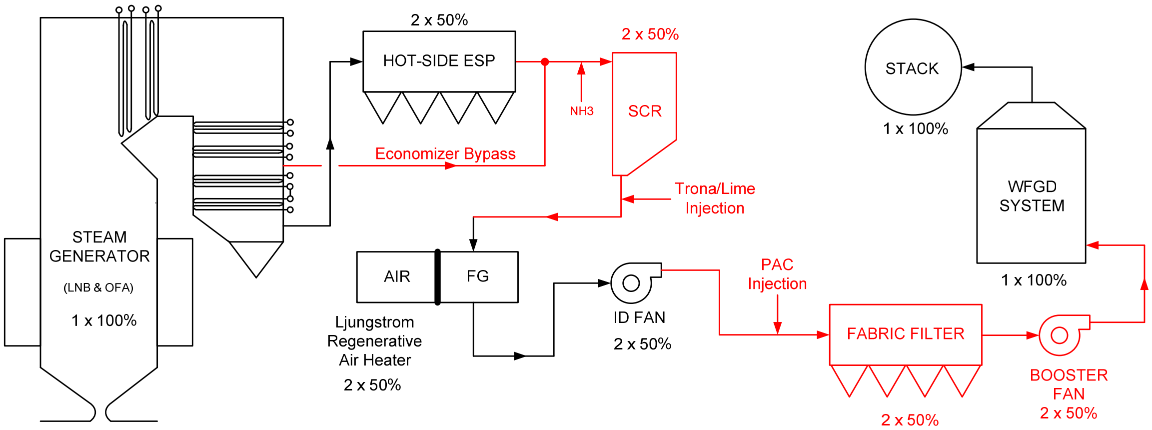


Figure 6-2. Unit 2 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 2 future draft system at MCR are as follows in Table 6-3. Note that the items in bold in Table 6-3 are new.

Table 6-3. Unit 2 Future Draft System Characteristics at MCR

ESP leakage	5% (estimated)
SCR system leakage	**2%**
Air heater leakage	10% (estimated)
PJFF leakage	**3%**
Flue gas temperatures	
Boiler outlet	610° F
ESP outlet	605° F
SCR outlet	**605° F**
Air heater outlet	309° F
PJFF outlet	**309° F**
ID fan outlet	~325° F (calculated)
Booster fan outlet	**~325° F (calculated)**
WFGD outlet	~125° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.6 inw
ESP	5.7 inw
SCR	**10.0 inw**
Air heater	7.8 inw
PJFF	**8.0 inw**
WFGD	9.9 inw
Stack	1.5 inw

Based on the layout of the future draft system in Figure 6-2 and the future draft system characteristics in Table 6-3, the estimated performance requirements of the new ID fans at MCR are shown in Table 6-4. Also in Table 6-4 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 25 and 43 percent, respectively. To keep the booster fan Test Block pressure margin within the typical range of 35 to 45 percent the 1.0 inw control allowance was removed.

Table 6-4. Unit 2 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)	0.0490	0.0471
Flow per Fan (acfm) *	1,088,000	1,364,000
Inlet Pressure (inwg)	-8.0	-11.3
Outlet Pressure (inwg)	11.4	16.5
Static Pressure Rise (inw)	19.4	27.8
Shaft Power Required (HP) **	4,000	7,100
Efficiency (percent)**	85	85
Number of Fans	2	2
Flow Margin (percent)	---------	25
Pressure Margin (percent)	---------	43

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

6.1.3 Unit 3

Based on the additions to the Unit 3 draft system 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 finer particulate. The three new 33 percent centrifugal ID fans, assumed to be equipped with variable speed control, would then draw the flue gas out of the PJFF system and send it to the WFGD system. An illustration of the Unit 3 future draft system based on this description is shown in Figure 6-3.

Due to operation and maintenance issues with the recently installed two 50 percent axial ID fans, the plant would like them to be replaced and bypassed with new centrifugal type fans. However, due to the B&V recommended margins on flow and pressure (Test Block conditions) above the MCR conditions with the addition of a PJFF system, the new centrifugal ID fans will be required to be in a three fan arrangement. An illustration of the Unit 3 future draft system based on this description is shown in Figure 6-3.

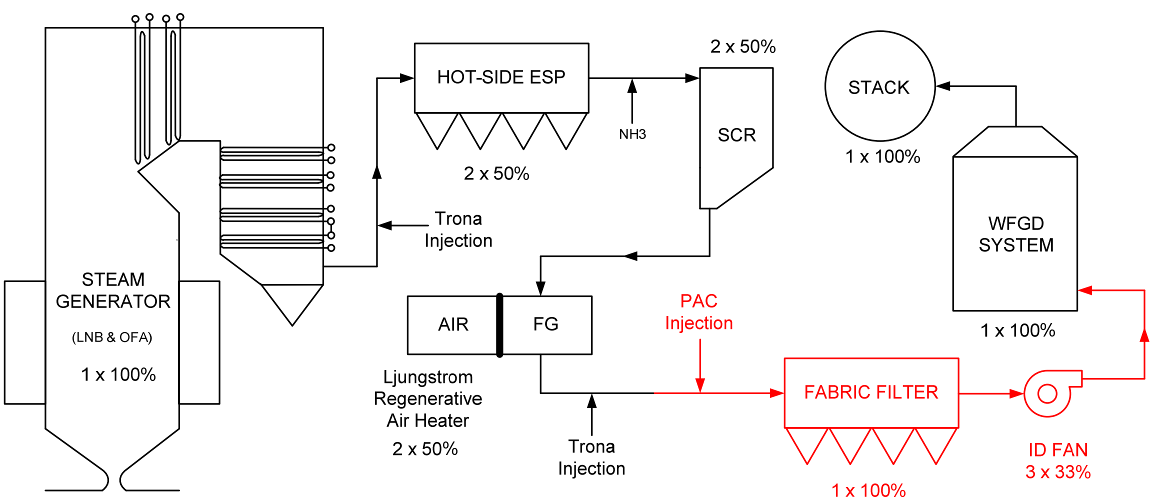


Figure 6-3. Unit 3 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 3 future draft system at MCR are as follows in Table 6-5. Note that the items in bold in Table 6-5 are new.

Table 6-5. Unit 3 Future Draft System Characteristics at MCR

SCR system leakage	2% (estimated)
Air heater leakage	10% (estimated)
ESP leakage	5% (estimated)
PJFF leakage	**3%**
Flue gas temperatures	
Boiler outlet	731° F
ESP outlet	708° F
SCR outlet	708° F
Air heater outlet	322° F
PJFF outlet	**322° F**
ID fan outlet	~**350° F (calculated)**
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.6 inw
ESP	5.8 inw
SCR	10.0 inw
Air heater	15.2 inw
PJFF	**8.0 inw**
WFGD	3.9 inw
Stack	2.0 inw

Based on the layout of the future draft system in Figure 6-3 and the future draft system characteristics in Table 6-5, the estimated performance requirements of the new ID fans at MCR are shown in Table 6-6. Also in Table 6-6 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 25 and 38 percent, respectively. To keep the ID fan Test Block flow and pressure margin within the typical ranges the 50 percent leakage margin and 50 percent margin on air heater differential pressure were both decreased to 25 percent.

Table 6-6. Unit 3 New ID Fan
MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	------	900
Inlet Temperature (°F)	322	347
Inlet Density (lb/ft^3)	0.0446	0.0413
Flow per Fan (acfm) *	796,000	991,000
Inlet Pressure (inwg)	-44.1	-60.0
Outlet Pressure (inwg)	5.9	8.8
Static Pressure Rise (inw)	50.0	68.8
Shaft Power Required (HP) **	7,400	12,700
Efficiency (percent)**	85	85
Number of Fans	3	3
Flow Margin (percent)	---------	25
Pressure Margin (percent)	---------	38

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

6.1.4 Unit 4

Based on the additions to the Unit 4 draft system 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 finer particulate. The three new 33 percent centrifugal ID fans, assumed to be equipped with variable speed control, would then draw the flue gas out of the PJFF system and send it to the WFGD system. An illustration of the Unit 4 future draft system based on this description is shown in Figure 6-3.

Due to operation and maintenance issues with the recently installed two 50 percent axial ID fans, the plant would like them to be replaced and bypassed with new centrifugal type fans. However, due to the B&V recommended margins on flow and pressure (Test Block conditions) above the MCR conditions with the addition of a PJFF system, the new centrifugal ID fans will be required to be in a three fan arrangement. An illustration of the Unit 4 future draft system based on this description is shown in Figure 6-4.

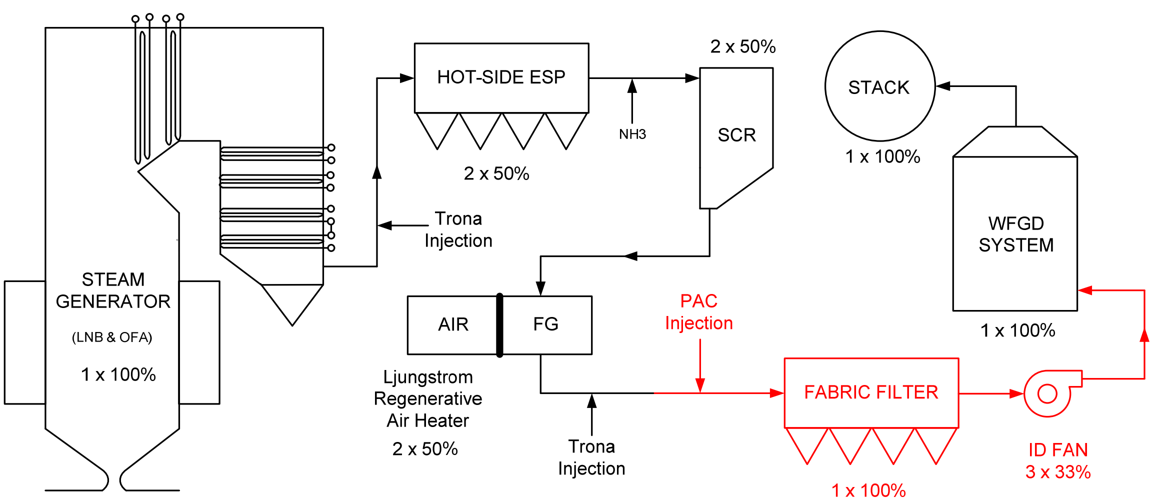


Figure 6-4. Unit 4 Future Draft System

Future Draft System Characteristics

The major performance characteristics of the Unit 4 future draft system at MCR are as follows in Table 6-7. Note that the items in bold in Table 6-7 are new.

Table 6-7. Unit 4 Future Draft System Characteristics at MCR

SCR system leakage	2% (estimated)
Air heater leakage	10% (estimated)
ESP leakage	5% (estimated)
PJFF leakage	**3%**
Flue gas temperatures	
Boiler outlet	791° F
ESP outlet	770° F
SCR outlet	770° F
Air heater outlet	309° F
PJFF outlet	**309° F**
ID fan outlet	**~340° F (calculated)**
WFGD outlet	~125° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.0 inw
ESP	6.3 inw
SCR	10.0 inw
Air heater	8.6 inw
PJFF	**8.0 inw**
WFGD	13.0 inw
Stack	1.6 inw

Based on the layout of the future draft system in Figure 6-4 and the future draft system characteristics in Table 6-7, the estimated performance requirements of the new ID fans at MCR are shown in Table 6-8. Also in Table 6-8 are the recommended Test Block conditions developed using the Black & Veatch fan sizing philosophy previously outlined in this section. Note the flow and pressure margins of 23 and 35 percent, respectively. To keep the ID fan Test Block flow and pressure margin within the typical ranges the 50 percent leakage margin and 50 percent margin on air heater differential pressure were both decreased to 25 percent.

Table 6-8. Unit 4 New ID Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	------	900
Inlet Temperature (°F)	309	334
Inlet Density (lb/ft^3)	0.0462	0.0433
Flow per Fan (acfm) *	760,000	935,000
Inlet Pressure (inwg)	-37.4	-49.6
Outlet Pressure (inwg)	14.6	20.4
Static Pressure Rise (inw)	52.0	70.0
Shaft Power Required (HP) **	7,400	12,200
Efficiency (percent) **	85	85
Number of Fans	3	3
Flow Margin (percent)	---------	23
Pressure Margin (percent)	---------	35

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

6.1.5 Draft System Transient Design Pressures

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 National Fire Protection Association (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 (it should be implied that this would include booster fans) be designed for transient pressures of ± 35 inwg at a minimum per Section 6.5. Further research is needed to determine whether the existing boilers and draft systems of each of the Ghent units meets this criteria or if they will require stiffening. Each new piece of AQC equipment, and its associated ductwork, being considered for the Ghent units will also be required to meet this NFPA 85 requirement. Additionally, in some sections of the future draft systems, the transient design pressures will need to exceed the ± 35 inwg due to high negative draft pressures.

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 (fan Test Block) operating 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, if a section of ductwork is expected to be exposed to negative draft pressures of -30 inwg when the ID fans are operating at Test Block conditions, the calculated negative transient design pressure would be 44 percent higher or -43.2 inwg. The positive transient design pressure would still be +35 inwg. Since NFPA 85 requires that flue gas ductwork between the boiler outlet and the ID fan inlet 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. For calculated transient design pressures over ± 35 inwg such as in the previous example, the calculated pressure is used.

6.2 Auxiliary Electrical System Analysis

The existing Ghent auxiliary power systems includes 25 kV switchyard switchgear two bus system where 25 kV Bus A is fed from 138 kV–25 kV Reserve Auxiliary Transformer (RAT) A, and 25 kV Bus B is fed from 138 kV–25 kV RAT B. The 25 kV switchgear buses provide startup/backup power for each unit, and the unit scrubber FGD auxiliary electrical systems with the exception of Unit 2 scrubber FGD auxiliary electrical system. Unit 2 Scrubber FGD auxiliary electrical system 4KV buses 5A and 5B are fed from 25 kV–4.16 kV scrubber transformers SST FGD 5A and 5B.

The 25 kV switchgear bus A supplies reserve power to Unit 1 scrubber 25 kV–4.16 kV RAT 1C, Unit 1 and Unit 2 RAT1/2, and Plant Limestone Prep SST-LSA. The 25 kV switchgear bus B supplies reserve power to Unit 3 and Unit 4 scrubber 25 kV–13.8 kV RAT 3C and 4C, and 25 kV–4.16 kV RAT3/4, and Plant Limestone Prep SST-LSB. The RATs and SST-LSs auxiliary transformers are connected in an "A" or "B" fashion to each of the units' 4.16 kV and 13.8 kV auxiliary electrical reserve incoming circuit breakers for startup and backup power.

All units main plant auxiliary electrical system 4.16 kV switchgear buses UA and UB are fed from their own respective two two-winding unit auxiliary transformer (UAT) that is powered from their respective generator leads. Unit 1 4.16 kV switchgear scrubber buses FGD1A and FGD1B are fed respectively from one three winding UAT1C that is powered from Unit 1 generator leads. Unit 2 4.16 kV switchgear scrubber buses FGD5A and FGD5B are fed respectively from two two-winding 25 kV–4.16 kV SSTFG-5A and 5B respectively as described above. Unit 3 and Unit 4 13.8 kV switchgear scrubber buses FGD3A and FGD3B, and FGD4A and FGD4B are fed respectively from each of their respective two winding UAT3C/4C that is powered from their respective Unit 3 and Unit 4 generator leads. Each 13.8 kV switchgear bus will feed a 13.8 kV–4.16 kV step down transformer that provides power to the Unit 3 and Unit 4 4.16 kV switchgear buses.

The addition of PJFF on each unit and a SCR on Unit 2 will require the addition of new ID Fans (Unit 3 and 4) or new booster fans (Units 1 and 2). All new fans will have variable frequency drives (VFDs). The existing unit auxiliary transformers, reserve auxiliary transformers, and 13.8 kV/4.16 kV switchgear buses were determined to have insufficient spare capacity and short circuit ratings to power the PJFF and SCR additions, which include new technology and fan electrical loads.

Each unit will require one new two winding AQC UAT that will be fed from their respective generator leads. The secondary windings will power the new AQC 13.8 kV and 4.16 kV switchgear buses for the fans and other various AQC loads. The reserve/backup power for new AQC 13.8 kV and 4.16 kV switchgear buses will be fed from new outdoor AQC 25 kV reserve switchgear and two new Unit 1 and Unit 2 AQC 25 kV–4.16 kV, and two new Unit 3 and Unit 4 AQC 25 kV–13.8 kV two winding RATs fed from existing 25 kV switchgear described above. Unit 3 and Unit 4 AQC 13.8 kV buses will each supply power to a two winding 13.8 kV–4.16 kV transformers which supply power to the Unit 3 and Unit 4 AQC 4.16 kV switchgear buses. Further electrical studies (short circuit, motor starting, etc.) will be performed during detailed design to determine the final transformer impedance and MVA ratings. Also, further field investigation will be required to determine the best way to connect the new AQC 25 kV switchgear into the existing 25 kV buses A and B.

The recommended location of the four new AQC RATs that will be connected to the new 25 kV AQC switchgear will be in close proximity to the tie-in points on the south side of the units. The recommended locations of each of the four new AQC UATs will be in close proximity to each of their respective generator leads. Cable bus will be routed during detailed design from the secondary windings of these auxiliary transformers to the new AQC electrical buildings. The new electrical AQC buildings would be located in the vicinity of the PJFF equipment as shown in the conceptual sketches in Appendix A. The buildings will contain the new medium voltage (MV) and low voltage (LV) switchgear, motor control centers (MCCs), and distributed control system (DCS) cabinets. A DC and UPS system will also be included in the electrical buildings to provide control power to the switchgear and DCS system. Motor control centers and DCS I/O cabinets may be installed in a small electrical building adjacent to remote AQC equipment to minimize cable lengths for the equipment in this area.

6.3 AQC Mass Balance Analysis

Addition of PJFF will increase the amount of ash removed from the Ghent Units.

- **Ash Handling**--Additional new ash handling system will be required for new PJFF. Additional ash handling equipment may include but is not limited to pipes, blowers, valves, etc. There will be approximately total of 10,760 lb/hr of additional waste (ash) generated for Ghent Station.

6.4 Reagent Impact Analysis

- **Anhydrous Ammonia System**--There will be an increase in the amount of ammonia required if SCR systems are implemented on Unit 2. Additional equipment required for anhydrous ammonia system may include but is not limited to ammonia storage tank, ammonia feed pumps, dilution air blowers, vaporizers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 508 lb/hr of more anhydrous ammonia required for Ghent Unit 2.
- **PAC Injection System**--A new PAC injection system will be required for mercury and dioxin/furan control. Additional equipment required for PAC injection system may include but is not limited to PAC storage silo, PAC injection lances, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 5,173 lb/hr of PAC required for Ghent Station.

- **Trona/Lime/SBS Injection System**-- A new sorbent (trona/lime/SBS) injection system will be required for SO_3 control on Unit 2. Additional equipment required for sorbent injection system may include but is not limited to sorbent storage silo, injection lances, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately total of 6,329 lb/hr of sorbent (trona) required for Ghent Unit 2.

6.5 Chimney Analysis

Based on the recommendations made in Section 5.2, analysis of the chimneys at Ghent Station is not required. The Ghent Station units 1-4 will reuse the existing chimneys.

6.6 Constructability Analysis

Several major AQC construction projects have been executed at the Ghent plant site over the last several years, with some projects still actively in construction as of the date of this report. The construction facilities, utilities, and services established to support these projects, such as parking, material laydown, fabrication areas, temporary utilities, and support services are expected to be adequate to support the work scope presented in this study. Some adjustment to construction facilities will be required to support unit-specific project execution. These needs will be addressed in the detailed construction execution plan submitted by the installing Contractor.

"Brown-field" construction of major new equipment on the existing Ghent plant footprint will present significant challenges in construction due to congestion, obstructions, and the need to keep existing units on line during construction. Each of the four units present unique access and construction execution challenges to implementing the selected AQC technologies. Accordingly, a high level constructability analysis was completed as part of this study in order to identify and evaluate potential concerns with the arrangement presented for each unit. A total of three conceptual plan sketches with corresponding elevation sketches are attached to this study in Appendix A. Each sketch depicts the current proposed arrangement, including refinements made per two site walk down inspections and joint project team discussion. Following is a generalized discussion of the sequence and concerns identified with the arrangement presented for each unit.

Because of limited onsite construction facilities and laydown area, the difficulty in outage scheduling, congested access, and the general confusion and complexity of several simultaneous projects, it is assumed that the work described below will be done sequentially by unit and not simultaneously. Due to the potential of new construction at

Unit 1 impacting construction access to the east side of Unit 2, consideration should be given to completing work at Unit 2 prior to start of work at Unit 1. Similarly, although of less concern, completion of Unit 2 modifications prior to Unit 3 would allow better access to Unit 2 from the courtyard area than after the addition of new structures required for Unit 3.

6.6.1 Unit 1 Arrangement

The AQC technology proposed for Unit 1 consists of a two 50 percent PJFFs, two 50 percent VFDs booster fans, PAC and trona transfer equipment, and the associated ductwork and ancillary equipment required to tie this equipment into the exhaust gas air stream.

The major equipment is proposed to be located immediately south of the southwest end of Unit 2 mechanical draft cooling tower, and west of the Unit 1 WFGD. The PJFF equipment will be located above, and straddle, the existing Unit 1 WFGD inlet duct. The new booster fans will be located below (west fan) or just south of (east fan) the existing inlet duct and new PJFFs adjacent to the existing Unit 2 ID fans. This arrangement minimizes obstruction to cooling tower inlet air flow, but places the PJFFs above the outlet stacks of the cooling tower draft fans. This may create icing conditions on the PJFFs during certain weather events. Crane access to the construction area is limited. The main erection crane can be established on the northwest corner of the proposed footprint; however, extensive temporary structural fill and crane matting will be required to protect the half-buried cooling water piping running through this area. Additional crane and construction access can be established along the north side of the proposed footprint, in the cooling tower maintenance road.

Construction activities must be closely coordinated with plant operations to ensure adequate access is maintained on the west end of the Unit 2 cooling tower to conduct routine maintenance. The congested footprint has limited area to stage material. Major components of ductwork and PJFFs must be modularized for efficient execution of the work scope. It is assumed that the major component modules will be fabricated in remote fabrication areas, transported to the work site via the north plant access road, raised over the Unit 2 cooling tower and set in place by the main lift crane located on the northwest end of the construction footprint.

The expected sequence of construction (and estimated timeframe) for installation for the Unit 1 arrangement is as follows and as noted:

- Install new flanges/blanking plates and transition duct pieces in the existing WFGD inlet duct and at the ID fan (2 weeks, outage, this work could also be completed at the time of the ductwork tie-in).

- Construct new foundations and any supporting structural steel superstructure for the PJFF, ductwork and booster fans (5 months, non-outage).
- Install new PJFF, booster fans, ancillary systems such as PAC, trona and ash handling, plus ductwork to tie-in points (16 months, non-outage).
- Complete tie-in of ductwork to existing WFGD inlet duct and ID fans (2 weeks, outage).
- Start-up and tune new PJFF, booster fans, PAC, trona, and ash handling systems (10 weeks, combined outage and non-outage).

The main crane will have a limited boom swing due to its close proximity to the Unit 2 chimney. Detailed rigging and lift plans must be developed for each major component installed. The proposed arrangement requires the PJFF to be installed above the existing WFGD inlet duct, requiring substantial work at heights and the resulting complications and inefficiencies. Installation of foundations will be problematic due to the existing congestion and the need to maintain unit operation to the extent practical. Micropiles may be required for the booster fan foundations and the support steel foundations on the south side of the inlet duct. In addition, the following issues will have to be addressed in detail to support construction at Unit 1.

- Above and below ground utility interferences and relocations may be necessary, especially low overhead obstructions along the north access road.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed and special precautions taken in the area of the semi-exposed Unit 2 cooling water piping.
- The potential and magnitude of existing equipment relocations needed to support access, crane setting, construction traffic flow, construction operations activities, and placement of new AQC equipment and ancillary equipment must be investigated.
- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment.
- Existing plant traffic along the north access road will be interrupted and must be rerouted. Existing traffic patterns must be reestablished prior to start of construction.
- Demolition/modification of existing ductwork will require selective dismantling operations in order to work around existing equipment and ancillaries.

- Elevating the PJFF and ductwork above the existing equipment and structures will require a substantial new foundation and superstructure.
- New PAC and trona silos and associated transfer equipment must be carefully located to maintain crane access to Unit 2 SCR and PJFF construction activities. Combining the PAC and trona silos and associated equipment for both Unit 1 and Unit 2 should be considered.

6.6.2 Unit 2 Arrangement

The AQC technology proposed for Unit 2 consists of a two 50% PJFFs, two 50% VFD booster fans, two 50 percent SCR reactors, PAC and trona silos and transfer equipment; and the associated ductwork and ancillary equipment required to tie this equipment into the exhaust gas air stream.

The two SCR modules are proposed to be located close to their respective exhaust gas trains in order to facilitate construction access and minimize new ductwork. The conceptual arrangement places the east SCR module above an existing structural steel frame supporting the Unit 1 SCR located immediately east of the Unit 2 east ESP. The arrangement tentatively includes a new structural steel tower straddling the existing steel frame, although ideally the existing framing might be incorporated into the support for the Unit 2 SCR. The construction footprint can be accessed by construction equipment via a narrow lane running north/south from the north access road, then along the east side of Unit 2 chimney to the existing structural support frame. It is proposed that a lattice boom crawler crane or large hydraulic truck crane can be located immediately northeast of the support frame and used to erect the new steel support and then lift pre-fabricated SCR and ductwork modules into place on the framing.

The west SCR module is conceptually placed on a new structural support frame located on the southwest corner of Unit 2 west ESP, and below the Unit 3 and 4 coal conveyor. It is proposed that a large lattice boom crawler crane be assembled in the "courtyard" immediately southwest of the SCR footprint and used to lift pre-fabricated support steel, SCR module, and ductwork modules into place. Construction materials can be transported to the footprint via the north/south access alley running immediately east of the existing Unit 2 absorbers, or from the south through existing roll up doors installed in the enclosed ground level utility corridor. Components too large to pass through the roll up doors can be lifted over the existing personnel skywalk, utility corridor and maintenance shops using a second crane located to the south.

The following issues will have to be addressed in detail to support construction of the east and west SCR modules and ductwork at Unit 2.

- The new steel structure supporting the east SCR module must be designed to coexist with the existing structural frame. Additional investigation regarding the actual incorporation of the existing support tower into the support for the new SCR module must be completed at time of detail design to ensure that the existing structure and its foundation can support the loads imposed by the new construction.
- Above and below ground utility interferences and relocations will be necessary to install the foundations and structural framing for the west SCR module. Additional investigation is recommended at both locations to identify and locate any underground utilities that might be impacted.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed, especially in the area of the Unit 2 cooling water lines east of Unit 2.
- The potential and magnitude of existing equipment and facility relocations needed to support crane setting, construction traffic flow, construction operations activities, and placement of new AQC equipment and ancillary equipment must be investigated. This will be of particular importance in the area of the west SCR support tower due to existing congestion. A series of existing overhead power lines west of Unit 2 will likely require relocation, along with the demolition of several abandoned foundations in the area.
- The design of the support tower for the west SCR module must take into account existing equipment and structures that likely cannot be relocated. A support bent for the overhead coal conveyor, an existing elevated cable tray, and the Service Water Pump House are all located in the immediate area proposed for the west tower and the final arrangement and design must accommodate these obstructions.
- The west SCR is tentatively located directly beneath existing Coal Conveyor 3J, significantly complicating crane operation in the area. Although prefabrication of SCR support framing, modules, and ductwork sections should be used to the extent it is practical, size and weight of lifted components will be limited to that which can be maneuvered around the conveyor. Some temporary shoring or framing may be required to "land" prefabricated sections where they can be slid into place under the conveyor.

- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment. Special consideration must be given to protecting the Unit 3 coal conveyor from damage during SCR erection.
- Plant traffic along the north access road and in the "courtyard" area will be interrupted by construction and must be rerouted. Essential plant operations traffic patterns must be defined and re-established prior to starting the project.
- Demolition/modification of existing ESP ductwork will require selective dismantling operations to be scheduled into plant outages in order to work around existing equipment and ancillaries.
- The support structures for both SCR modules and their ductwork will require substantial new foundations and superstructures installed in very congested areas. Micropiles may be required for the foundations.

The two PJFFs, two booster fans, PAC and trona silos and transfer equipment, and associated ductwork are proposed to be located immediately north of the existing Unit 2 ESPs. The footprint for the new equipment must be reclaimed by eliminating existing ductwork in this area. This will require installation of a bypass duct connecting the common duct ending at the north end of the ESPs and the existing duct leading to the inlets of the absorbers. The bypass will allow the remaining common duct to the north to be demolished and the area prepared for foundation and support steel framing erection. The dimensions of the proposed PJFF extend across the existing north access road. The PJFF, associated structural support frame, and ductwork must be elevated in order to allow the road to pass beneath the new construction. In addition, elevating the new equipment allows new electrical auxiliaries and ash handling equipment to be located beneath the elevated structure, concentrating equipment in the area it is needed and reducing the overall "sprawl" of the new construction.

The congested construction footprint contains limited area in which to stage material. Major components such as ductwork, booster fans, and PJFFs must be modularized for efficient execution of the work scope. It is assumed that the major component modules will be fabricated/dressed out in remote fabrication areas, transported to the work site via the north plant access road, and set in place by the main lift crane, which would be located in the access road on the east or west sides of the construction footprint. It should be noted that the cranes established on the west side of the PJFF construction will likely be hydraulic, truck mount units. The PJFF support steel spanning the roadway to the east and the low overhead obstructions spanning the roadway to the west will not allow a lattice boom crawler crane to walk into place along the west side of the new construction. These obstructions will also make it difficult to lay a lattice work crane boom down along the roadway in severe weather

The following issues will have to be addressed in detail to support construction of the PJFFs, booster fans, and ductwork at Unit 2.

- Above and below ground utility interferences must be identified and relocated in order to install the foundations and structural framing for the PJFF support frame.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed.
- The elevated structure supporting the PJFFs will require careful coordination with the existing road and the elevated piperack immediately to the north of the road. The piperack serves all four units; it cannot be taken out of service and must be accommodated in the structure's design. The foundations beneath the northernmost supports of the structure must also take into account the steeply sloping riverbank immediately to the north of the piperack.
- The magnitude of existing equipment and facility relocations needed to support crane setting, construction traffic flow, construction execution, and placement of new AQC equipment and ancillary equipment must be investigated, quantified and resolved. Special consideration must be given to relocation of overhead electrical lines for the existing scrubbers and modification of exhaust gas ductwork during outages.
- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment. Special consideration must be given to protecting the piperack north of the main access road.
- Plant traffic along the north access road will be interrupted by construction and must be rerouted. Essential plant operations traffic patterns must be defined and re-established prior to starting the project.
- Demolition/modification of existing ESP ductwork will require selective dismantling operations to be scheduled into plant outages in order to work around existing equipment and ancillaries.

The expected sequence of construction (and estimated timeframe) for installation for the total Unit 2 arrangement is as follows and as noted:

- Install foundations and structural steel support frame for by-pass ductwork at PJFF (2 months, non-outage).
- Install new flanges/blanking plates on existing ductwork as necessary to install by-pass damper and install by-pass ductwork at PJFF (6 weeks, outage).
- Demo by-passed ductwork and associated support steel at PJFF (3 months, non-outage).
- Install foundations and superstructure for PJFF and ductwork support frame and booster fans (5 months, non-outage).
- Install PJFF, ductwork up to tie-in points, PAC/trona equipment, ash handling, and booster fans (16 months, non-outage)
- Install ductwork to tie PJFF into existing ductwork (2 weeks, outage)
- Start-up and tune new PJFF, booster fans, PAC, trona, and ash handling systems (10 weeks, combined outage and non-outage).
- Install foundations and structural steel framing supporting east side SCR reactor (4 months, non-outage)
- Install new flanges/blanking plates on existing ductwork as necessary to install east SCR inlet and outlet ductwork (4 weeks, outage).
- Erect east side SCR and ductwork up to tie-in points (18 months, non-outage).
- Tie-in east side SCR ductwork into existing duct and install blanking plates to re-direct flow through SCR (6 weeks, outage).
- Relocate overhead electrical lines and underground piping and ductbanks necessary to install foundations for west side SCR reactor. (6 weeks, outage, could be partially concurrent with outage for the east side SCR)
- Install foundations for west side SCR reactor structural steel support frame (4 months, non-outage, could be concurrent with east side SCR)
- Install new flanges/blanking plates on existing ductwork as necessary to install west SCR inlet and outlet ductwork (4 weeks, outage, could be concurrent with east side SCR).
- Install foundations and structural steel framing supporting for west side SCR reactor and ductwork (4 months, non-outage, could be concurrent with east side SCR).

- Erect west side SCR and ductwork up to tie-in points (18 months, non-outage, could be concurrent with east side SCR).
- Tie-in west side SCR ductwork into existing duct and install blanking plates to re-direct flow through SCR (6 weeks, outage, could be concurrent with east side SCR).
- Start-up and tune both east and west side SCRs (10 weeks, combined outage and non-outage).

6.6.3 Unit 3 Arrangement

The AQC technology proposed for Unit 3 consists of a single 100% PJFF, three 50% VFD ID fans, PAC and trona transfer equipment, and the associated ductwork and ancillary equipment required to tie this equipment into the exhaust gas air stream.

The major equipment is proposed to be located in the courtyard area south of the Unit 3 ID fans and east of the Unit 3 powerblock. The PJFF equipment will be elevated to allow ground-level access to existing silos and equipment east of Unit 3. The elevated PJFF will straddle the utility corridor currently located in the walkway enclosure between Units 2 and 3. New ductwork will connect the exhaust ductwork upstream of the existing ID fans to the PJFF inlet. New ID fans will be located at ground level between the PJFF outlet and existing Coal Transfer House 5 and adjacent waste sump. New ductwork downstream of the ID fans will connect to existing ductwork upstream of the Unit 3 scrubber inlet, bypassing the existing ID fans. The existing machine shop will require relocation to accommodate the PJFF and the skywalk will be temporarily removed during construction and then reincorporated into the new superstructures when complete.

The expected sequence of construction (and estimated timeframe) for installation for the Unit 3 construction is as follows:

- Demo and/or relocate existing structures in the way of new construction, i.e.; utility corridor walkway enclosure, maintenance shop, personnel skywalk, etc. (3 months, non-outage).
- Install new flanges/blanking plates and transition duct pieces in the existing inlet and outlet ductwork adjacent to the existing Unit 3 ID fans (2 weeks, outage, this work could also be completed at the time of the ductwork tie-in).
- Construct new foundations and any supporting structural steel superstructure for the PJFF, ductwork and booster fans. (4 months, non-outage).
- Install new PJFF, booster fans, ancillary systems such as PAC, trona and ash handling, plus ductwork to tie-in points. (16 months, non-outage).

- Complete tie-in of ductwork to existing scrubber inlet duct and ID fans (3 weeks, outage).
- Start-up new PJFF, booster fans, PAC, trona, and ash handling systems (10 weeks, combined outage and non-outage).
- Reinstall modified utility corridor walkway enclosure and elevated skywalk (2 months, non-outage).

The main crane will be located in the “courtyard” area, in close proximity to operating plant systems. Limited amounts of construction material can be staged in the courtyard, making modularization of major ductwork and PJFFs components a necessity. Major component modules will be fabricated in remote fabrication areas, transported to the work site via the south plant access road, raised over the ground level pipe corridor by a second crane, and set in place by the main lift crane located in the courtyard. Detailed rigging and lift plans must be developed for each major component installed. The proposed arrangement requires the PJFF to be installed above the existing utility corridor between Unit 2 and Unit 3, and below the Unit 3 coal conveyor. This configuration will require substantial work at heights and the resulting complications and inefficiencies. Installation of foundations will be problematic due to the existing congestion of underground utilities and existing pipe trench, and the need to maintain unit operation to the extent practical. Micropiles may be required for the ID fan foundations and the ductwork support steel foundations located adjacent to existing Unit 3 building structure. In addition, the following issues will have to be addressed in detail to support construction at Unit 3.

- The new steel structure supporting the PJFF must be designed to maintain vehicle access to the east side of Unit 3, avoid disrupting the utility corridor in the ground level walkway, and avoid impact to the existing tanks to the south.
- Above and below ground utility interferences and relocations may be necessary, especially in the “courtyard” area. Particular care will be required to minimize impact on the existing pipe trench and the coal transfer house foundation.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed.
- The potential and magnitude of existing equipment relocations needed to support access, crane setting, construction traffic flow, construction operations activities, and placement of new AQC equipment and ancillary equipment must be investigated. A series of existing overhead power lines across the north side of the courtyard will likely require relocation.

- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment. Special consideration must be given to incorporating the re-established ground level walkway and elevated skyway between Units 2 and 3 after completion of PJFF erection.
- Existing plant traffic along the utility corridor, maintenance skywalk, and "courtyard" area will be interrupted and must be rerouted. Existing traffic patterns must be reestablished prior to start of construction.
- Demolition/modification of existing ductwork will require selective dismantling operations in order to work around existing equipment and ancillaries.
- Elevating the PJFF and ductwork above the existing equipment and structures will require a substantial new foundation and superstructure.

6.6.4 Unit 4 Arrangement

The AQC technology proposed for Unit 4 consists of a single 100% PJFF, three 50% VFD ID fans, PAC and trona transfer equipment, and the associated ductwork and ancillary equipment required to tie this equipment into the exhaust gas air stream.

The major equipment is proposed to be located in the area west of the Unit 4 ESP area currently occupied by a warehouse. The PJFF equipment will be constructed on a ground-level foundation with inlet and outlet both on the east end of the PJFF. New common ductwork will connect the two exhaust ductwork trains immediately north of the Unit 4 powerblock and forward it to the PJFF. Three new ID fans will be located at ground level at the PJFF outlet and common ductwork will forward the treated exhaust to a tie-in point upstream of the existing WFGD. The existing ID fans will be bypassed.

The expected sequence of construction (and estimated timeframe) for installation for the Unit 4 arrangement is as follows and as noted:

- Demolish existing warehouse structure and foundation (6 weeks, non-outage)
- Install new flanges/blanking plates and transition duct pieces in the existing Unit 4 outlet duct and the inlet duct to the scrubber (3 weeks, outage, this work could also be completed at the time of the ductwork tie-in).
- Construct new foundations and any supporting structural steel superstructure for the PJFF, ductwork and ID fans (3 months, non-outage).

- Install new PJFF, ID fans, ancillary systems such as PAC, trona and ash handling, plus ductwork to tie-in points (16 months, non-outage).
- Complete tie-in of ductwork to existing scrubber inlet duct and duct upstream of the existing ID fans (6 weeks, outage).
- Start-up new PJFF, booster fans, PAC, trona, and ash handling systems (10 weeks, combined outage and non-outage).

Crane access for construction of Unit 4 appears relatively good, although access may be limited to a great extent to the north side due to the shallow embedment of large bore circulating water piping on the south side of the construction footprint. Extensive coordination of existing ductwork modification and the installation of new ductwork on downstream of Unit 4 and around the existing ID fans will be required to minimize outage schedule. In addition, the following issues will have to be addressed in detail to support construction at Unit 4.

- Above and below ground utility interferences and relocations may be necessary, especially on the south side of the PJFF construction footprint in the area of the circ water pipe corridor. Ductwork supports in the pipe corridor area may be required to “bridge” the corridor to avoid excavations within the corridor.
- Ground and soil stability for setting cranes and heavy haul traffic must be confirmed, especially in the pipe corridor area.
- The potential and magnitude of existing equipment relocations needed to support access, crane setting, construction traffic flow, construction operations activities, and placement of new AQC equipment and ancillary equipment must be investigated.
- Conflicts with existing plant operations must be evaluated and minimized. Isolation of the work area from operating areas must be considered if practical, while still allowing maintenance access to existing equipment.
- Existing plant traffic along the west end of the north access road will be interrupted and must be rerouted. Existing traffic patterns must be reestablished prior to start of construction.
- Demolition/modification of existing WFGD inlet and ID fan ductwork will require selective dismantling operations in order to work around existing equipment and ancillaries.
- Design and installation of ductwork support foundations in the area of the existing ID fans will require careful coordination due to the congestion in the area. Micropiles may be required for those foundations.

6.7 Truck/Rail Traffic Analysis

The modifications proposed for the four Ghent units will result in additional bulk material required to support the AQC processes. These materials will be delivered from offsite on a regular basis and stored onsite for use. Preliminary estimates of the rate of use of sorbents or reagents required in the proposed AQC processes by unit are listed in Table 6-9. Additional delivery traffic for the site as a whole will be addressed accordingly.

Table 6-9. Sorbents and Reagents Consumption Rates (tph)

Material	**Unit 1**	**Unit 2**	**Unit 3**	**Unit 4**	**Station Total**
PAC	0.636	0.621	0.681	0.649	2.59
Sorbent (trona)	Note 1	3.16	Note 1	Note 1	3.16 addn'l
Anhydrous ammonia	Note 2	0.254	Note 2	Note 2	0.254 addn'l

tph - tons per hour.

Notes:
1. Current rate of consumption of trona at Units 1, 3 and 4 will remain essentially unchanged.
2. Current rate of consumption of anhydrous ammonia at Units 1, 3 and 4 will remain essentially unchanged.

Although a rail spur exists and passes by the Ghent Station, it is not currently used for any materials deliveries. Due to the distance between the existing trackage and the units, using the existing rail system for periodic delivery of other bulk materials would be problematic. Accordingly, delivery of bulk sorbents and reagents for the proposed AQC systems will be assumed to be via truck on existing roads.

Dry bulk material, such as PAC and sorbent (trona), is normally delivered in fully-enclosed bulk delivery trucks and offloaded using a pneumatic transfer system integral to the truck. A standard over-the-road trailer truck size for these materials is nominally 20 tons per load. Anhydrous ammonia is usually transported in a pressurized tank truck with a nominal capacity of 10,000 gallons. Based on the consumption rates in the Table 6-9 above and the nominal truck sizes, the additional truck deliveries to the Ghent site can be summarized as follows.

- PAC 22 loads per week
- Sorbent (trona) 27 loads per week additional
- Anhydrous ammonia 1.7 loads per week additional

Therefore, the total additional truck deliveries estimated to provide sorbents or reagents is approximately 50 loads per week. Assuming delivery operations are limited to five days a week and an 8-hour day, the maximum additional truck deliveries to site would be approximately 10 per day or 1 every 48 minutes over and above the current deliveries being made. Existing roads onsite should be able to accommodate the additional deliveries. A tank or silo is often provided for each material at each unit to minimize the size and length of distribution systems. However, where practical, consideration should be given to consolidated tanks or silos located so as to serve more than one unit, in order to minimize unloading time and extended truck travel onsite. The arrangements as proposed combine the silos for Units 1 and 2 to minimize the new construction as well as decrease congestion.

The PJFF system added at each unit will capture additional particulate that will need to be landfilled. The total expected additional fly ash removed from the exhaust streams of the four units is estimated at 10,760 lb/hr, or approximately 129 tons per day of operation of all four units. This increased volume will require additional operating time for the existing (and augmented) ash transfer systems to deliver the ash to the ash handling area. Current ash disposal activities will have to increase accordingly.

The modifications proposed include no changes to the existing FGD scrubbers at any of the four units. Therefore limestone consumption and gypsum or scrubber byproduct production are not expected to change appreciably. No modifications to the existing limestone or scrubber byproduct bulk materials handling systems are expected to be required.

7.0 Conclusion

This Air Quality Control Validation Report confirms the feasibility of installing certain AQC equipment at Ghent Station and presents the supporting considerations, arrangements, and preliminary validation analyses for the AQC equipment that will be built upon in the next steps of the project to complete the conceptual design and budgetary cost estimate.

After review of the presented information and further discussions, LG&E/KU has directed B&V to proceed to the conceptual design and budgetary cost estimate steps based on the following arrangements and summarized in Table 7-1.

Unit 1 shall include the existing SCR, existing sorbent injection system, existing CS-ESP, existing ID fans, new PAC injection system, new PJFF, new booster fans, existing WFGD, and existing chimney. A neural network shall also be included. Ghent Unit 1 Arrangement with the new split box PJFF (2 x 50%) located above the existing WFGD Supply ductwork is to be utilized.

Unit 2 shall include a new SCR, new sorbent injection system, existing ID fans, new PAC injection system, new PJFF, new booster fans, existing WFGD, and existing chimney. A neural network shall also be included. The Ghent Unit 2 Arrangement described below shall be utilized. One side of the new split SCR reactor (2 x 50%) shall be located to the east of the Unit 2 east HS-ESP above the current Unit 1 structural steel SCR support structure. The other side of the split SCR reactor shall be located near the southwest corner of the Unit 2 west HS-ESP above the electrical cable tray and below the existing Unit 3 and 4 coal conveyor. The PJFF shall be located at the north end of the existing HS-ESP and will extend above and over the main plant access road. Cost associated with installation of the SCR shall be easily identifiable and separated for further consideration based on final regulations.

Unit 3 shall include the existing HS-ESP, existing SCR, existing sorbent injection system, new PAC injection system, new PJFF, new ID fans, existing WFGD, and existing chimney. A neural network shall also be included. Ghent Unit 3 Arrangement Flow Biasing Option 1 with the new split box PJFF and four ID Fans located in the courtyard area is to be utilized. For the complete Flow Biasing Report refer to Appendix B.

Unit 4 shall include the existing HS-ESP, existing SCR, existing sorbent injection system, new PAC injection system, new PJFF, new ID fans, existing WFGD, and existing chimney. A neural network shall also be included. Ghent Unit 4 Arrangement Flow Biasing Option 1 with the new split box PJFF and four ID Fans located in the west of the unit and north of the WFGD is to be utilized.

Table 7-1. AQC Technologies				
	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**
NO_x Control	Existing SCR	New SCR	Existing SCR	Existing SCR
SO_2 Control	Existing WFGD	Existing WFGD	Existing WFGD	Existing WFGD
PM Control	New PJFF	New PJFF	New PJFF	New PJFF
HCl Control	Existing WFGD and Existing Sorbent Injection	Existing WFGD and New Sorbent Injection	Existing WFGD and Existing Sorbent Injection	Existing WFGD and Existing Sorbent Injection
CO Control	New NN	New NN	New NN	New NN
SO_3 Control	Existing Sorbent Injection	New Sorbent Injection	Existing Sorbent Injection	Existing Sorbent Injection
Hg Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Dioxin/Furan Control	New PAC Injection	New PAC Injection	New PAC Injection	New PAC Injection
Fly Ash Sales	Existing CS-ESP	Existing HS-ESP	Existing HS-ESP	Existing HS-ESP

In addition, the following items shall also be considered in the next step of the project.

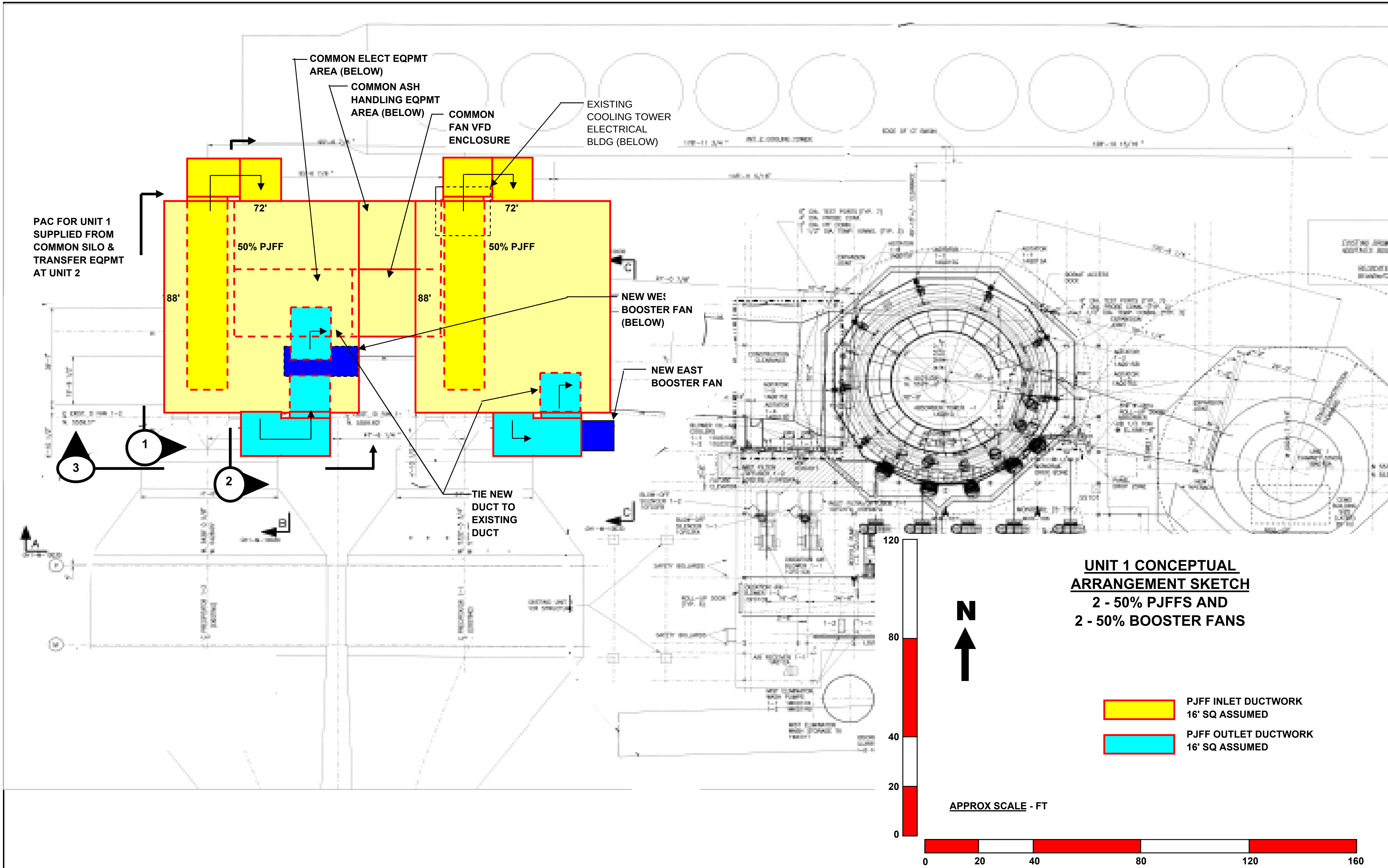
- Consideration of high air heater exit gas temperatures on all units may require higher temperature PJFF bags.
- Include fire protection requirements for PJFF as directed by LG&E/KU.
- Coordinate and consider how the on-going ash handling system modifications being completed under separate study by LG&E/KU and B&V may be affected by the potential installation of the PJFFs at all four units.
- Include demolition costs in the cost estimates for any existing equipment bypassed or abandoned as separate line items in the cost estimates.
- For Unit 2, relocate sorbent injection point to downstream of the air heater.
- An economizer bypass system should be included as required to provide Unit 2 turndown capability with respect to SCR operation and inlet temperature control.
- For Units 3 and 4, consider Option 1 from Flow Biasing Options report for balancing or biasing flows as can be done under current

operation. Refer to Appendix A for the conceptual sketches of the three options and refer to Appendix B for the report.

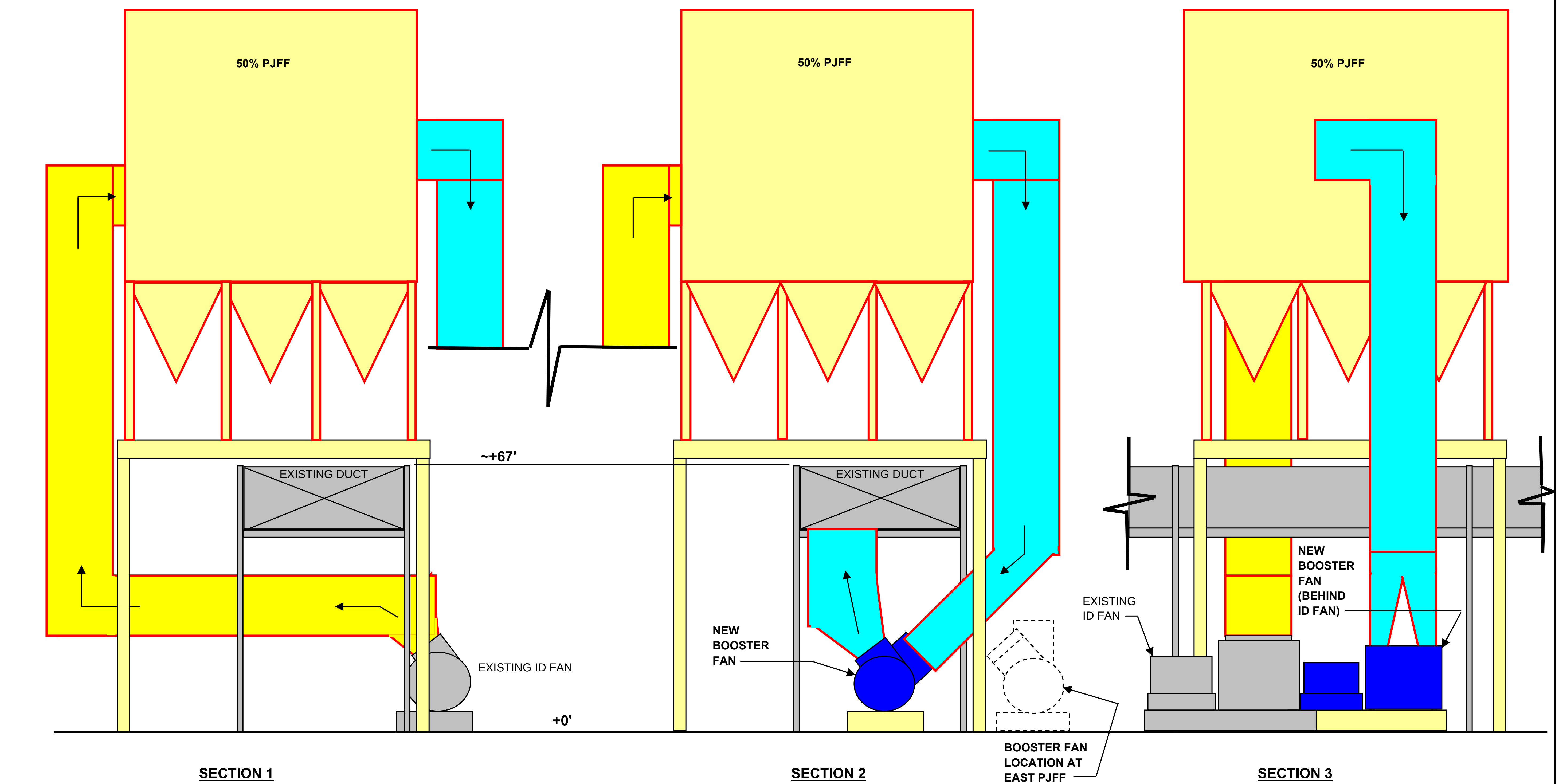
- Include siding over all exposed areas and equipment near the Unit 2 cooling tower.
- Investigate if there are any Unit 2 cooling tower performance concerns with the proposed arrangement of the Unit 1 PJFF.
- If Unit 2 SCR is installed first and the unit will be required to run in this configuration, a new ID Fan power supply transformer will be required.
- Separate redundant silos for PAC shall be included for each unit. New redundant sorbent silos to be included for Unit 2.
- Review and modify the Unit 2 west low dust SCR arrangement with consideration for a larger high dust SCR arrangement based on physical space constraints due to the existing Unit 3 and 4 coal conveyor.
- Consider adding a permanent tank for chemical cleaning if too much of the courtyard area gets consumed with Unit 3 equipment.
- To the greatest extent possible, the same type of bags and cages for use in the PJFFs should be used across the entire LG&E/KU fleet to minimize spare part requirements. Additional warehousing should be included to store a minimum of one entire set of bags and cages.
- Include higher flue gas temperatures provided by LG&E/KU in the draft system analysis for all units.

Appendix A
Conceptual Sketches

Unit 1 Arrangements



COMMON ELECT EQPMT AREA (BELOW)
COMMON ASH HANDLING EQPMT AREA (BELOW)
COMMON FAN VFD ENCLOSURE
EXISTING COOLING TOWER ELECTRICAL BLDG (BELOW)
PAC FOR UNIT 1 SUPPLIED FROM COMMON SILO & TRANSFER EQPMT AT UNIT 2
72'
72'
50% PJFF
50% PJFF
88'
88'
NEW WES BOOSTER FAN (BELOW)
NEW EAST BOOSTER FAN
TIE NEW DUCT TO EXISTING DUCT
1
2
3
UNIT 1 CONCEPTUAL ARRANGEMENT SKETCH
2 - 50% PJFFS AND
2 - 50% BOOSTER FANS
N
PJFF INLET DUCTWORK 16' SQ ASSUMED
PJFF OUTLET DUCTWORK 16' SQ ASSUMED
APPROX SCALE - FT
120
80
40
20
0
0
20
40
80
120
160



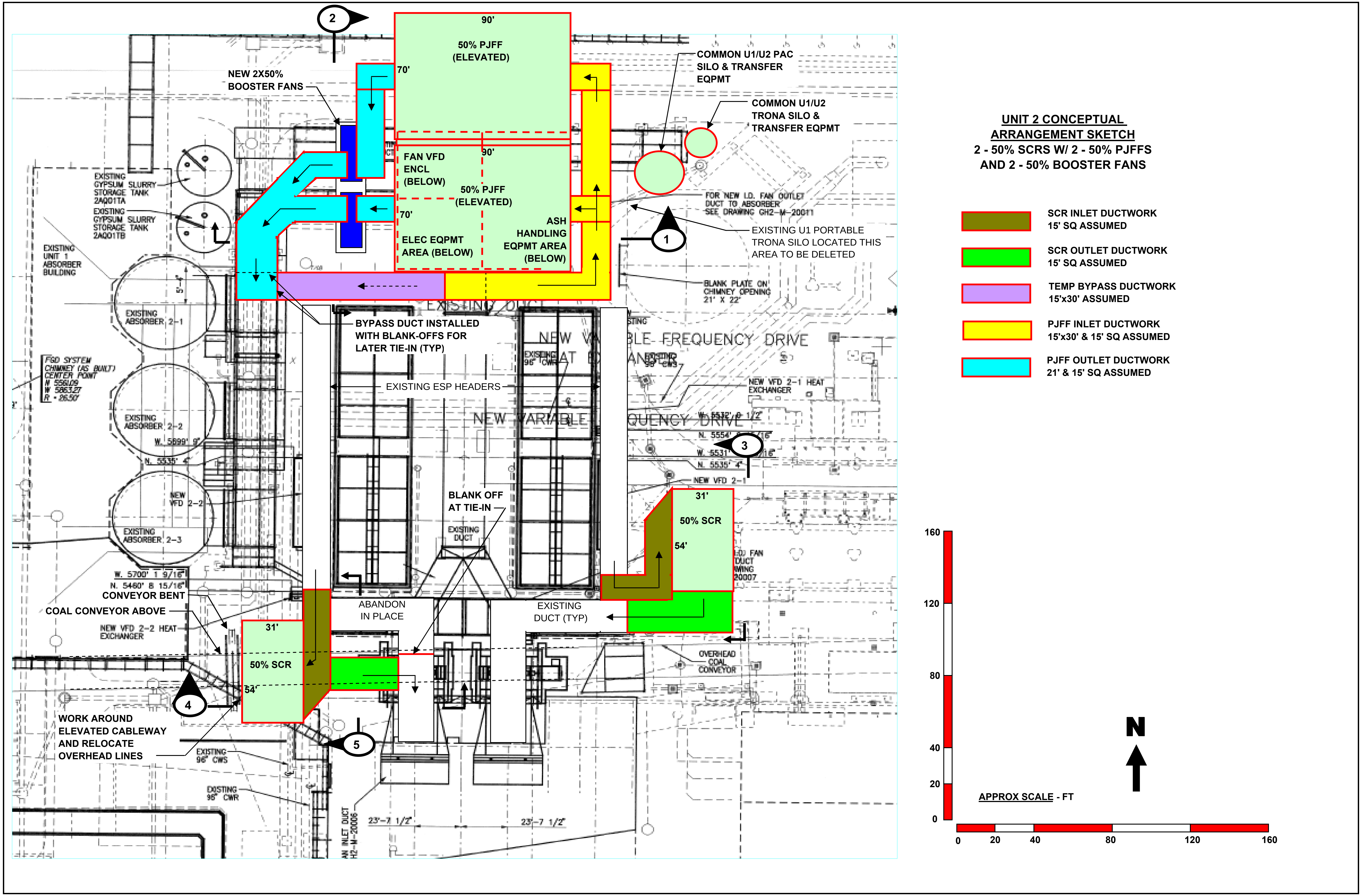
SECTION 1
EAST PJFF SIMILAR
NOT TO SCALE

SECTION 2
EAST PJFF SIMILAR AND AS NOTED
NOT TO SCALE

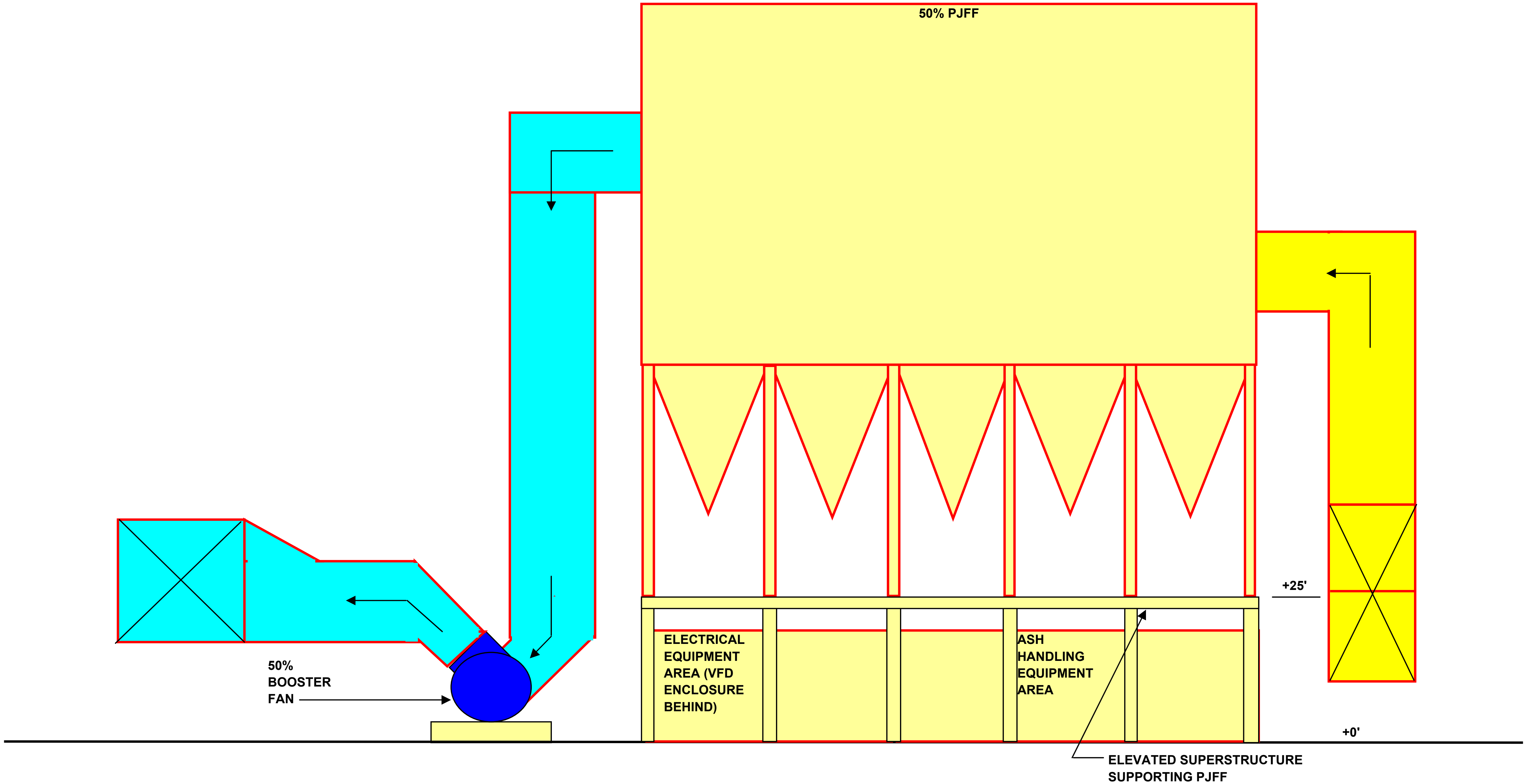
SECTION 3
EAST PJFF SIMILAR
NOT TO SCALE

UNIT 1 CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS

Unit 2 Arrangements

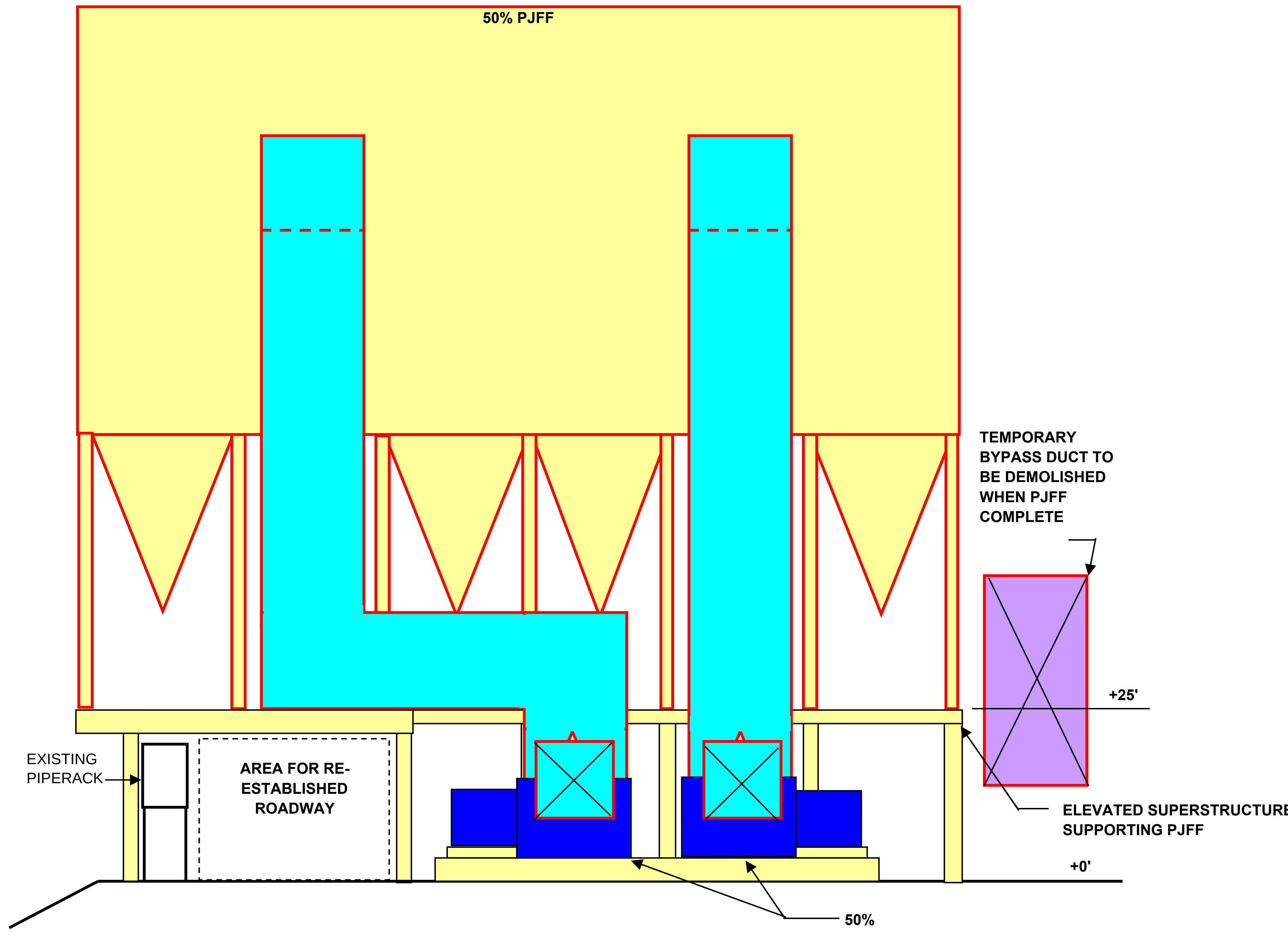


UNIT 2 CONCEPTUAL ARRANGEMENT SKETCH
2 - 50% SCRS W/ 2 - 50% PJFFS AND 2 - 50% BOOSTER FANS
SCR INLET DUCTWORK 15' SQ ASSUMED
SCR OUTLET DUCTWORK 15' SQ ASSUMED
TEMP BYPASS DUCTWORK 15'x30' ASSUMED
PJFF INLET DUCTWORK 15'x30' & 15' SQ ASSUMED
PJFF OUTLET DUCTWORK 21' & 15' SQ ASSUMED
90'
50% PJFF (ELEVATED)
70'
NEW 2X50% BOOSTER FANS
FAN VFD ENCL (BELOW)
50% PJFF (ELEVATED)
ELEC EQPMT AREA (BELOW)
ASH HANDLING EQPMT AREA (BELOW)
COMMON U1/U2 PAC SILO & TRANSFER EQPMT
COMMON U1/U2 TRONA SILO & TRANSFER EQPMT
EXISTING U1 PORTABLE TRONA SILO LOCATED THIS AREA TO BE DELETED
BYPASS DUCT INSTALLED WITH BLANK-OFFS FOR LATER TIE-IN (TYP)
EXISTING ESP HEADERS
BLANK OFF AT TIE-IN
ABANDON IN PLACE
EXISTING DUCT (TYP)
31'
50% SCR
54'
CONVEYOR BENT
COAL CONVEYOR ABOVE
WORK AROUND ELEVATED CABLEWAY AND RELOCATE OVERHEAD LINES
EXISTING GYPSUM SLURRY STORAGE TANK 2AQ01TA
EXISTING GYPSUM SLURRY STORAGE TANK 2AQ01TB
EXISTING UNIT 1 ABSORBER BUILDING
EXISTING ABSORBER 2-1
EXISTING ABSORBER 2-2
EXISTING ABSORBER 2-3
NEW VFD 2-2
NEW VFD 2-2 HEAT EXCHANGER
NEW VFD 2-1 HEAT EXCHANGER
NEW VFD 2-1
OVERHEAD COAL CONVEYOR
EXISTING 96" CWS
EXISTING 96" CWR
1
2
3
4
5
APPROX SCALE - FT
0
20
40
80
120
160
N



SECTION 1
NOT TO SCALE

UNIT 2 CONCEPTUAL ARRANGEMENT SKETCH SECTIONS



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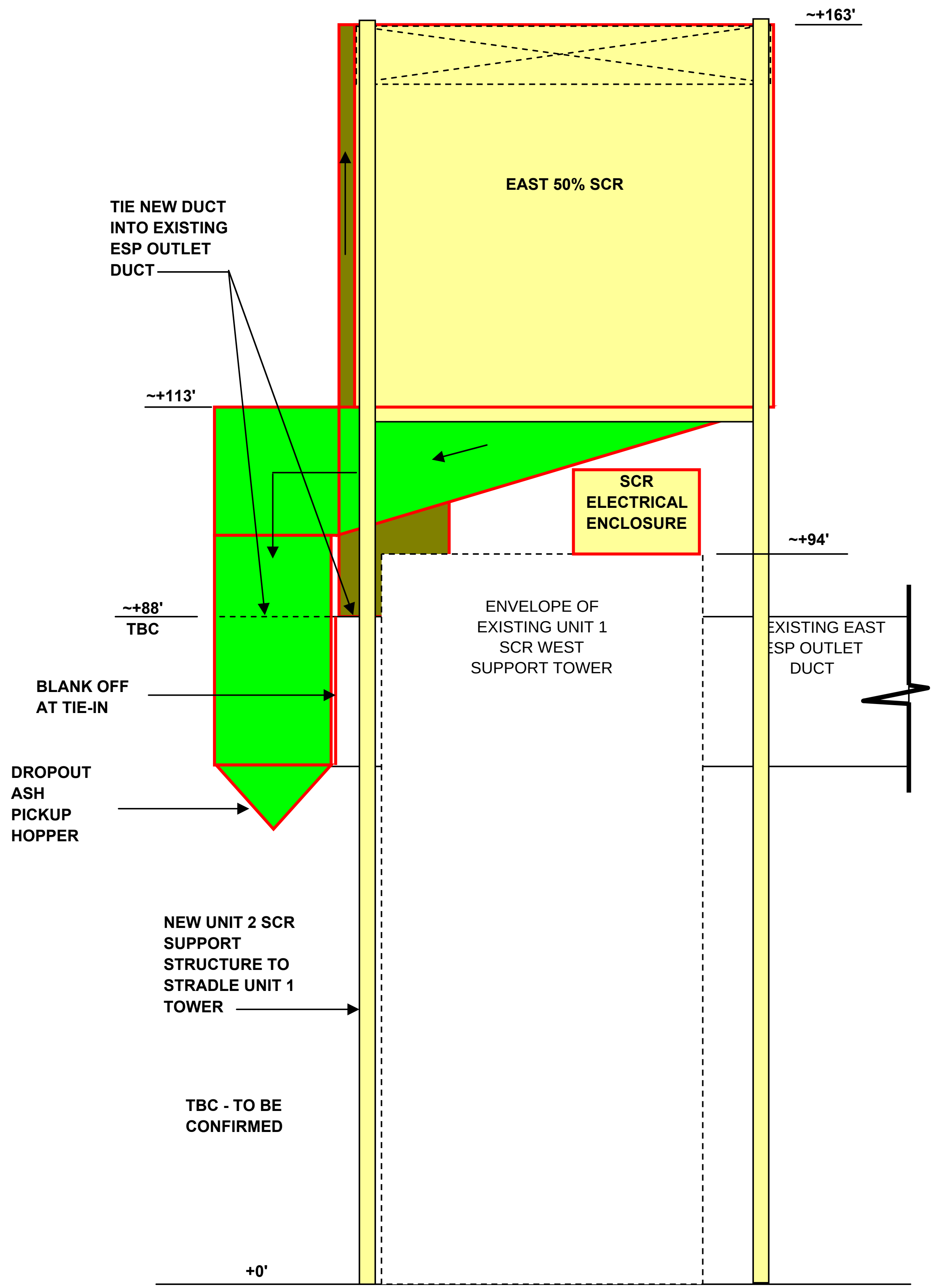
UNIT 2 CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



UNIT 2 CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS

SECTION 3
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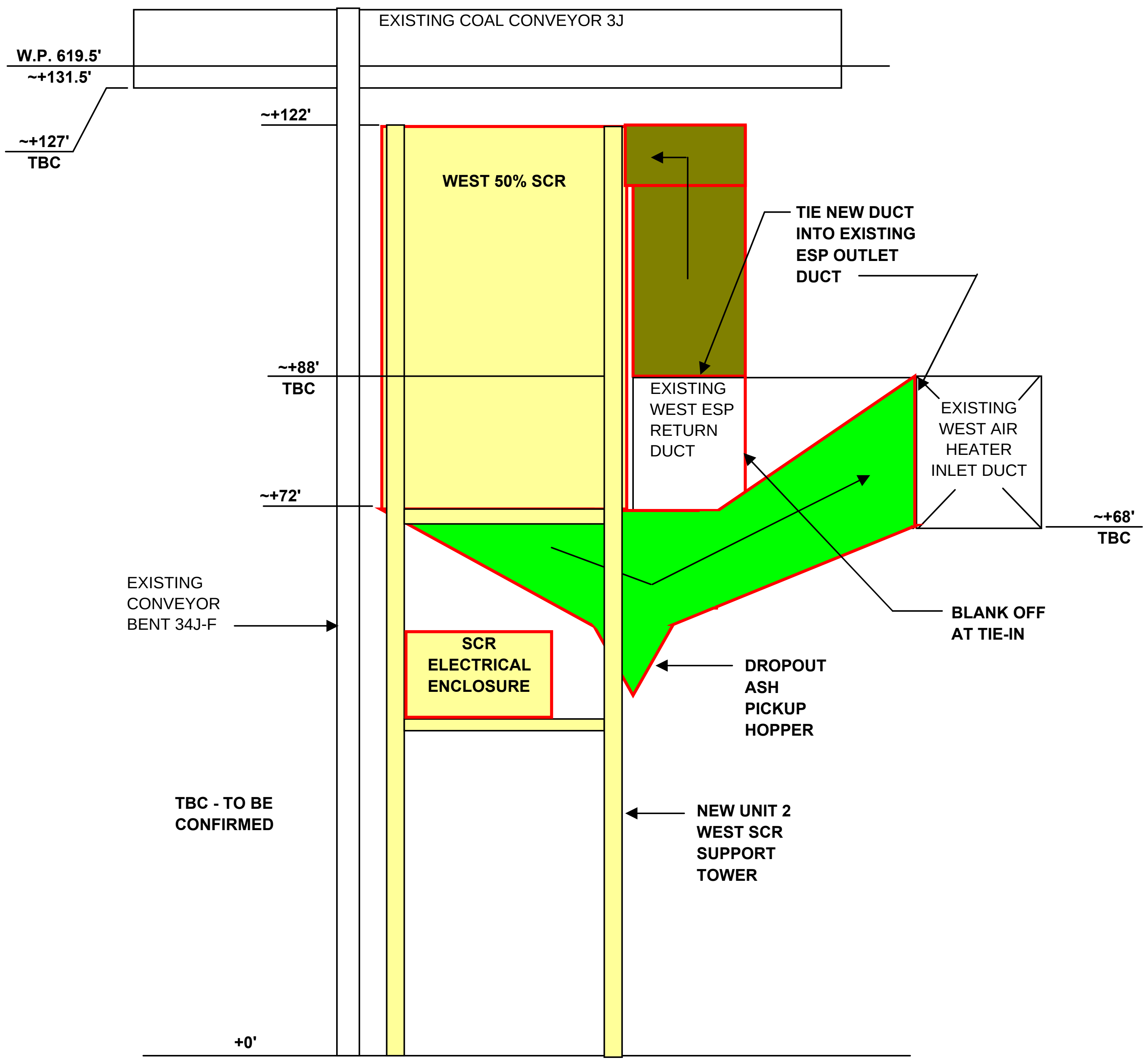

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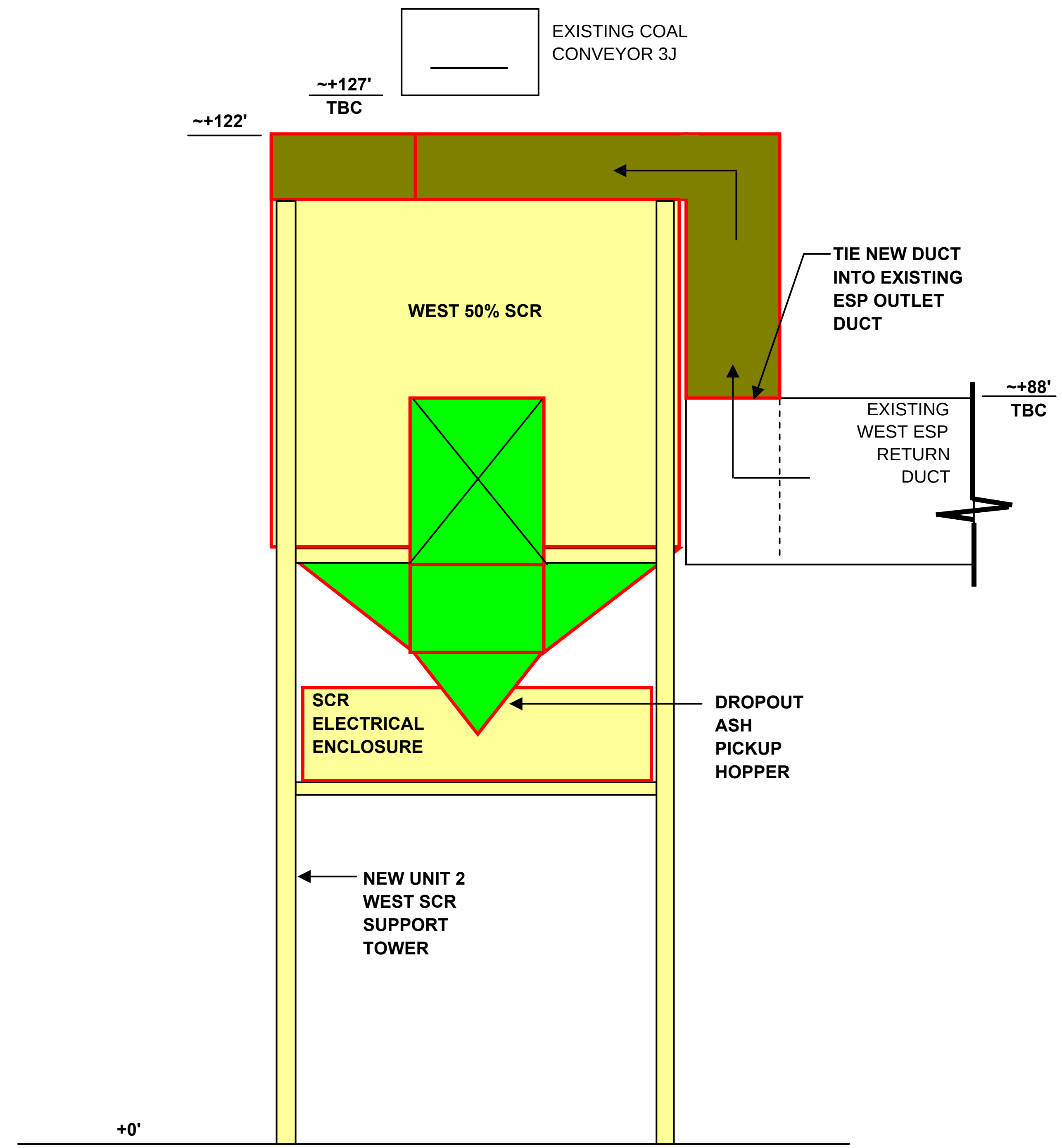

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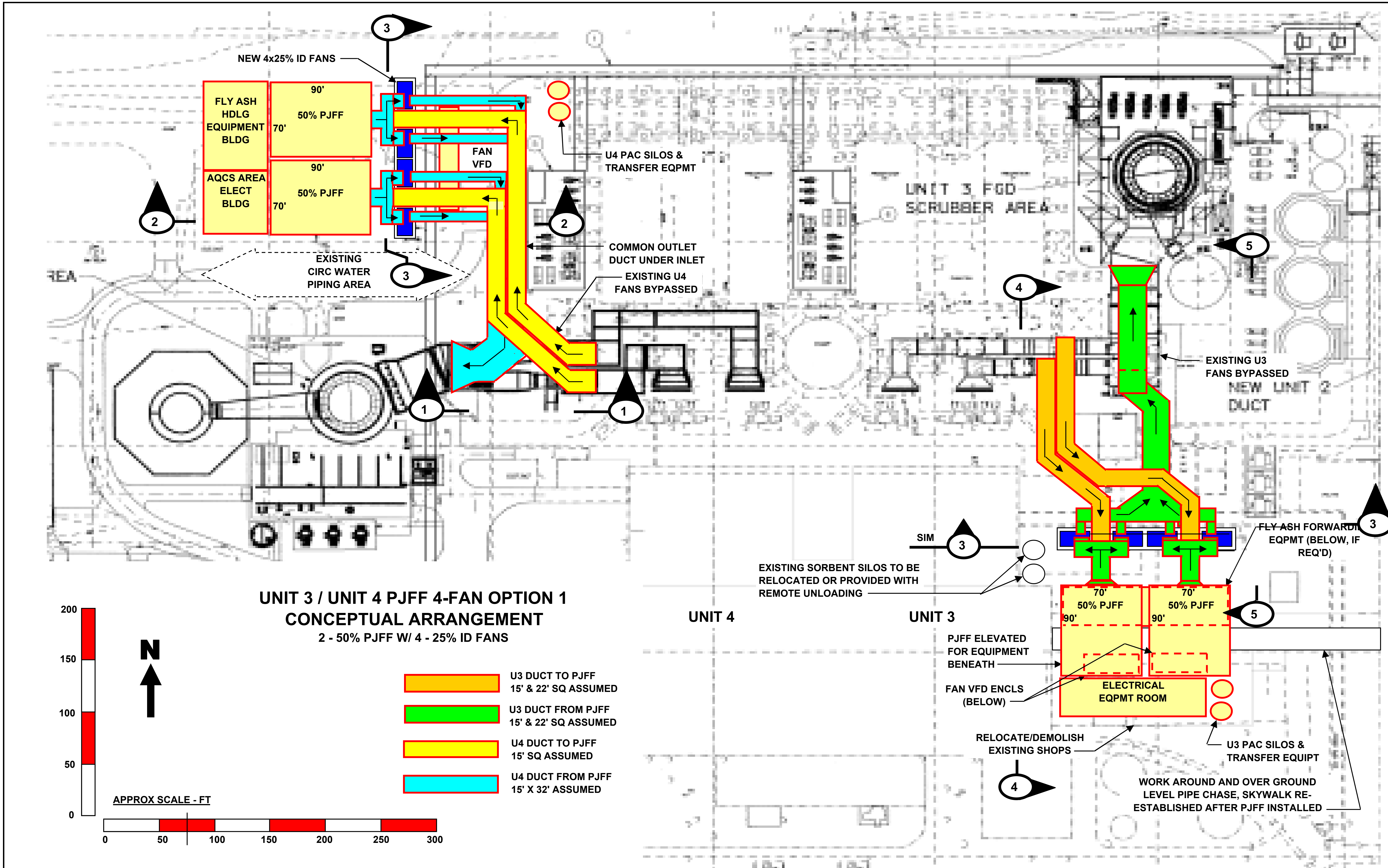
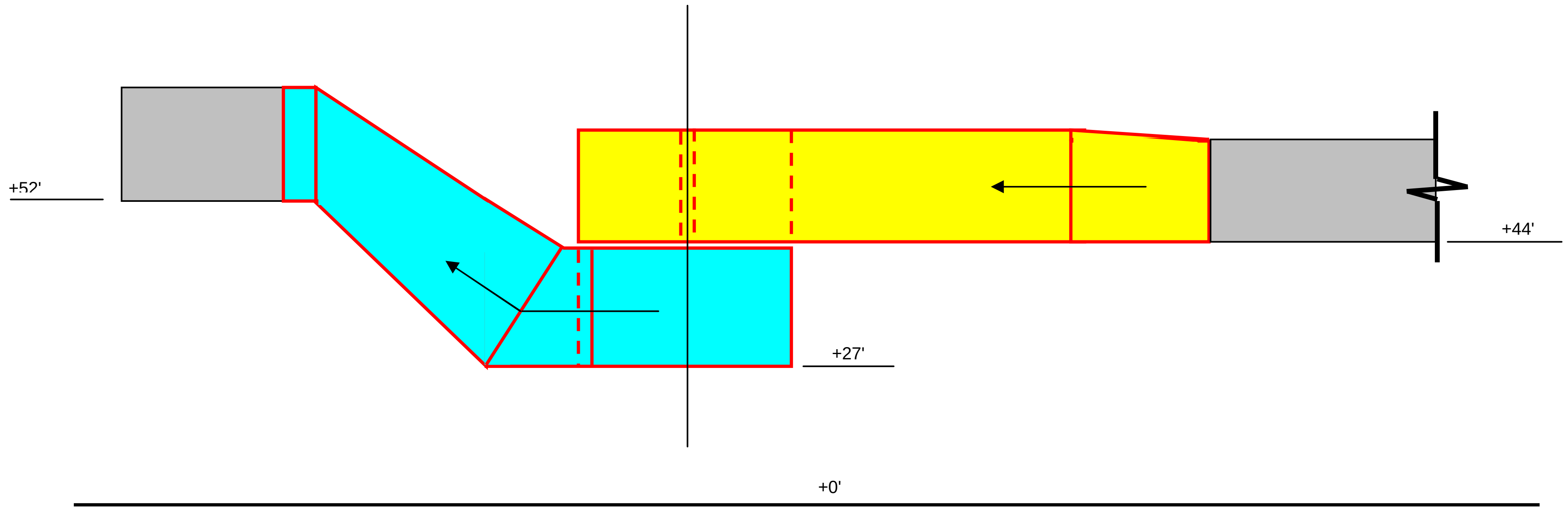
UNIT 2 CONCEPTUAL ARRANGEMENT SKETCH SECTIONS

Unit 3 and 4 Arrangements – Option 1



NEW 4x25% ID FANS
FLY ASH HDLG EQUIPMENT BLDG
90'
50% PJFF
70'
AQCS AREA ELECT BLDG
90'
50% PJFF
70'
FAN VFD
U4 PAC SILOS & TRANSFER EQPMT
COMMON OUTLET DUCT UNDER INLET
EXISTING U4 FANS BYPASSED
EXISTING CIRC WATER PIPING AREA
UNIT 3 FGD SCRUBBER AREA
EXISTING U3 FANS BYPASSED
NEW UNIT 2 DUCT
SIM
EXISTING SORBENT SILOS TO BE RELOCATED OR PROVIDED WITH REMOTE UNLOADING
FLY ASH FORWARDING EQPMT (BELOW, IF REQ'D)
70'
50% PJFF
90'
70'
50% PJFF
90'
UNIT 4
UNIT 3
PJFF ELEVATED FOR EQUIPMENT BENEATH
FAN VFD ENCLS (BELOW)
ELECTRICAL EQPMT ROOM
RELOCATE/DEMOLISH EXISTING SHOPS
U3 PAC SILOS & TRANSFER EQUIPT
WORK AROUND AND OVER GROUND LEVEL PIPE CHASE, SKYWALK RE-ESTABLISHED AFTER PJFF INSTALLED
UNIT 3 / UNIT 4 PJFF 4-FAN OPTION 1
CONCEPTUAL ARRANGEMENT
2 - 50% PJFF W/ 4 - 25% ID FANS
N
U3 DUCT TO PJFF 15' & 22' SQ ASSUMED
U3 DUCT FROM PJFF 15' & 22' SQ ASSUMED
U4 DUCT TO PJFF 15' SQ ASSUMED
U4 DUCT FROM PJFF 15' X 32' ASSUMED
200
150
100
50
0
APPROX SCALE - FT
0
50
100
150
200
250
300

UNIT 3/4 4-FAN PJFF OPTION 1
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



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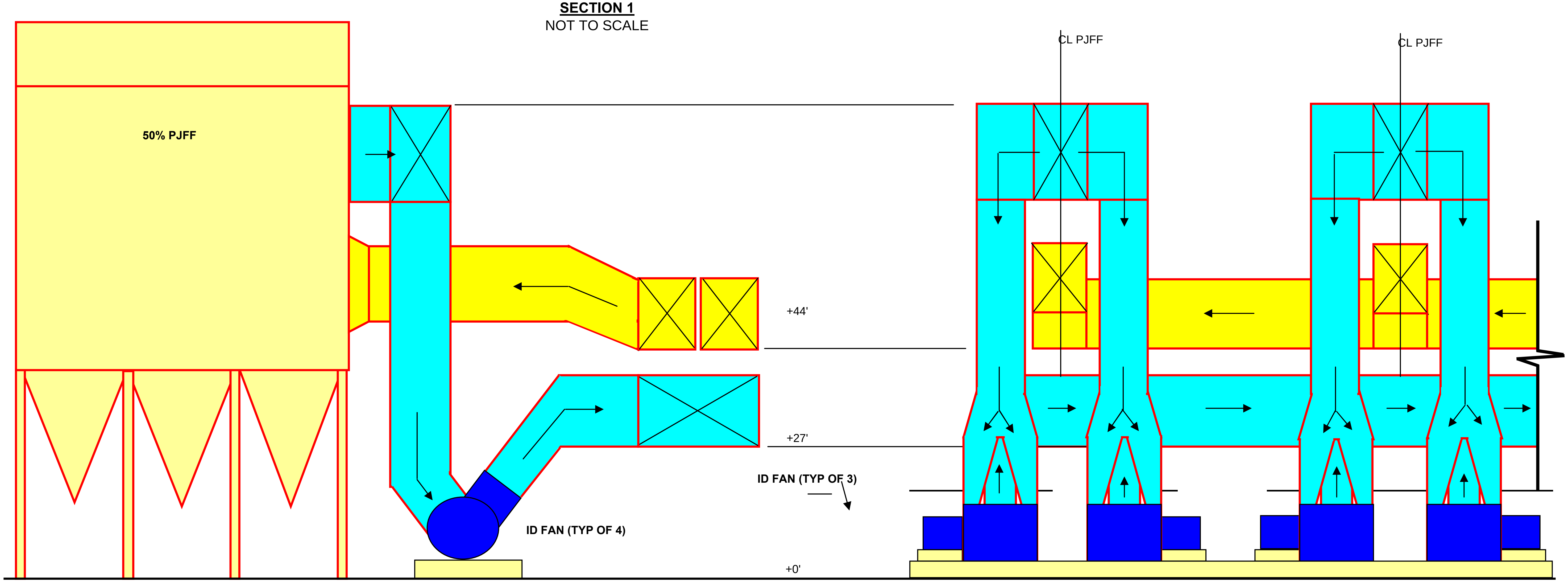
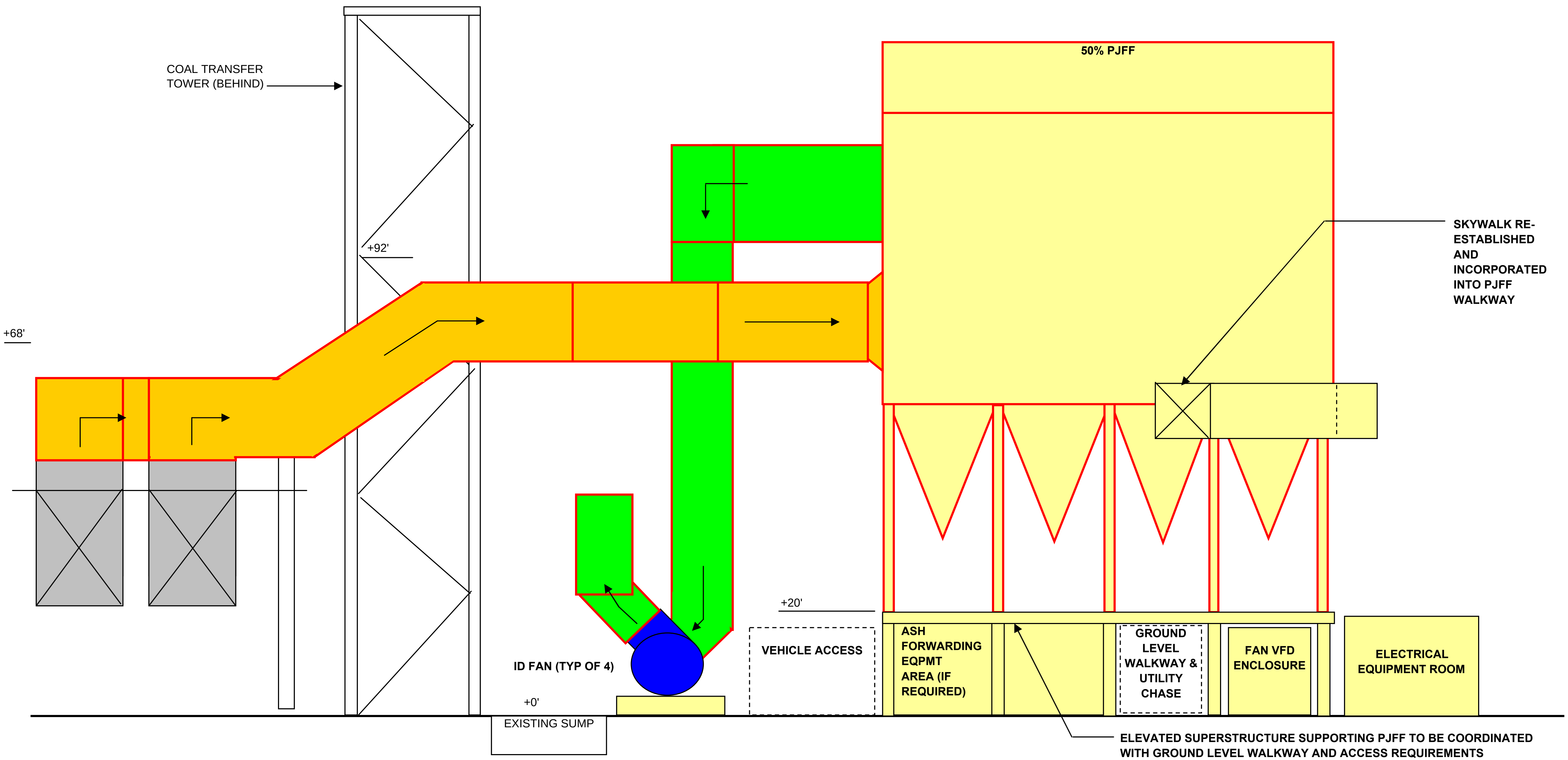


SECTION 2
NOT TO SCALE

SECTION 3
NOT TO SCALE

UNIT 3/4 4-FAN PJFF OPTION 1 CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



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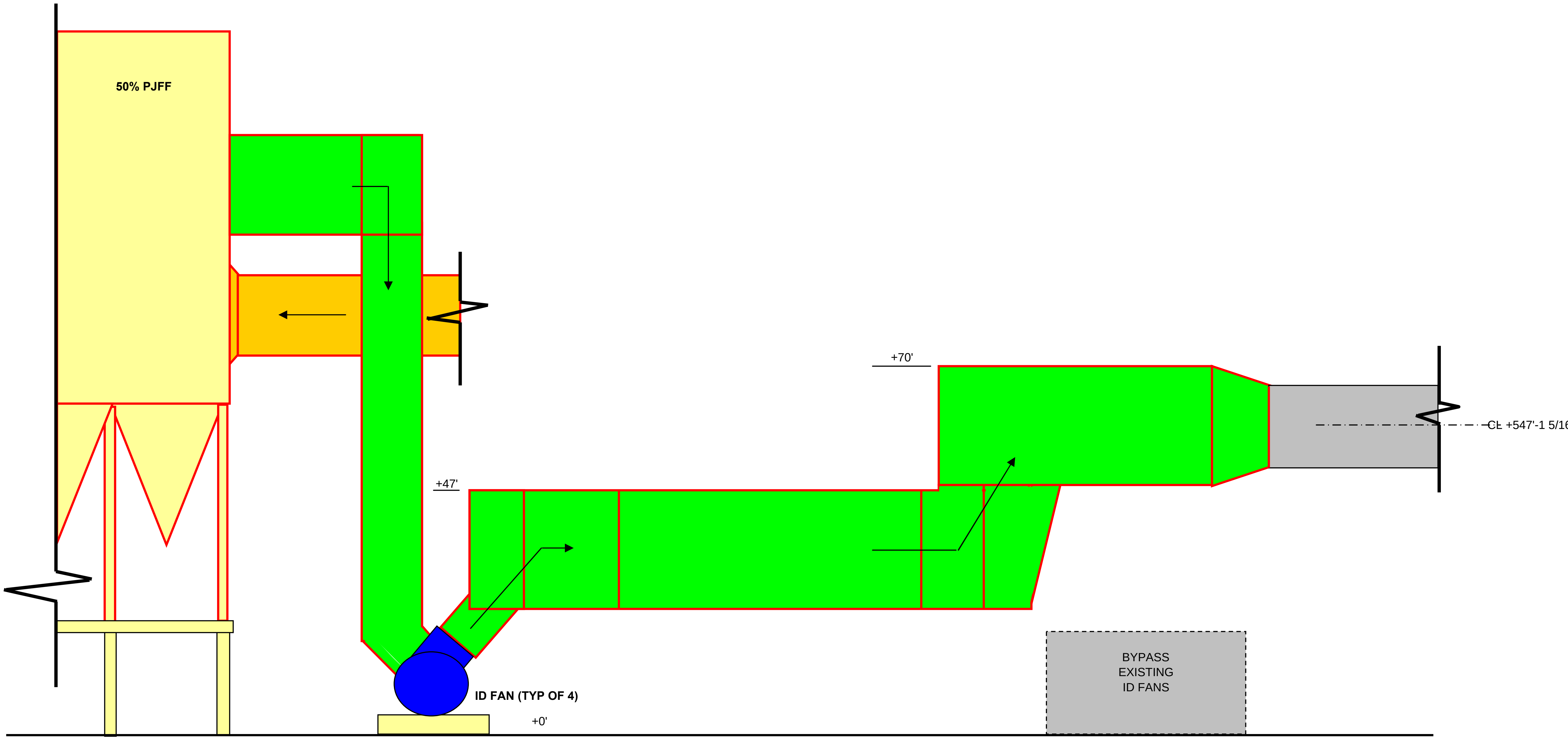
UNIT 3/4 4-FAN PJFF OPTION 1
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



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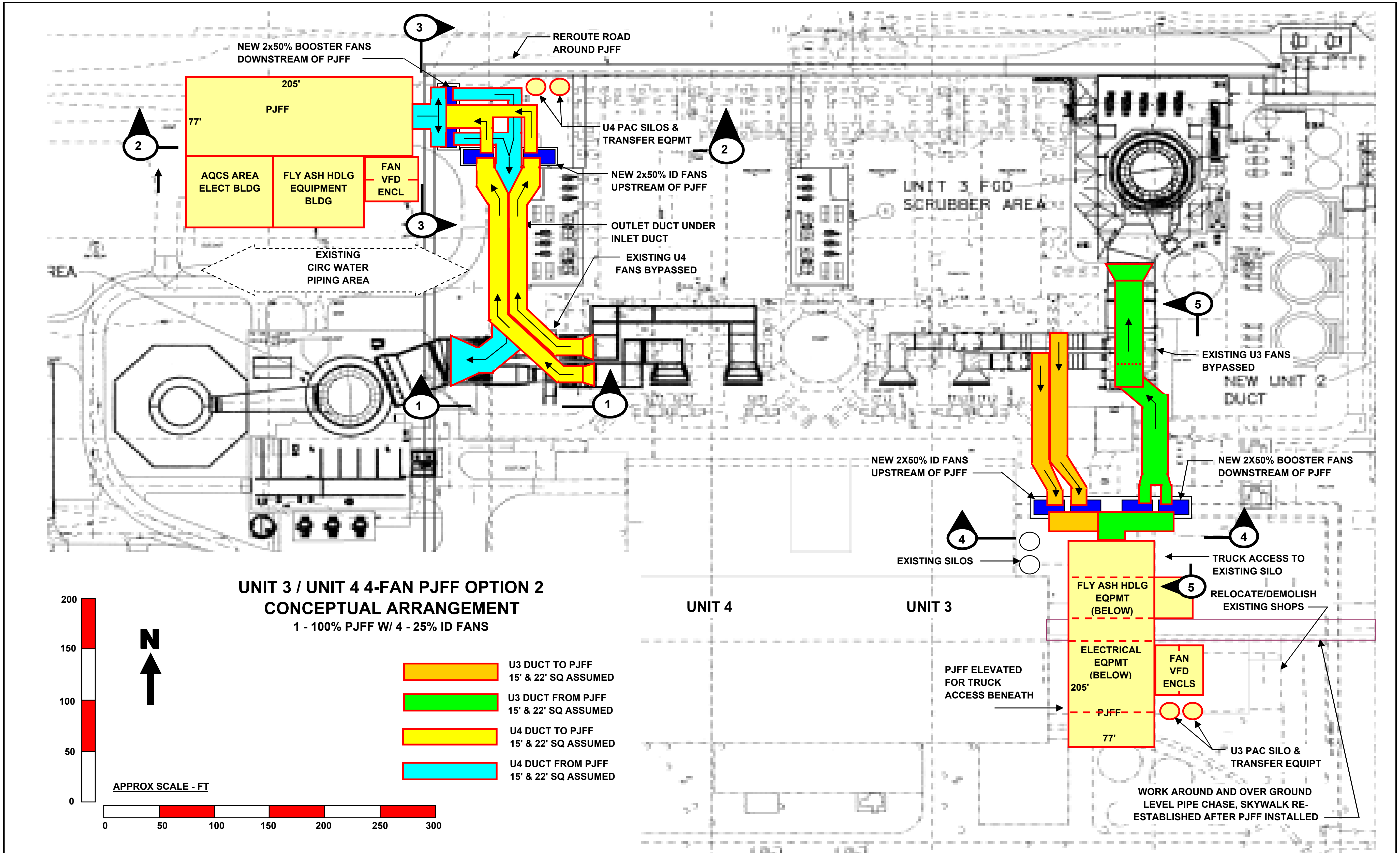
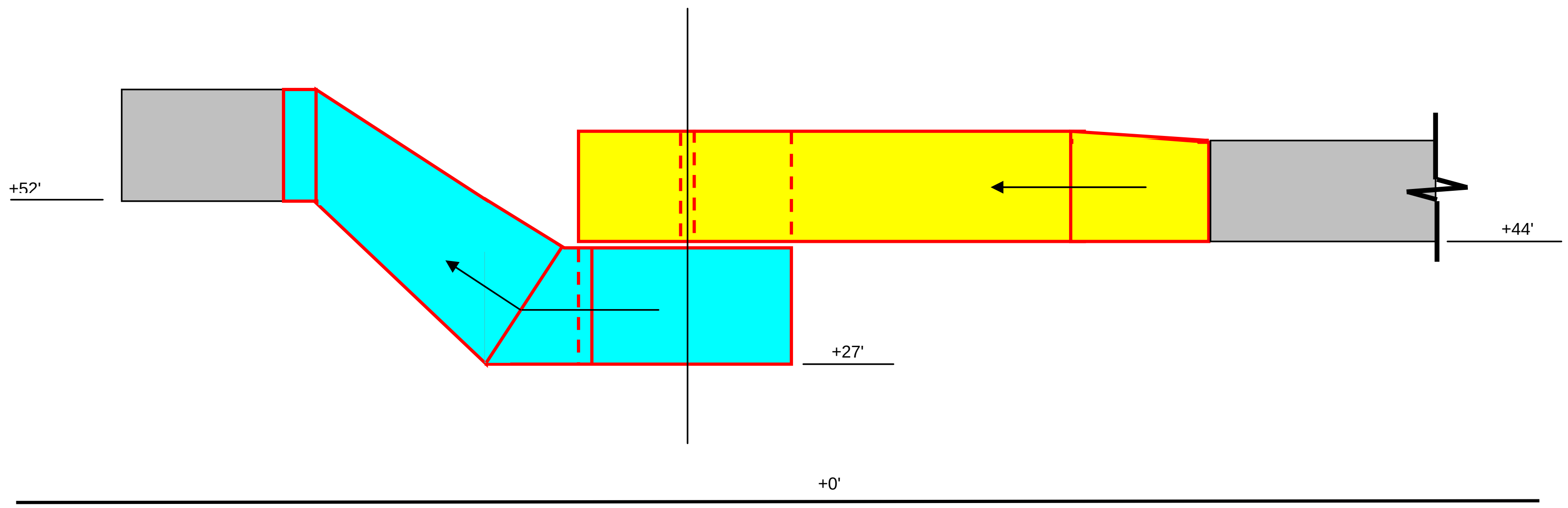
Unit 3 and 4 Arrangements – Option 2



UNIT 3 / UNIT 4 4-FAN PJFF OPTION 2
CONCEPTUAL ARRANGEMENT
1 - 100% PJFF W/ 4 - 25% ID FANS

UNIT 3/4 4-FAN PJFF OPTION 2
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



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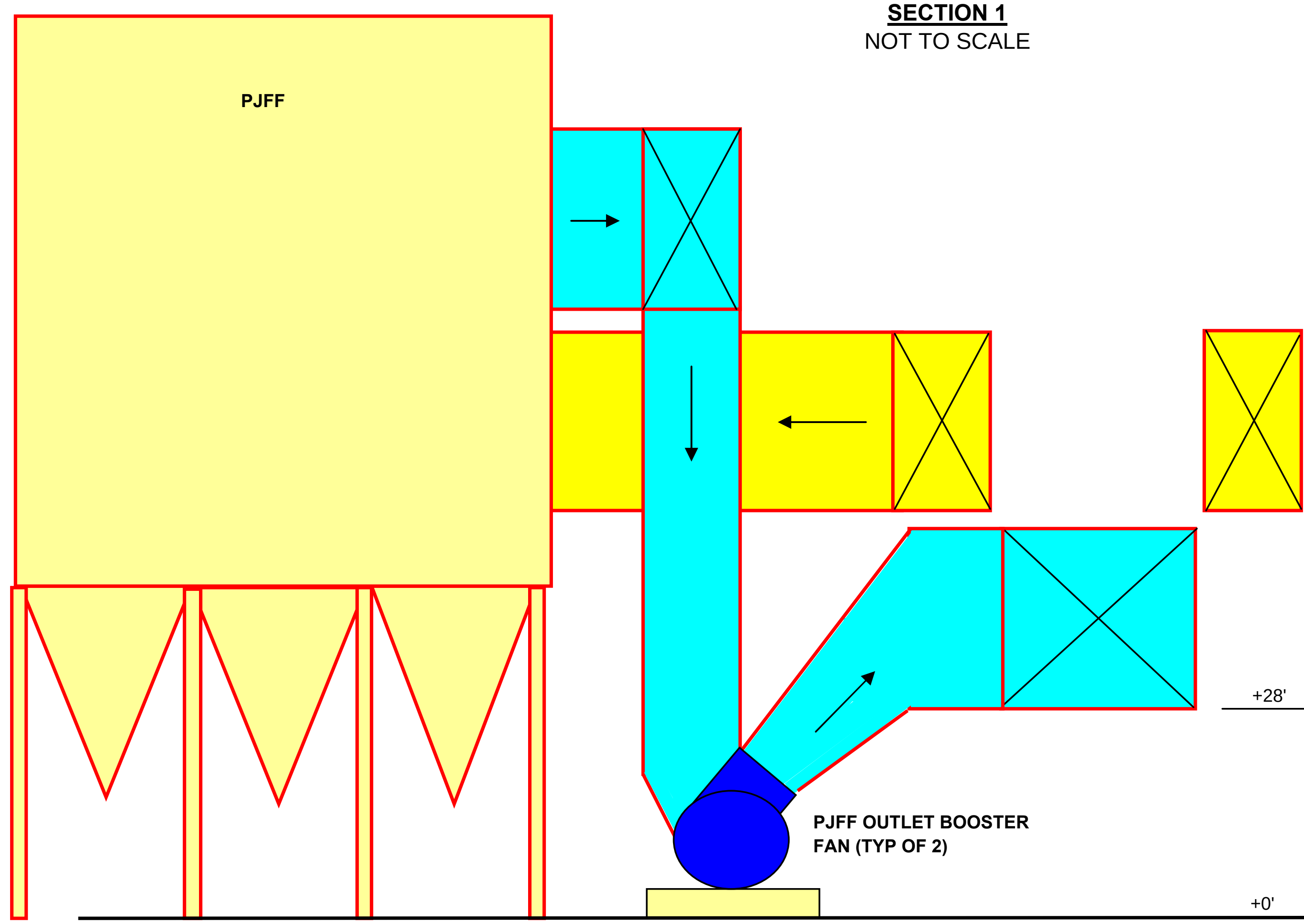

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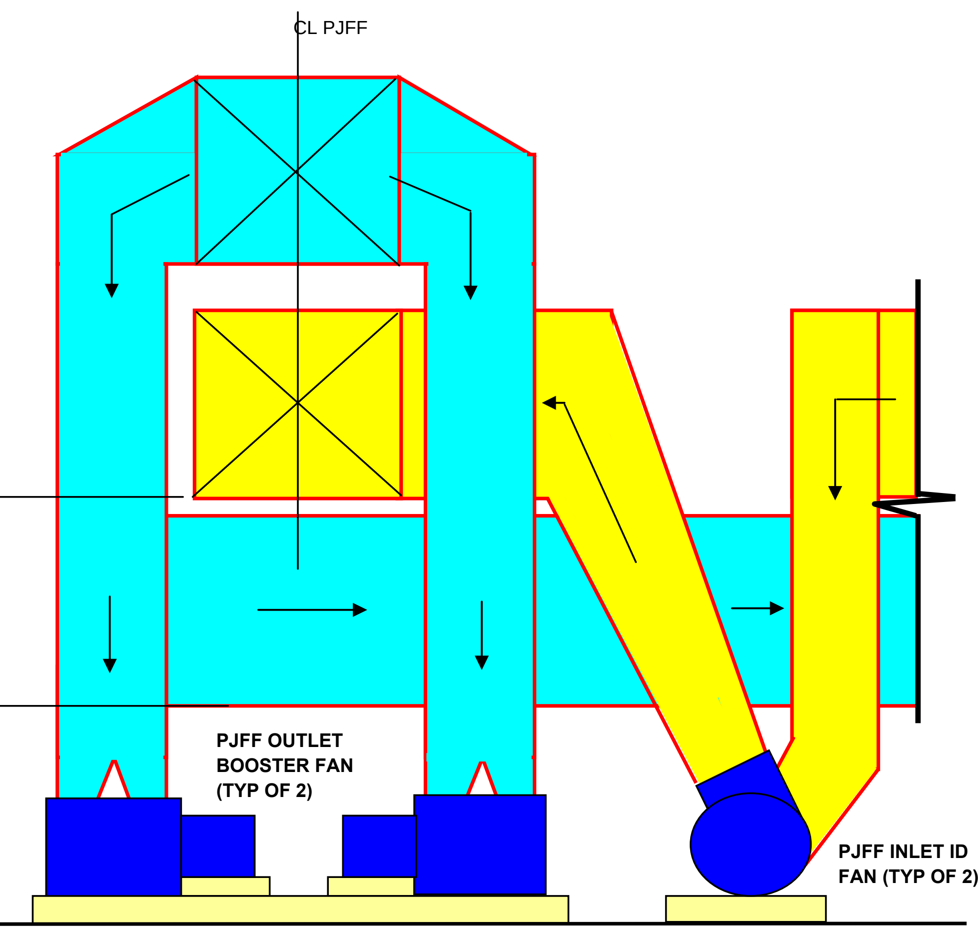

SECTION 3
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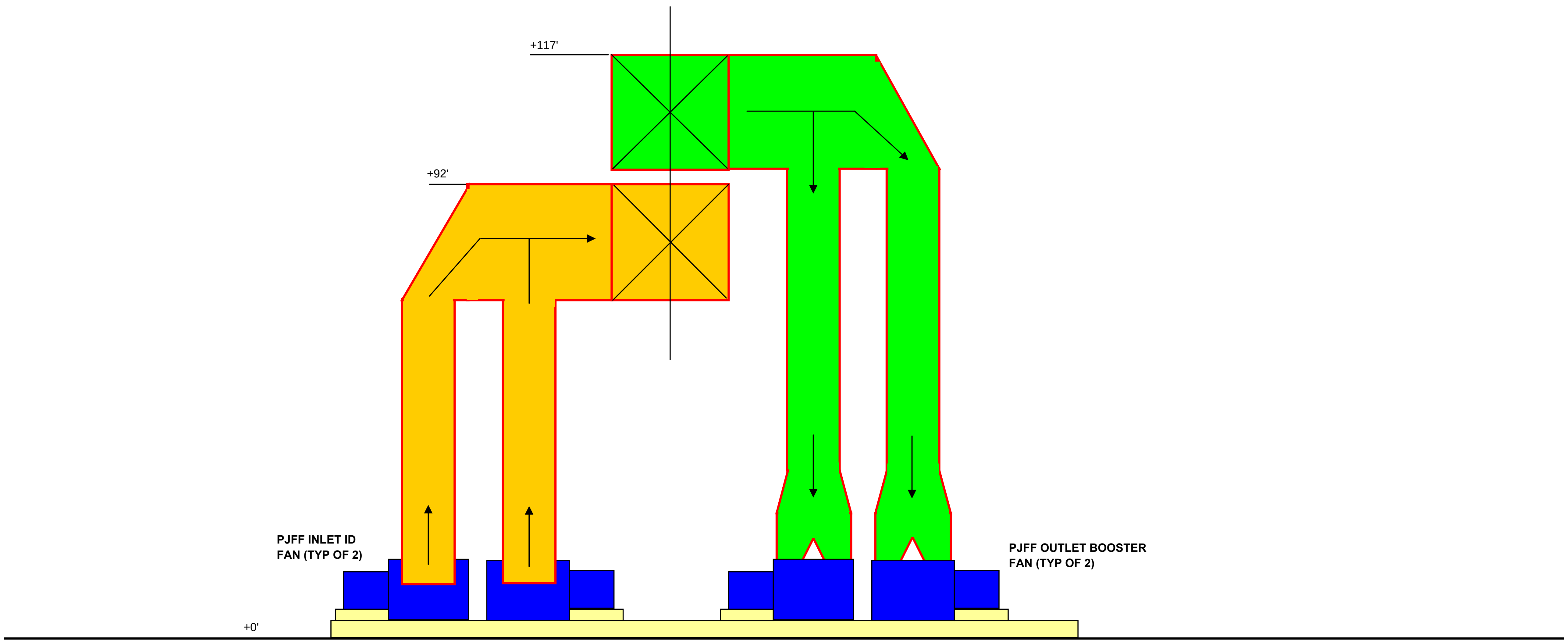
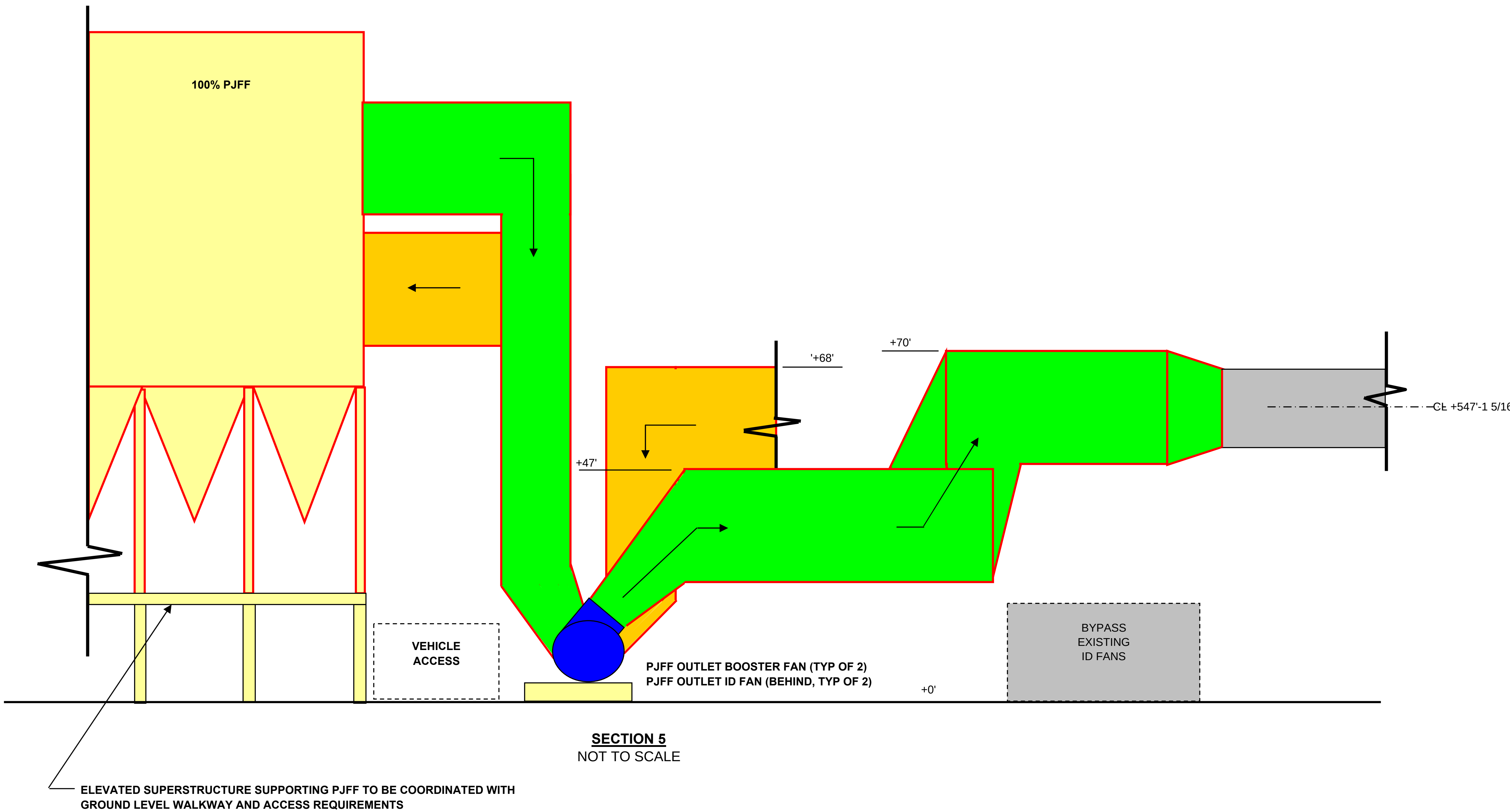
UNIT 3/4 4-FAN PJFF OPTION 2
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



SECTION 4
NOT TO SCALE

UNIT 3/4 4-FAN PJFF OPTION 2
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



SECTION 5
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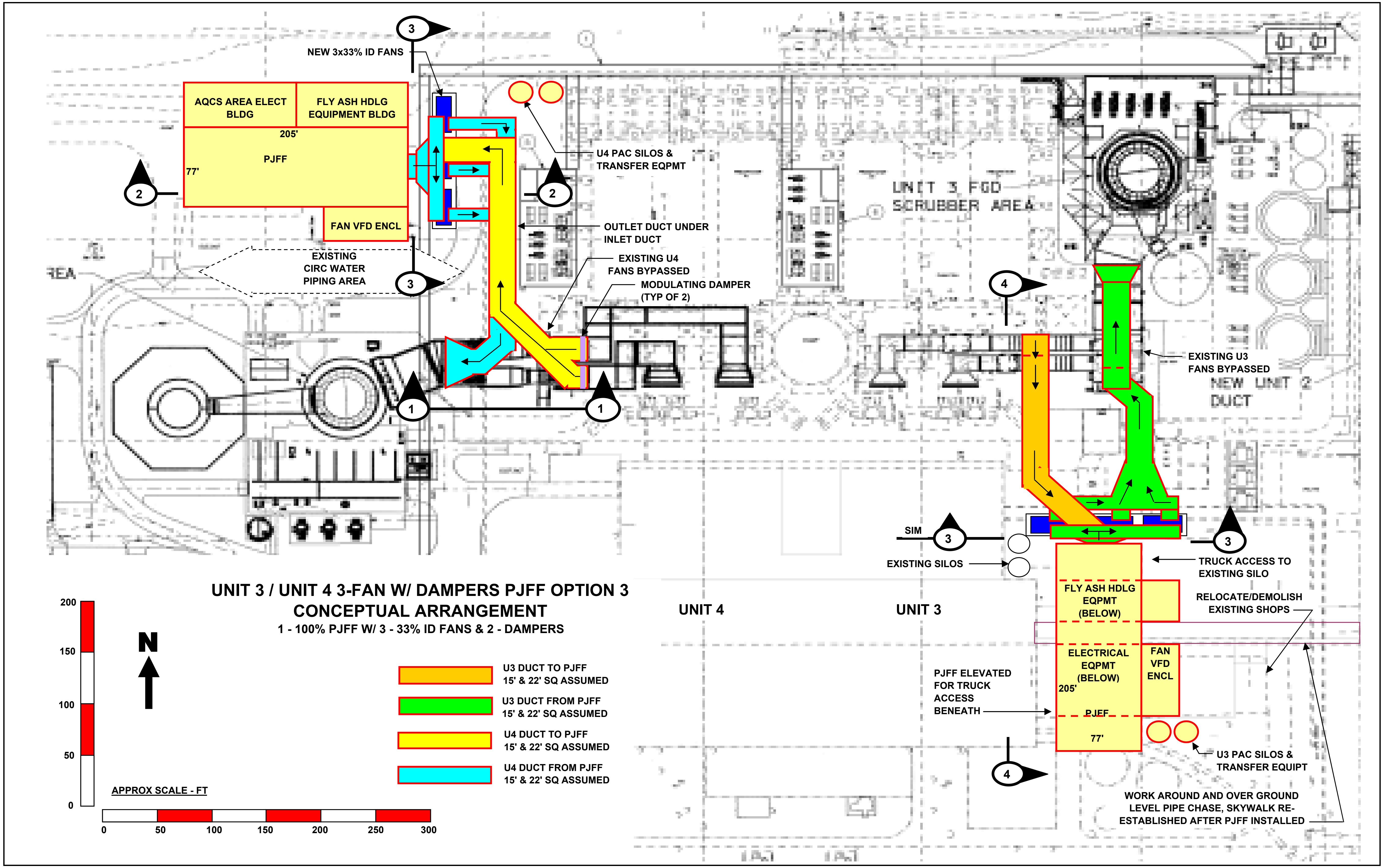
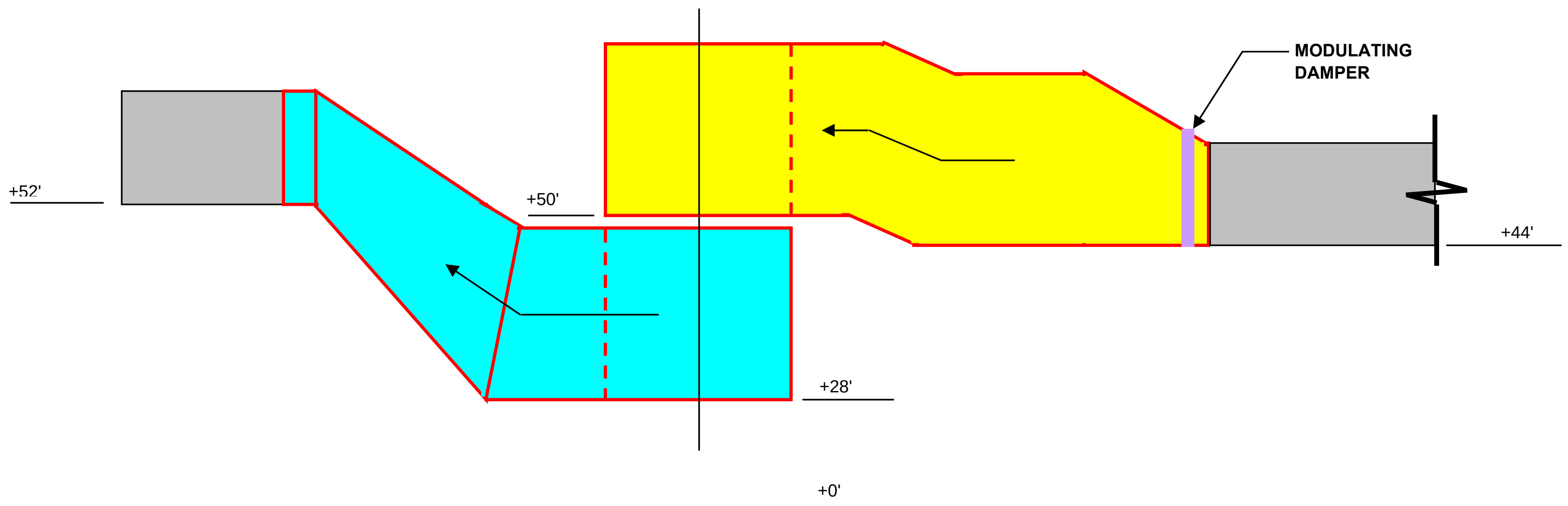
Unit 3 and 4 Arrangements – Option 3


NEW 3x33% ID FANS
AQCS AREA ELECT BLDG
FLY ASH HDLG EQUIPMENT BLDG
205'
PJFF
77'
FAN VFD ENCL
U4 PAC SILOS & TRANSFER EQPMT
OUTLET DUCT UNDER INLET DUCT
EXISTING U4 FANS BYPASSED
MODULATING DAMPER (TYP OF 2)
EXISTING CIRC WATER PIPING AREA
UNIT 3 FGD SCRUBBER AREA
EXISTING U3 FANS BYPASSED
NEW UNIT 2 DUCT
SIM
EXISTING SILOS
TRUCK ACCESS TO EXISTING SILO
FLY ASH HDLG EQPMT (BELOW)
RELOCATE/DEMOLISH EXISTING SHOPS
ELECTRICAL EQPMT (BELOW)
FAN VFD ENCL
PJFF ELEVATED FOR TRUCK ACCESS BENEATH
205'
PJFF
77'
U3 PAC SILOS & TRANSFER EQUIPT
WORK AROUND AND OVER GROUND LEVEL PIPE CHASE, SKYWALK RE-ESTABLISHED AFTER PJFF INSTALLED
UNIT 4
UNIT 3
UNIT 3 / UNIT 4 3-FAN W/ DAMPERS PJFF OPTION 3
CONCEPTUAL ARRANGEMENT
1 - 100% PJFF W/ 3 - 33% ID FANS & 2 - DAMPERS
N
U3 DUCT TO PJFF 15' & 22' SQ ASSUMED
U3 DUCT FROM PJFF 15' & 22' SQ ASSUMED
U4 DUCT TO PJFF 15' & 22' SQ ASSUMED
U4 DUCT FROM PJFF 15' & 22' SQ ASSUMED
APPROX SCALE - FT
0 50 100 150 200 250 300
200 150 100 50 0

UNIT 3/4 3-FAN W/ DAMPERS OPTION 3
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



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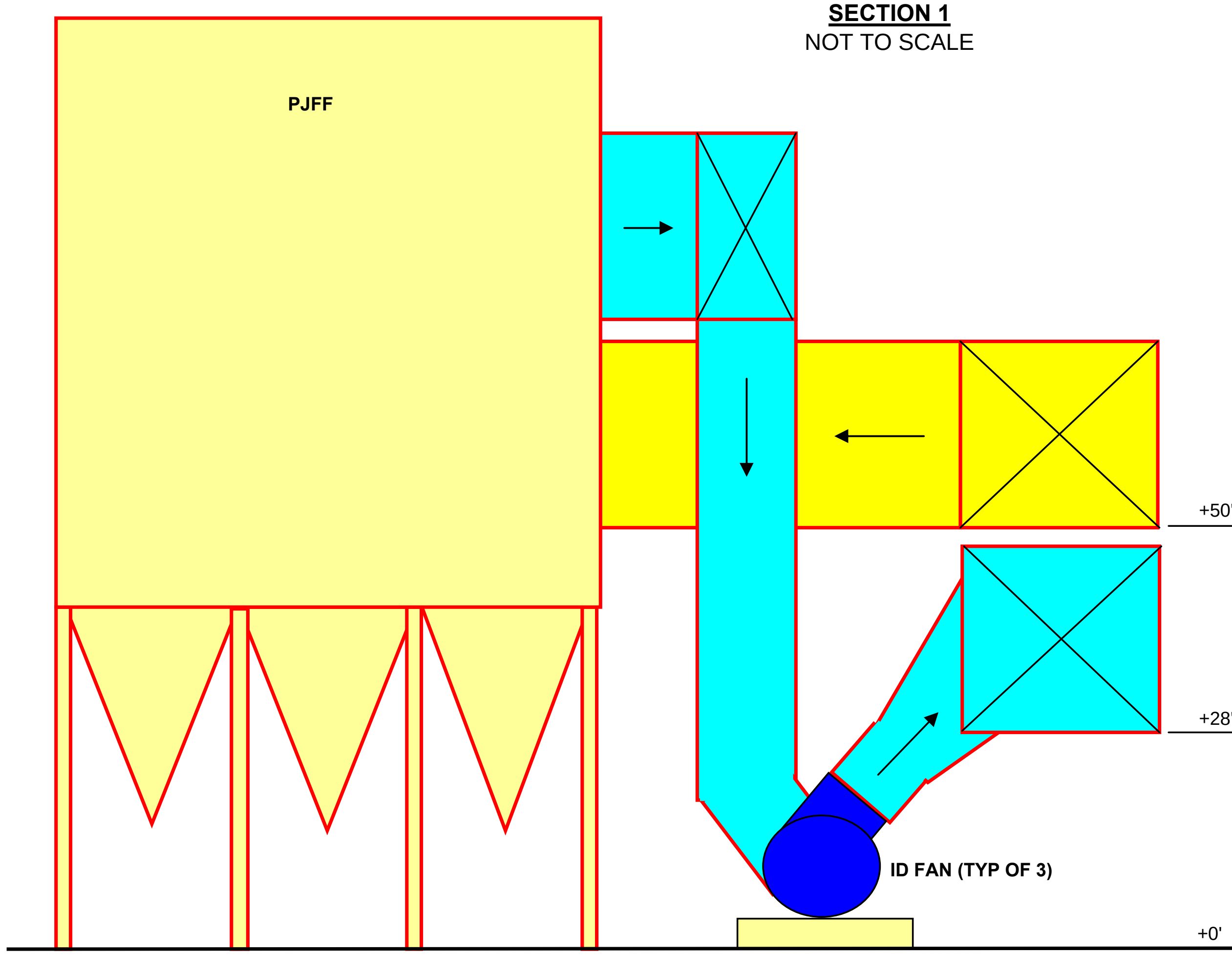

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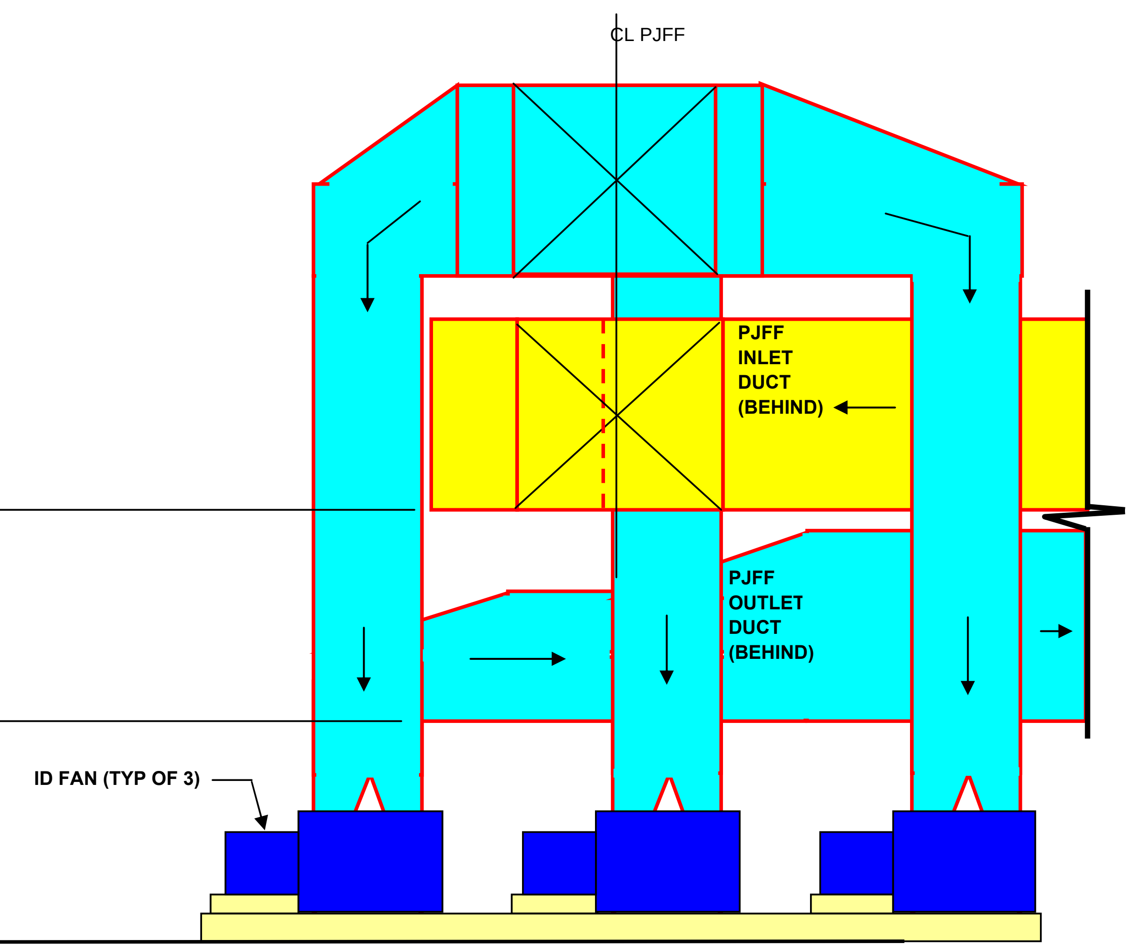
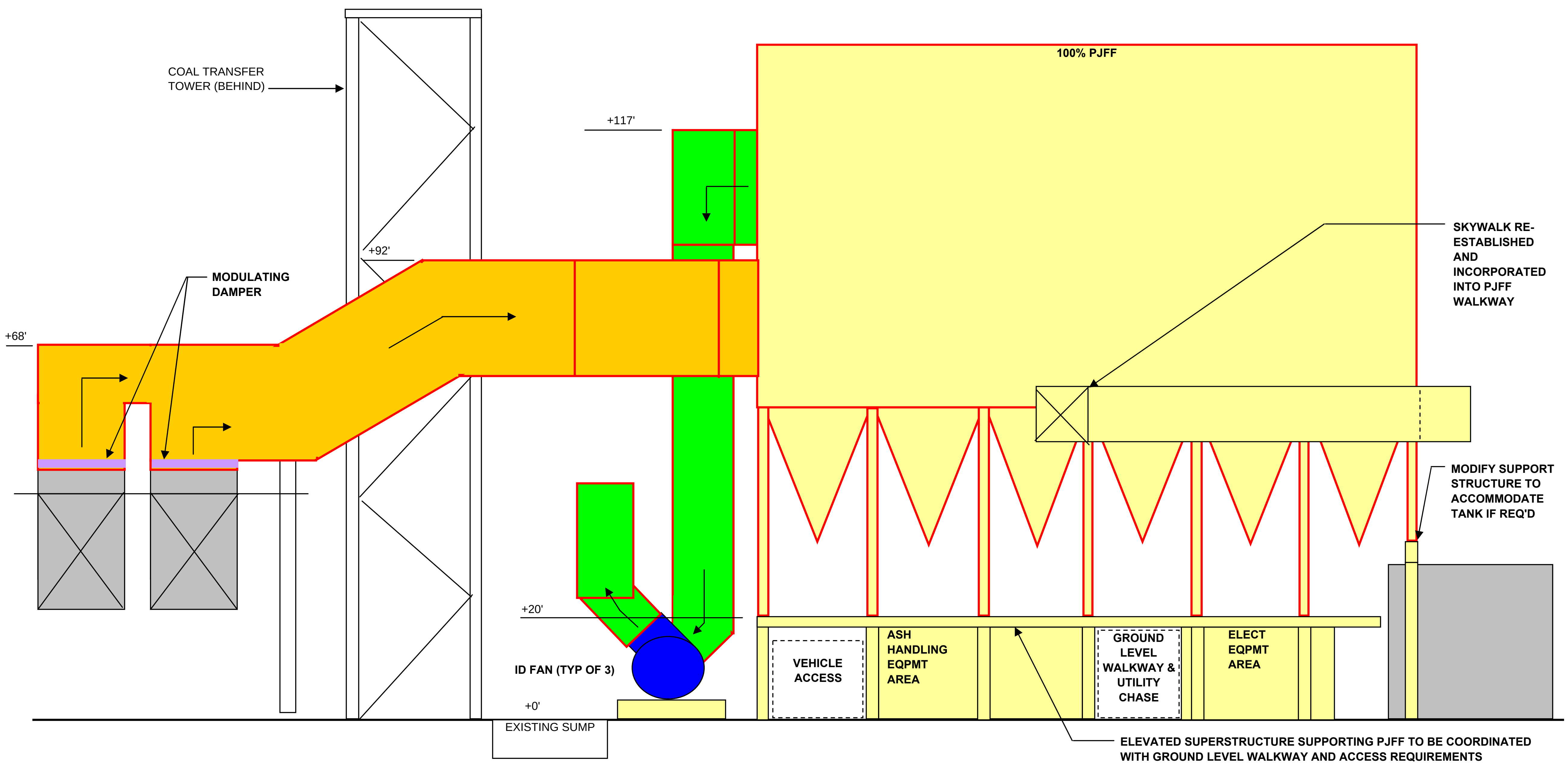


SECTION 3
NOT TO SCALE

UNIT 3/4 3-FAN W/ DAMPERS OPTION 3
CONCEPTUAL ARRANGEMENT SKETCH
SECTIONS



SECTION 4
NOT TO SCALE

Appendix B
Flow Biasing Options

LG&E/KU – Ghent Station

Phase II Air Quality Control Study

Flow Biasing Options

January 24, 2011
Revision B – Issued For Client Review

B&V File Number 41.0814.3

Table of Contents

Figures

Tables

1.0 Introduction

1.1 Project Overview

LG&E/KU has commissioned Black & Veatch (B&V) to develop a conceptual design of the draft system modifications needed at the Ghent units to support additional air quality control (AQC) equipment that may be needed in the future. The draft system modifications being considered for all Ghent units consist of the installation of pulse jet fabric filter (PJFF) systems with the replacement of ID fans, addition of booster fans, or both. In addition, a selective catalytic reduction (SCR) system is being considered for Unit 2.

1.2 Objective

The objective of this document is to discuss arrangement options that will allow the incorporation of flow biasing on Ghent Units 3 and 4 draft systems.

1.3 Background

During the AQC validation meeting on 12/7/2010, LG&E/KU personnel discussed with B&V that plant operators at each Ghent unit bias flue gas flows through each 50 percent equipment train using the ID fans to compensate for various draft system issues that may arise. This was brought up during discussions on Unit 3 and Unit 4 since B&V is proposing a single PJFF due to expected space constraints and the need for at least three centrifugal type ID fans to replace the two existing axial ID fans. Combining both flue gas ductwork trains into common ductwork and PJFF equipment on Unit 3, as well as Unit 4, would eliminate the ability to bias flue gas flow through each equipment train with the ID fans. In contrast, the new AQC equipment that B&V is proposing on Units 1 and 2 is not an issue because it allows for separate flue gas ductwork and equipment trains to remain in place. Therefore, Units 3 and 4 will be the concentration of this document. See Figure 1 for the flow diagram of the existing draft system for Units 3 and 4.

During the brief flow biasing discussion, LG&E/KU mentioned that the inlet flue gas pressures of the ID fans are used as one of the inputs for the flow biasing decisions that are made on a daily basis. It was unclear to B&V whether these pressures were the static inlet pressures or the inlet box differential pressures for each ID fan. Also discussed were a couple of solutions for Units 3 and 4 if the flue gas path is to be combined upstream of the ID fans. One of these solutions included the use of louver dampers downstream of each air heater gas outlet to allow flow biasing. However, it was also noted that the operation of louver dampers in flue gas streams is known to be problematic. The item was then tabled until B&V could further review the issue.

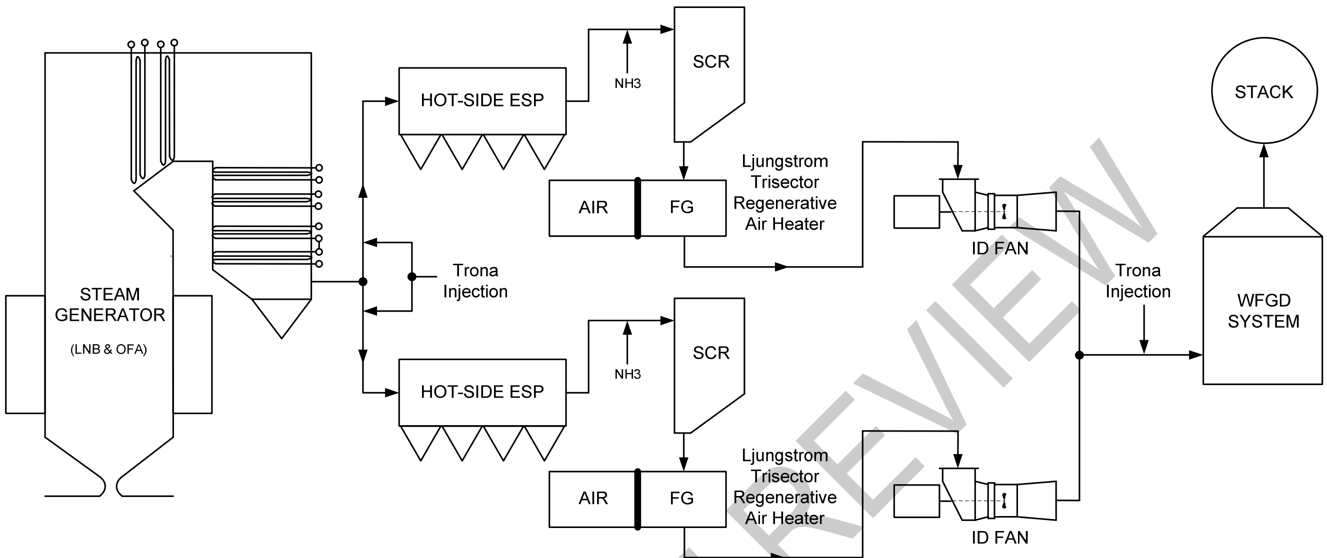


Figure 1 – Units 3 and 4 Existing Draft System

2.0 Flow Biasing Options

A further discussion on flow biasing for Ghent Units 3 and 4 took place on 1/12/2011 with a conference call between LG&E/KU and B&V to better understand the reasons for flow biasing. As a result of the discussions it was determined that the flow biasing currently being done between different trains of flue gas draft system components is heavily desired due to the multitude of conditions that it is used to control. Therefore, three different draft system layout options were discussed to allow the ability to continue to bias flows. The three options, discussed further in this document, are as follows:

- Option 1: Two separate PJFFs with two ID fans per PJFF
- Option 2: One common PJFF with two ID fans upstream and two booster fans downstream
- Option 3: One common PJFF and three ID fans with modulating dampers upstream of PJFF (B&V initially proposed layout)

This document is intended to document and condense previous discussions and to provide a basis on which LG&E/KU can decide how best to continue development of the conceptual design for Units 3 and 4.

2.1 Option 1

With Option 1 the flue gas flow between the two trains remains separated entering each new 50 percent capacity PJFF, each with its own set of two new 25 percent capacity ID fans. Figure 2 illustrates this concept and the Option 1 plant layout sketches in Appendix A show this in more detail. This arrangement offers advantages over the other two options that will be discussed later. First is that there is no need to install extra dampers in each flue gas path to bias the flows between each train; the biasing can be accomplished through the ID fans as configured. Next, all four centrifugal ID fans will be sized with the same performance characteristics potentially decreasing the cost of the draft fans. Additionally, in the future, if the plant decides to permanently shutdown the hot-side ESPs due to temperature drop, leakage, collection issues, etc., the draft system is set up to accommodate this transition. This is because the draft fans are all downstream of the PJFF and would still not be subject to high particulate loading. There may be a need for modifications to the SCR system and/or the air heaters (AH) to accommodate the much higher particulate loading, however.

A disadvantage associated with Option 1 is that it would likely have the highest cost of the three options. The incorporation of two PJFFs and an additional ID fan beyond the three in Option 3 are the main reasons for the higher cost. Another disadvantage is that the two PJFFs would occupy most of the courtyard space between Units 2 and 3. Lastly, the ductwork arrangement for Option 1 is more complex and likely more expensive to construct. See Table 1 for a summary of the advantages and disadvantages of Option 1.

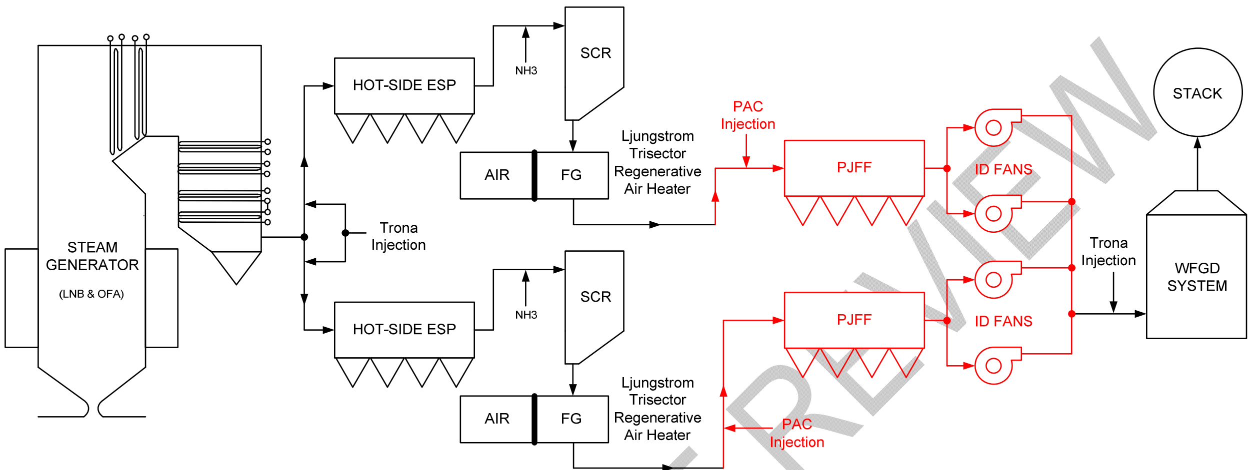


Figure 2 – Option 1: Units 3 and 4 Future Draft System, Two PJFF with Two ID fans Downstream Each

2.2 Option 2

With Option 2 the flue gas flow between the two trains would remain separated entering two new 50 percent capacity ID fans. Flue gas would then be drawn through a single new 100 percent PJFF with two new 50 percent booster fans. Figure 3 illustrates this concept and the Option 2 plant layout sketches in Appendix A show this in more detail. Option 2 is similar to the draft system arrangement for Units 1 and 2. This arrangement offers a similar advantage as Option 1 in that flow biasing would be accomplished through the use of the ID fans as it currently is. Extra dampers would not be needed. An advantage that Option 2 offers over Option 1 is that only one PJFF is needed decreasing equipment and layout complexity. Additionally, there is the possibility that the existing axial ID fans could be used as the booster fans significantly decreasing the cost and footprint that would be otherwise required for two new booster fans.

However, placing a set of ID fans upstream of the new PJFF would not allow the hot-side ESP to be shutdown in the future. The pressure drop, air in-leakage, and temperature drop that the hot-side ESPs contribute to the draft system would be more likely to remain than with Options 1 and 3. Additionally, the ID fans and booster fans would be of different sizes and performance with the potential for higher costs than fans of similar performance. Control additions would also be required to accommodate the booster fans. Similar to Option 1, adding the second set of fans will increase the complexity and cost of the ductwork. See Table 1 for a summary of the advantages and disadvantages of Option 2.

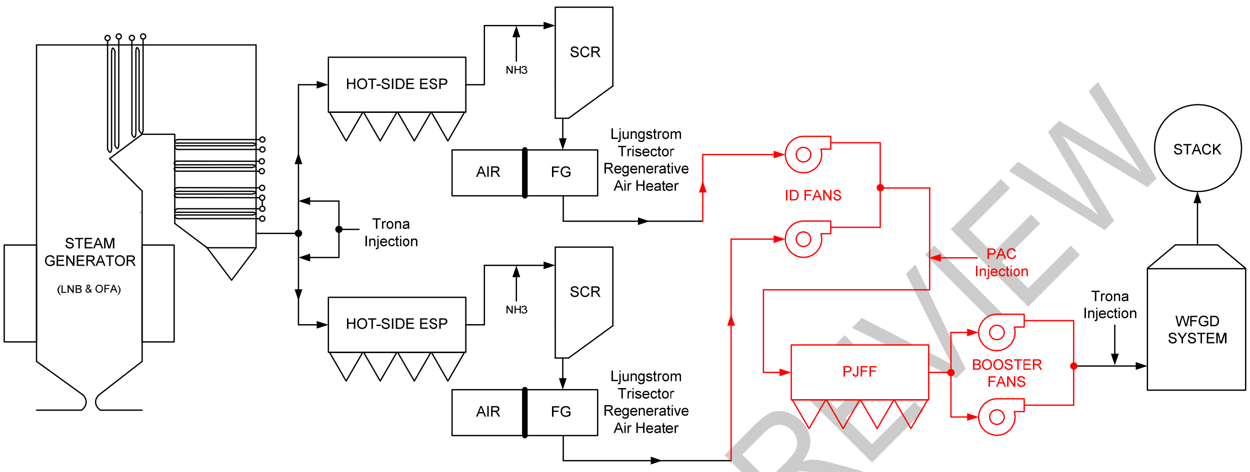


Figure 3 – Option 2: Units 3 and 4 Future Draft System, Single PJFF with Two ID fans Upstream and Two Booster Fans Downstream

2.3 Option 3

As previously mentioned, Option 3 is the initial layout that B&V proposed which is in the Ghent AQC Validation report. In order for flow biasing to be accomplished with this layout, modulating dampers would need to be installed in a section of the draft system upstream of the new PJFF where the flue gas paths are still split. Figure 4 illustrates this concept and the Option 3 plant layout sketches in Appendix A show this in more detail. One advantage of this option that is similar to those discussed for Option 1 includes the use of similarly sized ID fans potentially leading to a cost savings. Also, similar to Option 2, a single PJFF would be used which is expected to decrease equipment and layout complexity over a two PJFF arrangement. Similar to Option 1, the Option 3 arrangement is more conducive to allowing the unit to discontinue the use of the hot-side ESPs at some time in the future. Some additional advantages consist of the use of only three ID fans allowing for one less fan foundation, less ductwork, and other equipment associated with a fourth fan. It is expected that this Option would be the least expensive of the three options due to the three ID fans and single PJFF. Adding the modulating dampers to allow for flow biasing should be relatively inexpensive.

There are several disadvantages to this option as well. First, flow biasing through the use of the ID fans would no longer be available. The flow biasing duties would be transferred to the dampers creating another resistance in the draft system. Secondly, working with odd numbers of fans is more challenging from an electrical power and control point of view. A three bus electrical system would be expected and may nullify the cost savings of installing only three fans. Additional controls would also be needed for the flow biasing dampers. Lastly, there are concerns with the additional maintenance, reliability, and life expectancy associated with flue gas dampers that would be continuously modulated due to the environments to which they would be subjected.

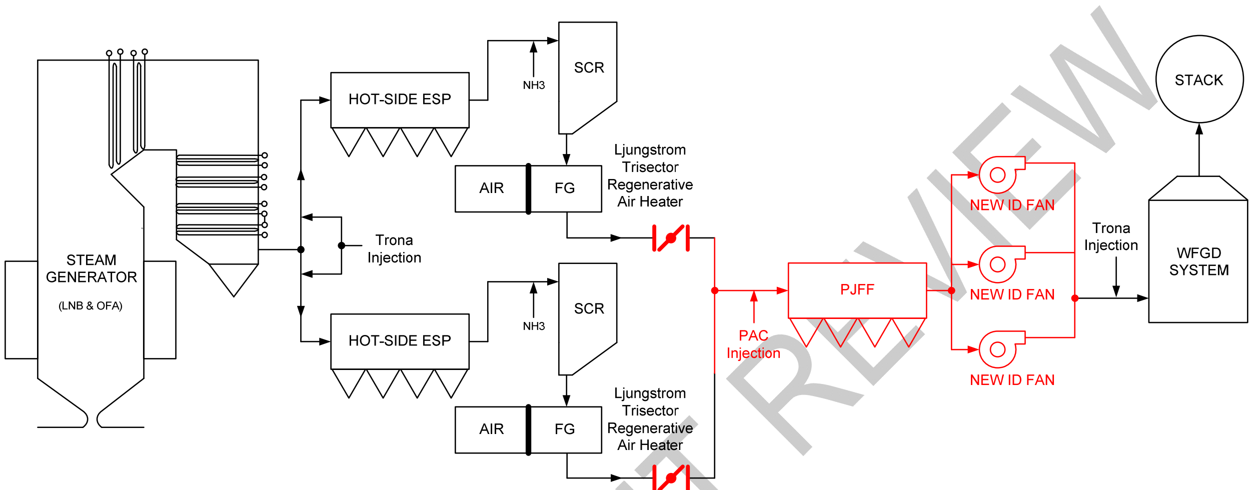


Figure 4 – Option 3: Units 3 and 4 Future Draft System, Modulating Dampers Upstream of a Single PJFF with Three ID Fans Downstream

One of the environments that the flow biasing dampers may be subject to is upstream of the hot-side electrostatic precipitators (ESP) where high temperatures and high particulate loading exist. This service would be similar to dampers that control reheat steam temperatures in the back passes of many boilers. The relatively high temperatures would cause the dampers to expand and contract significantly more when cycling through plant shutdowns and startups than if the dampers were placed downstream of the air heaters. This may increase the potential for material failures over time and/or draft system leaks. The high particulate loading would be expected to cause significantly more wear, affecting performance, and decreased life expectancy than downstream of the ESPs which is another potential location. Placing the dampers downstream of the ESPs would still subject them to relatively high temperatures; however the significant decrease in particulate loading would be beneficial. The same would apply with the dampers downstream of the SCR systems except that cold spots on the dampers near the edges of the duct may allow for conditions where ammonium bisulfate (ABS) would form. The accumulation of this solid would potentially cause the dampers to loose part or all of their ability to modulate flows. Locating modulating dampers downstream of the air heaters would subject them to much cooler temperatures with little particulate loading and the expectation of no ABS formation. Figure 4 shows dampers in this location. However, the potential for the condensation of acid gases considerably increases with the cooler temperatures subjecting the dampers to a corrosive environment. If Option 3 is chosen, further discussions will need to take place to determine the location in the split draft system that these dampers should be placed with the greatest potential to minimize wear and maintenance. See Table 1 for a summary of the advantages and disadvantages of Option 3.

3.0 Summary

In review, Option 1 incorporates the use of two separate fabric filters with the use of two ID fans per fabric filter. Option 2 uses only one common fabric filter with two ID fans upstream and two booster fans downstream. Option 3 is the layout that B&V initially proposed but with the incorporation of modulating dampers. Figures 2, 3, and 4, as well as the plant layout sketches in Appendix A, illustrate these options. Any of these three options discussed would allow flue gas flow biasing up through the air heaters on Ghent Units 3 and 4 and as the detailed description of each option revealed, there are a multitude of advantages and disadvantages associated with each. Furthermore, B&V is confident that each of the three options would fit within the site real estate available with reasonable costs associated with the appropriate site preparations and modifications. Table 1 in this document has been created to summarize these advantages and disadvantages, or pros and cons.

B&V requests that LG&E/KU review the pros and cons of these three options and provide comments. If needed, another teleconference can be setup to allow further discussions. Further discussion and possibly a chosen option will allow LG&E/KU and B&V to have a more defined direction to proceed forward with to allow flue gas flow biasing.

Table 1 – Ghent Flow Biasing Options Summary

Options	**Option 1** Two PJFFs 4 ID Fans	**Option 2** Common PJFF 2 ID & 2 Booster Fans	**Option 3** Common PJFF 3 ID Fans & Dampers
Pros	• Extra dampers in flue gas stream not required • All draft fans are same size and performance • Continued flow biasing through ID fan control • Can abandon hot-side ESP in future (potential SCR and AH modifications)	• Separate dampers in flue gas stream not required • Continued flow biasing through ID fan control • Existing axial ID fans could be used as boosters decreasing cost and footprint • Arranged similarly to Unit 2 • Single PJFF – decreased equipment & layout complexity	• Least expensive • All draft fans are same size and performance • Can abandon hot-side ESP in future (potential SCR and AH modifications) • Single PJFF – decreased equipment & layout complexity
Cons	• Most expensive • More complex ductwork and equipment arrangement • Occupies most courtyard space between Units 2 and 3	• ID and Booster fans different sizes and performance • Cannot abandon hot-side ESP in future • Control additions required for booster fans • More complex ductwork arrangement	• Inability to flow bias with ID fans • Damper reliability concerns • Additional damper maintenance • Damper life expectancy concerns • Added pressure drop in flue gas stream • Additional controls required for dampers • Odd fan number, more challenging electrical & control scheme