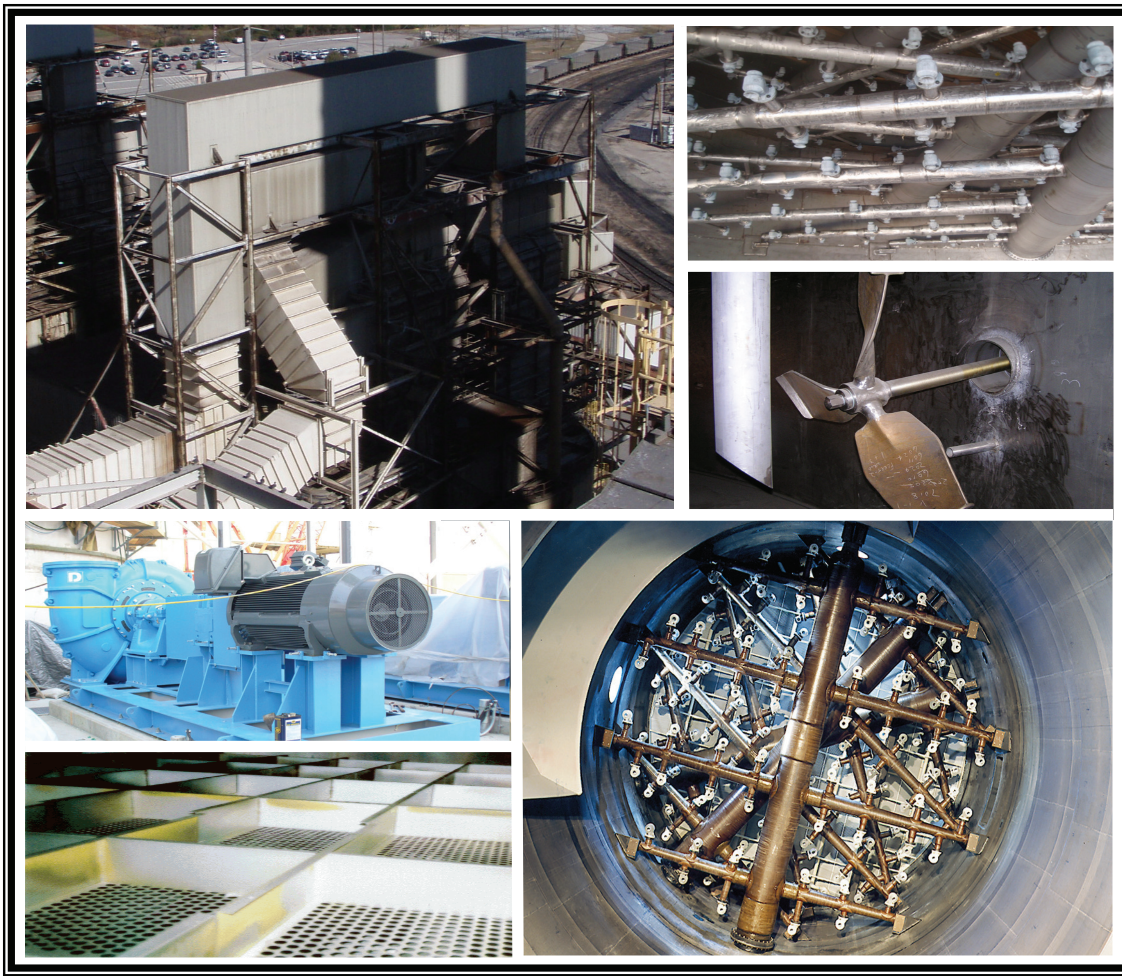
LG&E Services Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study



Assess the feasibility of upgrading the Mill Creek Units 1 & 2 FGD's and upgrading the existing Mill Creek 4 FGD and utilizing it for Mill Creek Unit 3

BabcockPower ENVIRONMENTAL

February 2011

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February 15, 2011

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1 EXECUTIVE SUMMARY

Babcock Power Environmental Inc. (BPEI) has conducted an extensive evaluation of the existing Wet Flue Gas Desulfurization (WFGD) Systems at Louisville Gas and Electric's (LG&E's) Mill Creek Generating Station, Units 1, 2 and 4. The purpose of the evaluation was to determine the feasibility of modifying the existing WFGD equipment to enhance the overall SO_2 emissions performance. BPEI was requested to prepare three primary options for LG&E's consideration, as follows:

- **Base Case – Current SO_2 Removal Efficiency**
- **Case 2 – System Upgrade – Target: 96% SO_2 Removal Efficiency**
- **Case 3 – System Optimization Upgrade: 98% SO_2 Removal Efficiency**

BPEI evaluated multiple alternatives to accomplish LG&E's objectives, from minimal change to extensive retrofit, and presents in this report the most favorable options for LG&E's consideration. BPEI utilized proprietary process software modeling as well as graphical depictions of each phase and any required process infrastructure upgrades. Discussions with plant engineers and reviews of existing plant equipment provided the necessary information to develop a baseline performance model from which to launch the analysis of each option.

The report also includes the following Project Deliverables:

- Basis of Design Description
- Process Flow Diagrams
- Absorber System General Arrangement Drawings
- Description of Equipment being Modified
- Work Breakdown Structure
- Overall Project Schedule
- Construction and Outage High Level Schedule
- Budget Engineering, Procurement and Construction Estimate

The evaluation was based on the flue gas from Unit 3 being routed to the existing Unit 4 WFGD and a new WFGD installed to condition the flue gas from Unit 4. For the purposes of this report and in regard to scrubber modifications, "Unit 3" refers the Unit 3 boiler train ducted to the current Unit 4 WFGD system.

Unit Descriptions

Mill Creek Units 1 and 2 are 330 MW each, controlled circulation, pulverized coal fired boilers, manufactured by Combustion Engineering. They have been in service since 1972 and 1975, respectively. During operation, flue gas exits the air heaters and passes through the ESP, Booster Fans and WFGD and then exits through the stack. The original WFGD systems were provided by Combustion Engineering and have been modified multiple times throughout their operational history. Recently, spray headers were modified and perforated trays added between spray levels 1 and 2. Today, Units 1 and 2 operate with all spray levels in service.

Mill Creek Unit 3 is a 425 MW pulverized coal fired boiler, manufactured by Babcock & Wilcox Co. It has been in service since 1978. Flue gas exits the air heaters and passes through the ESP, ID Fan and WFGD and then exits through the stack. This unit also includes an SCR System that was designed and supplied by Riley Power Inc. (RPI), a Babcock Power Inc. Company.

Today, Units 1 and 2 operate with all spray levels in service. The Units burn bituminous coal with an SO_2 level of 5.4 lb./MMBtu. The reported SO_2 removal is 90-92%, with the reaction tank pH normally set to 5.7.

This evaluation will utilize a design coal that has an SO_2 level of 6.3 lb./MMBtu.

Base Case - Current SO_2 Removal Efficiency

Technical Description – The task objective of the Base Case is to determine the maximum achievable SO_2 efficiency without performing modifications to the existing equipment, based on a specified design coal with an SO_2 level of 6.3 lb./MMBtu. The work associated with the Base Case has been completed by BPEI and is presented in this report.

Engineering Scope of Work – The mechanisms for achieving the required performance are optimization of the spray coverage and droplet distribution, while maintaining droplet size for peak liquid-to-gas interaction. This is performed by modifying some of the existing equipment and adding new equipment.

BPEI modeled the existing absorber systems on Mill Creek Units 1, 2, and 3 (Unit 3 flue gas to be redirected to existing Unit 4 WFGD system) using proprietary software and data obtained from plant personnel to create a realistic baseline performance model. BPEI analyzed performance of the model, altering key variables such as flue gas flow, coal sulfur content, recycle pump flow and pressure, recycle spray nozzle type, nozzle spray angles, nozzle coverage, etc. to determine what modifications to the existing systems would provide the most economical reliable performance enhancements for each system. The base model also provides critical feedback to the design engineers to confirm that theories and calculations used in the model are accurate and appropriate as a starting point for performance enhancement using BPEI's proven techniques. The evaluation was based on the flue gas from Unit 3 being routed to the existing Unit 4 WFGD and a new WFGD installed to condition the flue gas from Unit 4.

Performance – Based on BPEI's evaluation of the existing equipment and performance capabilities, it has been determined that Units 1 and 2 can be expected to achieve a maximum 88% SO_2 removal. Unit 3 can be expected to achieve a maximum 91% SO_2 removal. Both of these values are based on a design coal that has an SO_2 level of 6.3 lb./MMBtu. The results are based on the spray nozzles and recycle pumps operating as designed. Also, the results reflect a plant modification to route the flue gas from Unit 3 to the Unit 4 WFGD, which has an absorber with 25% additional capacity. The higher removal in Unit 3 is attributed to this modification.

Case 2 – System Upgrade – Target: 96% SO_2 Removal Efficiency

Technical Description – The task objective of Case 2 was to provide to LG&E the most economical, reliable method to obtain 96% SO_2 removal for each of the Mill Creek Units. BPEI modeled the existing absorber systems on Mill Creek Units 1, 2, and 3 (Unit 3 flue gas to be redirected to existing Unit 4 WFGD system) using proprietary software and data obtained from plant personnel to create a realistic baseline performance model. The process parameters were then modified using BPEI's historical experience as follows:

Units 1 and 2:

- Change Spray Level 1 nozzles from down-only to dual-flow, double-down nozzles.
- Change Spray Level 2 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 3 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 4 nozzles from down-only to dual-flow, double-down nozzles.
- Change spray nozzle angle on Units 1 and 2 from 80^o to 120^o.
- Add wall baffles to Spray Levels 2 and 3.

Unit 3

- Change Spray Level 1 nozzles from down-only to dual-flow, double-down nozzles.
- Change Spray Level 2 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 3 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 4 nozzles from down-only to dual-flow, double-down nozzles.
- Add wall baffles to Spray Levels 2 and 3.

The model was then used to determine the required recycle pump flow to achieve 96% SO_2 removal.

Units 1 and 2

- Increase the recycle pump capacity from all at 600 hp to 3 pumps at 500 hp and 5 pumps at 700 hp resulting in a change to the Liquid-to-Gas (L/G) ratio, from 112 gal/kacf to 141 gal/kacf. The recycle pump capacity change in Units 1 and 2 will alter the Liquid-to-Gas (L/G) ratio. Generally L/G ratio trends with removal rate, therefore increasing the flow through the recycle pumps and nozzles corresponds to greater SO_2 removal.

Unit 3

- No change to the recycle pump capacity is required.

BPEI will install agitators on each reaction tank, replacing the existing sparger system, which has a tendency to clog and hinder performance.

Unit 1

- Install six (6) agitators on each reactor tank.

Unit 2

- Install five (5) agitators on each reactor tank.

Several chemical and reaction rate modifications were analyzed, namely liquids residence time and solids residence time. Optimum values for each of these reaction rate parameters have been worked into the existing scrubber operation by revising current ranges for operational level in the reaction tanks, absorber slurry solids ranges, and limestone grind fineness. Finally the forced oxidation system was evaluated with emphasis on achieving superior mixing of injected oxidation air, suspension of slurry in the vessel, and complete oxidation of SO_2 removed by the absorber. The results of this analysis recommend the following operating changes:

Units 1 and 2

- Increase absorber slurry solids from 10-12% to 14-16% RETURN TO ORIGINAL DESIGN
- Increase absorber reaction tank level from 31.5’ to 35.5’ RETURN TO ORIGINAL DESIGN

Unit 3

- Increase absorber slurry solids from 10-12% to 14-16%
- Increase absorber reaction tank level from 15’ to 18’

Performance – Based on BPEI’s evaluation of the existing equipment and performance capabilities and the modeling effort described above, it has been determined that all three units can be expected to achieve the 96% SO_2 removal target. These values are based on a design coal that has an SO_2 level of 6.3 lb./MMBtu. Also, the results reflect a plant modification to route the flue gas from Unit 3 to the Unit 4 WFGD, which has an absorber with 25% additional capacity.

Engineering Scope of Work – BPEI will perform engineering activities associated with the changes noted above. BPEI will also perform CFD modeling to determine the modifications required to the absorber inlet and confirm the spray nozzle layout and coverage area.

Procurement Scope of Work – The materials required to modify the WFGD and achieve the target performance of 96% SO_2 removal efficiency are detailed in the table below:

CASE 2 LIST OF MATERIALS		Unit 1		Unit 2		Unit 3	
Description	Size	Qty	Units	Qty	Units	Qty	Units
Slurry Recycle System							
Recycle Pumps	700 HP	3	ea.	3	ea.		
Recycle Pumps	800 HP	5	ea.	5	ea.		
Recycle Discharge Piping	30"	2000	LF	2000	LF		
Recycle Suction Pipe/Flanges	30"	8	ea.	8	ea.		
Recycle System Valves and Inline Equipment	30"	TBD		TBD			
Spray Nozzles (double down)	120^o spray	168	ea.	168	ea.	288	ea.
Spray Nozzles (bi-directional)	120^o spray	168	ea.	168	ea.	288	ea.
Wall Baffles							
Wall Baffles		4	ea.	4	ea.	8	ea.
Oxidation Air System							
Oxidation Air Lances	8" x 40" lg.	6	ea.	6	ea.	10	ea.
Air Lance Supports		6	ea.	6	ea.	10	ea.
Air Piping External to Sump	20" C.S.	1000	LF	1000	LF	TBD	LF
Air Piping Hangers		59	ea.	59	ea.	TBD	ea.
Agitators		6	ea.	6	ea.	10	ea.

Construction Plan – Prior to construction BPEI will integrate engineering and fabrication into a detailed fabrication plan. The plan will consider constructability, value engineering, estimating, scheduling, safety, quality, project controls and execution. The objective is to assure that construction is a seamless part of the project delivery.

Following mobilization, BPEI will perform pre-construction activities, including receipt of materials, erection of scaffolding and installation of the recycle pump foundations. The remaining activities will be completed during the outage, which is considered of sufficient duration to complete all of the work. The major work activities include the following:

Units 1 and 2

- Replace existing recycle pumps and piping with new recycle pumps and associated piping
- Replace existing spray nozzles with new spray nozzles
- Install new wall baffles at Spray Levels 2 and 3
- Remove existing spargers
- Install new agitators and oxidation air lances, and associated piping

Unit 3

- Replace existing spray nozzles with new spray nozzles
- Install new wall baffles at Spray Levels 2 and 3
- Remove existing spargers
- Install new agitators and oxidation air lances, and associated piping

Construction will entail four (4) months of pre-outage activity followed by a 3-week outage.

- The pre-outage construction utilizes one (1) shift, ten (10) hours per shift, five (5) days per week.

- The outage construction utilizes two (2) shifts, ten (10) hours per shift, six (6) days per week.

Cost – The Rough Order of Magnitude (ROM) estimate for labor, materials and construction for each unit is as follows:

Unit 1 - $10,541,512
Unit 2 - $10,632,006
Unit 3 - $14,035,835

Case 3 – System Optimization Upgrade: 98% SO_2 Removal Efficiency

Technical Description – The task objective of Case 3 was to provide to LG&E the most economical, reliable method to obtain 98% SO_2 removal for each of the Mill Creek Units, which considered the maximum attainable performance. BPEI modeled the existing absorber systems on Mill Creek Units 1, 2, and 3 (Unit 3 flue gas to be redirected to existing Unit 4 WFGD system) using proprietary software and data obtained from plant personnel to create a realistic baseline performance model. The process parameters were then modified using BPEI's historical experience.

Spray header layout and nozzle selection are optimized based on the overall absorber shell dimensions for absolute maximum performance based on the existing reactor tower dimensions. For Units 1 & 2, recycle pumps are pushed further and piping is resized for greater flow to increase L/G significantly over the original and 96% removal option.

Unit 3 does not require higher L/G ratio to maximize SO_2 removal. Spray header spacing is increased and placement is altered to allow for multiple levels of bidirectional nozzles, which have proven to be superior in performance compared to down-only nozzles. Spray header layout is altered to provide added spray density and prevent any holes in spray coverage by moving the position of individual nozzles on the headers.

Units 1 and 2:

- Move Spray Level 1 from below the tray to 5' above the tray
- Space all 4 spray levels 5' apart
- Stagger spray header layout
- Increase spray density by increasing the number of nozzles per spray level from 42 to 54
- Change Spray Level 1 nozzles from down-only to dual-flow, double-down nozzles.
- Change Spray Level 2 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 3 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 4 nozzles from down-only to dual-flow, double-down nozzles.
- Change interior nozzle spray angle from 80^o to 120^o
- Change wall nozzle spray angle from 80^o to 90^o
- Decrease spray pressure from 10 psig to 8 psig
- Add wall baffles to Spray Levels 2 and 3.

Unit 3

- Move Spray Level 1 from below the tray to 5' above the tray
- Space all 4 spray levels 5' apart
- Stagger spray header layout
- Increase spray density by increasing the number of nozzles per spray level from 36 to 52
- Change Spray Level 1 nozzles from down-only to dual-flow, double-down nozzles.
- Change Spray Level 2 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 3 nozzles from down-only to dual-flow, up-down nozzles.
- Change Spray Level 4 nozzles from down-only to dual-flow, double-down nozzles.
- Change wall nozzle spray angle from 120^o to 90^o
- Decrease spray pressure from 10 psig to 8 psig
- Add wall baffles to Spray Levels 2 and 3.

The model was then used to determine the required recycle pump flow to achieve 96% SO_2 removal.

Units 1 and 2

- Increase the recycle pump capacity from all at 600 hp to 3 pumps at 500 hp and 5 pumps at 700 hp resulting in a change to the Liquid-to-Gas (L/G) ratio, from 112 gal/kacf to 144 gal/kacf. The recycle pump capacity change in Units 1 and 2 will alter the Liquid-to-Gas (L/G) ratio. Generally L/G ratio trends with removal rate, therefore increasing the flow through the recycle pumps and nozzles corresponds to greater SO_2 removal.

Unit 3

- Replace the recycle pump gear boxes to increase capacity.

BPEI will install agitators on each reaction tank, replacing the existing sparger system, which has a tendency to clog and hinder performance and add new mist eliminators.

Unit 1

- Install six (6) agitators on each reactor tank.
- Install mist eliminators

Unit 2

- Install five (5) agitators on each reactor tank.
- Install mist eliminators

Several chemical and reaction rate modifications were analyzed, namely liquids residence time and solids residence time. Optimum values for each of these reaction rate parameters have been worked into the existing scrubber operation by revising current ranges for operational level in the reaction tanks, absorber slurry solids ranges, and limestone grind fineness. Finally the forced oxidation system was evaluated with emphasis on achieving superior mixing of injected oxidation air, suspension of slurry in the vessel, and complete oxidation of SO_2 removed by the absorber. The results of this analysis recommend the following operating changes:

Units 1 and 2

- Increase absorber slurry solids from 10-12% to 14-16% RETURN TO ORIGINAL DESIGN
- Increase absorber reaction tank level from 31.5' to 35.5' RETURN TO ORIGINAL DESIGN

Unit 3

- Increase absorber slurry solids from 10-12% to 14-16%
- Increase absorber reaction tank level from 15' to 18'

Performance – Based on BPEI's evaluation of the existing equipment and performance capabilities and the modeling effort described above, it has been determined that all three units can be expected to achieve the 98% SO_2 removal efficiency These values are based on a design coal that has an SO_2 level of 6.3 lb./MMBtu. Also, the results reflect a plant modification to route the flue gas from Unit 3 to the Unit 4 WFGD, which has an absorber with 25% additional capacity.

Engineering Scope of Work – BPEI will perform engineering activities associated with the changes noted above. BPEI will also perform CFD modeling to determine the modifications required to the absorber inlet and confirm the spray nozzle layout and coverage area.

Procurement Scope of Work – The materials required to modify the WFGD and achieve the target performance of 98% SO_2 removal efficiency are detailed in the table below:

CASE 3 LIST OF MATERIALS		Unit 1		Unit 2		Unit 3	
Description	**Size**	**Qty**	**Units**	**Qty**	**Units**	**Qty**	**Units**
Slurry Recycle System							
Recycle Pumps	700 HP	3	ea.	3	ea.		
Recycle Pumps	800 HP	5	ea.	5	ea.		
Gear Boxes						8	ea.
Recycle Discharge Piping	30"	TBD	LF	TBD	LF		
Recycle Suction Pipe/Flanges	30"	8	ea.	8	ea.		
Recycle System Valves and Inline Equipment	30"	TBD		TBD			
Spray Nozzles (double down)	120° spray	324	ea.	324	ea.	624	ea.
Spray Nozzles (bi-directional)	120° spray	108	ea.	108	ea.	208	ea.
Spray Headers		8	ea.	8	ea.	16	ea.
Spray Pipe Hangers		TBD		TBD		TBD	
Wall Baffles							
Wall Baffles		4	ea.	4	ea.	8	ea.
Oxidation Air System							
Oxidation Air Lances	8" x 40" lg.	6	ea.	6	ea.	10	ea.
Air Lance Supports		6	ea.	6	ea.	10	ea.
Air Piping External to Sump	20" C.S.	1000	LF	1000	LF	TBD	LF
Air Piping Hangers		59	ea.	59	ea.	TBD	ea.
Agitators		6	ea.	6	ea.	10	ea.
Absorber Shell and Ductwork Modifications							
Outlet Expansion Joint		88	LF	88	LF	TBD	
317L Absorber Shell		16,744	sq. ft.	16,744	sq. ft.		
Absorber Reheater Section		1	Lot	1	Lot	1	Lot
DV210 Mist Eliminator and Spray Wash System		TBD		TBD		TBD	

Construction Plan – Prior to construction BPEI will integrate engineering and fabrication into a detailed fabrication plan. The plan will consider constructability, value engineering, estimating, scheduling, safety, quality, project controls and execution. The objective is to assure that construction is a seamless part of the project delivery.

Following mobilization, BPEI will perform pre-construction activities, including receipt of materials, erection of scaffolding and installation of the recycle pump foundations. The remaining activities will be completed during the outage, which is considered of sufficient duration to complete all of the work. The major work activities include the following:

Units 1 and 2

- Replace existing recycle pumps and piping with new recycle pumps and associated piping
- Replace existing spray nozzles with new spray nozzles
- Install new wall baffles at Spray Levels 2 and 3
- Remove existing spargers
- Install new agitators and oxidation air lances, and associated piping
- Perform absorber shell and duct modifications

Unit 3

- Replace existing spray nozzles with new spray nozzles
- Install new wall baffles at Spray Levels 2 and 3
- Remove existing spargers
- Install new agitators and oxidation air lances, and associated piping
- Perform absorber shell and duct modifications

Construction will entail six (6) six months of pre-outage activity followed by a 3-week outage.

- The pre-outage construction utilizes one (1) shift, ten (10) hours per shift, five (5) days per week.

- The outage construction utilizes two (2) shifts, ten (10) hours per shift, seven (7) days per week.

Cost – The Rough Order of Magnitude (ROM) estimate for labor, materials and construction for each unit is as follows:

Unit 1 - $20,428,467
Unit 2 - $20,567,445
Unit 3 - $32,944,117

Summary

Table 1 summarizes all planned modifications for each option analyzed in the feasibility study. Differences between Units 1, 2 and 3 are noted where applicable.

	Base Case As Installed	Case 2 96% Removal	Case 3 Maximum Removal
Spray Header Location	No Change (1 spray header below the tray)	No Change	All 4 headers installed above the tray spaced 5' apart
Spray Header Arrangement	Stacked (As installed)	Stacked (As installed)	Staggered Layout
Spray Nozzle Layout	As installed	No Change	Increase Spray Density
Type of Spray Nozzles	No Change	Level 1: Double-Down Level 2: Up/Down Level 3: Up/Down Level 4: Double-Down	Level 1: Up/Down Level 2: Up/Down Level 3: Up/Down Level 4: Double-Down
Spray Angle	U1&2: All 80^o U3: All 120^o	U1&2&3:Interior: 120^o Wall: 120^o	U1&2&3:Interior: 120^o Wall: 90^o
Spray Pressure	10 psig	10 psig	8 psig
Wall Rings	None	Installed at Spray Levels 2 & 3	Installed at Spray Levels 2 & 3
Absorber Tray	No Change	No Change	No Change
Absorber Solids	10-12%	14-16%	14-16%
Absorber Level	U1&2: 31.5' U3:15'	U1&2: 35.5' U3:18'	U1&2: 35.5' U3:18'
L/G Ratio	U1&2: 112 gal/kacf U3: 151 gal/kacf	U1&2: 141 gal/kacf U3: 151 gal/kacf	U1&2: 144 gal/kacf U3: 151 gal/kacf
Recycle Pumps	U1&2: No Change U3: U4 No Change	U1&2: New Pumps and Piping or Alternative U3: No Change	U1&2: New Pumps and Piping U3: New Gear Boxes
Absorber Inlet Duct	No Change	Modify, as required, based on modeling	Modify, as required, based on modeling
ME/Reheater	No Change	No Change	Remove reheat section and supply ME section
Oxidation Air Blower/Agitators	No Change	No change to blower. Modify piping to match air lances w/ agitators	No change to blower. Modify piping to match air lances w/ agitators
Predicted SO_2 Removal Performance	U1&2: 88% U3: 91% (in U4 abs)	96%	+98%

Table 1: Mill Creek Upgrades Summary

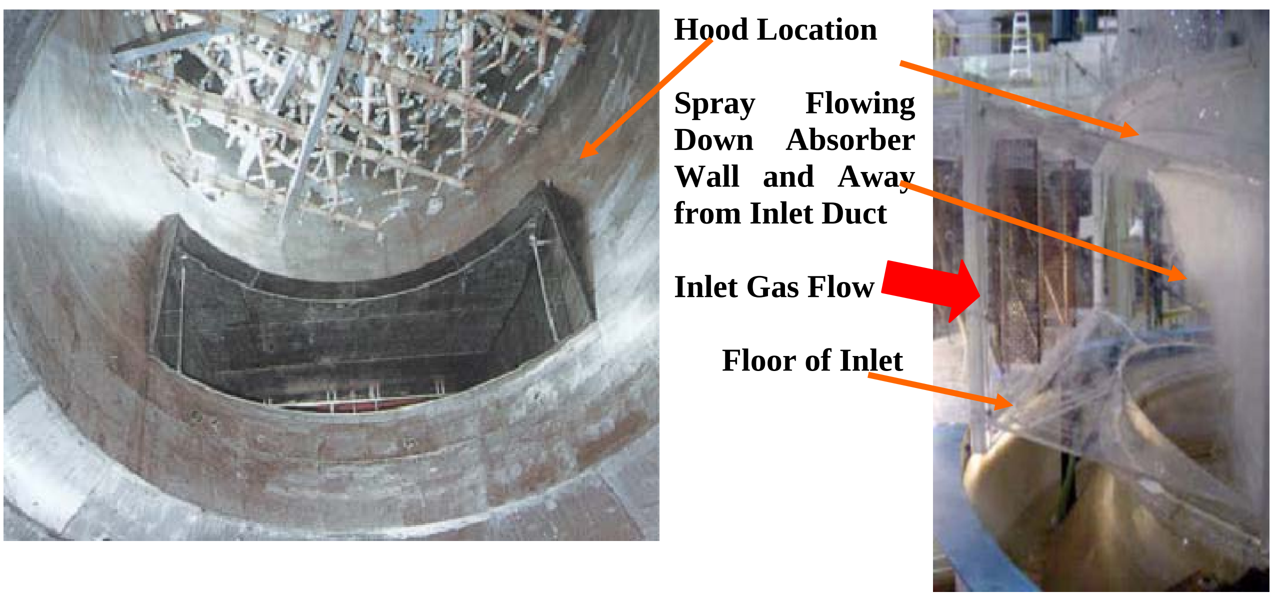
2 BPEI WFGD Technical Features and Benefits

All WFGDs utilize the same fundamental technology for SO_2 absorption. Where BPEI's design and performance differ from others is in the amount of power and liquid required to achieve the maximum SO_2 removal efficiency. BPEI maximizes the contact between the gas and the absorptive liquid by optimizing the design of the spray zone and using wall rings to eliminate "gas sneakage." This maximizes the utilization of each droplet, while minimizing power consumption from the draft and recycle systems.

BPEI utilizes both co-current and counter-current spray nozzles, in addition to absorber wall rings, to continuously achieve high SO_2 removals. This performance has been demonstrated at multiple installations. While many of these components and features are common to open spray tower technologies, the unique design configurations employed by BPEI provide the ability to reliably produce high removal efficiencies. To identify how BPEI achieves these results, each of the critical design components is described below:

2.1 Extensive 3-D Modeling Technology

BPEI uses an absorber flue gas inlet configuration that effectively introduces the flue gas to the absorber below the first spray level and distributes it uniformly over the entire cross-sectional area of the absorber. This avoids excessive deposits of solids in the 'wet-dry' zone where the incoming hot gases contact the slurry spray flow.

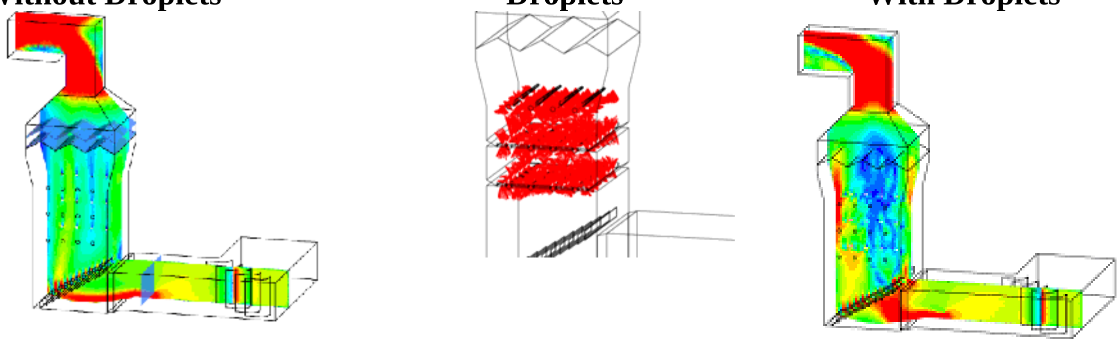


BPEI makes extensive use of 3-D modeling technology. From past experience, BPEI has discovered that physical and/or computational models are an important tool in developing the design of WFGD systems. Applications of modeling include:

- The prediction of gas distribution at the absorber inlet and into the first spray level.

- The prediction of recirculation tank agitator performance as it relates to both suspension of solids and distribution of oxidation air for maximum effectiveness.
- Optimization of gas and spray nozzles droplet distribution and interaction through the absorber.

Without Droplets **Droplets** **With Droplets**



The liquid film resistance in the liquid-to-gas (L/G) interface is the limiting factor that regulates the rate at which the SO_2 absorption occurs. Beyond the (L/G) ratio, the absorption section of the WFGD system must also be designed to maximize the contact between the liquid and the incoming flue gas. High efficiencies are accomplished by designing the spray zone with dual-directional, wide-angle, hollow-cone spray nozzles. This arrangement provides:

- Excellent liquid distribution over the entire spray level cross-sectional area, ensuring that all the flue gas is treated.
- A staggered spray pattern from one level to the next, avoiding flue gas 'laning' through paths of low liquid flow; i.e., paths of least resistance.
- A hydrodynamic 'ring' along the absorber wall, formed by the use of high liquid flow, narrower spray angle nozzles around the full perimeter. This ring counters the 'wall effect' and ensures that the gas flowing upward along the walls is fully treated. It also reduces the amount of water lost' by being directly sprayed on the absorber wall.
- A physical wall ring plate, which diverts and mixes the gas flow at the wall around the full inside perimeter of the absorber.

The advantage BPEI has over other suppliers of dual-flow nozzles and wall rings is the ability to accurately model the performance and minimize the L/G ratio necessary to achieve high SO_2 removal efficiencies.

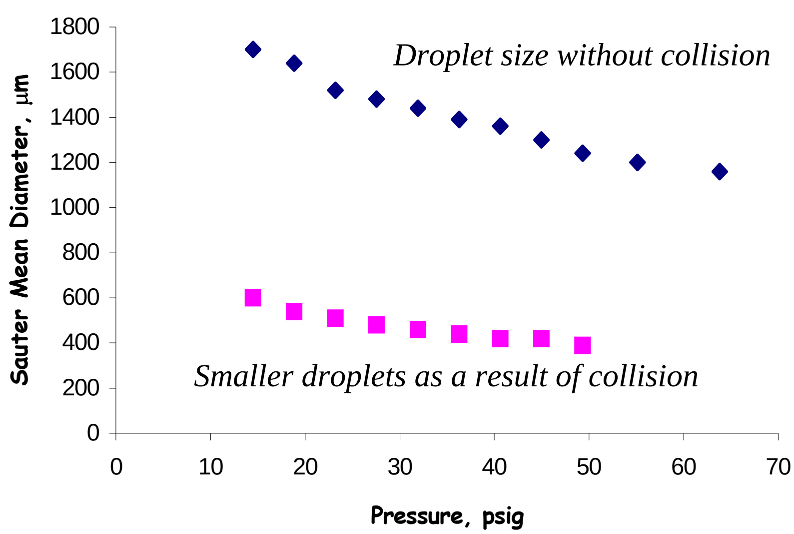
2.2 Dual Flow Nozzles

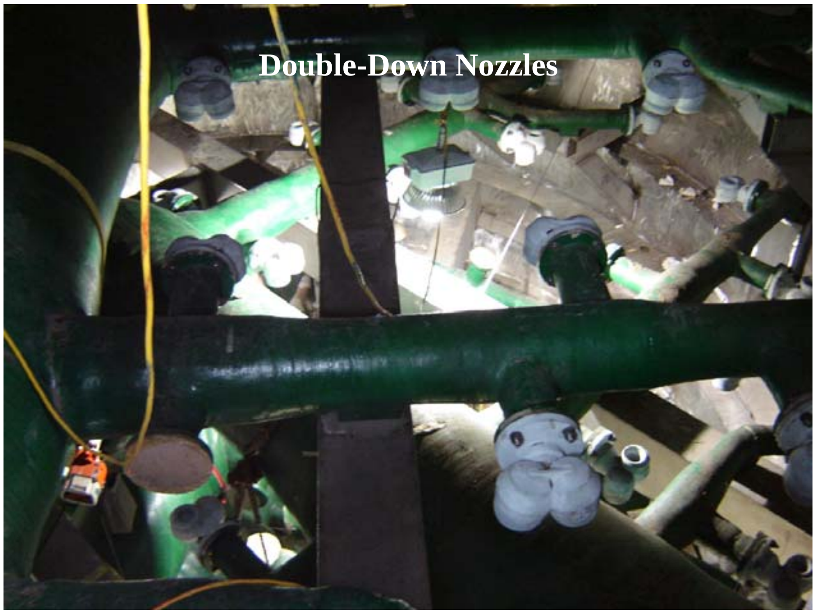
The features of dual flow nozzles are as follows:

- Liquid flow is both counter-current and co-current with respect to gas flow, providing good gas-spray mixing and gas-liquid contact.
- The number of nozzle liquid discharge holes doubles over a down-flow only design, yielding smaller droplet size at same pump power, thereby improving performance.

- With the 'hourglass' shaped spray pattern, the flue gas must travel through twice the number of slurry spray cones as there are levels, insuring better gas-slurry contact.
- Also, with the hourglass shape the number of spray-to-spray intersections between adjacent spray cones is greatly increased. The intersections of adjacent spray cones further enhances SO_2 removal by:

    - Generating small 'mist' droplets as the droplets collide, providing increased liquid surface-to-mass ratio.
    - Mixing and reforming droplets, providing 'fresh' droplet surface for gaseous absorption.
    - Increasing the gas-liquid mass transfer at low liquid flow rates, thereby reducing pump power.

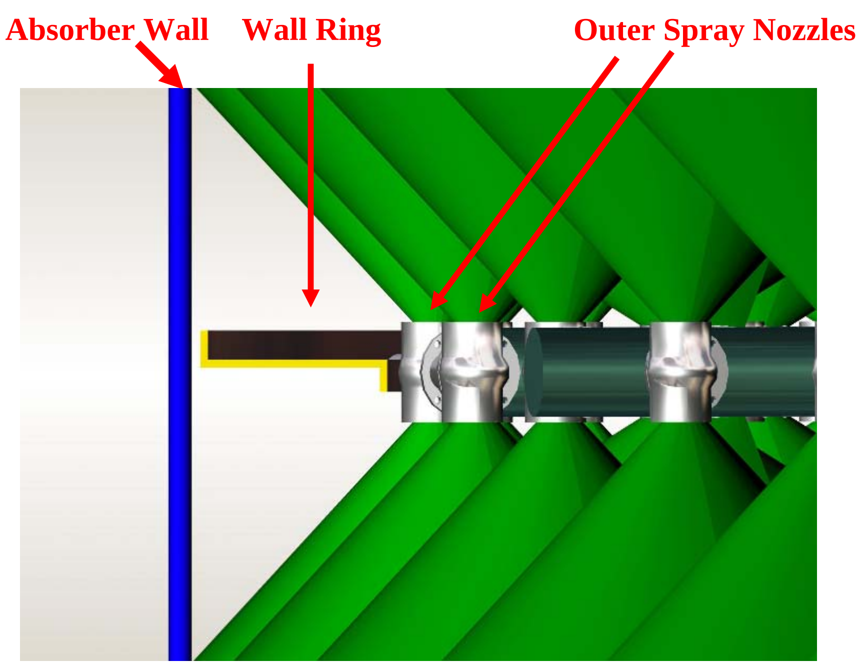


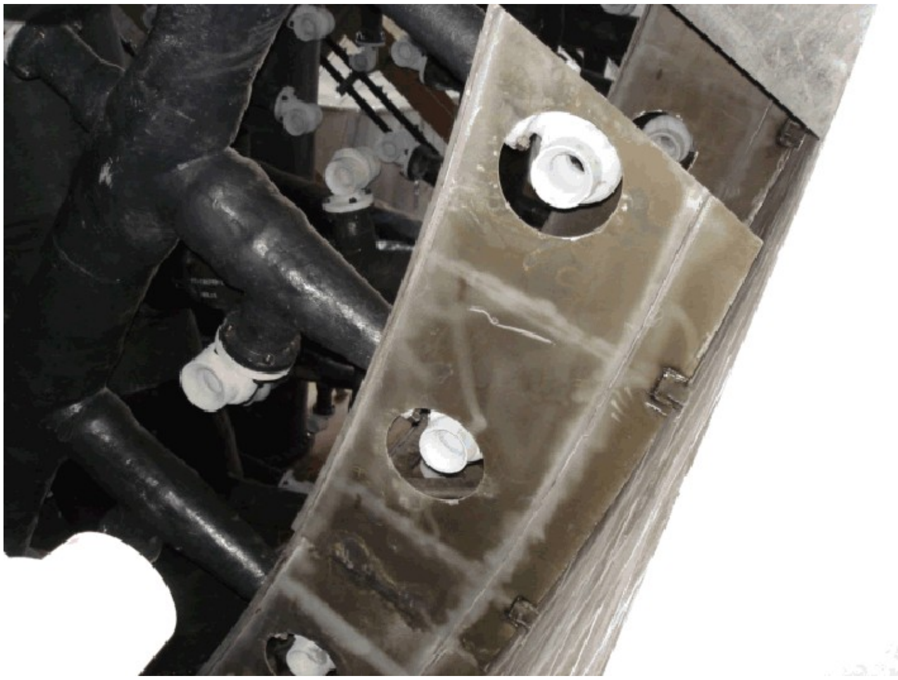


2.3 Wall Rings

Features of wall rings are as follows:

- A physical barrier by which untreated gas along the wall is driven into the spray zone for treatment.
- Full perimeter coverage with no direct spray impact on the ring itself.
- Excellent gas-liquid mixing and re-distribution.
- Low gas side pressure drop.

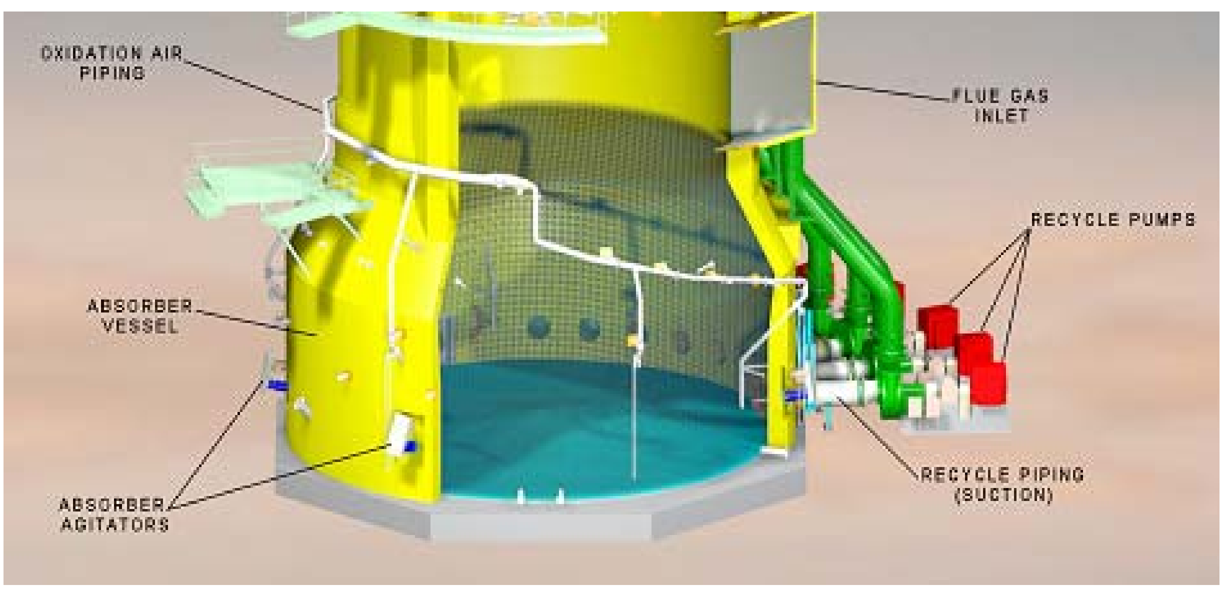




Wall Rings Installed at Ghent

2.4 Agitators and Oxidation Air System

Side mounted agitators are designed to provide complete dispersion of air and suspension of solids. In order to provide high reliability, these systems are designed such that any one of the agitators can be off-line for maintenance while the absorber remains online for operation. The agitator seal between the rotating shaft and the absorber wall can be replaced with the tank full of slurry, thereby providing additional flexibility and minimal need to drain the tank.



The oxidation air system piping delivers air to each agitator. The agitator slurry flow is towards the center of the tank, slightly off radial and slightly downward. The moving slurry 'sweeps' the floor and provides ‘off bottom suspension’; i.e., no accumulation of solids on the tank floor. The slurry reaches the center of the tank in a slightly off radial direction and turns upward in a helical pattern to the slurry surface. It then travels radially outward, turns down at the tank wall and returns to the agitators. This is a long and useful travel path, providing good mixing and a long time for all the chemical reactions to reach completion.

Each agitator is equipped with an oxidation air injection lance. The air exits the end of this lance in the fast moving slurry at the ‘backwash’ of the agitator. This causes the air to be striped into small bubbles, which follow the slurry flow path. This path, as described above, is long and allows time for the oxygen to be absorbed into the slurry.

2.5 Mist Eliminators

DV210 Mist Eliminators (shown in the photo below) are an alternative to traditional flat mist eliminator arrangements. The installation of a single layer benefits installation time and requires only one layer of support beams instead of two. The other advantages of DV210 Mist Eliminators are:

- Minimal pressure loss
- Good elimination performance at medium velocities
- Suitable for retrofit with existing washers
- Provides a higher net face area than any other design

Mist Eliminator System

2.6 Recycle Pumps

BPEI works with all the major recycle pump suppliers to provide the best fit in terms of:

- Application,
- Reliability
- Power requirements
- Maintenance
- Noise
- Cost
- Delivery

The predominant difference between the major suppliers is the design of wetted elements. Weir pumps have a replaceable natural rubber liner insert with a high chrome iron impeller and throat bushing. The liner is a robust fitted insert that is specifically designed and formulated for WFGD slurry service. Duchting pumps have an iron shell with a cast-in-place liner and impeller made of a composite of silicon carbide grains with an epoxy binder. The GIW pumps are designed with high chrome iron for all wetted surfaces. Each project requires are thorough evaluation of the recycle pump vendors to determine the best fit in the specific application.

High-Volume Direct-Drive Recycle Pumps

3 BASE CASE - Current SO_2 Removal Efficiency

3.1 Technical Summary – Base Case

A thorough understanding of current plant operational characteristics and an accurate baseline model are required to complete a performance enhancement study for the Mill Creek WFGD systems. BPEI modeled the existing absorber systems on Mill Creek Units 1, 2, and 3 (Unit 3 flue gas to be redirected to existing Unit 4 WFGD system) using proprietary software and data obtained from plant personnel to create a realistic baseline performance model. BPEI analyzed performance of the model, altering key variables such as flue gas flow, coal sulfur content, recycle pump flow and pressure, recycle spray nozzle type, nozzle spray angles, nozzle coverage, etc. to determine what modifications to the existing systems would provide the most economical reliable performance enhancements for each system. The base model also provides critical feedback to the design engineers to confirm that theories and calculations used in the model are accurate and appropriate as a starting point for performance enhancement using BPEI's proven techniques.

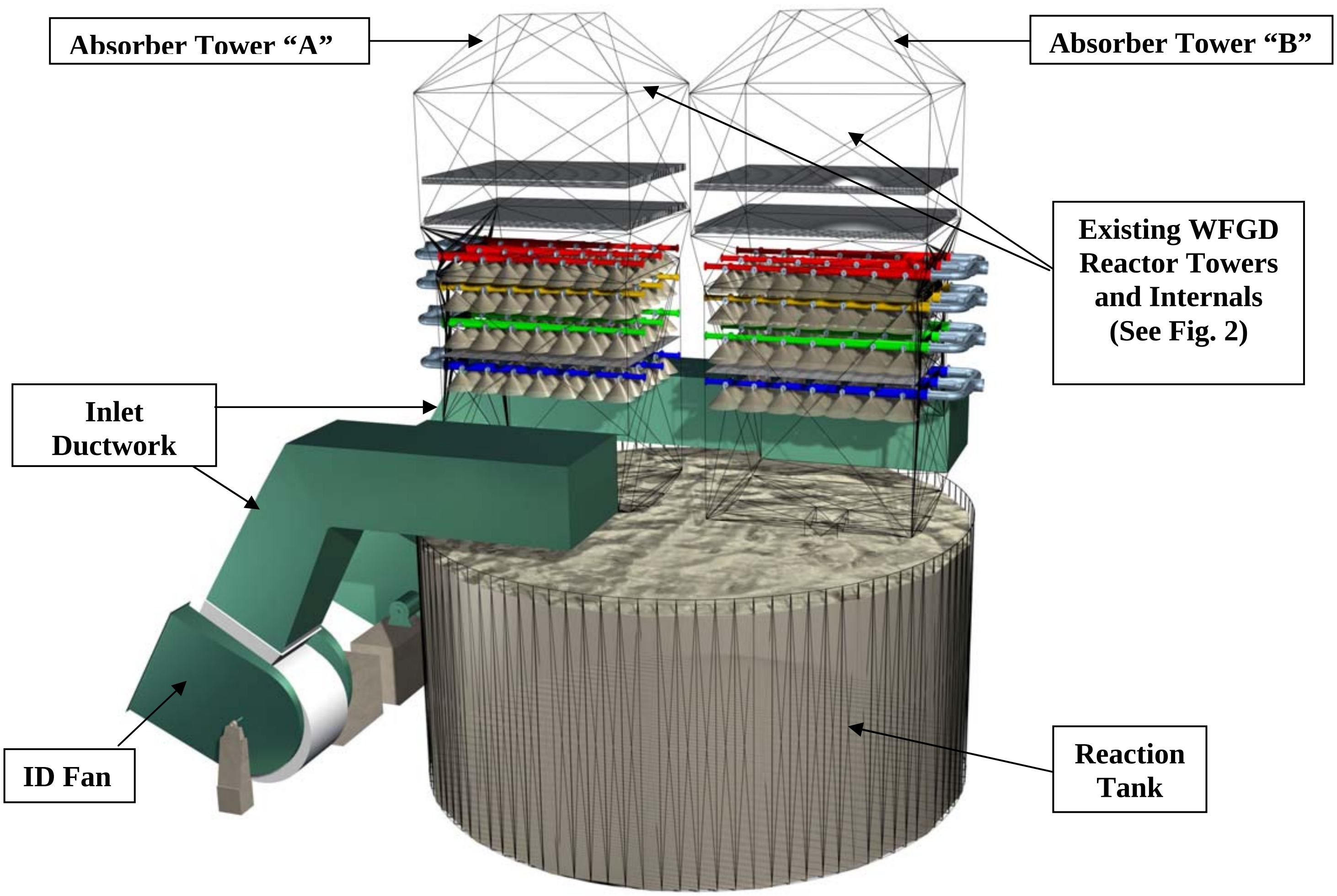


Figure 1: Mill Creek Units 1 & 2, Current

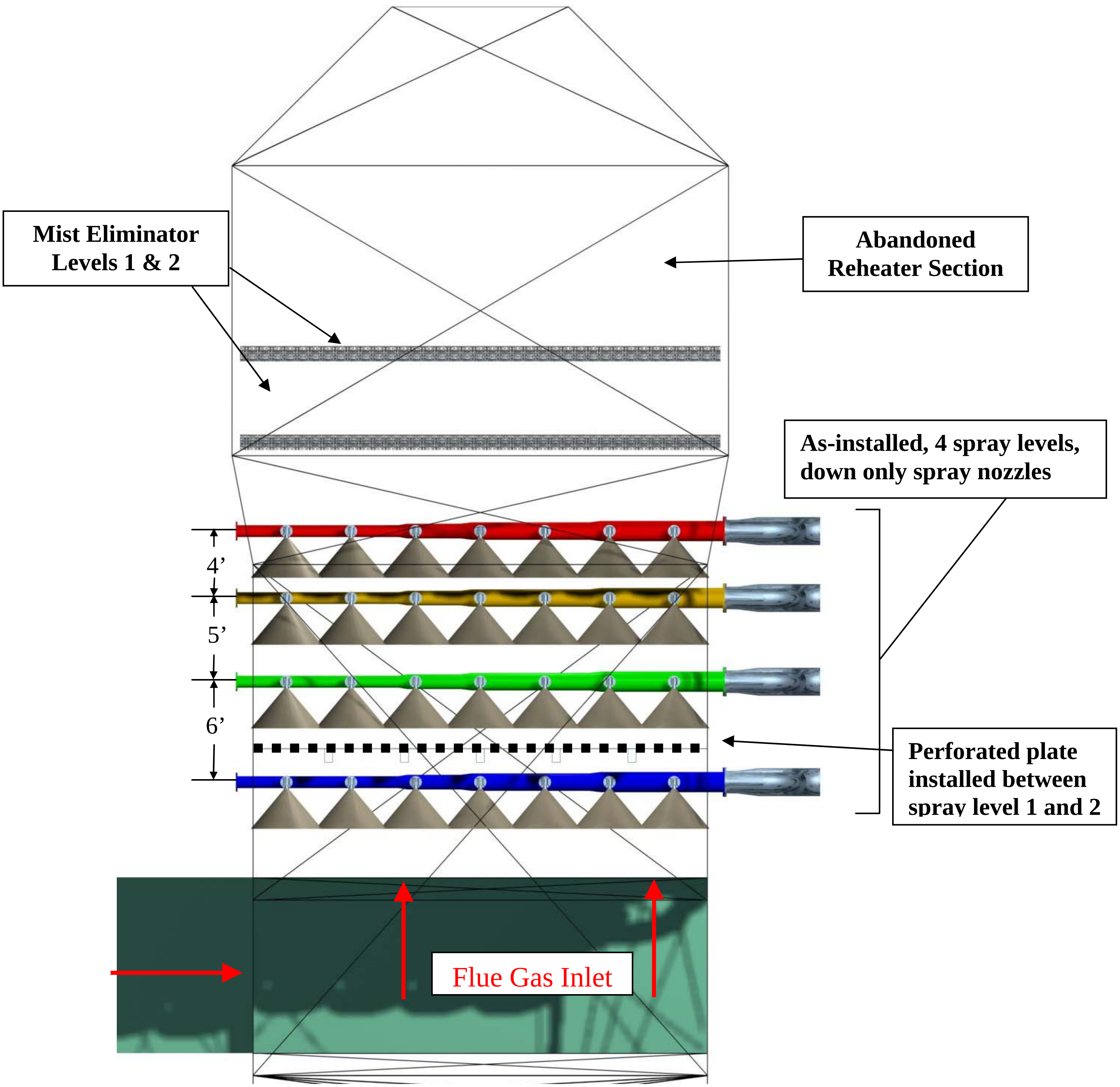


Figure 2: Mill Creek Units 1 & 2, Current Reactor Tower Arrangement

3.2 System Description

Flue gas production is directed by means of two ID fans in parallel feeding the unit A and B absorbers.

The absorbers share a single reaction tank. Eight recycle pumps four feeding each absorber provide the total slurry from the tank to the absorbers.

Oxidation air is introduced thru a sparger type system. The sparger is arranged as a single header located above the floor introducing air evenly throughout the absorber.

Flue gas vertically moves through each of the four spray headers. Above the first spray header LG&E has installed a perforated plate or tray for the purpose of providing even flue gas distribution.

The flue gas exits the absorbers through the mist eliminators to the stack.

Figure 3: Mill Creek Units 1 & 2

3.3 Current Process Operation

Discussions held with onsite engineers and operators as well as reviews of historical data were used to better understand current operation of the three absorber units. On average the units burn a coal with sulfur content of 5.4 lb SO_2/MBtu. Limestone used in the WFGD process to neutralize SO_2 is finely ground to 95% passing 325 mesh. The absorbers reliably maintain 90-92% SO_2 removal by maintaining an absorber slurry pH in the reaction tank of 5.7-5.8. Absorber slurry solids is maintained between 10-12 wt% and controlled with a bleed system. An oxidation air sparger ring is designed to oxidize the SO_2 removed from the flue gas and maintain agitation in the reaction tank.

The level in the absorber reaction tanks are controlled at lower set points compared to original design conditions. The absorber slurry solid concentration is also controlled at a lower density than is typical for limestone, forced-oxidation wet FGD systems. Reported unreliability of the absorber bleed system to maintain absorber slurry density resulted in the reduced density control range. It may also be problematic to maintain absorber slurry solids concentration because of the lack of agitation in the absorber reaction tank. Currently the only mixing in the reaction tank is an air sparger ring which has been reported to plug up whenever an oxidation air blower trips out of service and slowly plug up over time with regular operation. The air sparger ring assembly appears to be the highest cause of unreliability in the scrubber process operation. Operating at reduced absorber slurry density and absorber levels reduces the liquids and solids retention time in the absorber reaction tank, which may have the following consequences:

- Negative impact on the gypsum quality - smaller crystal size impacting dewatering operations
- Increase the amount of excess limestone required for SO_2 removal - higher pHs required to maintain SO_2 removal efficiency
- Reduced Hydrocyclone performance – decreased solids in the underflow to the dewatering process and increased fraction of gypsum fines removed in the overflow purge stream
- Flue gas off-gassing between the absorber module and the absorber reaction tank causing area corrosion issues - no seal is maintained

3.4 Spray Header Arrangement / Spray Nozzle Coverage

The high-flow, hollow-cone spray nozzles currently installed in the absorber are designed to produce small droplets with a high spray pressure of 20 psig at a spray angle of 80^o on Units 1 and 2 and a spray pressure of 10 psig at a spray angle of 120^o on Unit 3. Figure 5 shows the spray coverage with the existing spray header and nozzle configuration. As can be seen there is very little spray coverage along the absorber wall and between the absorber nozzles. The four spray headers are identical in layout such that some channeling of the flue gas through the absorber is likely to occur.

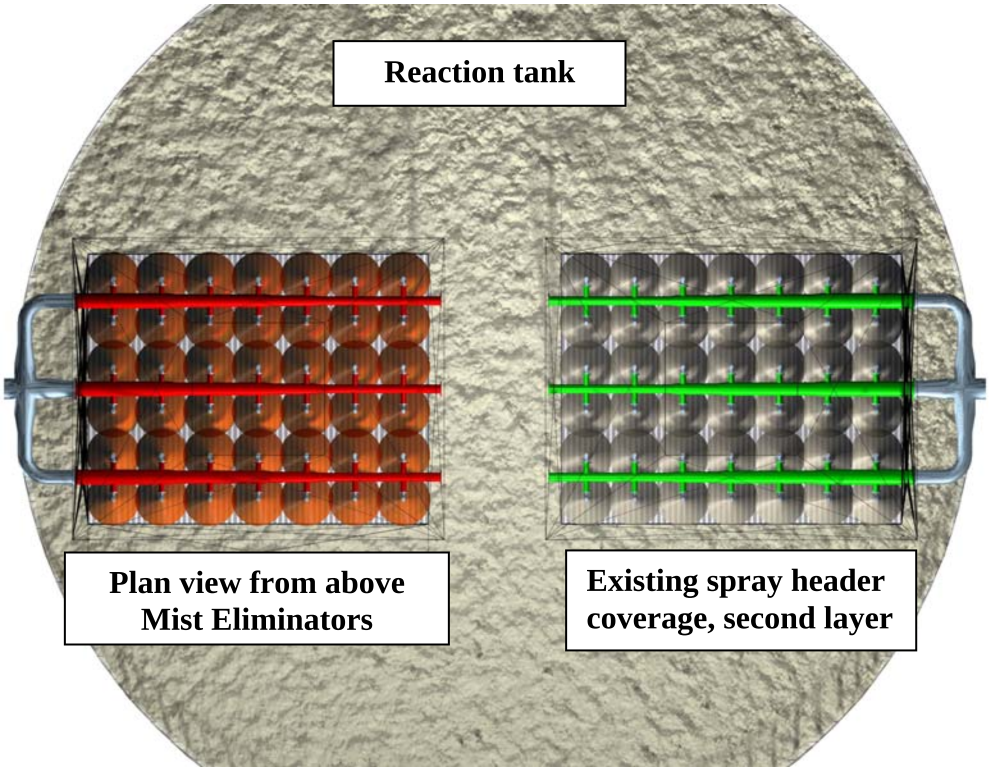


Figure 4: Mill Creek Units 1 & 2 Plan View, Base Case

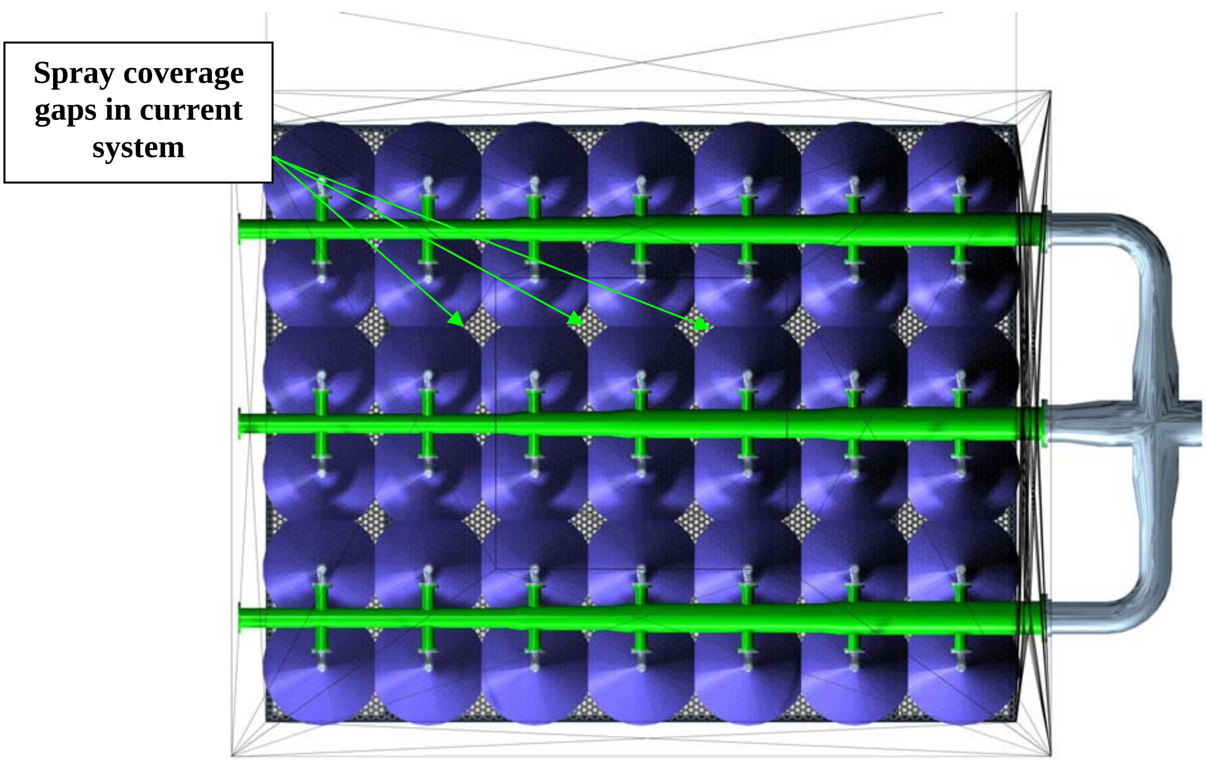


Figure 5: Mill Creek Units 1 & 2 Plan View, Base Case

BPEI recommends testing the spray nozzle performance of each nozzle type to fully understand the current nozzle performance. This is especially critical for Units 1 and 2 because understanding the improvement in performance between current operation and Case 2 might make the difference between utilizing the existing recycle pumps or replacing the recycle pumps. This is covered in more detail in Section 4.

3.5 Recycle Pump Performance

A generic pump curve was provided for the recycle pumps installed on Units 1 and 2 absorbers. Nozzle data was provided regarding the total number of spray nozzles, nozzle flow rate, spray angle, and spray pressure. The recycle pump total dynamic head (TDH) does not correspond to a spray pressure of 20 psig when recycle pumps and piping were modeled. Instead the spray pressure appears to correspond closer to 10 psig spray nozzles. At the lower supply pressure the nozzle performance in terms of spray angle and droplet size and flow rate will not be at design. Conservative assumptions will have to be made regarding the current pump performance and change in pump performance when changing spray header elevations.

Pump curves were provided for the recycle pumps installed on the future Unit 3 absorbers (currently absorber is treating Unit 4 flue gas) and nozzle data corresponds to the pump performance.

BPEI recommends testing recycle pump performance on all three units to fully understand current pump performance. The pump performance testing would be similar to what was conducted at Trimble County in terms of measuring motor amperage, pump rpm, pump flow rates, and pressure at each pump suction and discharge to locate the actual operating point on the pump curve. The data will be used to evaluate the possibility of utilizing the current recycle pumps with dual spray nozzles for high SO_2 removal and determining if new gear boxes on Unit 3 recycle pumps will be appropriate for maximum SO_2 removal.

3.6 Absorber Inlet Design

On all units the absorber flue gas inlet is shorter and has a larger surface area than typical for new absorber designs. The length of the absorber inlet is designed to minimize splash back of absorber slurry into the carbon steel ductwork. Flue gas velocity in the absorber is controlled with the size of the absorber inlet to evenly distribute flue gas prior to the first spray level, to eliminate any reverse flow in the duct, and to maintain the wet/dry interface in the absorber area. Otherwise, a large, shallow absorber inlet may result in corrosion of the ductwork upstream of the absorber. Computational flow modeling will determine if the installed tray offsets the negative impact of the current absorber inlet design or if modifications are required to the absorber inlet. Physical flow modeling is recommended at a minimum for Unit 3 since ductwork would need to be re-routed to Unit 4 absorbers.

Turning vanes, a perforated plate, and modifications to the inlet duct at Trimble County are an example of how to optimize flue gas flow through the absorber and eliminate the potential for reverse flow into the ductwork. Figure 6 shows some of the modifications completed to Trimble County absorber inlet. These modifications were completed based on CFD modeling.

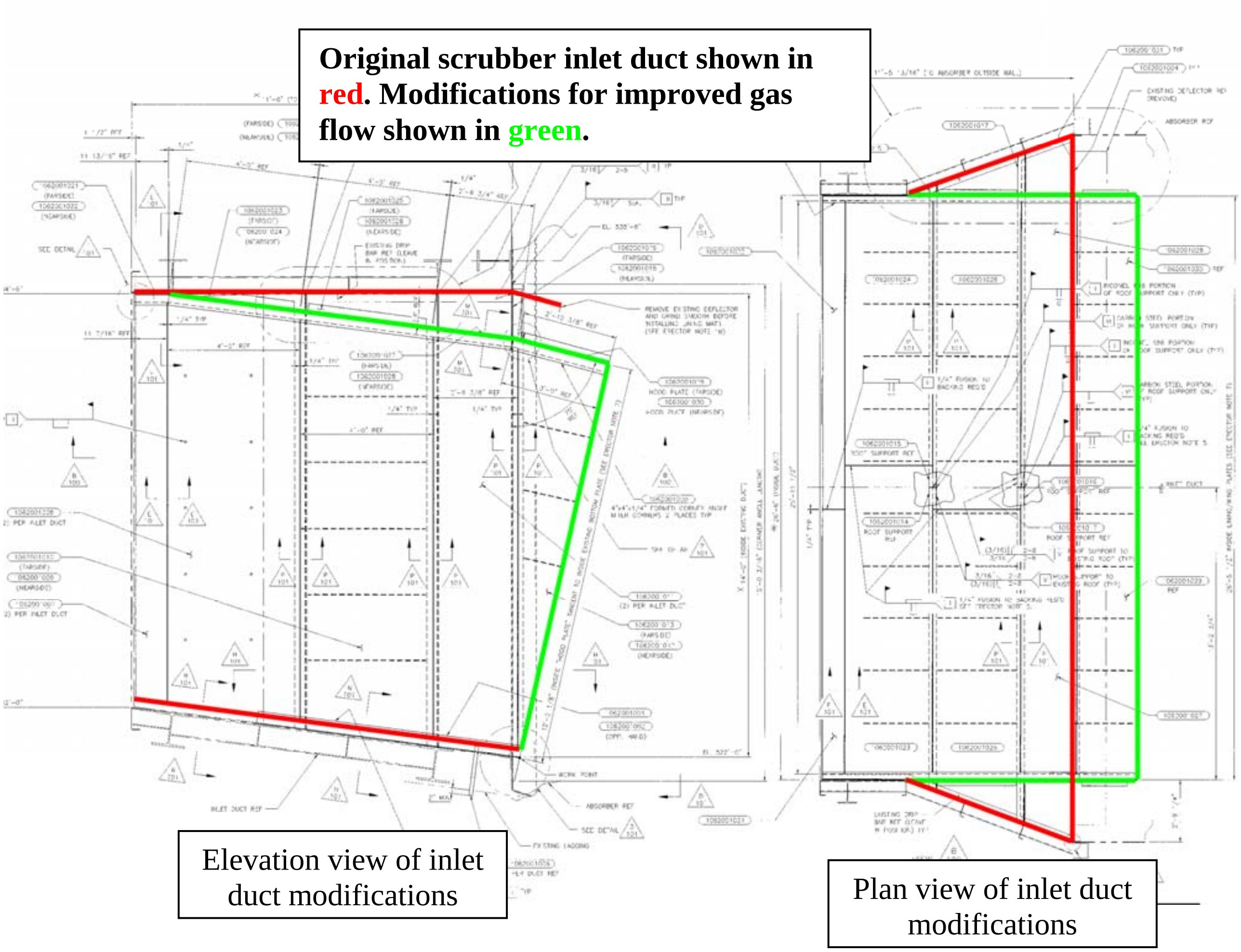


Figure 6: Inlet Ductwork Modifications at LG&E Trimble County

3.7 Design Basis

Table 2 provides a summary of coal analyses for the Mill Creek Station. The first set of data is a summary of the average fuel burned at Mill Creek in 2009. On average Mill Creek burned a coal with an inlet SO_2 concentration of 5.4 lb/MBtu based on the average coal sulfur content and high heating value. The specified fuel for this study is a design coal similar to what was used for Ghent Station Units 1,3 & 4 and Brown Station WFGD Systems with an inlet SO_2 concentration of 6.3 lb/MBtu and heating value of 12,500 Btu's/lb used to evaluate current absorber performance and absorber performance for Cases 2 and 3. The higher sulfur content is designed to represent future operation at Mill Creek Station.

Fuel	Units	2009 Average	Design
Coal Ultimate Analysis			
Carbon (C)	wt.%	61.61	60.30
Hydrogen (H)	wt.%	4.22	4.50
Oxygen (O_2)	wt.%	7.01	6.80
Nitrogen (N_2)	wt.%	1.28	1.17
Sulfur (S)	wt.%	3.02	3.47
Chlorine (Cl)	wt.%	0.06	0.07
Fluorine (Fl)	wt.%	0.01	0.01
Moisture (Water, H_2O)	wt.%	11.43	9.56
Ash	wt.%	11.36	14.12
Total	wt.%	100.0	100.0
Volatile	wt.%	35.68	33.00
Fixed Carbon	wt.%	41.54	42.00
Higher Heating Value	Btu/lb	11,115	11,000
Inlet SO_2	lb/MBtu	5.4	6.3

Table 2: Summary of Coal Quality

3.8 Predicted Absorber Performance

Absorber performance was predicted using design coal sulfur conditions of 6.3 lb SO_2/MBtu, assuming no change to Units 1 and 2 absorbers, and directing Unit 3 flue gas to Unit 4 absorbers. Approximately 88% removal is predicted with the existing absorber configuration for Units 1 and 2. Approximately 91% removal is predicted with the existing Unit 4 absorber configuration for Unit 3 flue gas. The higher removal is attributed to the larger recycle pumps.

Figure 7 shows the existing spray level spacing for the three units. The existing spray header layout is also used in the Case 2 evaluation.

3.9 Construction

3.9.1 Construction – BPEI has no construction for the base case.

3.9.2 Schedule – No outage scheduled.

3.9.3 Pricing – No price included.

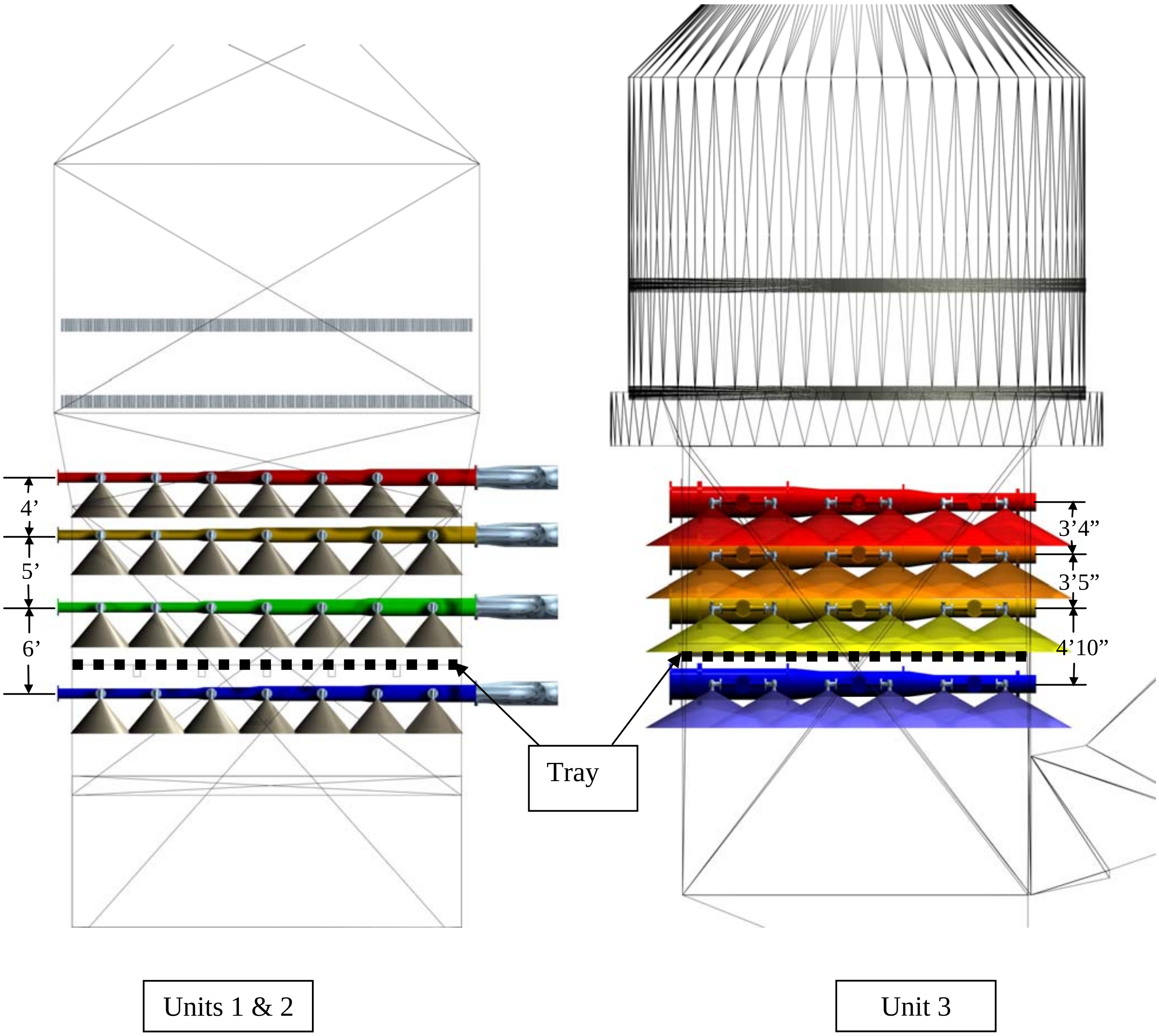


Figure 7: Existing Spray Header Spacing

4 CASE 2 - 96% SO_2 Removal Efficiency

4.1 Technical Summary – Case 2

In this section of the report, BPEI's task objective was to provide to LG&E the most economical, reliable method to obtain 96% SO_2 removal for Mill Creek Units 1, 2 and 3. The process models were taken from the baseline condition and modified using a variety of techniques in several stages. Multiple variables were adjusted by application of BPEI's experience in WFGD and experimental results from the process model. Nozzle spray angle, type, pressure, flow, and arrangement were fine-tuned to provide optimum spray coverage and droplet distribution while maintaining droplet size for peak liquid to gas interaction. Addition of wall rings, a BPEI licensed and patented technology, was evaluated to improve flue gas distribution and prevent laning of gas along the perimeter of the vessels. Changes to the Liquid-to-Gas (L/G) ratio were evaluated via changes in recycle pump flow, pressure, and nozzle flow. Generally L/G ratio trends with removal rate, therefore increasing the flow through the recycle pumps and nozzles corresponds to greater SO_2 removal. Several chemical and reaction rate modifications were analyzed, namely liquids residence time and solids residence time. Optimum values for each of these reaction rate parameters have been worked into the existing scrubber operation by revising current ranges for operational level in the reaction tanks, absorber slurry solids ranges, and limestone grind fineness. Finally the forced oxidation system was evaluated with emphasis on achieving superior mixing of injected oxidation air, suspension of slurry in the vessel, and complete oxidation of SO_2 removed by the absorber. A summary of the planned modifications respective to each vessel is shown on Table 1.

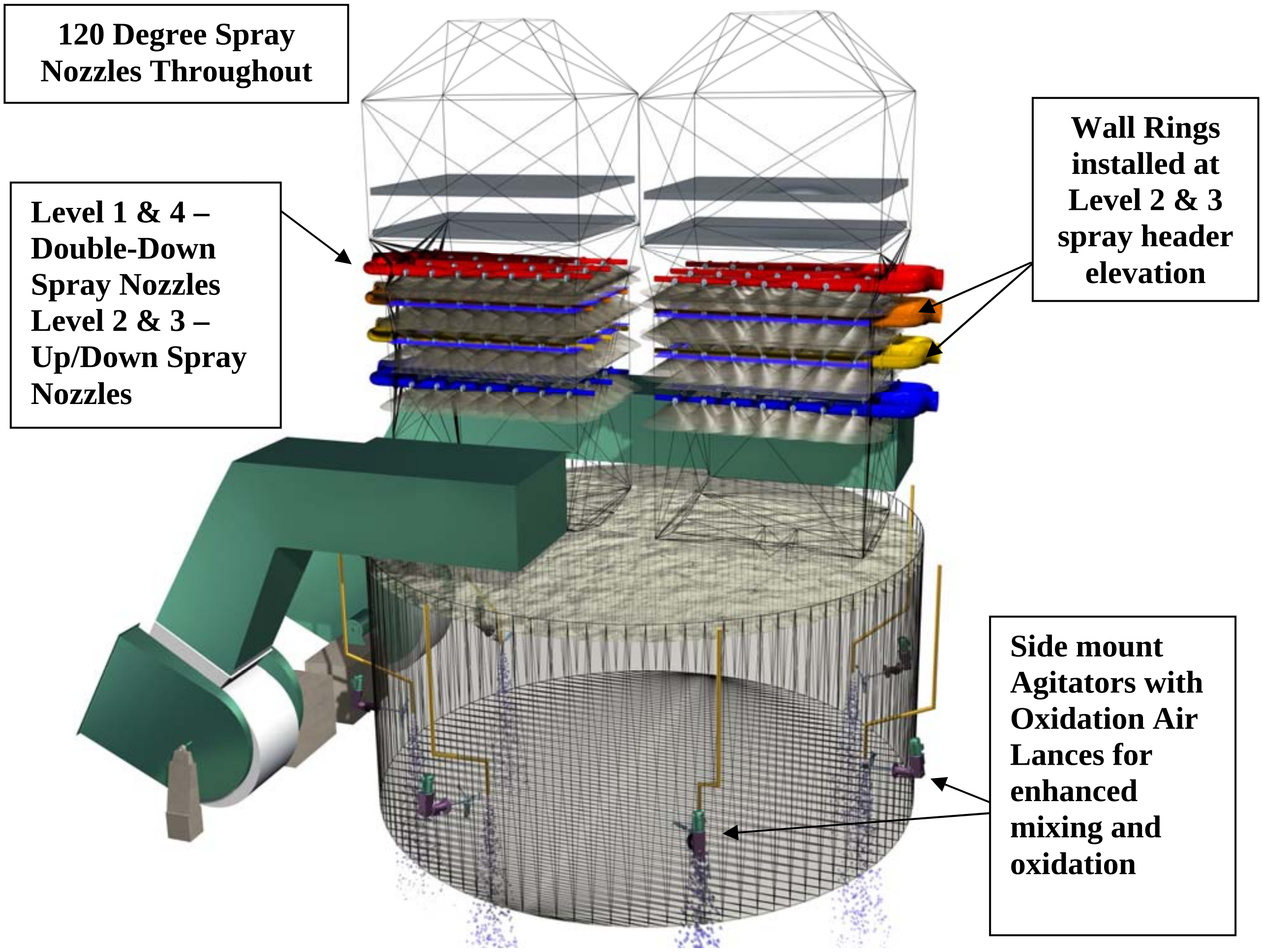


Figure 9: Mill Creek Units 1&2, Case 2 Upgrades

4.2 Case 2 – Work Scope

The Case 2 work scope consists of the following:

- Type of spray nozzles – up/down & double down.
- Spray angle – changed.
- Wall Rings – installed at spray levels 2 & 3.
- Recycle pumps – Unit 1 & 2 new pumps, Unit 3 no change.
- Side mounted agitators with oxidation air lances.

4.3 Spray Header Arrangement / Spray Nozzle Coverage

Spray nozzle coverage can be significantly improved utilizing wider spray angle nozzles on the existing spray header arrangement. Spray nozzle coverage more than doubles by utilizing wider spray angle nozzles on Units 1 and 2. The nozzle coverage doubles by increasing the nozzles spray angle to 120 deg. from the existing 80 deg. nozzles. Utilizing dual-flow nozzles on all three units produces an even larger surface area. Dual-orifice spray nozzles increase the number of droplets and the number of droplet collisions. Increasing the number of droplet collisions results in smaller droplets and a significant improvement in SO_2 removal efficiency because the area available for SO_2 absorption has been increased. Spray level 1 will utilize double-downward nozzles since this spray header is located just below the tray. Dual direction nozzles proposed for spray levels 2 and 3 also have additional benefit of increasing the number of collisions and increasing the residence time of droplets in the absorber. Spray level 4 utilizes double-downward nozzles to minimize carryover into the mist eliminator section. Figure 10 is example of a bi-directional spray nozzle being tested.

BPEI proposes increasing the spray angle from 80^o to 120^o on Units 1 and 2. Figures 11, 12, and 13 show the additional coverage achieved with the dual flow nozzles.

Figure 10: Bi-directional spray nozzle testing

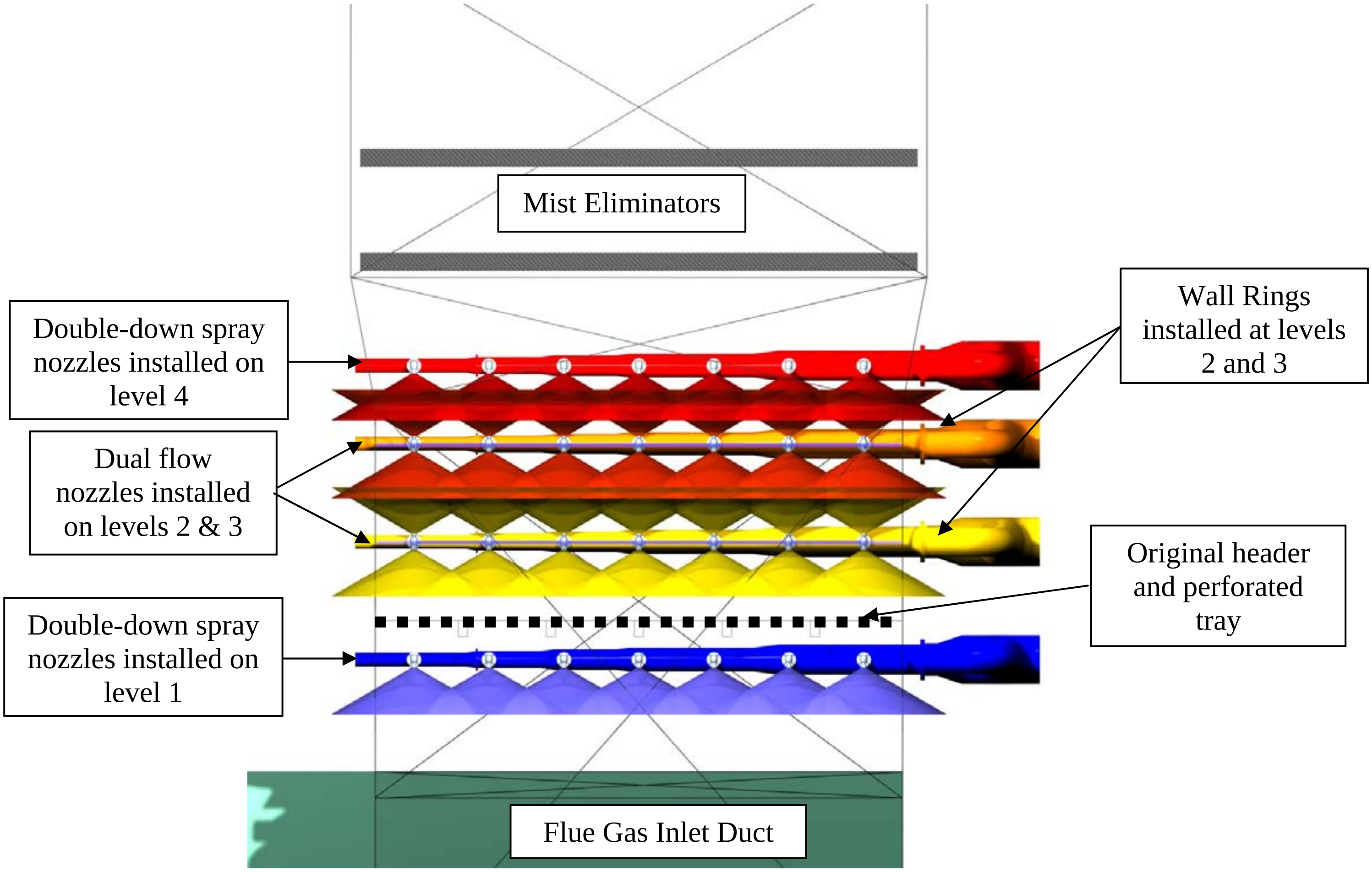


Figure 11: Mill Creek Units 1 & 2, Case 2 Elevation View

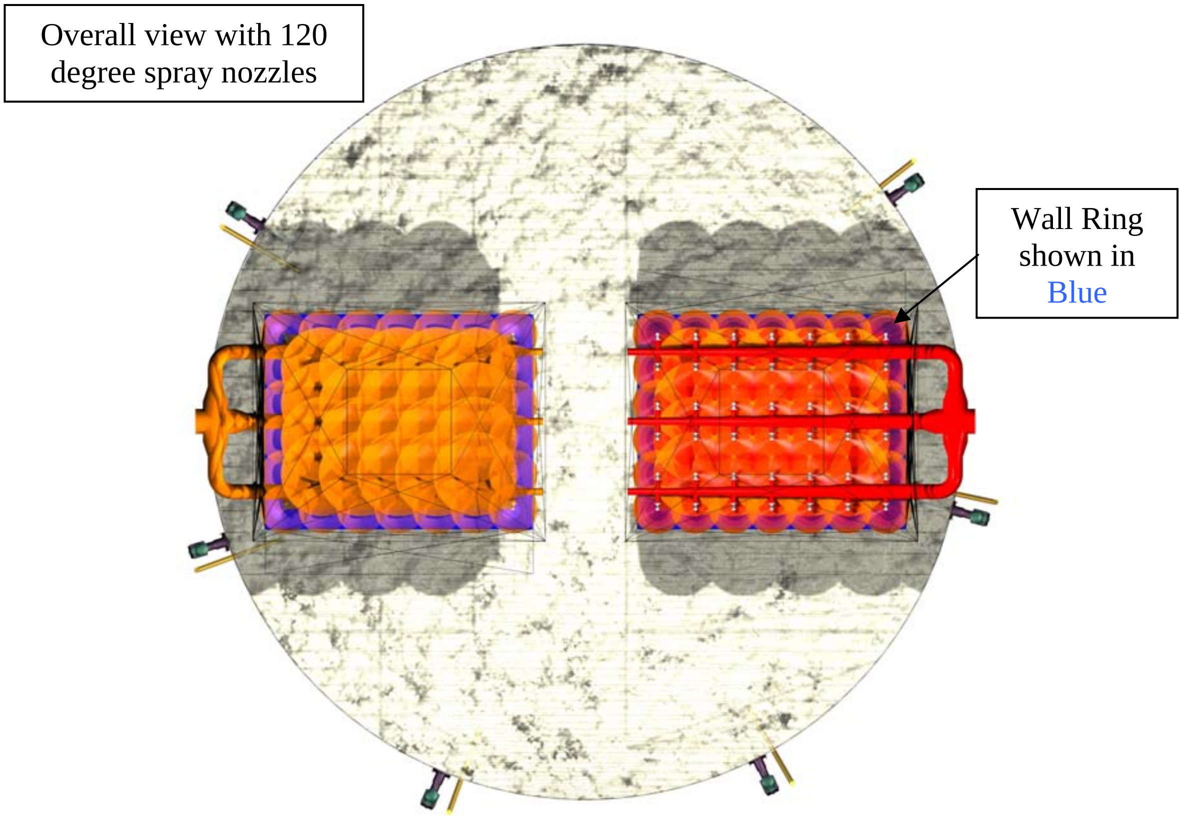


Figure 12: Mill Creek Units 1 & 2 Plan View, Case 2 Upgrades

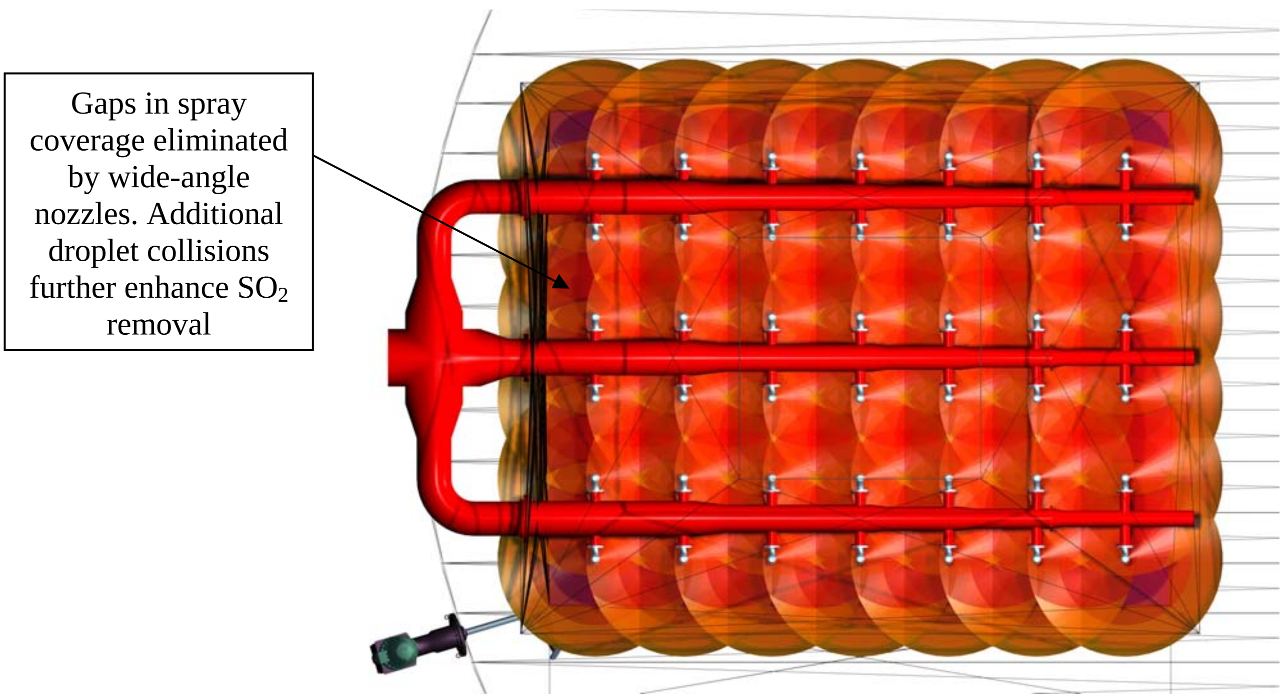


Figure 13: Mill Creek Units 1 & 2 Plan View, Case 2 Upgrades

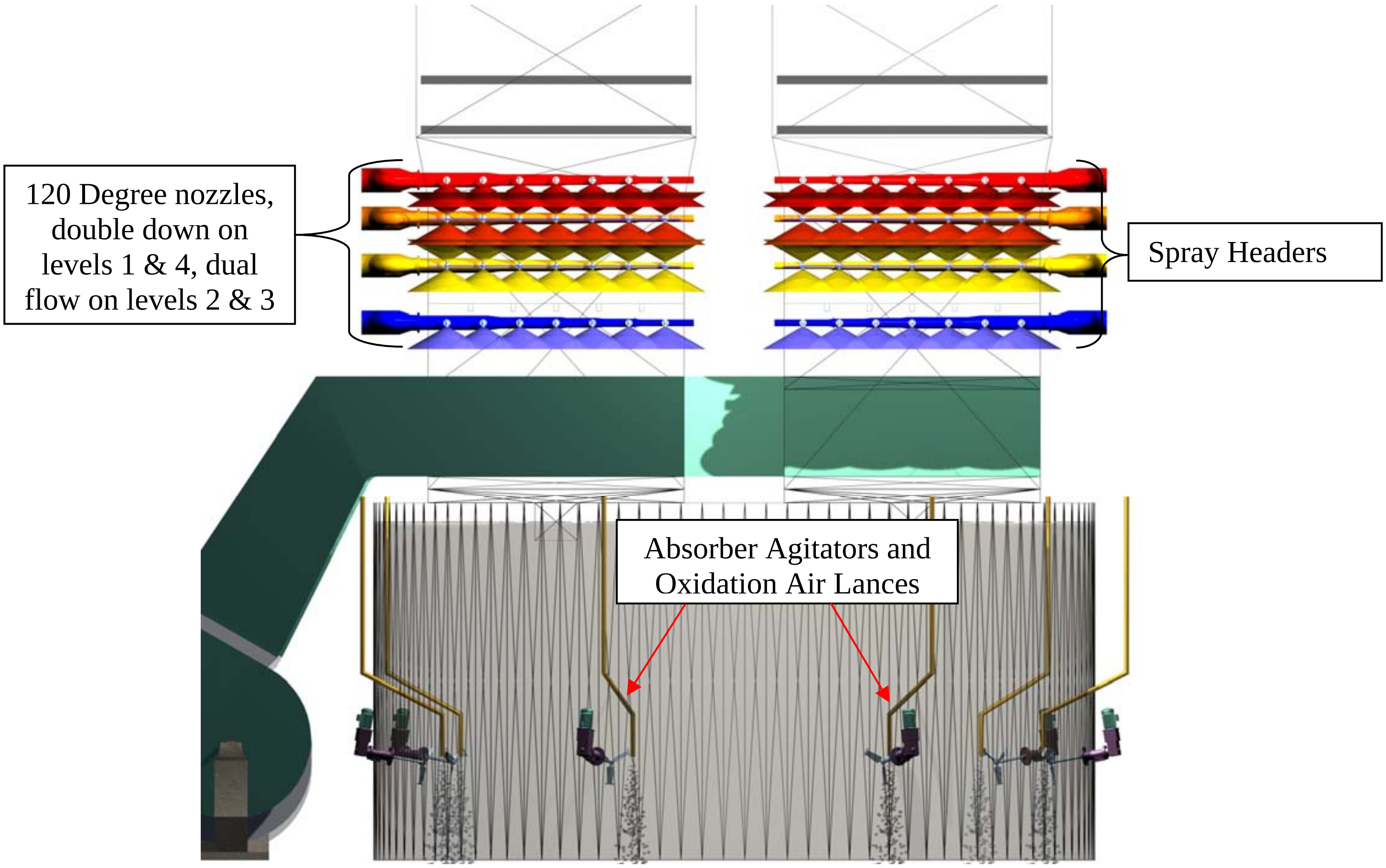


Figure 14: Mill Creek Units 1 & 2 Elevation View, Case 2 Upgrades

4.4 Wall Rings

There is a physical limit to the degree of spray coverage along the wall of the absorbers especially in the corners of square reactor modules. Increased flue gas flow is expected along the wall because of the decreased resistance from this reduced coverage. BPEI will add wall rings to deflect flue gas from the absorber wall into the interior of the absorber where there is a greater chance of interaction with recycle spray droplets. This also promotes more thorough mixing of the flue gas, ensuring no areas of high SO_2 concentration along the walls are allowed to bypass the effective spray zones. Figure 15 below shows a typical wall ring installation in a circular, tile-lined vessel.

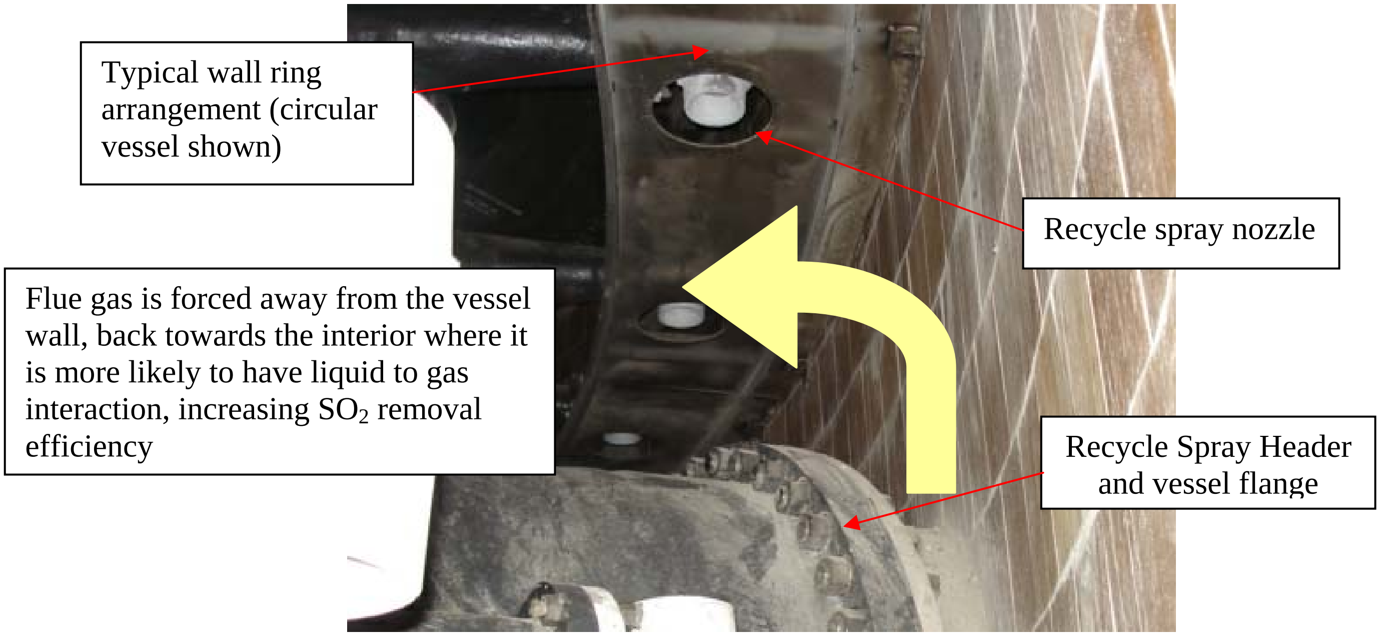


Figure 15: Typical Wall Ring Arrangement (Ghent Plant)

Wall rings will be added at spray levels 2 and 3 to maximize the benefit of contacting flue gas with the slurry spray while minimizing the impact on pressure drop across the absorber. Preliminarily, the pressure drop increase is expected to be minimal. Figure(s) 16 is a graphic representation of the wall rings proposed for Mill Creek absorbers.

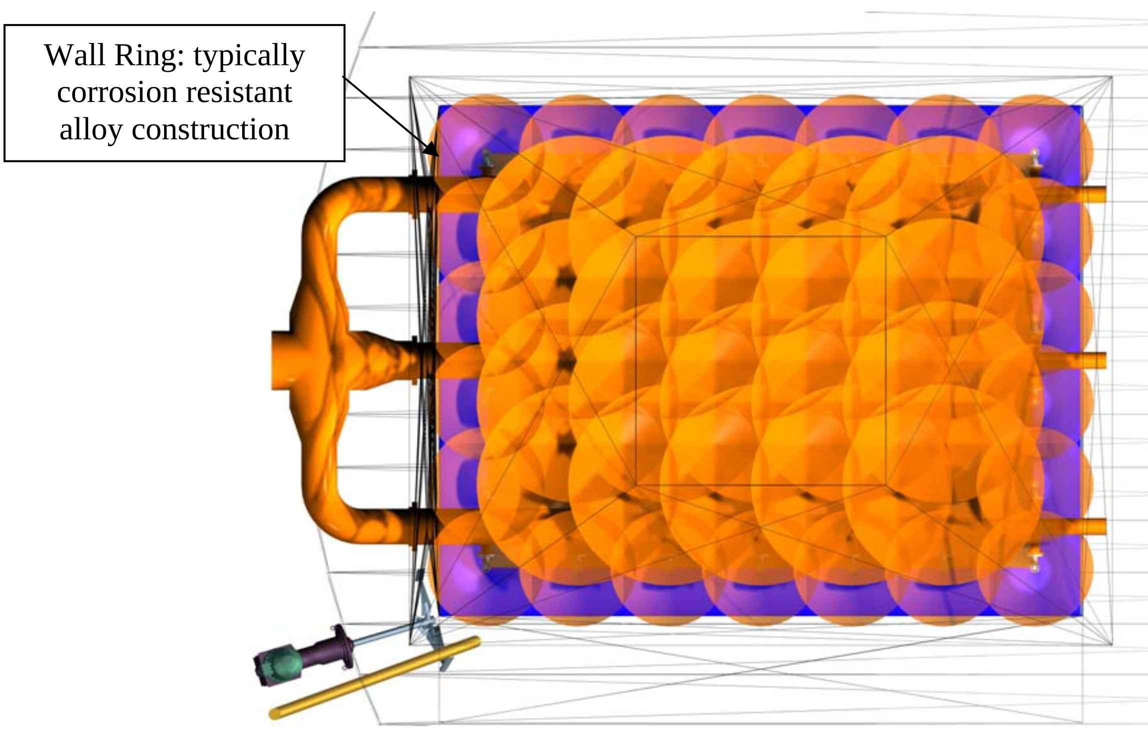


Figure 16: Proposed Wall Ring, typical arrangement

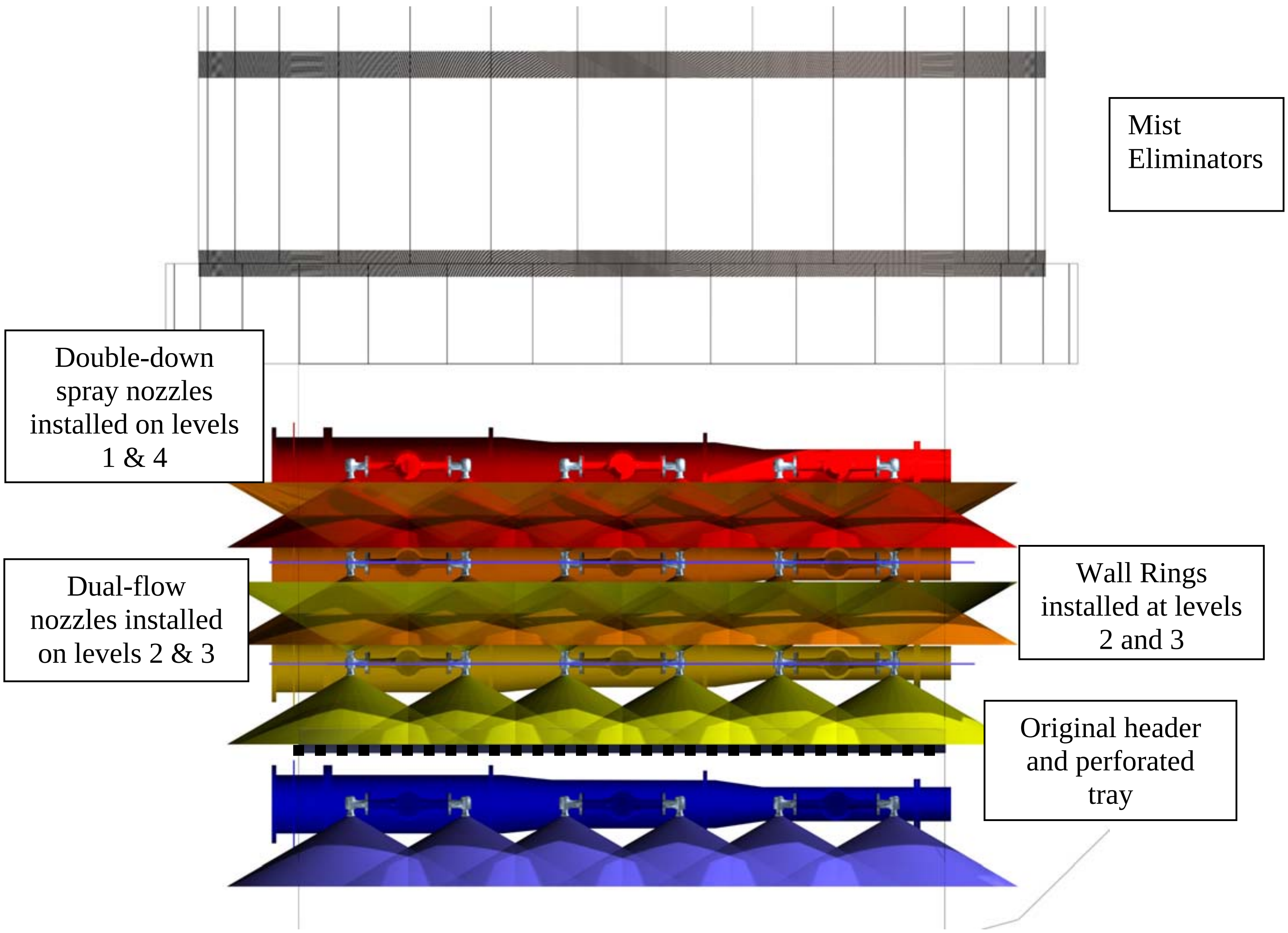


Figure 17: Mill Creek Unit 3 Elevation View, Case 2 Upgrades

4.5 Liquid-to-Gas Ratio

The Liquid-to-Gas Ratio (L/G) is a sizing criteria for absorbers that compares the slurry recirculation rate to the flue gas flow rate. Presently the L/G ratio for Units 1 and 2 is estimated to fall between 112 gal/kacf and 129 gal/kacf based on available recycle pump data. The L/G of 112 gal/kacf assumes a design flue gas flow rate based on Ghent and Brown flue gas flow rates and scaled down for Mill Creek Units 1 and 2. This flue gas flow rate results in a gas velocity through the absorber of 15.5 ft/sec which is close to what plant personal reported for these units. The higher L/G ratio of 129 gal/kacf is calculated when the original absorber design flue gas flow rates are modeled. The reduced flue gas flow rate results in a reduced flue gas velocity of 13.3 ft/sec through the absorber. For the purpose of this study, the worst-case high flue gas flow rates/reduced L/G ratios were used to evaluate improvements to these units.

The L/G ratio for Unit 3 is 153 gal/kacf. There is more data available for Unit 3 flue gas flow rates as a result of baseline testing completed on Unit 3. Unit 4 absorber cross-sectional area is approximately 23% greater than the original Unit 3 absorbers and as a result the flue gas velocity is reduced compared to Units 1 and 2 at 10.8 ft/sec (versus the original flue gas velocity of 13.4 ft/sec through the existing Unit 3 absorbers). The higher L/G is also a result of the higher recycle pump flow rates for the current Unit 4/future Unit 3 absorber. The design basis for the flue gas is summarized in Appendix Basis of Design Description.

The units were modeled with the dual spray nozzles and wall rings installed. Unit 3 is expected to achieve 96% removal provided other process issues are addressed as discussed in the following sections. Units 1 and 2 will require a higher L/G ratio of 141 gal/kacf to achieve 96% removal. The higher L/G ratio is equivalent to a pump flow rate of 19,000 gpm requiring new recycle pumps to be able to achieve 96% removal. The slurry velocity through the recycle piping for Units 1 and 2 is already 50% higher than what BPEI would recommend to minimize erosion issues. Utilizing higher flow pumps would also require replacing the recycle piping, pump isolation valves, and larger spray headers. The higher pump flow rate will also increase the pressure drop across the absorber and impact ID fan performance. This is why a thorough understanding of the existing recycle pump and spray nozzle performance through physical testing is required to determine if this is necessary.

In addition, more cost effective options are available as an alternative to replacing recycle pumps to achieve 96% SO_2 removal on Units 1 and 2. Alternative options include utilizing limestone slurry with a finer grind and the addition of organic acid to these absorbers. Either of these options will increase SO_2 removal efficiency without a negative impact on current absorber layout and ID fan performance. The absorber design is not very far off from making the 96% removal mark based on current absorber performance. While replacing recycle pumps may be desirable to achieve maximum removal efficiency with these absorbers. BPEI recommends maximizing SO_2 removal in Unit 1 and 2 absorbers with modifications of dual-flow nozzles and wall rings and then making process changes if necessary to achieve 96% SO_2 removal.

4.6 Absorber Solids/Liquid Residence Time

As previously mentioned the WFGD systems at Mill Creek are normally operated at reduced slurry solids concentration and reduced reaction tank levels compared to original design set points. These operating conditions coupled with higher inlet SO_2 concentrations and higher SO_2 removals to be considered for this retrofit reduces the solids and liquid residence time in the absorbers. New limestone, forced-oxidized absorber systems are traditionally designed to maintain a solids residence time of 15 hours and a liquid residence time of 5 minutes. Solids residence time is necessary to provide adequate time in the reaction tank for gypsum crystal growth. The purpose of liquid residence time is to minimize the amount of excess limestone required to maintain SO_2 removal by allowing adequate time for the limestone to dissolve. This is especially important in the production of wallboard grade gypsum. Five minutes is standard liquid residence time for the limestone grind fineness and the limestone reactivity typical of limestone used at Mill Creek. In retrofit projects BPEI tries to maintain at minimum 12 hours solids residence time and 4.5 minutes liquid residence time. The absorber trays are designed to add to the liquid residence time because of slurry holdup on the tray itself. However, BPEI does not have data available to evaluate the benefit of the tray on liquid residence time.

Unit 1 and 2 reaction tanks are appropriately sized. At the reduced solids density and reduced tank levels the solids residence time is 15.1 hours and the liquid residence time 7.0 minutes. At minimum BPEI recommends increasing the reaction tank level set point from 31.5' to the original design level of 35.5' to maintain a liquid seal between the absorber modules and the reaction tanks and eliminate the potential for flue gas corrosion above the reaction tank. There are several other areas in inlet and outlet ductwork where flue gas leakage is occurring. The corrosion and gas leakage issues are not discussed in this report.

Unit 3 reaction tanks are very small and were originally designed for a lime-slurry, natural-oxidation process. Lime slurry has a faster dissolution rate compared to limestone slurry so reaction tanks are normally designed with reduced liquid residence times. Also, higher solids residence times did not improve the dewatering properties of calcium sulfite hemi-hydrate crystals. Even though Unit 3 is a larger unit compared to Units 1 or 2 (425 MW vs 330 MW), the total reaction tank volume is 25% less than Units 1 and 2 reaction tank volumes. At the reduced solids density and reduced tank levels the solids residence time is 8.3 hours and the liquid residence time 3.2 minutes. BPEI recommends increasing the reaction tank level set point from 15' to original design level of 18' to increase these residence times and to maintain a liquid seal between the absorber modules and the reaction tanks.

BPEI also recommends improving the reliability of the absorber bleed system so that absorber slurry density can be maintained within controlled limits. Improving the reliability of the bleed system requires an evaluation of the bleed control valves and bleed logic. Brown has a similar bleed system design as Mill Creek with a Hydrocyclone assembly installed at the absorber. This system operates with high reliability and BPEI believes the reliability of the bleed system at Mill Creek can be improved to maintain a solids concentration approximately 15 wt%, which is typical of limestone forced-oxidation systems. Increasing the reaction tank level and absorber slurry solids increases the solids residence time to 13.8 hours and the liquid residence time to 3.8 minutes.

The liquid residence time is still below minimum recommendations for this process. The negative impact is increased excess limestone required (higher absorber slurry pH) to maintain SO_2 removal. The absorber tray may eliminate this issue however alternatives to increasing liquid residence time were evaluated. One way to increase liquid residence time is to increase the volume of the reaction tanks. This is a less desirable solution and would require changing the geometry of the transition from absorber to the reaction tank and increasing the level of the reaction tank. Additionally, liquid residence time can be increased by reducing recycle pump flow to 25,000 gpm. As a result SO_2 removal will be close but may not necessarily be maintained at 96%. Reducing pump flow rates will also require modifications to the recycle pump impellers. Alternatively, limestone grind fineness can be increased to offset the decreased liquid residence time. This option will be discussed in more detail in Section 5 of this report.

4.7 Oxidation Air Blowers and Agitators

Poor mixing of air and absorber slurry can reduce the performance of the absorber. The oxidation air sparger ring currently installed requires higher oxygen to SO_2 ($O:SO_2$) ratios to provide enough excess air to complete the reaction of SO_2 removed by the absorber to gypsum. The air sparger ring is also a source of high unreliability in the absorber system causing forced unit outages whenever the oxidation air system is out of service greater than 30 minutes or the sparger ring plugs up over time. BPEI recommends adding agitator and air lance assemblies which will reduce the $O:SO_2$ requirements, increase agitation in the absorber allowing the absorber to be maintained at design solids concentration, improve reactivity by decreasing excess limestone in the absorber, and most importantly improve reliability of the WFGD system. Oxidation air lances will be between 8” and 10” in diameter, which will eliminate issues with pluggage even if the oxidation air blower is out of service for several hours. Figures 18 and 19 show graphically agitators and oxidation air lances on one of the reaction tanks. The agitators will be appropriately spaced from the recycle pumps to avoid entraining air in the recycle pump suction and causing cavitation issues. The number and size of agitators and air lances required is a function of the reaction tank diameter, absorber slurry level in the reaction tank, and volume of oxidation air required to maintain full oxidation.

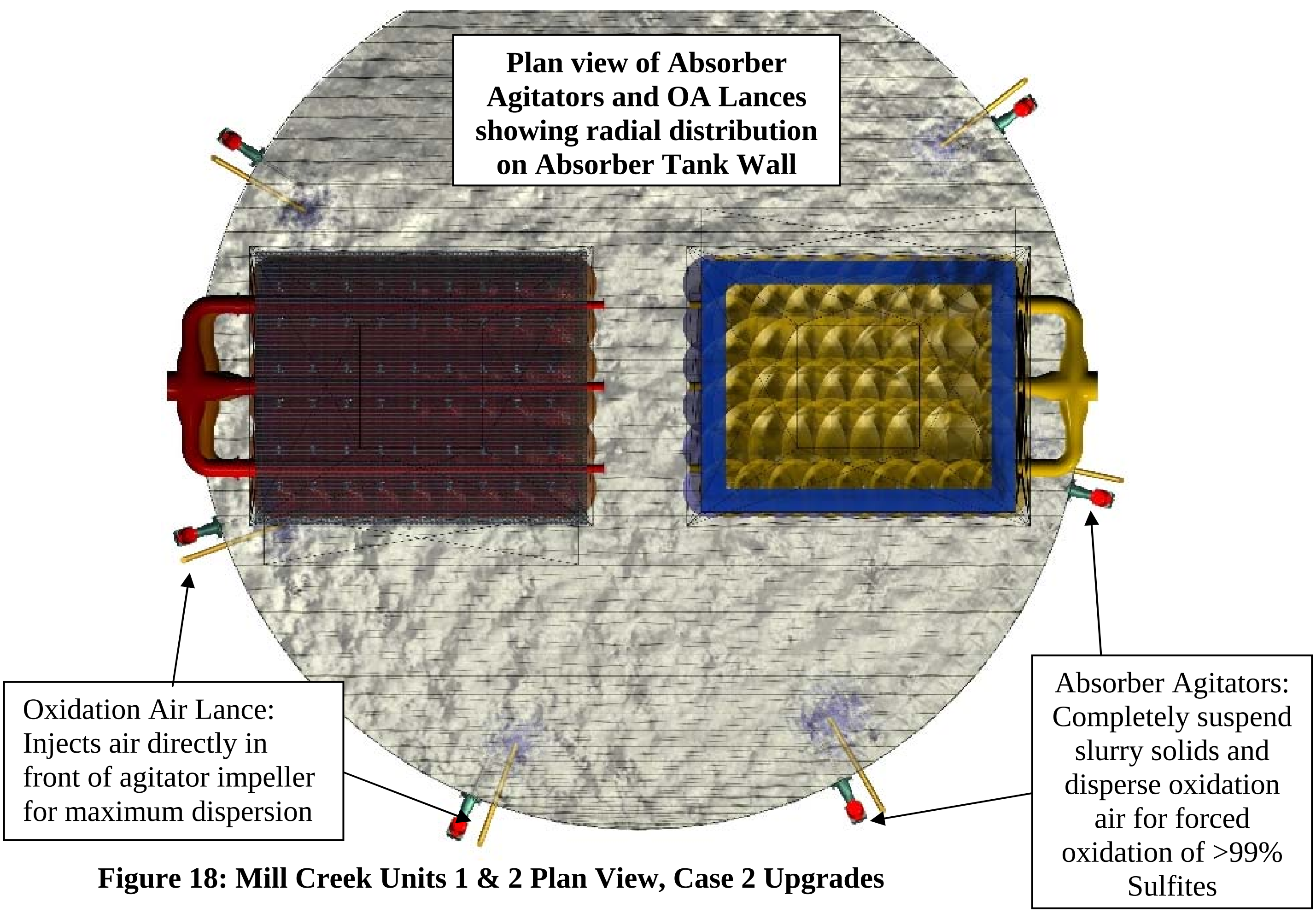


Figure 18: Mill Creek Units 1 & 2 Plan View, Case 2 Upgrades

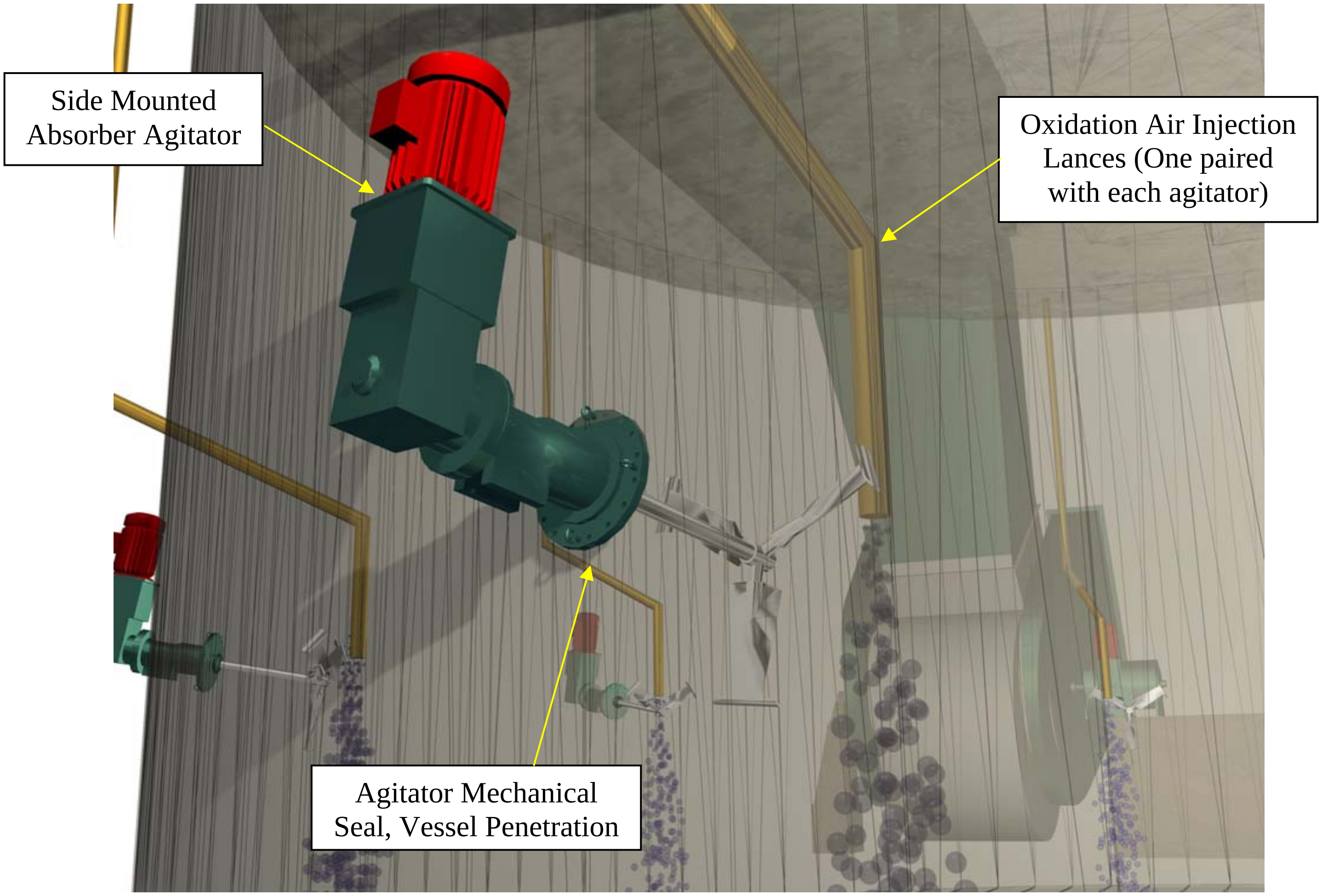


Figure 19: Absorber Agitator/Lance

Oxidation air rates required for the high sulfur, high SO_2 removal on Units 1 and 2 is 10,300 scfm with a supply pressure of 14.6 psig per unit. At present conditions the oxidation air blowers run at minimum levels to maintain the airflow necessary for high oxidation. Oxidation air is provided to Units 1 and 2 with a common blower. Based on present blower operation and the air compressor size (Atlas Copco HA10) it is believed the existing blowers can be used with the new agitator/lance design. The oxidation air rate required for Unit 3 is 14,000 scfm with a supply pressure of 7.2 psig. Unit 3 oxidation air is provided by a dedicated blower. The existing air compressor is capable of maintaining adequate airflow for Unit 3 with the blower operating at minimum load. However, with the relatively short reaction tank levels the blower discharge pressure is relatively low. The piping system may require an orifice to keep the air compressor operating on its curve.

Figure 20: Oxidation Air Lance and Agitator Impeller

Additional modeling is recommended to verify mixing and ensure the oxidation air can be dispersed in the reaction tanks to complete oxidation. Unit 3 may require a higher $O:SO_2$ ratio than is typical for WFGDs but preliminarily the blower appears to have the capacity to accommodate higher air flows if necessary.

4.8 Construction

The Case 2 construction will consist of replacing the unit 1&2 recycle pumps and piping to the spray headers unit 3 will not be changed. BPEI will be adding spray nozzles, wall rings and agitators to units 1,2 &3.

BPEI is planning to work four months at 1-10-5 shifting to install recycle pump foundations on units 1&2 and receive materials and set up scaffolding for the outage work.

During the three week outage BPEI will replace the recycle pumps and pipes on units 1&2 only. The unit 3 recycle pumps and pipes will not be changed out. All three units will have wall rings, spray nozzles and agitators added.

The ROM estimate for BPEI to provide engineering, materials and construction is as follows:

- Case 2: Unit 1 - $10,541,512
- Case 2: Unit 2 - $10,632,006
- Case 2: Unit 3 - $14,035,835

4.9 Schedule

Our preliminary schedule included in the attachments section is based on the following:

Case 2: Units 1, 2, & 3:4

- (4) Month construction schedule working (1-10-5)
  One shift, ten hours per day for five days
- (3) week outage schedule working (2-10-6)
  Two shifts, ten hours per shift, six days per week

5 CASE 3 +98% SO_2 Removal Efficiency

5.1 Technical Summary – Case 3

In the final stage of analysis all available methods for performance enhancement are brought into play. Spray header layout and nozzle selection are optimized based on the overall absorber shell dimensions for absolute maximum performance based on the existing reactor tower dimensions. For Units 1 & 2, recycle pumps are pushed further and piping is resized for greater flow to increase L/G significantly over the original and 96% removal option. Unit 3 does not require higher L/G ratio to maximize SO_2 removal. Spray header spacing is increased and placement is altered to allow for multiple levels of bidirectional nozzles, which have proven to be superior in performance compared to down-only nozzles. Spray header layout is altered to provide added spray density and prevent any holes in spray coverage by moving the position of individual nozzles on the headers.

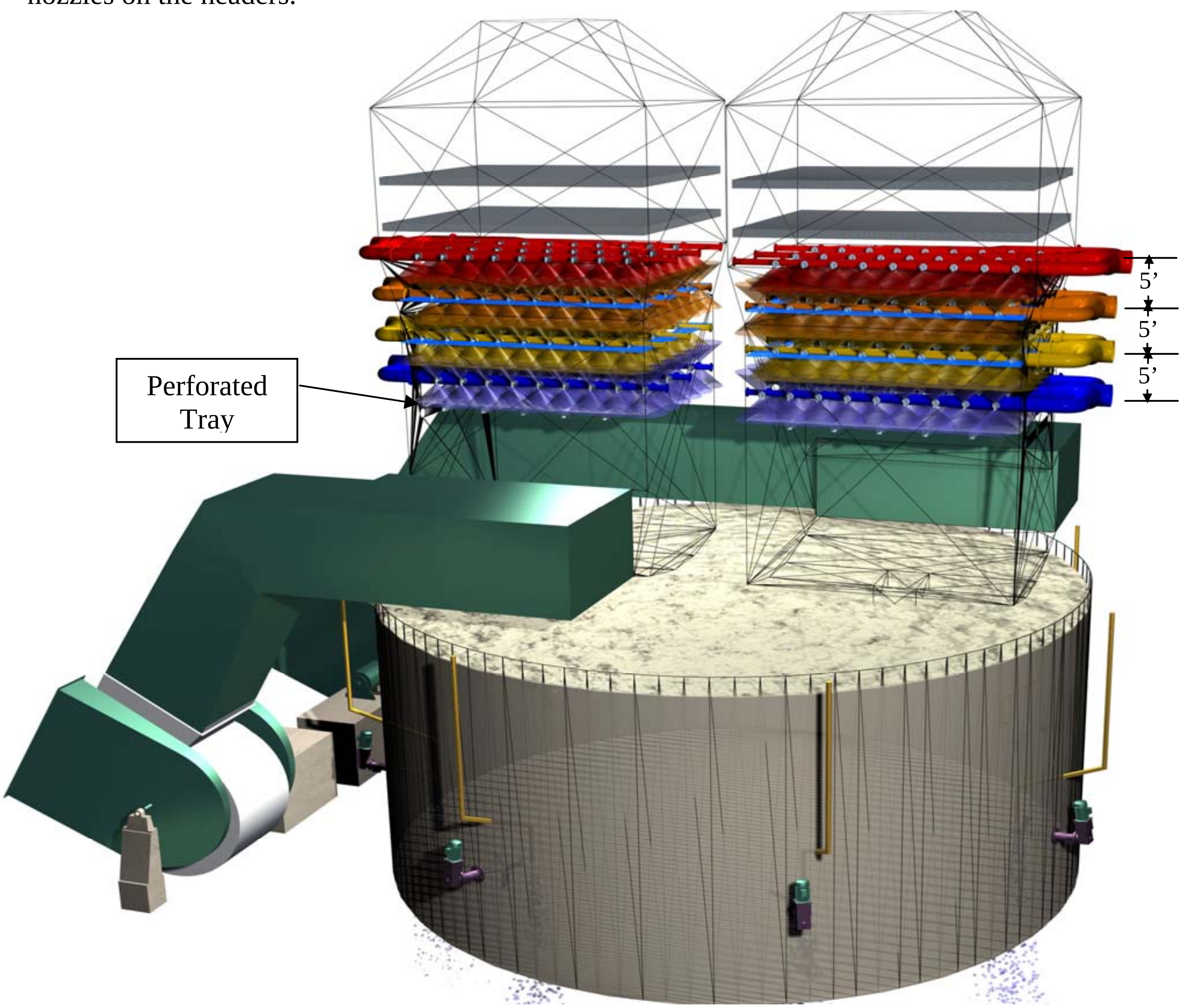


Figure 21: Mill Creek Units 1 and 2, Case 3 Upgrades

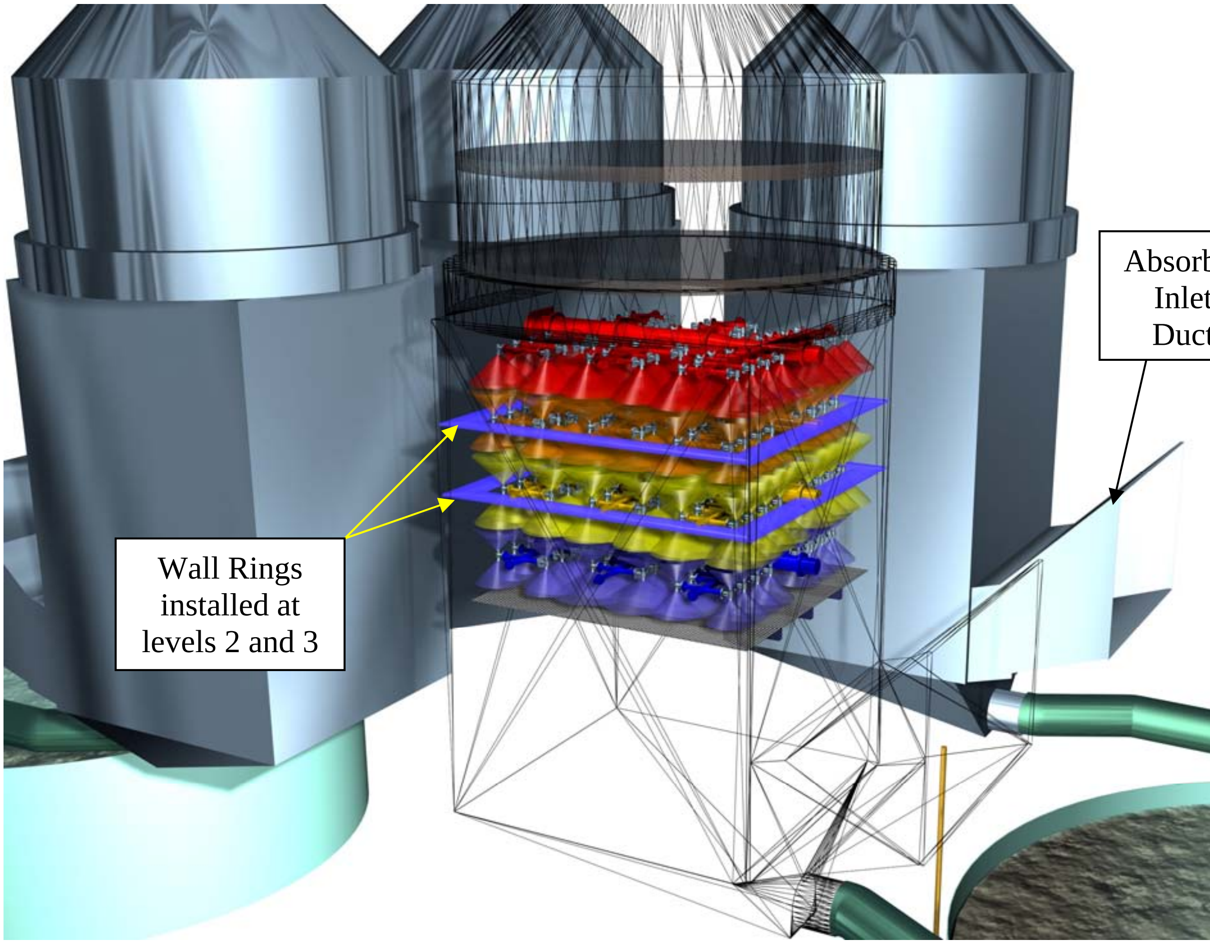


Figure 22: Mill Creek Unit 3, Case 3 Upgrades

Chemical changes including addition of an organic acid and increasing limestone grind fineness are considered as additional methods to improve the removal reaction rate. Finalizing the maximum removal upgrade options is a series of recommendations for process optimization involving control hardware and logic modifications. Over many iterations of design and control philosophy BPEI has refined WFGD control logic to provide to our clients a simple and efficient means of reliably removing SO_2 from flue gas. Modifications to the existing control scheme and potential hardware changes are addressed in this final section.

5.2 Case 3 – Scope of work

The Case 3 work scope consists of the following:

- Spray header location – All four headers above the tray spaced 5' apart.
- Spray header arrangement – Staggered layout.
- Spray nozzle layout – Increase spray density.
- Type of spray nozzles – up/down & double down.

- Spray angle – changed.
- Wall Rings – installed at spray levels 2 & 3.
- Side mounted agitators with oxidation air lances
- Recycle pumps – U1&2: new pumps, U3: new gearboxes.
- Mist eliminator – Install new DV210.

5.3 Optimization of Absorber General Arrangement

The current arrangement of the tray and spray headers is less than optimal for maximum SO_2 removal. The spray headers are spaced closely together and the tray is currently installed between spray levels 1 and 2 eliminating the use of dual-flow bi-directional spray nozzles on the first spray level. Additionally, the nozzle arrangement is identical between spray levels which can result in flue gas channeling ("laning") through the absorber, reducing SO_2 removal potential. BPEI proposes the following to maximize SO_2 removal efficiency across the absorber:

- Relocate bottom spray header above the perforated tray
- Space the spray levels 5 ft apart
- Stagger nozzle layout between spray levels
- Increase spray density

Originally trays were installed in open spray towers with a spray header installed below the tray to quench the flue gas and minimize scaling on the tray. This was especially an issue on natural oxidation systems. Research has since been completed to demonstrate a quench spray header is not necessary for limestone, forced-oxidation systems. BPEI proposes leaving the installed tray in its existing location and rearranging the spray headers so that they are all located above the tray. Relocating the first spray header will also allow the use of dual-flow, bi-directional spray nozzles on an additional spray header.

Spray Header Spacing

- The spray headers will be relocated 5 ft apart to match current design practices for high efficiency absorbers.
- To create the extra space required in the spray zone section, BPEI proposes removing the abandoned re-heater section and relocating the mist eliminator section in this unused section.
- Moving the spray headers in this manner allows the use of bi-directional nozzles on all but the top level spray header. Further, this spray header spacing provides for a providing more uniform distribution of slurry to the entire spray zone with enhanced droplet formation for more intimate contact between SO_2 molecules and slurry droplets.

Figures 22 through 26 show the original and proposed spray header spacing for Units 1 and 2 and Unit 3.

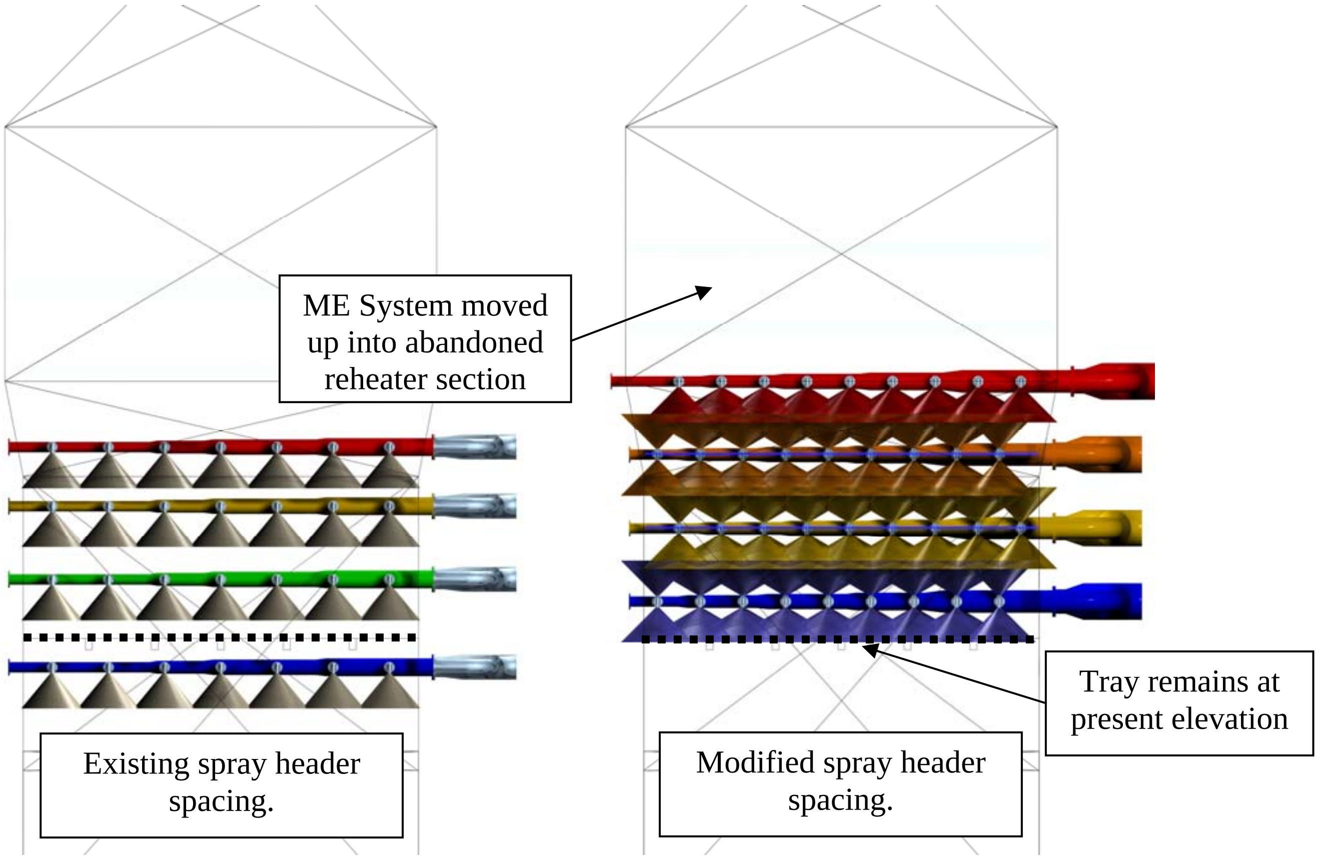


Figure 23: Units 1 and 2 Modified Elevation View

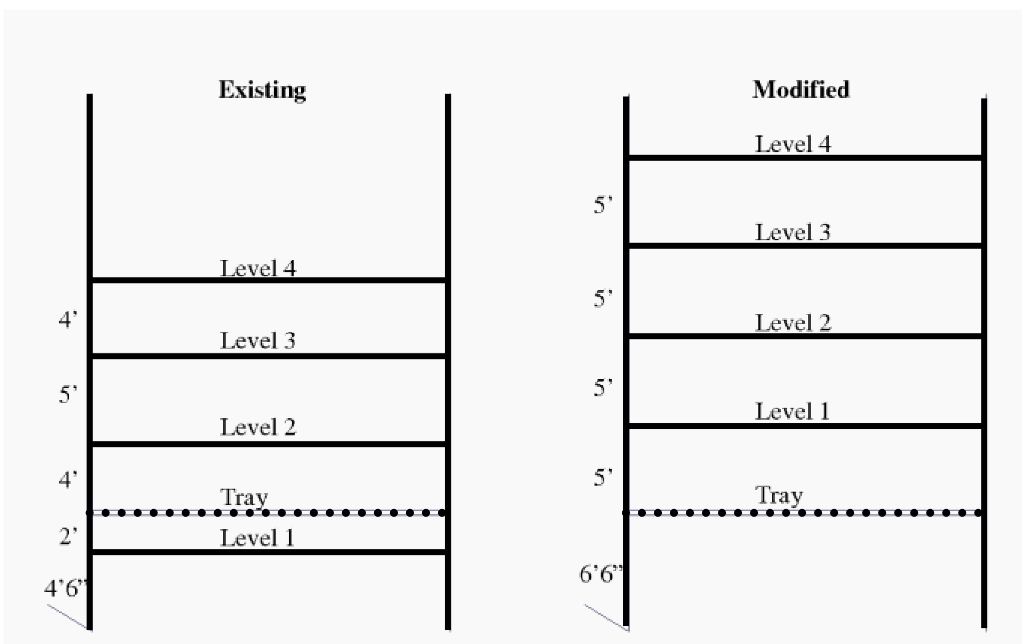


Figure 24: Units 1 and 2 Spray Header Spacing simplified sketch

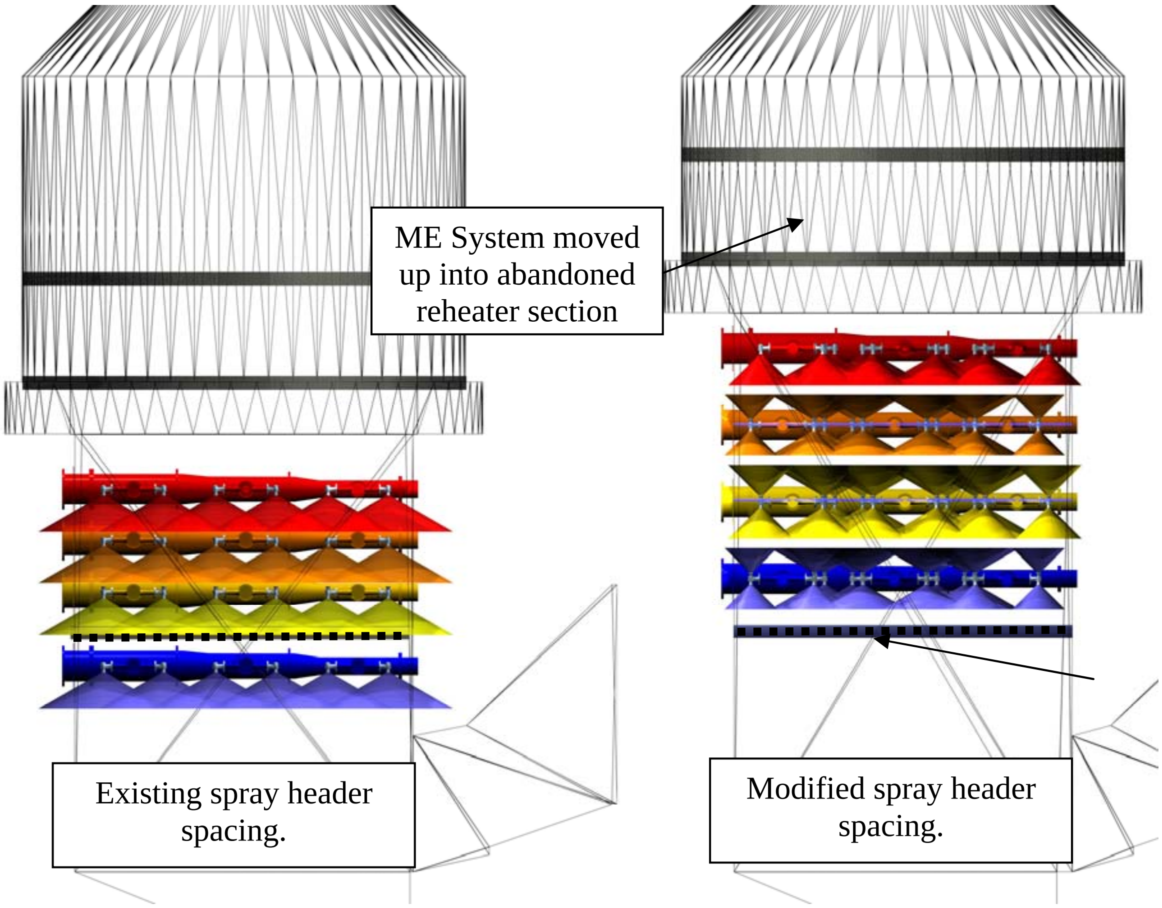


Figure 25: Unit 3 Modified Elevation View

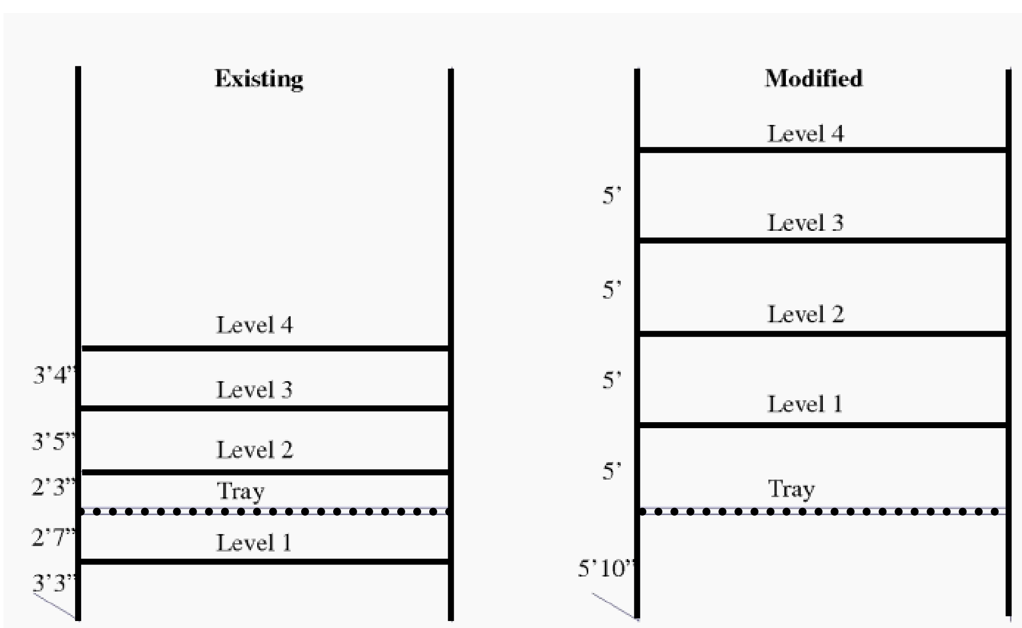


Figure 26: Unit 3 Spray Header Spacing simplified sketch

Staggered Nozzle Layout & Increased Spray Density

- Staggering the nozzle layout between spray headers minimizes the potential of gas channeling or 'laning' through paths of low liquid flow, i.e. paths of least resistance.
- Wall Rings along the full inner perimeter of the vessel counteract the 'wall effect' ensuring that the gas flowing upward along the walls is fully treated and reduces the amount of 'lost' slurry that is sprayed onto the wall by redirecting that slurry out into the spray zone.
- Good liquid distribution over the entire spray level cross-section ensures all flue gas that passes through the absorber is treated.
- On smaller absorbers with a standard nozzle layout as Mill Creek the flow rate per nozzle is higher than typical for high efficiency scrubber designs therefore to maintain a small droplet profile with high flow nozzles requires increasing the spray pressure, resulting in a higher TDH for the recycle pumps.
- Alternately, increasing the number of spray nozzles per spray header, thus increasing spray density, is the most effective use of the low spray pressure nozzles proposed for the Mill Creek upgrade.
- Increasing the spray density has the potential additional benefits of increasing the removal of particulate and acid gas (SO3) in the absorber.

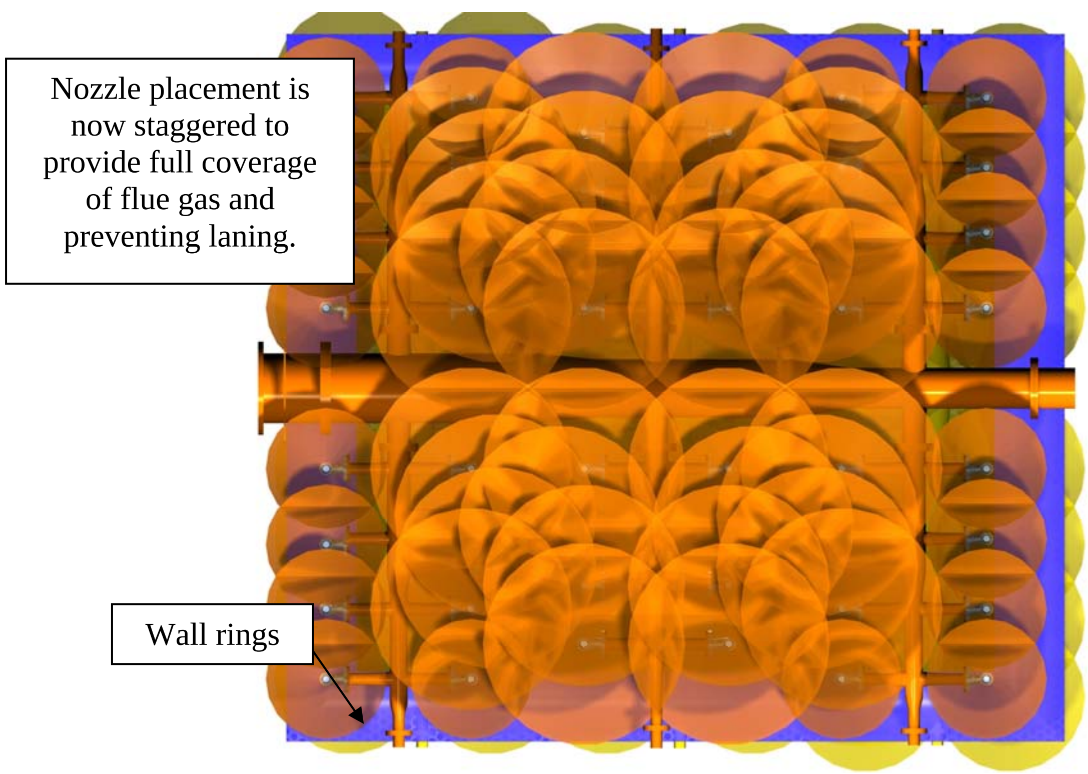


Figure 27: Unit 3 Modified Spray Header Layout

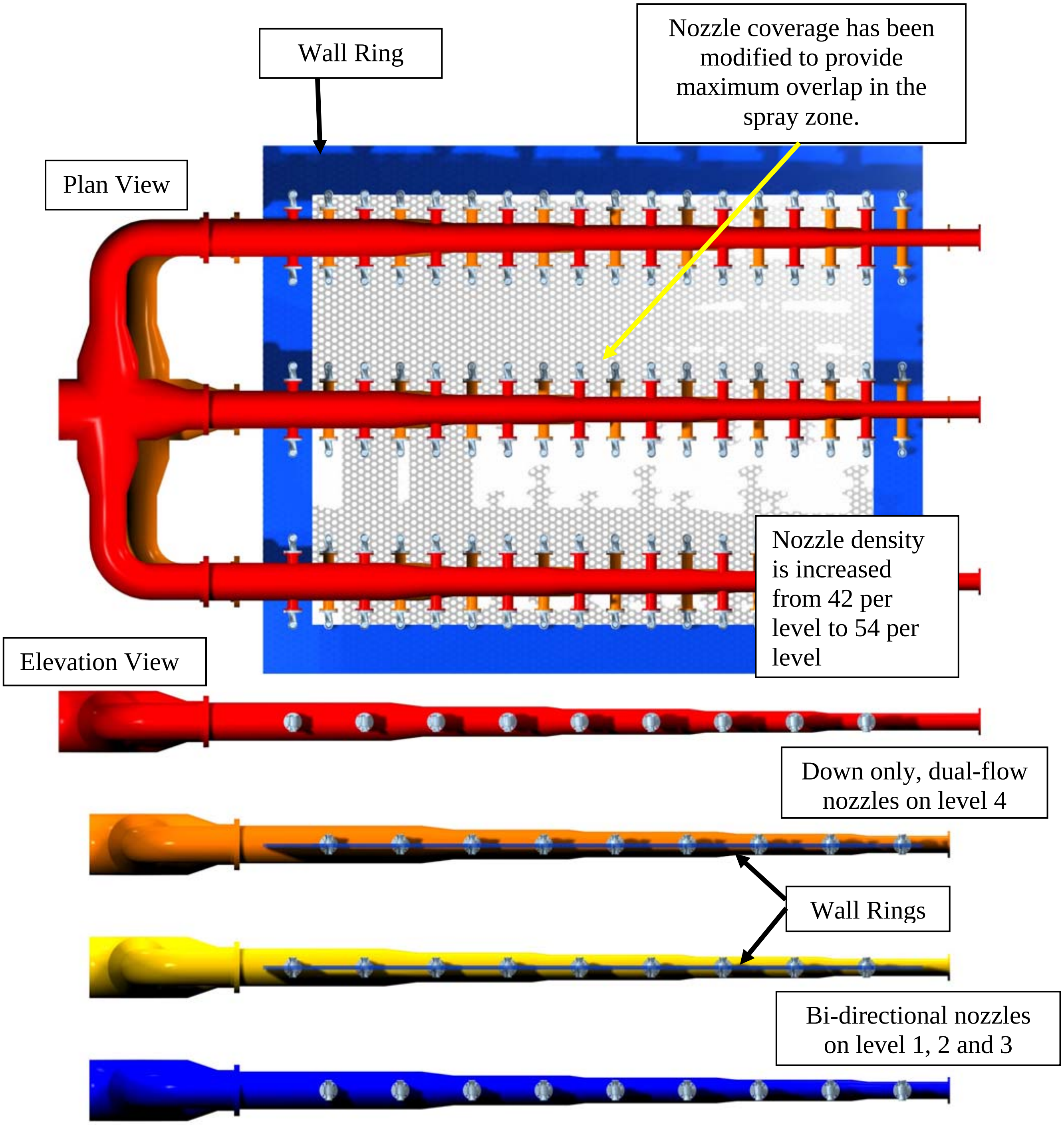


Figure 28: Mill Creek Units 1 & 2 Modified Nozzle Arrangement

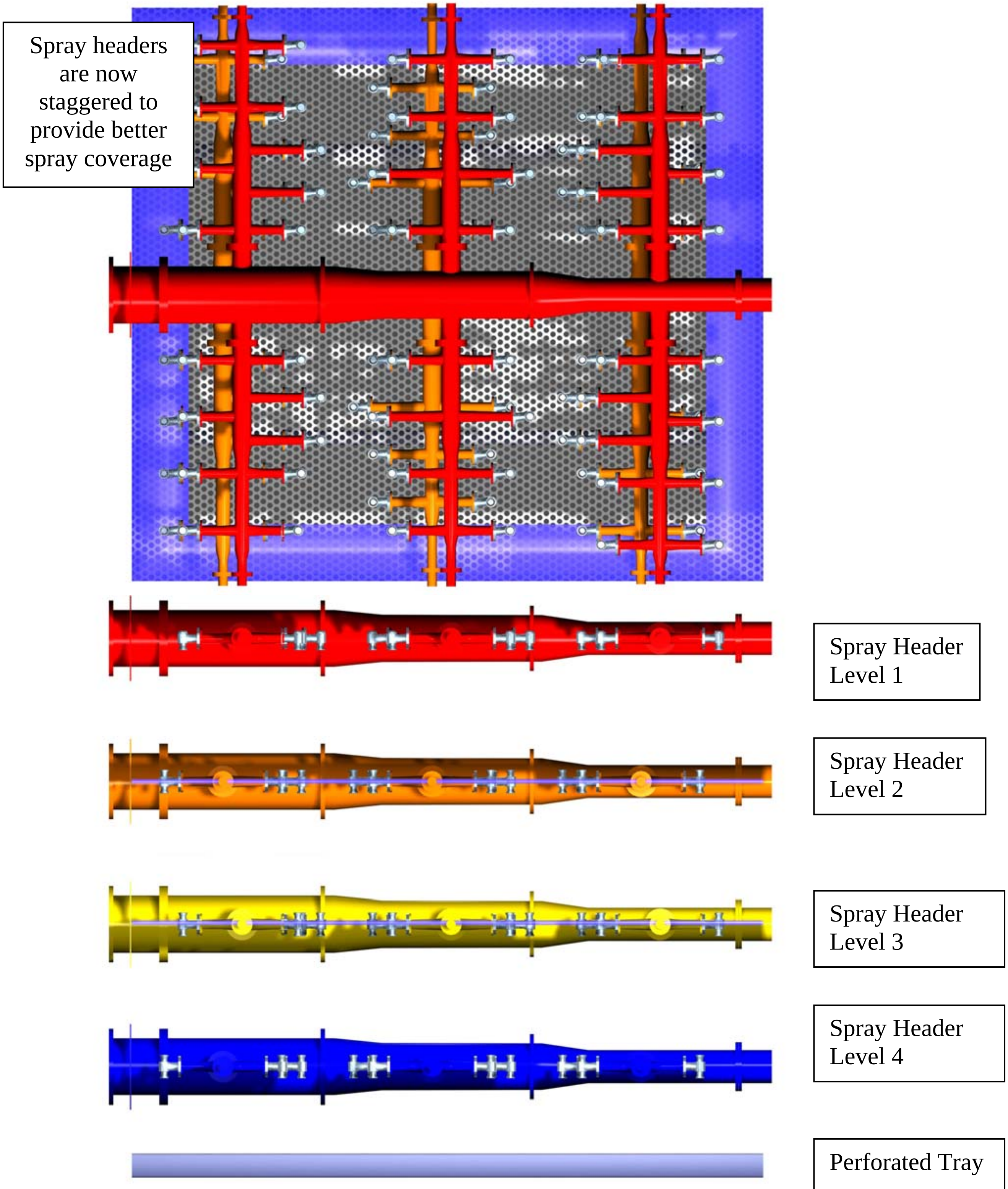


Figure 29: Mill Creek Unit 3 Modified Nozzle Arrangement

Figures 30 and 31 are Process Flow Diagrams with the new spray header layout for Units 1 and 2 and Unit 3.

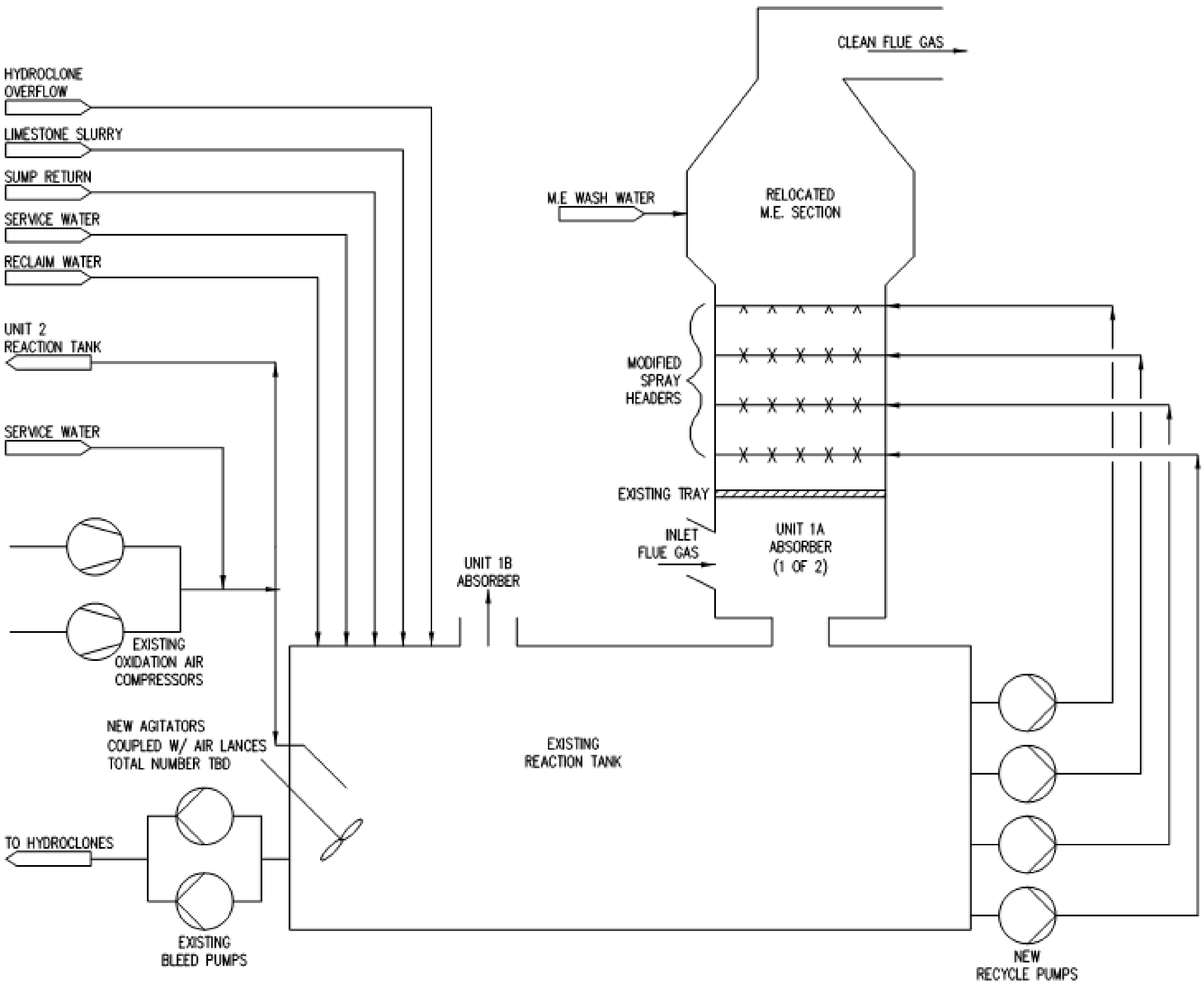


Figure 30: Unit 1 Process Flow Diagram

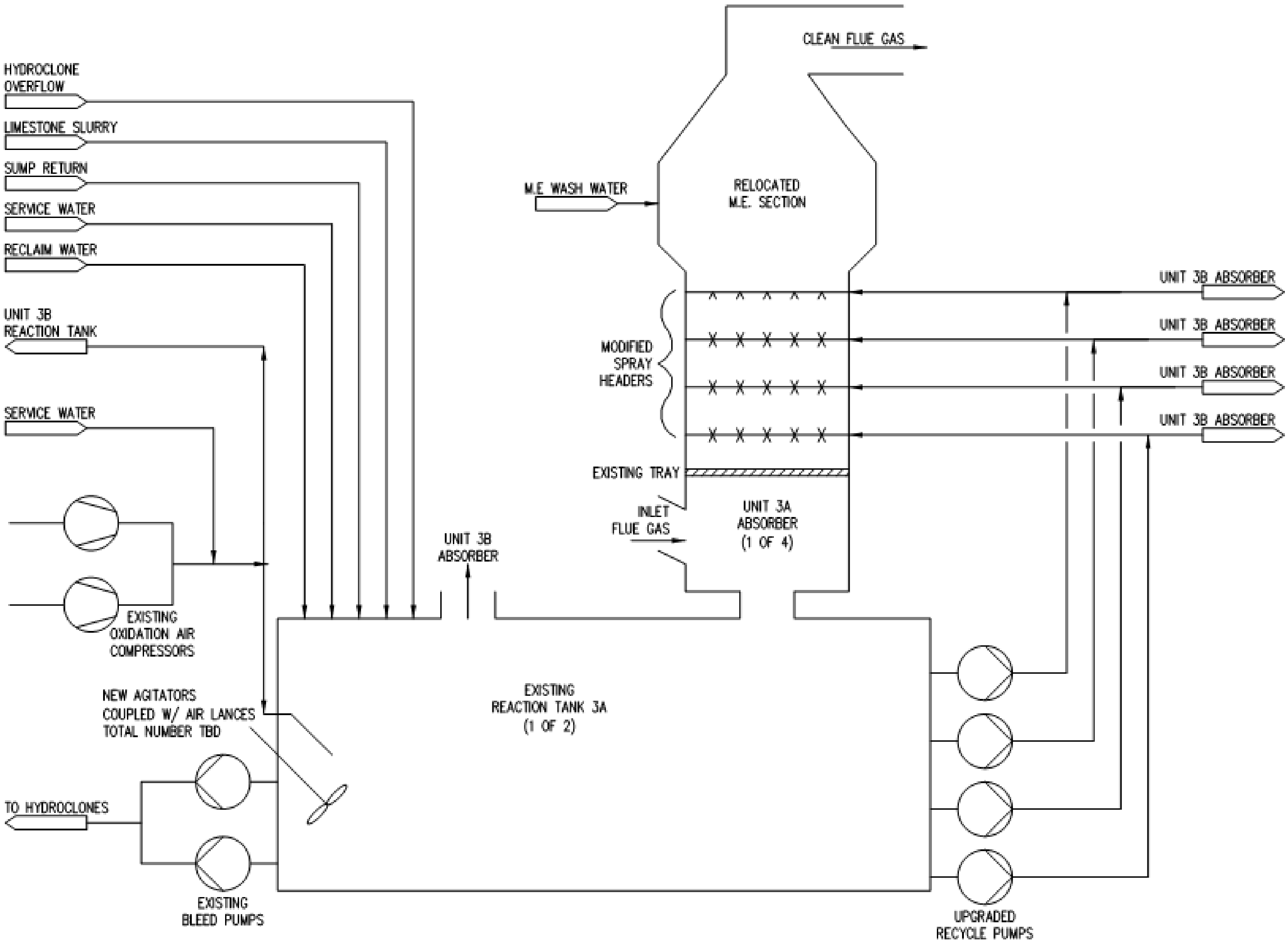


Figure 31: Unit 3 Process Flow Diagram

Optimization of Absorber Process Conditions

The units were modeled with the above referenced spray header arrangement modifications. The recycle pump curves were used to estimate pump performance with the increased TDH (from the higher spray level elevation). Utilizing the existing recycle pumps for Units 1 and 2, the decreased pump flow rate with the new TDH is approximately 12,000 gpm, decreasing the L/G ratio to 89 gal/kacf. SO_2 removal efficiency is predicted to drop below 95% with the high sulfur coal. To achieve +98% SO_2 removal the existing recycle pumps will have to be replaced with pumps that can achieve 19,400 gpm flow which results in a L/G ratio of 144 gal/kacf. An additional case was considered leaving recycle spray levels 2 through 4 in the present location and only relocating spray header 1 to the top of the absorber area. To achieve 98+% SO_2 removal with the overall spray height reduced 2 ft requires increasing the L/G ratio from 144 to 151 gal/kacf.

Utilizing Unit 4 recycle pumps for Unit 3, the decreased pump flow rate with the new TDH is approximately 24,000 gpm (12,000 gpm/header), decreasing the L/G ratio to 134 gal/kacf. High SO_2 removal efficiency (>97%) is still predicted for this operating case. However, to maximize SO_2 removal potential, BPEI recommends increasing the recycle pump flow to the current rate of 27,500 gpm, returning the L/G ratio to 151 gal/kacf. Preliminary review of the Unit 3 recycle pumps indicates it may be possible to maintain the pump capacity to operate at the higher TDH by utilizing new gear boxes. A liquid residence time of 4.2 minutes is calculated for Unit 3 at this L/G ratio. Options available to address issues with the decreased residence time include using limestone slurry with a finer grind or adding organic acid to the process. These options are discussed in more detail below. The additional liquid residence typically achieved with the use of a tray should be enough to offset the physical limits of the reaction tanks.

An additional case was considered leaving recycle spray levels 2 through 4 in the present location and only relocating spray header 1 to the top of the absorber area. The distance between spray headers on Unit 3 absorbers are much shorter (~3.5 ft apart) compared to Units 1 and 2. To achieve 98+% SO_2 removal with the overall spray height reduced 6 ft requires increasing the L/G ratio from 151 to 174 gal/kacf. It may be possible to still utilize the recycle pumps utilizing new gear boxes and possibly impellers, however the higher L/G has a negative impact on liquid residence time. The residence time is reduced to 3.6 minutes which may or may not be offset with the absorber tray and chemical adjustments such as finer ground limestone slurry or the addition of organic acid. The reduced spray height also impacts the benefits of the dual-dual flow nozzles.

The overall recycle pump flow rate does not change on Unit 3. The recycle piping is 36” in diameter. The slurry velocity of 8.7 ft/sec is within the limits of 5 to 10 ft/sec recommended by BPEI. When the recycle piping splits between the two absorbers the slurry velocity increases to 9.8 ft/sec. No modifications to the recycle piping is anticipated.

The required recycle pump flow rate increases 30% for Units 1 and 2. The recycle piping diameter is 20”. The line velocity with the current recycle pump flow is already high at 15 ft/sec . High slurry velocities will result in increased erosion of the recycle piping especially in piping bends. It is recommended to increase the recycle piping diameter to 30” to bring the slurry velocity down to 9 ft/sec with the higher pump flows. The three branches at each spray level will increase from 14” to 18” to maintain slurry velocity. These modifications also require replacing the recycle pump suction valves and installing new nozzles on the absorber recycle tank for the larger pump suctions. Since recycle piping and headers require modification there is no benefit leaving spray levels 2 through 4 in their present location but proceeding with maintaining the optimal spray header distance of 5 ft between spray headers to maximize SO_2 removal.

The new pump flow rates will also increase the pressure drop across the absorbers impacting ID fan performance. Based on conversations with plant personal, it is understood that the ID fans are already operating at their maximum capacity and that either new ID fans or booster fans are planned to accommodate a future SCR and fabric filter for Units 1 and 2. Increase pressure drop across the absorbers to accommodate higher L/G ratios for maximum SO_2 removal should be considered in the new fan design. If the planned absorber modifications are to be completed prior to any modifications/additions to the upstream fans there is an alternative option to increase SO_2 removal while minimizing the impact of absorber pressure drop. This option requires removal of the absorber tray and increasing the L/G ratio from 144 gal/acf to 172 gal/acf. Further review to understand the pressure drop across the absorber tray versus maintaining a higher L/G ratio would have to be completed prior to following this recommendation. If the tray is removed from the absorber, the first absorber spray level would be located at the elevation of the tray and the subsequent spray levels spaced 5 ft apart from each other.

BPEI recommends adding pressure instrumentation on the pump suctions and discharges to monitor pump performance and adding logic to protect the recycle pumps from cavitation if there is a sudden loss of suction pressure. It is also recommended to add control valves to the pump flush water connections and pumps drain to incorporate an automatic flush and drain sequence.

The absorber control logic at Mill Creek controls limestone slurry feed by maintaining an absorber reaction tank pH set point. To maintain high SO_2 removal efficiency and optimize limestone consumption BPEI recommends going to a feed-forward logic loop with feedback trims to control limestone slurry feed to the reaction tanks. Feed-forward logic, calculates limestone slurry rate based on inlet SO_2, an SO_2 removal or emissions set point, limestone slurry concentration, and unit load or flue gas flow rate. There are two feedback trims to the calculated limestone slurry feed rate. The first feedback trim looks at the actual SO_2 removal or emissions rate and adds more limestone slurry if the unit is under-scrubbing or decreases limestone slurry feed rate if unit is over-scrubbing. The second feedback trim looks at reaction tank pH and will override SO_2 trim, if necessary, to maintain the reaction tank pH between 5 and 6. This type of feed-forward logic allows for tighter control because the limestone slurry feed rate is adjusted as inlet conditions (such as unit load) change instead of a system that is reactive and swinging up and down around the set point. BPEI recommends a review of the absorber control logic and to consider using CEMs instrumentation, if abandoned on the old Unit 3 system, to measure inlet SO_2 on Units 1 and 2.

5.4 Impact of Reagent Grind Size

The limestone grind maintained at Mill Creek is consistently finer than 95% passing 325 mesh which is the minimum grind BPEI recommends for high SO_2 removal efficiency absorbers. Increasing the limestone grind to greater than 99% passing 325 mesh increases the rate the limestone dissolves in the reaction tank. Increasing the rate of limestone dissolution will offset the short liquid residence time in Unit 3 reaction tanks. This would only be necessary if the excess limestone required for high SO_2 removal has a negative impact on gypsum quality. In reality if Unit 3 hydrocyclone underflow is being mixed with the underflow slurries from the other three operating units, it is unlikely there will be an overall negative impact gypsum quality.

Finer grind can also be utilized to improve SO_2 removal performance on Units 1 and 2 to achieve 96% removal reliably in place of replacing recycle pumps for this phase.

Mill Creek is currently looking to increase the capacity of their reagent preparation system. Producing ultra fine grind limestone slurry results in diminished capacity of the reagent preparation system thus increasing the power required per ton of limestone processed through the reagent preparation system. This cost can be weighed against the benefit of maintaining SO_2 removal and/or avoiding a unit de-rate if recycle pumps have to be taken out of service for maintenance.

5.5 Impact of Organic Acid

An organic acid, sodium formate, is currently added to the existing Unit 3 absorber system. Unit 3 reaction tanks are odd shaped with very poor mixing. Because of the poor mixing excess limestone is required to maintain SO_2 removal. The organic acid buffers the pH in the reaction tank reducing the amount of excess limestone required to maintain SO_2 removal and gypsum quality. Organic acid is already piped the new reaction tanks to be used when treating Unit 3 gas. Similar to the benefit of finer ground limestone, the organic acid can be used to offset any negative impact the small reaction tanks may have on liquid residence time or to improve Units 1 and 2 absorber performance in Case 2. Additional piping and logic is required to implement organic acid addition to Units 1 and 2.

At other WFGD system organic acid is utilized as a “spare” recycle pump to maintain high SO_2 removal efficiencies if a recycle pump has to be taken out of service. The benefit of organic acid over ultra fine grind limestone is that the effect is immediate. There is no turnover of a slurry tank prior to the organic acid impacting absorber performance.

If there are no permit restrictions on the organic acid in the water purge from the WFGD system, BPEI recommends completing a cost/benefit analysis of operating with 4 recycle pumps versus adding organic acid and operating with 3 recycle pumps in the three absorber units.

5.6 Performance Testing and Modeling

BPEI recommends a standard baseline performance test as well as advanced Computational Fluid Dynamics (CFD) and physical modeling of planned modifications. Changes to ductwork (Unit 3 into Unit 4 Scrubber) can result in unforeseen gas dynamics that could be detrimental to the process if the appropriate internal flow control devices are not installed. BPEI makes extensive use of modeling technology retrofit modifications such as those proposed for Mill Creek Generating Station. Some of the applications of this modeling are as follows:

- Prediction of gas distribution at the absorber inlet and into the first spray level
- Prediction of gas distribution and slurry spray distribution within the absorber spray zone, including advanced CFD droplet analysis for enhanced accuracy at predictions of liquid-to-gas interaction

- Prediction of absorber sump recirculation for agitator performance as it relates to both suspension of solids and distribution of oxidation air for maximum effectiveness

Typical physical models are scaled for geometry and operate at full gas velocity, with the mist eliminators modeled in full scale. For this type of model, BPEI is able to analyze gas flow behavior at the gas inlet, entering, within the absorber, leaving the spray zone, and entering and leaving the mist eliminators. The results of these model tests are incorporated into the actual absorber design (ductwork layout, spray header layout, nozzle spacing, etc.) to ensure controlled gas behavior, uniform gas flow, high liquid-gas contact for maximum efficiency with installed components, and uniform gas flow to the mist eliminators for consistent mist elimination from the flue gas.

Computational Fluid Dynamics (CFD) is also relied upon for design input. The below model was created to study the effects of retrofitting an additional spray level to an absorber to accommodate the use of higher sulfur coal at higher unit load, while maintaining the same outlet emission. Once again, uniformity of flow for high performance with a low gas side pressure drop was achieved in the model and then replicated in the actual unit. The plant is E.ON's Schkopau, and the change was executed on four absorbers at 240MW each.

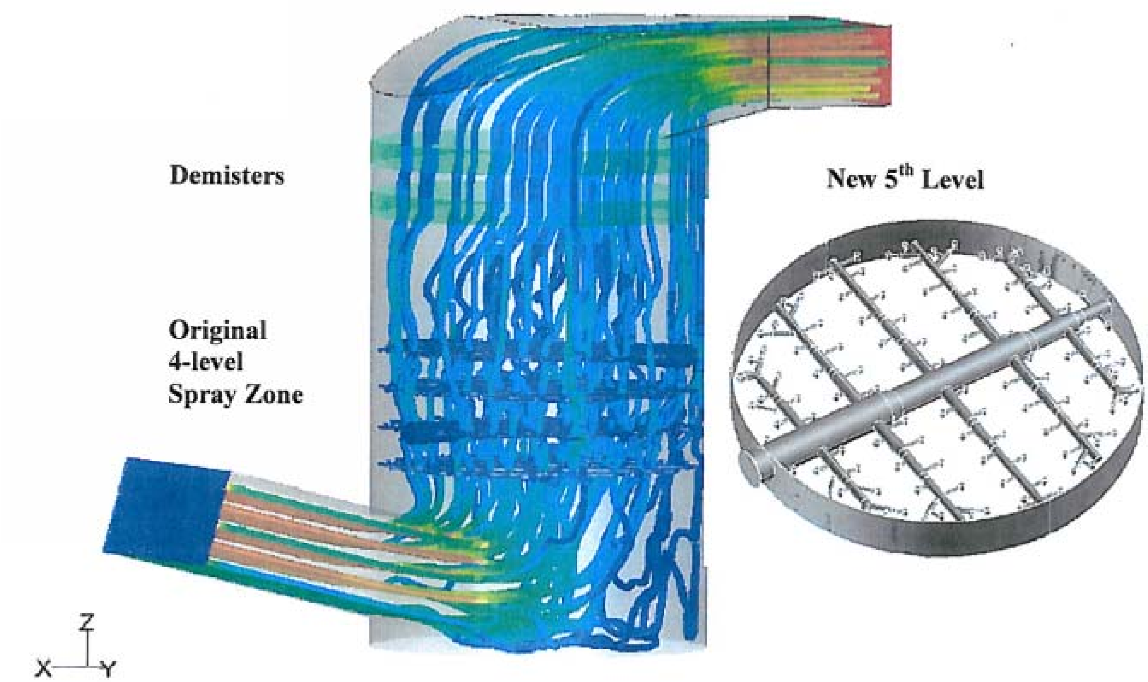


Figure 32: Sample of CFD Model Output

Gas distribution, as predicted at the absorber inlet, in the spray zone, and through the mist eliminators is shown modeled with four spray levels in service. The geometry of the added fifth spray level, shown on the right, was tested and confirmed to improve SO_2 efficiency, with no adverse effect on the existing absorber or mist eliminator configuration.

A similar approach could be taken to Mill Creek Units 1, 2, and 3 for predictions of gas distribution with modifications to inlet ductwork, spray header spacing, spray header layout, number and type of nozzles. CFD modeling would be especially advantageous on Unit 3 because of the shift to a different absorber unit and all the ductwork modifications associated with that change.

5.7 Construction

The Case 3 construction will consist of replacing the unit 1&2 recycle pumps, piping and spray headers, unit 3 spray pipes, spray headers and recycle gearboxes will be replaced. BPEI will be adding spray nozzles, wall rings and DV210 mist eliminators on units 1,2 &3.

BPEI is planning to work six months at 1-10-5 shifting to install recycle pump foundations on units 1&2 and receive materials and set up scaffolding for the outage work. The Case 3 outage is based on installing mist eliminator, spray headers, spray nozzles and wall rings into a new absorber module. This will allow the ground fabrication of the absorber and internals to take place before the outage.

During a six week outage working 2-10-7 BPEI will replace the recycle pumps on units 1&2 only. On unit 3 BPEI will replace the recycle gearboxes. All three units will have the absorbers and new internals changed out as modules to reduce the outage schedule.

The ROM estimate for BPEI to provide engineering, materials and construction is as follows:

- Case 3: Unit 1 - $20,428,467
- Case 3: Unit 2 - $20,567,445
- Case 3: Unit 3 - $32,944,117

5.8 Schedule

Our preliminary schedule included in the attachments section is based on the following:

Case 3: Units 1, 2, & 3:4
- (6) month construction schedule working (1-10-5)
  One shift, ten hours per day, five days per week
- (6) week outage schedule working (2-10-7)
  Two shifts, ten hours per shift, seven days per week

6. Construction Plan

6.1 Organization Overview

Babcock Power Environmental, Inc. has developed a preliminary Construction Plan that capitalizes on its engineering, product fabrication, installation, and startup expertise to provide LG&E services with an efficient retrofit design to provide low project price and short outage schedule.

6.2 Execution

Pre-Construction

Upon Notice to proceed BPEI will develop a pre-construction team that will integrate BPEI engineering and fabrication with construction and develop a detailed design, project plan, and schedule. We will develop the details for constructability, value engineering, estimating, and scheduling. During this period we will refine our budgets, safety, quality, project controls, and execution plans to reflect more detailed design information. Our objective will be to assure the construction phase in a seamless part of the project delivery method. The integration of our proposal, pre-construction and construction teams will facilitate the most effective transfer of ownership and job knowledge, ensuring project safety and timely completion of construction and startup.

Construction

Following the integrated project schedule, BPEI will mobilize on the Mill Creek site and prepare for the receipt of WFGD components. We will construct the Recycle Pump foundations before the outages begin in order to reduce the outage lengths.

Outage

The duration of the outage on Case 2 or Case 3 is based on work being completed during the construction phase. It is BPEI’s intention to minimize the outage duration to assist LG&E services in keeping the Mill Creek boilers operating.

7. Budget Price

LG&E Services Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study

Budget Engineering, Procurement and Construction Estimate

February 15, 2011

Description	Engineering	Equipment	Construction	Total
Case 2: Unit 1	$1,922,629	$5,365,667	$3,253,216	$10,541,512
Case 2: Unit 2	$1,922,629	$5,365,667	$3,343,710	$10,632,006
Case 2: Unit 3	$1,922,629	$6,735,206	$5,378,000	$14,035,835
Case 3: Unit 1	$2,949,580	$10,573,006	$6,905,881	$20,428,467
Case 3: Unit 2	$2,949,580	$10,573,006	$7,044,859	$20,567,445
Case 3: Unit 3	$2,949,580	$17,504,859	$12,489,678	$32,944,117

Note: The estimate for the Mill Creek WFGD Study is a ROM (rough order of magnitude) estimate. The accuracy is based on +25% to – 10%. The pricing is based on current 2011 dollars with no escalation.

The scope of the pricing for the Mill Creek Study is limited to WFGD Performance retrofit improvements. There are no other maintenance upgrades to the absorber structure or reaction tank included.

8. Project Schedule

Our preliminary schedule included in the attachments section is based on the following:

Case 2: Units 1, 2, & 3:4

- (4) Month construction schedule working (1-10-5)
  One shift, ten hours per day for five days
- (3) week outage schedule working (2-10-6)
  Two shifts, ten hours per shift, six days per week

Case 3: Units 1, 2, & 3:4

- (6) month construction schedule working (1-10-5)
  One shift, ten hours per day, five days per week
- (6) week outage schedule working (2-10-7)
  Two shifts, ten hours per shift, seven days per week

BabcockPower ENVIRONMENTAL

Flue Gas Desulfurization Design Basis Spreadsheet

Project Number:	100524
Revision Number:	Rev. 0
Customer Name:	LG&E Energy
Project Name:	Mill Creek Units 1, 2, and 3
Location, City, State	Kosmodale, KY
Description	WFGD Upgrade
Report Title (shown on printed sheets)	

Email changes to		
Prepared	Name	Suzette Puski
Prepared	Date	1/25/11
Checked	Name	Matt Quitadamo
Checked	Date	1/25/2011
Customer Signed	Name	
Customer Signed	Date	
Remarks:		

BabcockPower ENVIRONMENTAL	Mill Creek Units 1, 2, and 3 Rev. 0			
FGD Design Basis Spreadsheet				
Scope of Supply				
Plant Name:				
Plant Location				
	U1&U2 Case 2	**U3 Case 2**	**U1&U2 Case 3**	**U3 3 Case 3**
Flue Gas Path				
Equipment for Partical Removal				
Equipment for Draft System				
Inlet Duct Modifications	x	x	x	x
Equipment for SO2 Removal				
Install Wall Rings on Spray Levels 2 and 3	8 Wall Rings	8 Wall Rings	8 Wall Rings	8 Wall Rings
Install Up/Down Interior Spray Nozzles	160	128	336	336
Install Up/Down Interior Wall Ring Nozzles	176	160	312	288
Install Double-Down Interior Spray Nozzles	160	128	112	112
Install Double-Down Wall Ring Spray Nozzles	176	160	104	96
Replace Recycle Pumps	8 Pumps		8 Pumps	
Replace Recycle Pump Piping	x		x	
Replace Recycle Pump Gear Boxes				8 Pumps
Add Agitators and Air Lances	12	10	12	10
Equipment for SO3 Removal				
Equipment for Hg Removal				
Equipment for NOx Removal				
Equipment for Mist Removal				
Replace ME Section w/ DV210			x	x
other				
Waste Water Treatment				
Utilities				
Reagent				
Equipment for Reagant Unloading				
Equipment for Reagent Storage				
Equipment for Reagent Day Storage				
Equipment for Reagent Slurry Preparation				
Increase Limestone Grind	Possible Alternative			May be Required
Organic Acid				
Equipment for Organic Acid System				
Add organic feed system to Units 1 and 2	Possible Alternative			
Byproduct				
Equipment for Byproduct Treatment				
Equipment for Byproduct Storage				
Equipment for Byproduct Loading				
Fly Ash				
Equipment for Flyash Treatment				
Equipment for Flyash Storage				
Equipment for Flyash Loading				
Balance of Plant				
Water Supply				
Service Air Supply				
Instrument Air Supply				
Cooling Water Supply				
Process Control				
Evaluate revising control logic for SO2 removal	x	x	x	x
Electrical Equipment				
Structural Steel				
Civil				
Construction				
Process Equipment				
Balance of Plant Equipment				
Process Control incl. Wiring				
Electrical Equipment incl. Wiring				
Structural Steel				
Civil				
Commissioning				Yes
Performance Test				No

BabcockPower ENVIRONMENTAL	FGD Design Basis Spreadsheet	Mill Creek Units 1, 2, and 3 Rev. 0
Plant Data Sheet	Units	**DESIGN**
Plant Name:		**Mill Creek Units 1, 2, and 3**
Plant Location		**Kosmodale, KY**
Site Conditions		
Seismic Zone		(Av/Aa) 0.09/0.07
Design Ambient Temp	^oF	68
Maximum Summer Ambient Temp	^oF	105 (per Trimble County Design)
Minimum Winter Ambient Temp	^oF	-10 (per Trimble County Design)
Indoor Temperature Design / Range	^oF	
Plant Elevation @ Grade	ft	460
Elevation @ Absorber Inlet	ft above TOC	Units 1 & 2: 39.5, Unit 3: 28.2
Atmospheric Pr. @ Absorber Inlet Elevation	psia	Units 1 & 2: 14.43, Unit 3: 14.44
Absolute Humidity Average	%	max 100%
Average Rainfall	inches/year	50 (per Trimble County Design)
Wind Speed CRM 780 section 1611.0	MPH	70 (per Trimble County Design)
Snow Load CMR 780 Section 1610.0	lb/sf	15 (per Trimble County Design)
Earthquake Loads CMR 780 Section 1612.0		
FGD Operation		
Mode	Part/Continuous	Continuous
Months of FGD operation/yr - Design	Mon/yr	12
Months of FGD operation/yr - Future	Mon/yr	12
Number of Boilers served by one Scrubber	#	Each Unit has a dedicated mult-module absorber system
Bypass Operation required	Yes / No	No Bypass Allowed
Equipment Installation Indoor/Outdoor		

BabcockPower ENVIRONMENTAL	FGD Design Basis Spreadsheet	Mill Creek Units 1, 2, and 3 Rev. 0	
Boiler Data Sheet	Units	**DESIGN**	
		Units 1 & 2	**Unit 3**
LOAD	% MCR	100	100
Nominal Rating	MW, Gross	350	410
	MW, Net		386
Boiler Manufacturer	-	Combustion Engineering	Babcock & Wilcox
Fuel Fired	Coal/Gas/Oil	Coal	Coal
Firing Method	Dry Bot/Wet Bot/Cyclone		Opposed Wall Fired Boiler (5x4 high) w/ LNB
MCR Steam Flow (Design)	pph	2,326,000	3,144,000
Boiler Type	Balanced Draft/Pressurized	Balanced Draft	Balanced Draft
Plant Capacity Factor	Percent of Year		74.9 Gross/ 73.6 Net
Hours of operation per year	Hours		in 2000 7447 hrs
Number of Cold Starts per year	Target/Actual		2 actual
Number of Hot Restarts per year	Target / Actual		22 actual
Ignition Fuel Fired	Oil/Gas	Oil	Oil
Ignition Fuel Fired	Hours/Year		800,000 gal
Minimum Load for FGD Operation	MWnet		193 MW net
Flue Gas Recirculation	Y/N	N	N
SCR			
SCR Reactor - Number Installed		N/A	2
Catalyst Type			Hitachi Plate
NOx inlet / outlet	lbs/Mbtu		0.347 / 0.035
NH3 Slip	ppmdv @ ref O2		< 2.0 @ the End of Life
Air Heater			
Air Heater - Number Installed	-	2	2
Air Heater Type	Rotary/Tubualr	Ljungstrom Rotary	Ljungstrom Rotary
Air Heater Orientation	V-Shaft or H-S	V-Shaft	V-Shaft
Will Air Heater be changed?	Y/N & to what?	N	N
Air Heater Surface configuration	Model Numbers & Materials	27-VI-63	29-VI-54
Air Heater Cleaning Device	-	Steam Soot Blowers	Steam Soot Blowers
Air Heater Leakage	Percent		8 @ as-found condition Baseline Test
ESP			
ESP's - Number Installed	Number	2	2
ESP Info - Configuration	Single layer or Stacked		TBD by LG&E
ESP Info - Location	Cold or Hot	Cold	Cold
ESP Dust Loading @ ESP Temp	grains/ACF @°F		3.375 @ 300°F
Dust Loading @ Eco. Out Temp	grains/ACF @°F		2.294 @ 648°F
ESP Info - Outlet Dust Loading	grains/ACF @°F		TBD by LG&E
ESP Efficiency	%		TBD by LG&E
WFGD			
WFGD - Original Supplier	Name	Combustion Engineering	American Filter
WFGD - Number Absorbers Operating / Installed	Number	2 / 2	4 / 4
WFGD Info - Type	Single Loop or Double Loop	Single	Single
WFGD Info - Spray Configuration	Co-Current or Counter Current	Counter Current	Counter Current (Co-Current on Level 2)
WFGD Info - Spray Level Configuration	Operating + Spare	4+0 + Tray	4+0 + Tray
WFGD Info - Reagent	Lime or Limestone	Limestone	Limestone
WFGD Info - Original Design SO2 Loading	lbs/Mbtu	6.3	6.3
WFGD Info - SO2 Removal Efficiency	%	Phase 1: 96, Phase 2: 98+	Phase 1: 96, Phase 2: 98+
Other			
Ash Reinjection	Yes or No	No	No
Draft System			
FD Fan, Existing	Number		2 / American Standard (595 rpm @ 110°F)
Design Pressure	IWG		
Fan HP	HP		
ID Fan, Existing	Number	2/ American Standard (690,000 cfm @ 300°F)	2 / American Standard (834,950 cfm @ 300°F)
Design Pressure	IWG	20	45
Fan HP	HP		
ID Booster Fan, Existing	Number	N/A	N/A
Design Pressure	IWG	N/A	N/A
Booster Fan HP	HP	N/A	N/A

FGD Design Basis Spreadsheet

LG&E Mill Creek

Rev. 0

FGD Load Data Sheet

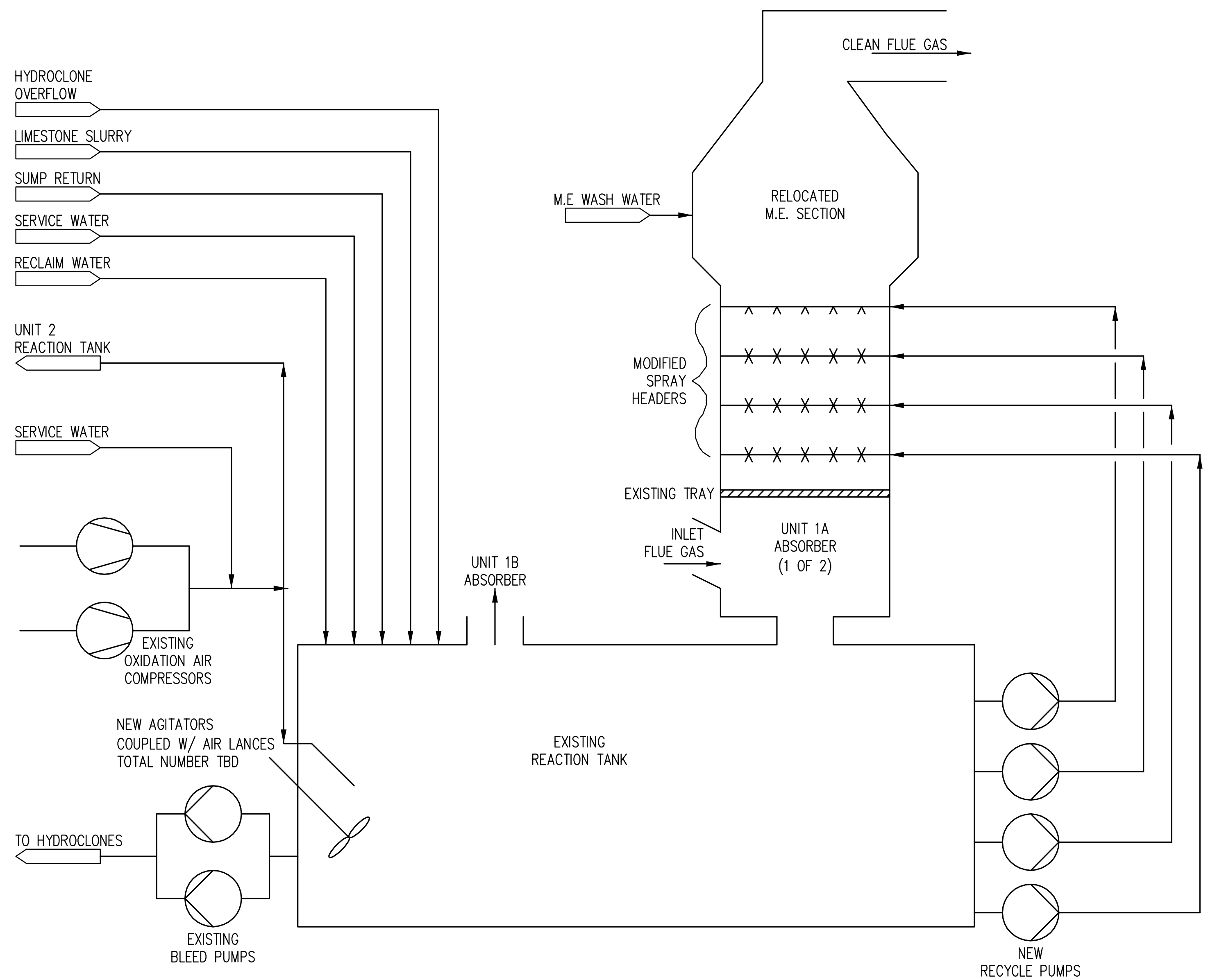
	Units						
Load Name		Brown	Units 1 & 2	Unit 3	Units 1 & 2	Unit 3	
Load	MW	750	330	425	330	425	
Fuel Flow Rate	lb/hr	676,790	148,894	148,894	128,049	95,879	
Firing Rate	Gross10^6 BTU/Hr	5,400	5,400	5,400	5,400	5,400	
Excess Air	%	25.0	25.0	21.5	25.0	25.0	
In-Leakage	%	20.0	20.0	23.5	20.0	20.0	
Flue Gas Conditions @ Inlet Scope of Supply			Ratio	SCR Test	Old Mat Bal	Ratio	
Flow Basis	per Absorber	1	1 of 2	1 of 4	1 of 2	1 of 4	
Flue Gas Flow Rate	lbs/h wet	9,676,853	2,128,908	1,418,869	1,832,990	1,370,888	
Flue Gas Flow Rate	lbs/h dry	9,252,111	2,035,464	1,356,591	1,752,535	1,310,716	
Flue Gas Flow Rate	scfm wet	1,971,997	433,839	289,144	373,536	279,366	
Flue Gas Flow Rate	scfm dry	1,830,923	402,803	268,459	346,813	259,381	
Flue Gas Flow Rate	acfm	3,159,481	695,086	463,259	598,469	447,593	
Flue Gas Temperature	°F	330	330	313	330	313	
Flue Gas Pressure	I.W.G.	14.73	14.43	14.44	14.43	14.44	
Flue Gas O2	% vol, dry	7.9	7.9	7.9	7.9	7.9	
Flue Gas CO2	% vol, dry	11.0	11.0	11.0	11.0	11.0	
Flue Gas H2O	% vol wet	7.1	7.1	7.1	7.1	7.1	
Flue Gas reference O2	% vol dry	6.0	6.0	6.0	6.0	6.0	
Flue Gas SO2 *)	ppmdv @ act O2 / lbs/MBTu	2,623 / 6.9	2,395 / 6.3	2,395 / 6.3	2,395 / 6.3	2,395 / 6.3	
Flue Gas SO3 *)	ppmdv @ act O2 / lbs/MBTu	26	8	8	8	8	
Flue Gas HCl *)	ppmdv @ act O2 / lbs/MBTu	44	44	44	44	44	
Flue Gas HF*)	ppmdv @ act O2 / lbs/MBTu	9	9	9	9	9	
Flue Gas NOx *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas NH3 *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas Dust *)	grains/ dcfm lbs/MBTU	0.07 / 0.41	0.07 / 0.41	0.07 / 0.41	0.07 / 0.41	0.07 / 0.41	
Flue Gas Hg *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas Cd *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas Heavy Metals *)	ppmdv @ act O2 / lbs/MBTu						
*) Concentration range is independent of the boiler load							
Flue Gas Conditions @ outlet Scope of Supply expected values							
Flue Gas Flow Rate	lbs/h wet	10,356,857	2,278,509	1,518,574	1,961,796	1,467,221	
Flue Gas Flow Rate	lbs/h dry	8,704,210	1,914,926	1,276,255	1,648,751	1,233,096	
Flue Gas Flow Rate	scfm wet	2,184,799	480,656	320,346	413,845	309,513	
Flue Gas Flow Rate	scfm dry	1,861,975	409,635	273,012	352,695	263,780	
Flue Gas Flow Rate	acfm	2,624,304	577,347	384,789	497,096	371,776	
Flue Gas Temperature	°F	128	128	128	128	128	
Flue Gas Pressure	I.W.G.	14.62					
Flue Gas O2	% vol wet	11.1	11.1	11.1	11.1	11.1	
Flue Gas CO2	% vol wet	8	8	8	8	8	
Flue Gas H2O	% vol wet	14.8	14.8	14.8	14.8	14.8	
Flue Gas SO2 *)	ppmdv @ act O2 / lbs/MBTu	52 / 0.14	47 / 0.13	47 / 0.13	47 / 0.13	47 / 0.13	
Flue Gas SO3 *)	ppmdv @ act O2 / lbs/MBTu	8	2	2	2	2	
Flue Gas HCl *)	ppmdv @ act O2 / lbs/MBTu	0	0	0	0	0	
Flue Gas HF*)	ppmdv @ act O2 / lbs/MBTu	0	0	0	0	0	
Flue Gas NOx *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas Dust *)	grains/ dcfm lbs/MBTU	0.02 / 0.12	0.02 / 0.12	0.02 / 0.12	0.02 / 0.12	0.02 / 0.12	
Flue Gas Hg *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas Cd *)	ppmdv @ act O2 / lbs/MBTu						
Flue Gas Heavy Metals *)	ppmdv @ act O2 / lbs/MBTu						
*) Concentration range is independent of the boiler load							

BabcockPower ENVIRONMENTAL	FGD Design Basis Spreadsheet	LG&E Mill Creek Rev. 0					
Coal & Reagent Data Sheet	**Units**	**Unit 1 & 2**	**Unit 3**	**Unit 1 & 2**	**Unit 3**		
Design Coal Name	Must be filled in						
Coal Source:	Coal Mine	2009	2009				
Date Sample Taken:	Date	Average	Average	Design	Design		
Coal Ultimate Analysis	As Received						
Carbon (C)	Wt%	61.61	61.61	60.30	60.30		
Hydrogen (H)	Wt%	4.22	4.22	4.50	4.50		
Oxygen (O_2)	Wt%	7.01	7.01	6.80	6.80		
Nitrogen (N_2)	Wt%	1.28	1.28	1.17	1.17		
Sulfur (S)	Wt%	3.02	3.02	3.47	3.47		
Chlorine (Cl)	Wt%	0.06	0.06	0.07	0.07		
Fluorine (Fl)	Wt%	0.01	0.01	0.01	0.01		
Moisture (Water H_2O)	Wt%	11.43	11.43	9.56	9.56		
Ash	Wt%	11.36	11.36	14.12	14.12		
Total	Wt%	100.00	100.00	100.00	100.00		
Wt. % Volatile	Wt%	35.68	35.68	33.00	33.00		
Wt % Fixed Carbon	Wt%	41.54	41.54	42.00	42.00		
Higher Heating Value	Btu/lb, As Recvd	11,115	11,115	11,000	11,000		
Reagent Name:							
Reagent Source:							
Date Sample Taken:							
Reagent Analysis							
CaCO3	wt.%						
reactive CaCO3	wt.%						
CaO	wt.%						
Ca(OH)2	wt.%						
Fe2O3	wt.%						
Al2O3	wt.%						
SiO2	wt.%						
MgCO3	wt.%						
MgO	wt.%						
Mg(OH)2	wt.%						
Chlorine (Cl)	ppm						
Fluorine (Fl)	ppm						
Moisture	wt%						
Inert	wt%						

BabcockPower ENVIRONMENTAL	FGD Design Basis Spreadsheet	Mill Creek Units 1, 2, and 3 Rev. 0		
Process Water Data Sheet	**Units**	**Design**	**Min**	**Max**
Mist Eliminator Wash Water Analysis				
pH				
Conductivity	mS/m			
Total hardness	mg/l			
Carbonate hardness	mg/l			
Temperature	°F			
Suspended solids	mg/l			
Calcium as Ca^{2+}	mg/l			
Magnesium as Mg^{2+}	mg/l			
Sodium as Na^{+}	mg/l			
Chloride as Cl^{-}	mg/l			
Sulphate SO_4^{2-}	mg/l			
Sulphite SO_3^{2-}	mg/l			
Make-Up Water Analysis				
pH				
Conductivity	mS/m			
Total hardness	mg/l			
Carbonate hardness	mg/l			
Temperature	°F			
Suspended solids	mg/l			
Calcium as Ca^{2+}	mg/l			
Magnesium as Mg^{2+}	mg/l			
Sodium as Na^{+}	mg/l			
Chloride as Cl^{-}	mg/l			
Sulphate SO_4^{2-}	mg/l			
Sulphite SO_3^{2-}	mg/l			
Reclaim Water Analysis				
pH				
Conductivity	mS/m			
Total hardness	mg/l			
Carbonate hardness	mg/l			
Temperature	°F			
Suspended solids	mg/l			
Calcium as Ca^{2+}	mg/l			
Magnesium as Mg^{2+}	mg/l			
Sodium as Na^{+}	mg/l			
Chloride as Cl^{-}	mg/l			
Sulphate SO_4^{2-}	mg/l			
Sulphite SO_3^{2-}	mg/l			
Service Water Analysis				
pH				
Conductivity	mS/m			
Total hardness	mg/l			
Carbonate hardness	mg/l			
Temperature	°F			
Suspended solids	mg/l			
Calcium as Ca^{2+}	mg/l			
Magnesium as Mg^{2+}	mg/l			
Sodium as Na^{+}	mg/l			
Chloride as Cl^{-}	mg/l			
Sulphate SO_4^{2-}	mg/l			
Sulphite SO_3^{2-}				

BabcockPower ENVIRONMENTAL	FGD Design Basis Spreadsheet	Mill Creek Units 1, 2, and 3 Rev. 0			
Gypsum Slurry Data Sheet	**Units**	**U1&2 - Case 2**	**U1&2 Case 3**	**U3 Case 2**	**U3 Case 3**
Recycle Slurry Analysis					
Mass Flow Rate, per pump	lb/hr	10,363,636	10,581,818	15,000,000	15,000,000
Volume Flow rate, per pump	gpm	19,000	19,400	27,500	27,500
Estimated TDH					
Spray Level 1	ft, H2O	47.3	54.7	56.4	59.7
Spray Level 2	ft, H2O	53.3	59.7	61.2	64.7
Spray Level 3	ft, H2O	58.3	64.7	64.6	69.7
Spray Level 4	ft, H2O	62.3	69.7	68.0	74.7
Specific Gravity		1.08-1.11	1.08-1.11	1.08-1.11	1.08-1.11
Density	lb/ft^3	66.8-69.3	66.8-69.3	66.8-69.3	66.8-69.3
Temperature	°F	125-135	125-135	125-135	125-135
pH		5 to 6	5 to 6	5 to 6	5 to 6
Chloride as Cl-	mg/l	5,000	5,000	5,000	5,000
Viscosity	cp	7.00	7.00	7.00	7.00
Solids Content	wt.%	14-18	14-18	14-18	14-18
Solids Stream					
Gypsum	wt.% dry	85-95	85-95	85-95	85-95
Limestone	wt.% dry	1-3	1-3	1-3	1-3
Inert	wt.% dry	5-15	5-15	5-15	5-15
Special Notes:		Compressed air is injected in the reaction tank to complete oxidation reaction No Change to existing Unit 3 pumps in Phase 1 Pump TDH calculations are preliminary for cost estimate purposes only			

DWG. NO. 100524-093000110



REVISION	NO.	BY	CHK	DATE	APP'D	DATE

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RELEASED & APPROVED ____ DATE ____

DO NOT SCALE
USE DIMENSIONS ONLY

DRAWN JWL
DATE 01/17/11
CHECKED
DATE
APP'D
DATE
SCALE NTS IN. = 1 FT.

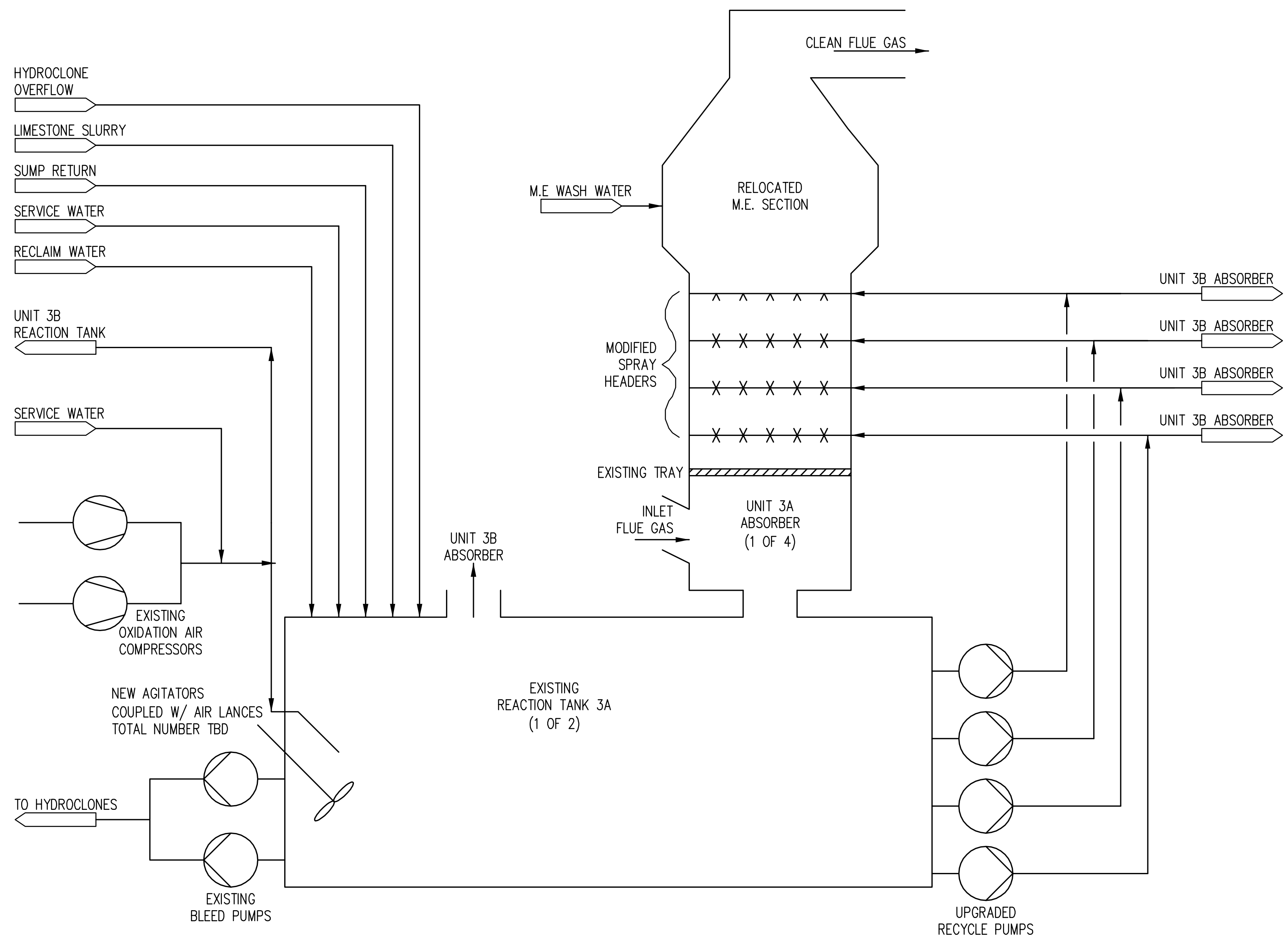
BABCOCK POWER ENVIRONMENTAL INC.

PROCESS FLOW DIAGRAM

LOUISVILLE GAS AND ELECTRIC
MILL CREEK UNIT 1

DWG. NO. 100524-093000110-P0

DWG. NO. 100524-093000130



REVISION	NO.	BY	CHK	DATE	APP'D	DATE

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RELEASED & APPROVED ____ DATE ____

DO NOT SCALE
USE DIMENSIONS ONLY

DRAWN JWL
DATE 01/17/11
CHECKED
DATE
APP'D
DATE
SCALE NTS IN. = 1 FT.

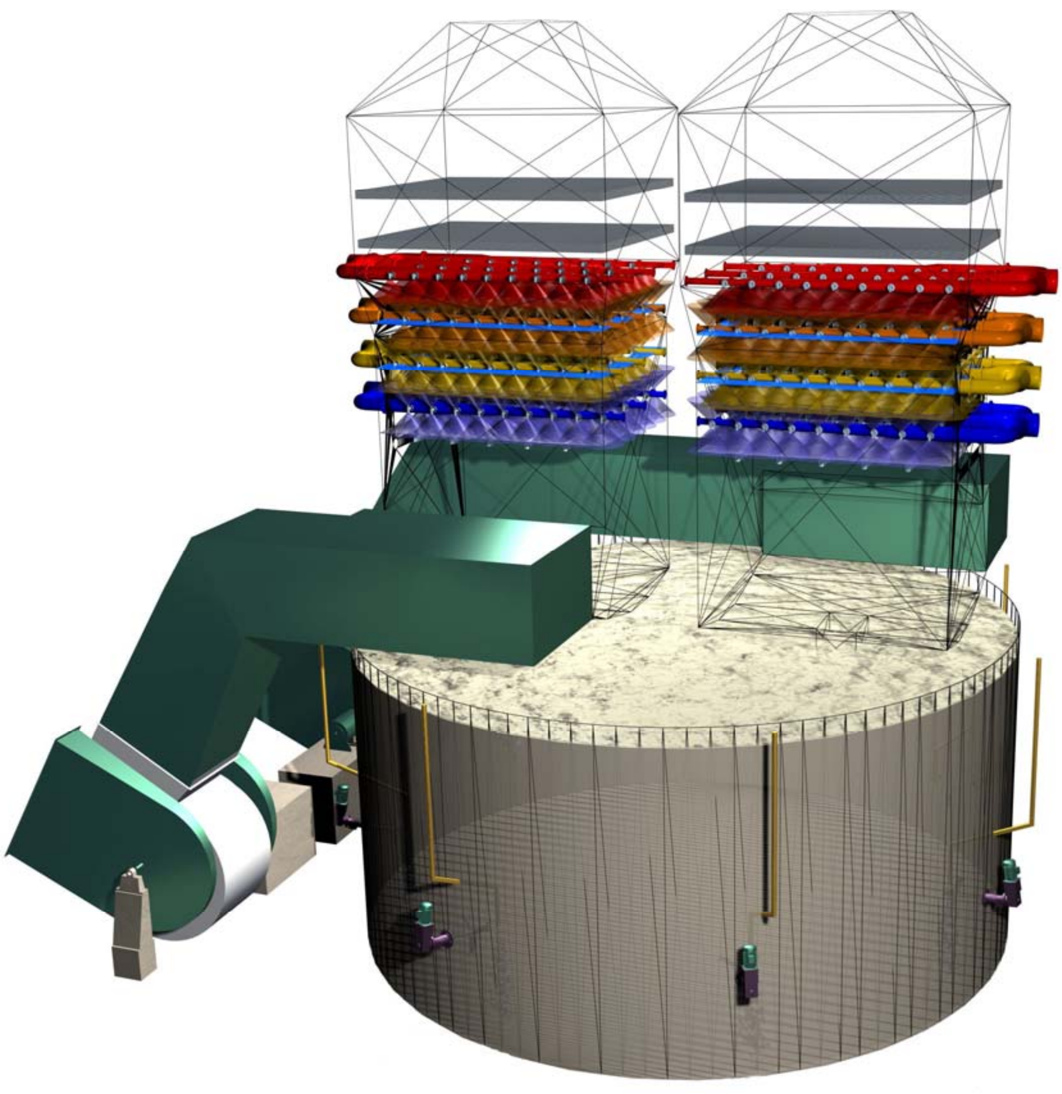
BABCOCK POWER ENVIRONMENTAL INC.

PROCESS FLOW DIAGRAM

LOUISVILLE GAS AND ELECTRIC
MILL CREEK UNIT 3

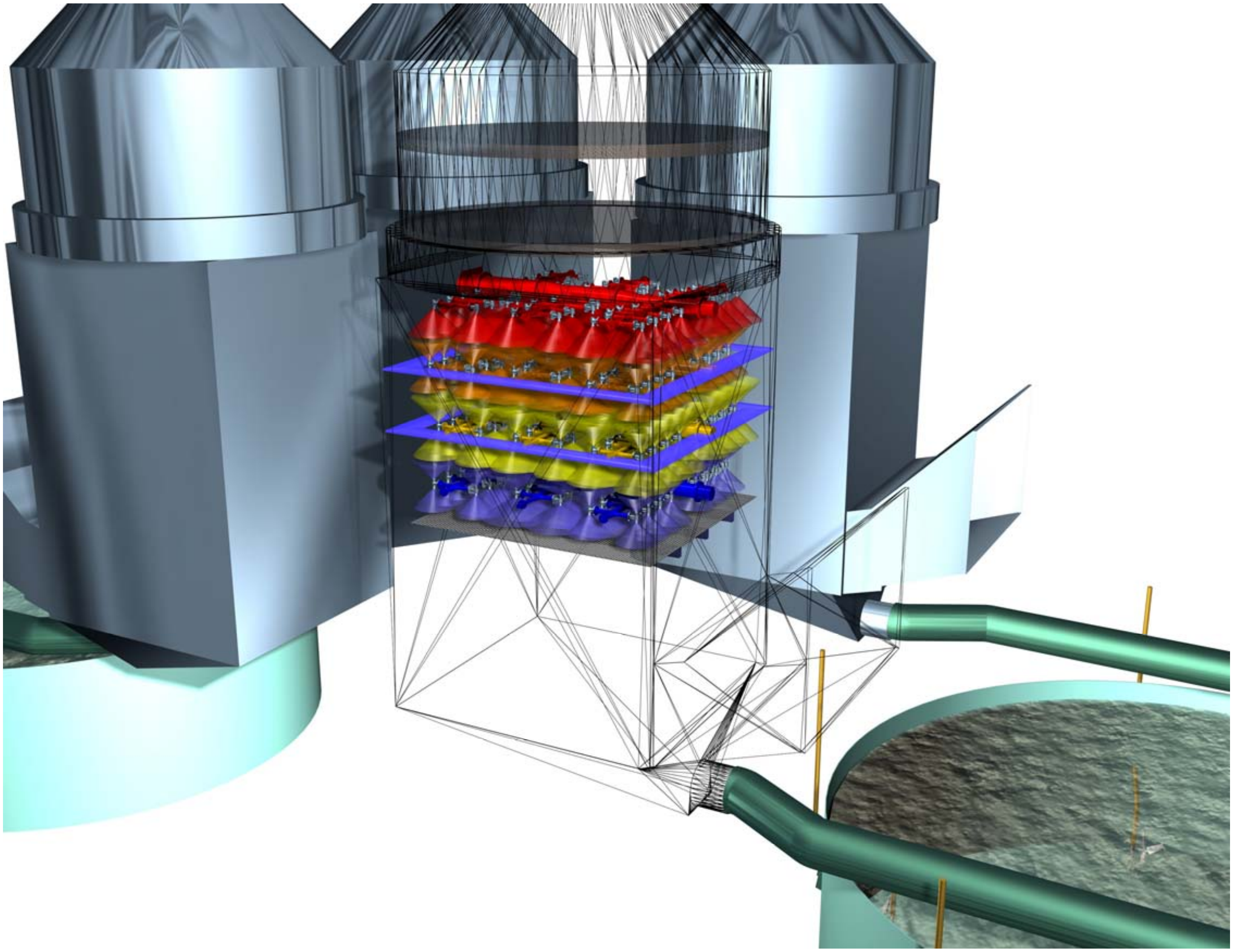
DWG. NO. 100524-093000130-P0

LG&E Services Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study



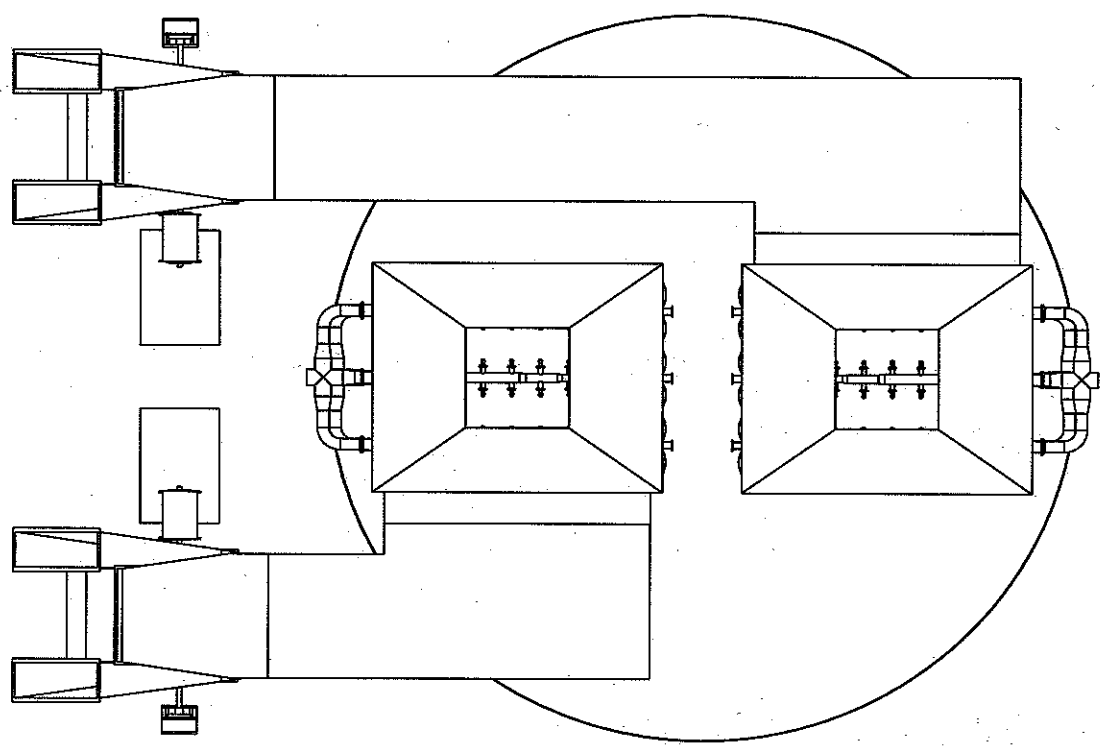
Units 1 & 2

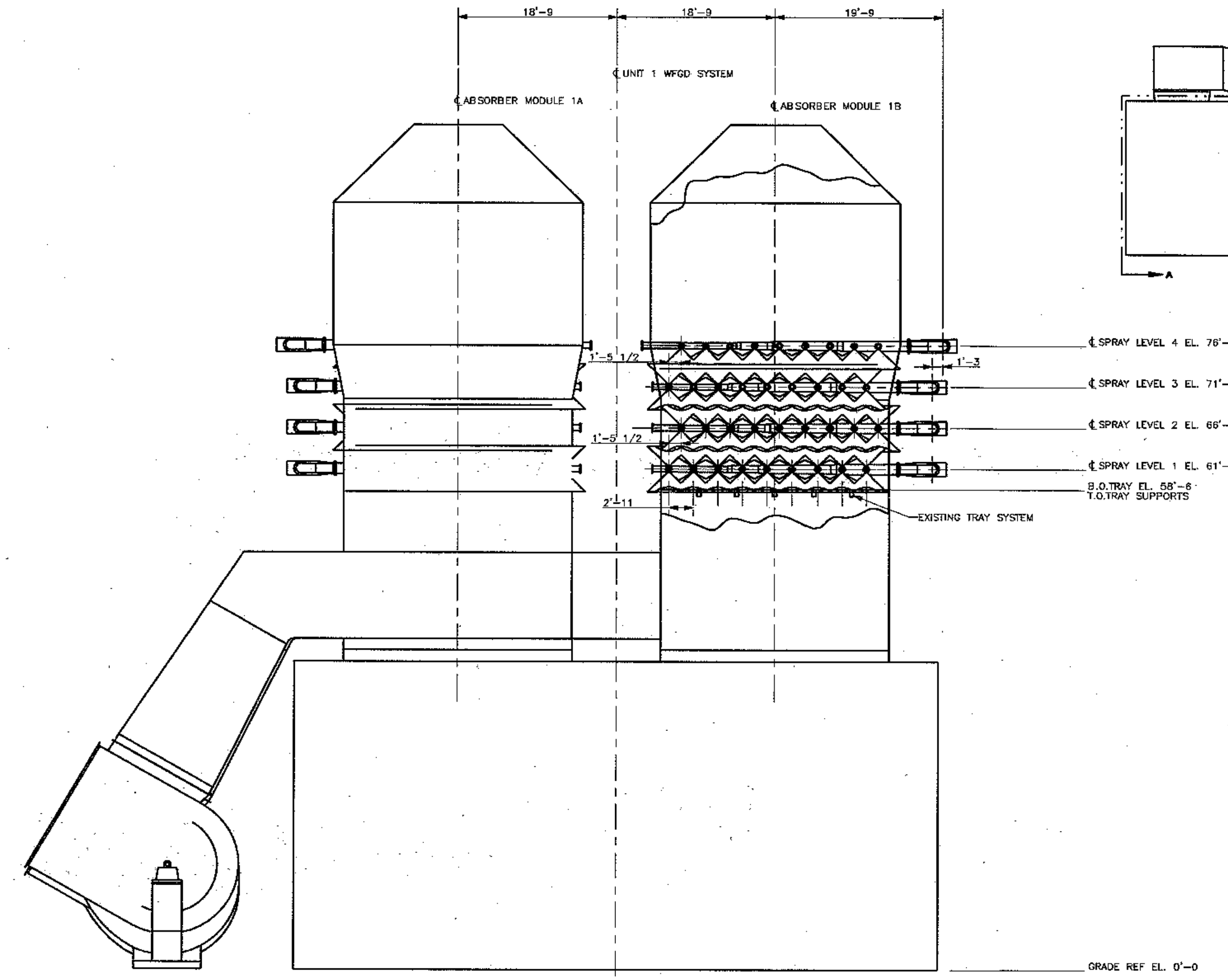
LG&E Services Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study

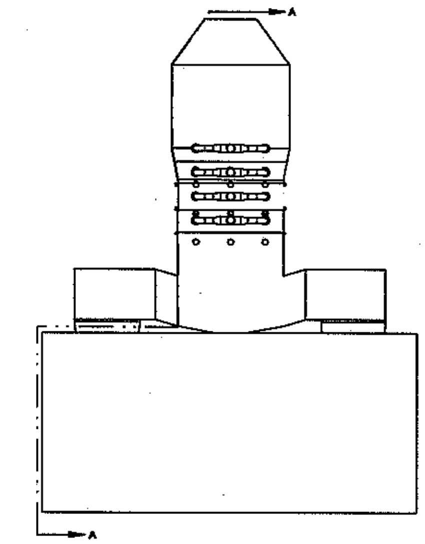


Units 3 & 4

DWG. NO. 100524-102675200







ELEVATION LOOKING NORTH
PHASE II WFGD UPGRADE
SECTION A-A
SCALE 0.010

IN PROGRESS
18-Jan-11

REVISION	NO	BY	CHK	DATE	APP'D	DATE

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RELEASED & APPROVED ______ DATE ______

DO NOT SCALE
USE DIMENSIONS ONLY

DRAWN J.GARIEPY
DATE 18-Jan-11
CHECKED
DATE
APP'D
DATE
SCALE ____ IN. = 1 FT.

PHASE II WFGD UPGRADE
UNIT 1

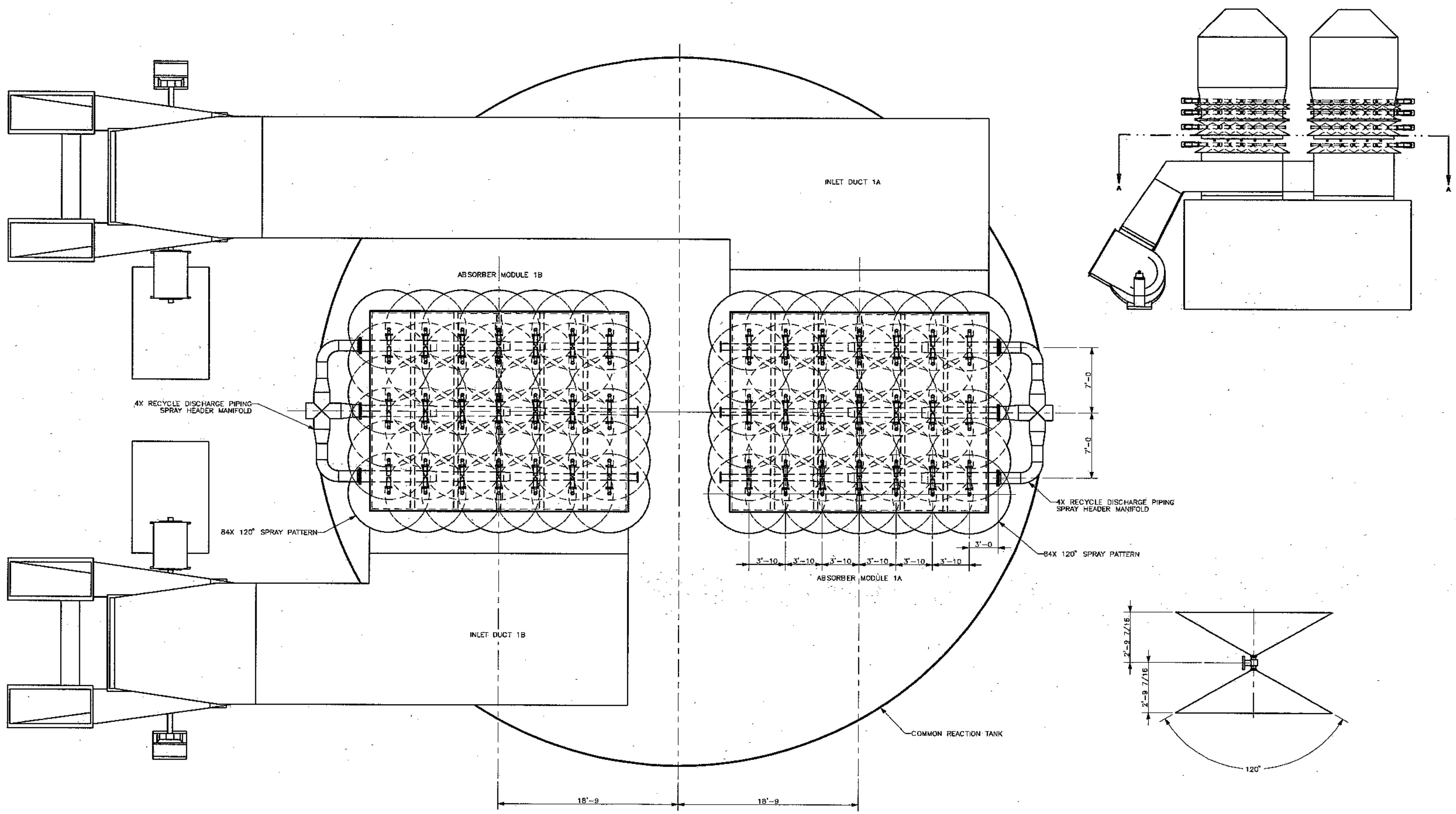
BABCOCK POWER ENVIRONMENTAL INC.

GENERAL ARRANGEMENT
WFGD SYSTEM UPGRADE

LG&E ENERGY
MILL CREEK GENERATING STA. UNIT 1
LOUISVILLE, KY

DWG. NO. 100524-102675200-00

DWG. NO. 100524-102675100



SECTION A-A
PHASE I PLAN VIEW
SCALE 0.016

IN PROGRESS
16-Jan-11

REVISION	NO	BY	CHK	DATE	APP'D	DATE

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RELEASED & APPROVED ______ DATE ______

DO NOT SCALE
USE DIMENSIONS ONLY

DRAWN J.GARIEPY
DATE 16-Jan-11
CHECKED
DATE
APP'D
DATE
SCALE ___ IN. = 1 FT.

PHASE I WFGD UPGRADE
UNIT 1

BABCOCK POWER ENVIRONMENTAL INC.

GENERAL ARRANGEMENT
WFGD SYSTEM UPGRADE

LG&E ENERGY
MILL CREEK GENERATING STA. UNIT 1
LOUISVILLE, KY

DWG. NO. 100524-102675100-00

Babcock Power ENVIRONMENTAL			Mill Creek Units 1, 2 and 3 Rev. 0			LG&E
Case 2	FGD Upgrades - Equipment to be Modified					
	Unit 1		Unit 2		Unit 3	
Materials	**Qty**	**Comments**	**Qty**	**Comments**	**Qty**	**Comments**
Slurry Recycle System						
Recycle Pumps		Replace existing 8 recycle pumps and motors with gear driven centrifugal pumps, 3 at 700 HP, 5 at 800 HP		Replace existing 8 recycle pumps and motors with gear driven centrifugal pumps, 3 at 700 HP, 5 at 800 HP		No Modifications
Recycle Discharge Piping	2000 LF	Increase diameter of all external recycle piping to 30"	2000 LF	Increase diameter of all external recycle piping to 30"		No Modifications
Recycle suction pipe/flanges	8 pcs	Increase diameter of all external recycle pump suction piping to 30"	8 pcs	Increase diameter of all external recycle pump suction piping to 30"		No Modifications
Recycle System Valves and inline equipment	TBD	Replacement of all inline equipment in recycle system with 30" Dia. Includes valves, gaskets, replacement bolting, fittings.	TBD	Replacement of all inline equipment in recycle system with 30" Dia. Includes valves, gaskets, replacement bolting, fittings.		No Modifications
Spray Nozzles	336	Replace all spray nozzles with 120 degree spray patter, Levels 1 & 4 will use double-down nozzles, Levels 2 & 3 will use bi-directional nozzles, all will be bolted connection type to connect to existing spray header, all alloy hardware for bolting.	336	Replace all spray nozzles with 120 degree spray patter, Levels 1 & 4 will use double-down nozzles, Levels 2 & 3 will use bi-directional nozzles, all will be bolted connection type to connect to existing spray header, all alloy hardware for bolting.	576	Replace all spray nozzles with 120 degree spray patter, Levels 1 & 4 will use double-down nozzles, Levels 2 & 3 will use bi-directional nozzles, all will use victaulic couplings to connect to existing spray header, with alloy pin and bolt on coupling.
Wall Baffles						
Wall Baffles	4	Install 2 Wall Baffles, one at Spray level 2 centerline, one at Spray level 3 centerline, with cutouts as necessary for nozzle installation.	4	Install 2 Wall Baffles, one at Spray level 2 centerline, one at Spray level 3 centerline, with cutouts as necessary for nozzle installation.	8	Install 2 Wall Baffles, one at Spray level 2 centerline, one at Spray level 3 centerline, with cutouts as necessary for nozzle installation.
Oxidation Air System						
Oxidation Air Lances	240 LF	Install one Oxidation Air lance per absorber agitator (6 total). Requires new vessel penetration, internal and external supports. 8" Dia Nickel Alloy Piping material.	240 LF	Install one Oxidation Air lance per absorber agitator (6 total). Requires new vessel penetration, internal and external supports. 8" Dia Nickel Alloy Piping material.	10 pcs	Install one Oxidation Air lance per absorber agitator (5 Per absorber sump, 10 total). Requires new vessel penetration, internal and external supports. 8" Dia Nickel Alloy Piping material.
Air Lance Supports	6 pcs	High Nickel Alloy Material to be used consistent with process and Stress analysis	6 pcs	High Nickel Alloy Material to be used consistent with process and Stress analysis	10 pcs	High Nickel Alloy Material to be used consistent with process and Stress analysis
Air piping external to sump	1000 LF	Modify existing Oxidation Air Piping external to absorber to accommodate a ring header for distribution of Oxidation air to all lances. 20" Dia CS Piping material for ring header, down to 8" external feeding each lance.	1000 LF	Modify existing Oxidation Air Piping external to absorber to accommodate a ring header for distribution of Oxidation air to all lances. 20" Dia CS Piping material for ring header, down to 8" external feeding each lance.	TBD	Modify existing Oxidation Air Piping external to absorber to accommodate a ring header for distribution of Oxidation air to all lances. 20" Dia CS Piping material for ring header, down to 8" external feeding each lance.
Air Piping hangers	59 pcs	External Oxidation Air pipe supports to be installed on vessel	59 pcs	External Oxidation Air pipe supports to be installed on vessel	TBD	External Oxidation Air pipe supports to be installed on vessel
Agitators	6	Install (6) side mount absorber agitators, new vessel penetration, external supports to grade required for each. Ekato, 2M blades anticipated for use.	6	Install (6) side mount absorber agitators, new vessel penetration, external supports to grade required for each. Ekato, 2M blades anticipated for use.	10	Install (5) side mount absorber agitators per sump (10 total), new vessel penetration, external supports to grade required for each. Ekato, 1.6M blades anticipated for use.

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Case 3

FGD Upgrades - Equipment to be Modified

Materials	Unit 1 Qty	Unit 1 Comments	Unit 2 Qty	Unit 2 Comments	Unit 3 Qty	Unit 3 Comments
Slurry Recycle System						
Recycle Pumps	8	Replace existing 8 recycle pumps and motors with gear driven centrifugal pumps, 3 at 700 HP, 5 at 800 HP	8	Replace existing 8 recycle pumps and motors with gear driven centrifugal pumps, 3 at 700 HP, 5 at 800 HP	8	Gear Boxes regeared
Recycle Discharge Piping	2000 LF	Increase diameter of all external recycle piping to 30"	2000 LF	Increase diameter of all external recycle piping to 30"		N/A
Recycle suction pipe/flanges	8 pcs	Increase diameter of all external recycle pump suction piping to 30"	8 pcs	Increase diameter of all external recycle pump suction piping to 30"		No Modifications
Recycle System Valves and inline equipment		Replacement of all inline equipment in recycle system with 30" Dia. Includes valves, gaskets, replacement bolting, fittings.		Replacement of all inline equipment in recycle system with 30" Dia. Includes valves, gaskets, replacement bolting, fittings.		No Modifications
Spray Nozzles	432	Replace all spray nozzles with 120 degree spray patter, Level 4 will use double-down nozzles, Levels 1, 2 & 3 will use bi-directional nozzles, all will be bolted connection type to connect to existing spray header, all alloy hardware for bolting.	432	Replace all spray nozzles with 120 degree spray patter, Level 4 will use double-down nozzles, Levels 1, 2 & 3 will use bi-directional nozzles, all will be bolted connection type to connect to existing spray header, all alloy hardware for bolting.	832	Replace all spray nozzles with 120 degree spray patter, Level 4 will use double-down nozzles, Levels 1, 2 & 3 will use bi-directional nozzles, all will use victaulic couplings to connect to existing spray header, with alloy pin and bolt on coupling.
Spray Headers	8	Spray headers will be modified by addition of nozzles to each level and relocation of the levels to BPEI specified elevations above the perforated tray	8	Spray headers will be modified by addition of nozzles to each level and relocation of the levels to BPEI specified elevations above the perforated tray	16	Spray headers will be modified by addition of nozzles to each level and relocation of the levels to BPEI specified elevations above the perforated tray
Spray pipe hangers	TBD	Additional pipe hangers will be installed to accommodate the additional nozzles and spray header piping added.	TBD	Additional pipe hangers will be installed to accommodate the additional nozzles and spray header piping added.	TBD	Additional pipe hangers will be installed to accommodate the additional nozzles and spray header piping added.
Wall Baffles						
Wall Baffles	4	Install 2 Wall Baffles, one at Spray level 2 centerline, one at Spray level 3 centerline, with cutouts as necessary for nozzle installation.	4	Install 2 Wall Baffles, one at Spray level 2 centerline, one at Spray level 3 centerline, with cutouts as necessary for nozzle installation.	8	Install 2 Wall Baffles, one at Spray level 2 centerline, one at Spray level 3 centerline, with cutouts as necessary for nozzle installation.
Oxidation Air System						
Oxidation Air Lances	6pcs	Install one Oxidation Air lance per absorber agitator (6 total). Requires new vessel penetration, internal and external supports. 8" Dia Nickel Alloy Piping material.	6pcs	Install one Oxidation Air lance per absorber agitator (6 total). Requires new vessel penetration, internal and external supports. 8" Dia Nickel Alloy Piping material.	10 pcs	Install one Oxidation Air lance per absorber agitator (5 Per absorber sump, 10 total). Requires new vessel penetration, internal and external supports. 8" Dia Nickel Alloy Piping material.
Air Lance Supports	6 pcs	High Nickel Alloy Material to be used consistent with process and Stress analysis	6 pcs	High Nickel Alloy Material to be used consistent with process and Stress analysis	10 pcs	High Nickel Alloy Material to be used consistent with process and Stress analysis
Air piping external to sump	1000 LF	Modify existing Oxidation Air Piping external to absorber to accommodate a ring header for distribution of Oxidation air to all lances. 20" Dia CS Piping material for ring header, down to 8" external feeding each lance.	1000 LF	Modify existing Oxidation Air Piping external to absorber to accommodate a ring header for distribution of Oxidation air to all lances. 20" Dia CS Piping material for ring header, down to 8" external feeding each lance.	TBD	Modify existing Oxidation Air Piping external to absorber to accommodate a ring header for distribution of Oxidation air to all lances. 20" Dia CS Piping material for ring header, down to 8" external feeding each lance.
Air Piping hangers	59 pcs	External Oxidation Air pipe supports to be installed on vessel	59 pcs	External Oxidation Air pipe supports to be installed on vessel	TBD	External Oxidation Air pipe supports to be installed on vessel

Agitators	6	Install (6) side mount absorber agitators, new vessel penetration, external supports to grade required for each. Ekato, 2M blades anticipated for use.		6	Install (6) side mount absorber agitators, new vessel penetration, external supports to grade required for each. Ekato, 2M blades anticipated for use.		10	Install (5) side mount absorber agitators per sump (10 total), new vessel penetration, external supports to grade required for each. Ekato, 1.6M blades anticipated for use.
Absorber Shell and Ductwork Modifications								
Outlet expansion joint	88 lf	Outlet Duct Expansion joints will be replaced.		88 lf	Outlet Duct Expansion joints will be replaced.		TBD	Outlet Duct Expansion joints will be replaced.
317L Absorber shell	16,744 sf	Absorber shell will be modified with relocation of Spray Headers. Original penetrations will be filled while new ones are cut.		16,744 sf	Absorber shell will be modified with relocation of Spray Headers. Original penetrations will be filled while new ones are cut.			Absorber shell will be modified with relocation of Spray Headers. Original penetrations will be filled while new ones are cut.
Absorber Reheater Section		Reheater section will be removed and new ME section will be installed in its place			Reheater section will be removed and new ME section will be installed in its place			Reheater section will be removed and new ME section will be installed in its place
DV 210 Mist Eliminator and spray wash system	TBD	In the previous Reheat section new Munters DV210 modular Mist Eliminator sections will be installed along with new ME wash piping system to supply wash water.		TBD	In the previous Reheat section new Munters DV210 modular Mist Eliminator sections will be installed along with new ME wash piping system to supply wash water.		TBD	In the previous Reheat section new Munters DV210 modular Mist Eliminator sections will be installed along with new ME wash piping system to supply wash water.

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AREA	ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commission	Test	Training

A **Oxidation Air System**

ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commission	Test	Training
Oxidation Air Compressor	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Oxidation Air Agitators	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Oxidation Air Pressure Relief Valves	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
External Headers	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Internal Lances	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Spray Nozzles	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Inlet Silencer	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Inlet Filter	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Instrumentation	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Control Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Actuated Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Manuel Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
PLC Controls	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Access Steel (including handrails, platforms, stairs, flooring, grating e	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Foundations	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Electrical Hoists	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Electrical Power Supply	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Motor Starters and Control Centers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Motors low Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Motors medium Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Pipes > 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Pipes < 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Raceway, Conduit, Pullboxes, Wiring, Cabling on Skids	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Heat Tracing (Freeze Protection)	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Cathodic Protection	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Plant Electrical and Mechanical Tie-In	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others

A **Absorber Recycle Pumps System**

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AREA	ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commission	Test	Training
	Absorber Recycle Pumps incl Gear Box	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Oil Circulation and Coolers	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Absorber Recycle Pipes External	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Absorber Recycle Pipes Internal	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	expansion Joints	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Spray Nozzles	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Instrumentation	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Actuated Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Manuel Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	PLC Controls	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Access Steel (including handrails, platforms, stairs, flooring, grating e	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Foundations	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Electrical Hoists	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Power Supply	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Motor Starters and Control Centers	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Motors low Voltage	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Motors medium Voltage	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Pipes > 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Pipes < 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Raceway, Conduit, Pullboxes, Wiring, Cabling on Skids	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Heat Tracing (Freeze Protection)	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Cathodic Protection	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Plant Electrical and Mechanical Tie-In	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
A	**Absorber Tower**										
	Flow Models	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Absorber Material	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Side-Mounted Agitators	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Mist Eliminators Blades	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Mist Eliminators Support Structure	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Mist Eliminator Wash Headers internal	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others

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	Mist Eliminator Wash Headers external	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Mist Eliminator Wash Headers internal Support	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Absorber Internals	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Inspection Access Doors	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Gas Sample Test Ports	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Instrumentation	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Access Steel (including handrails, platforms, stairs, flooring, grating ε	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Foundations	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Hoists	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Power Supply	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motor Starters and Control Centers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motors low Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Plant Electrical and Mechanical Tie-In	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others

Project / Construction Administration

Enviromental Licensing and Permits	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Building Licensing and Permits	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Limestone Licensing and Permits	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Project Master Schedule	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Project Schedule- Design,Procure,Fabricate&Deliver	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Construction Safety Program	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Project Labor Plan	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
QA/QC Program	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Start-up Field Service, Equipment Commisioning & Turnover	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Personnel Training	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
O & M Manuals	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Optimization & Acceptance Testing	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Equipment Storage	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Equipment Precommision Maintenance	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Construction Facilities - Temporary	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI

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	Construction Facilities - Permanent	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Site Clean-up	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Asbestos Testing & Removal	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Lead Paint Testing & Removal	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Finish Painting and Field Touch-up	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI

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AREA	ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commissio n	Test	Training
C	**Gas Path**										
	Inlet Ductwork	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Outlet Ductwork	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Flow Models	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Expansion Joints	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Ductwork Internals (flow screen, hoist beam)	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	New ID & Booster Fans	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	New ID & Booster Fan Motors	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Inspection Access Doors	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Gas Sample Test Ports	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Insulation & Lagging For All Components	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Instrumentation	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Actuated Valves/Dampers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Manuel Valves/Dampers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Access Steel (including handrails, platforms, stairs, flooring, grating e	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Foundations	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Power Supply	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motor Starters and Control Centers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motors low Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Pipes > 2 in incl Support	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Pipes < 2 in incl Support	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Heat Tracing (Freeze Protection)	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Cathodic Protection	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Plant Electrical and Mechanical Tie-In	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
A	**Oxidation Air System**										
	Oxidation Air Compressor	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Oxidation Air Agitators	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Oxidation Air Pressure Relief Valves	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	External Headers	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI

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Contract No. 501654
Mill Creek FGD Performance Upgrade Study
Case 3 : Units 1, 2 & 3:4

Rev 0

AREA	ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commissio n	Test	Training
	Internal Lances	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Spray Nozzles	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Inlet Silencer	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Inlet Filter	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Instrumentation	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Control Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Actuated Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Manuel Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	PLC Controls	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Access Steel (including handrails, platforms, stairs, flooring, grating e	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Foundations	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Hoists	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Power Supply	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motor Starters and Control Centers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motors low Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motors medium Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Pipes > 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Pipes < 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Raceway, Conduit, Pullboxes, Wiring, Cabling on Skids	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Heat Tracing (Freeze Protection)	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Cathodic Protection	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Plant Electrical and Mechanical Tie-In	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
A	**Absorber Recycle Pumps System**										
	Absorber Recycle Pumps incl Gear Box - Unit 3 Gear Boxes only	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Oil Circulation and Coolers	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Absorber Recycle Pipes External	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Absorber Recycle Pipes Internal	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	expansion Joints	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Spray Nozzles	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Instrumentation	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI

LG&E Service Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study
Case 3 : Units 1, 2 & 3:4

Rev 0

AREA	ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commission	Test	Training
	Actuated Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Manuel Valves	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	PLC Controls	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Access Steel (including handrails, platforms, stairs, flooring, grating ε	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Foundations	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Electrical Hoists	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Power Supply	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Motor Starters and Control Centers	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Motors low Voltage	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Motors medium Voltage	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Pipes > 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Pipes < 2 in incl Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Raceway, Conduit, Pullboxes, Wiring, Cabling on Skids	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Heat Tracing (Freeze Protection)	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Cathodic Protection	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Plant Electrical and Mechanical Tie-In	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
A	**Absorber Tower**										
	Flow Models	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Absorber Material	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Side-Mounted Agitators	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Mist Eliminators Blades	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Mist Eliminators Support Structure	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Mist Eliminator Wash Headers internal	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Mist Eliminator Wash Headers external	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Mist Eliminator Wash Headers internal Support	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Absorber Internals	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Inspection Access Doors	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Gas Sample Test Ports	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Instrumentation	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
	Access Steel (including handrails, platforms, stairs, flooring, grating ε	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others

LG&E Service Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study
Case 3 : Units 1, 2 & 3:4

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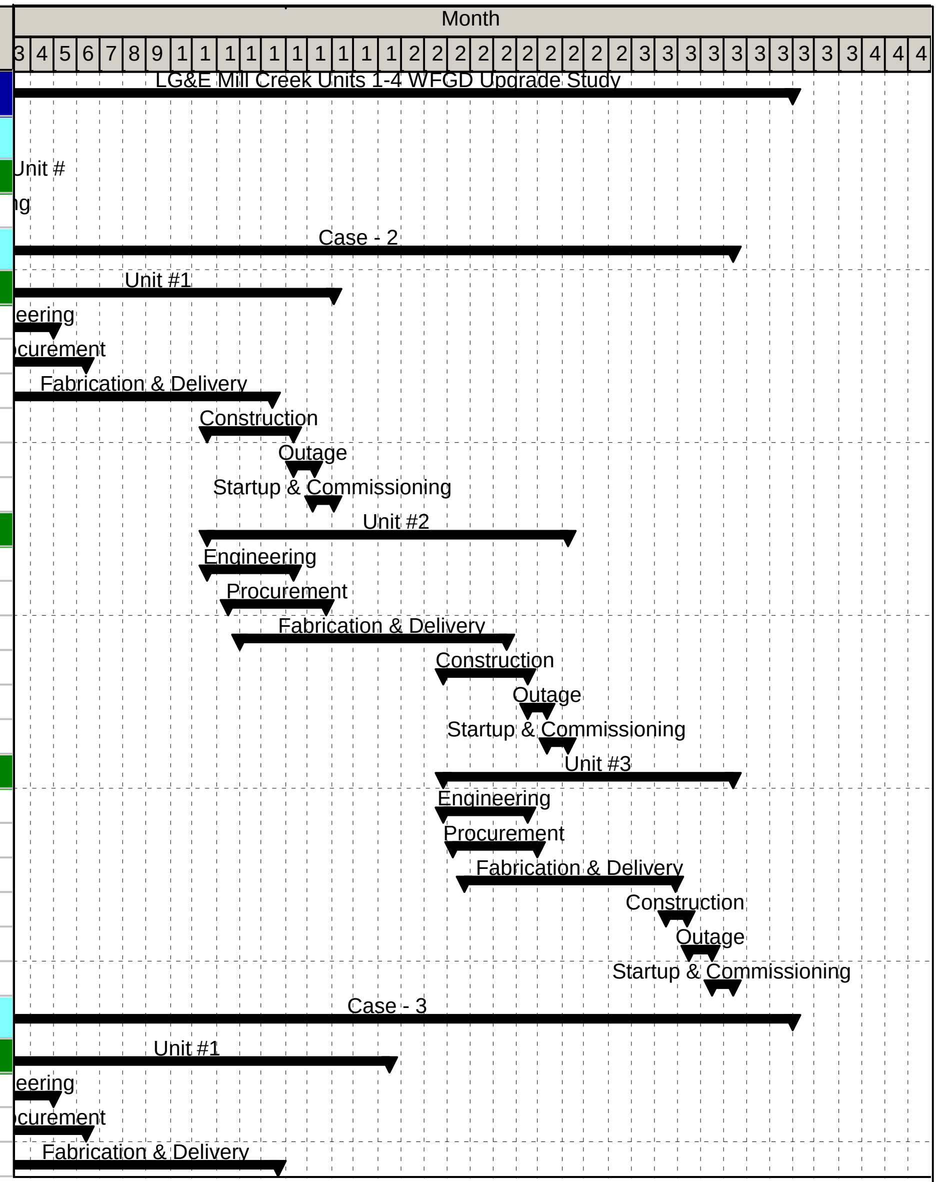
AREA	ITEM DESCRIPTION	Basic Engrg	Detail Design	Procure	Fab	Deliver	Erect Consult	Erection	Commission	Test	Training
	Structural Steel	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Foundations	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Hoists	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Electrical Power Supply	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motor Starters and Control Centers	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Motors low Voltage	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Raceway, Conduit, Pullboxes, Wiring, Cabling (excludes skid equipm	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
	Plant Electrical and Mechanical Tie-In	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others

Project / Construction Administration

Enviromental Licensing and Permits	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Building Licensing and Permits	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Limestone Licensing and Permits	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Project Master Schedule	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Project Schedule- Design,Procure,Fabricate&Deliver	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Construction Safety Program	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Project Labor Plan	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
QA/QC Program	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Start-up Field Service, Equipment Commisioning & Turnover	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Personnel Training	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
O & M Manuals	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Optimization & Acceptance Testing	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Equipment Storage	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Equipment Precommision Maintenance	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Construction Facilities - Temporary	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Construction Facilities - Permanent	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Site Clean-up	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI
Asbestos Testing & Removal	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Lead Paint Testing & Removal	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others	By Others
Finish Painting and Field Touch-up	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI	BPEI

Activity Name	Contract Number	Orig Dur
LG&E Mill Creek Units 1-4 WFGD Upgrade Study		771
		0
No Mill Creek Unit #		0
Engineering		0
Case - 2		714
Unit #1		337
Engineering		80
Procurement		93
Fabrication & Delivery		253
Construction		80
Outage		19
Startup & Commissioning		20
Unit #2		337
Engineering		80
Procurement		93
Fabrication & Delivery		253
Construction		80
Outage		19
Startup & Commissioning		20
Unit #3		274
Engineering		80
Procurement		80
Fabrication & Delivery		200
Construction		21
Outage		23
Startup & Commissioning		20
Case - 3		771
Unit #1		391
Engineering		80
Procurement		93
Fabrication & Delivery		258



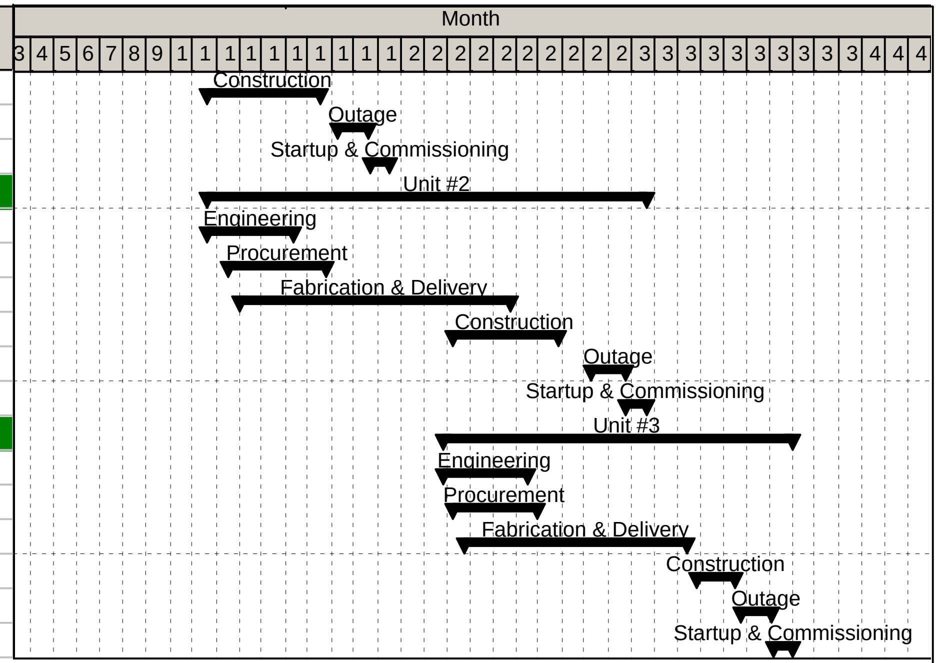
Remaining Work
Critical Remaining Work
Milestone
Summary

Babcock Power Environmental Inc

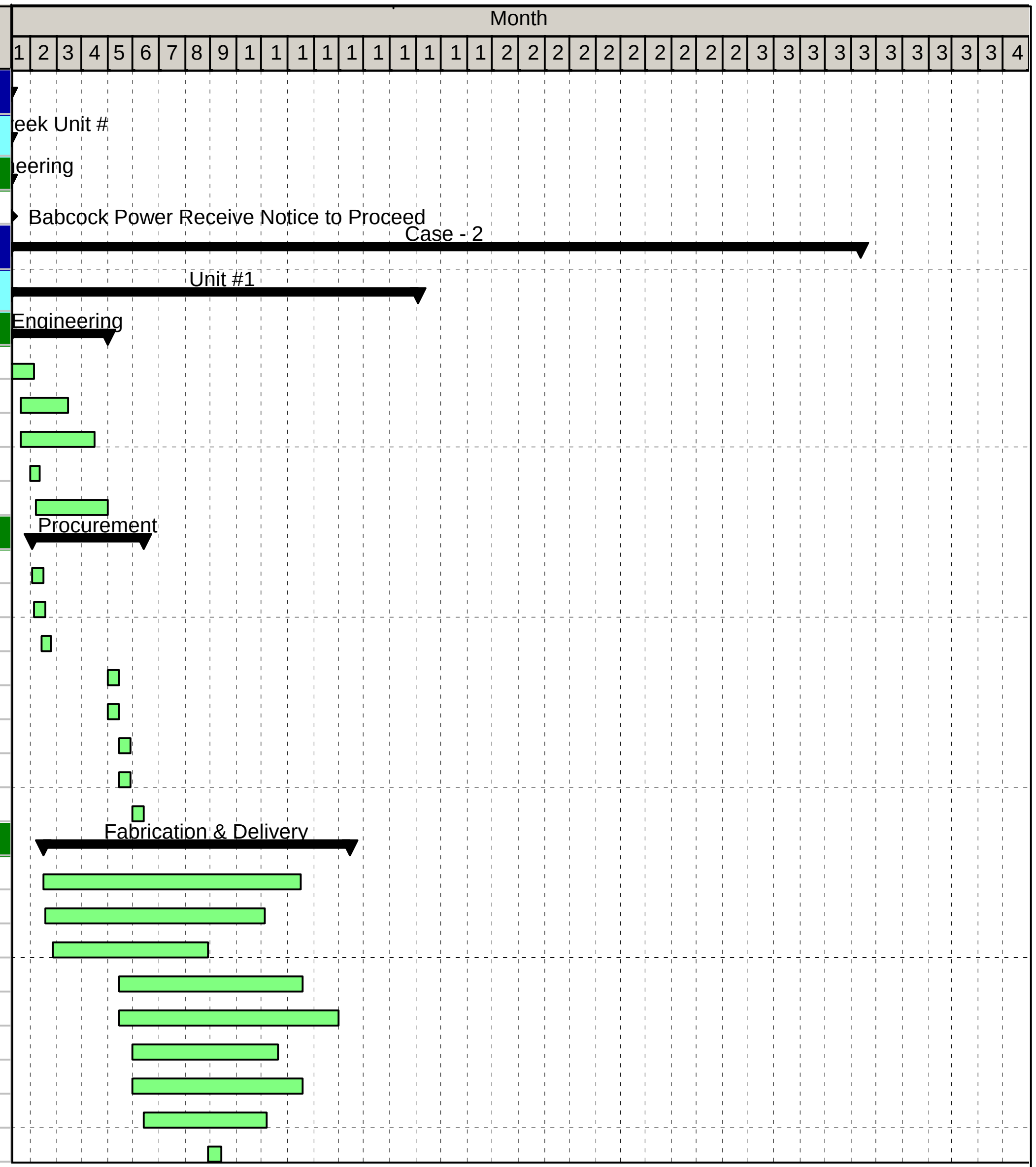
Mill Creek FGD EPC Summary

BabcockPower ENVIRONMENTAL

Activity Name	Contract Number	Orig Dur
Construction		105
Outage		31
Startup & Commissioning		20
Unit #2		412
Engineering		80
Procurement		93
Fabrication & Delivery		258
Construction		100
Outage		32
Startup & Commissioning		20
Unit #3		331
Engineering		80
Procurement		80
Fabrication & Delivery		210
Construction		35
Outage		31
Startup & Commissioning		20



Activity Name	Orig Dur
	0
No Mill Creek Unit #	0
Engineering	0
Babcock Power Receive Notice to Proceed	0
Case - 2	714
Unit #1	337
Engineering	80
Design Calculations	20
Conduct CFD Modeling	40
Conduct Physical Modeling	60
Develop Equipment D&R Sheets	10
Develop Mechanical Drawings	60
Procurement	93
Issue P.O. Recycle Pumps	10
Issue P.O. Agitators	10
Issue P.O. Spray Nozzles	10
Issue P.O. Recycle Piping	10
Issue P.O. Wall Rings	10
Issue P.O. Modified Oxidation Air Lances	10
Issue P.O. Spray Piping Hangers & Hardware	10
Issue P.O. Air Piping, Hangers & Hardware	10
Fabrication & Delivery	253
Fabricate Recycle Pumps	210
Fabricate Agitators	180
Fabricate Spray Nozzles	130
Fabricate Wall Rings	150
Fabricate Recycle Piping	180
Fabricate Spray Piping Hangers & Hardware	120
Fabricate Modified Oxidation Air Lances	140
Fabricate Air Piping, Hangers & Hardware	100
Deliver Spray Nozzles	10



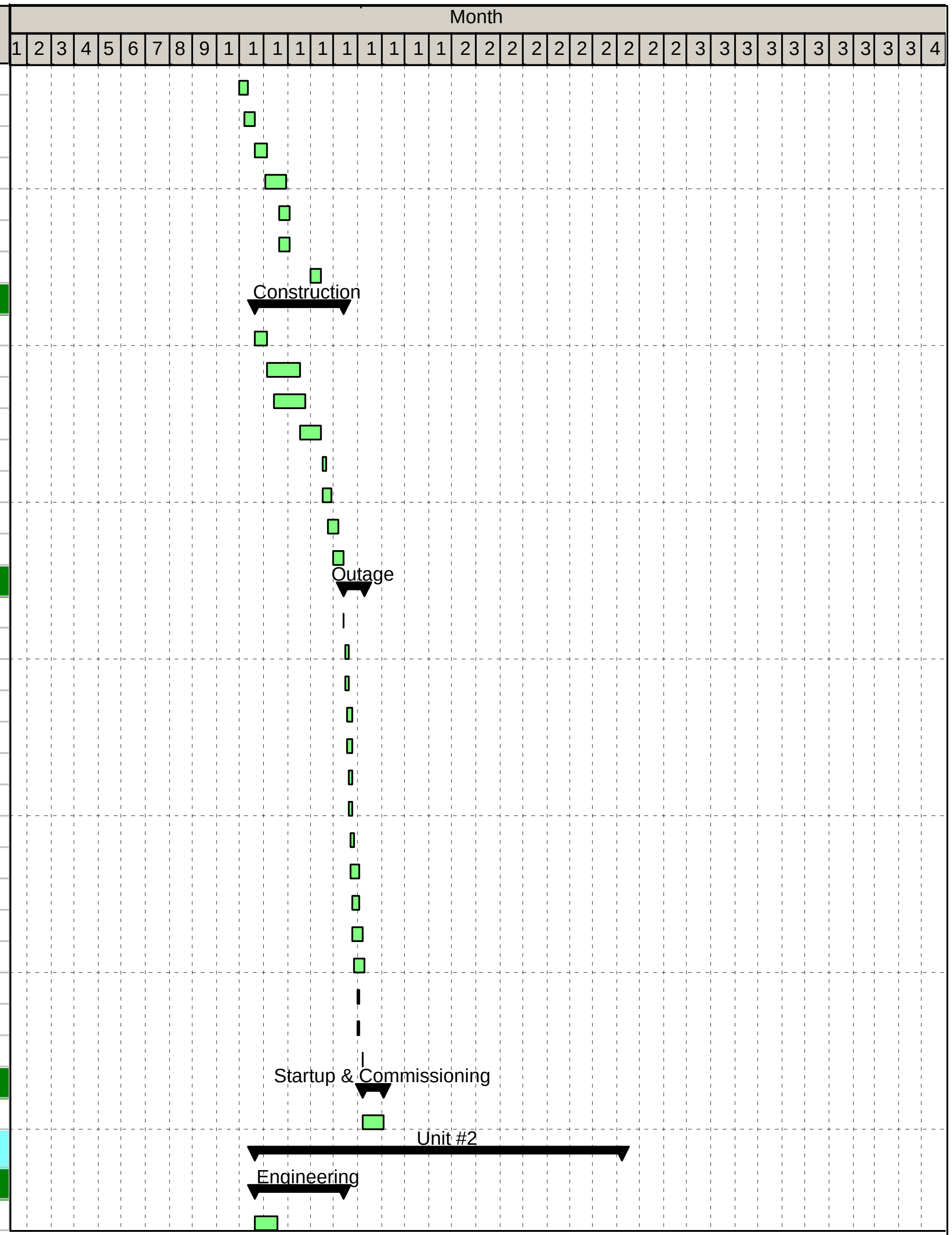
Remaining Work
Critical Remaining Work
Milestone
Summary

Babcock Power Environmental Inc

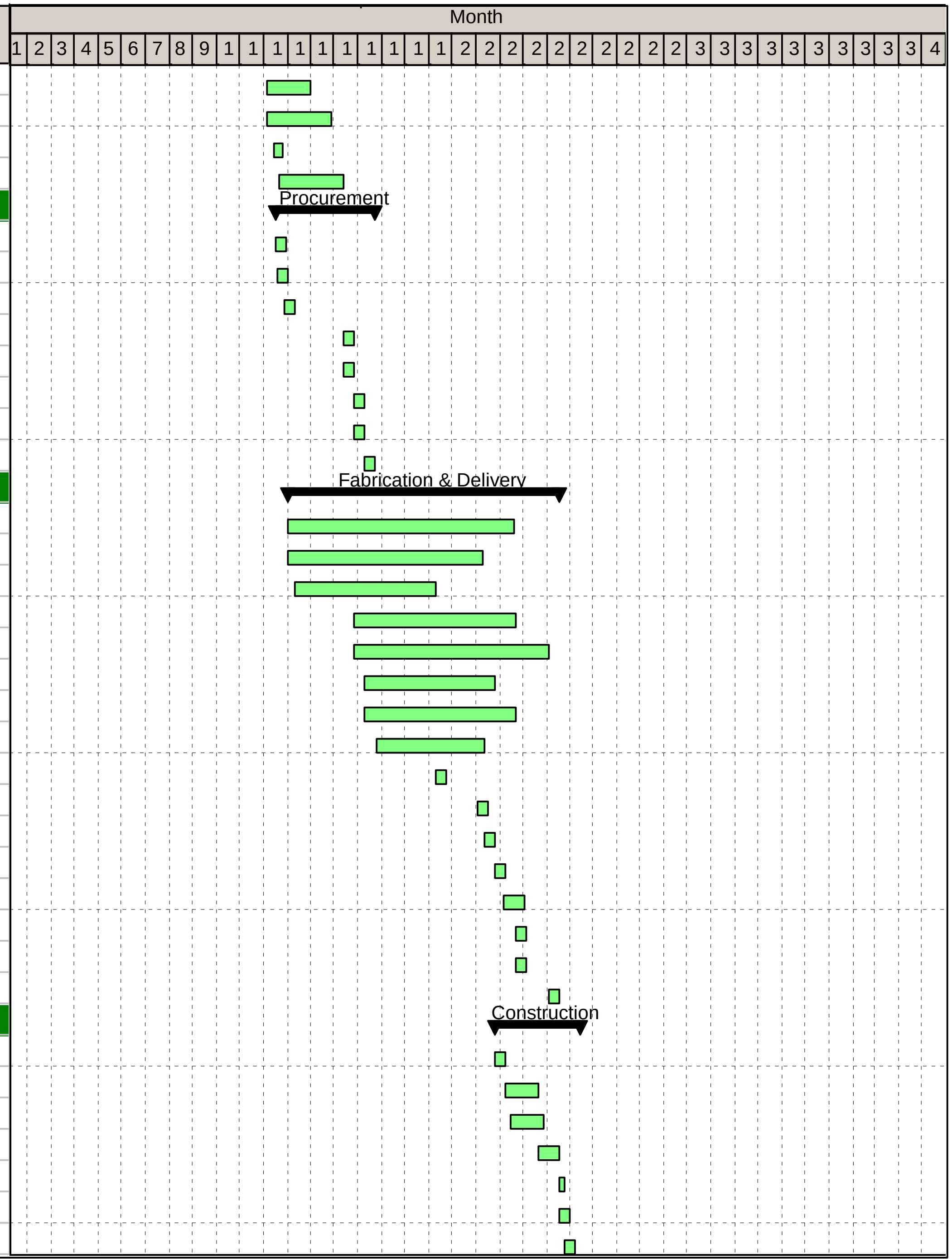
Mill Creek FGD EPC Detailed

BabcockPower ENVIRONMENTAL

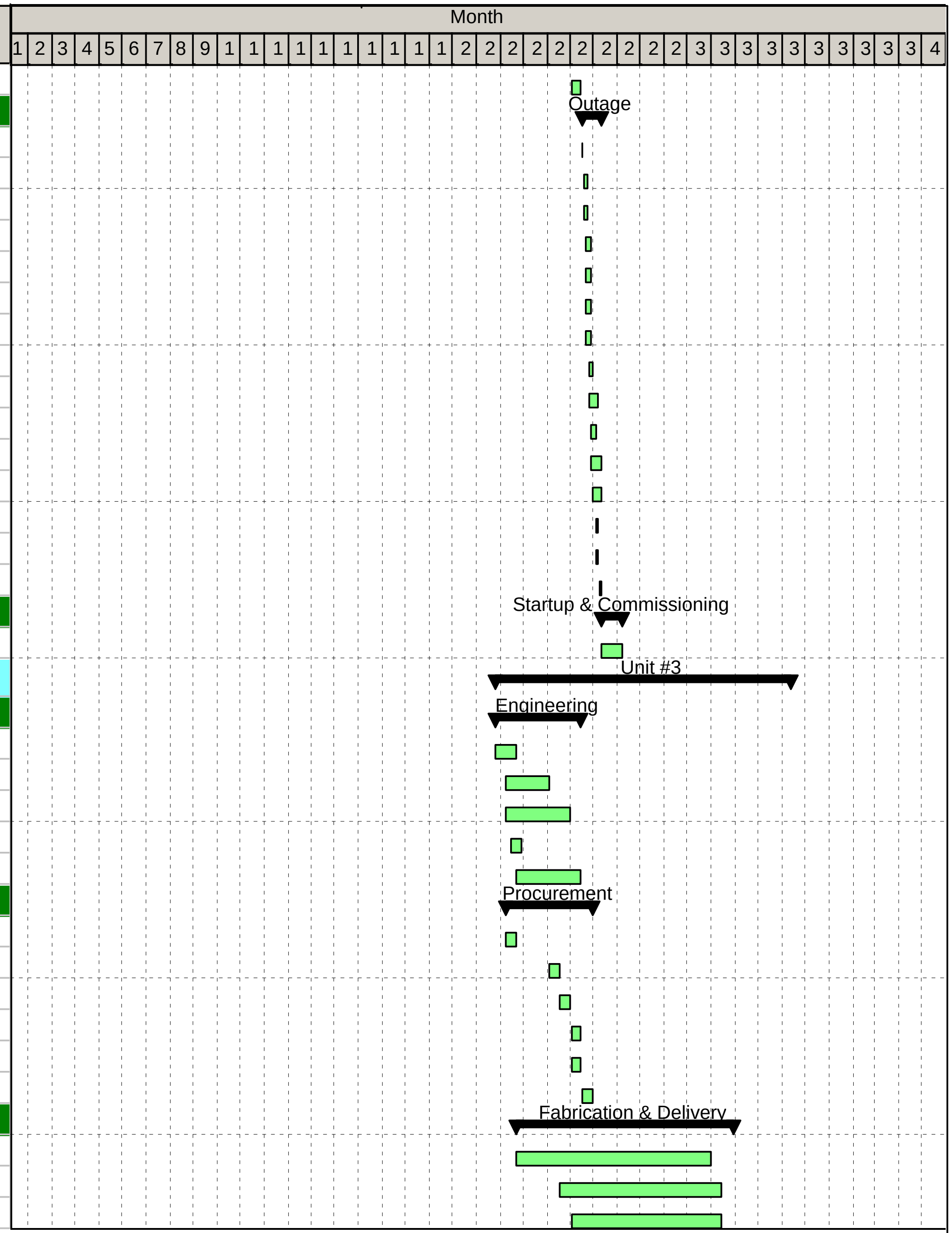
Activity Name	Orig Dur
Deliver Agitators	10
Deliver Air Piping, Hangers and Hardware	10
Deliver Spray Piping Hangers and Hardware	10
Deliver Recycle Pumps	20
Deliver Wall Rings	10
Deliver Modified Oxidation Air Lances	10
Deliver Recycle Piping	10
Construction	80
Mobilze Construction	10
Excavate Recycle Pump Foundations	30
Form & Pour Recycle Pump Foundations	30
Run New Electrical Cables to Recycle Pumps	20
Unload Outage Materials	5
Set Up Scaffolding for Outage	10
Inventory and Store Outage Material	10
Set Up Recycle Line Rigging	10
Outage	19
Commence Outage	1
Remove Electrical Recycle Pump & Motor	5
Remove Misc. Electrical Interferences & Instrumentation	5
Demo Recycle Pump and Motors	6
Demo Recycle Outlet Lines to Spray Headers	5
Set Recycle Pumps	5
Install Wall Rings	5
Remove Recycle Spray Nozzles	4
Install Recycle Piping	10
Install Agitators	7
Align Recycle Pumps	10
Install Oxidation Air Nozzles	10
Reinstall Electrical Removed for Access.	3
Reinstall Instrumentation Removed for Access.	3
Outage Complete	1
Startup & Commissioning	20
Start Up and Commissioning	20
Unit #2	337
Engineering	80
Design Calculations	20



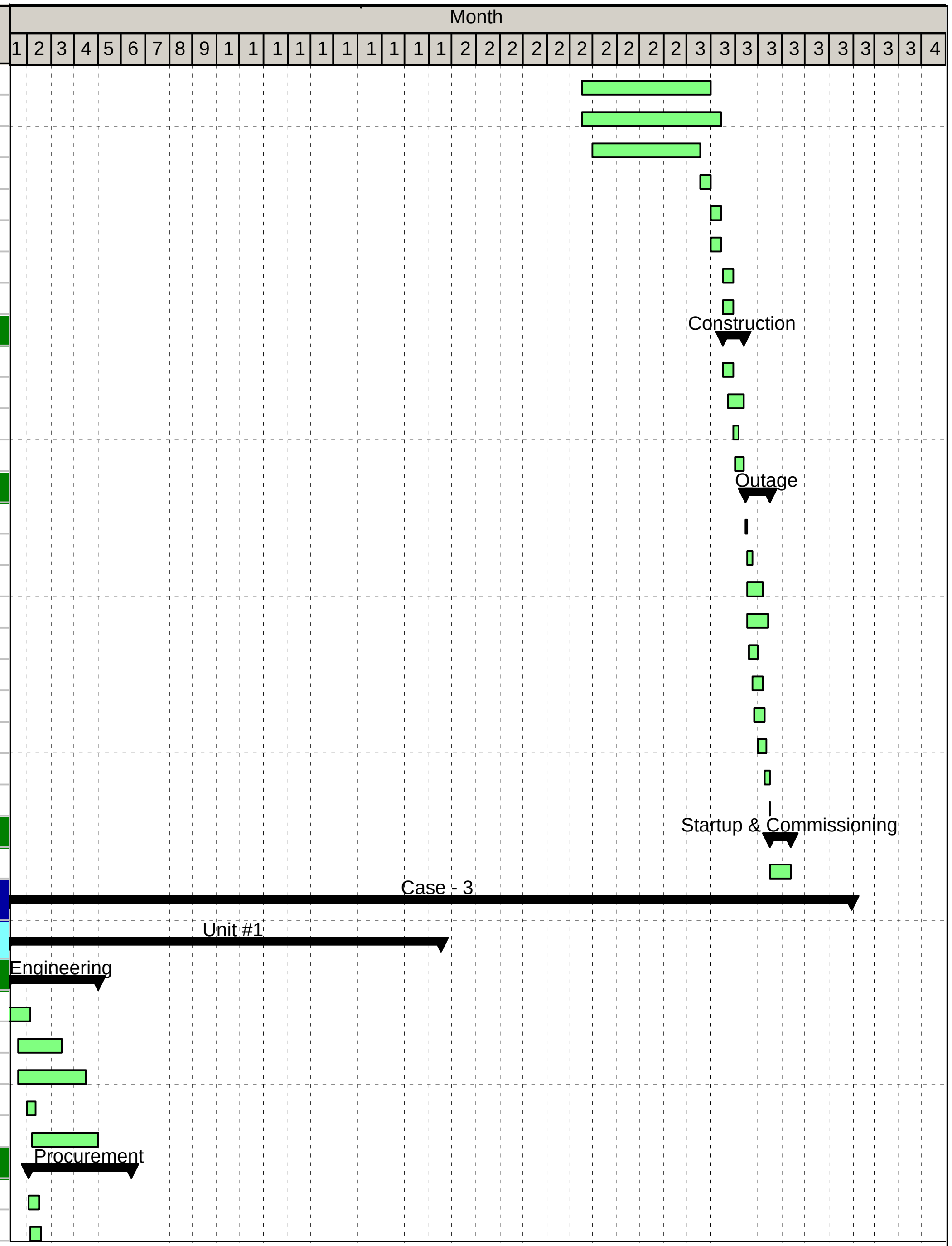
Activity Name	Orig Dur
Conduct CFD Modeling	40
Conduct Physical Modeling	60
Develop Equipment D&R Sheets	10
Develop Mechanical Drawings	60
Procurement	**93**
Issue P.O. Recycle Pumps	10
Issue P.O. Agitators	10
Issue P.O. Spray Nozzles	10
Issue P.O. Recycle Piping	10
Issue P.O. Wall Rings	10
Issue P.O. Modified Oxidation Air Lances	10
Issue P.O. Spray Piping Hangers & Hardware	10
Issue P.O. Air Piping, Hangers & Hardware	10
Fabrication & Delivery	**253**
Fabricate Recycle Pumps	210
Fabricate Agitators	180
Fabricate Spray Nozzles	130
Fabricate Wall Rings	150
Fabricate Recycle Piping	180
Fabricate Spray Piping Hangers & Hardware	120
Fabricate Modified Oxidation Air Lances	140
Fabricate Air Piping, Hangers & Hardware	100
Deliver Spray Nozzles	10
Deliver Agitators	10
Deliver Air Piping, Hangers and Hardware	10
Deliver Spray Piping Hangers and Hardware	10
Deliver Recycle Pumps	20
Deliver Wall Rings	10
Deliver Modified Oxidation Air Lances	10
Deliver Recycle Piping	10
Construction	**80**
Mobilze Construction	10
Excavate Recycle Pump Foundations	30
Form & Pour Recycle Pump Foundations	30
Run New Electrical Cables to Recycle Pumps	20
Unload Outage Materials	5
Set Up Scaffolding for Outage	10
Inventory and Store Outage Material	10



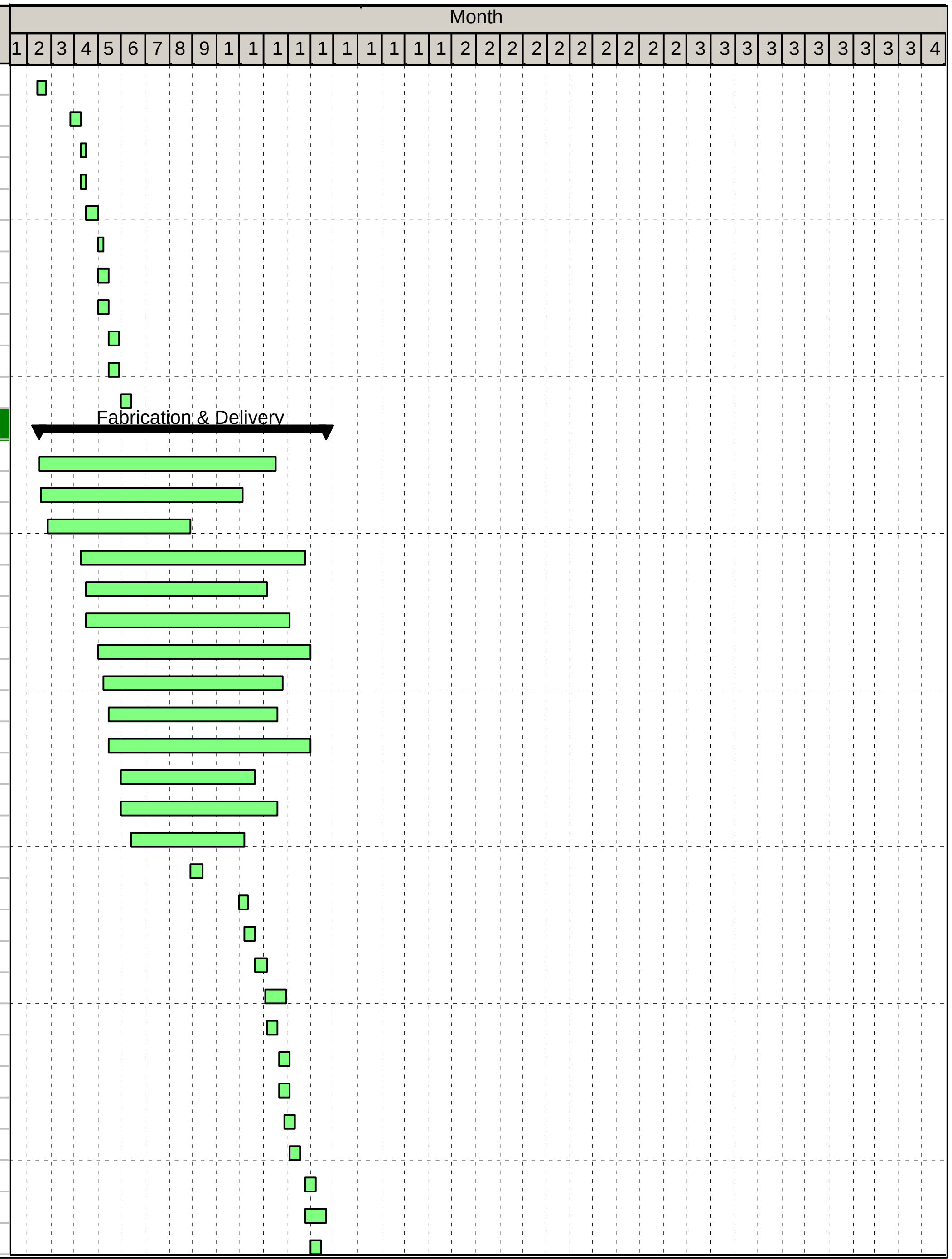
Activity Name	Orig Dur
Set Up Recycle Line Rigging	10
Outage	19
Commence Outage	1
Remove Electrical Recycle Pump & Motor	5
Remove Misc. Electrical Interferences & Instrumentation	5
Demo Recycle Pump and Motors	6
Demo Recycle Outlet Lines to Spray Headers	5
Set Recycle Pumps	5
Install Wall Rings	5
Remove Recycle Spray Nozzles	4
Install Recycle Piping	10
Install Agitators	7
Align Recycle Pumps	10
Install Oxidation Air Nozzles	10
Reinstall Electrical Removed for Access.	3
Reinstall Instrumentation Removed for Access.	3
Outage Complete	1
Startup & Commissioning	20
Start Up and Commissioning	20
Unit #3	274
Engineering	80
Design Calculations	20
Conduct CFD Modeling	40
Conduct Physical Modeling	60
Develop Equipment D&R Sheets	10
Develop Mechanical Drawings	60
Procurement	80
Issue P.O. Agitators	10
Issue P.O. Wall Rings	10
Issue P.O. Modified Oxidation Air Lances	10
Issue P.O. Spray Nozzles	10
Issue P.O. Spray Piping Hangers & Hardware	10
Issue P.O. Air Piping, Hangers & Hardware	10
Fabrication & Delivery	200
Fabricate Agitators	180
Fabricate Wall Rings	150
Fabricate Modified Oxidation Air Lances	140



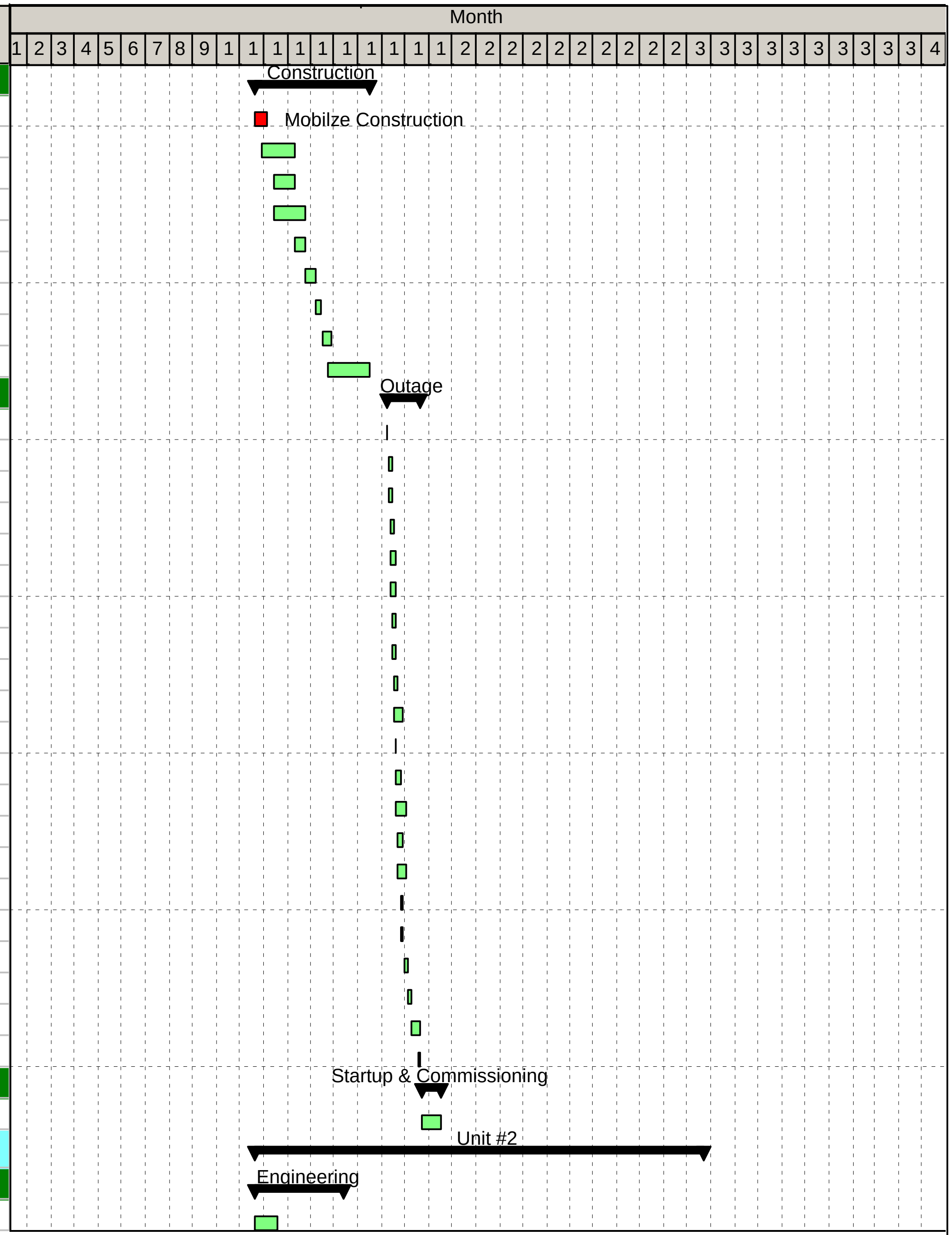
Activity Name	Orig Dur
Fabricate Spray Piping Hangers & Hardware	120
Fabricate Spray Nozzles	130
Fabricate Air Piping, Hangers & Hardware	100
Deliver Air Piping, Hangers and Hardware	10
Deliver Agitators	10
Deliver Spray Piping Hangers and Hardware	10
Deliver Wall Rings	10
Deliver Spray Nozzles	10
Construction	21
Mobilze Construction	10
Remove Electrical and I&C Interferences	15
Unload Outage Materials	5
Inventory and Store Outage Material	10
Outage	23
Commence Outage	1
Install Wall Rings	5
Remove Recycle Spray Nozzles	15
Set New Recycle Pump Gear Boxes	20
Install Agitators	7
Install Oxidation Air Nozzles	10
Reinstall Electrical Removed for Access.	10
Reinstall Instrumentation Removed for Access.	10
Align Recycle Pump Gear Boxes	5
Outage Complete	1
Startup & Commissioning	20
Start Up and Commissioning	20
Case - 3	771
Unit #1	391
Engineering	80
Design Calculations	20
Conduct CFD Modeling	40
Conduct Physical Modeling	60
Develop Equipment D&R Sheets	10
Develop Mechanical Drawings	60
Procurement	93
Issue P.O. Recycle Pumps	10
Issue P.O. Agitators	10



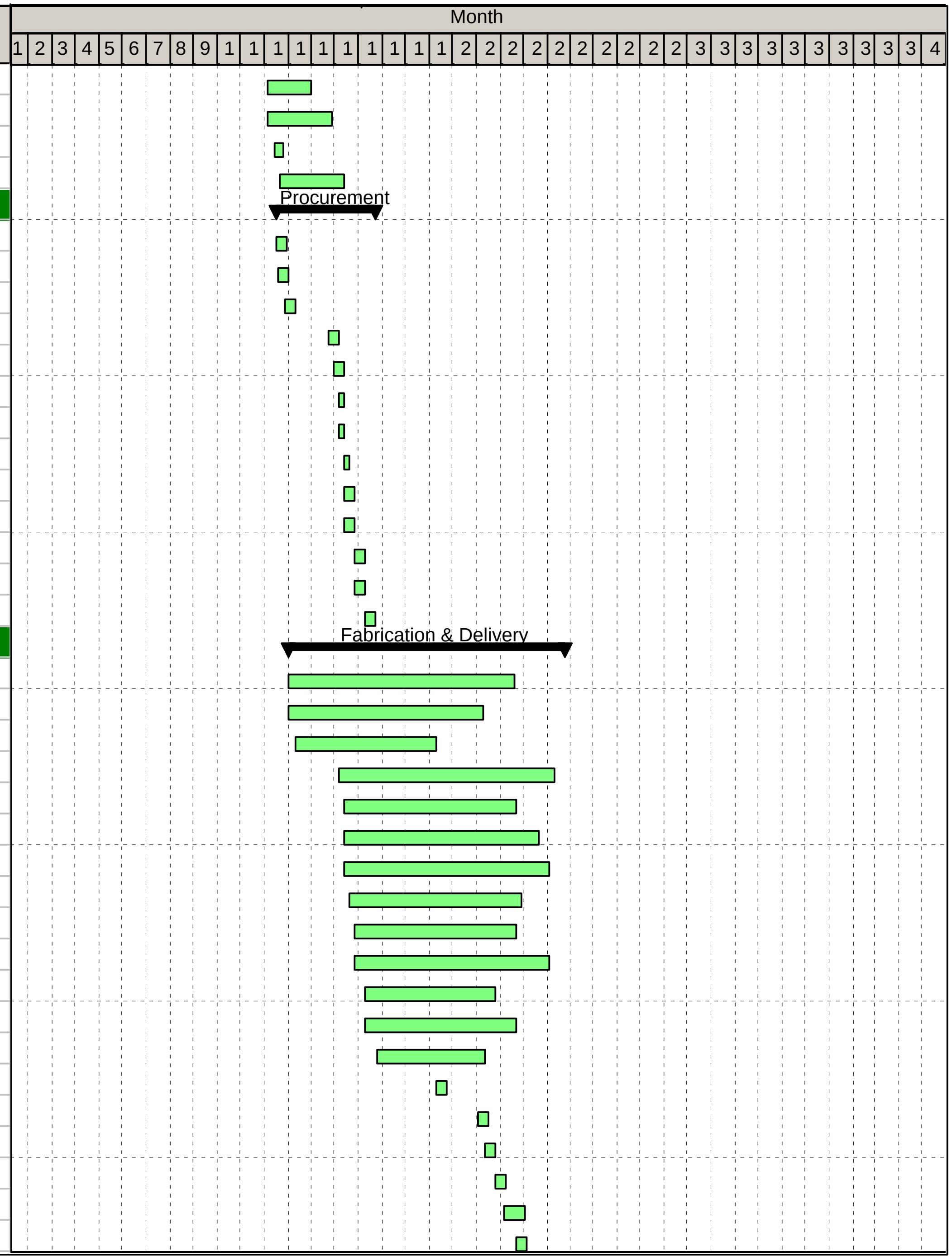
Activity Name	Orig Dur
Issue P.O. Spray Nozzles	10
Issue P.O. Recycle Spray Headers	10
Issue P.O. Recycle Spray Bull Horns	5
Issue P.O. Mist Eliminator	5
Issue P.O. Absorber Shell	10
Issue P.O. Outlet Expansion Joint	5
Issue P.O. Recycle Piping	10
Issue P.O. Wall Rings	10
Issue P.O. Modified Oxidation Air Lances	10
Issue P.O. Spray Piping Hangers & Hardware	10
Issue P.O. Air Piping, Hangers & Hardware	10
Fabrication & Delivery	**258**
Fabricate Recycle Pumps	210
Fabricate Agitators	180
Fabricate Spray Nozzles	130
Fabricate Recycle Spray Headers	200
Fabricate Mist Eliminator	160
Fabricate Recycle Spray Bull Horns	180
Fabricate Absorber Shell	190
Fabricate Outlet Expansion Joint	160
Fabricate Wall Rings	150
Fabricate Recycle Piping	180
Fabricate Spray Piping Hangers & Hardware	120
Fabricate Modified Oxidation Air Lances	140
Fabricate Air Piping, Hangers & Hardware	100
Deliver Spray Nozzles	10
Deliver Agitators	10
Deliver Air Piping, Hangers and Hardware	10
Deliver Spray Piping Hangers and Hardware	10
Deliver Recycle Pumps	20
Deliver Mist Eliminator	10
Deliver Wall Rings	10
Deliver Modified Oxidation Air Lances	10
Deliver Outlet Expansion Joint	10
Deliver Recycle Spray Bull Horns	10
Deliver Recycle Spray Headers	10
Deliver Absorber Shell	20
Deliver Recycle Piping	10



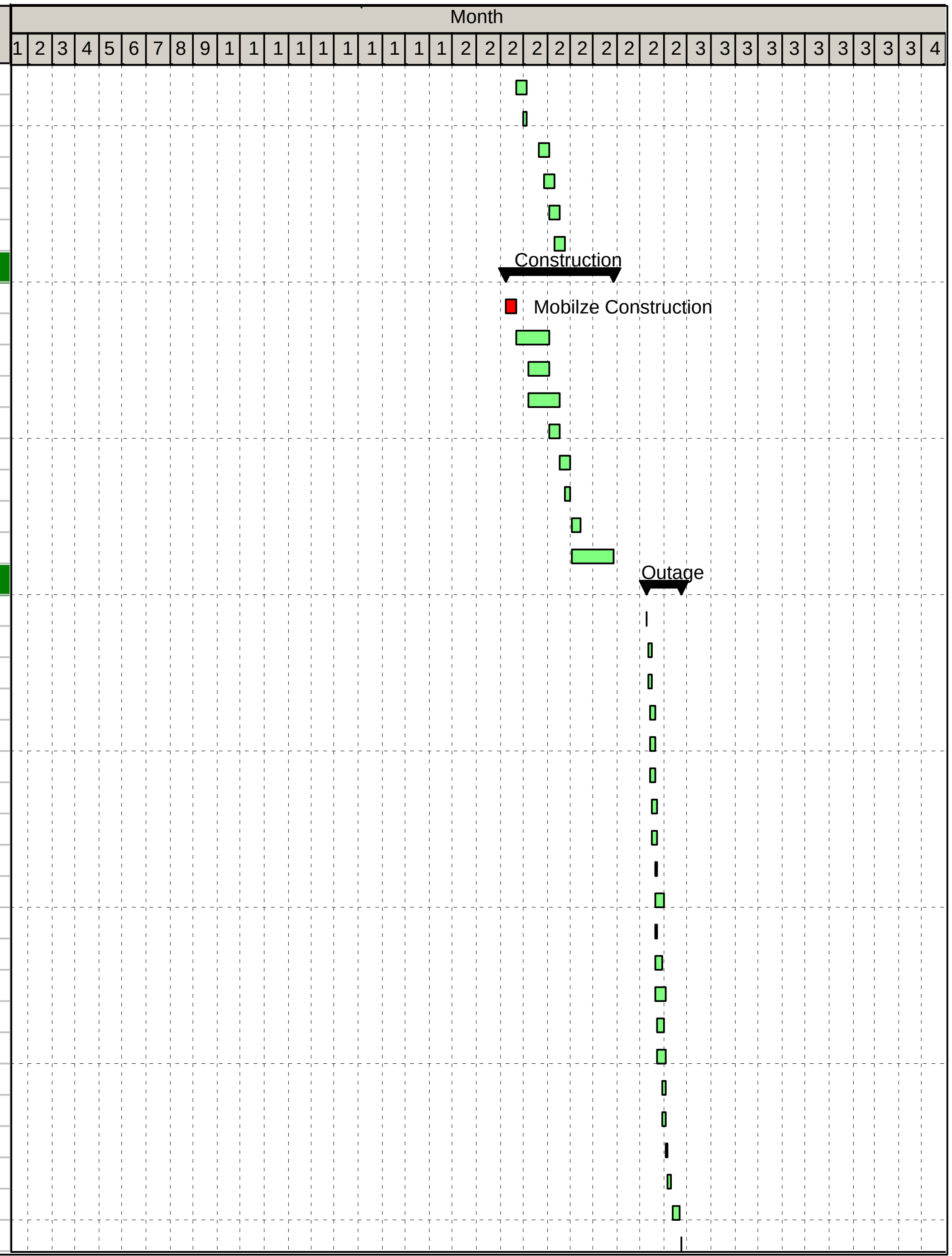
Activity Name	Orig Dur
Construction	105
Mobilze Construction	10
Excavate Recycle Pump Foundations	30
Run New Electrical Cables to Recycle Pumps	20
Form & Pour Recycle Pump Foundations	30
Set Up Scaffolding for Outage	10
Set Up Recycle Line Rigging	10
Unload Outage Materials	5
Inventory and Store Outage Material	10
Ground Fab Absorber Assembly	40
Outage	31
Commence Outage	1
Remove Electrical Recycle Pump & Motor	5
Remove Misc. Electrical Interferences & Instrumentation	5
Demo Existing Absorber	5
Demo Recycle Pump and Motors	6
Demo Recycle Outlet Lines to Spray Headers	5
Set Recycle Pumps	5
Install Wall Rings	5
Remove Recycle Spray Nozzles	4
Install Recycle Piping	10
Raise & Rig Absorber Section	2
Install Agitators	7
Align Recycle Pumps	10
Weld Absorber Section	7
Install Oxidation Air Nozzles	8
Reinstall Electrical Removed for Access.	3
Reinstall Instrumentation Removed for Access.	3
Install New Outlet Expansion Joint	3
Connect Exist. Outlet Ductwork to New Absorber	4
Install Insulatation and Lagging to Absorber	8
Outage Complete	1
Startup & Commissioning	20
Start Up and Commissioning	20
Unit #2	412
Engineering	80
Design Calculations	20



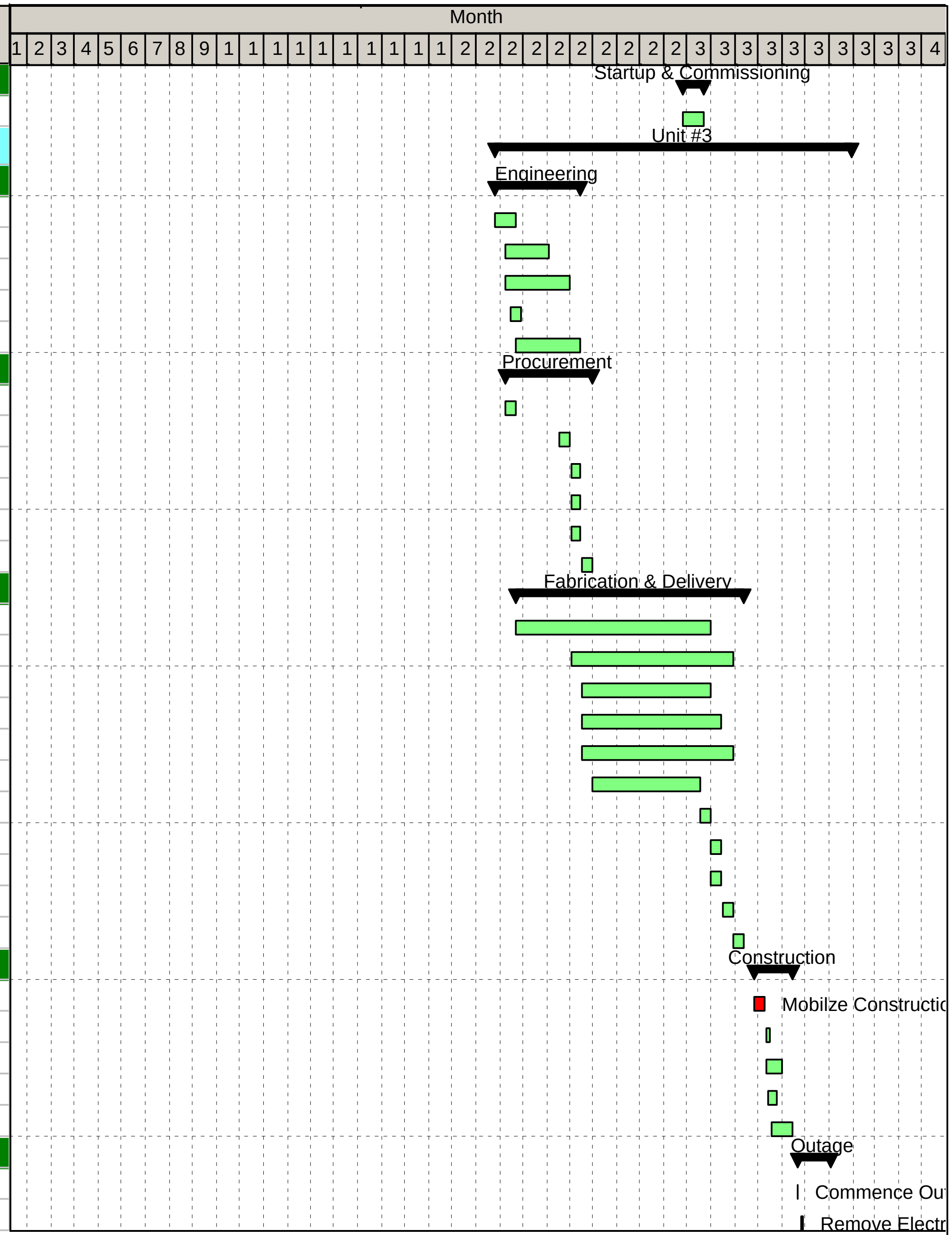
Activity Name	Orig Dur
Conduct CFD Modeling	40
Conduct Physical Modeling	60
Develop Equipment D&R Sheets	10
Develop Mechanical Drawings	60
Procurement	93
Issue P.O. Recycle Pumps	10
Issue P.O. Agitators	10
Issue P.O. Spray Nozzles	10
Issue P.O. Recycle Spray Headers	10
Issue P.O. Absorber Shell	10
Issue P.O. Recycle Spray Bull Horns	5
Issue P.O. Mist Eliminator	5
Issue P.O. Outlet Expansion Joint	5
Issue P.O. Recycle Piping	10
Issue P.O. Wall Rings	10
Issue P.O. Modified Oxidation Air Lances	10
Issue P.O. Spray Piping Hangers & Hardware	10
Issue P.O. Air Piping, Hangers & Hardware	10
Fabrication & Delivery	258
Fabricate Recycle Pumps	210
Fabricate Agitators	180
Fabricate Spray Nozzles	130
Fabricate Recycle Spray Headers	200
Fabricate Mist Eliminator	160
Fabricate Recycle Spray Bull Horns	180
Fabricate Absorber Shell	190
Fabricate Outlet Expansion Joint	160
Fabricate Wall Rings	150
Fabricate Recycle Piping	180
Fabricate Spray Piping Hangers & Hardware	120
Fabricate Modified Oxidation Air Lances	140
Fabricate Air Piping, Hangers & Hardware	100
Deliver Spray Nozzles	10
Deliver Agitators	10
Deliver Air Piping, Hangers and Hardware	10
Deliver Spray Piping Hangers and Hardware	10
Deliver Recycle Pumps	20
Deliver Modified Oxidation Air Lances	10



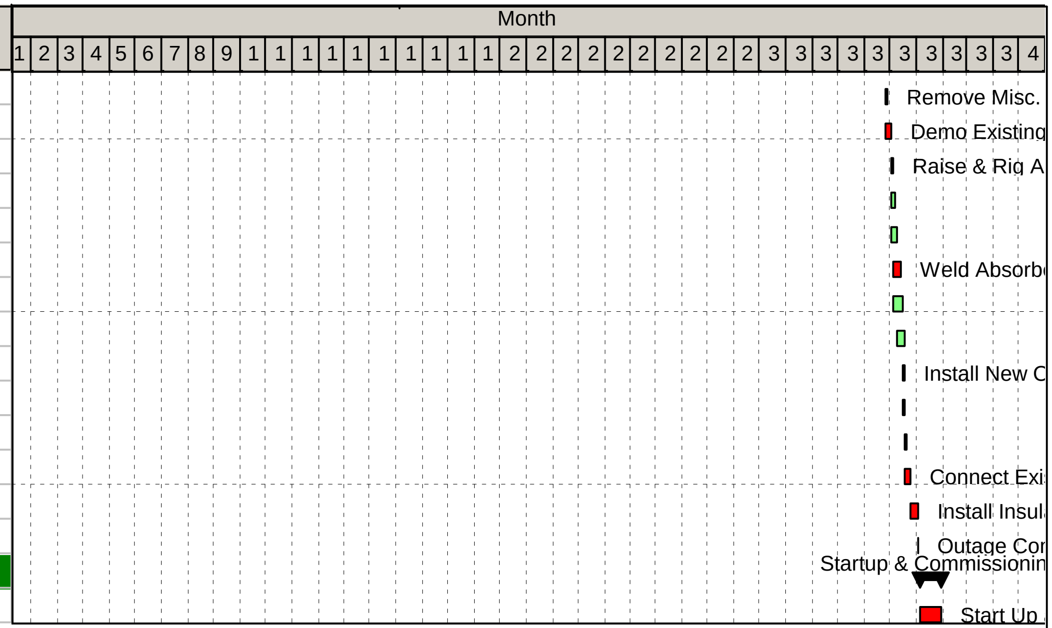
Activity Name	Orig Dur
Deliver Mist Eliminator	10
Deliver Outlet Expansion Joint	5
Deliver Recycle Spray Bull Horns	10
Deliver Absorber Shell	10
Deliver Recycle Piping	10
Deliver Recycle Spray Headers	10
Construction	100
Mobilze Construction	10
Excavate Recycle Pump Foundations	30
Run New Electrical Cables to Recycle Pumps	20
Form & Pour Recycle Pump Foundations	30
Set Up Scaffolding for Outage	10
Set Up Recycle Line Rigging	10
Unload Outage Materials	5
Inventory and Store Outage Material	10
Ground Fab Absorber Assembly	40
Outage	32
Commence Outage	1
Remove Electrical Recycle Pump & Motor	5
Remove Misc. Electrical Interferences & Instrumentation	5
Demo Existing Absorber	5
Demo Recycle Pump and Motors	6
Demo Recycle Outlet Lines to Spray Headers	5
Install Wall Rings	5
Set Recycle Pumps	5
Remove Recycle Spray Nozzles	4
Install Recycle Piping	10
Raise & Rig Absorber Section	2
Install Agitators	7
Align Recycle Pumps	10
Weld Absorber Section	7
Install Oxidation Air Nozzles	8
Reinstall Electrical Removed for Access.	3
Reinstall Instrumentation Removed for Access.	3
Install New Outlet Expansion Joint	3
Connect Exist. Outlet Ductwork to New Absorber	4
Install Insulatation and Lagging to Absorber	8
Outage Complete	1



Activity Name	Orig Dur
Startup & Commissioning	20
Start Up and Commissioning	20
Unit #3	331
Engineering	80
Design Calculations	20
Conduct CFD Modeling	40
Conduct Physical Modeling	60
Develop Equipment D&R Sheets	10
Develop Mechanical Drawings	60
Procurement	80
Issue P.O. Agitators	10
Issue P.O. Wall Rings	10
Issue P.O. Spray Nozzles	10
Issue P.O. Spray Piping Hangers & Hardware	10
Issue P.O. Modified Oxidation Air Lances	10
Issue P.O. Air Piping, Hangers & Hardware	10
Fabrication & Delivery	210
Fabricate Agitators	180
Fabricate Wall Rings	150
Fabricate Spray Piping Hangers & Hardware	120
Fabricate Spray Nozzles	130
Fabricate Modified Oxidation Air Lances	140
Fabricate Air Piping, Hangers & Hardware	100
Deliver Air Piping, Hangers and Hardware	10
Deliver Agitators	10
Deliver Spray Piping Hangers and Hardware	10
Deliver Spray Nozzles	10
Deliver Wall Rings	10
Construction	35
Mobilze Construction	10
Unload Outage Materials	5
Remove Electrical and I&C Interferences	15
Inventory and Store Outage Material	10
Ground Fab Absorber Assembly	20
Outage	31
Commence Outage	1
Remove Electrical Recycle Pump & Motor	5



Activity Name	Orig Dur
Remove Misc. Electrical Interferences & Instrumentation	5
Demo Existing Absorber	5
Raise & Rig Absorber Section	2
Remove Recycle Spray Nozzles	4
Install Wall Rings	5
Weld Absorber Section	7
Install Agitators	7
Install Oxidation Air Nozzles	8
Install New Outlet Expansion Joint	3
Reinstall Electrical Removed for Access.	3
Reinstall Instrumentation Removed for Access.	3
Connect Exist. Outlet Ductwork to New Absorber	4
Install Insulatation and Lagging to Absorber	8
Outage Complete	1
Startup & Commissioning	20
Start Up and Commissioning	20



LG&E Services Company
Contract No. 501654
Mill Creek FGD Performance Upgrade Study

Budget Engineering, Procurement and Construction Estimate

February 15, 2011

Description	Engineering	Equipment	Construction	Total
Case 2: Unit 1	$1,922,629	$5,365,667	$3,253,216	$10,541,512
Case 2: Unit 2	$1,922,629	$5,365,667	$3,343,710	$10,632,006
Case 2: Unit 3	$1,922,629	$6,735,206	$5,378,000	$14,035,835
Case 3: Unit 1	$2,949,580	$10,573,006	$6,905,881	$20,428,467
Case 3: Unit 2	$2,949,580	$10,573,006	$7,044,859	$20,567,445
Case 3: Unit 3	$2,949,580	$17,504,859	$12,489,678	$32,944,117