LG&E/KU – E.W. Brown Station

Phase II Air Quality Control Study

Air Quality Control Validation Report

February 28, 2011
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-DESP	Cold-side Dry Electrostatic Precipitator
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
FA	Fly Ash
H_2SO_4	Sulfuric Acid
HCl	Hydrogen Chloride
Hg	Mercury
ID	Induced Draft
inw	Inch of Water
LNB	Low NO_x Burners
LOI	Loss On Ignition
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
UAT	Unit Auxiliary Transformer
USS	Unit Secondary Substation
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 E.W. Brown Generating Station (Brown). The following AQC technology options have been assessed in this report:

- PJFF on Units 1-3.
- Sorbent injection (trona/lime/SBS) injection on Units 1-2.
- SCR on Unit 1 and 2.
- Powdered activated carbon (PAC) injection on Units 1-3.
- Feasibility of neural network (NN) on Units 1-3.

This validation study confirms the feasibility of installing the aforementioned AQC equipment at Brown, 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 Brown - Units 1, 2, and 3

The E.W. Brown Station is located on Herrington Lake in Mercer County, Kentucky, between Shakertown and Burgin, off of Hwy 33. The station was constructed on the west side of Herrington Lake, the impoundment behind Dix Dam. The plant began commercial operation in 1957. The station includes three pulverized coal fired electric generating units with a total nameplate capacity of 747 MW gross. The electrical power from the E.W. Brown Station units is used to provide both load and voltage support for the 138 kV transmission systems.

The plant site also includes seven simple cycle combustion turbines located on the northwest side of the site.

All three steam generators (boilers) fire high sulfur bituminous coal. Unit 1 has a gross capacity of 110 MW and is equipped with old generation Low NO_x Burners (LNBs) and Cold-side Dry Electrostatic Precipitator (CS-DESP) for nitrogen oxide (NO_x) and particulate matter (PM) control, respectively. Unit 2 has a gross capacity of 180 MW and is equipped with LNBs, Overfire Air (OFA), and CS-DESP for NO_x and PM control. Unit 3 has a gross capacity of 457 MW and is equipped with LNBs, OFA, and CS-DESP for NO_x and PM control. LG&E/KU is in the process of installing a Selective Catalytic Reduction (SCR) module (in-service date, 2012) on Unit 3 to control NO_x. LG&E/KU recently installed a common Wet Flue Gas Desulfurization (WFGD) for sulfur dioxide (SO_2) control for Units 1, 2, and 3. Unit 2 is also equipped with a WFGD bypass system which directs flue gas to the Unit 3 chimney. Lower sulfur coal will be fired in Unit 2 during bypass operation.

Gypsum, a scrubber by-product, produced at Brown is stored in the on-site landfill. Fly ash and bottom ash is sluiced to on-site storage pond. All three units are cooled using mechanical draft cooling towers. Arrangements developed for the Unit 3 SCR will be taken into account during the Phase II Air Quality Control Study.

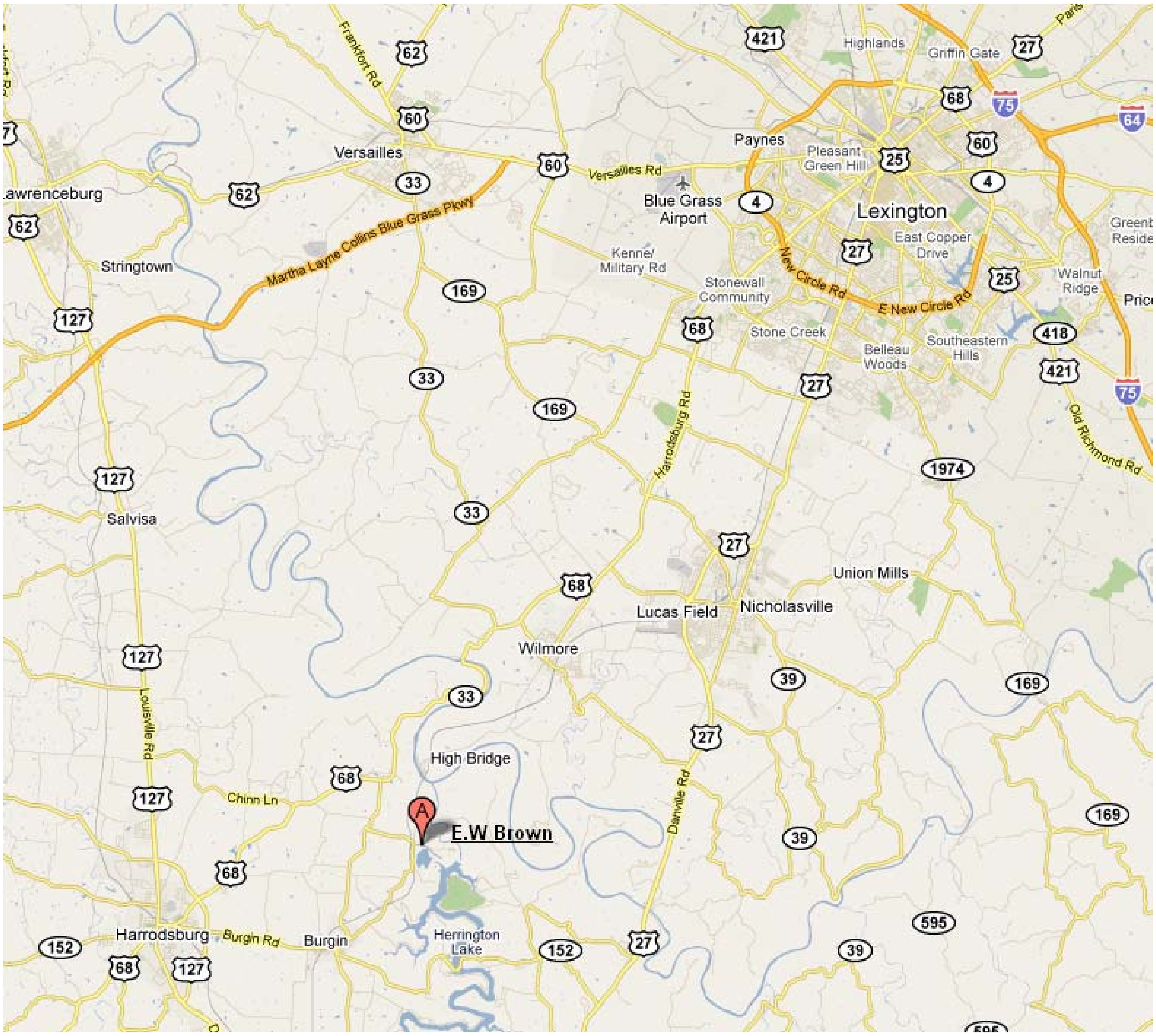
Figures 2-1 and 2-2 illustrate the plant location and Table 2-1 summarizes the plant's existing facilities.

NORTH

SOUTH

Figure 2-1. Brown Power Plant Site

NORTH



SOUTH

Figure 2-2. Brown and Surrounding Area Map

Table 2-1. Existing Brown Plant Facilities	
Existing On Site Generation Units:	• Unit 1 - 110 gross MW (in-service date 1957) • Unit 2 - 180 gross MW (in-service date 1963) • Unit 3 - 457 gross MW (in-service date 1969)
Existing AQC Equipment:	• Unit 1 - LNBs, CS-DESP, Common WFGD with Units 2 and 3 • Unit 2 - LNBs, OFA System, CS-DESP, Common WFGD with Units 1 and 3 • Unit 3 - LNBs, OFA, CS-DESP, Common WFGD with Units 1 and 2, and Future SCR (in-service date, 2012)

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
NO_x	0.156 lb/MBtu[c]	0.156 lb/MBtu[c]	N/A[b]
SO_2	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
Mercury (Hg)	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
PM[c],[d]	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
CO	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

Data from LG&E/KU E.W Brown Station kickoff meeting November 10, 2010 (Gary Revlett handouts and meeting notes) unless noted otherwise.
[a] Units provided in ppmvd at 3% O_2 Control of sulfuric acid (H_2SO_4) emission from the installation of new Unit 1 and 2 SCRs and the Unit 3 SCR currently in design.
[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., 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 Brown Generating Station.

4.1 Site Visit Observations and AQC

The following observations are from the November 10-11 2010 site visit and summarize the site and equipment constraints. The following excerpts are from the site visit meeting minutes and focus specifically on the installation of specified AQC equipment.

- For the purpose of the Phase II cost estimate, B&V should assume that SCRs are required on Units 1 and 2.
- B&V to consider re-using the recently installed induced draft (ID) fan on Unit 1.
- The sulfur trioxide (SO_3) mitigation silos are currently planned to be located in the same general area as the proposed future Unit 3 PJFF. B&V to take the drawings from the SO_3 mitigation project into consideration.
- Air heater temperature control and leakage are current issues at Unit 1.
- LG&E/KU wants to keep the ability to bypass the WFGD on Unit 2, and add the same capability for a Unit 1 bypass with the future AQC retrofit if reasonably possible.
- Units 1 and 2:
  - The existing Unit 1 economizer and air heater arrangement are not suitable for adding a new SCR due to tie-in duct connection challenges. Also, since the existing ESPs will not be used, adding a new single air heater at the bottom of a new SCR would ease the construction and reduce the extended flue gas ductwork and supporting structural steel. A new single FD fan would be added and the combustion air ductwork would be tied back to existing wind boxes plenum. The economizer outlet duct would be extended north out of the boiler building by cutting the east-west wind box ductwork section and then connected to SCR located at east of Unit 1. The new air heater gas side outlet will then be connected to a new Unit 1 PJFF and a new single ID fan. The new ID fan discharge will then be connected to the Unit 1 existing round ductwork connecting further downstream to existing new WFGD. The Unit 1 and Unit 2 PJFF will be co-located east-west

with ID fans on the west side. Similar to Unit 1, the SCR and new air heater for Unit 2 will be co-located with Unit 1 in the same general area. A new FD fan for Unit 2 will be added and the combustion air duct will be connected back to Unit 2 wind box plenum. A set of four ducts, including flue gas and combustion air duct for Unit 1 and Unit 2, will be stacked and paired in the alley between the boiler building and the Unit 1 ID fan structure.

- SCRs for both Unit 1 and Unit 2 are located to the east of the existing Unit 1 ID fan area, with individual unit PJFFs shown downstream of the SCRs. Individual ID fans (either new or possibly reused existing fans) are located downstream of the PJFFs to forward the clean exhaust gas to the WFGD and to control unit operating pressures.
- Due to the extreme congestion at the air heater in Unit 1, a new air heater would be located below the new SCR and the existing air heater abandoned or removed. A new FD fan would provide draft air through the new air heater and back to the Unit 1 windbox. Ductwork would connect the economizer outlet to the SCR and the cold-side air heater outlet to the windbox. This would minimize the required work inside Unit 1 and in the congested area to the north.
- The ductwork in and out of the existing air heater at Unit 2 is less congested, and the Unit 2 air heater and FD fans can remain in place. However, should it be advantageous, a new Unit 2 air heater and FD fan could be installed under the SCR as with Unit 1. The ductwork serving the Unit 2 SCR (and new air heater and fan, if so determined) would be stacked with the new Unit 1 ductwork in the area immediately north of the existing building.
- The “remote” location of the SCRs is suggested due to the lack of available room in the area north of the building and the extremely poor construction access to the area that does exist. With only ductwork being located immediately north of the building, it is expected that the existing chimney would not require demolition and modification of the existing duct support tower upstream of the Unit 1 ID fan could be avoided. The ash capture duct and the existing (but not in service) demin equipment room would have to be demolished to make room for the ductwork.

  - The new Unit 1 and 2 PJFFs are proposed to be located in the parking lot, and not in the common ductwork near the WFGD, to avoid the ash dropout and high ash loading in the long run of existing horizontal duct upstream of the common WFGD.
  - The arrangement is intended to allow the reuse of major sections of the existing new Unit 1 ductwork. The ductwork will be evaluated to determine whether the new current Unit 1 duct work can handle exhaust flow from both Units 1 and 2 from the PJFFs, minimizing new construction.
  - Neither arrangement currently impacts the office building, but both will displace significant areas of the existing parking lot.
  - Unit 1 and Unit 2 combined PJFF can be located near the new WFGD absorber if Unit 1 and Unit 2 can survive without new SCRs. However, due to space limitation on site and the complexities of installation of this equipment as noted above, it may be advantageous for the arrangement for Units 1 and 2 (with and without SCRs) to be the same in spacing and orientation in order to allow for the future installation of SCRs should it be required.
- Unit 3:
  - The new Unit 3 PJFF will be located west of existing ID fans and south of the new WFGD absorber. The existing series of ESPs on side A and side B will be bypassed and retired in place. At the inlet of the existing primary ESPs, a new ductwork will be added blocking the flow to the existing ESP inlet nozzle. The new ductwork will be designed in such a way that the new SCR structure will not pose any obstructions. However, it may be advantageous if the new SCR structure can be used to support the new PJFF ductwork connection. The new SCR structure, as well as foundation loading modification request, would need to be communicated to Riley Power if this is a possibility. The new PJFF ductwork will then be connected to the new PJFF on east side and the PJFF outlet duct will then be routed back to the existing ID fans on the same side as the inlet. Bypassing the existing ESPs will potentially allow the reuse of existing ID fans if found capable. It is estimated that the bypassing the existing ESPs and connected ductwork could save about 4-5” of w.g.

- The PJFF would be located in the area west of the Unit 3 ID fans and south of the FGD scrubber. A common duct would be routed from the air heater outlet duct just outside the Unit 3 Boiler Building, turn immediately west before the ESPs, and routed over the Unit 3 exhaust duct to the PJFF inlet. The PJFF outlet duct would be routed to the existing ID fan inlets to allow re-use of the fans in their current location, if practical. Duct downstream of the ID fans would not be modified. The PJFF and its ductwork would be arranged to allow installation of the planned SO_3 mitigation equipment beneath.
- The PJFF can be constructed high enough to allow vehicle traffic underneath if acceptable traffic patterns around the superstructure cannot be established.
- If the ductwork can be successfully routed to avoid the ESPs, the ESPs can be abandoned in place or demolished after the fact as desired by LG&E/KU. However, whether or not the exhaust duct can be routed around the new SCR and its supporting superstructure is the greater concern.

5.0 Selected Air Quality Control Technology

The following sections present a general description of the AQC technologies considered for Brown, 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**
NO_x Control	New SCR	New SCR	Future[(a)] SCR
SO_2 Control	Existing WFGD	Existing WFGD	Existing WFGD
PM Control	New PJFF	New PJFF	New PJFF
HCl Control	Existing WFGD and New Sorbent Injection	Existing WFGD and New Sorbent Injection	Existing WFGD and Future[(a)] Sorbent Injection
CO Control	New NN	New NN	New NN
SO_3 Control	New Sorbent Injection[(b)]	New Sorbent Injection[(b)]	Future[(a)] Sorbent Injection
Hg Control	New PAC Injection	New PAC Injection	New PAC Injection
Dioxin/Furan Control	New PAC Injection	New PAC Injection	New PAC Injection
Fly Ash Sales	None	None	None

[(a)]Planned in-service date of 2012.
[(b)]Sorbent injection system may also be required to meet the primary design emission targets (Table 3-1) if SCR is not installed.

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.

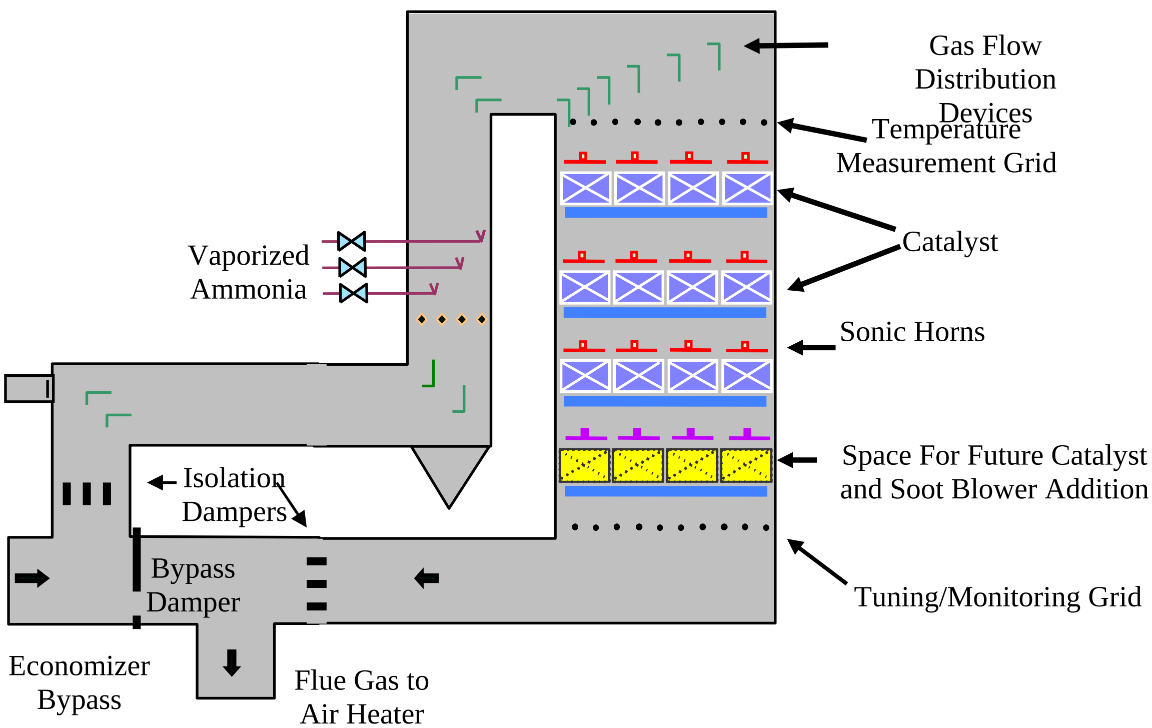


Figure 5-1. Schematic Diagram of a Typical SCR Reactor

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.

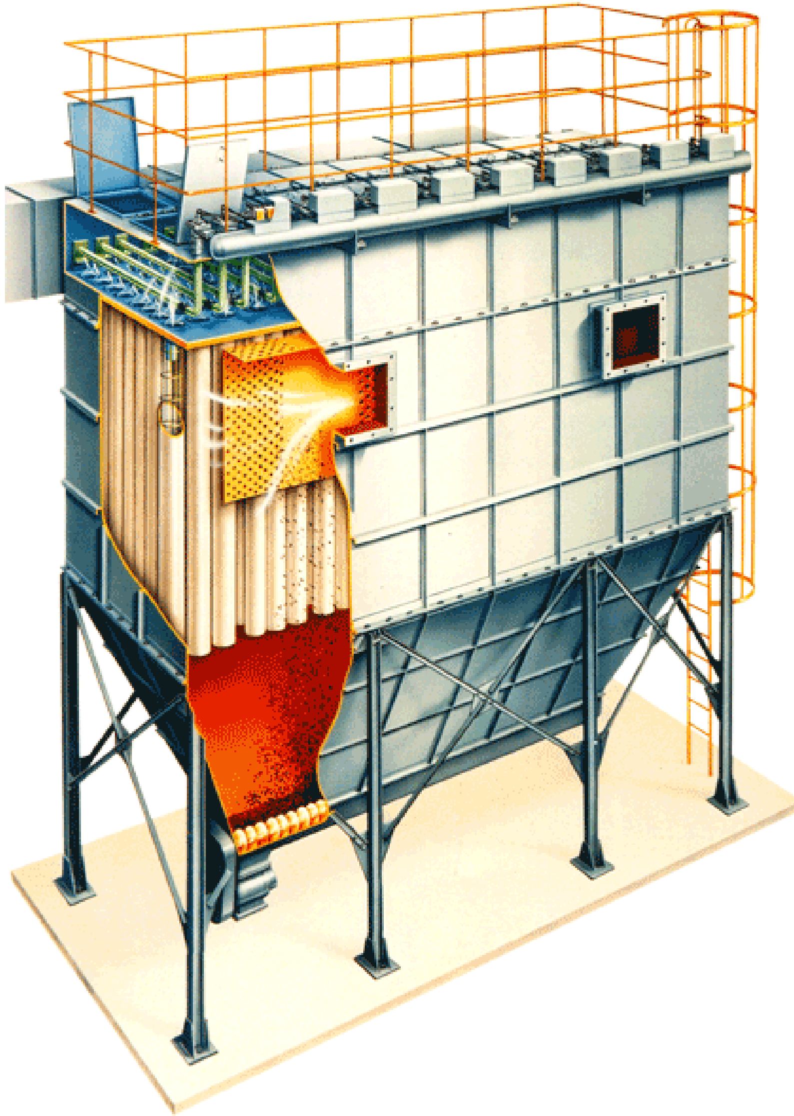


Figure 5-2. Pulse Jet Fabric Filter Compartment

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.

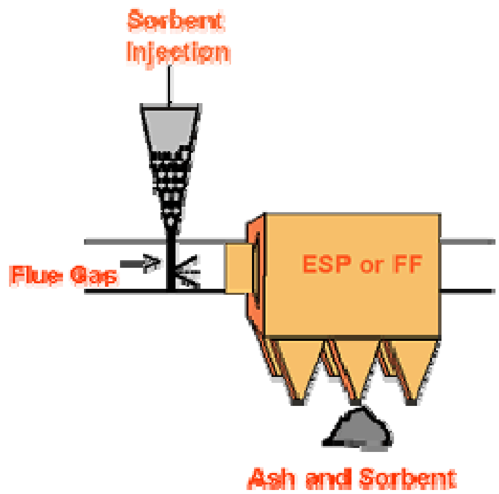


Figure 5-3. Activated Carbon Injection System

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 cold-side electrostatic precipitator (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 Brown, 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 validation process, as well as information provided by LG&E/KU.

5.2.1 Brown Unit 1

Table 5-2 identifies the selected AQC technologies for Brown 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 SCR	NO_x
New Sorbent Injection	SO_3, HCl
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF	PM

New SCR

- SCR can consistently achieve NO_x emissions of lower than 0.156 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 system would increase the pressure drop of the draft system requiring the draft system to be investigated for available capacity. Additional auxiliary power would be required as a result of the increase in pressure drop.
- Due to the proposed bypass and abandonment of the existing air heaters, a new air heater would be required. The gas side would be placed downstream of the SCR system.
- In the absence of applicable sulfuric acid emission test data, B&V performed emission combustion calculations with an assumed 1 percent conversion of SO_2 to SO_3 in the boiler. Sulfuric acid emissions from Unit 1 without the installation of SCR will exceed 25 ppmvd @ 3% O_2. This calculation does not assume any removal of SO_3 in air heater or new pulse jet fabric filter. Therefore, in order to achieve sulfuric acid emissions below the primary design emission targets of 10 ppmvd @ 3% O_2, a sorbent injection system will be required.
- Due to the proposed abandonment of the existing FD fans, the combustion air system needs to be investigated and a new FD fan and air preheat system would be required. Additional auxiliary power and steam cycle heat balance requirements would need to be considered for the new FD fan and air preheat 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 to accommodate the Unit 1 ammonia supply.

- The use of ammonia will slightly increase the truck traffic at the plant.
- An SO_3 mitigation system like alkali injection and PJFF will be required.
- A new SCR can be located downstream of the existing economizer and upstream of the new air heater.
- A new SCR will be arranged as 1 x 100% reactor.
- The SCR will be located on the east side of the existing Unit 1 AQC equipment area.

New SO_3 Control System (Sorbent Injection)

A sorbent 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 sorbent injection system.
- Trona/lime/SBS would be injected downstream of the SCR but upstream of the air heater.
- Sorbent 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. A sorbent receiving and storage system common to both Units 1 and 2 will limit the areas subject to the increased traffic as well as minimize the infrastructure required.

New PAC Injection

- A PJFF is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the 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. A PAC receiving and storage system

common to both Units 1 and 2 will limit the areas subject to the increased traffic as well as minimize the infrastructure required.

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 draft system. Preliminary investigation has determined that the existing 100 percent capacity ID fan possesses sufficient margin to accommodate the increased pressure drop. Accordingly, the existing ID fan would be incorporated in the draft system downstream of the PJFF and no new ID fan would be required. Any additional auxiliary power required due to the increased load on the existing fan would need to be considered.
- The existing ESP will be bypassed and abandoned in place.
- 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 new air heater and upstream of the existing ID fan 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 east side of the existing Unit 1 AQC equipment area and south of the existing coal conveyor.
- A major portion of the existing parking lot needs to be relocated.

5.2.2 Brown Unit 2

Table 5-3 identifies the selected AQC technologies for Brown 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 Sorbent Injection	SO_3, HCl
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF	PM

New SCR

- SCR can consistently achieve NO_x emissions of lower than 0.156 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 draft system, so the draft system needs to be investigated and a new ID fan would likely be required. Additional auxiliary power requirements would need to be considered for a new ID fan.
- Due to the possible bypass and abandonment of the existing air heaters, a new air heater may be required. The gas side would be placed downstream of the SCR system.
- In the absence of applicable sulfuric acid emission test data, B&V performed emission combustion calculations with an assumed 1 percent conversion of SO_2 to SO_3 in the boiler. Sulfuric acid emissions from Unit 1 without the installation of SCR will exceed 25 ppmvd @ 3% O_2. This calculation does not assume any removal of SO_3 in air heater or new pulse jet fabric filter. Therefore, in order to achieve sulfuric acid emissions below the primary design emission targets of 10 ppmvd @ 3% O_2, a sorbent injection system will be required.
- Due to the possible abandonment of the existing FD fans, the combustion air system needs to be investigated and a new FD fan and air preheat system may be required. Additional auxiliary power and steam cycle heat balance requirements would need to be considered for new FD fan(s).

- 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 to accommodate the Unit 2 ammonia supply.
- The use of ammonia will slightly increase the truck traffic at the plant.
- An SO_3 mitigation system like alkali injection and PJFF will be required.
- A new SCR can be located downstream of the existing economizer and upstream of the new air heater.
- A new SCR will be arranged as 1 x 100% reactor.
- The SCR will be located on the east side of the existing Unit 1 AQC equipment area.

New SO_3 Control System (Sorbent Injection)

A sorbent 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 sorbent injection system.
- Trona/lime/SBS would be injected downstream of the SCR but upstream of the air heater.
- Sorbent 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. A sorbent receiving and storage system common to both Units 1 and 2 will limit the areas subject to the increased traffic as well as minimize the infrastructure required.

New PAC Injection

- A PJFF is recommended in conjunction with PAC injection.
- PAC to be injected downstream of the 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. A PAC receiving and storage system common to both Units 1 and 2 will limit the areas subject to the increased traffic as well as minimize the infrastructure required.

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 draft system. As such, the draft system needs to be investigated and a new ID fan would likely be required. Additional auxiliary power requirements would need to be considered for a new ID fan.
- The existing ESP will be bypassed and abandoned in place.
- 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 new 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 2 will be located on the east side of the existing Unit 1 AQC equipment area adjacent to the Unit 1 PJFF.
- A major portion of the existing parking lot needs to be relocated.

5.2.3 Brown Unit 3

Table 5-4 identifies the selected AQC technologies for Brown Unit 3. 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 – AQC Technology Selection

AQC Equipment	Pollutant
New Sorbent Injection	SO_3, HCl
New PAC Injection	Hg, Dioxin/Furan
New stand-alone full size PJFF	PM

Future SO_3 Control System (Sorbent Injection)

A sorbent injection system that injects trona, lime or SBS into the flue gas to remove SO_3 is currently being planned in the area of the Unit 3 ID fans. It is expected this system will not require modification as part of Phase II work.

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 draft system. However, preliminary investigation has determined that the two existing 50 percent capacity ID fans possess sufficient margin to accommodate the increased pressure drop of the PJFF as well as the SCR system. Accordingly, the existing ID fans would be incorporated into the draft system downstream of the new PJFF. Any additional auxiliary power required due to the increased load on the existing fans would need to be considered.
- The existing ESPs will be bypassed and abandoned in place, except as required to be removed for installation of new ductwork to the PJFF.
- 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 existing 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 west side of the existing Unit 3 ID fans and south side of the combined common WFGD absorber module.
- 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 Brown, 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 and 2, the modifications and additions to the draft system being considered include new SCR systems for removing NO_x emissions and new PJFF systems that will replace the existing electrostatic precipitators (ESP) in the removal of particulate. For Unit 3 the draft system modifications and additions being considered include a new PJFF system. For more detail on the AQC equipment modifications, additions, etc. for each Brown unit refer to Section 5.0.

For the sizing of any new fans for the Brown site, the standard Black & Veatch fan sizing philosophy for developing Test Block conditions as additional margin on MCR conditions is recommended. 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^{o}F temperature increase at the fan inlet.
- Adjustments of draft system pressure drops to correspond with increased Test Block flow rates.
- 1.0 inch of water (inw) control allowance.

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

Additionally, following the preliminary analyses of the Brown 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, the flue gas flow through the draft system would change as follows. At the outlet of the existing boiler it is expected that the flue gas would bypass the existing air heaters and travel to the new SCR system before entering a new 100 percent capacity air heater. It is expected that the existing air heaters would not be reused and abandoned in place. This is due to the congestion in their current location that would result in significant construction difficulties if they were to be reused. Once the flue gas is through the new air heater it would travel directly to the new PJFF. The existing cold-side ESP would not be used and abandoned in place. The existing ID fan would then draw the flue gas through the PJFF and new ductwork and then send it to the common WFGD system through existing ductwork. Along with the previously mentioned new air heater, a new FD fan and air preheat system must be considered as well to accommodate the relocation of the air heater. Lastly, it expected that an economizer bypass system of some type will be required to maintain flue gas temperatures entering the SCR system above a minimum reaction temperature. An illustration of the Unit 1 future draft system based on these changes (in red) is shown in Figure 6-1.

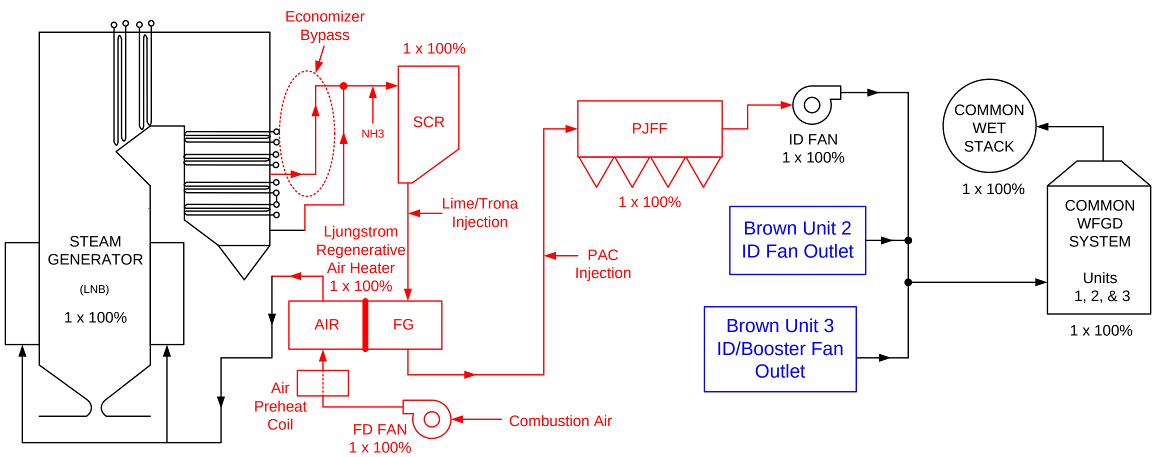


Figure 6-1. Unit 1 Future Draft System

Also, Unit 1 currently does not have the ability to bypass the common WFGD and the desire for this has recently been discussed. B&V has determined that adding this capability may be feasible with the assumption that the common WFGD would always be offline when bypassing. Existing Unit 1 exhaust duct could be interconnected with appropriate dampers to existing Unit 2 exhaust duct to allow Unit 1 exhaust to be directed to the old Unit 3 chimney, bypassing the WFGD. Since exhaust flow from Unit 1 is less than that from Unit 2, which currently can be bypassed, minimal problems are expected from the ductwork flow if Unit 1 is bypassed instead of Unit 2. However, if exhaust flows from both Unit 1 and Unit 2 are intended to be directed to the Unit 3 chimney simultaneously, the impact of the combined flow characteristics through existing duct must be investigated. In either case, the air permit regulatory requirements of the bypass scenario would need to be investigated. B&V is open to future discussions regarding adding this capability.

Typically SCR systems are installed between the existing boiler outlet and existing air heater gas inlet. However, in this case with Unit 1 there is the potential for construction difficulties next to the Unit 1 boiler building. Therefore, one of the arrangement options that Black & Veatch is considering includes the installation of a new 100 percent capacity air heater and a new 100 percent capacity FD fan, as shown in Figure 6-1. This will minimize the construction activities next to the Unit 1 boiler building. In addition, air heaters typically require major modifications with the installation of SCR systems and the installation of a new air heater will simplify that process. A single train of equipment is being considered to minimize capital costs to this relatively small unit and due to the new single ID fan that will be reused. The existing 50 percent capacity air heaters and FD fans would be bypassed and abandoned.

With the expected addition of an SCR system and a PJFF system to the existing draft system, the pressure demand on the draft fan system will be significantly higher than what the existing ID fan is currently experiencing. However, due to the selected capacity of the newly installed existing ID fan, it is expected that enough capacity is available to compensate for the AQC additions and still allow for adequate margins. The existing ID fan is expected to be reused as shown in Figure 6-1.

Future Draft System Characteristics

The major performance characteristics of the Unit 1 boiler and future draft system at MCR are as follows in Tables 6-1 and 6-2. Note that the items in bold in Table 6-2 are new.

Table 6-1. Unit 1 Boiler Characteristics at MCR	
Boiler total heat input	1,000 MBtu/hr (based on net plant output of 102,000 kW and heat rate of 9,802 Btu/kWh)
Boiler excess air	34.3% (5.0% oxygen, wet basis)
Loss On Ignition (LOI)	2.0% (estimated)
Ambient conditions	
Dry bulb temperature	74° F
Relative humidity	60%
Barometric pressure	28.97 inHg

Table 6-2. Unit 1 Future Draft System Characteristics at MCR	
SCR system leakage	**2.0%**
Air heater leakage	**6.0%**
PJFF system leakage	**3.0%**
Flue gas temperatures	
Boiler outlet	650° F
SCR outlet	**650° F**
Air heater outlet	350° F
ESP outlet	**(Abandoned)**
PJFF outlet	**350° F**
ID fan outlet	~375° F (calculated)
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	7.5 inw
SCR	**10.0 inw**
Air heater	**6.0 inw**
ESP	**(Abandoned)**
PJFF	**6.0 inw**
Duct to WFGD	2.0 inw
WFGD	10.0 inw
Stack	1.0 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 existing ID fan at MCR are shown in Figure 6-2 as the MCR Point. Also in Figure 6-2 is the Maximum Fan Runout illustrating the maximum capability of the existing ID fan in the future draft system. Note the estimated flow and pressure margins of 13 and 27 percent, respectively. These margins are below the typical ranges of the Black & Veatch recommended margins. However, they are adequate enough to warrant the reuse of the newly installed Unit 1 ID fan to limit the capital costs of the AQC upgrades being considered. Black & Veatch recommends the continued use of the existing Unit 1 ID fan in support of the proposed AQC upgrades.

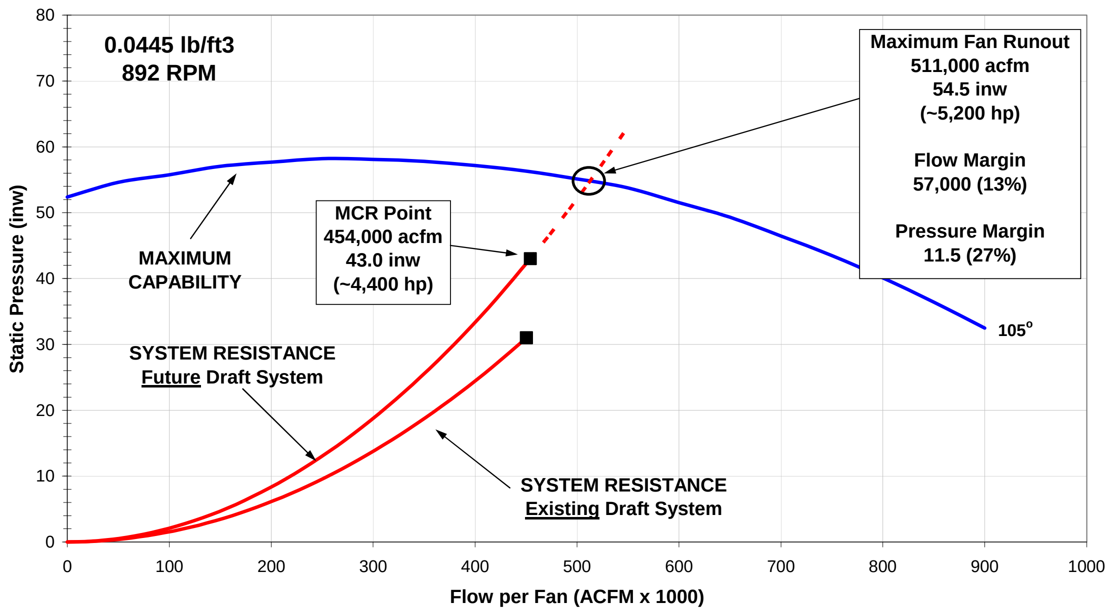


Figure 6-2. Unit 1 Existing ID Fan Performance

For the sizing of the new air heater, the performance of the existing equipment will be matched. For this validation stage, the single air heater will be of the Ljungstrom bisector regenerative type in a vertical shaft orientation.

Similarly, for the sizing of the new FD fans, the performance of the existing equipment will be approximately matched. For this validation stage, the single FD fan will be of the centrifugal type with the estimated MCR performance requirements listed in Table 6-3. Also in Table 6-3 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 19 and 50 percent, respectively. Various means of flow control can be discussed and analyzed in the future, however, for now it will be assumed that inlet vanes will be used in a single speed application.

In contrast, the sizing of the new air preheat system will be different than the existing equipment. The existing air preheat system on Unit 1 uses a hot air recirculation fan. With this system, a fan intakes hot air at the air heater air outlet and forces it back into the air heater air inlet to control air heater gas outlet temperatures. For the purposes of conducting this study B&V is proposing the installation of a more traditional preheat system through the use of a hot water air preheat system with a coil at the air heater air inlet that would operate similar to the system on Unit 2. However, B&V is open to further discussions in the future on the appropriate type of preheat system to install on Unit 1.

Table 6-3. Unit 1 New FD Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	85	110
Inlet Density (lb/ft^3)	0.0704	0.0673
Flow per Fan (acfm) *	255,000	303,000
Inlet Pressure (inwg)	-1.0	-1.3
Outlet Pressure (inwg)	11.0	16.7
Static Pressure Rise (inw)	12.0	18.0
Shaft Power Required (HP) **	700	1,000
Efficiency (%) **	70	85
Number of Fans	1	1
Flow Margin (%)	--	19
Pressure Margin (%)	--	50

* Per fan basis with both fans in operation.
** Estimated – assumes single speed damper flow control.

6.1.2 Unit 2

Based on the additions to the Unit 2 draft system previously discussed, the flue gas flow through the draft system would change as follows. At the outlet of the existing boiler it is expected that the flue gas would bypass the existing air heaters and travel to the new SCR system before entering a new 100 percent capacity air heater. It is expected that the existing air heaters would not be reused and abandoned in place. This is due to the congestion in their current location that would lead to significant construction difficulties. Once the flue gas is through the new air heater it would travel directly to the new PJFF. The existing cold-side ESPs would not be used and abandoned in place. A new 100 percent capacity ID fan would then draw the flue gas through the PJFF and send it to the common WFGD system. New ductwork would be constructed to interface with the ductwork currently in place that allows Unit 2 to either send flue gas to the common WFGD system or bypass it. Along with the previously mentioned new air heater, a new FD fan and air preheat coil must be considered as well to accommodate the relocation of the air heater. Lastly, an economizer bypass system of some type may be required to maintain flue gas temperatures entering the SCR system above a minimum reaction temperature. An illustration of the Unit 2 future draft system based on these changes (in red) is shown in Figure 6-3.

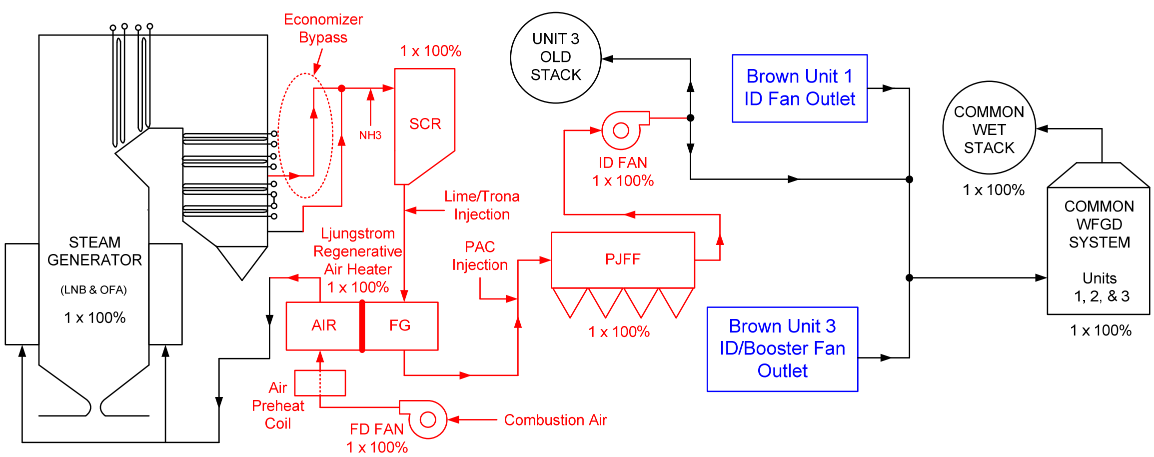


Figure 6-3. Unit 2 Future Draft System

Typically SCR systems are installed between the existing boiler outlet and existing air heater gas inlet. However, in this case with Unit 2 there is the potential for construction difficulties next to the Unit 2 boiler building as with Unit 1. Therefore, one of the arrangement options that Black & Veatch is considering includes the installation of a new 100 percent capacity air heater and a new 100 percent capacity FD fan, as shown in Figure 6-3, due to similar reasons discussed for Unit 1. The existing 50 percent capacity air heaters and FD fans would be bypassed and abandoned. Other arrangement options involve the continued use of the existing air heaters and FD fans, however, these options are not shown or discussed in this section.

With the expected addition of an SCR system and a PJFF system to the existing draft system, the pressure demand on the draft fan system will be significantly higher than what the existing ID fans currently experience. It is expected that the Unit 2 ID fans will not have the available capacity to overcome these AQC equipment additions and that a new ID fan system will be required. Therefore, a new 100 percent capacity ID fan has been shown in Figure 6-3.

Future Draft System Characteristics

The major performance characteristics of the Unit 2 boiler and future draft system at MCR are as follows in Tables 6-4 and 6-5. Note that the items in bold in Table 6-5 are new.

Table 6-4. Unit 2 Boiler Characteristics at MCR

Boiler total heat input	1,665 MBtu/hr (based on net plant output of 169,000 kW and heat rate of 9,855 Btu/kWh)
Boiler excess air	18.2% (3.0% oxygen, wet basis)
LOI	2.0% (estimated)
Ambient conditions	
Dry bulb temperature	74° F
Relative humidity	60%
Barometric pressure	28.97 inHg

Table 6-5. Unit 2 Future Draft System Characteristics at MCR

SCR system leakage	**2.0%**
Air heater leakage	**6.0%**
PJFF system leakage	**3.0%**
Flue gas temperatures	
Boiler outlet	730° F
SCR outlet	**730° F**
Air heater outlet	330° F
ESP outlet	**(Abandoned)**
PJFF outlet	**330° F**
ID fan outlet	**~350° F (calculated)**
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	3.2 inw
SCR	**10.0 inw**
Air heater	**6.0 inw**
ESP	**(Abandoned)**
PJFF	**6.0 inw**
Duct to WFGD	2.0 inw
WFGD	10.0 inw
Stack	1.0 inw
Stack	1.0 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 existing ID fans is shown in Figure 6-4 as the MCR Point. As expected, the performance requirements of the future Unit 2 draft system are beyond the capabilities of the existing ID fans. The existing ID fans will either need to be upgraded or replaced. For the purposes of conducting this initial validation process B&V has decided to replace the existing ID fans with a new 100 percent capacity ID fan since the existing ESPs will not be used, to minimize construction activities near the Unit 2 boiler building, and to maintain similarity to Unit 1. Operational preferences of Brown station personnel and/or future analyses of the Unit 2 draft system may reveal a different arrangement at a later time.

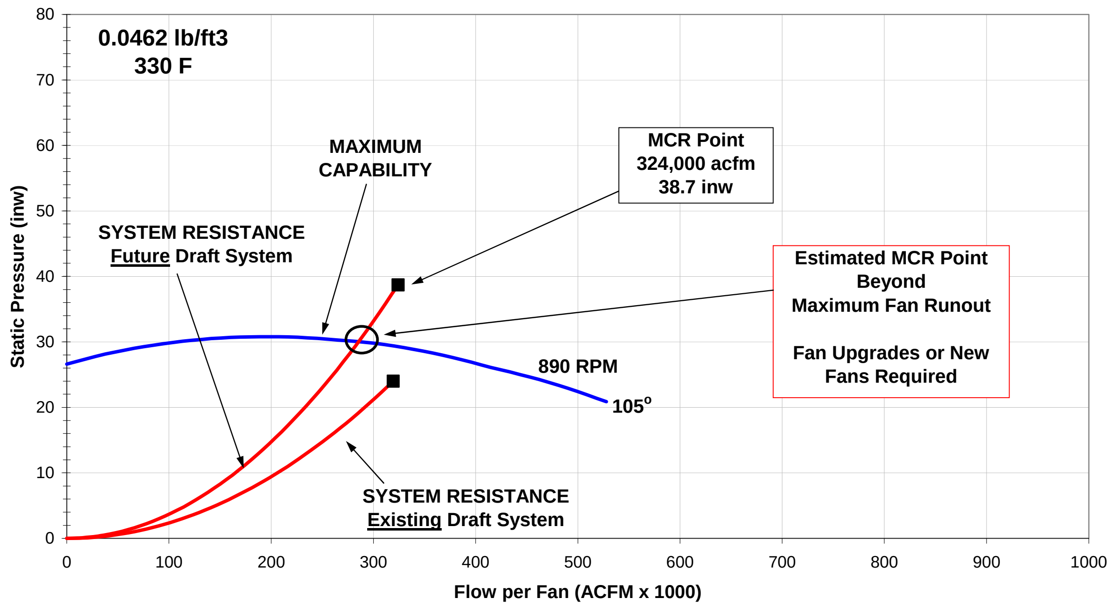


Figure 6-4. Unit 2 Existing ID Fan Performance

Based on the future draft system characteristics in Table 6-5, the estimated performance requirements of the new ID fan at MCR is 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 23 and 40 percent, respectively.

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

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	330	355
Inlet Density (lb/ft^3)	0.0463	0.0437
Flow per Fan (acfm) *	647,000	795,000
Inlet Pressure (inwg)	-25.7	-35.6
Outlet Pressure (inwg)	13.0	18.5
Static Pressure Rise (inw)	38.7	54.1
Shaft Power Required (HP) **	5,600	8,000
Efficiency (%) **	70	85
Number of Fans	2	2
Flow Margin (%)	--	23
Pressure Margin (%)	--	40

* Per fan basis with both fans in operation.
** Estimated – assumes single speed damper flow control.

For the sizing of the new air heater and hot water air preheat coil, the performance of the existing equipment will be matched. For this validation stage, the single air heater will be of the Ljungtrom bisector regenerative type in a vertical shaft orientation. The air preheat coil will require that condensate lines to and from the existing support equipment be routed to the new location near the new air heater. It is recommended that the existing hot water air preheat support equipment be evaluated to confirm that the additional pipe lengths can be accommodated.

In contrast, the sizing of the new FD fans will be different that the existing equipment due to the lower capacity required now that Unit 2 is a balanced draft unit. The existing two FD fans are carryover equipment from when Unit 2 operated as a forced draft unit with approximately 2,800 horsepower combined. The current balanced draft capacity will be matched with a single centrifugal FD fan with the estimated MCR performance requirements listed in Table 6-7. Also in Table 6-7 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 15 and 38 percent, respectively. Various means of flow control can be discussed and analyzed in the future, however, for now it will be assumed that inlet vanes will be used in a single speed application.

Table 6-7. Unit 2 New FD Fan MCR and Recommended Test Block Conditions

	MCR	Test Block
Fan Speed (rpm), maximum	900	900
Inlet Temperature (°F)	85	110
Inlet Density (lb/ft^3)	0.0704	0.0673
Flow per Fan (acfm) *	351,000	404,000
Inlet Pressure (inwg)	-1.0	-1.2
Outlet Pressure (inwg)	13.0	18.2
Static Pressure Rise (inw)	14.0	19.4
Shaft Power Required (HP) **	1,100	1,500
Efficiency (%) **	70	85
Number of Fans	1	1
Flow Margin (%)	--	15
Pressure Margin (%)	--	38

* Per fan basis with both fans in operation.
** Estimated – assumes single speed damper flow control.

6.1.3 Unit 3

Based on the additions to the Unit 3 draft system previously discussed, the flue gas flow through the draft system would change as follows. At the outlet of the existing air heaters the flue gas would bypass both sets of the existing cold-side ESPs and travel through new ductwork directly to the new PJFF. The existing cold-side ESPs would not be used and abandoned in place. The newly installed existing 50 percent capacity ID fans would then draw the flue gas through the PJFF and new ductwork and then send it to the common WFGD system. An illustration of the Unit 2 future draft system based on these changes (in red) is shown in Figure 6-5.

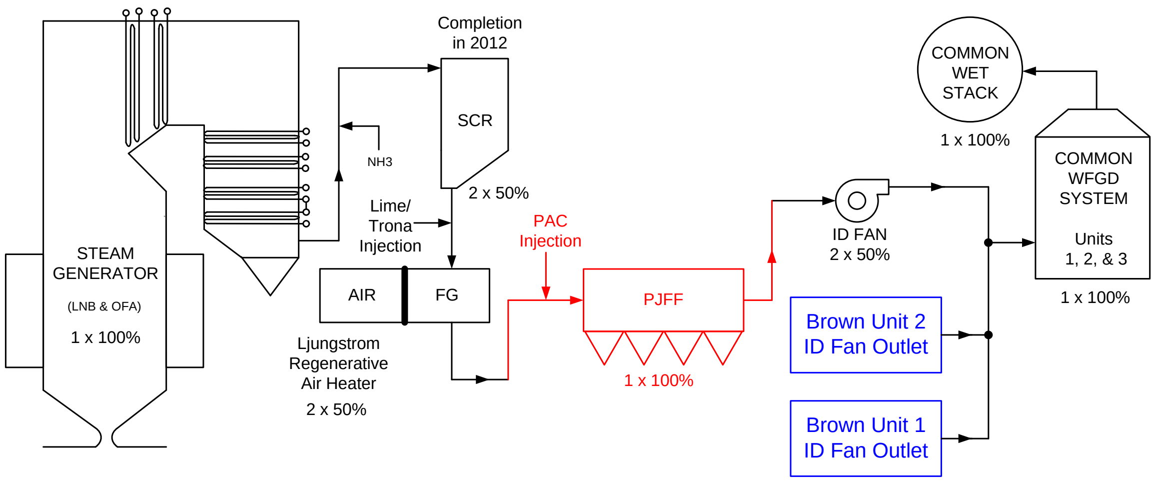


Figure 6-5. Unit 3 Future Draft System

With the expected addition of a PJFF system to the existing draft system, the pressure demand on the draft fan system will be higher than what the existing ID fans are currently experiencing. However, due to the selected capacity of the newly installed existing ID fans, it is expected that enough capacity is available to compensate for the PJFF addition and still allow for adequate margins. The existing ID fans are expected to be reused as shown in Figure 6-5.

Future Draft System Characteristics

The major performance characteristics of the Unit 3 boiler and future draft system at MCR are as follows in Tables 6-8 and 6-9. Note that the items in bold in Table 6-9 are new.

Table 6-8. Unit 3 Boiler Characteristics at MCR

Boiler total heat input	4,120 MBtu/hr (based on net plant output of 433,000 kW and heat rate of 9,516 Btu/kWh)
Boiler excess air	16.8% (2.8% oxygen, wet basis)
LOI	2.0% (estimated)
Ambient conditions	
Dry bulb temperature	74° F
Relative humidity	60%
Barometric pressure	28.97 inHg

Based on the layout of the future draft system in Figure 6-5 and the future draft system characteristics in Table 6-9, the estimated performance requirements of the existing ID fans at MCR are shown in Figure 6-6 as the MCR Point. Also in Figure 6-6 is the Maximum Fan Runout illustrating the maximum capability of the existing ID fans in the future draft system. Note the estimated flow and pressure margins of 15 and 33 percent, respectively. These margins are below the typical ranges of the Black & Veatch recommended margins. However, they are adequate enough to warrant the reuse of the newly installed Unit 3 ID fans to limit the capital costs of the AQC upgrades being considered. Black & Veatch recommends the continued use of the existing Unit 3 ID fans in support of the proposed AQC upgrades.

Table 6-9. Unit 3 Future Draft System Characteristics at MCR	
SCR system leakage	2.0% (estimated)
Air heater leakage	10.0% (estimated)
PJFF system leakage	**3.0%**
Flue gas temperatures	
Boiler outlet	730° F
SCR outlet	730° F
Air heater outlet	340° F
ESP outlet	**(Abandoned)**
PJFF outlet	**340° F**
ID fan outlet	~370° F (calculated)
WFGD outlet	~130° F (calculated)
Furnace pressure	-0.5 inwg
Draft system differential pressures	
Boiler	4.5 inw
SCR	10.0 inw (estimated)
Air heater	13.0 inw
ESP	**(Abandoned)**
Duct to PJFF	**1.0 inw**
PJFF	**6.0 inw**
Duct to WFGD	1.0 inw
WFGD	10.0 inw
Stack	1.0 inw

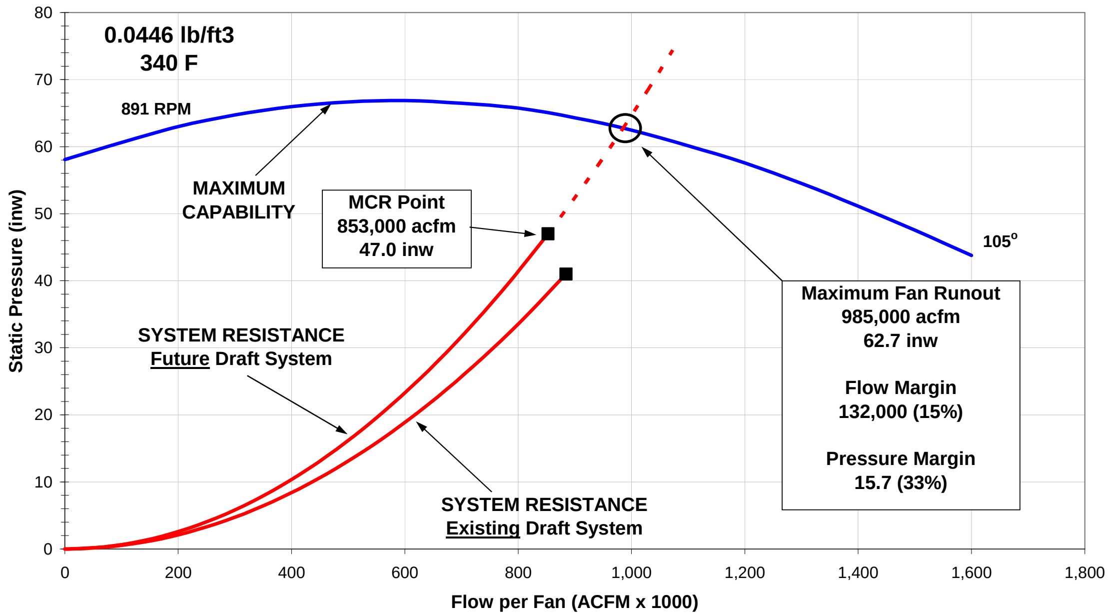


Figure 6-6. Unit 3 Existing ID Fan Performance

6.1.4 Draft System Transient Design Pressures

The AQC equipment additions and changes to all of the Brown units will likely be considered major alterations or extensions to the existing facilities per the 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 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 Brown units meets this criteria or if they will require stiffening. Each new piece of AQC equipment, and its associated ductwork, being considered for the Brown 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

All units main plant auxiliary electrical system 2.4 kV or 4.16 kV auxiliary switchgear buses UA and UB are fed from their own respective two-winding unit auxiliary transformer (UAT) that is powered from their respective generator leads. UAT 1 is rated 10,000 kVA, 13.2 kV-2.4 kV supplying 2.4 kV auxiliary switchgear buses 1A and 1B, UAT 2 is rated 10,000/12,500 kVA, 17.1 kV-2.4 kV supplying 2.4 kV auxiliary switchgear buses 2A and 2B, and UAT 3 is rated 15,100/20,100/25,200 kVA 24 kV-4.25 kV supplying 4.16 kV auxiliary switchgear buses 3A and 3B. Reserve power to Unit 1 and 2 auxiliary switchgear buses is provided from the 138 kV Substation (South) through a two-winding Reserve Auxiliary Transformer (RAT) rated 10,000/12,500 kVA, 138 kV-2.4 kV. Reserve power to Unit 3 auxiliary switchgear buses is provided from the West Cliff Substation 138/69/13.2 kV transformer through a two-winding RAT rated 31,360 kVA FOA, 13.2 kV-4.25/2.45 kV.

Unit 1, 2, and 3 13.2 kV FGD switchgear buses 0AP01E-A and 0AP01E-B are fed respectively from the two-winding UAT-3C that is powered from Unit 3 generator leads. UAT-3C is rated 33,600/44,800/56,000 kVA, 25 kV-13.2 kV. Reserve power to Unit 1, 2, and 3 13.2 kV FGD switchgear buses is provided from the Unit 1 13.2 kV Generator leads through a Clip PME Triggered Current Limiter connected between the Unit 1 Generator Breaker and the Unit 1 Main Transformer 1 low voltage terminals, via 15 kV cable bus consisting of 4-1/C 500KCMIL/PH conductors. Each 13.2 kV FGD switchgear bus feed a 13.2 kV–4.16 kV step down transformer rated 13,400/17,900/22,400 kVA, that provides power to the 4.16 kV FGD switchgear buses 0AP02E-A and 0AP02E-B.

The addition of SCR and PJFF and fly ash (FA) handling equipment on Unit 1 would require the addition of one new 1,000 HP FD Fan motor. The addition of SCR and PJFF and FA Handling equipment on Unit 2 may require the addition of one new 1,500 HP FD Fan motor, and will require one 8,000 HP ID fan motor. The addition of a PJFF and FA Handling equipment on Unit 3 would not require the addition of any new significant loads. The existing Unit 1 and 3 ID fans were determined sufficient size to handle the new SCR and PJFF equipment. The new Unit 3 SCR that is being installed under a separate contract. The new total Units 1, 2, and 3 connected electrical load for the new SCR/PJFF/FA equipment including new fan loads was estimated to be approximately 20,000 kVA. The existing unit auxiliary transformers, reserve auxiliary transformers or existing FGD13.2 kV switchgear buses were determined to have insufficient spare capacity, spare circuit breakers, single speed motor starting and voltage limitations, and short circuit ratings to power all of the total loads of the PJFF, SCR and FA additions. Also, existing units 2.4 kV and 4.16 kV auxiliary switchgear buses are older vintage equipment where new additions and spare parts may be an issue.

Unit 1 and 2 will require new 13.2 kV AQC switchgear buses A and B that will be fed respectively from one two-winding UAT-3D that is powered from Unit 3 generator leads. The new UAT-3D will be rated approximately 16,500/22,000/27,500 kVA, 25 kV-13.2 kV. Reserve power to the new Unit 1, and 2 13.2 kV AQC switchgear buses will be provided existing FGD 13.2 kV switchgear supply, via a new 15 kV cable bus consisting of -1/C 500KCMIL/PH conductors.. Each new Units 1 and 2 13.2 kV AQC switchgear bus will feed a 13.2 kV–4.16 kV step down auxiliary transformer rated approximately 5,000 kVA, that will provide power to the 4.16 kV AQC switchgear buses A and B. The new 13.2 kV AQC switchgear buses A and B will also supply power to each of the new AQC unit secondary substation (USS) transformers that will power the 480V USS for Units 1 and 2 SCR, PJFF, and FA additions

The existing 13.2 kV FGD switchgear buses will supply power to each of the new Unit 3 AQC USS transformers, and most likely power the Unit 3 SCR being installed under a separate contract. Any Unit 3 AQC medium voltage motor loads will be powered from the existing 4.16 kV FGD 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 reserve 13.2 kV cable bus to the existing Unit 1 13.2 kV source, and to connect to the existing UAT-3C 25 kV Isolated Phase Bus Duct connection. In addition to verify spare breaker positions are available on the existing FGD switchgear buses, and to verify how Unit 3 SCR will be powered.

The recommended location of the new Units 1 and 2 AQC 13.2 kV reserve power supply that will be connected to the new Unit 1 and 2 13.2 kV AQC switchgear will be at the existing FGD 13.2 kV supply connections . The recommended location of the new AQC UAT-3D will be in close proximity to the existing UAT-3C. Cable bus will be routed during detailed design from the secondary windings of the UAT-3D to the new Unit 1 and 2 AQC electrical building close to the new Unit 1 and 2 AQC major loads. The new Unit 3 AQC electrical equipment will be located in the new Unit 3 AQC electrical building. The new AQC electrical buildings will be located in the vicinity of the PJFF and SCR equipment for each unit 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 Unit 1 and 2 AQC electrical building to provide control power to the switchgear and DCS system. Existing DC and UPS power from the existing Unit 3 FGD electrical building will be used for the new Unit 3 AQC Electrical Equipment Building needs. 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

The addition of PJFF equipment will increase the amount of ash removed from the Brown 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 6,200 lb/hr of additional waste (ash) generated for Brown 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 Brown Unit 1 and Unit 2. Additional equipment required for anhydrous ammonia system may include but is not limited to an ammonia storage tank, ammonia feed pumps, dilution air blowers, vaporizers, pipes, valves, instrumentation and control equipments etc. There will be approximately 300 lb/hr of additional anhydrous ammonia required for Brown Unit 1 and 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 a PAC storage silo, PAC injection lances, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately 1,675 lb/hr of PAC required for the Brown Station.

- **Trona/Lime/SBS Injection System**--A new sorbent (trona/lime/SBS) injection system will be required for SO_3 control for Units 1 and 2. Additional equipment required for sorbent injection system may include but is not limited to a sorbent storage silo, injection lances, blowers, pipes, valves, instrumentation and control equipments etc. There will be approximately 3,183 lb/hr of sorbent (trona) required for the Brown Station if SCRs are added on Units 1 and 2 and 1,061 lb/hr of sorbent (trona) required if no SCRs are added on Units 1 and 2.

6.5 Chimney Analysis

Based on the recommendations made in Section 5.2, analysis of the chimneys at the Brown Station is not required. The Brown Station Units 1-3 will continue to use the single common chimney downstream of the existing common WFGD. As proposed, the ductwork will also retain the capability to allow exhaust from Unit 2 to bypass the WFGD to the old Unit 3 chimney, as is currently possible. LG&E/KU requested that consideration be given to providing the same bypass potential to Unit 1. Preliminary investigation determined that providing a means to bypass the WFGD and direct exhaust from Unit 1 to the old Unit 3 chimney may be feasible with the addition of interconnecting ductwork between existing Unit 1 and Unit 2 exhaust ductwork. As previously discussed, if operating Unit 1 in bypass instead of or in addition to Unit 2 is acceptable from a air permit regulatory standpoint, further investigation can be made. From a technical perspective, it is expected that the major concern would be whether the existing ductwork to the old Unit 3 chimney is sufficiently sized to carry exhaust from both Units 1 and 2 with an acceptable flow velocity.

6.6 Constructability Analysis

Several major AQC construction projects have been executed at the Brown plant site over the last several years, with at least one additional project (SCR at Unit 3) in the planning stage 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. Several of the close-in staging and final assembly areas used in the previous projects will, however, be occupied by the proposed new construction and some adjustment in laydown, staging areas, and other 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 Brown 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 three units presents 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. Two conceptual arrangement plan sketches (one covering both Units 1 and 2, the other covering Unit 3) with corresponding elevation sketches are attached to this study in Appendix A. Each sketch depicts the current proposed arrangement, including refinements made per site walk down inspections and joint project team discussion. Because of the need to maintain generation capacity to the maximum practical, it is expected that major work requiring a unit outage will be done sequentially by unit and not simultaneously. However, Unit 1 and Unit 2 are enclosed in a common building structure, require similar modifications, and share a portion of the new ductwork support frame. For the purposes of this study, it is assumed a large majority of the non-outage work for Units 1 and 2 will be executed concurrently as a single construction project to minimize staggered remobilization and access concerns. Any work expected to be completed concurrently for Units 1 and 2 will be so noted in the description that follows. The planned construction for Unit 3 is located well away from Units 1 and 2, and will be considered independently.

Following is a generalized discussion of the sequence and concerns identified with the arrangement presented for Units 1 and 2 and for Unit 3.

6.6.1 Unit 1 and Unit 2 Arrangement

As detailed on the conceptual arrangement plan, the AQC technology proposed for both Unit 1 and Unit 2 consists of replacing the existing air heater and FD fan with new equipment "remote" from that existing. Both Units 1 and 2 will each be provided with a new 100 percent capacity SCR and a corresponding 100 percent PJFF. A preliminary check confirmed that the existing Unit 1 ID fan is adequately sized for the new design conditions and will be reused in its current location. The two 50 percent ID fans existing at Unit 2 will be replaced with a single new 100 percent capacity ID fan. PAC and sorbent transfer equipment, associated ductwork, and ancillary electrical and ash handling equipment required for Units 1 and 2 will be provided in facilities common for both units, to the extent practical.

The area directly north of the existing Unit 1 and Unit 2 powerblock structure is extremely congested with ductwork, the Unit 2 chimney, the (mostly inoperative) Water

Treatment Building, and other equipment. Reclaiming this area for new construction would involve extensive demolition and unacceptably long unit outages.

Accordingly, the major equipment required for Units 1 and 2 is proposed to be located in the parking lot area east of the Unit 1 ID fan. A new structure supporting a new FD fan, new air heater, and new SCR module would be erected for each unit in the area closest to the Unit 1 ID fan. A new PJFF would be erected for each unit immediately east of the SCR/air heater structures. The new Unit 2 ID fan would be located between the Unit 2 SCR/air heater structure and the Unit 2 PJFF. The remainder of the area west and south of the existing coal conveyor would be reserved for ash handling, electrical power and control, and PAC and sorbent facilities common to both Unit 1 and Unit 2.

Exhaust ductwork downstream of the PJFFs would remain unit-dedicated. Unit 1 exhaust ductwork would be routed from the Unit 1 PJFF outlet to the inlet of the existing Unit 1 ID fan, with the new arrangement reusing the fan in its current location. Ductwork downstream of the Unit 1 ID fan outlet would remain unchanged to the extent practical. Unit 2 exhaust ductwork would be routed from the Unit 2 PJFF outlet, through the new Unit 2 ID fan, and parallel as practical to the Unit 1 duct. It would then turn and tie into the existing Unit 2 exhaust ductwork above, and bypassing, the existing Unit 2 ID fans. Separate routing of Unit 1 and 2 exhaust ductwork will allow maximum reuse of existing duct as well as maintain Unit 2's ability to discharge to the old Unit 3 chimney, bypassing the WFGD if required.

Ductwork between Units 1 and 2 and the new air heaters and SCRs would be routed immediately adjacent to the north wall of the powerblock structure. The ductwork would be stacked to minimize its footprint and thus reduce the amount of demolition or relocation of existing equipment north of the powerblock. It is expected, however, that existing chemical storage tanks and pumps in the area will have to be relocated or demolished, and the old Water Treatment Building and the dust collection ductwork and hoppers at Unit 2 will have to be demolished to gain sufficient access along the north building wall to install the ductwork support foundations and structural framing. It is anticipated the foundations will be supported from micropiles due to the limited access available for construction equipment.

The congestion north of the powerblock building, the extensive ductwork in the area, and the coal conveyor greatly complicate crane access for installation of the new ductwork next to the building. It is expected that a common steel structure carrying both Unit 1 and Unit 2 ductwork would be constructed with a crane located to the east of this area. To minimize foundations, the support structure would likely be designed as a series of trussed "bridges" sharing foundations. Each section of ductwork would be swung into the east end of the bridge, drifted horizontally to the west on a rail or roller system, and jacked into its final location within the trusswork. Due to routing limitations, Unit 1 ductwork must be erected first on the top tier of the support frame. However, by simultaneously installing the maximum amount of Unit 1 and Unit 2 ductwork in one operation, the crane will be allowed to "work bottom to top and west to east" as ductwork for both units is completed while maintaining the east end of the trusswork support frame open to land and jack ductwork segments into place. It may be possible to set some sections of the ductwork directly in place on the support frame as the frame is erected if the lifting crane can be positioned to avoid vertical obstructions and maintain a suitable swing radius. This would eliminate jacking of the ductwork, but may complicate the frame design and rigging plans. Main crane access for construction of Unit 1 and Unit 2 would be from the parking lot area to the east, with a secondary crane located between Unit 1 and Unit 2 cooling towers for installation of downstream exhaust duct.

Construction activities must be closely coordinated with plant operations to ensure adequate access is maintained to both Units 1 and 2 ESPs, ID fans, and associated ductwork while construction is ongoing. The congested footprint limits available 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 parking lot area east of Unit 1 or between the two cooling towers, and set in place by the main lift cranes located as noted above.

As part of each unit outage, the respective existing air heater and FD fan will need to be bypassed inside the powerblock building. Tie in work will likely begin prior to the outage by modifying the north exterior boiler wall and associated structural wall girts adjacent to each tie in point at Unit 1 and Unit 2. Temporary rigging and support steel will be installed as required to remove existing ductwork and install modified tie-in duct sections. In addition, lagging and insulation will be removed from the ductwork around the tie-in points and new ductwork flat panel sections will be staged in available floor space inside the boiler building. During the outage, existing ductwork will be demolished at the tie-in point(s) and connecting flanges installed to accept the new ductwork section(s). Once the old ductwork sections have been removed, new duct section(s) will be fabricated in place from the flat panel duct pieces previously staged in the boiler building. Post outage work will likely include insulating and lagging the new ductwork, closing the north exterior wall around the duct penetrations, and removing demolished material from the building.

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

- Demolish/relocate chemical tanks and equipment and portions of the Water Treatment Building necessary to install the ductwork support structure adjacent to the Unit 1/Unit 2 powerblock building. (3 months, non-outage)
- Install foundations and structural steel for the common ductwork support structure to the extent allowed with units on line. Set, slide, and jack sections of Unit 1 and Unit 2 ductwork in and on the common support structure. (4 months, non-outage).
- Construct new foundations and any supporting structural steel superstructure for the Unit 1 and 2 SCRs, air heaters, PJFFs, and dedicated ductwork, plus foundations for common facilities (5 months, non-outage).
- Install new Unit 1 FD fan, air heater, SCR, and PJFF, plus remaining ductwork upstream and downstream to tie-in points (14 months, non-outage, to work concurrently with Unit 2 similar work scope).
- Install new Unit 2 FD fan, air heater, SCR, PJFF and ID fan, plus remaining ductwork upstream and downstream to tie-in points (16 months, non-outage, to work concurrently with Unit 1 similar work scope).
- Install common facilities such as the ash handling equipment, electrical facilities, and PAC and sorbent storage and transfer equipment (6 months, non-outage).
- Demolish required portions of Unit 1 ductwork and equipment to complete tie-in of ductwork to existing Unit 1 ductwork and ID fan (6 weeks, outage).
- Start-up and tune new Unit 1 SCR, air heater, PJFF, FD fans, PAC, sorbent, and ash handling systems (10 weeks, combined outage and non-outage).
- Demolish required portions of Unit 2 ductwork and equipment to complete tie-in of ductwork to existing Unit 2 ductwork (6 weeks, outage).
- Start-up and tune new Unit 2 SCR, air heater, PJFF, FD fans, PAC, sorbent, and ash handling systems (10 weeks, combined outage and non-outage).

The main crane east of Unit 1 will have a limited boom swing due to its close proximity to Unit 1 and the coal conveyor. Detailed rigging and lift plans must be developed for each major component installed. Installation of foundations for the common ductwork support will be problematic due to the existing congestion and the need to maintain unit operation to the extent practical. Micropiles may be required for these foundations. In addition, the following issues will have to be addressed in detail to support construction at Unit 1.

- Above and below grade utility interferences must be identified 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 1 and 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. The existing circulating water piping, valves and pumps located at the northeast corner of Unit 1 must be protected from damage during installation of ductwork support frame foundations and structural steel.
- 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 and plant parking east of Unit 1 interrupted/displaced and must be rerouted. Existing traffic patterns must be re-established prior to start of construction and parking area permanently lost due to new equipment must be relocated.
- Demolition/modification of existing ductwork, especially the ductwork located inside the powerblock building, will require selective dismantling operations in order to work around existing equipment and ancillaries.

In addition to the conceptual arrangement plan for Units 1 and 2, two alternate arrangements were developed and are included in the sketches in Appendix A. Alternate 1 was developed at the request of LG&E/KU and illustrates a conceptual arrangement for when SCRs are not included within the modification scope. However, it should be noted that it is possible that SCRs may ultimately be required at some point, even if not included as part of the modifications being studied. For that reason the new equipment shown on the Alternate 1 arrangements is located to allow installation of SCRs at both Units 1 and 2 at some point in the future.

Ductwork and access at the existing air heaters in Unit 2, although limited and congested, is not as severe as that at Unit 1. It is expected that simplicity, operability, and maintenance considerations would dictate that a new air heater and FD fan be installed at both Unit 1 and Unit 2, but consideration may be given to reusing the existing Unit 2 air heaters and FD fans. Accordingly, an Alternate 2 arrangement was developed to illustrate a conceptual arrangement if no new air heater or FD fan was included at Unit 2. It should be noted that this arrangement actually increases the amount of ductwork required in the congested area directly north of the Unit 1/Unit 2 powerblock building.

The two alternate arrangements and supporting details are presented for information. The majority of the constructability analysis developed for the initial conceptual arrangement would remain applicable to either of these alternates, if considered.

6.6.2 Unit 3 Arrangement

The AQC technology proposed for Unit 3 consists primarily of a 100 percent PJFF, PAC silos and transfer equipment; and the associated ductwork and ancillary equipment required to tie this equipment into the exhaust gas air stream. The two existing 50 percent ID fans are expected to be re-used in place and a new SCR and sorbent injection system are expected to be in place and operational prior to installation of the PJFF.

The new PJFF is proposed to be located south of the existing WFGD module and west of the existing ID fans. A relatively significant difference in grade exists between the area to receive the PJFF and that surrounding the WFGD. Grade stabilization and possibly a retaining wall will be required between the WFGD and the PJFF to maintain stability of the PJFF without compromising the foundation at the WFGD.

New ductwork is routed from the Unit 3 air heater outlets just inside the south wall of the Unit 3 powerblock building. The ductwork exits the Unit 3 boiler building under the new SCR facility, then turns west, and crosses over the access road and the existing Unit 3 ductwork downstream of the ID fans to the PJFF inlet. New ductwork is also routed from the PJFF outlet to the inlets of the existing ID fans. No changes are expected to any equipment downstream of the ID fans. Existing ESPs south of Unit 3 will be bypassed and abandoned in place to the extent practical. New ash handling equipment will be located near the PJFF with short access to the existing ash transfer pipelines. New electrical power and control equipment will be located adjacent to the PJFF and a new PAC station and transfer station will be located accessible from the road west of Unit 3. The conceptual arrangement takes into account the currently planned SO_3-control sorbent handling facility west of the ID fans.

A major constructability concern will be installation of new ductwork beneath the SCR south of Unit 3. Routing of the new ductwork must take into account the SCR support structure, the existing ductwork in the area, and the to-be-bypassed ESP. If the ductwork is supported from a dedicated structure, foundations for new ductwork supports must be installed in extremely congested locations with the unit on line to avoid extended outages. Special "bridged" duct support framework, similar to that conceived for Units 1 and 2, and independent of the SCR framework, must be installed to allow sections of ductwork to be set from the west side of the SCR area, drifted horizontally to the east on a rail or roller system, and jacked into place on the support framework. A report titled, "Review of Constructability and Coordination Issues at Unit 3 SCR," File 41.0403, compiled separately, recommends designing the new SCR superstructure to support the PJFF ductwork for this project. This document has been included for reference in Appendix B. A combined structure supporting both the SCR and the ductwork is expected to be overall more economical and allow faster and easier installation than two separate support structures.

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

- Demolish and/or relocate existing structures in the way of new construction, i.e.; fire hydrant station and underground utilities, demolished building slab, etc. Complete necessary earthworks and retaining wall, if necessary, to accommodate the existing grade immediately surrounding the WFGD (3 months, non-outage).
- Construct new foundations for the PJFF, ductwork, PAC station, and associated ancillary facilities (4 months, non-outage).
- Install new PJFF and ancillary systems such as PAC, electrical gear, and ash handling, plus ductwork to tie-in points. (16 months, non-outage).
- Complete tie-in of ductwork to existing air heater outlet scrubber and ID fans. This includes selected demolition of the existing ESP units to allow installation of ductwork exiting the building from the air heater outlet. This is assumed to include removal of a section of inlet ductwork from each ESP, modifying structural framing to accommodate the removed section(s), and installation of vertical blanking plates over exposed ends. (8 weeks, outage).
- Start-up new PJFF, booster fans, PAC, and ash handling systems (10 weeks, combined outage and non-outage).

The main crane for PJFF construction will be located in the roadway south of the PJFF, with a second crane for ductwork installation located in the area west of the SCR. Limited amounts of construction material can be staged in these areas, making modularization of major ductwork and PJFF components a necessity. Major component modules will be fabricated in remote fabrication areas, transported to the work site via the plant access roads, raised over or around existing obstructions, and set in place by the cranes. At locations overhead access is blocked by existing components, as under the SCR, duct sections will be set on the end of the steel support superstructure, drifted horizontally on a rail or roller system, and jacked into final position. Detailed rigging and lift plans must be developed for each major component installed. Micropiles will likely be required for the ductwork foundations under the SCR. In addition, the following issues will have to be addressed in detail to support construction at Unit 3.

- Above and below grade utility interferences must be identified and relocations may be necessary, especially in the area to receive the PJFF and adjacent structures.
- 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.
- 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 south plant road and road west of Unit 3 will be interrupted and must be rerouted. Existing traffic patterns must be reestablished prior to start of construction.
- Demolition/modification of existing ductwork and necessary portions of the ESP will require selective dismantling operations in order to work around the existing SCR, support structure, and ancillaries.

6.7 Truck/Rail Traffic Analysis

The modifications proposed for the three Brown 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 6-10. Additional delivery traffic for the site as a whole will be addressed accordingly. A new SCR and a new SO_3 (sorbent injection) system are already being planned for Unit 3 by others, and ammonia and sorbent storage facilities for Unit 3 are included in those plans. Table 6-10 reflects the ammonia and sorbent usage rates for Units 1 and 2 only with and without a new SCR, as well as the PAC usage rates for all three units.

Table 6-10. Sorbents and Reagents Consumption Rates (lb/hr)				
Material	**Unit 1**	**Unit 2**	**Unit 3**	**Station Total**
PAC	278	394	1,003	1,675
With a new SCR				
Sorbent (trona)	1,194	1,989	N/A	3,183 additional
Sorbent (lime)	1,237	2,061	N/A	3,298 additional
Anhydrous ammonia	114	184	N/A	298 additional
Without a new SCR				
Sorbent (trona)	398	663	N/A	1,061 additional
Sorbent (lime)	412	687	N/A	1,099 additional

The table lists both trona and lime as possible sorbents. Either one or the other, not both, would be used in SO_3 control. The usage rate for lime is slightly higher than that for trona and thus more lime than trona would be required for continuous operation. For purposes of delivery and traffic analysis, the usage rate for lime would result in slightly more conservative results. Accordingly, bulk delivery for sorbent will be based on the usage rates for lime, noting that deliveries would be slightly less if trona is ultimately used instead.

Although a rail spur exists at the Brown Station, its use is primarily for coal delivery and no onsite spurs exist to the expected loading and storage areas for the sorbent and reagent bulk materials. Using the existing rail system for periodic delivery of other bulk materials would be expensive in terms of additional facilities required and potentially disruptive to coal delivery. 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, 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 with the addition of SCRs on Unit 1 and 2 in Table 6-10 above and nominal truck sizes, the additional truck deliveries to the Brown site can be summarized as follows.

- PAC — 7 loads per week
- Sorbent — 14 loads per week additional
- Anhydrous ammonia — 1 load per week additional

Therefore, the total additional truck deliveries estimated to provide sorbents or reagents is approximately 22 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 4.4 per day or 1 every 110 minutes over and above the current deliveries planned or already being made. Existing roads onsite should be able to accommodate the additional deliveries.

Bins or silos are often provided for each material at each unit to minimize the size and length of distribution systems. However, since the AQCS systems proposed for Units 1 and 2 are located adjacently, a single unloading and storage location is recommended 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. To ensure continuous operation in case one silo is out of service, two PAC storage silos and two sorbent storage silos are proposed near Units 1 and 2, each able to serve both units. Another set of four silos will be located near Unit 3; two for PAC as proposed by Phase II and two for sorbent as planned by others. Each silo is sized to store 3.5 days' usage of material to ensure 7 days total storage onsite. Estimated silo sizes, including area for transfer equipment beneath, are as follows.

- Unit 1 and 2 PAC Storage Silo – 2 x 14 foot diameter x 60 feet high
- Unit 1 and 2 Sorbent Storage Silo – 2 x 14 foot diameter x 70 feet high
- Unit 3 PAC Storage Silo – 2 x 14 foot diameter x 85 feet high
- Unit 3 Sorbent Storage Silo – (By Others)

An ammonia storage tank facility is currently being planned as part of the Unit 3 SCR addition, to be located west of the Unit 3 cooling towers. Because of the hazardous nature of stored ammonia, concentration of all ammonia storage facilities in one location is often preferred over multiple storage locations. Accordingly, it is recommended that LG&E/KU consider expansion of the planned ammonia storage facility to include storage for the ammonia to be used at Units 1 and 2. The additional volume required to store seven days' usage for Units 1 and 2 would be approximately 10,000 gallons. Placing all ammonia unloading and storage at one location has the added benefit of reducing truck traffic in other areas of the plant.

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 three units is estimated at 6,200 lb/hr, or approximately 74 tons per day of operation of all three 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 common WFGD scrubber. 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 E.W. Brown 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 a new FD fan, new air heater, new SCR, new sorbent injection system, new PAC injection system, new PJFF, existing ID fan, existing common WFGD, and existing chimney. A neural network shall also be included. Brown Unit 1 Arrangement with the new SCR located above the new air heater and FD fan and single PJFF located in the existing parking lot northeast of Unit 1 boiler is to be utilized. Cost associated with installation of the SCR shall be easily identifiable and separated for further consideration based on final regulations.

Unit 2 shall include a new FD fan, new air heater, a new SCR, new sorbent injection system, new PAC injection system, new PJFF, new ID fan, existing common WFGD, and existing common chimney. A neural network shall also be included. Brown Unit 2 Arrangement with the new SCR located above the new air heater and FD fan and single PJFF located in the existing parking lot northeast of Unit 1 boiler is to be utilized. 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 future existing SCR, future existing sorbent injection system, new PAC injection system, new PJFF, existing ID fans, existing common WFGD, and existing common chimney. A neural network shall also be included. Brown Unit 3 Arrangement with the new single PJFF located south of the common WFGD is to be utilized.

Table 7-1. AQC Technologies

	Unit 1	Unit 2	Unit 3
NO_x Control	New SCR	New SCR	Future[(a)] SCR
SO_2 Control	Existing WFGD	Existing WFGD	Existing WFGD
PM Control	New PJFF	New PJFF	New PJFF
HCl Control	Existing WFGD and New Sorbent Injection	Existing WFGD and New Sorbent Injection	Existing WFGD and Future[(a)] Sorbent Injection
CO Control	New NN	New NN	New NN
SO_3 Control	New Sorbent Injection[(b)]	New Sorbent Injection[(b)]	Future[(a)] Sorbent Injection
Hg Control	New PAC Injection	New PAC Injection	New PAC Injection
Dioxin/Furan Control	New PAC Injection	New PAC Injection	New PAC Injection
Fly Ash Sales	None	None	None

[(a)]Planned in-service date of 2012.
[(b)]Sorbent injection system may also be required to meet the primary design emission targets (Table 3-1) if SCR is not installed.

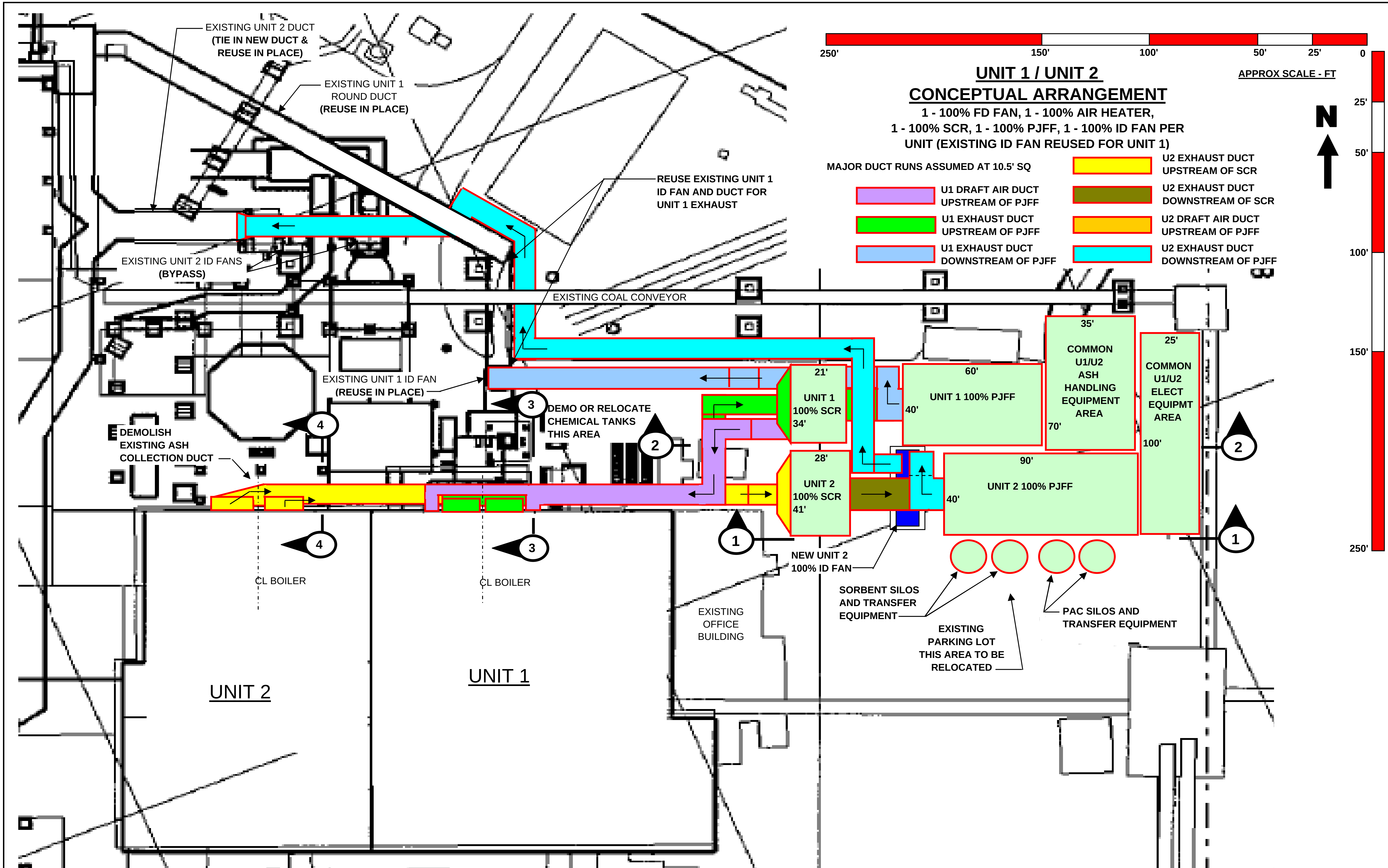
In addition, the following items shall also be considered in the next step of the project.

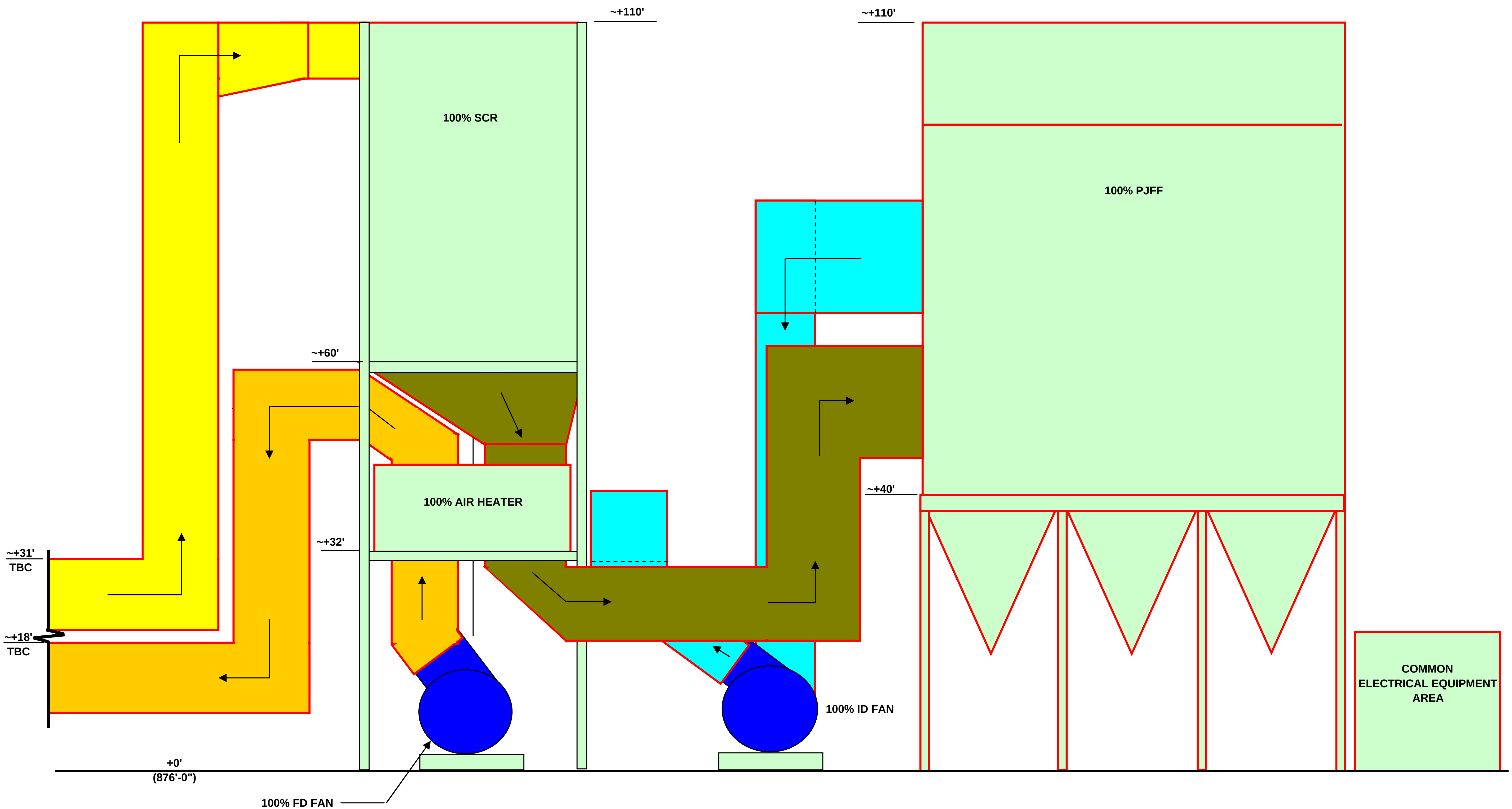
- Current emission levels and preliminary design emission targets were reviewed and it was determined sorbent injection systems will still be required if SCRs are not installed on Units 1 and 2.
- Include the costs for new dry ash systems capable of transporting the ash to the area of the new dry landfill.
- Investigate maintaining a traffic continuation loop in the vicinity of the new Unit 1 and 2 AQC equipment by connecting to the road east of the Unit 1 cooling tower.
- Add the new oil storage building currently under construction north of the warehouse located between the Unit 1 and Unit 2 cooling towers to the site arrangement drawings.
- Include the Unit 1 and Unit 2 bypass option in the cost estimate as a line item. Refer to conceptual sketches in appendix A for sketch of bypass option.

- Modify the Unit 3 arrangement including demolishing warehouse 3 and reshaping the plant road and access area around the WFGD.
- Assume new steel and foundations are required for the Unit 3 PJFF ductwork. Refer to Appendix B for constructability and coordination issues between new Unit 3 PJFF and future Unit 3 SCR.
- Include the potential of partial demolition of the Unit 3 ESP in the report.
- Review the NFPA boiler natural draft requirements and incorporate any necessary changes into our conceptual design/cost estimate.
- Include plant parking alternatives.

Appendix A
Conceptual Sketches

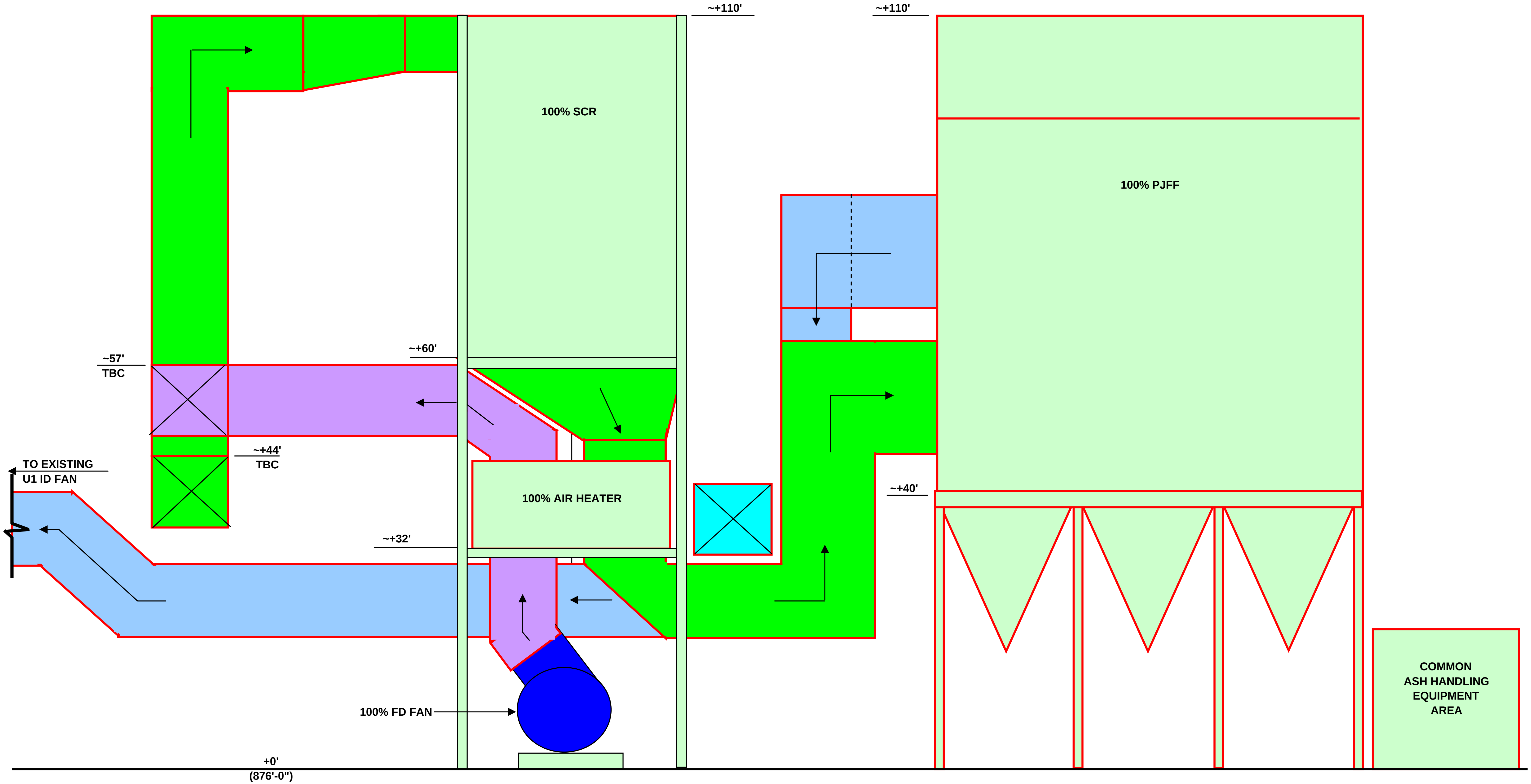
Unit 1 & 2 Arrangements with SCR, New Air Heater, and FD Fan


UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
1 - 100% FD FAN, 1 - 100% AIR HEATER,
1 - 100% SCR, 1 - 100% PJFF, 1 - 100% ID FAN PER
UNIT (EXISTING ID FAN REUSED FOR UNIT 1)
APPROX SCALE - FT
250' 150' 100' 50' 25' 0
25' 50' 100' 150' 250'
N
MAJOR DUCT RUNS ASSUMED AT 10.5' SQ
U1 DRAFT AIR DUCT UPSTREAM OF PJFF
U1 EXHAUST DUCT UPSTREAM OF PJFF
U1 EXHAUST DUCT DOWNSTREAM OF PJFF
U2 EXHAUST DUCT UPSTREAM OF SCR
U2 EXHAUST DUCT DOWNSTREAM OF SCR
U2 DRAFT AIR DUCT UPSTREAM OF PJFF
U2 EXHAUST DUCT DOWNSTREAM OF PJFF
EXISTING UNIT 2 DUCT (TIE IN NEW DUCT & REUSE IN PLACE)
EXISTING UNIT 1 ROUND DUCT (REUSE IN PLACE)
REUSE EXISTING UNIT 1 ID FAN AND DUCT FOR UNIT 1 EXHAUST
EXISTING UNIT 2 ID FANS (BYPASS)
EXISTING COAL CONVEYOR
EXISTING UNIT 1 ID FAN (REUSE IN PLACE)
DEMO OR RELOCATE CHEMICAL TANKS THIS AREA
DEMOLISH EXISTING ASH COLLECTION DUCT
21' UNIT 1 100% SCR 34'
28' UNIT 2 100% SCR 41'
60' UNIT 1 100% PJFF 40'
90' UNIT 2 100% PJFF 40'
35' COMMON U1/U2 ASH HANDLING EQUIPMENT AREA 70'
25' COMMON U1/U2 ELECT EQUIPMT AREA 100'
NEW UNIT 2 100% ID FAN
SORBENT SILOS AND TRANSFER EQUIPMENT
PAC SILOS AND TRANSFER EQUIPMENT
EXISTING PARKING LOT THIS AREA TO BE RELOCATED
EXISTING OFFICE BUILDING
CL BOILER
CL BOILER
UNIT 2
UNIT 1
1 2 3 4



SECTION 1
UNIT 2 ELEVATION
NOT TO SCALE

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
SECTIONS



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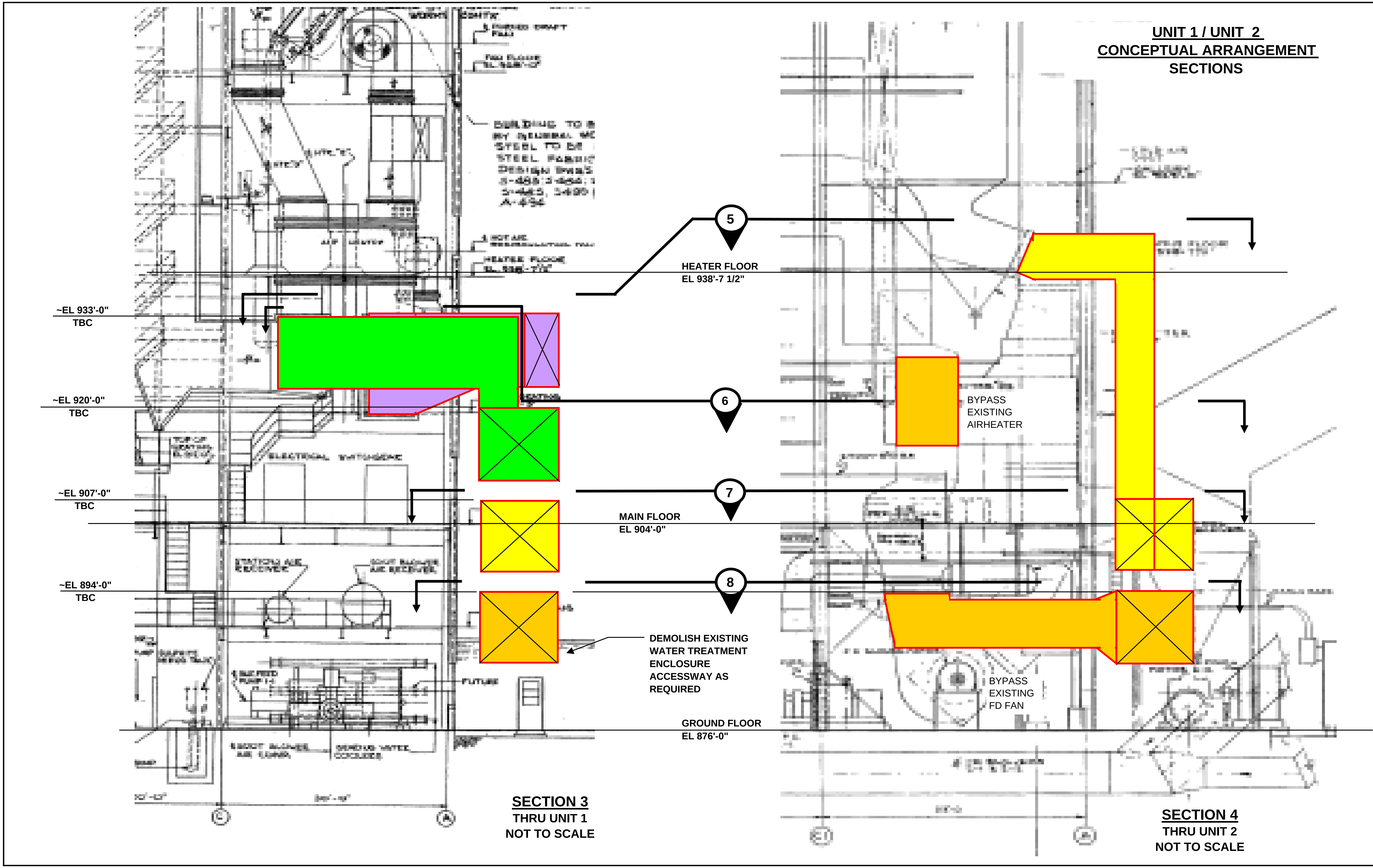
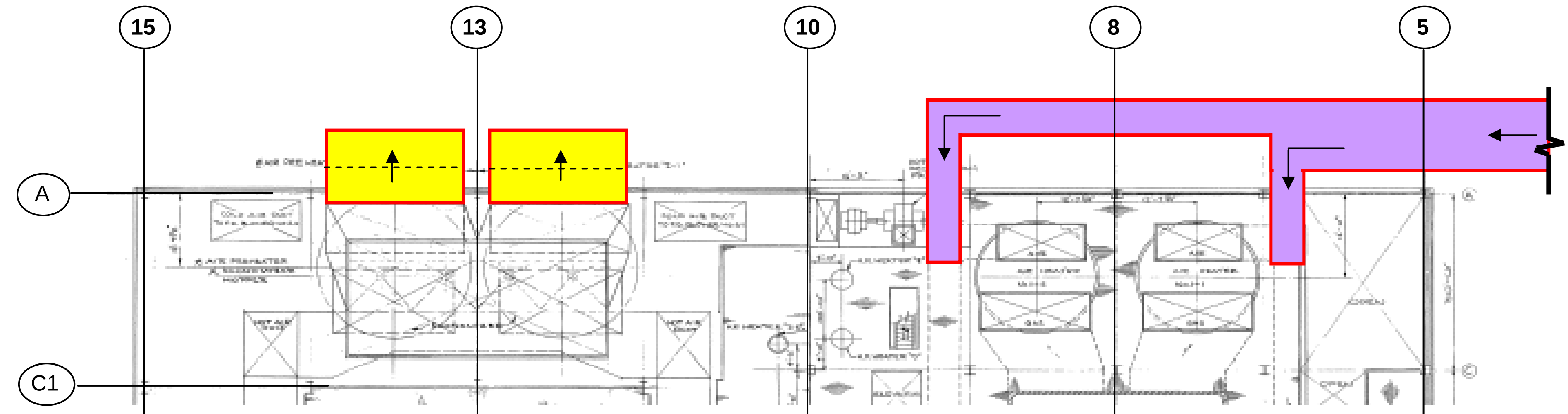
UNIT 1 ELEVATION
NOT TO SCALE

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
SECTIONS


UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
SECTIONS
5
6
7
8
HEATER FLOOR
EL 938'-7 1/2"
~EL 933'-0"
TBC
~EL 920'-0"
TBC
~EL 907'-0"
TBC
~EL 894'-0"
TBC
MAIN FLOOR
EL 904'-0"
GROUND FLOOR
EL 876'-0"
BYPASS
EXISTING
AIRHEATER
BYPASS
EXISTING
FD FAN
DEMOLISH EXISTING
WATER TREATMENT
ENCLOSURE
ACCESSWAY AS
REQUIRED
SECTION 3
THRU UNIT 1
NOT TO SCALE
SECTION 4
THRU UNIT 2
NOT TO SCALE



SECTION 5
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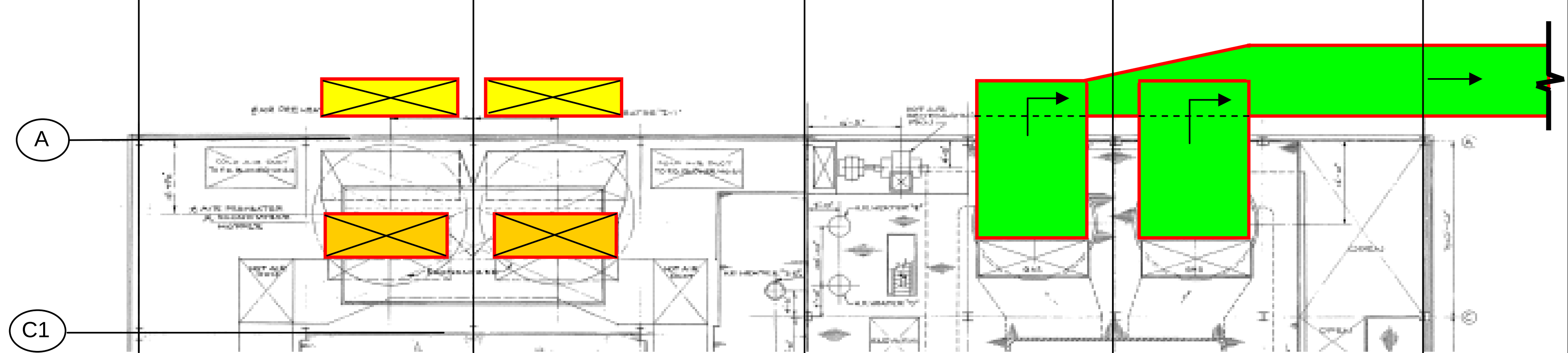

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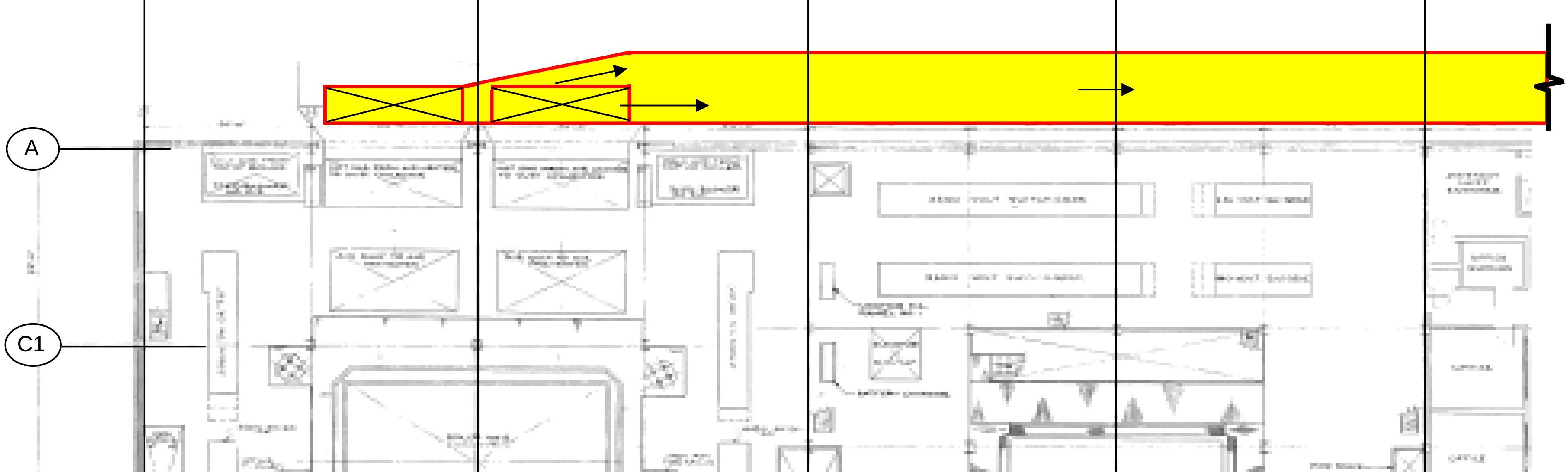

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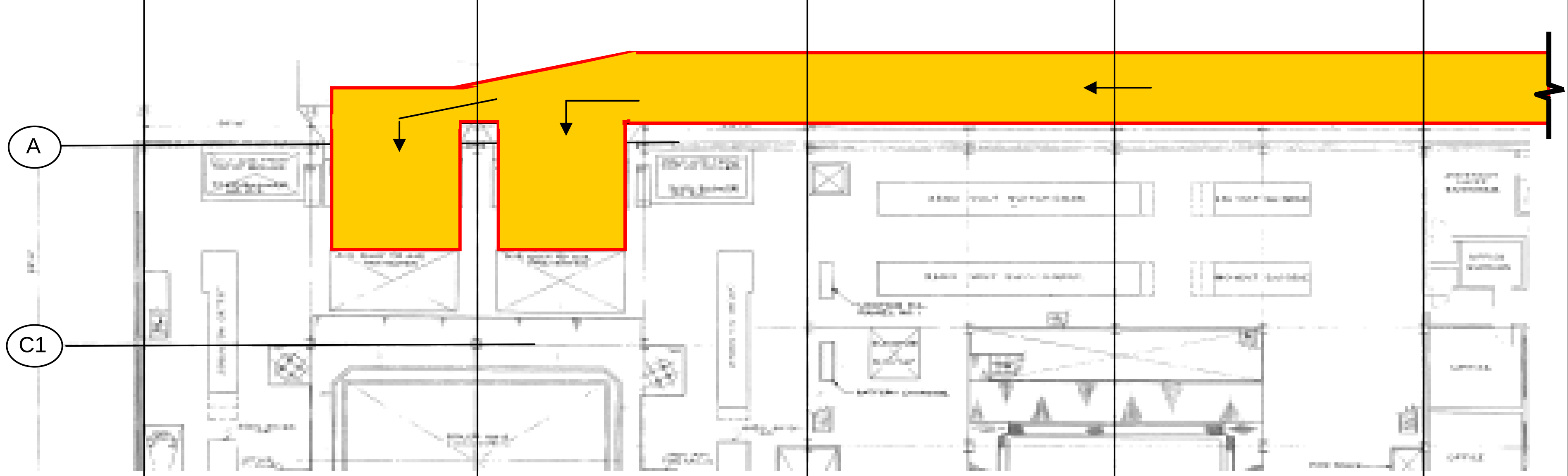
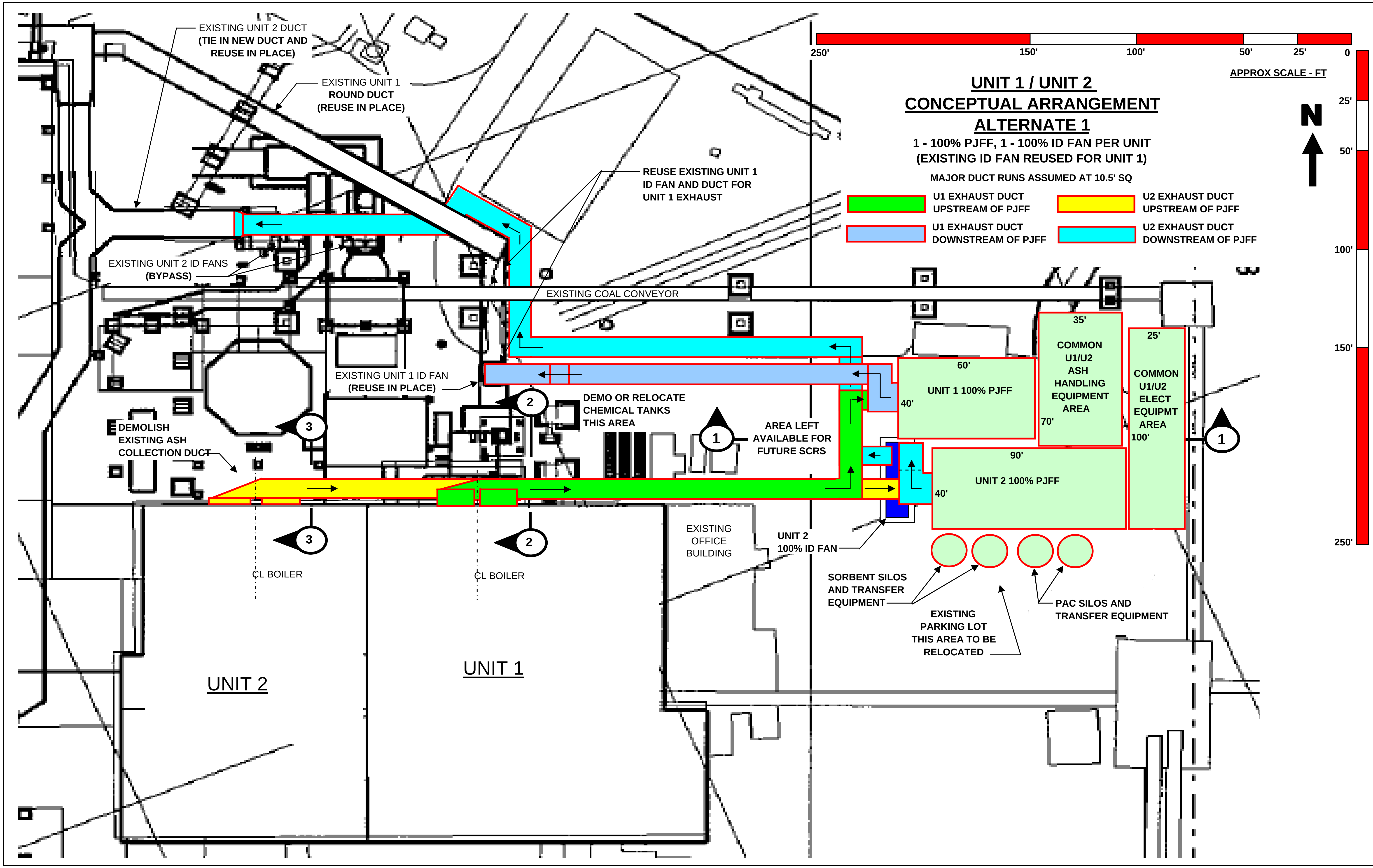


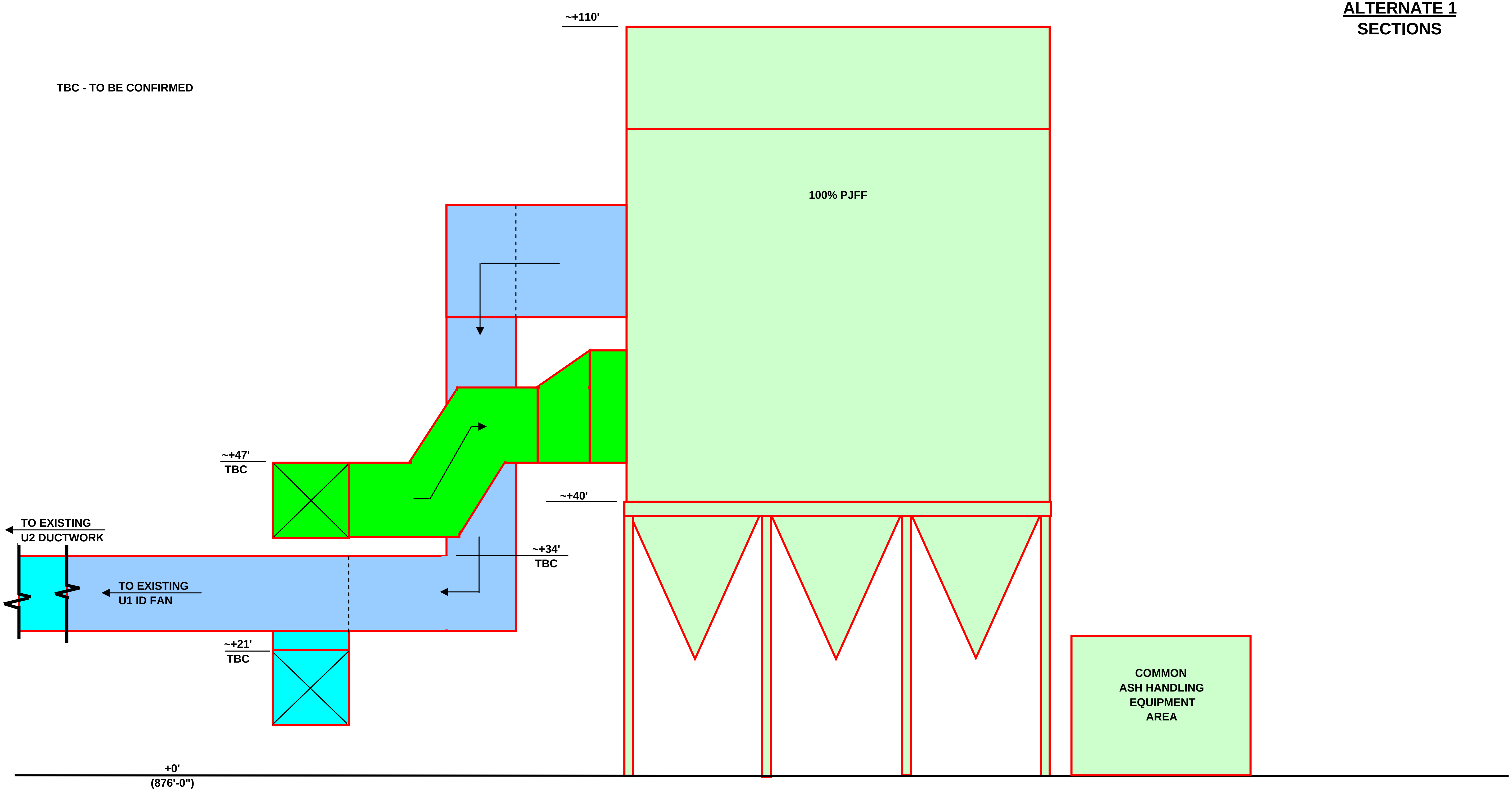
SECTION 8
NOT TO SCALE

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
SECTIONS

Unit 1 & 2 Arrangements without SCR, New Air Heater, and FD Fan

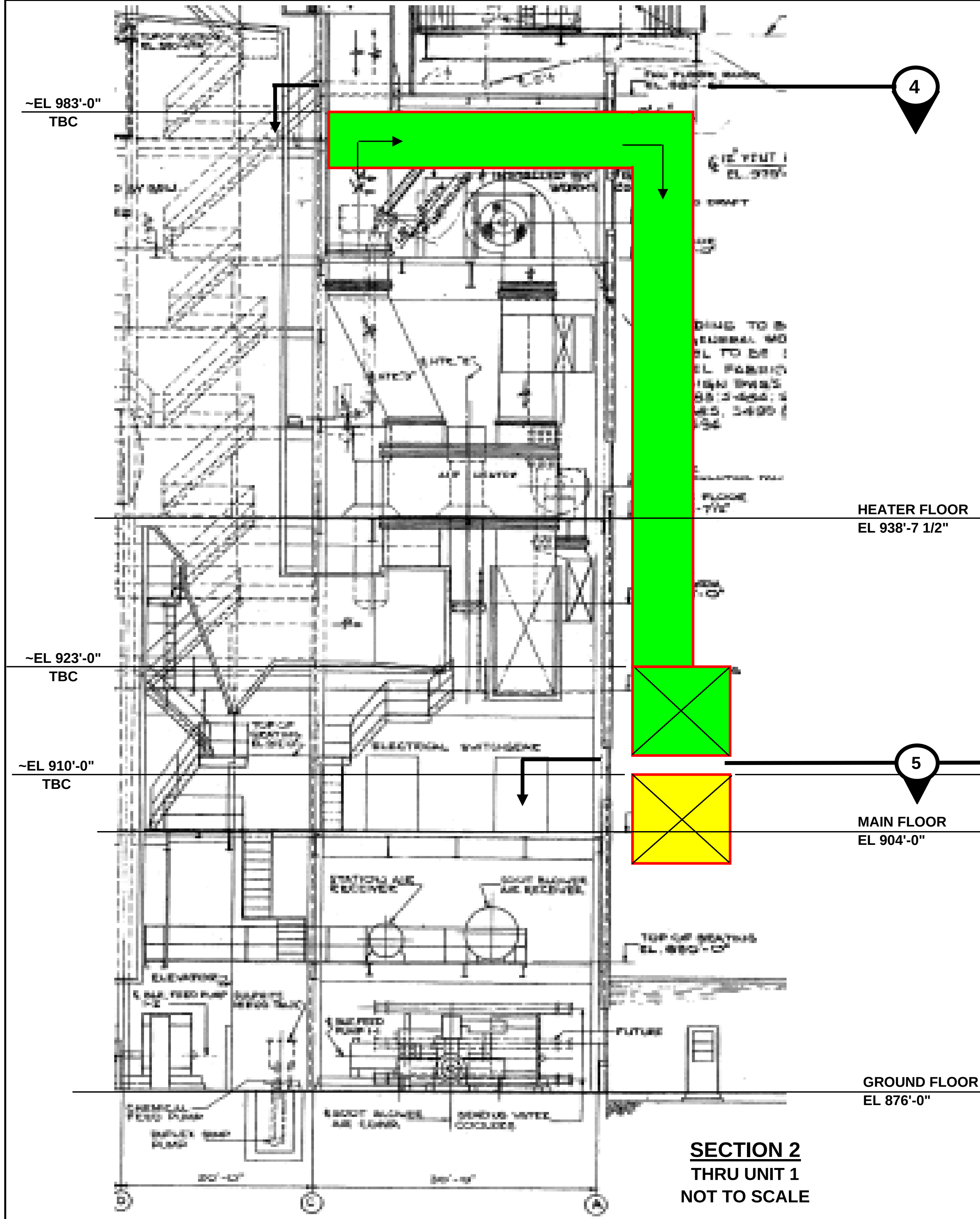

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 1
1 - 100% PJFF, 1 - 100% ID FAN PER UNIT
(EXISTING ID FAN REUSED FOR UNIT 1)
MAJOR DUCT RUNS ASSUMED AT 10.5' SQ
U1 EXHAUST DUCT UPSTREAM OF PJFF
U2 EXHAUST DUCT UPSTREAM OF PJFF
U1 EXHAUST DUCT DOWNSTREAM OF PJFF
U2 EXHAUST DUCT DOWNSTREAM OF PJFF
APPROX SCALE - FT
250' 150' 100' 50' 25' 0
25' 50' 100' 150' 250'
N
EXISTING UNIT 2 DUCT (TIE IN NEW DUCT AND REUSE IN PLACE)
EXISTING UNIT 1 ROUND DUCT (REUSE IN PLACE)
REUSE EXISTING UNIT 1 ID FAN AND DUCT FOR UNIT 1 EXHAUST
EXISTING UNIT 2 ID FANS (BYPASS)
EXISTING COAL CONVEYOR
EXISTING UNIT 1 ID FAN (REUSE IN PLACE)
DEMO OR RELOCATE CHEMICAL TANKS THIS AREA
DEMOLISH EXISTING ASH COLLECTION DUCT
AREA LEFT AVAILABLE FOR FUTURE SCRS
60'
UNIT 1 100% PJFF
40'
35'
COMMON U1/U2 ASH HANDLING EQUIPMENT AREA
70'
25'
COMMON U1/U2 ELECT EQUIPMT AREA
100'
90'
UNIT 2 100% PJFF
40'
EXISTING OFFICE BUILDING
UNIT 2 100% ID FAN
SORBENT SILOS AND TRANSFER EQUIPMENT
EXISTING PARKING LOT THIS AREA TO BE RELOCATED
PAC SILOS AND TRANSFER EQUIPMENT
CL BOILER
CL BOILER
UNIT 2
UNIT 1
1
1
2
2
3
3

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 1
SECTIONS

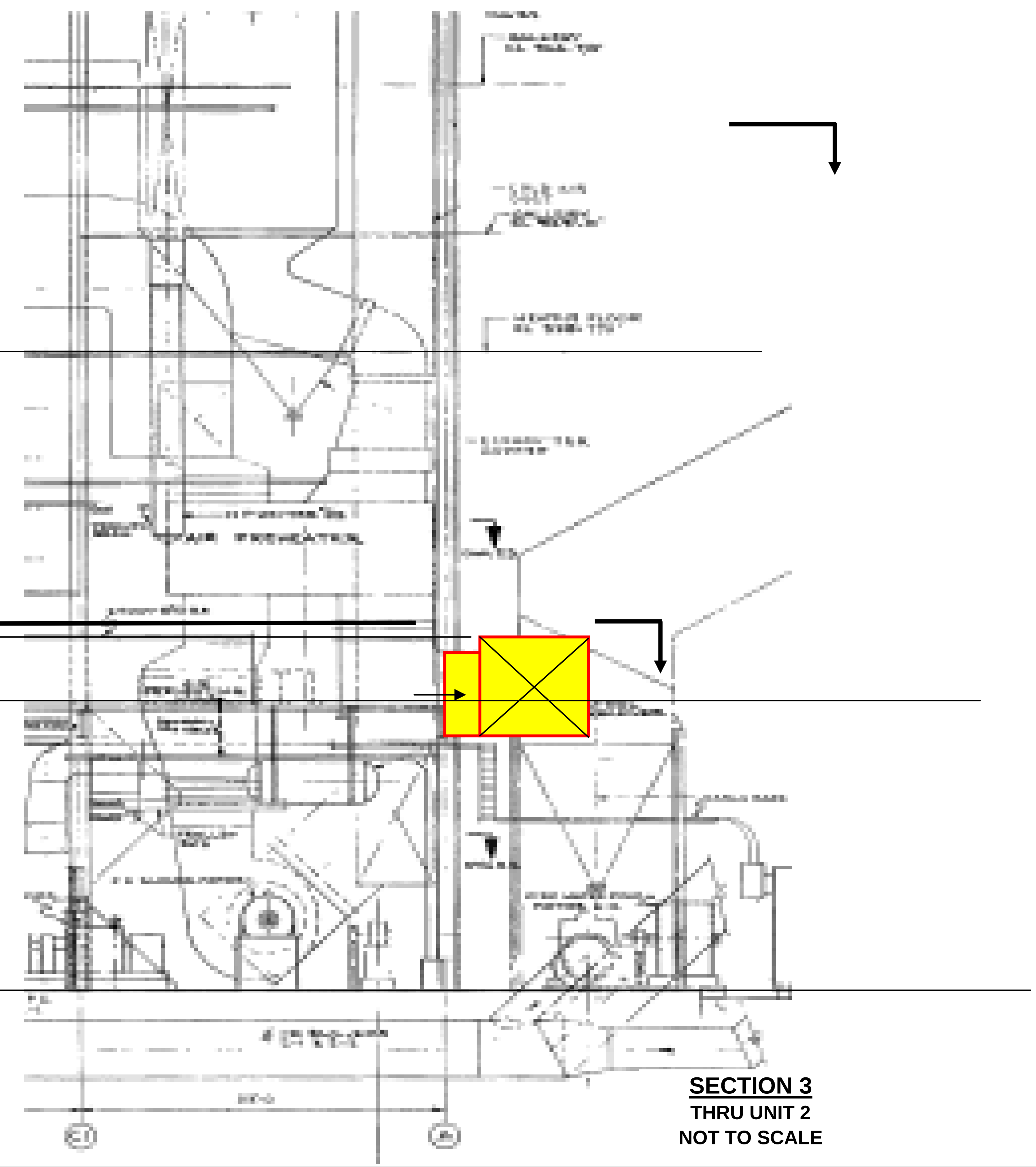


SECTION 1
UNIT 1 ELEVATION
NOT TO SCALE

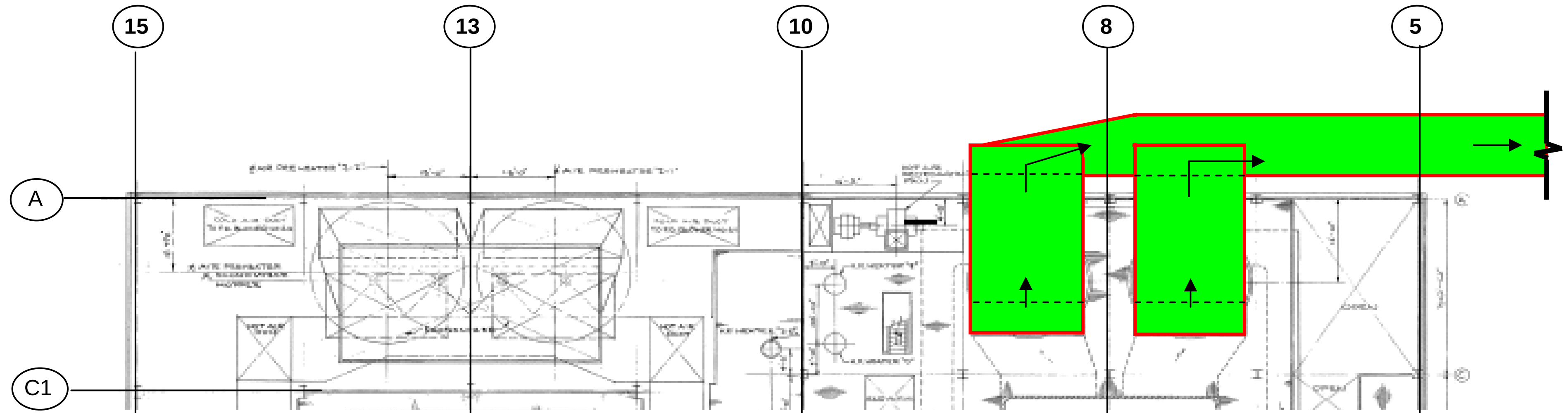
UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 1
SECTIONS



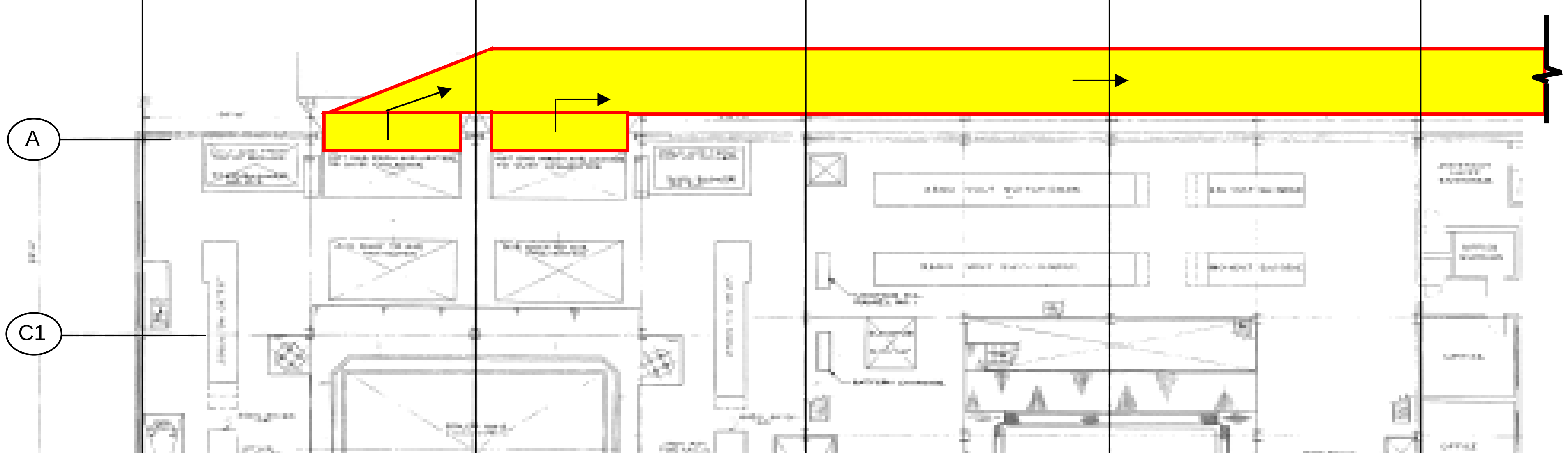
SECTION 2
THRU UNIT 1
NOT TO SCALE



SECTION 3
THRU UNIT 2
NOT TO SCALE



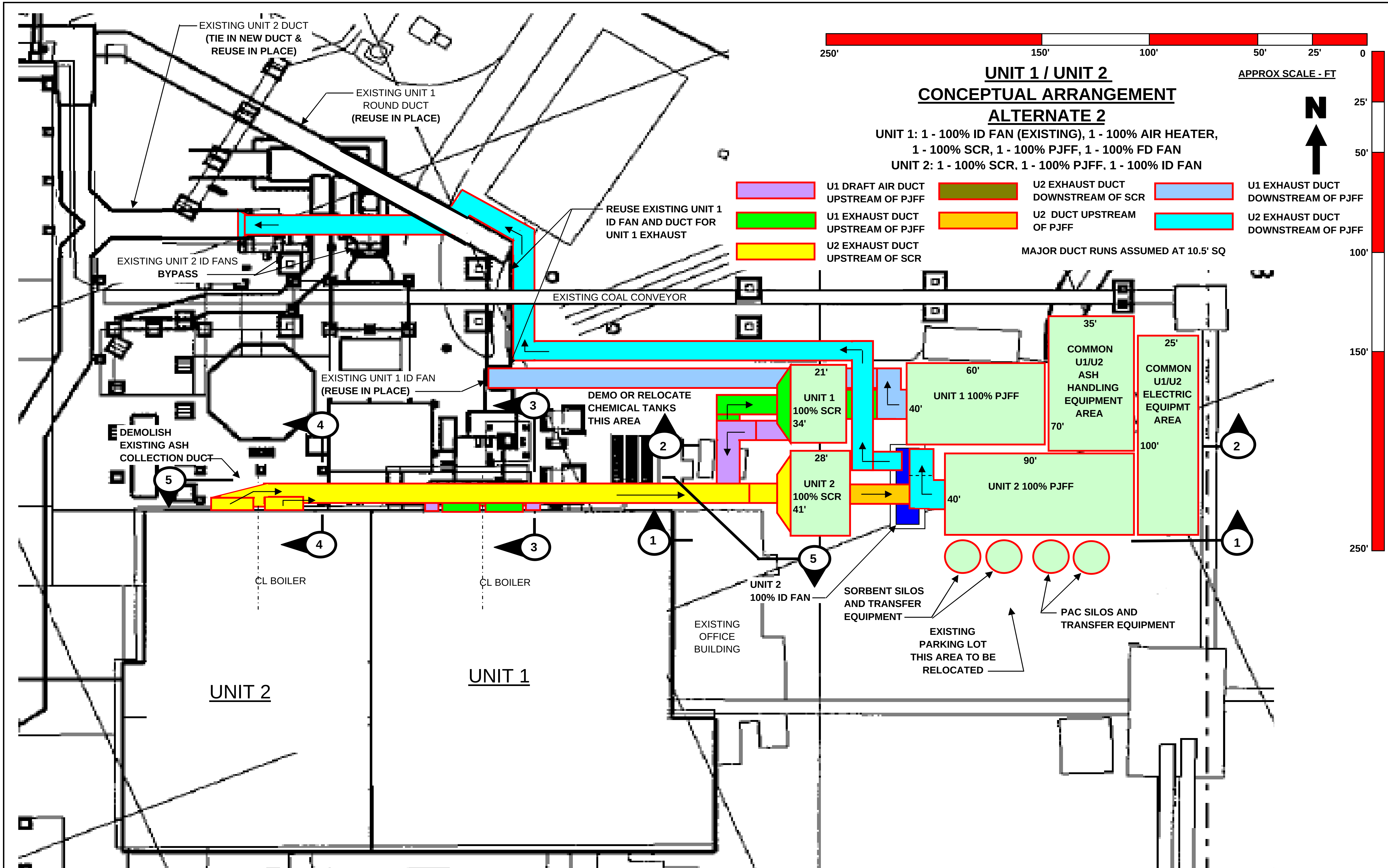
SECTION 4
NOT TO SCALE



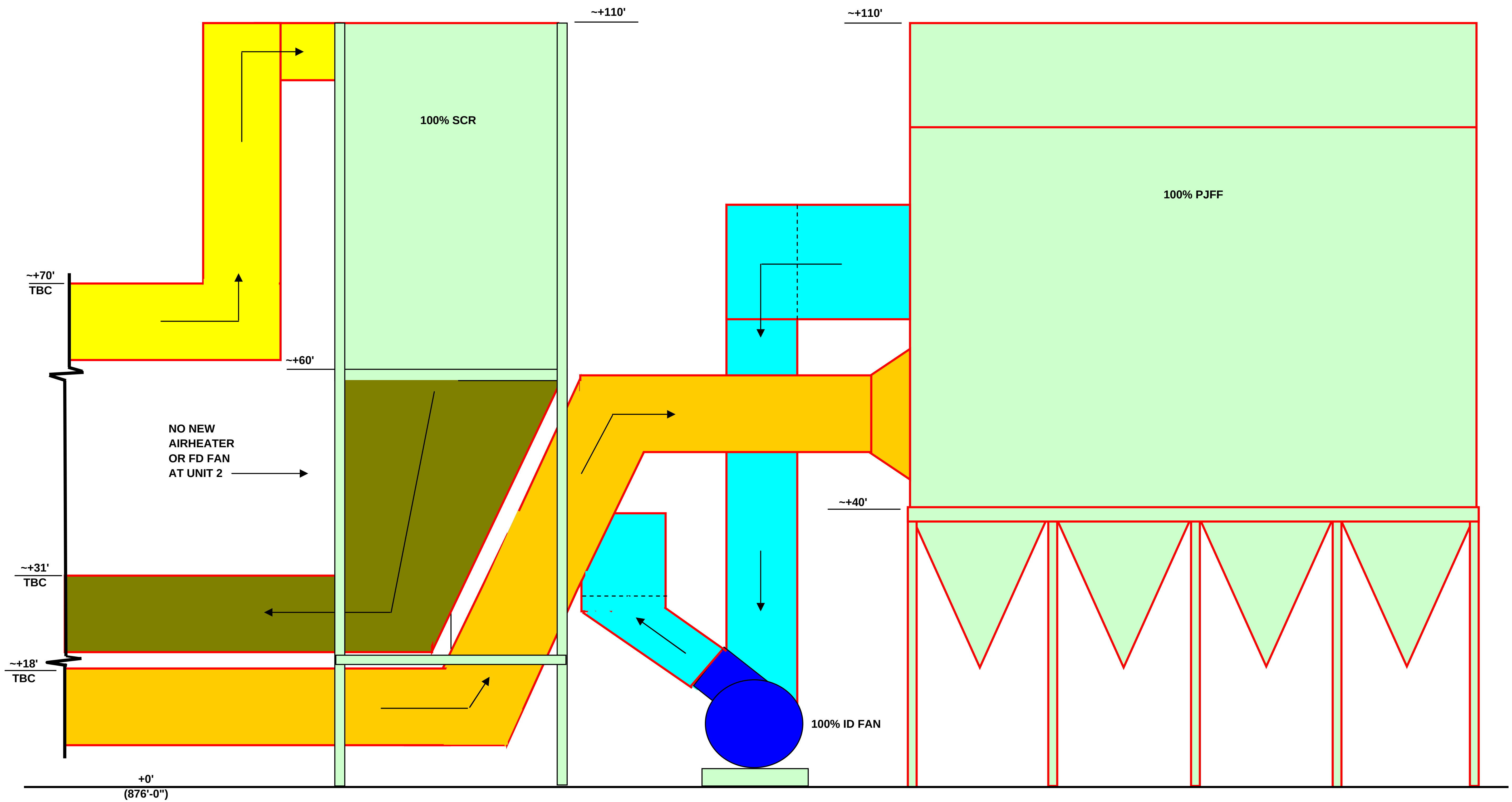
SECTION 5
NOT TO SCALE

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 1
SECTIONS

Unit 1 and 2 Arrangements with SCR at Both Units, and New Air Heater and FD Fan at Unit 1 Only



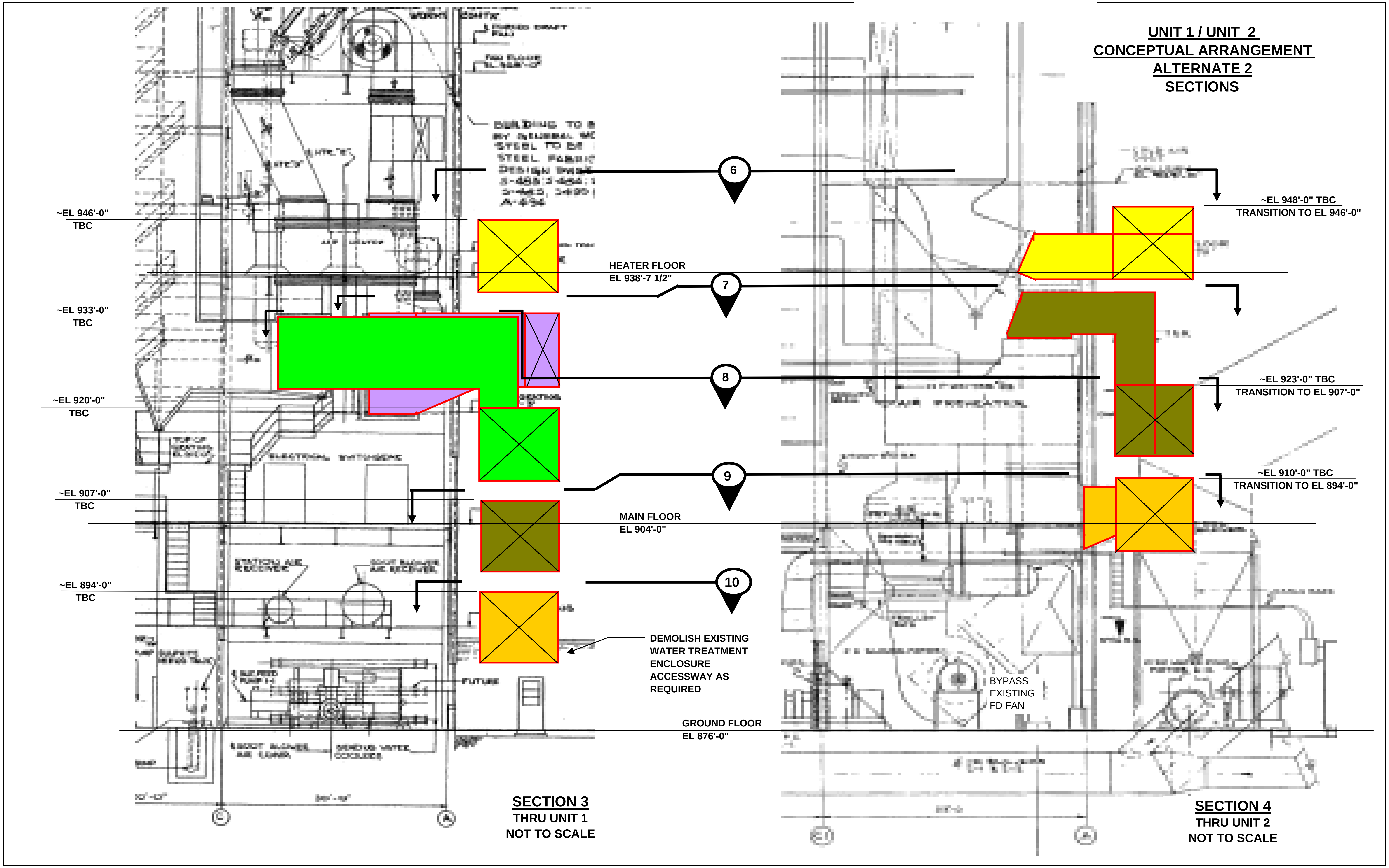
UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 2
UNIT 1: 1 - 100% ID FAN (EXISTING), 1 - 100% AIR HEATER,
1 - 100% SCR, 1 - 100% PJFF, 1 - 100% FD FAN
UNIT 2: 1 - 100% SCR, 1 - 100% PJFF, 1 - 100% ID FAN
APPROX SCALE - FT
250'
150'
100'
50'
25'
0
N
U1 DRAFT AIR DUCT UPSTREAM OF PJFF
U1 EXHAUST DUCT UPSTREAM OF PJFF
U2 EXHAUST DUCT UPSTREAM OF SCR
U2 EXHAUST DUCT DOWNSTREAM OF SCR
U2 DUCT UPSTREAM OF PJFF
U1 EXHAUST DUCT DOWNSTREAM OF PJFF
U2 EXHAUST DUCT DOWNSTREAM OF PJFF
MAJOR DUCT RUNS ASSUMED AT 10.5' SQ
EXISTING UNIT 2 DUCT (TIE IN NEW DUCT & REUSE IN PLACE)
EXISTING UNIT 1 ROUND DUCT (REUSE IN PLACE)
REUSE EXISTING UNIT 1 ID FAN AND DUCT FOR UNIT 1 EXHAUST
EXISTING UNIT 2 ID FANS BYPASS
EXISTING COAL CONVEYOR
EXISTING UNIT 1 ID FAN (REUSE IN PLACE)
DEMO OR RELOCATE CHEMICAL TANKS THIS AREA
DEMOLISH EXISTING ASH COLLECTION DUCT
UNIT 1 100% SCR
21'
34'
UNIT 2 100% SCR
28'
41'
UNIT 1 100% PJFF
60'
40'
UNIT 2 100% PJFF
90'
40'
COMMON U1/U2 ASH HANDLING EQUIPMENT AREA
35'
70'
COMMON U1/U2 ELECTRIC EQUIPMT AREA
25'
100'
UNIT 2 100% ID FAN
SORBENT SILOS AND TRANSFER EQUIPMENT
PAC SILOS AND TRANSFER EQUIPMENT
EXISTING PARKING LOT THIS AREA TO BE RELOCATED
EXISTING OFFICE BUILDING
CL BOILER
CL BOILER
UNIT 2
UNIT 1
1
2
3
4
5



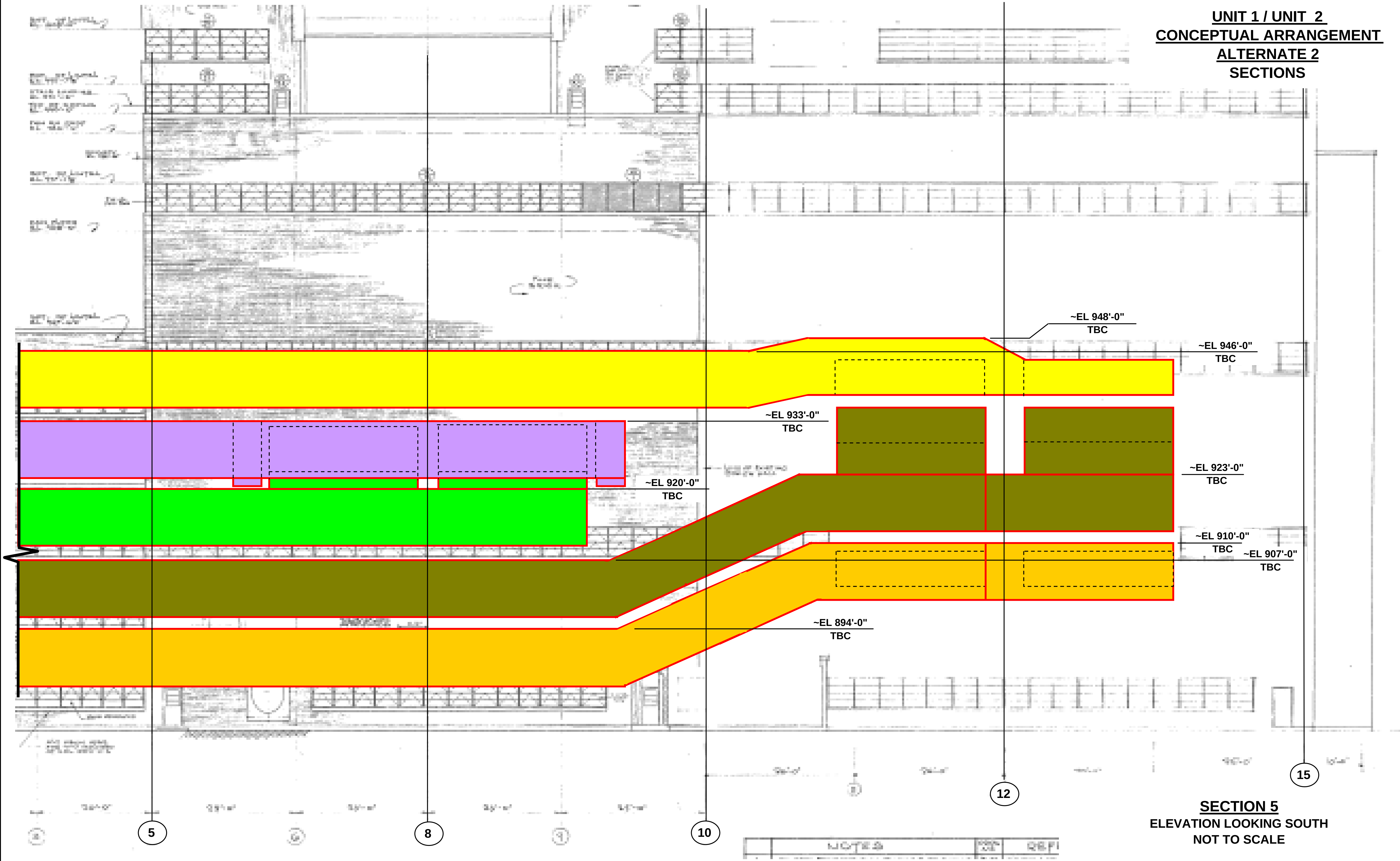
SECTION 2
THRU UNIT 1 SIMILAR TO SECTION 1 ON
ORIGINAL CONCEPTUAL ARRANGEMENT
NOT TO SCALE

SECTION 1
THRU UNIT 2
NOT TO SCALE

UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 2
SECTIONS


UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 2
SECTIONS
~EL 946'-0"
TBC
HEATER FLOOR
EL 938'-7 1/2"
~EL 933'-0"
TBC
~EL 920'-0"
TBC
~EL 907'-0"
TBC
MAIN FLOOR
EL 904'-0"
~EL 894'-0"
TBC
DEMOLISH EXISTING
WATER TREATMENT
ENCLOSURE
ACCESSWAY AS
REQUIRED
GROUND FLOOR
EL 876'-0"
6
7
8
9
10
~EL 948'-0" TBC
TRANSITION TO EL 946'-0"
~EL 923'-0" TBC
TRANSITION TO EL 907'-0"
~EL 910'-0" TBC
TRANSITION TO EL 894'-0"
BYPASS
EXISTING
FD FAN
SECTION 3
THRU UNIT 1
NOT TO SCALE
SECTION 4
THRU UNIT 2
NOT TO SCALE

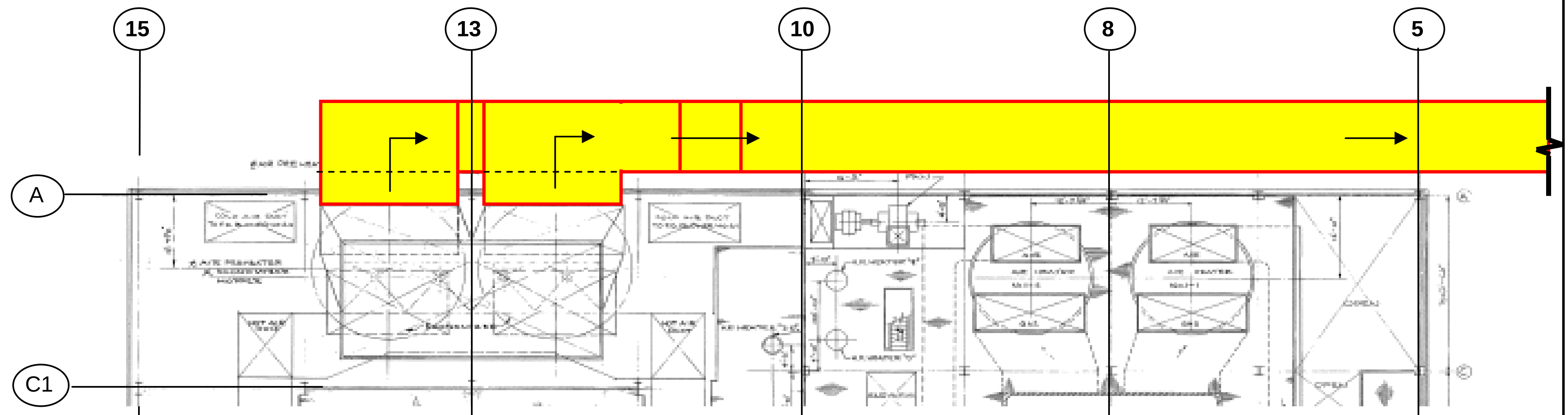
UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 2
SECTIONS



SECTION 5

ELEVATION LOOKING SOUTH

NOT TO SCALE



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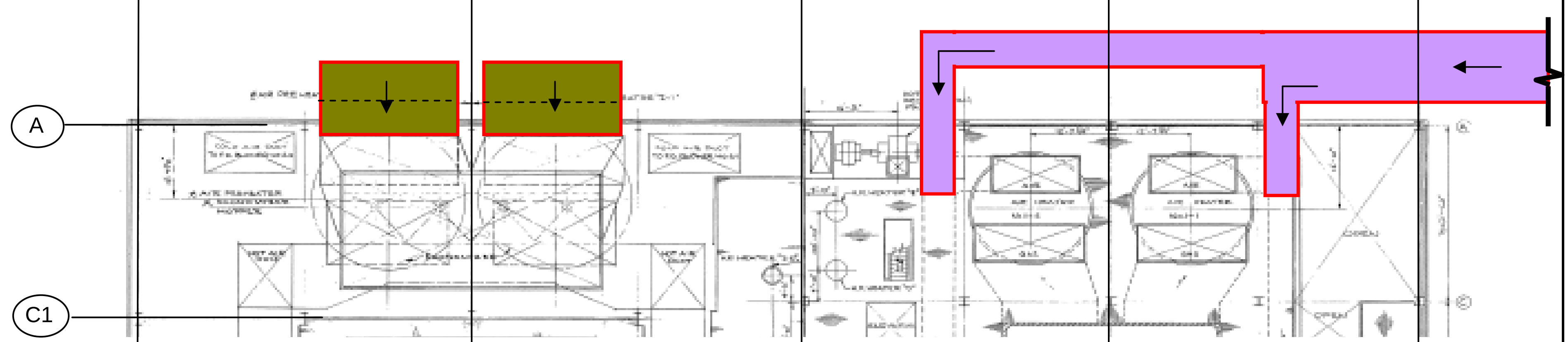

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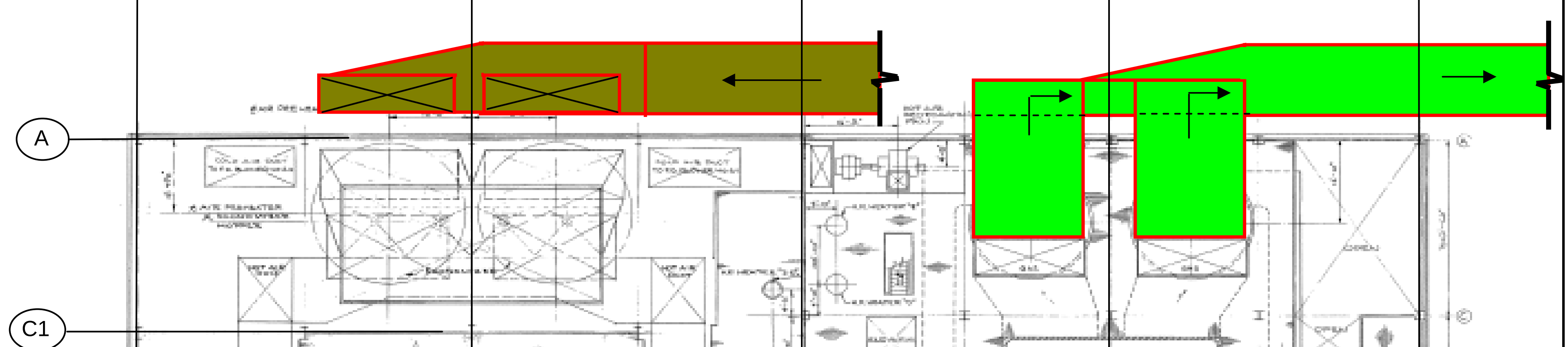
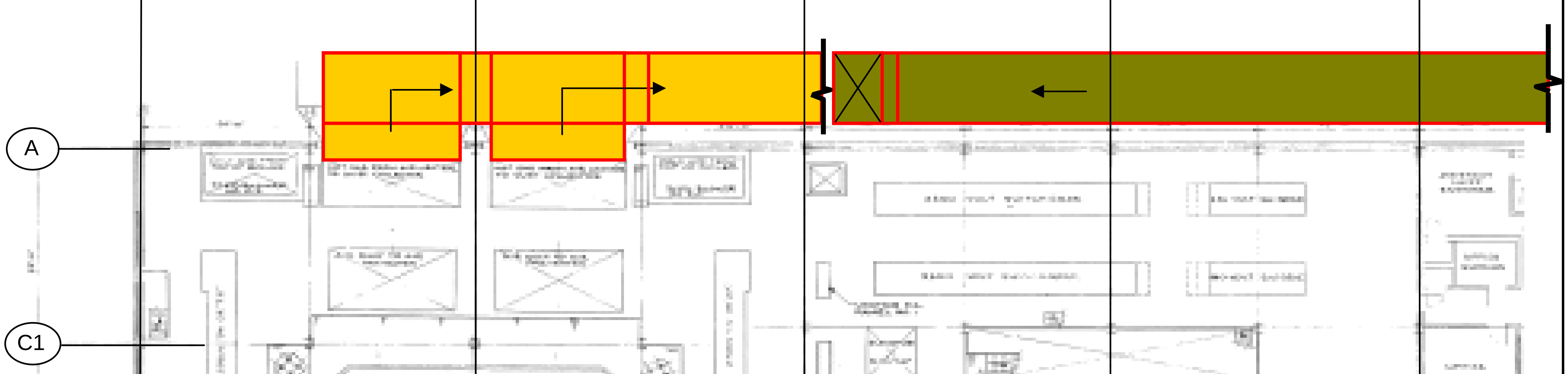
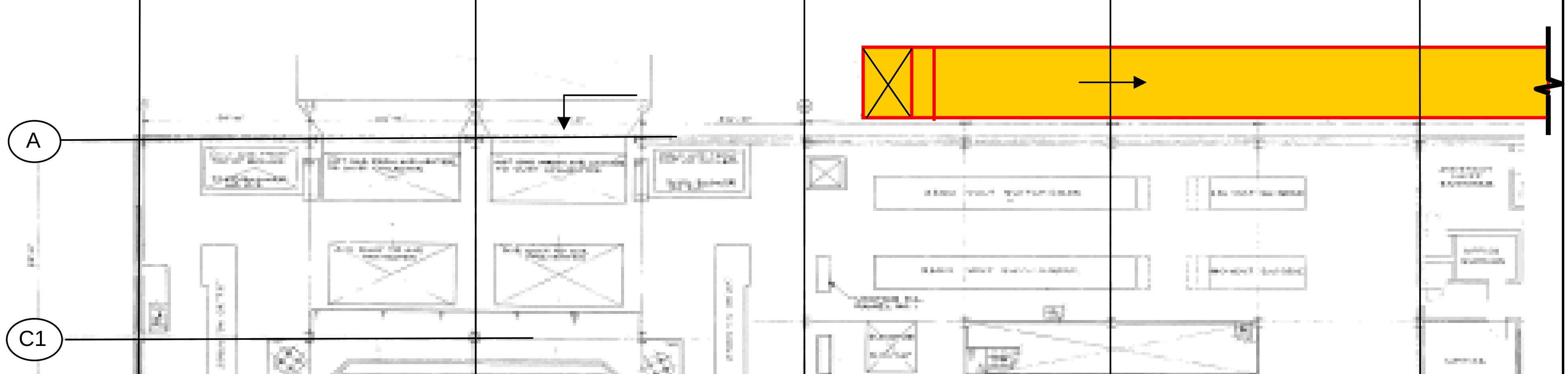


SECTION 8
NOT TO SCALE



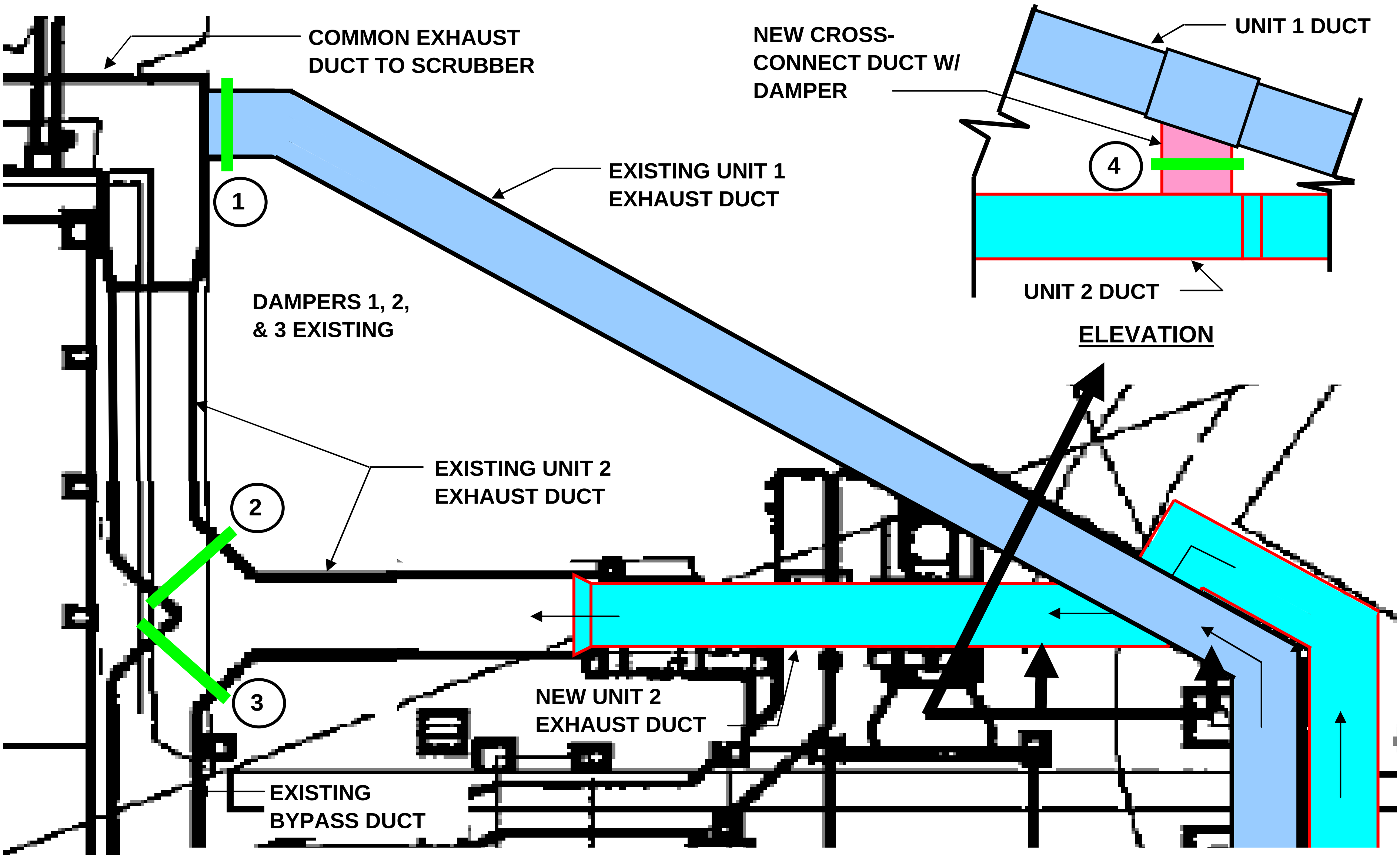
SECTION 9
NOT TO SCALE



SECTION 10
NOT TO SCALE

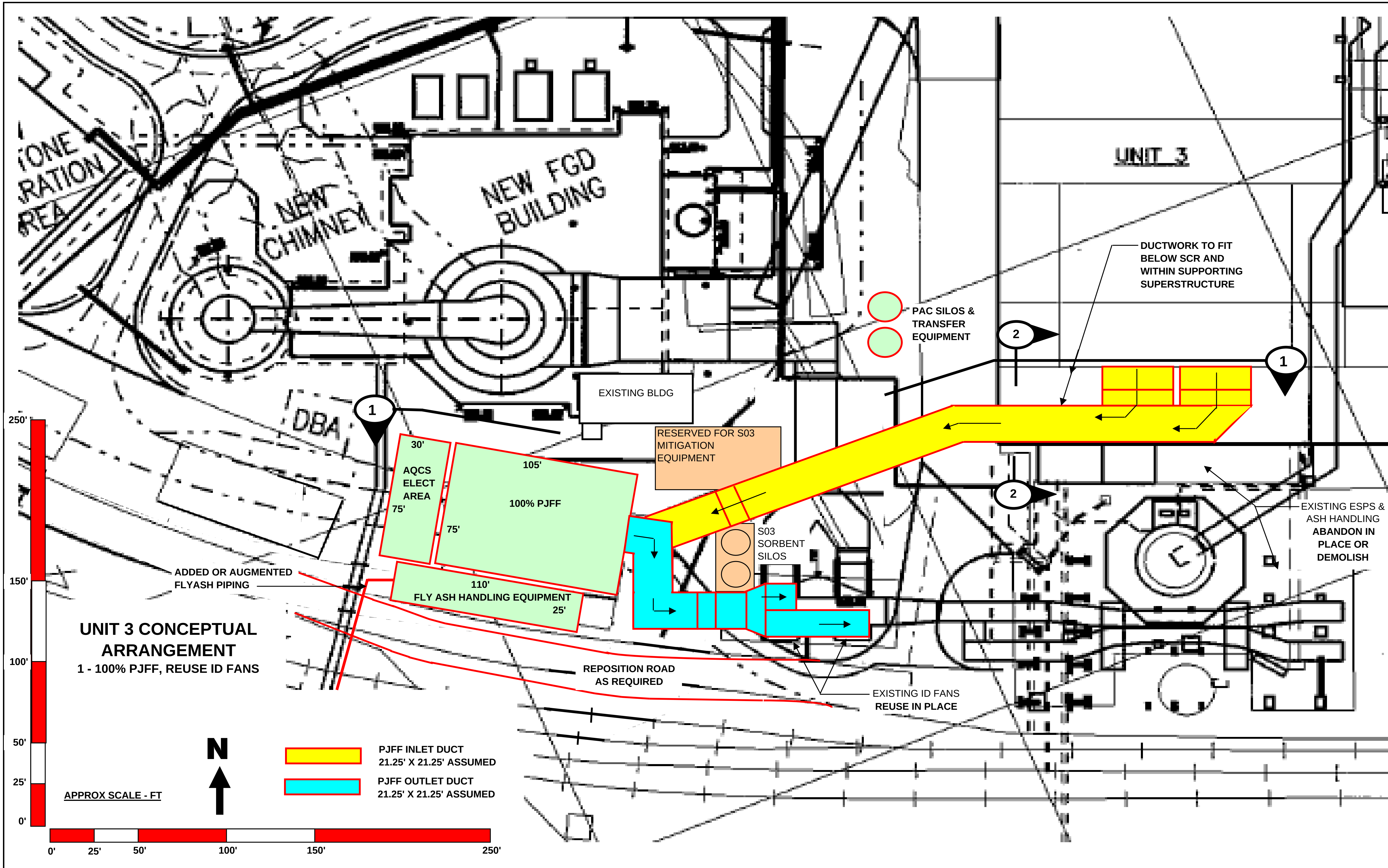
UNIT 1 / UNIT 2
CONCEPTUAL ARRANGEMENT
ALTERNATE 2
SECTIONS

Unit 1 and 2 Bypass

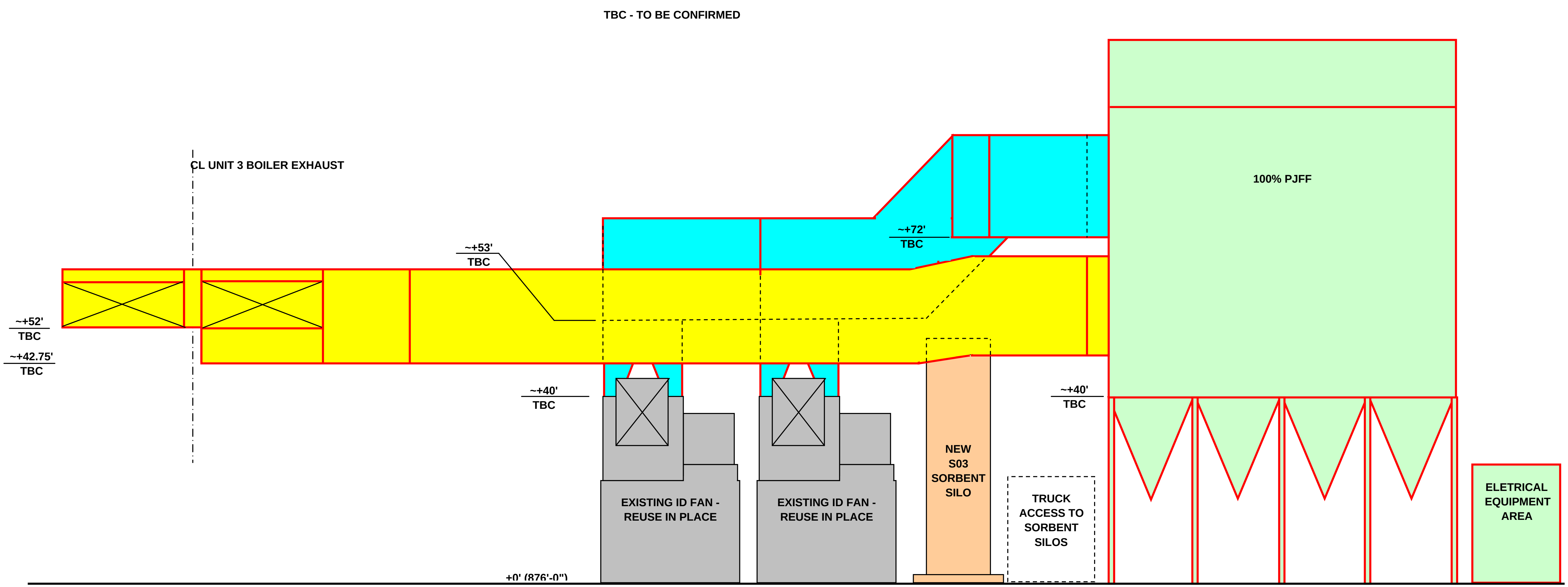


NORMAL OPERATION	UNIT 2 IN BYPASS	UNIT 1 IN BYPASS	UNITS 1 & 2 IN BYPASS
DAMPER 1 - OPEN	DAMPER 1 - CLOSED	DAMPER 1 - CLOSED	DAMPER 1 - CLOSED
DAMPER 2 - OPEN	DAMPER 2 - CLOSED	DAMPER 2 - CLOSED	DAMPER 2 - CLOSED
DAMPER 3 - CLOSED	DAMPER 3 - OPEN	DAMPER 3 - OPEN	DAMPER 3 - OPEN
DAMPER 4 - CLOSED	DAMPER 4 - CLOSED	DAMPER 4 - OPEN	DAMPER 4 - OPEN

Unit 3 Arrangement

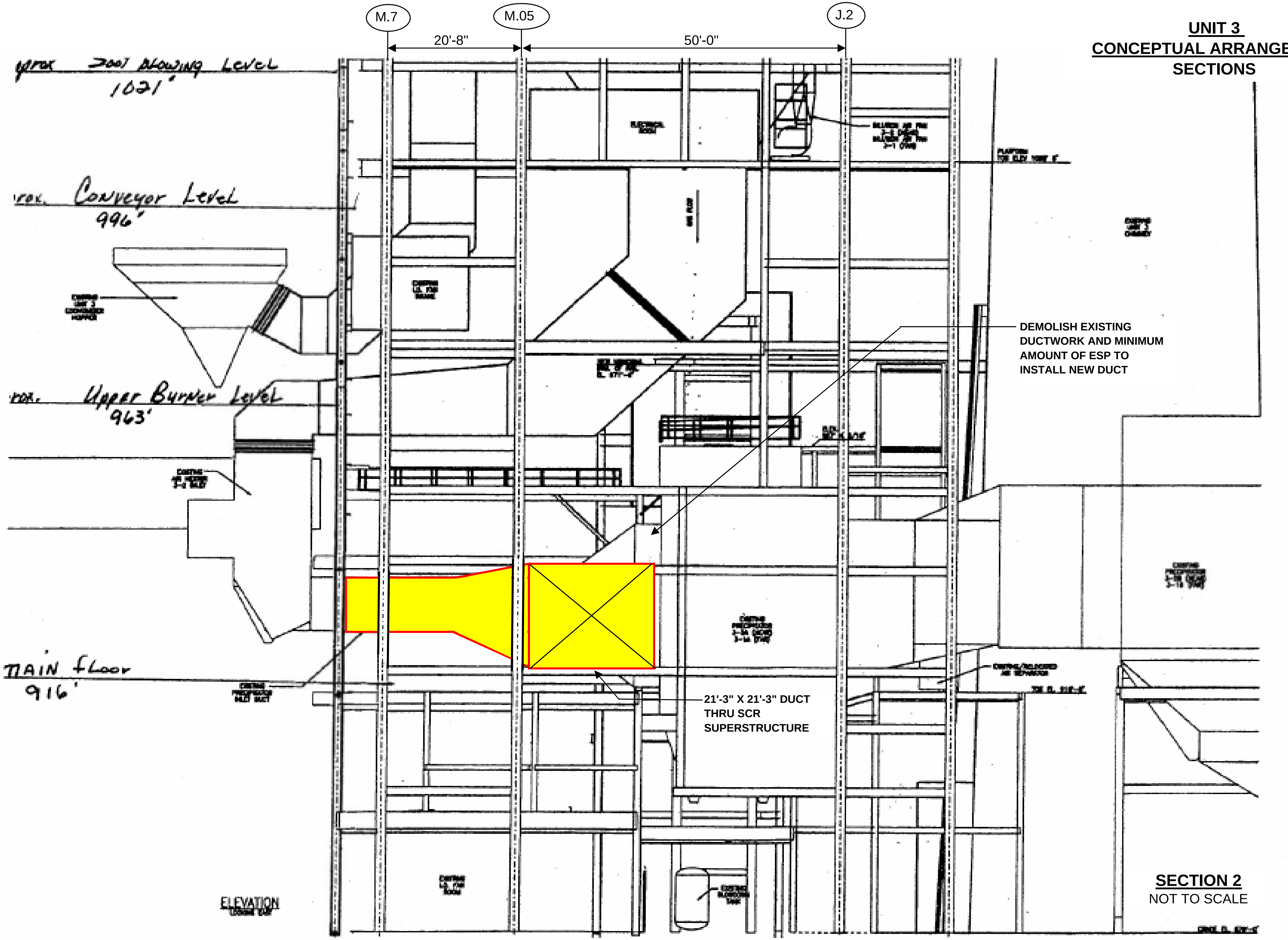

UNIT 3 CONCEPTUAL ARRANGEMENT
1 - 100% PJFF, REUSE ID FANS
NEW FGD BUILDING
NEW CHIMNEY
UNIT 3
DBA
EXISTING BLDG
RESERVED FOR S03 MITIGATION EQUIPMENT
PAC SILOS & TRANSFER EQUIPMENT
DUCTWORK TO FIT BELOW SCR AND WITHIN SUPPORTING SUPERSTRUCTURE
AQCS ELECT AREA
30'
75'
105'
100% PJFF
75'
110'
FLY ASH HANDLING EQUIPMENT
25'
S03 SORBENT SILOS
ADDED OR AUGMENTED FLYASH PIPING
REPOSITION ROAD AS REQUIRED
EXISTING ID FANS REUSE IN PLACE
EXISTING ESPS & ASH HANDLING ABANDON IN PLACE OR DEMOLISH
1
2
N
PJFF INLET DUCT 21.25' X 21.25' ASSUMED
PJFF OUTLET DUCT 21.25' X 21.25' ASSUMED
APPROX SCALE - FT
0'
25'
50'
100'
150'
250'

UNIT 3 CONCEPTUAL ARRANGEMENT SECTIONS



SECTION 1
NOT TO SCALE

UNIT 3
CONCEPTUAL ARRANGEMENT
SECTIONS



SECTION 2
NOT TO SCALE

Appendix B
Review of Constructability and Coordination Issues at Unit 3 SCR

LG&E/KU – E. W. Brown Station

Phase II Air Quality Control Study

Review of Constructability and Coordination Issues at Unit 3 SCR

January 5, 2011
Revision B – Issued For Client Review

B&V File Number 41.0803

Table of Contents

1.0 Introduction

As part of the Phase II Air Quality Control System (AQCS) modification at the E. W. Brown Station, a pulse jet fabric filter (PJFF) is proposed to be added at Unit 3. Ductwork would be routed from the existing air heaters located in the Unit 3 Boiler Building to the new PJFF, with the ductwork starting near the south side of the building and turning to the west.

In the same area south of the Unit 3 Boiler Building, LG&E/KU is currently planning to construct a selective catalyst reduction (SCR) system. The SCR is supported some distance above the ductwork proposed for the PJFF, but the ductwork would have to coexist with the structural steel supporting the SCR above.

The area beneath both the planned SCR and the proposed ductwork to the PJFF is already extremely congested, making new construction difficult. Further, only limited pre-demolition of existing obstacles is possible to avoid extended outages while the SCR and the PJFF are being constructed.

Design of the SCR and its support steel has already been initiated and somewhat detailed conceptual information and arrangements already exist. The purpose of this study is to review at a high overview level the conceptual information already developed for the SCR and supporting superstructure and confirm the compatibility of the ductwork routing proposed to the PJFF with the SCR structures. Further, this study is to develop high-level estimated loads resulting from the proposed ductwork to allow consideration of their inclusion in the SCR support steel design.

2.0 Arrangement Comparison

A conceptual design and preliminary arrangement for the SCR and its supporting structure have previously been developed by others. LG&E/KU has provided this arrangement information to allow coordination of the conceptual SCR arrangements with the ductwork routing to be considered for the Phase II Air Quality Control Study. B&V has reviewed the information and reflected it in the proposed ductwork arrangement described below.

2.1 List of SCR Information Reviewed

The following drawings containing the conceptual arrangement of the SCR and its support structure were reviewed as part of this study.

SCR General Arrangement – Riley Power Inc. Drawings

- 100468-092675100-01 – SCR General Arrangement, Plan View
- 100468-092675101-01 – SCR General Arrangement, Side Elevation View A-A
- 100468-092675102-01 – SCR General Arrangement, Elevation View B-B
- 100468-092675104-01 – SCR General Arrangement, Elevation View D-D
- 100468-092675105-01 – SCR General Arrangement, Front Elevation View E-E

SCR Support Structure – Zachry Corporation Drawings

- E013992-SCRS23610, Sheet 5, Rev A – SCR Support Structure, Isometric View
- E013992-SCRS23610, Sheet 6, Rev B – SCR Support Structure, Isometric View
- E013992-SCRS13200, Sheet 1, Rev A – SCR Support Structure, Pile Plan
- E013992-SCRS13200, Sheet 2, Rev A – SCR Support Structure, Foundation Plan

2.2 Description of Proposed Ductwork

The ductwork assumed for the Phase II Air Quality Control Study must carry the exhaust gas exiting the two Unit 3 air heaters to the inlet of the PJFF tentatively located south of the common wet flue gas desulfurization (WFGD) unit to the west. Pending confirmation required during detailed design, the two existing ducts penetrating the south wall of the Unit 3 Boiler Building are approximately 31’-9” wide by 8’-0” high, inside dimensions. Top of duct elevation is approximately El 936’-0”. New ductwork must mate to the existing ductwork at an expansion joint tentatively located just inside the

Boiler Building and extend south out of the building. The two new ducts must then turn direction to the west to avoid the existing chimney and minimize the need for demolition of the existing ESPs and ductwork to the south. At minimum, the existing ductwork between the expansion joint and the original ESP must be removed to install the new ductwork. The new ductwork may remain as two separate ducts each carrying 50% of the total unit exhaust flow or may be combined into a single 100% capacity duct extending to the PJFF inlet.

To match the existing ductwork downstream of the air heaters, the new ductwork must start as 31'-9" x 8'-0", but may then transition to a different shape. The size of the transitioned shape would be such that the minimum flow velocity through the duct would be no less than 3,500 ft/min to minimize settlement of entrained fly ash out of the flow. Velocities significantly greater than 3,500 ft/min are normally avoided to minimize erosion of the duct wall due to the fly ash particles carried in the gas stream. Based on the expected exhaust flow at Unit 3 and the recommended flow velocity, the open flow area of the ductwork routed to the PJFF should total approximately 460 square feet.

Ideally, to minimize frictional losses through the ductwork, round ductwork would be specified. However, round ductwork of this size is difficult to support and extremely difficult to fabricate in transitions or turns. The installed cost of large round ductwork is therefore relatively high. Accordingly, most exhaust gas ductwork is rectangular in shape; with the most efficient non-round shape approximately square (its "aspect ratio" of height vs. width ideally approaching 1.0). Rectangular ductwork of other aspect ratios can obviously be used, providing the associated frictional losses are reflected in the design.

Thus at Unit 3, the exhaust ductwork would ideally transition from the 31'-9" x 8'-0" shapes to two rectangular shapes approximately 15'-3" square inside dimension if the two-duct configuration is maintained or to a 21'-6" square inside dimension if the two ducts are combined into one.

Exhaust ductwork is constructed of welded steel plate to maintain a gastight conduit. To minimize the thickness of the plate used and thus decrease both its cost and the loads on supports, ductwork is commonly made up of thin plate (1/4" to 3/8") stiffened with steel beam or channel sections to provide the necessary strength to carry design loads. In addition, hot ductwork is normally covered with insulation and lagging to prevent heat loss to the environment as well as for personnel protection. The thickness of the stiffeners and insulation must be added to the theoretical open height by width of the duct to determine an acceptable routing without interferences. For this ductwork an 18-inch allowance was added all around to the theoretical dimensions to account for stiffeners and insulation.

Ductwork can be supported either from below by a steel superstructure on a foundation or hung from above if suitable superstructure is available. The ductwork is anchored at a fixed point and designed to expand and contract due to the hot gases within in all directions from that "point of zero movement."

The description above was used as the basis for a conceptual design of ductwork to be routed beneath the SCR.

2.3 Impact of SCR Structure on Ductwork Routing

From the Riley drawings review, it appeared that all components of the SCR equipment itself south of the Unit 3 Boiler Building are located above El 956'-7". Accordingly, if the ductwork is kept below that elevation, it should not interfere with any part of the SCR itself. The new ductwork is tentatively routed with the interior surface of the duct no higher than El 940'-0". With the additional 18 inch allowance for stiffeners and insulation noted in Section 2.2, the top of the ductwork envelope should be no higher than El 941'-6". It appears that the new ductwork should not interfere with the SCR equipment above.

The two Zachry isometric drawings were reviewed to determine the extent of the superstructure supporting the SCR. These drawings are undimensioned and do not contain member size information. The review was completed based on dimensions from other drawings and under the assumption the isometric drawings are somewhat to scale.

Likely because of the difficulty of installing foundations in the congested, low-clearance area beneath the existing ductwork, Zachry laid out the SCR support structure to "bridge" across this area. Large "legs" consisting of heavily-braced column steel support the bridge at the corners outside the footprint of obstructions above, plus two more legs located in the center of the area at the north and south edges. The bridge steel is composed of several layers, but no layer appears to extend below the El 945'-0" elevation at the north-south truss along Column Line 22. Again, as currently routed, the ductwork should not interfere with the horizontal steel supporting the SCR.

The northwest leg of the support structure consists of a braced tower that extends to approximately 30'-0" south of N-line in the Boiler Building. It is unlikely that bracing in this tower could be removed to allow passage of a duct between the tower columns without seriously compromising the tower's structural integrity. Accordingly, it is assumed that the duct routed west from the area under the SCR must be located south of the tower to avoid interference. The clearance to the tower in the southwest corner is over 40 feet, leaving plenty of room in between in which to route the ductwork.

The isometric drawing shows a kneebrace structure on both towers on the west side of the support, intruding on the open area between the towers. The function of the kneebraces is not apparent from the drawings reviewed, but the kneebraces appear to extend no higher than approximately El 916’-0”.

From the information provided, it appears that there is adequate room to route ductwork from the air heaters towards the PJFF without interfering with the SCR or the support structure. The duct should extend no higher than El 945’-0”, no lower than El 916’-0”, and be routed as close as practical south of the columns at Column Line SCR-D.

2.4 Proposed Ductwork Routing

A tentative conceptual ductwork arrangement meeting the above requirements is shown on the sketches included in Appendix A. Reference Sketch 1 for a plan view of the arrangement and Sketch 2 for elevations illustrating the relationship between the ductwork and other structures. All elevations and dimensions are preliminary and must be confirmed as design of the SCR and support structure is completed.

Two ducts sized to match the existing ductwork exiting the air heaters extend south from the Boiler Building. Nominal top of duct interior is El 936’-0”, with an allowance for stiffeners and lagging, El 937’-6”. This is well below the expected SCR support structure at El 945’-0”.

The two ducts transition into a combined duct running east-west with an interior size of 21’-6” x 21’-6”. Nominal top of duct interior is El 940’-0”; nominal bottom of duct interior is El 918’-6”. With an allowance for stiffeners and lagging all around, the insulated duct envelope would extend from El 941’-6” to El 917’-0”. Again, the duct should clear the SCR support structure steel top and bottom. The duct would end in another expansion joint located just outside the footprint of the SCR support structure to allow expansion of the ductwork as well as isolation of loads from ductwork downstream.

The north interior surface of the 21’-6” square duct is located 31’-0 1/2” south of N-line, making the south interior surface 52’-6 1/2” south of N-line. With the 18 inch clearance all around, the insulated duct should lie between 29’-5 1/2” south of N-line to 54’-0 1/2” south of N-line. This should clear the columns of the support structure tower at Column Line SCR-D. However, it will interfere with the existing original ESP located approximately 47’-0” south of N-line. That will require the original ESP to be at least partially demolished to allow installation of the ductwork.

The conceptual ductwork sketch shows an abrupt transition between the two rectangular and single common square ducts. At final design the duct will actually be designed with a more gradual transition between the two sizes of duct to minimize disturbances to the flow and unnecessarily high friction losses. Final duct configuration would be based on the results of flow modeling. But for purposes of demonstrating general size and orientation of the proposed duct, the approximate arrangement shown in the sketch is deemed adequate.

The duct could be supported from below on its own dedicated support framing. As indicated on the Zachry foundation drawings, the foundations currently existing in the area beneath the duct are extensive and congested. Moreover, the existence of the ductwork overhead would significantly interfere with installation of foundations below. As done with the SCR support structure, the ductwork could be supported on a trussed "bridge" to minimize the number of individual foundations required. However, the foundations supporting the ends of the bridge would, by necessity, be much heavier and more complex. Tentative foundation locations for a dedicated ductwork support framing are shown on Sketch 3 in Appendix A.

As an alternative to a separate ductwork support structure and additional foundations in an already congested area, consideration could be given to supporting the new ductwork off the planned SCR support structure. The SCR support structure would have to be modified during design to carry the additional load. The expected additional load would need to be estimated to allow LG&E/KU to consult with the SCR support structure designer to determine the practicality of this approach.

2.5 Estimated Ductwork Loads on SCR Support Structure

Estimates of the gravity (vertical) loads inherent in the proposed ductwork arrangement are included in Table 2-1. Loads are provided both on a per-linear-foot basis and on a total by-ductwork-section basis. Since the SCR support structure designer must determine where the best ductwork support points in his structure are located, it is believed that the per-linear-foot loads will allow him to apportion the loads appropriately among the selected support points. The ductwork sections noted in the table below are delineated in Sketch 1. The intent of providing the preliminary estimated loads is to allow consideration of the feasibility and cost effectiveness of adding support of the ductwork to the design of the SCR. Should the initial evaluation prove promising, more detailed design of the ductwork would be required to confirm the arrangement and the resulting loads.

Depending on the building code used in the design, loads of different types (dead load, live load, etc.) are incorporated into design equations differently. Accordingly, the loads listed in Table 2-1 are broken into categories for the designer's use in the design equations as follows.

- Dead Load. This is the gravity load of the plates, stiffeners, and integral support steel making up the ductwork itself. It can also be considered the "reliable" dead load available to resist uplift under overturning load cases.

- Insulation and Lagging Load. This is an allowance for the weight of the insulation and outer metal lagging on the ductwork exterior. It is broken out separately but is usually treated as a dead load for gravity load design. It is, however, often not considered as "reliable" dead load for uplift conditions since it is an allowance only.
- Live Load and Snow Load. Depending on the building code design combinations, live load and snow load are used somewhat interchangeably. An estimate was made for both live load and snow load and a single value included covering both. This load is applied only to the top surface (roof) of the ductwork.
- Ash Load. No matter how well proportioned the ductwork, some fly ash carried by the exhaust gas will settle out of the flow and accumulate on the floor of the ductwork. The ductwork proposed contains several direction changes and shape changes, both of which contribute to ash drop-out and accumulation. A fairly significant allowance is included in Table 2-1 to cover ash accumulation on the ductwork floor. Ash is also considered as dead load for gravity conditions but cannot be considered as "reliable" dead load against uplift.

It should be noted that wind and seismic loads are not included in the table. Determination of wind and seismic loads are dependent on the support arrangements and locations as well as the method used to design the SCR support structure. Should the initial evaluation using gravity loads warrant it, wind and seismic loads can be developed as part of the more detailed design. In any case, the relatively small, light, and lower-elevation ductwork should generate far less horizontal wind and seismic loads than those resulting from the SCR above.

Table 2-1
Loading Summary for Proposed Ductwork
Reference Attached Sketches for Duct Section Identification

Description	Section of Duct			
	Section 1A	Section 1B	Section 2	Section 3
Interior Dimension Width, ft	31.75	31.75	21.5	N/A
Interior Dimension Height, ft	8.00	8.00	21.5	N/A
Total Length, ft	30.0	30.0	133.0	N/A
Surface Area per linear foot, sf*	254	254	462	N/A
Surface Area over Total Length, sf	7,620	7,620	61,479	1130
On Per Foot Basis				
Dead Load of 30 psf, klf	7.6	7.6	13.9	N/A
Insulation/Lagging of 10 psf, klf	2.5	2.5	4.6	N/A
Live/Snow Load of 20 psf, klf	0.6	0.6	0.4	N/A
Ash Load of 100 psf, klf	3.2	3.2	2.2	N/A
Total Load Per Foot Length, klf	13.9	13.9	21.1	N/A
On Total Length Basis				
Dead Load of 30 psf, k	229	229	1,814	34
Insulation/Lagging of 10 psf, k	76	76	615	11
Live/Snow Load of 20 psf, k	19	19	57	3
Ash Load of 100 psf, k	95	95	286	17
Total Load Per Section, k	419	419	2,772	65
Total Load Overall, k	3,675			

* The eliminated wall area in Section 2 duct due to the intersection of the Section 1 runs are ignored in the per foot calculation and reflected only in the total surface area.

3.0 Summary of Investigation

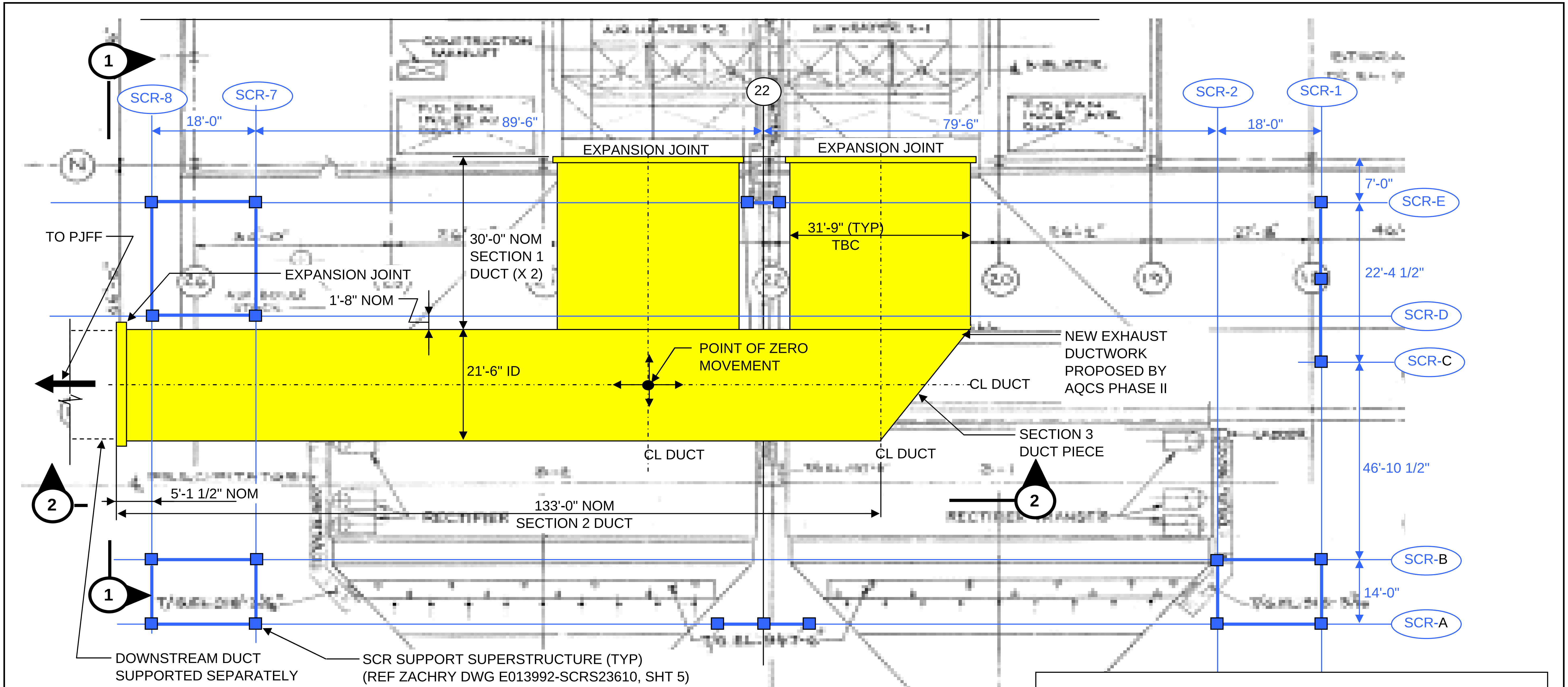
Based on the information reviewed, it appears reasonable to assume that exhaust ductwork from the Unit 3 air heaters to the new PJFF can be successfully routed beneath the planned SCR and through the supporting structure beneath. This investigation is based on conceptual information only and would have to be confirmed as additional information on the design of the SCR and its supports becomes available. The preliminary investigation concludes that sufficient space is available to accommodate the expected ductwork. However, it is likely that the existing (and to be bypassed) ESP immediately south of the Unit 3 Boiler Building will have to be demolished before the ductwork can be installed.

To avoid the costly and schedule-intensive work of installing a separate ductwork support structure and its foundations in the area, consideration should be given to supporting the new ductwork from the structure planned for supporting the SCR. This will require further investigation by LG&E/KU and the SCR support structure designer to verify the feasibility of this approach. Supporting the ductwork from the SCR support structure will likely result in some redesign, and associated cost increases, to that scope. To allow determination of the conceptual feasibility of this approach, high level approximate loads for the proposed ductwork were developed for the SCR designer's information and use. The loads are contained in Table 2-1, within.

Should a preliminary evaluation of the estimated loads conclude that incorporating support of the new ductwork into the support structure carrying the SCR is warranted, additional design work and coordination with the SCR support designer is recommended. The preliminary ductwork design described herein should be refined and more exact determination of expected loads at specific load points chosen by the SCR support structure designer should be completed.

Appendix A
Conceptual Sketches

Ductwork/SCR Interface – Plan View



NOTES:

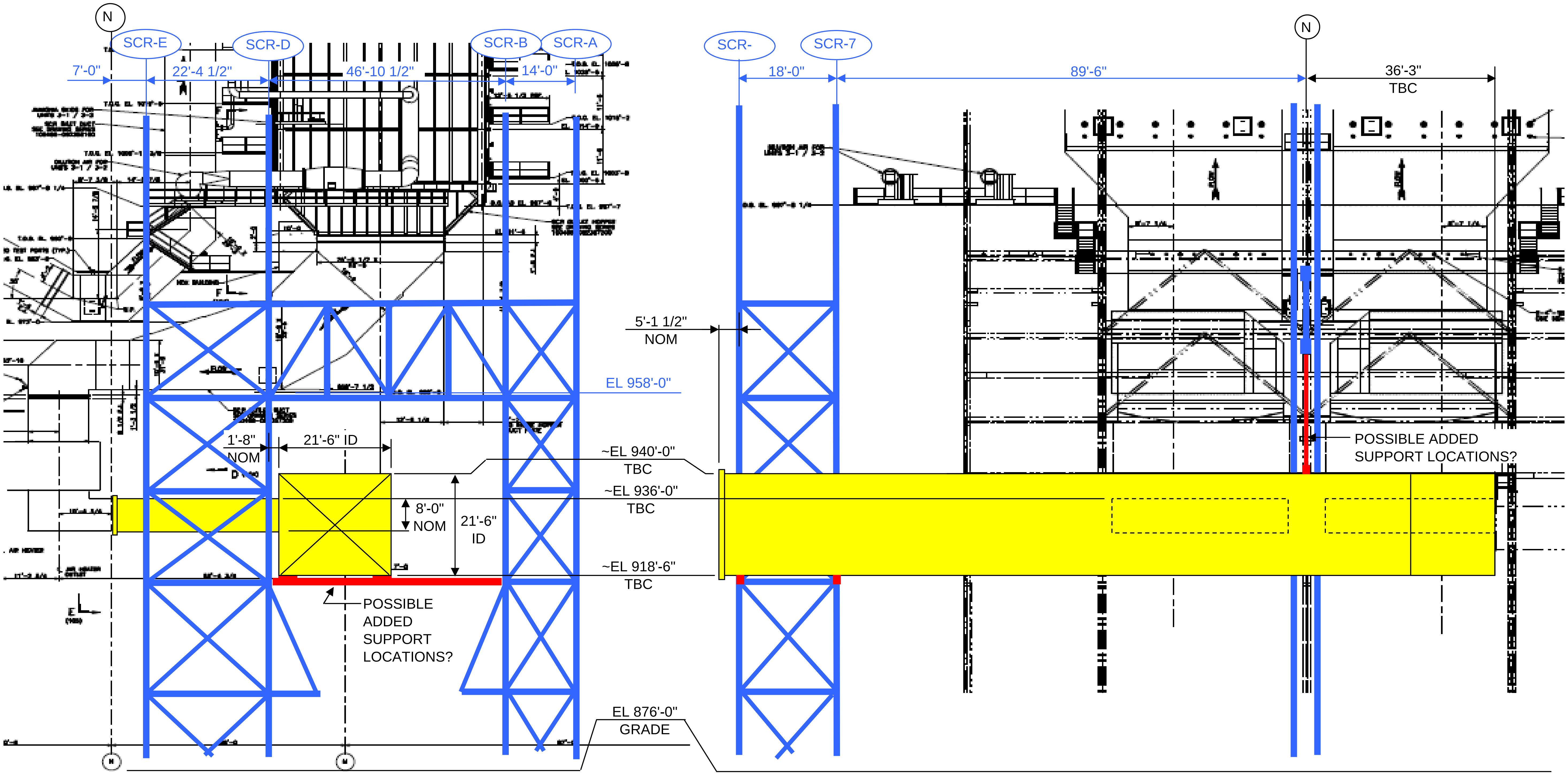
1. THIS DRAWING IS INTENDED TO PROVIDE AN APPROXIMATE ARRANGEMENT AND THE RELATIONSHIP BETWEEN NEW PROPOSED DUCTWORK AND THE SUPPORT SUPERSTRUCTURE CARRYING THE UNIT 3 SCR.
2. THE LOAD SUMMARY APPRXOXIMATES THE GRAVITY LOADS THAT WOULD RESULT ON A STRUCTURE SUPPORTING THE DUCT, BOTH ON A TOTAL AND PER LINEAR FOOT OF LENGTH BASIS.

"TBC" - TO BE CONFIRMED

APPENDIX A
CONCEPTUAL SKETCH 1
DUCTWORK/SCR INTERFACE - PLAN VIEW

LOAD SUMMARY	K PER LF	K TOTAL
SECTION 1 (TYP OF 2)		
DEAD LOAD INCLUDING INSULATION	10.1	305
LIVE/SNOW LOAD	0.6	19
ASH ALLOWANCE LOAD	3.2	95
SECTION 2		
DEAD LOAD INCLUDING INSULATION	18.5	2429
LIVE/SNOW LOAD	0.4	57
ASH ALLOWANCE LOAD	2.2	286
SECTION 3		
DEAD LOAD INCLUDING INSULATION	N/A	45
LIVE/SNOW LOAD	N/A	3
ASH ALLOWANCE LOAD	N/A	17

Ductwork/SCR Interface – Elevations



SECTION 1-1

SECTION 2-2

NOTES:

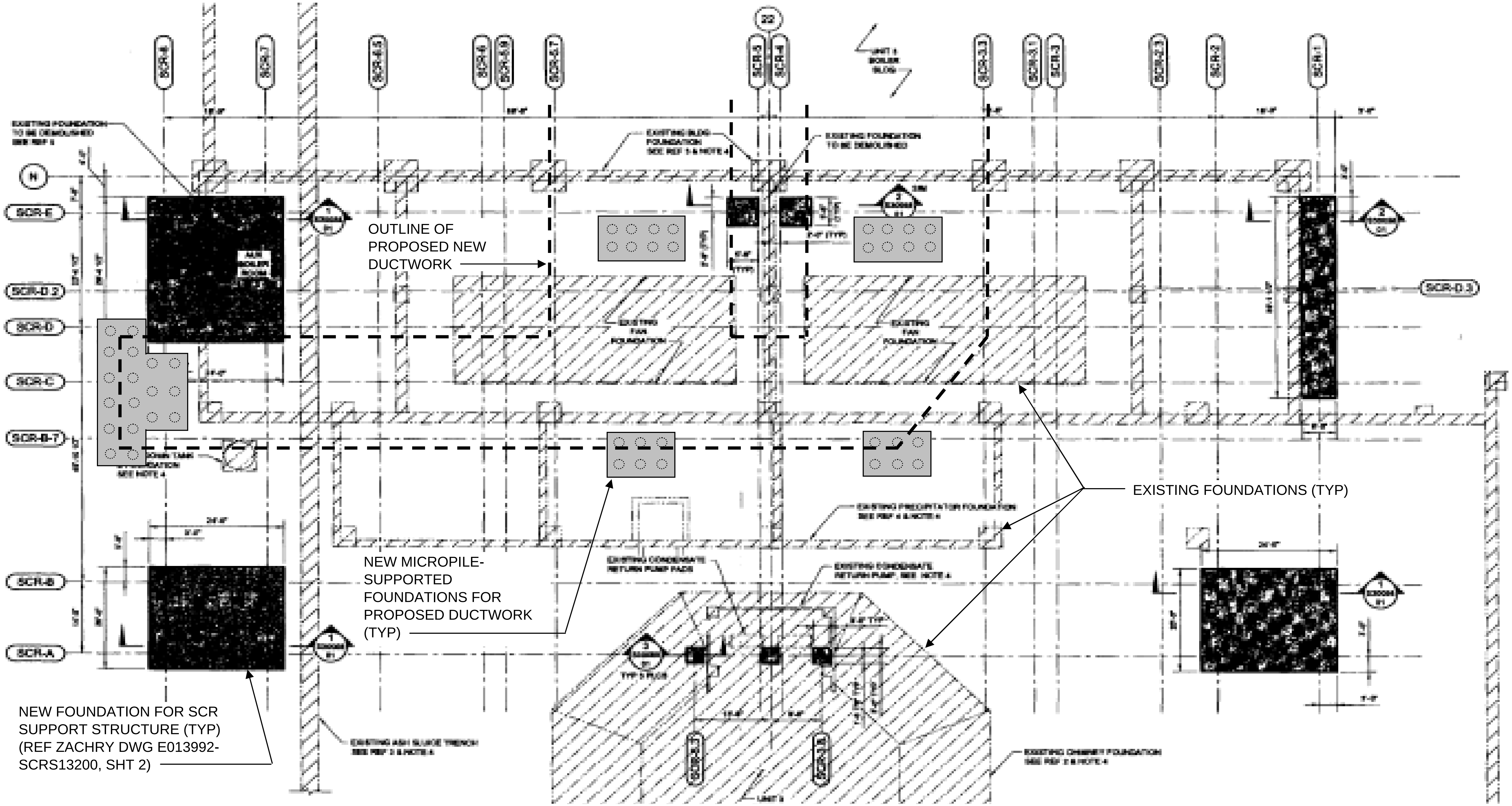
1. THIS DRAWING IS INTENDED TO PROVIDE AN APPROXIMATE ARRANGEMENT AND THE RELATIONSHIP BETWEEN NEW PROPOSED DUCTWORK AND THE SUPERSTRUCTURE CARRYING THE UNIT 3 SCR.
2. POSSIBLE DUCTWORK SUPPORT LOCATIONS ARE NOTED FOR CONSIDERATION.

APPENDIX A

CONCEPTUAL SKETCH 2

DUCTWORK/SCR INTERFACE - ELEVATIONS

Ductwork/SCR Interface – Foundations



APPENDIX A

CONCEPTUAL SKETCH 3

DUCTWORK/SCR INTERFACE - FOUNDATIONS

NOTES:

1. THIS DRAWING IS INTENDED TO ILLUSTRATE A CONCEPTUAL RELATIONSHIP BETWEEN EXISTING, SCR, AND DUCTWORK FOUNDATIONS SHOULD THE DUCTWORK NOT BE SUPPORTED BY THE SCR SUPPORT STRUCTURE.