Content

Page

1. Introduction.. 2

2. Abbreviations.. 2

3. Plant specification... 3

3.1 Pre-Treatment Section 3

3.1.1 Feed Chemistry 3

3.1.2 Wastewater Storage Tanks 4

3.1.3 Removal of Hardness 4

3.1.4 Lime Addition... 4

3.1.5 Soda Ash Addition 5

3.1.6 Clarifier 5

3.1.7 Sludge Removal 5

3.1.8 Filtration 5

3.2 Zero Liquid Discharge Section.. 6

3.2.1 Feed Chemistry 6

3.2.2 Chemical Additions.. 6

3.2.3 Heat Recovery... 7

3.2.4 Deaeration... 7

3.2.5 Evaporation 7

3.2.6 Brine Concentrator 8

3.2.7 Crystallization 9

3.3 Utilities 10

3.3.1 Steam... 10

3.3.2 Seal Water... 10

3.3.3 Instrument Air 11

3.3.4 Plant Sumps 11

1. Introduction

Kusile Power Station's aim to partner with an experienced contractor to treat the flue gas desulphurization chloride purge wastewater, provide Plant Maintenance as per the maintenance philosophy and supply the required chemicals to provide sufficient treatment and eliminate discharge of liquid. The treatment plant consists of two main process areas, namely Pre-treatment and Zero Liquid discharge (ZLD).

- Pre-treatment (PT)

The purpose of the pre-treatment system is to partially soften the wastewater before it is fed to the evaporation process system to prevent scale formation on heat exchange components. It is designed to provide the Evaporation system a feed with a hardness of approximately 1500mg/l calcium and 320mg/l magnesium as ion. The heavy metals are expected to also be reduced to very low concentrations in the pre-treatment process.

- Zero Liquid Discharge (ZLD)

From the common pre-treatment system, the softened wastewater flows to the Zero Liquid Discharge area which consists of an Evaporation/ Brine concentration stage and the Crystallisation stage. This section of the plant consists of two independent trains however both trains are capable of being run simultaneously.

In order to improve the availability and reliability, the plant should be operated within the initially intended performance envelope in a safe and efficient manner to ensure compliance to the environmental regulations.

2. Abbreviations

Abbreviation	Explanation
BC	Brine Concentrator
Demin	Demineralisation
FGD	Flu gas Desulphurization
H&S	Health and Safety
LRT	Lime Reaction Tank
NCR	Non-Conformance Report
OEM	Original Equipment Manufacturer
OHSA	Occupational Health and Safety Act
PIS	Plant Information System
PT	Pre-Treatment
SHE	Safety Health and Environment
SOW	Scope of Work
TSC	Term Service Contract
URS	User Requirement Specification
WWTP	Wastewater treatment Plant

Abbreviation	Explanation
BC	Brine Concentrator
ZLD	Zero Liquid Discharge

3. Plant specification.

3.1 Pre-Treatment Section

The PT Section consists of a single train rated for 200% of the anticipated FGD blowdown flows and is designed to process 50 m³/h of waste water.

NOTE 1: The flow from FGD blowdown is considerably lower during the initial stage of commissioning and it reach the design flow once the commissioning of the station is complete (6X Units in-service)

3.1.1 Feed Chemistry

The FGD scrubber blowdown chemistry ranges are shown in Table 4.

Table 4: PT Feed Chemistry

Parameter	Concentration (mg/L as ion)
Chloride	30000
Sulfate	1500 – 8000
Sulfite	< 20
Nitrate	100 – 1500
Fluoride	30 – 200
Calcium	4000 – 20000
Magnesium	200 – 5600
Sodium	75 – 1200
Iron	30 – 400
Aluminium	50 – 800
Arsenic	0.05 – 3.00
Boron	20 – 40
Cadmium	0.04 – 0.50
Cobalt	0.05 – 0.40
Chromium Total	0.3 – 5.0
Copper	0.10 – 0.85
Mercury	0.05 – 0.8
Nickel	0.2 – 6.0
Lead	0.1 – 3.0

Parameter	Concentration (mg/L as ion)
Selenium	0.2 – 1.0
Vanadium	0.0 – 2.4
Zinc	5 – 10
Ammonium	<10 – 100
COD	100 – 150
pH	4 – 7
TSS	300 – 20000

NOTE 2: The scrubber blowdown can contain as much as 4% suspended solids and The feed chemistry will be dependent on the FGD Blowdown Regime which is designed to be at 30000ppm Chridde.

3.1.2 Wastewater Storage Tanks

Waste water from the FGD scrubbers enters the Waste Water Storage Tanks. The two tanks are connected by an equalisation line, keeping the level the same in both tanks. The tanks are sized to provide a feed buffer of about 20-hours to the PT Section. From the Waste Water Storage Tanks the water is fed to the Lime Reaction Tank.

3.1.3 Removal of Hardness

As shown in the PT feed chemistry, the FGD scrubber blowdown can potentially be high in calcium, magnesium, sulphate and aluminium. To reduce the hardness, lime and soda ash are added individually in their own dedicated reaction tanks as described below.

3.1.4 Lime Addition

To reduce magnesium and metals present in the wastewater, lime is added to an agitated reaction tank with a 30-minute residence time. The lime dosing rate is controlled by maintaining a pH of 10.5 in the Lime Reaction Tank. At this pH, metals such as aluminium will precipitate as metal hydroxides and magnesium will precipitate as a hydroxide. As silica co-precipitates with magnesium, some of the silica will also be removed from the wastewater.

To neutralize charges on the precipitated particles, ferric chloride is added to the Lime Reaction Tank as a coagulant. The ferric chloride dosing rate is controlled proportional to the waste water feed rate.

The lime addition system includes a storage silo for dry hydrated lime. The lime is metered to the Lime Mix Tank via a volumetric feeder according to an analogue control signal. The Lime Mix Tank includes a mixer, make-up water valve and level controls. Centrifugal pumps (1-duty and 1-standby) then pump the lime slurry from the slurry mix tank to the Lime Reaction Tank.

3.1.5 Soda Ash Addition

After the lime addition, soda ash is added to the wastewater to reduce the concentration of calcium. Calcium in the wastewater reacts with soda ash to form insoluble calcium carbonate. Therefore, the more soda ash is added, the more calcium is reduced from the wastewater. The soda ash dosing rate is controlled proportional to the wastewater feed rate.

There are two equally sized, 30-minute residence time, agitated reaction tanks for the soda ash addition system. All the soda ash is added to Soda Ash Reaction Tank 1, while Soda Ash Reaction Tank 2 prolongs the mixing and reaction times.

The soda ash addition system includes a storage silo with a volumetric screw conveyor to deliver dry powder to soda ash reaction tank 1.

3.1.6 Clarifier

Before the slurry enters the Clarifier, it is dosed with a polymer. The polymer improves the settling characteristics of the solids and the dosing rate is controlled proportional to the wastewater feed rate.

The Clarifier is a large settling tank with approximately 20-hours residence time to allow for separation of the sludge created from lime – and soda ash addition. Precipitated particles in the feedwell migrate from the mixing zone outward to the settling zone of the Clarifier, to settle in this quiescent region. The Clarifier rake arms continuously move the precipitates to the central sludge pit where they are further concentrated before being blown down to the Sludge Holding Tank.

If required to improve the performance of the clarifier through solids contacting, a portion of the Clarifier underflow can be returned to the Lime Reaction Tank.

Clarifier overflow is collected in a trough along the periphery of the Clarifier from where it is gravity fed to the Clearwell.

3.1.7 Sludge Removal

Clarifier underflow is forwarded to the Sludge Holding Tank to provide surge capacity for operation of the Plate Filter Presses. There are two identical Plate Filter Presses which are alternated in service; allowing for continuous operation of the PT Section. Each Plate Filter Press holds about 5 m^3 of dewatered sludge which is then dumped and hauled away.

The filtrate, along with Plate Filter Press Cloth Wash water, is collected in the Filtrate Tank. From the Filtrate Tank it is pumped back to the Clarifier for reprocessing.

3.1.8 Filtration

From the Clearwell, partially softened wastewater is forwarded to the Automatic Back-washable Strainers and then to the Brine Concentrator (BC) Feed Tanks.

Sulfuric acid is added to the Clearwell to drop the pH to between 7 and 8; thereby preventing precipitation on the downstream Automatic Back-washable Strainers. The sulfuric acid dosing rate is controlled by maintaining the pH in the Clearwell.

A slipstream of filtered water is pulled off for use as lime make-up – and carrier water.

3.2 Zero Liquid Discharge Section

The ZLD Section consists of two independent, redundant trains. Each train is designed to process 25 m³/h of wastewater. The ZLD plant is capable of treating a total of 50 m³/h if both trains are operated simultaneously.

3.2.1 Feed Chemistry

The feed chemistry to the ZLD is shown in Table 5. The expected TDS feeding the ZLD is approximately 50000 mg/L.

Table 5: ZLD Feed Chemistry

Parameter	Concentration (mg/L as ion)
Chloride	30000
Sulfate	948
Sulfite	10
Nitrate	800
Fluoride	15
Bicarbonate	50
Boron (as HBO_3)	166
Calcium	1500
Magnesium	320
Sodium	18316
Ammonia	55
Silica	15
TOC	36

3.2.2 Chemical Additions

Three chemicals are added to the BC feed: sulfuric acid, sodium sulphate and scale inhibitor. The purpose of each chemical is described below.

3.2.2.1 Sulfuric Acid Addition

Sulfuric acid is added to the BC Feed Tank to decrease the pH to between 4 and 5 and convert 90-95% of the bicarbonate to unbound carbon dioxide gas. This gas is later stripped in the downstream BC Feed Deaerator. Eliminating the alkalinity mitigates carbonate scaling on the heat transfer surfaces of both the BC Feed Heat exchanger and the BC Condenser Tubes.

From the BC Feed Tank, the water is pumped through the BC Feed Heat Exchanger to the top of the BC Feed Deaerator.

3.2.2.2 Sodium Sulphate Addition

After the PT Section, there is not sufficient sulphate species to properly support the seeded slurry operation of the Brine Concentrator; therefore, sodium sulphate is added to the BC Feed Tank. As the constituents in the wastewater are concentrated up in the Brine Concentrator, calcium sulphate will eventually be saturated and precipitated as crystals.

Dry sodium sulphate powder is added directly to the BC Feed Tank via a screw feeder. The screw feeder is controlled proportional to the BC feed rate to ensure that the proper dosage is added.

3.2.2.3 Scale Inhibitor Addition

After the PT Section, calcium sulphate precipitation in the BC Feed Heat Exchanger is significantly reduced. Calcium sulphate scale inhibitor is added to the BC Feed Tank as a precaution against unexpected BC Feed Heat Exchanger scaling. The dosing rate is controlled proportional to the BC feed rate.

3.2.3 Heat Recovery

The heat recovery system preheats the BC Feed Water via the outgoing distillate from the BC. It consists of a plate and frame heat exchanger. The cold stream, acidified feed, enters the BC Feed Heat Exchanger at 37 °C and is heated to 96 °C by a counter flowing hot distillate stream pumped from the BC Distillate Tank. Sensible heat is recovered from the distillate as its temperature decreases from 107 °C to 46 °C. The source of the distillate is from both the Brine Concentrator and Crystallizer condensed vapours.

The BC Feed Pump pumps the feed water through the BC Feed Heat Exchanger to the top of the BC Feed Deaerator.

3.2.4 Deaeration

The BC Feed Deaerator is a steam-driven stripper column, which removes carbon dioxide, air and other non-condensable gases from the BC feed water with a counter-current flow of steam in order to minimise scaling and corrosion in the Brine Concentrator. Under normal operations the stripping steam is excess vent steam from the BC Distillate Tank. During start-up or upset conditions, steam can be admitted to the BC Feed Deaerator directly from the auxiliary steam header. The stripping steam, laden with non-condensable gases, is vented out the roof of the building.

After the feed is deaerated, the liquid in the BC Feed Deaerator drains by gravity to the BC Sump.

3.2.5 Evaporation

The Brine Concentrator operates with suspended solids (mostly calcium sulphate) in the recirculating brine (seeded slurry mode). The brine from the BC sump is continuously recirculated to the top of the vertical heat-transfer tubes where it flows through a distributor inserted into the top of each tube and then falls down as a thin film inside. A portion of the thin film is vaporised.

In the vapor compressor thermodynamic cycle, the vapor is compressed in a compression cycle and introduced into the shell side of the vertical tube bundle. The temperature difference between the vapor and the brine film causes the vapor to release its heat of condensation to the falling brine and to condense on the outside of the tubes as distilled water. The distillate is collected at the bottom of the condenser and flows to the BC Distillate Tank through a pipe handling both liquid and steam. A small vent stream from the distillate tank maintains the evaporator vessel at a slightly positive pressure. The hot distillate is pumped through the BC Feed Heat Exchanger where it gives up its sensible heat to the incoming feed. A portion of the distillate is used as Mist Eliminator wash fluid. The cooled distillate is blended with the Crystallizer condensate (a small portion is diverted for usage as seal water) before being discharged to the Process Drains Recovery Tank (PDRT) in the Water Treatment Plant (WTP).

3.2.6 Brine Concentrator

The Brine Concentrator consists of a shell and tube heat exchanger (the condenser) which is vertically mounted on top of a sump. The upper condenser tube sheet forms the floor of the flood-box. The lower condenser tube sheet is located in the upper section of the sump. Additional ancillary equipment includes the BC Vapor Compressor, BC Recirculation Pump and Mist Eliminators.

The flood-box is a chamber above the top tube sheet where the recirculated brine is distributed to the inside of the condenser tubes. The flow per tube and the recirculation rate is designed to maintain a flooded level above the upper condenser tube sheet.

The BC Sump is the collection area for the recirculating brine and provides adequate net positive suction head for the BC Recirculation Pump. To avoid solids settling, the concentrated brine slurry is kept recirculating at all times. The top of the BC Sump wall is angled inward to form an inverted conical section which supports the condenser. The condenser extends down just past the bottom of the cone where the lower tube sheet is suspended above the liquid level. Mist Eliminators are placed in the annular space between the sump wall and the condenser liquid level. The vapor flows through the Mist Eliminators where water droplets and entrained solids are removed before flowing to the BC Vapor Compressors.

The Vapor Compressor system is a two-stage centrifugal fan set. Each fan is driven by an elecrical motor. Guide vanes control the vapor flow to each compressor. Compressed vapor enters the condenser shell side at between 35 and 48 kPa higher than its inlet pressure and gives up latent heat to the recirculating brine on the inside tube walls while condensate forms on the outside surfaces of the tubes. Eventually the steam condensate accumulates and falls down to the bottom tube sheet where a stream of mostly condensate and vapor exits the Brine Concentrator to the BC Distillate Tank. Excess steam exits the BC Distillate Tank to the BC Feed Deaerator while the condensate is transferred to heat recovery.

The BC Recirculation Pump takes suction at the bottom of the BC Sump and pumps brine to the floodbox at the top of the condenser where the brine passes through a strainer to remove lumps and floods the upper tube sheet. The brine slurry enters the distributors and flows down the tubes as a thin film back to the BC Sump.

A portion of the concentrated brine is continuously withdrawn from the sump and directed to the Crystallizer Feed Tank. The brine discharge rate is controlled to maintain the desired cycles of concentration in the BC Sump.

There are two chemical additions to the Brine Concentrator: antifoam and caustic. From the feed chemistry, there is organic matter in the feed water. TOC is known to cause foaming in evaporators and crystallizers; hence an antifoam dosing system is added to the Brine Concentrator. The dosing rate is controlled proportional to the BC feed rate. The pH in the recirculating brine is maintained between 4 and 5 by the addition of caustic.

3.2.6.1 Brine Concentrator Wasting and Seed Recycle System

The concentration of both TDS and TSS in the recirculating brine is crucial to preventing scale in the Brine Concentrator and is the basis of the seeded slurry process. The seed has a great surface area which is many times the surface area of the heat transfer tubes. Thus, when calcium sulfate starts to precipitate, precipitation will take place on the seed instead of the tube walls. The seeded slurry process also supports other precipitates such as silica, calcium fluoride and calcium phosphate.

Two independent waste systems are utilised to maintain close control of the recirculating brine chemistry. One system will control the waste rate of a predominantly TDS stream while another will control the waste rate of a solids rich stream (high in TSS).

Manipulating the concentrated brine blowdown flow rate from the recirculating brine allows for TSS concentration control. Manipulating the blowdown flow rate from the Seed Recycle Hydrocyclone overflow allows for TDS concentration control.

A seed recycle system is used to recover and recycle seed from the waste brine stream back to the recirculating brine. The Seed Recycle Pump boosts the pressure of the recirculating brine and transfers it to the Seed Recycle Hydrocyclone which causes a high centrifugal velocity on the brine. Brine, which is essentially free of seed, comes out of the top of the hydrocyclone and is discharged on a controlled basis to maintain the correct TDS concentration in the recirculating brine. The hydrocyclone underflow is enriched in seed concentration and is returned to the recirculating brine.

During a Brine Concentrator start-up, artificial seed must be added to the sump until the designed TDS concentration is reached. Gypsum (as calcium sulphate anhydrate) is mixed in the Seed Tank and pumped by the Seed Pump to the BC Sump.

3.2.7 Crystallization

The Crystallizer Feed Tank receives concentrated brine from the Brine Concentrators and is designed for a retention time of 48-hours with 1 train in operation. Steam from the auxiliary steam header is sparged into the tank to maintain the temperature at 93 °C in order to prevent corrosion to downstream equipment. The Crystallizer Feed Pump transfers the hot brine from the Crystallizer Feed Tank to the Crystallizer recirculation duct.

3.2.7.1 Crystallizer

The Crystallizer is a combination of a vapor body and a horizontal shell and tube heat exchanger. From the vapor body, brine is pumped to the heat exchanger; therefore the term: “forced circulation crystallizer”. Brine from the Crystallizer Feed Tank is pumped through the heat exchanger where it is heated by a few degrees. When the brine re-enters the Crystallizer Vapor Body, it flashes and salt crystals precipitate.

The vapors produced in the Crystallizer Vapor Body passes through an entrainment separator. Between 15 and 20% of the vapor is sent to the thermocompressors while the remainder is directed to the Crystallizer Vapor Condenser. Cooling water from the plant is used to condense the vapor. The condensate is pumped to the cooled BC distillate stream and eventually sent to the PDRT.

The Thermocompressors use high pressure auxiliary steam to drive the Crystallizer Heater. This high-pressure steam is mixed with Crystallizer Vapor Body process steam in the Thermocompressors. The steam mixture is discharged from the Thermocompressors and desuperheated to approximately 131 °C. This steam enters the shell side of the Crystallizer Heater and is the thermal force for evaporation. The condensate is collected in the Crystallizer Prime Condensate Tank and combined with the Brine Concentrator distillate for heat recovery purposes.

In the Brine Concentrator, the feed water is concentrated to the point of 80% sodium chloride saturation. In the Crystallizer, the brine is further concentrated past the saturation point and as a result, sodium chloride crystals are continuously formed within the Crystallizer Vapor Body. Following the heating and flashing of the brine, water is removed in the form of vapor. As the brine concentrates, it becomes salts which precipitate from solution.

Since the sodium chloride salt is very soluble, a hot water rinse, or “boil-out”, using distillate – or service water can be used to periodically clean the system. The Crystallizer typically runs two to four weeks between boil-outs.

The chemical additions to the Crystallizer are antifoam and caustic. From the feed chemistry, there is organic matter in the feed water. TOC is known to cause foaming in evaporators and crystallizers; hence antifoam is added to the recirculating brine. The pH in the Crystallizer Vapor Body is maintained at 7 by the addition of caustic in order to minimise corrosion concerns.

3.2.7.2Centrifuge

A slipstream of brine is drawn off the Crystallizer recirculation duct and directed to the Centrifuge. The horizontal bowl Centrifuge is designed to separate solids from the brine by using centrifugal separation.

The suspension of salt crystals is continuously fed through the feed pipe directed to the cylindrical bowl that rotates at 2170 rpm which creates the necessary centrifugal force to cause the suspended solids to settle on the inner wall of the bowl. A screw conveyor then transports the solids out of the bowl to the solids outlet where it falls into large holding bins and await off-site disposal. The centrate, consisting of brine with solid fines, is gravity drained to the Crystallizer Centrate Tank from where it is recycled back into the Crystallizer recirculation duct by the Crystallizer Centrate Pump.

3.3 Utilities

3.3.1 Steam

Auxiliary steam is supplied to the WWTP at 1800 kPa(g) and 290 °C. The bulk of this high pressure steam is sent to the Thermocompressors to thermally drive the Crystallizer Heater. The other minor consumers are the Brine Concentrator System (start-up) and the Crystallizer Feed Tank.

3.3.2 Seal Water

The source of the seal water is from the Seal Water Tank. A small portion of the cooled distillate is bled to this tank. The Seal Water Supply Pump will transfer the water to various pumps requiring seal water. Potable Water is the designed seal water back-up.

3.3.3 Instrument Air

Air is supplied to the plant at 700 to 900 kPa(g) with a pressure dew point of -40 °C. Instrument air is mainly used to actuate control valves in the plant.

3.3.4 Plant Sumps

There is one sump located in the PT Section and one sump located in the ZLD Section.

The PT Sump is used to collect process spills and to return filtrate water from the Plate Filter Presses. It also serves to collect water from the PT area washdowns. The PT Sump is a lined concrete sump with sump pumps to transfer the contents to the Clarifier.

The ZLD Sump is used to collect brine when draining the Brine Concentrator and Crystallizer ducts during maintenance or “boil-out” events. It also serves to collect water from the thermal equipment washdowns. The ZLD Sump is a lined concrete sump with sump pumps to transfer the contents to the Crystallizer Feed Tank.