

	SYSTEM DESCRIPTION	FILE NO. 141643.43.0251
	FGD ABSORBER SYSTEM (ZA)	AEP 031406-D

AMERICAN ELECTRIC POWER

Big Sandy Unit 2

FGD Absorber System (ZA)

FILE NO: 141643.43.0251

SYSTEM DESCRIPTION

**ISSUE DATE AND REVISION NO.
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1.0 Description of Process

1.1 General

The principal function of the flue gas desulfurization (FGD) absorber is to reduce emission of sulfur dioxide (SO₂) in the flue gas. A secondary function of the absorber is to control emissions of hydrogen chloride (HCl), particulate matter (fly ash), mercury, and other pollutants that may be present in the flue gas.

1.2 System Design

The FGD absorber employs a Chiyoda CT-121 jet bubbling reactor (JBR) absorber for liquid-gas contact. A schematic diagram of the JBR absorber is shown on Figure 1-1, located at the end of this section.

In the flue gas path, the JBR absorber is located between the induced draft fans and the chimney.

Flue gas leaving the induced draft fans enters the JBR absorber gas cooler. In the gas cooler, the flue gas is cooled and saturated by three sets of spray headers arranged in series. The function of these sprays is to ensure that the flue gas has achieved complete saturation before it enters the JBR absorber inlet plenum. Each of the three sets of spray headers uses a different source of water or slurry, as described below. All water and slurry are collected and drained into the JBR absorber.

The first set of spray headers consists of two subsets which use water supplied by the FGD Service Water System (SW). The first subset of headers sprays water under all flue gas flow conditions. This flow is continuous and its rate varies in proportion to the flue gas flow rate. The second subset of headers sprays water only at high flue gas flow rates and are turned off at low flue gas flow rates to minimize excess water to the JBR. When in operation, flow to the second subset of headers is also continuous and proportional to the flue gas flow rate.

The second set of spray headers is for the emergency cooling of the flue gas in case of loss of flow to the other two spray headers. The source of this water is from either the emergency quench pump in the FGD Emergency Quench System

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(ZQ) or the FGD Service Water System (SW). These spray headers are used only in emergency conditions (transients resulting in high temperature excursions due to black shutdown or loss of an air heater) and provide a flow sufficient to completely quench the flue gas at design gas flow conditions. The emergency quench system operation is described in detail in the FGD Emergency Quench System (ZQ) description.

The third set of spray headers operates continuously and uses slurry from the JBR absorber supplied by the gas cooling pumps. The slurry flow rate provides a liquid-to-gas ratio of 18.8 gallons per 1,000 standard cubic feet (2.7 liters per normal cubic meter) at design gas flow conditions.

The quenched flue gas passes from the gas cooler into the JBR absorber inlet plenum, which is formed by the upper and lower tube decks. The flue gas then flows into the JBR absorber's reaction area through 5,048 six-inch diameter, vertically oriented, gas sparger tubes that pass through the lower deck. The discharge end of each sparger tube is submerged 16 inches beneath the level of the slurry in the JBR absorber when burning 4.5 lb SO₂/MMBtu fuel. The bubbling action created as the flue gas exits the sparger tubes and rises through the slurry creates a froth zone that provides very efficient SO₂ absorption.

The bubbles burst and the treated flue gas is directed from the JBR absorber reaction area to the JBR absorber outlet plenum by 253 twenty-six inch diameter gas risers that pass through both the lower and upper decks. The flue gas leaves the outlet plenum through a two-stage, horizontal gas flow mist eliminator that removes residual mist carried over from the JBR absorber.

The front and back of the first-stage mist eliminator and the front of the second stage mist eliminator are washed with service water from the FGD Service Water System (SW). The wash intensity of both the front and back washes is 1.5 gpm/ft². Each wash system is divided into eight horizontal segments. Starting with the uppermost segment, the segments are washed one at a time for approximately 1 minute every 8 hours.

All of the mist eliminator wash water is collected and drained to the JBR absorber's reaction tank.

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The SO₂ absorbed from the flue gas is neutralized with limestone reagent (calcium carbonate, CaCO₃). The limestone reagent consumed in this reaction is continuously replaced by reagent slurry from the FGD Reagent Preparation System (ZP).

To supply new reagent to the JBR, the FGD Reagent Preparation System (ZP) pumps slurry to a distribution tank located on top of the JBR. Slurry is then gravity-fed from this tank down distribution lines and into the JBR absorber reaction tank. The outlet end of the distribution lines are located near the JBR agitator impellers to ensure that the new reagent is well mixed with the existing slurry.

Sufficient oxidation air is added to the JBR absorber through a sparger system to convert over 99 percent of the reaction products formed into insoluble calcium sulfate dihydrate (CaSO₄•2H₂O), also known as gypsum. Oxidation air is provided from the centrifugal blowers in the FGD Oxidation Air System (ZO). Water from the FGD Service Water System (SW) is added to cool and saturate the oxidation air prior to its discharge into the JBR absorber to minimize scaling in the oxidation air nozzles.

The density of byproduct solids (gypsum) in the reaction slurry tank is maintained at 20 weight percent by discharging a portion of the slurry to the FGD Byproduct Dewatering System (ZD) via the absorber bleed pumps.

Slurry from the JBR absorber is continuously sprayed across the lower deck via the gas cooling pumps to limit the buildup of scale inside the gas sparger tubes. This, in turn, limits the pressure drop increase through the JBR. The intensity of this spray is 0.75 gpm/ft².

Three times per day the upper tube deck and gas riser tubes are washed with service water from the FGD Service Water System (SW). Each wash system is divided into several segments, which are sequentially washed one segment at a time. The wash intensity is 0.75 gpm/ft² for 1 minute. Wash water is collected and drained to the JBR absorber through drain tubes.

A flue gas bypass duct is provided that connects the JBR inlet plenum to the outlet duct, just before the mist eliminators. This bypass duct is sized for 6.5

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percent of the maximum continuous rate (MCR) flow rate at a maximum gas velocity of 50 feet per second. The bypass duct is fiberglass reinforced plastic (FRP) with an air-actuated damper with C-276 louvers and a positive pressure air seal provided by the Bypass Damper Seal Air Skid. This bypass allows flue gas, which has been quenched to a maximum of 150 °F, to bypass the JBR.

The bypass damper is washed on both sides with service water from the FGD Service Water System (SW) to prevent solids from building up on the damper louvers. This wash occurs three times per day with a wash intensity of 0.75 gpm/ft² for 1 minute and is part of the upper tube desk and gas riser tube wash sequence. Wash water on the JBR inlet plenum side of the damper drains back into the JBR via the inlet plenum duct. Wash water on the outlet plenum side of the damper drains back to the JBR via a dedicated drain line.

To facilitate maintenance of the JBR absorber, a suitably sized maintenance tank will be utilized to hold the entire slurry contents of the JBR. Use of this tank will allow slurry to be stored during JBR maintenance activities instead of being discarded.

The majority of slurry is transferred to the maintenance tank using the JBR absorber bleed pumps. Slurry below the level of absorber bleed pump suction lines is transferred to the maintenance tank by using the JBR area sump and associated sump pump. The process of emptying the JBR absorber will be completed in less than 6 hours by using both absorber bleed pumps in parallel. The maintenance tank is supplied with an agitator to suspend the slurry solids during use and a transfer pump to return the slurry back to the JBR.

In order to collect equipment and maintenance drains, such as the JBR overflow, absorber bleed pump flush flows, and gas cooling pump flush flows, the JBR area is equipped with a sump system. Drain and waste flows from the FGD Absorber System (ZA) and FGD Service Water System (SW) are collected and directed to sump by means of trenches. The operator has the option to return sump fluids to the JBR, to either byproduct slurry tank, or to the maintenance tank.

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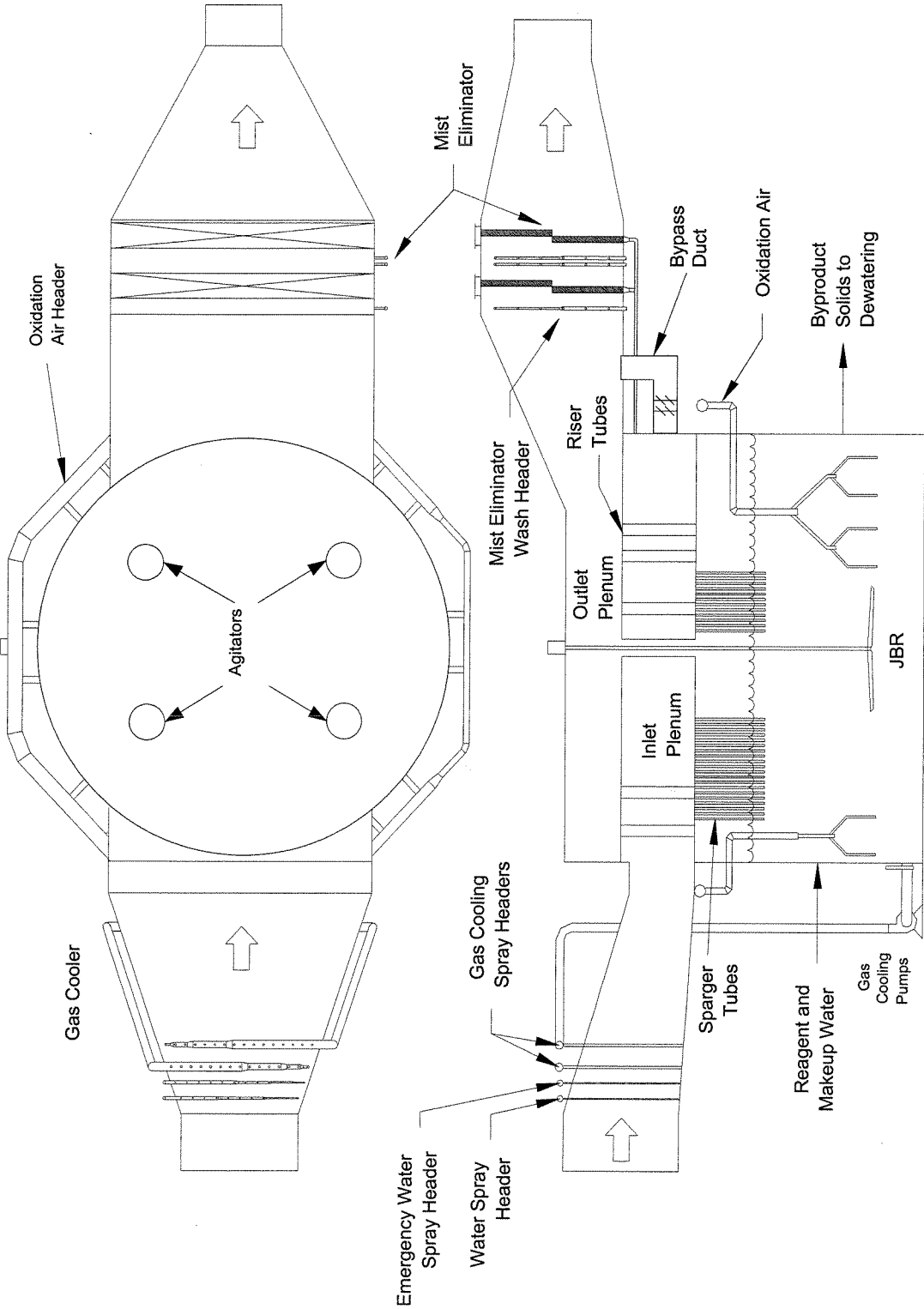


Figure 1-1. FGD Absorber Schematic Diagram

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2.0 Description of Major Equipment

2.1 Jet Bubbling Reactor (JBR) Absorber

2.1.1 Component Identification

Component Name: JBR Absorber
Component Identification No.: 02-ZA-AB-8001

2.1.2 Function

The function of the JBR absorber is to provide the required liquid-gas contact to absorb SO₂ from the flue gas. The JBR absorber also provides the liquid hold time for the required chemical reactions (dissolution, neutralization, oxidation, and precipitation) to occur. One JBR is provided for unit 2.

2.1.3 Description

The JBR absorber consists of three major components:

- Gas Cooler
- JBR Vessel
- Mist Eliminator

2.1.3.1 Gas Cooler

The gas cooler is a section of rectangular cross-section duct that transitions from the inlet duct to the JBR vessel inlet plenum. Three stages of spray headers are located in this duct:

- The makeup prequench cooling spray.
- The emergency quench water cooling spray.
- The slurry quenching sprays.

Each stage is composed of horizontal supply headers located outside the duct with several vertical headers located inside the duct.

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The makeup prequench cooling spray consists of two horizontal headers each with several rows of vertical headers using full-cone spray nozzles. The majority of vertical headers are attached to the primary horizontal header and are in continuous operation. Flow to the secondary horizontal header, and attached vertical headers, is controlled by an on/off valve which allows these headers to be shut off during low load operation.

The emergency quench water spray vertical headers are positioned in a single row and use full-cone type spray nozzles. Each of two horizontal headers is attached to half of the vertical headers. During high temperature excursions, such as an air heater failure, both horizontal headers are in use and are fed via a cross-tie from the FGD Service Water System (SW). During a black plant scenario only one horizontal header is used, which is fed via the FGD Emergency Quench System (ZQ).

The slurry quenching spray vertical headers are attached to two horizontal headers in two rows and use full-cone nozzles. The centerlines of these two headers are offset to maximize the spray coverage.

Drain pipes are provided across the width of the duct floor where the duct connects to the JBR vessel. The slurry collected in these pipes is directed to the JBR below the slurry level.

2.1.3.2 JBR Vessel

The JBR vessel is a cylindrical vessel 101 feet in diameter and 71 feet high and consists of the following areas:

- Inlet plenum
- Reaction tank
- Outlet plenum

The JBR absorber inlet plenum is formed by the upper and lower tube decks, which are constructed of FRP. It extends the entire diameter of the JBR absorber vessel. The inlet plenum receives the flue gas from the gas cooler and directs it into gas sparger tubes.

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There are 5,048 six inch diameter gas sparger tubes. The sparger tubes are constructed from polyvinyl chloride (PVC) and are attached to the lower deck by rubber bushings and special couplings. The lower ends of the sparger tubes are supported by a support grid constructed of FRP.

The inlet plenum is equipped with two wash systems. The first wash system uses full-cone spray nozzles and a feed from the gas cooling pumps to continuously spray slurry from the JBR absorber reaction tank onto the lower tube deck to prevent the buildup of solids in the gas sparger tubes. Slurry drains back to the reaction tank through the sparger tubes.

The second wash system uses full-cone spray nozzles to periodically wash the bottom of the upper deck and the gas riser tubes with service water to prevent a buildup of solids on these surfaces. Under normal operating conditions, this wash occurs for one minute every eight hours in each wash zone. The frequency and duration of the wash is controlled by the distributed control system (DCS). The wash water collects on the lower deck floor and is directed to the reaction tank through the sparger tubes.

The JBR absorber reaction tank is the portion of the JBR absorber below the lower tube deck. This reaction tank is divided into three operating zones: the reaction zone, the jet bubbling zone, and the disengagement zone.

The reaction zone is the portion of the tank containing 18 feet of FGD slurry. At design conditions, this zone provides 16 hours of slurry solids retention time¹ to promote complete oxidation of SO₂ and to facilitate gypsum crystal growth. The slurry in the reaction zone is kept in suspension by the four JBR absorber agitators and the turbulence created by the air introduced through the oxidation air lances.

The jet bubbling zone is a layer of froth composed of bubbles that continuously form and collapse. This froth is formed when the inlet flue gas leaves the gas sparger tubes through circumferential tube holes located approximately 16 inches below the liquid surface of the slurry in the reaction zone.

¹ Slurry solids retention time is calculated by dividing the liquid volume of the zone by the gypsum byproduct production rate.

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The disengagement zone is the area between the top of the jet bubbling zone and the bottom of the lower tube deck. This area provides a space for the flue gas to disengage from the froth bubbles and allows the scrubbed flue gas to exit through the gas risers and into the outlet plenum. The support grid for the lower end of the gas spargers is located in this zone.

To ensure complete oxidation of the SO₂, additional air supplied by the FGD Oxidation Air System (ZO) is injected into the slurry in the JBR absorber reaction zone. This is accomplished with a series of air pot and lance assemblies distributed throughout the JBR. The air pots, located underneath the sparger support grid, receive quenched air from the oxidation air header and feed vertically-oriented lances that are submerged in the gypsum slurry.

The outlet plenum collects the flue gas from all of the gas risers and directs it to the mist eliminator. The outlet plenum is formed by the upper tube deck and the JBR absorber roof. The outlet plenum extends the full diameter of the JBR absorber vessel.

The outlet plenum is equipped with a floor wash system. The floor is washed with service water to remove the slurry solids that may have accumulated on the floor. The wash system is divided into thirteen zones, and these zones are washed sequentially using a combination of full cone spray nozzles and flat fan spray nozzles. Under normal operating conditions, each zone is washed for one minute every eight hours. The frequency and duration of the deck wash is controlled by the DCS. The wash water is directed to the reaction tank through the floor drains.

2.1.3.3 Mist Eliminator

The horizontal gas flow mist eliminator consists of two stages of chevron blades, the supporting ductwork, and the wash system. The material for the blades is polysulfone. The frames, bolting, and drains are constructed of FRP. In this style of mist eliminator, the individual blades are oriented vertically and are supplied in pre-assembled panels, each panel containing many individual blades. Each stage of the mist eliminator is four panels high, and a separate drain collection system is provided for the upper panels.

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The mist eliminator blades are washed for one minute every eight hours to remove deposits. To prevent hydraulically overloading the mist eliminator blades, each mist eliminator panel is divided into multiple horizontal wash sections that are washed sequentially, starting at the uppermost section. The wash headers are arranged horizontally and use full-cone spray pattern nozzles.

The first-stage mist eliminator is washed from both the front and back sides. The second-stage mist eliminator is washed from the front side only.

The mist eliminator wash water and the mist droplets collected on the mist eliminator blades drain down the blades, are collected, and drain back to the JBR absorber reaction tank.

The frequency and duration of the mist eliminator washes are controlled by the DCS.

2.1.4 Sizing Criteria

The JBR absorber design parameters are presented in Table 2-1.

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Table 2-1. JBR Absorber – Equipment Design Criteria

Design Criteria	Value
SO ₂ Removal	98%
Gas cooler gas velocity	
Inlet	2,850 fpm
Outlet	2,350 fpm
Duct/vessel design pressure	
Positive, in. H ₂ O	30
Negative, in. H ₂ O	-5
Slurry quenching sprays, L/G	18.8 gal/1,000 scfm
Inlet and outlet plenum wash intensity	0.75 gpm/ft ²
JBR slurry solids content	
Maximum	25 wt%
Typical	20 wt%
JBR solids retention time	16 h
Mist eliminator superficial gas velocity	18.0 ft/sec
Mist eliminator wash intensity	1.5 gpm/ft ²
Maximum mist eliminator blade length	10 ft

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2.1.5 *Materials Selection*

The JBR absorber is constructed of a variety of corrosion- and erosion-resistant materials. The materials for the JBR absorber components are listed in Table 2-2.

Table 2-2. JBR Absorber – Materials of Construction

Component	Material
Gas cooler	
Through gas cooling nozzles	Solid nickel alloy, C-276
Downstream of gas cooling nozzles	C-276 clad carbon steel
JBR vessel shell	Alloy 2205 with alloy 255 band in the jet bubbling zone
JBR upper and lower tube decks	FRP
Gas sparger tubes	PVC
Gas risers	FRP with erosion-resistant lining on exterior of leading rows
Internal oxidation air headers	FRP
Mist eliminator blades	Polysulfone
Slurry piping	Abrasion-resistant FRP
Process water piping	FRP
Upper deck and inlet plenum wash piping	Chlorinated polyvinyl chloride (CPVC)
Lower deck wash piping	Abrasion-resistant FRP
Mist eliminator wash piping	FRP with alloy 2205 inserts
Gas cooling duct internal spray headers	
Makeup water cooling	C-276
Emergency water cooling	C-276
Slurry quenching	C-276

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Table 2-2. JBR Absorber – Materials of Construction (Continued)

Component	Material
Spray nozzles	
Makeup prequench water	C-276
Emergency quench water	C-276
Slurry quenching	Silicon carbide
Upper deck wash	CPVC
Gas riser wash	CPVC
Lower deck wash	Silicon carbide
Mist eliminator	Alloy 2205
Outlet duct	FRP

2.2 JBR Agitators

2.2.1 Component Identifications

Component Name: JBR Absorber Agitator
Component Identification No.: 02-ZA-AG-8001-01, 02-ZA-AG-8001-02
02-ZA-AG-8001-03, and 02-ZA-AG-8001-04

2.2.2 Function

The JBR absorber agitators provide the mixing necessary to maintain the absorber slurry solids in suspension in the JBR absorber. Four agitators are furnished for the JBR.

2.2.3 Description

Each JBR absorber agitator is a top-entry, gear-driven, axial-flow type agitators with a long cantilevered shaft. The agitator electric motor drive, speed reducer, and shaft bearings are located on the roof of the JBR absorber.

Depending on the vendor used, the agitator impeller may have either three or four blades.

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The agitators mix pattern is downward toward the JBR absorber floor. The JBR absorber vessel is provided with four baffles, located near the vessel walls, designed to minimize the swirl effects from the agitator mixing dynamics.

2.2.4 Sizing Criteria

The JBR absorber agitators are sized to produce off-bottom motion of all slurry particles and to ensure adequate mixing of the JBR absorber contents. The design conditions are up to 20 weight percent gypsum with a D_{50} of $70\ \mu\text{m}$.² The specific gravity of the slurry is 1.13 with a specific gravity of the particles being 2.32.

While the JBR absorber mixing is aided by the introduction of oxidation air, the agitators are designed to maintain “off-bottom” mixing without the addition of oxidation air.

2.2.5 Materials of Construction

The agitator shaft and blades are carbon steel covered with natural rubber.

2.3 Mist Eliminators

2.3.1 Component Identification

Component Name: Mist Eliminator First Stage
Mist Eliminator Second Stage
Component Identification No.: 02-ZE-QQ-8001 and 02-ZE-QQ-8002

2.3.2 Function

The mist eliminators remove the entrained water droplets from the flue gas before the gas is discharged to the stack.

² D_{50} is the diameter at which 50 percent of the slurry particles are finer and 50 percent are coarser.

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2.3.3 Description

The CT-121 JBR absorber uses a horizontal gas flow type mist eliminator with the blades arranged in two stages. Both stages use chevron profile blades that force the flue gas to make two or three changes of direction. The water droplets are unable to make the direction changes as readily as the gas, and their inertia carries them to the blade surface. The collected droplets flow down the blade length and are discharged into a drain header.

Individual mist eliminator blades are vertically mounted in a frame and installed in the outlet duct as a panel. The spacing between blades in the panel depends upon the liquid loading (larger spacing for higher loading) and design efficiency. The spacing of the second-stage mist eliminator, therefore, is closer than the first stage. The recommended spacing for each stage varies between mist eliminator suppliers based on their specific blade profiles.

Each stage of the mist eliminator is composed of several individual panels, each containing 50 or more blades. The exact number of blades per panel depends on the blade spacing and the specific vendor used, which will be determined during detail design.

2.3.4 Sizing Criteria

The effectiveness of the mist eliminator is increased by increasing the flue gas velocity, but if the velocity is too high, the collected droplets can be stripped off the blades. For this reason, the superficial gas velocity³ through the mist eliminators is typically limited to 18 ft/sec.

The spacing between individual blades in a panel depends on liquid loading and desired wash efficiency. Typically, the more highly loaded first stage uses blade spacing in the range of 1-3/8 to 1-1/2 inches. The second stage uses blade spacing in the range of 1 to 1-1/8 inches.

³ "Superficial gas velocity" is calculated by dividing the flue gas flow in acfm by the total cross sectional area of the duct. Because of the area lost by the blade thicknesses and support frame, the actual gas velocity is greater. However, this factor is considered in setting the superficial velocity.

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If the amount of water droplets flowing down the blades is too high, the flue gas can strip them off the blade and re-entrain them in the flue gas. To prevent this, the length of the blade is limited to approximately 10 feet. For ducts greater than 10 feet high, two or more panels are stacked. Each level has its own collection system for removal of droplets and wash water.

The front and back of the first-stage mist eliminator and the front of the second-stage mist eliminator are periodically washed at an intensity of 1.5 gpm/ft². The wash nozzle spray patterns have an overlap of 50 percent.

2.3.5 *Materials of Construction*

The mist eliminator blades are fabricated from polysulfone, which has a practical temperature limit of 340° F. The panel frames and blade spacers are fabricated from FRP.

2.4 Gas Cooling Pumps

2.4.1 *Component Identification*

Component Name: Gas Cooling Pumps
Component Identification No.: 02-ZG-PP-8001-01, 02-ZG-PP-8001-02,
and 02-ZG-PP-8001-03

2.4.2 *Function*

The gas cooling pumps provide JBR absorber slurry to the slurry quenching sprays in the gas cooler. These pumps also provide slurry to the lower deck wash system.

2.4.3 *Description*

Three 50 percent gas cooling pumps are provided for the JBR. The gas cooling pumps are vertically split case, end-suction centrifugal slurry pumps. These pumps handle abrasive slurry with up to 20 weight percent solids. They are equipped with mechanical shaft seals and are furnished with gear-reducer drives and 4 kV motors.

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2.4.4 Sizing Criteria

The gas cooling pumps are designed to provide sufficient slurry to the slurry quenching sprays to produce a liquid-to-gas ratio of 18.8 gallons of slurry per 1,000 standard cubic feet of flue gas. In selecting the pumps and motor drives, a design margin of 10 percent is applied to the calculated flow and head requirements to allow for pump performance degradation due to impeller wear. Three 50 percent capacity pumps are used.

The maximum slurry velocity at the pump discharge flange is 10 ft/sec.

2.4.5 Materials of Construction

The gas cooling pumps are fabricated from materials suitable for the corrosive and erosive nature of the slurry. The pump casing consists of hard metal or hard metal-lined materials. The pump impeller is abrasion-resistant high-chrome cast iron.

2.5 JBR Absorber Bleed Pumps

2.5.1 Component Identification

Component Name: JBR Absorber Bleed Pumps

Component Identification No.: 02-ZT-PP-8001-01 and 02-ZT-PP-8001-02

2.5.2 Function

The JBR absorber bleed pumps transfer the JBR absorber slurry from the JBR absorber to the hydroclone feed tanks, which are part of the FGD Byproduct Dewatering System (ZD).

2.5.3 Description

Two 100 percent JBR absorber bleed pumps are provided. The JBR absorber bleed pumps are vertically split case, end-suction centrifugal slurry pumps. These pumps handle abrasive slurry with up to 20 weight percent solids. They are equipped with mechanical shaft seals and belt driven 480 volt motors.

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2.5.4 Sizing Criteria

Each pump is designed to transfer the slurry solids at the rate produced at design operating conditions, assuming a slurry solids level of 20 weight percent. In selecting the pumps and motor drives, a design margin of 10 percent is applied to the calculated flow and head requirements to allow for pump performance degradation due to impeller wear.

The maximum slurry velocity at the pump discharge flange is 10 ft/sec.

2.5.5 Materials Selection

The absorber bleed pumps are fabricated from materials suitable for the corrosive and erosive nature of the slurry. The pump casing consists of hard metal or hard metal-lined materials. The pump impeller is abrasion-resistant high-chrome cast iron.

2.6 JBR Reagent Distribution Tank and Piping

2.6.1 Component Identification

Component Name: JBR Reagent Distribution Tank
Component Identification No.: 02-ZA-TK-8001

2.6.2 Function

The JBR reagent distribution tank receives fresh reagent from the FGD Reagent Preparation System (ZP) and slurry recirculated from the absorber bleed pumps and distributes the mix, via gravity feed, into the JBR absorber reaction tank.

2.6.3 Description

The JBR reagent distribution tank is a shop fabricated, closed-top, atmospheric tank. It is 2.5 feet in diameter by 3 feet tall. The tank is equipped with eight nozzles on the bottom that connect to eight distribution pipes. The distribution pipes run from the bottom of the distribution tank, across the roof of JBR, at a minimum 6 degree slope, and enter the JBR roof near the JBR agitator shafts. The distribution lines drop vertically through the JBR outlet plenum and pass into the reaction tank through eight of the 26 inch diameter gas risers. The

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distribution lines extend into the slurry so that their discharge is approximately three feet above the agitator impeller and one foot inside the impeller diameter. This location is chosen to ensure that the velocity of downward flow is sufficient to ensure good mixing with the exiting slurry.

2.6.4 Sizing Criteria

A single distribution tank exists on top of the JBR. The tank and associated piping are sized to accept the combination of the maximum reagent flow from the FGD Reagent Preparation System (ZP) and maximum recirculation of slurry from the absorber bleed pumps.

2.6.5 Materials Selection

The tank is fabricated from rubber-lined carbon steel. The distribution piping is fabricated of FRP with an internal abrasion-resistant lining at least 0.070 inch thick.

2.7 JBR Bypass Damper and Duct

2.7.1 Component Identification

Component Name: JBR Bypass Damper
Component Identification No.: 02-ZAAS-8023

2.7.2 Function

The function of the JBR bypass is to provide an open flow flue gas path on a black plant trip to meet system purge requirements. To fulfill this requirement, the bypass damper must fail in the open position to allow quenched flue gas to pass directly from the JBR inlet plenum into the outlet duct via the bypass duct.

2.7.3 Description

The JBR bypass damper is an air-actuated damper that uses a positive pressure air seal. Seal air is provided by the Bypass Damper Seal Air Skid. The damper is equipped with a dedicated accumulator that allows it to be operated manually, without requiring an electrical signal or plant air. This can be used to close the damper after system purge requirements have been met.

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The bypass duct is a 9 foot by 10 foot duct that connects the JBR inlet plenum to the JBR outlet duct upstream of the mist eliminators.

2.7.4 Sizing Criteria

The JBR bypass duct and damper are designed to allow 6.5 percent of the MCR flow rate at a maximum velocity of 50 feet per second. The front and back of the bypass damper are periodically washed at a rate of 0.75 gpm/ft².

2.7.5 Materials Selection

The bypass damper is constructed with C-276 louvers. The bypass duct is constructed from FRP.

2.8 JBR Area Sump

2.8.1 Component Identification

Component Name: JRB Area Sump
Component Identification No.: None

2.8.2 Function

The JBR area sump collects wastewater via trenches from the JBR absorber, gas cooling pump flush, JBR absorber bleed pumps flush, and service water tank drain.

2.8.3 Description

The sump is a below-grade, reinforced concrete structure coated with a lining suitable for the corrosive nature of the wastewater.

2.8.4 Sizing Criteria

The active volume of each JBR area sump is (Later) gallons. The active volume of each JBR area sump is based on maintaining the sump pumps to a maximum of 4 starts per hour. The maximum drain flow for the each sump is considered the JBR absorber overflow. In setting the active tank volume, the minimum slurry level takes into consideration the minimum submergence of the JBR sump agitator.

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2.8.5 Materials Selection

The sump is reinforced concrete structure coated with a protective lining suitable for the corrosive nature of the wastewater.

2.9 JBR Area Sump Agitators

2.9.1 Component Identification

Component Name: JBR Area Sump Agitator

Component Identification No.: 02-ZA-AG-8002

2.9.2 Function

The sump agitators keep the slurry solids contained in the sumps in suspension. A single agitator is supplied with the sump.

2.9.3 Description

The sump agitator is a top-entry, gear-driven, axial flow type agitator with a long, cantilevered shaft. The agitator's electric motor drive, speed reducer, and shaft bearings are located on support steel over the sump. Depending on the vendor and design selected, the agitator impeller may be either three- or four-bladed. The agitator's mix pattern is downward toward the sump floor.

2.9.4 Sizing Criteria

The agitator is sized to produce off-bottom motion of all slurry particles in the sump. The design conditions are up to 20 weight percent gypsum with a D_{50} of 70 μm . The specific gravity of the slurry is 1.13 and the particle specific gravity is 2.32

2.9.5 Materials Selection

The agitator shaft and blades are carbon steel covered with natural rubber.

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2.10 JBR Area Sump Pumps

2.10.1 Component Identification

Component Name: JBR Area Sump Pumps
Component Identification No.: 02-ZA-PP-8002-01 and 02-ZA-PP-8002-02

2.10.2 Function

The function of the JBR area sump pumps is to transfer the collected drains to either the JBR absorber or to the byproduct slurry tank. The operator also has an option of discharging these pumps into the maintenance tank.

2.10.3 Description

Two 100 percent submersible sump pumps are provided with the JBR area sump.

The sump pumps are submersible, constant-speed pumps designed for slurry service and fitted with mechanical seals. Motors are 480V.

2.10.4 Sizing Criteria

Each JBR area sump pump is sized to provide 100 percent of the design transfer requirements for the sump. The pumps are sized to maintain the velocity of the slurry in the sump pump piping in the range of 4 to 10 ft/sec for the required maximum sump input flow rate. The maximum input flow rate for the JBR area sump is the JBR absorber overflow.

2.10.5 Materials Selection

Pumps are of heavy-duty design with metallurgy (28% Cr) designed for the given application. The pumps have mechanical seals. The pump discharge line is heavy-duty slurry hose from pump discharge to a flange located at the top of the sump.

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2.11 Slurry Piping

2.11.1 Component Identification

Component Name: Slurry Piping

Component Identification No.: None

2.11.2 Function

The slurry piping transports JBR absorber slurry, FGD byproduct slurry, and reclaim water between the components of the FGD absorber.

2.11.3 Description

The slurry piping is pressure piping with materials of construction specifically selected for the abrasive and corrosive nature of the process flows handled.

2.11.4 Sizing Criteria

For piping handling limestone or gypsum slurries, the pipe size is selected to maintain the slurry velocity in the range of 4 to 10 ft/sec. Where practical, the slurry velocity is maintained in the more restrictive range of 5 to 8 ft/sec. Within the more restrictive range, there is less potential for the line to plug due to material settling out, and the rate of abrasive wear is lower.

For piping handling reclaim water, the pipe size is selected to maintain the slurry velocity in the range of 3 to 12 ft/sec. The higher velocity range is possible due to the much lower solids content of the filtrate.

2.11.5 Materials Selection

For primary flow slurry lines (i.e. pump suction and discharge piping), the pipe material is abrasion-resistant FRP. For secondary flow slurry lines (i.e. drains to sumps), the pipe material is non-abrasion resistant FRP.

Piping handling service water is fabricated of carbon steel or FRP without an internal abrasion-resistant lining.

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2.12 Slurry Valves

2.12.1 Component Identification

Component Name: Slurry Valves

Component Identification No.: Various

2.12.2 Function

Slurry valves are used for component isolation, flow control, or a combination of both services.

2.12.3 Description

Knifegate valves are used for component isolation in slurry service due to the erosive nature of the process fluid. The exception to this are the gas cooling pump isolation valves, which are butterfly valves specifically designed for slurry service.

Flow control applications in slurry service require the use of pinch valves or butterfly valves. Butterfly valves will be considered acceptable for use in slurry flow control if the solids content is less than 5 weight percent., otherwise pinch valves are used.

2.12.4 Sizing Criteria

Valve sizing is compatible with the slurry line in which the valve resides. The maximum slurry velocity through the valve is 10 ft/sec.

2.12.5 Materials Selection

The materials for the slurry valves are listed in Table 2-3.

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Table 2-3. Slurry Valves – Materials of Construction

Component	Material
Knifegate valves	
Valve body	Rubber-lined carbon steel
Valve gate	Alloy 2205 duplex stainless steel
Ball Valves (for instrumentation isolation)	
Valve body	FRP
Ball	FRP
Butterfly Valves	
Valve body	Rubber-lined carbon steel
Disk	Rubber-lined ductile iron
Pinch Valves	
Valve body	Ductile Iron
Elastomer sleeve	Gum rubber

3.0 Description of Major Interlocks and Alarms

An automated emergency shutdown sequence (master interlock) is installed to protect the components of the FGD absorber and gas ducts. This interlock coordinates the tripping of major electrical equipment to ensure a safe shutdown during emergency conditions.

Specific interlocks, trips, and alarms will be determined during detail design.

4.0 Description of System Operation and Control

4.1 Instrumentation and Control

The control of the FGD absorber is performed by a distributed control system (DCS), which allows control of the individual FGD absorber components in the

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remote automatic and remote manual modes. For some components, a local manual control station is provided for maintenance considerations.

In addition to control of individual components, the DCS provides overall process control of the following:

- Flue gas SO₂ removal efficiency.
- JBR absorber slurry level.
- JBR absorber slurry pH.
- JBR absorber slurry solids content.

4.1.1 JBR Control Loops

4.1.1.1 Flue Gas SO₂ Removal Efficiency

The measurement of SO₂ concentration in the flue gas entering and leaving the JBR absorber is continuously monitored and recorded by the DCS. An infrared photometric analyzer is used at the absorber inlet to detect SO₂ concentration due to its simplicity of operation and proven reliability. This type of analyzer is provided with an automatic blowback system and an automatic zero adjustment. A signal from the continuous emissions monitoring system (CEMS) is used to determine the SO₂ concentration at the absorber outlet.

The JBR absorber SO₂ removal efficiency is calculated within the DCS, using the following formula:

$$\eta = \left(1 - \frac{SO_{2\ out}}{SO_{2\ in}}\right) \times 100$$

where:

η = SO₂ removal efficiency, percent

SO_{2 out} = SO₂ content of flue gas leaving FGD System, ppm_{dv}

SO_{2 in} = SO₂ content of flue gas entering FGD System, ppm_{dv}

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The calculated SO₂ removal efficiency is continuously calculated and recorded by the DCS.

The SO₂ removal efficiency is a function of the gas sparger tube submergence depth in the JBR absorber, which is controlled by varying the JBR absorber slurry level.

The SO₂ removal efficiency is also indirectly proportional to pH.

4.1.1.2 JBR Absorber Slurry Level

The slurry level inside the JBR absorber is continuously monitored and recorded by the DCS. Direct level measurement methods are unsuitable to this application due to the existence of the froth zone. Therefore, the differential pressure between a point above the slurry level (just below the lower deck) and a point below the lowest measured slurry level is used to determine the slurry level inside the reaction tank. Diaphragm seal type differential pressure instruments are used for easy maintenance. The instrument valve and diaphragm are continuously purged with FGD reclaim water to prevent slurry solids buildup.

The control of slurry level inside the JBR absorber reaction tank (i.e., gas sparger tube submergence depth) has a direct impact on the SO₂ removal efficiency and is considered a primary control loop; therefore, redundant level sensors are used.

An automatic level control system is provided for the JBR absorber to control SO₂ removal efficiency. The amount of SO₂ in the flue gas varies widely depending on fuel burn rate, fuel composition, and other factors. The slurry level set point is adjusted by a feed-forward signal comprised of the flue gas flow rate and SO₂ concentration. The SO₂ removal efficiency achieved is compared against the SO₂ removal set point and the difference is used as a feedback signal to trim slurry level. When the amount of SO₂ entering the FGD system increases, or the actual SO₂ removal efficiency is less than the set point, the DCS automatically increases the slurry level (gas sparger submergence). Conversely, the DCS allows the slurry level to fall during periods of reduced amounts of inlet SO₂ and when the actual SO₂ removal efficiency exceeds the set point. Actual slurry level is also used as the final feedback for the DCS. This feed-forward scheme responds effectively to fast load swings.

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There are several control elements involved in maintaining or raising the slurry level inside the JBR absorber. The first control element is the makeup water flow control valve, which modulates the flow of water to the gas cooling spray headers in the absorber's gas cooler in proportion to the flue gas flow rate. The makeup water flow control valve contributes liquid to the JBR absorber and, therefore, raises the slurry level. This control loop is dependent only on flue gas flow and does not respond to actual slurry level.

Another control element is the mist eliminator wash system that sequentially washes sections of the mist eliminator. The mist eliminator wash water flows into the JBR absorber and, therefore, raises the slurry level. This control system is dependent only on time and does not respond to actual slurry level.

A third control element is the reagent feed system. The JBR absorber level is also raised by the slurry entering the JBR absorber via the reagent feed control valve. This control loop is dependent only on the pH in the JBR absorber and, therefore, does not react to actual slurry level.

The primary control element is the reclaim water return flow control valve that modulates the flow of reclaim water returning to the JBR absorber from the FGD Reclaim Water System (ZC) to control the slurry level at the desired set point.

Reducing the slurry level in the JBR absorber is accomplished indirectly. Water is continuously lost due to saturation of the flue gas, and slurry is sent to the FGD Byproduct Dewatering System (ZD) to reduce the contents of the JBR absorber. If not replaced by reclaim water, the slurry level in the reaction tank falls.

4.1.1.3 JBR Absorber pH

The slurry pH inside the JBR absorber is continuously monitored and recorded by the DCS. An immersion type probe with a glass electrode and an automatic chemical cleaning system is used. The insertion location is at the JBR absorber wall, just below the minimum operating depth. This is approximately the elevation of the discharge end of the gas sparger tubes. In this location, the reagent entering the JBR absorber should not affect pH directly, and the slurry flow is strong enough to avoid stagnation.

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The control of pH inside the JBR absorber has a direct impact on the SO₂ removal rate and is considered a primary control loop; therefore, redundant pH sensors are used.

To maintain the desired level of SO₂ removal efficiency, an automatic pH control system is provided for the JBR absorber. As SO₂ in the flue gas is absorbed into the JBR absorber slurry, the pH of the slurry drops. The pH is maintained at the desired set point of 5.2 by feeding reagent into the JBR absorber. The reagent feed rate set point is adjusted by a feed-forward signal comprised of the flue gas flow rate and SO₂ concentration. Actual pH is used as the final feedback for the controller. The feed-forward scheme is effective for fast load swings.

There is one control element used to maintain the JBR absorber pH. The control element is the reagent flow control valve, which modulates the flow of reagent into the JBR absorber to maintain the pH at the desired set point.

Slurry pH is constant and varies by 0.2 pH units during normal operation. Operators, however, may choose to lower the JBR absorber pH to overcome an aluminum fluoride blinding condition caused by an upset of the electrostatic precipitator (ESP). During upset condition operation, the reaction pH set point is reduced by the operator to overcome the upset condition. The actual pH set point during upset conditions will be determined through operational experience over time.

4.1.1.4 JBR Absorber Slurry Solids Content

The solids content of the slurry in the JBR absorber is continuously monitored and recorded by the DCS. The slurry density is measured using a nuclear density meter located in the absorber bleed pump discharge piping.

The control of slurry solids concentration inside the JBR absorber is necessary to remove the byproduct solids formed by removal of SO₂ from the flue gas.⁴ To maintain the JBR absorber slurry solids content in the correct operating range (20 to 25 weight percent), an automatic slurry solids content control system is

⁴ As SO₂ in the flue gas is absorbed into the JBR liquid slurry, 2.75 pounds of byproduct (gypsum) solids are produced for every pound of SO₂ removed.

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provided. This system uses the JBR absorber bleed pumps to transfer slurry from the JBR absorber to the FGD Byproduct Dewatering System (ZD).

The JBR absorber bleed pumps are constant speed pumps that continuously circulate slurry in a loop to the hydroclone feed tanks. Any slurry not discharged to the feed tanks is returned to the JBR absorber through a minimum recirculation control valve. When the slurry content in the JBR absorber reaches the designated set point, the DCS annunciates that a discharge of solids is required. The control logic regulates the flow control valve that varies the discharge rate to the hydroclone feed tanks. If the solids level in the reaction tank rises above the set point, the discharge control valve flow is increased. If the solids level falls below the set point, the control flow is decreased.

From this point forward, the set point of the vacuum filter feed control valve is automatically adjusted by a feed-forward signal comprised of the inlet flue gas flow rate and SO₂ concentration. The slurry solids content value is used as the final feedback for the controller.

4.1.2 DCS Control Modes

In the remote automatic control mode, the DCS opens/closes or starts/stops the components according to the programmed sequences and interlocks as directed by the control logic. In the remote manual control mode, the individual pumps, agitators, and valves can be opened/closed or started/stopped by the operator. The protective interlocks remain in service during remote manual operation.

4.1.3 JBR Area Sump Control

The JBR area sump contains two pumps that are controlled by the Distributed Control System (DCS) based on a sump level measurement system suitable for service in an agitated slurry environment. The control scheme selects a duty pump based on an alternating mode that automatically cycles between pumps to ensure even run time. The sump agitator is controlled by the DCS.

The level measurement system detects the sump level as follows.

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- When sump level reaches the high set point, the DCS starts the duty pump and a signal is sent to the DCS informing the FGD System operator that the sump pump is running.
- When the sump level reaches the low set point, the DCS stops the duty pump and the automatic discharge isolation valve is closed. The automatic valve providing flush water from the Reclaim Water System (ZC) opens, allowing reclaim water to flow into the sump pump discharge. This valve remains open for a set amount of time to flush the line before closing.
- If the sump level reaches the high set point before the reclaim flush cycle is complete, the reclaim water automatic valve closes. Then the duty sump pump is started, and the sump pump discharge automatic isolation valve opens.
- If sump level reaches the high-high set point, the DCS starts the standby sump pump and a signal is sent to the DCS informing the FGD System operator that the second pump is running and to annunciate the high-high level. At the low set point both pumps are shut off and the line is flushed as indicated above.
- If sump level reaches the very-high set point, a signal is sent to the DCS to annunciate very-high level.
- If sump level reaches the low-low set point, a signal is sent to the DCS to annunciate low-low level. At this point, the operator needs to add liquid to the sump level.

The sump pump system trouble alarm is sent to the DCS if either sump pump trips due to motor overload.

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4.2 System Operation

Specific information on system pre-startup, initial system fill, system startup, normal operation, and shutdown will be completed during detail design.

The FGD absorber inlet flue gas conditions are presented in the system mass balance. Please refer to this document for additional information.

The flue gas entering the FGD absorber has approximately the same temperature as the flue gas leaving the upstream FGD induced draft fan. The design FGD system inlet flue gas temperature is 350° F. The SO₂ removal efficiency is controlled by the submergence depth of the sparger tubes. The pressure drop across the FGD absorber is directly proportional to the flue gas flow rate and the sparger tube submergence depth.

In the JBR absorber gas cooler, located just before the JBR absorber inlet, the flue gas is quenched to its adiabatic saturation temperature, typically in the range of 125 to 130° F. The flue gas remains at this temperature as it passes through the remainder of the FGD absorber.

The operating conditions in the gas cooler and the inlet region of the inlet plenum are both corrosive and erosive. This region could be exposed to higher flue gas temperatures in the event of failure of the flue gas quenching process. Very brief excursions (less than 1 minute) to the inlet flue gas temperatures could occur in the event of the simultaneous loss of electrical power to the FGD absorber gas cooling pumps and FGD Service Water System (SW) service water pumps. In this scenario, the FGD Emergency Quench System (ZQ) would be activated.

The slurry in the JBR absorber is both corrosive, due to elevated levels of chlorides (up to 12,000 mg/L) and pH range (4.5 to 5.5), and erosive, due to the level of suspended solids in the process slurry (up to 25 weight percent). The slurry temperature is in the range of 125 to 130° F.

The FGD reagent feed is erosive with a suspended solids level of approximately 30 weight percent. This slurry has a temperature range of 40° F (winter minimum) to 100° F (summer maximum). The high summer temperature is the result of using reclaim water to produce the reagent slurry.

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Due to compression of the air, the temperature of the FGD oxidation air prior to humidification is 50 to 100° F above the ambient air temperature.

4.3 Functional Constraints

The system is designed to remove 98 percent of the inlet SO₂.

The FGD absorber must remain in service from the initial firing in the boiler through boiler purge on shutdown. It must be capable of achieving the required SO₂ removal efficiency from minimum through maximum design flue gas flows.

The FGD absorber must remain in service whenever the boiler is in service. Major maintenance shutdowns are assumed to occur at 4 year intervals. Equipment type, redundancy, materials of construction, and on-line maintenance capability are selected based on consideration of this maintenance interval.

All slurry pumps and piping in the FGD absorber must be automatically flushed with reclaim water and drained on shutdown to prevent solids from settling out.

The reagent feed control valves will gravity drain from the shutoff valve to the JBR absorber.

4.4 Redundancy

The primary gas path consists of a single 100 percent capacity gas cooler, JBR absorber, and two-stage mist eliminator.

The FGD absorber gas cooling pumps consist of three 50 percent capacity pumps. The absorber bleed pumps consist of two 100 percent capacity pumps.

The JBR area sump is equipped with a single agitator and two 100 percent capacity submersible sump pumps. The sump pumps are used individually or in parallel depending on liquid level in the sump. The pumps alternate starts in normal operation mode to ensure even run time.

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5.0 Description of Provisions for Flushing and Testing

All slurry pumps and piping in the FGD absorber are automatically flushed with reclaim water and drained on shutdown to prevent solids from settling out.

Additional flushing and testing specifications will be completed during detail design.

6.0 Description of Provisions for Maintenance

The description of the provisions for maintenance will be completed during detail design.

7.0 Description of Hazardous Areas/Materials

The description of hazardous areas and materials will be completed during detail design.

8.0 References

8.1 Flow Diagrams

Black & Veatch Drawing No.	AEP Drawing No.
141643-02ZA-M2251A	02-518003A
141643-02ZA-M2251B	02-518003B
141643-02ZA-M2251C	02-518003C
141643-02ZA-M2251D	02-518003D
141643-02ZA-M2251E	02-518003E
141643-02ZA-M2251F	02-518003F
141643-02ZE-M2255A	02-518006
141643-02ZT-M2263A	02-518010
141643-02ZZ-M2266C	02-518011C

8.2 General Arrangements

Later

8.3 Electrical One-Line Drawings

Later

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8.4 Descriptive Articles

Later

8.5 Codes and Standards

The FGD Absorber System is designed in accordance with the following codes and standards:

- API 620 – Design and Construction of Large, Welded, Low-Pressure Storage Tanks.
- API 650 – Welded Steel Tanks for Oil Storage.
- API 2255 – Method for Liquid Calibration of Tanks.
- ASTM B31.3, Chapter VII – Non-Metallic Piping and Piping Lined with Nonmetals.
- ASTM B31.1, Appendix III – Non-Mandatory Rules for Nonmetallic Pipe.
- ASTM D2992 – Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.
- American Society of Mechanical Engineers (ASME).
- American Welding Society (AWS).

8.6 Regulatory Requirements

FGD systems are installed to limit the emissions of SO₂. The level of these emissions are limited by federal statutes, regulations, and programs including the Clean Air Act and its amendments, New Source Performance Standards (NSPS), Ambient Air Quality Standards (AAQS), Prevention of Significant Deterioration (PSD) regulations, and Best Available Control Technology (BACT) determinations. There may also be applicable state and local regulations such as State Implementation Plans (SIPs). The applicable SO₂ emission limits at a specific site are set based on a detailed study of the emission source, other area

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sources, existing ambient air quality, and the requirements of the above laws and regulations.