# Operation & Maintenance Manual
# Saline Water Treatment Plant

# 6515-E-132-013-105-IOM-001

In Accordance with Water Licence 2AM-MEL1631

Prepared by:
Agnico Eagle Mines Limited – Meliadine Division

## EXECUTIVE SUMMARY

The Nunavut Water Board (NWB) has issued Type A Water Licence 2AM-MEL1631 to Agnico Eagle Mines Limited (Agnico Eagle) for the Meliadine Gold Project site, authorizing the use of water and the disposal of waste required by mining, milling, and associated uses.

Agnico Eagle has prepared the following document which summarizes the operational and maintenance procedures to be followed at the Saline Water Treatment Plant (SWTP).

This report documents the stand-alone Operation & Maintenance Manual – Saline Water Treatment Plant, as specified under Water Licence 2AM-MEL1631 Part F, Item 9 and includes the following requirements:

- The manual was prepared in accordance with the "Guidelines for the Preparation of an Operation and Maintenance Manual for Sewage and Solid Waste Disposal Facilities in the Northwest Territories, 1996", and adapted for the use of a mechanical contact water treatment facility;
- The manual includes contingency measures in the event of a plant malfunction; and
- The manual includes salt slurry and blowdown management procedures.

## IMPLEMENTATION SCHEDULE

As required by Water Licence 2AM-MEL1631, the proposed implementation schedule for this plan is outlined in this report.

This plan will be implemented upon Board approval and subject to any modifications proposed by the NWB as a result of the review and approval process.

## DISTRIBUTION LIST

Agnico Eagle Internal:

- Process Plant Superintendent
- Process Plant General Supervisor
- Environmental Superintendent
- Environment General Supervisor
- Environmental Coordinator
- Environmental Compliance Counselor
- Saline Water Treatment Plant Operator

## DOCUMENT CONTROL

| Version | Date (YMD) | Section | Page | Revision |
|---|---|---|---|---|
| 1 | 29/05/2018 | | | Operation and Maintenance Manual |

Prepared By:

Thomas Genty
Water Treatment Specialist

Blandine Arseneault

Signature numérique de Blandine Arseneault
DN : cn=Blandine Arseneault
Date : 2018.06.04 08:59:52 -04'00'

Blandine Arseneault
Project Environment Lead

Approved by:

normand.menard@agnicoeagle.com

Signature numérique de normand.menard@agnicoeagle.com
DN : cn=normand.menard@agnicoeagle.com
Date : 2018.06.01 13:48:04 -05'00'

Normand Ménard
Project Mechanic Lead

Jessica Huza
Environment General Supervisor

# TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF APPENDICES

## List of Acronyms, Abbreviations, Units and Symbols

| | |
|---|---|
| AC | Alternating Current |
| CIP | clean-in-place |
| CP1 | Collection Pond 1 |
| CPVC | Chlorinated Polyvinyl Chloride |
| ERT | Emergency Response Team |
| HDH | Humidification-Dehumidification |
| HMI | Human Machine Interface |
| I/O | Input/Output |
| km | kilometres |
| mA | milliampere |
| mS | millisiemens |
| NWB | Nunavut Water Board |
| OMM | Operation and Maintenance Manual |
| PLC | Programmable Logic Controller |
| PVC | Polyvinyl Chloride |
| RO | Reverse Osmosis |
| RTD | Resistance Temperature Detector |
| SWTP | Saline Water Treatment Plant |
| TDS | Total Dissolved Solids |
| V | volt |
| VFD | Variable Frequency Drive |

# 1 INTRODUCTION

## 1.1 PURPOSE

This Saline Water Treatment Plant (SWTP) Operation and Maintenance Manual (OMM) for the Meliadine Gold Project (the Project) has been prepared in accordance with the Nunavut Water Board (NWB) Type A Water Licence 2AM-MEL1631 (Type A Licence), Part F, Item 9, and is based on the "*Guidelines for the Preparation of an Operation and Maintenance Manual for Sewage and Solid Waste Disposal Facilities in the Northwest Territories, 1996, prepared by the Department of Municipal and Community Affairs, NWT*". The manual has been adapted for the use of a mechanical saline contact water treatment facility.

This manual is a component of the Meliadine Environmental Management System. The objectives of this plan are summarized as follows:

1. To define the location, design and operating procedures to be used in the treatment of saline contact water generated at the Project; and
2. To provide monitoring requirements for the SWTP.

## 1.2 BRIEF DESCRIPTION OF THE PROJECT

Agnico Eagle is developing the Project, located approximately 25 kilometres (km) north of Rankin Inlet, and 80 km southwest of the Hamlet of Chesterfield Inlet in the Kivalliq Region of Nunavut. Situated on the western shore of Hudson Bay, the Project site is located on a peninsula between the east, south, and west basins of Meliadine Lake (63°1'23.8'' N, 92°13'6.42"W) on Inuit Owned Land.

Gold will be extracted using traditional open-pit and underground mining methods during the mine life. Access to the site is via an all-weather access road from the Hamlet of Rankin Inlet. On-site facilities will include a mill, power plant, maintenance facilities, tank farm for fuel storage, effluent treatment plant, sewage treatment plant, SWTP as well as accommodation and kitchen facilities for 520 people.

During mine construction and operation, saline contact water originating from the underground mine will be collected and pumped to the Saline Pond. The underground saline contact water will be treated by the SWTP prior to discharge to Collection Pond 1 (CP1). Figures 1 and 2 illustrate the location and general arrangement of the SWTP.

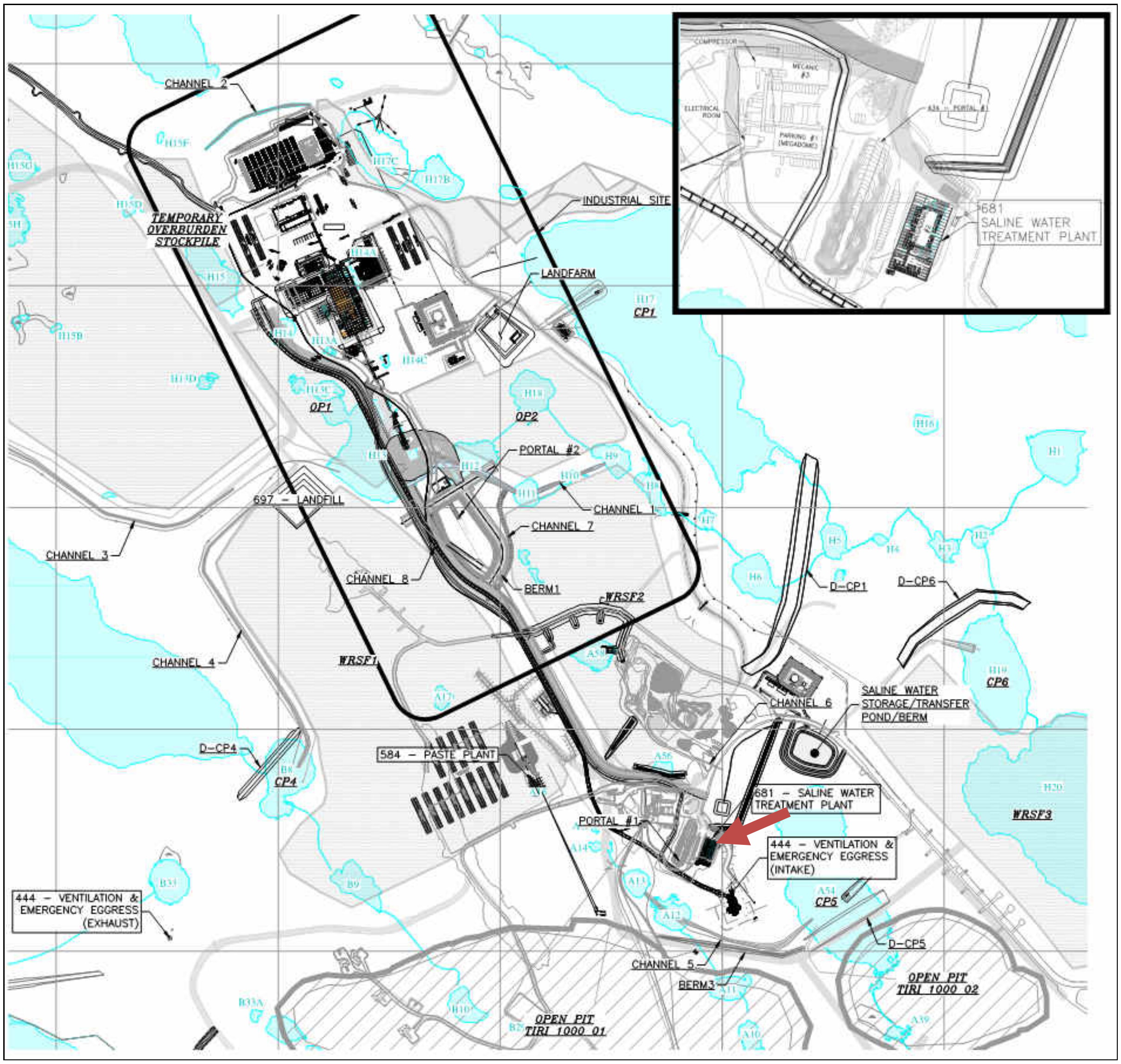



**Figure 1 – Location of SWTP at Meliadine site**

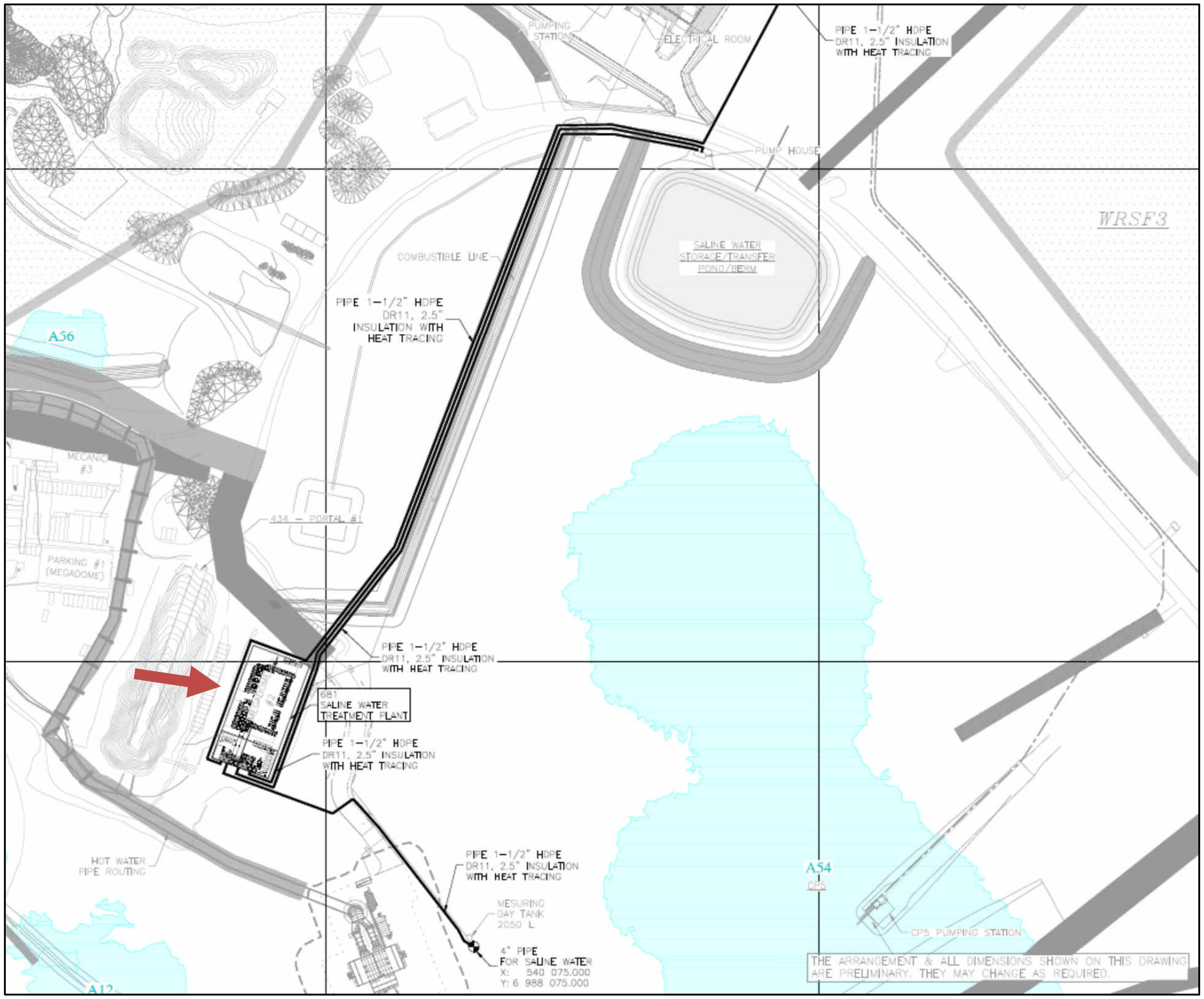
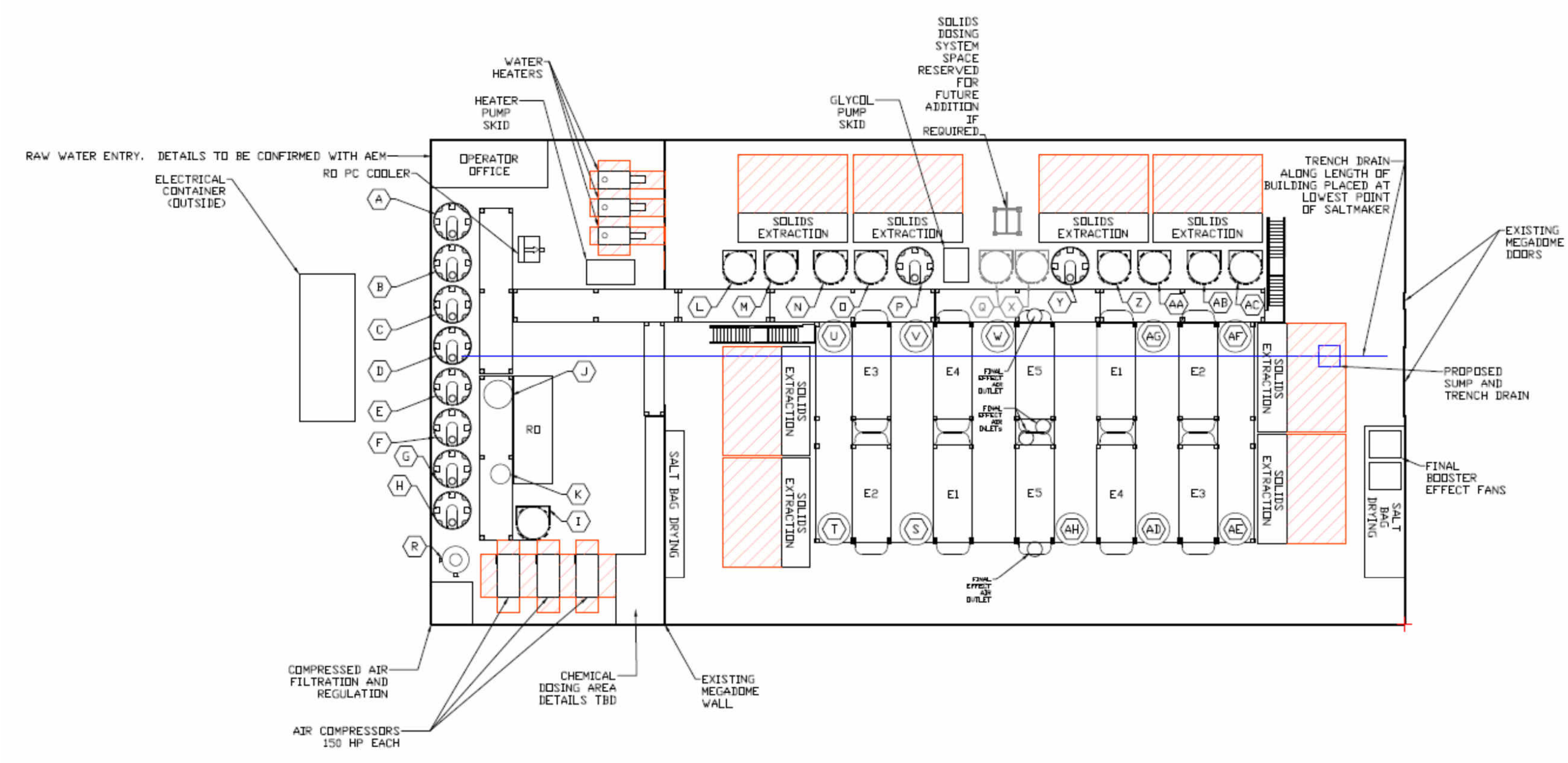



**Figure** 2 **– Location of Meliadine SWTP**




| LABEL | DESCRIPTION | STYLE | MATERIAL | VOLUME (m3) |
|---|---|---|---|---|
| A | RO PRE CONDITIONER (PC) | FLAT BOTTOM | HDPE | 21 |
| B | NITRITE DESTRUCTION | FLAT BOTTOM | HDPE | 21 |
| C | SM1 RAW FEED | 30 DEG CONE BOTTOM | HDPE | 24 |
| D | SM2 RAW FEED (IF REQUIRED) | 30 DEG CONE BOTTOM | HDPE | 24 |
| E | CLEAN RESERVE | FLAT BOTTOM | HDPE | 21 |
| F | TREATED WATER | FLAT BOTTOM | HDPE | 21 |
| G | HIGH SOLUBILITY BLOW DOWN | 30 DEG CONE BOTTOM | HDPE | 24 |
| H | RO BRINE FLUSH | 30 DEG CONE BOTTOM | HDPE | 24 |

| LABEL | DESCRIPTION | STYLE | MATERIAL | VOLUME (m3) |
|---|---|---|---|---|
| I | AMMONIA DESTRUCTION | 45 DEG CONE BOTTOM | FRP | 7.6 |
| J | RO FEED | FLAT BOTTOM | HDPE | |
| K | RO CIP | FLAT BOTTOM | HDPE | |
| L | SM1 CIP | 45 DEG CONE BOTTOM | FRP | 7.6 |
| M | SM1 CIP | 45 DEG CONE BOTTOM | FRP | 7.6 |
| N | SM1 EFFECT HOLD 2 | 45 DEG CONE BOTTOM | FRP | 7.6 |
| O | SM1 EFFECT HOLD 1 | 45 DEG CONE BOTTOM | FRP | 7.6 |
| P | SM1 SYSTEM HOLD | 30 DEG CONE BOTTOM | HDPE | 24 |

| LABEL | DESCRIPTION | STYLE | MATERIAL | VOLUME (m3) |
|---|---|---|---|---|
| Q | CALCIUM EXTRACTION | 45 DEG CONE BOTTOM | FRP | 3.6 |
| R | PRIMARY COMPRESSED AIR RECEIVER | VERTICAL RECEIVER | STEEL | 11 |
| S | EFFECT 1 RECIRCULATION TANK | 45 DEG CONE BOTTOM | FRP | 3.6 |
| T | EFFECT 2 RECIRCULATION TANK | 45 DEG CONE BOTTOM | FRP | 3.6 |
| U | EFFECT 3 RECIRCULATION TANK | 45 DEG CONE BOTTOM | FRP | 3.6 |
| V | EFFECT 4 RECIRCULATION TANK | 45 DEG CONE BOTTOM | FRP | 3.6 |
| W | EFFECT 5 RECIRCULATION TANK | 45 DEG CONE BOTTOM | FRP | 3.6 |
| X | CALCIUM EXTRACTION | 45 DEG CONE BOTTOM | FRP | 3.6 |

**Figure 3 – General Arrangement of Meliadine SWTP**

### 1.3 CONTACT INFORMATION

The individuals responsible for the operation of the SWTP are the following:

| | |
|---|---|
| Process Plant Superintendent | 819-759-3555 ext. 3093 |
| Process Plant General Supervisor | 819-759-3555 ext. 3079 |
| Environment General Supervisor | 819-759-3555 ext. 3079 |

# 2 DESCRIPTION

## 2.1 SALINE WATER TREATMENT PLANT (SWTP)

### *2.1.1 Process Summary*

The purpose of the SWTP is to remove total dissolved solids (TDS), which also referred to as salinity, in underground saline water. The expectedTDS in underground water varies from approximately 60 000 to 160 000 mg/L. The treated water will be discharged into CP1. The equipment has an operational flow rate of 120 $m^3/d$. It is expected that the SWTP will be in use 24 hours, 7 days per week.

The treatment concept is presented in Figure 3. Water is pumped from the underground sump to the saline storage pond or directly into the SWTP. Water then flows into the two SaltMaker S125 units. Three products are generated during the process: distilled water, a salt slurry and a high-salinity blowdown.

The distilled water is treated in an oxidation reactor for nitrite removal, followed by a reverse osmosis (RO) step used to remove ammonia. The RO permeate is then discharged into CP1. The RO brine containing high ammonia concentration is stored in a tank and oxidized with chorine before being cycled back to the two SaltMaker S125 units.

The salt slurry is discharged into a big bag rack. Free water is drained from the bag and recycled to the SaltMaker. The expected solid content into the big bag after drainage is estimated at approximately 80%.

The blowdown is a by-product containing high concentrations of nitrate. Evaporation efficiency depends on the viscosity of the water which can be affected by the high concentrations of nitrate that can occur within the SaltMaker due to its high degree of solubility. Nitrate accumulates within the system as a consequence of the different streams being recirculated.

The SWTP will be installed in 2018, and operational for the first quarter 2019.

The SWTP general flow diagram is illustrated in Figure 4.

The following sections describe the SWTP components.

### *2.1.2 Pre-Treatment*

Before being fed to the SaltMaker, water is filtered through strainers, on-line filters and heated to a specific temperature.

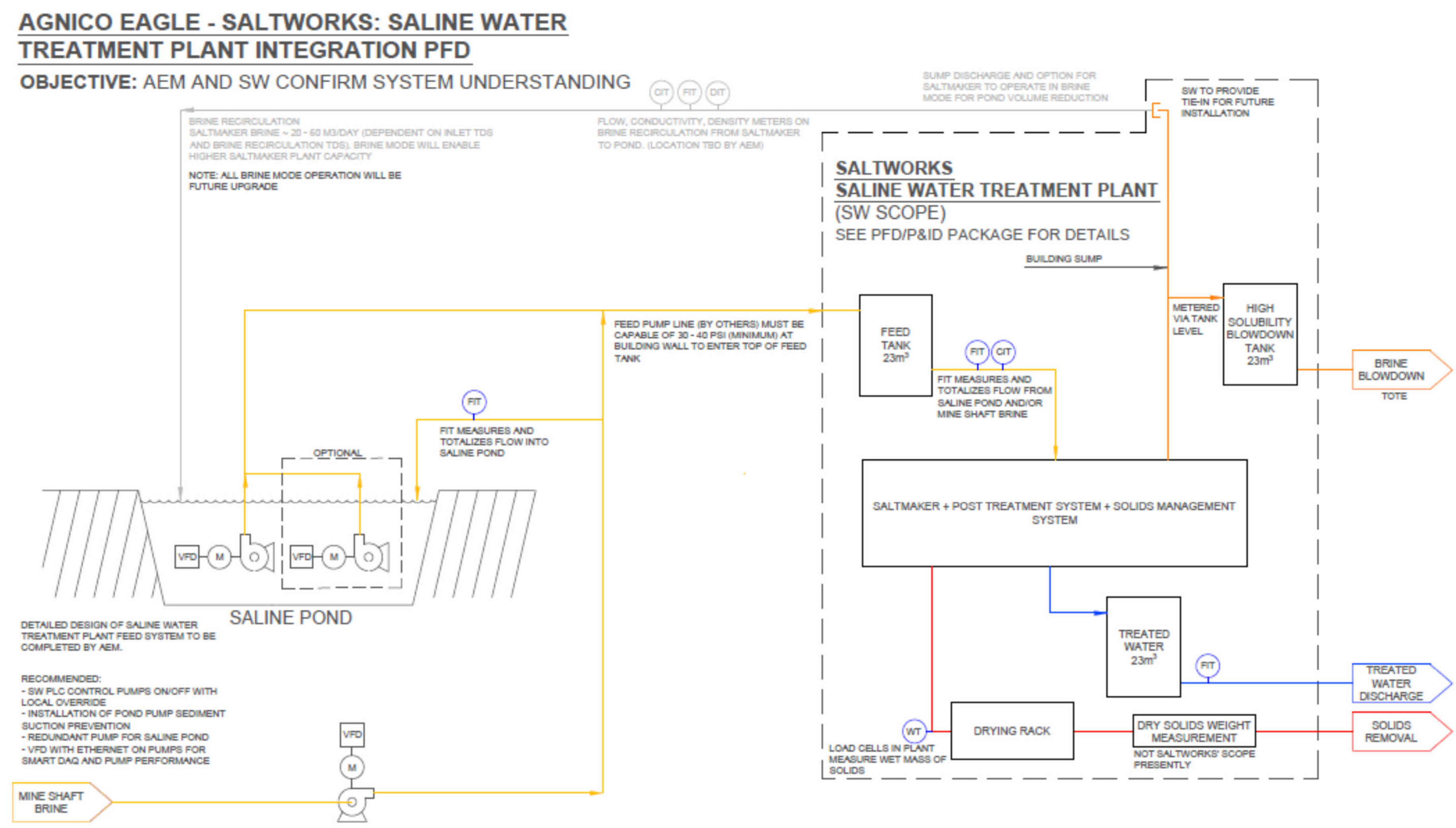



**Figure 2 – Meliadine SWTP Overall Process Concept**

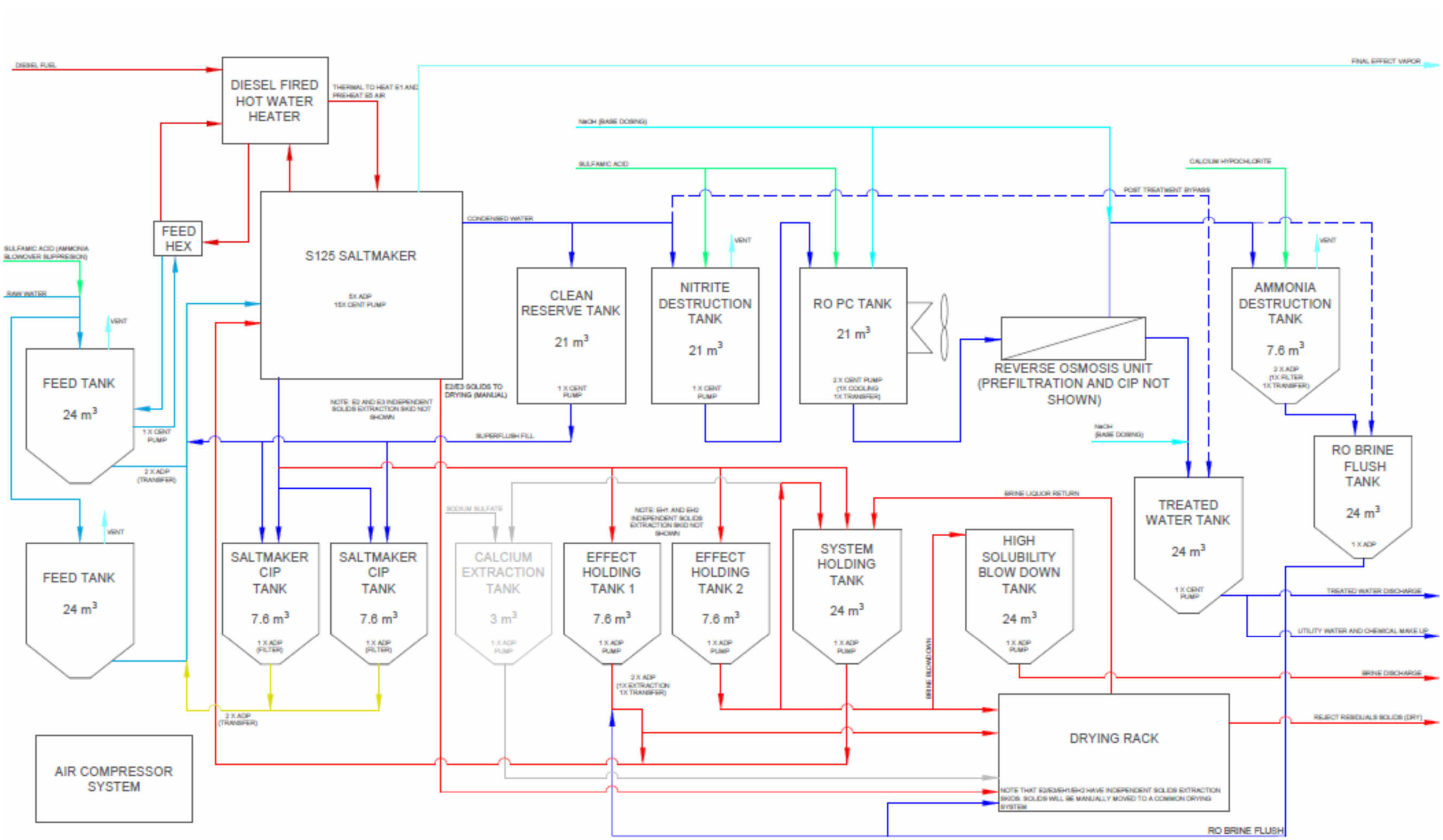



**Figure 3 – Meliadine SWTP Overall Process Flow Diagram**

### *2.1.3 SaltMaker*

The SaltMaker uses a Humidification-Dehumidification (HDH) cycle to concentrate saline water and produce freshwater. The use of a humidified air cycle enables operation at temperatures below 90ºC and pressures near atmospheric (1 bar). These attributes allow the use of engineered plastics in place of more costly corrosion-resistant metallic parts, thereby saving capital cost while also reducing scaling risk due to the much lower surface energy of plastics. In addition, evaporation occurs on a non-heated surface, further reducing scaling and enhancing reliability.

The SaltMaker is a thermally driven plant, producing freshwater and highly concentrated discharge and/or solids via a multiple-effects HDH cycle. The thermal energy is used to evaporate and condense water in successive “effects”. The latent heat of condensation is recycled as it is downgraded, with each effect operating at a temperature approximately 15°C lower than the previous one. Each effect produces freshwater and successively concentrates the saline water. The final effect uses the downgraded heat (<40°C) to concentrate brine into solids.

A simplified process diagram is shown in Figure 4. This diagram describes a four-effect concentration in which the first three effects entail a closed air loop and the fourth effect is open to the atmosphere. The S125 quoted herein is a five-effect plant which recycles the heat an additional time. The final effect can be a closed air loop for zero air emissions and more water recovery.

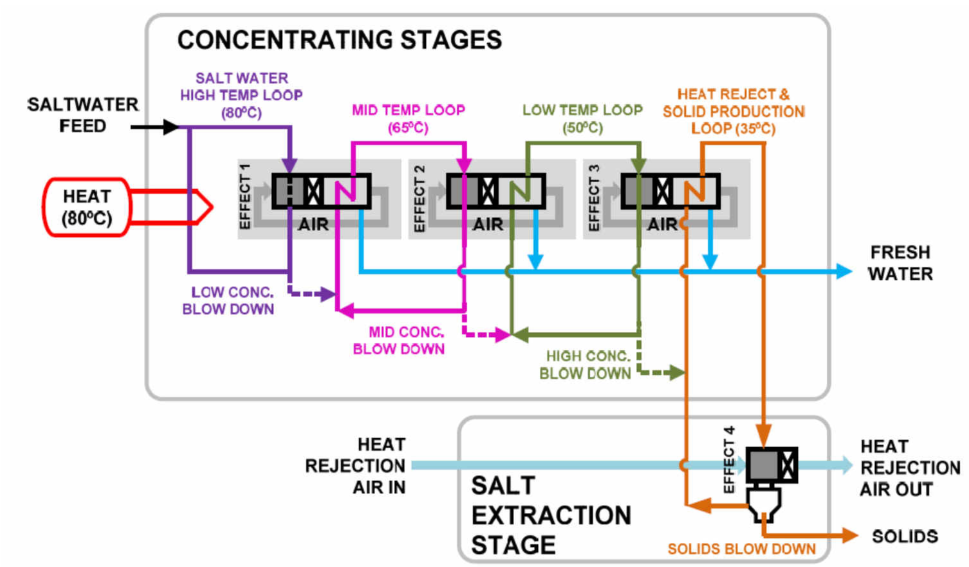



**Figure 4 – Conceptual Operation**

SaltMaker can accept any wastewater salinity; lower inlet TDS increases system freshwater recovery. Additionally, the scaling potential of the wastewater impacts the frequency of the wash cycles and the plant’s production capacity. However, the built-in cleaning systems are flexible enough to accept almost any water type.

The SaltMaker general flow diagram is illustrated in Figure 6.

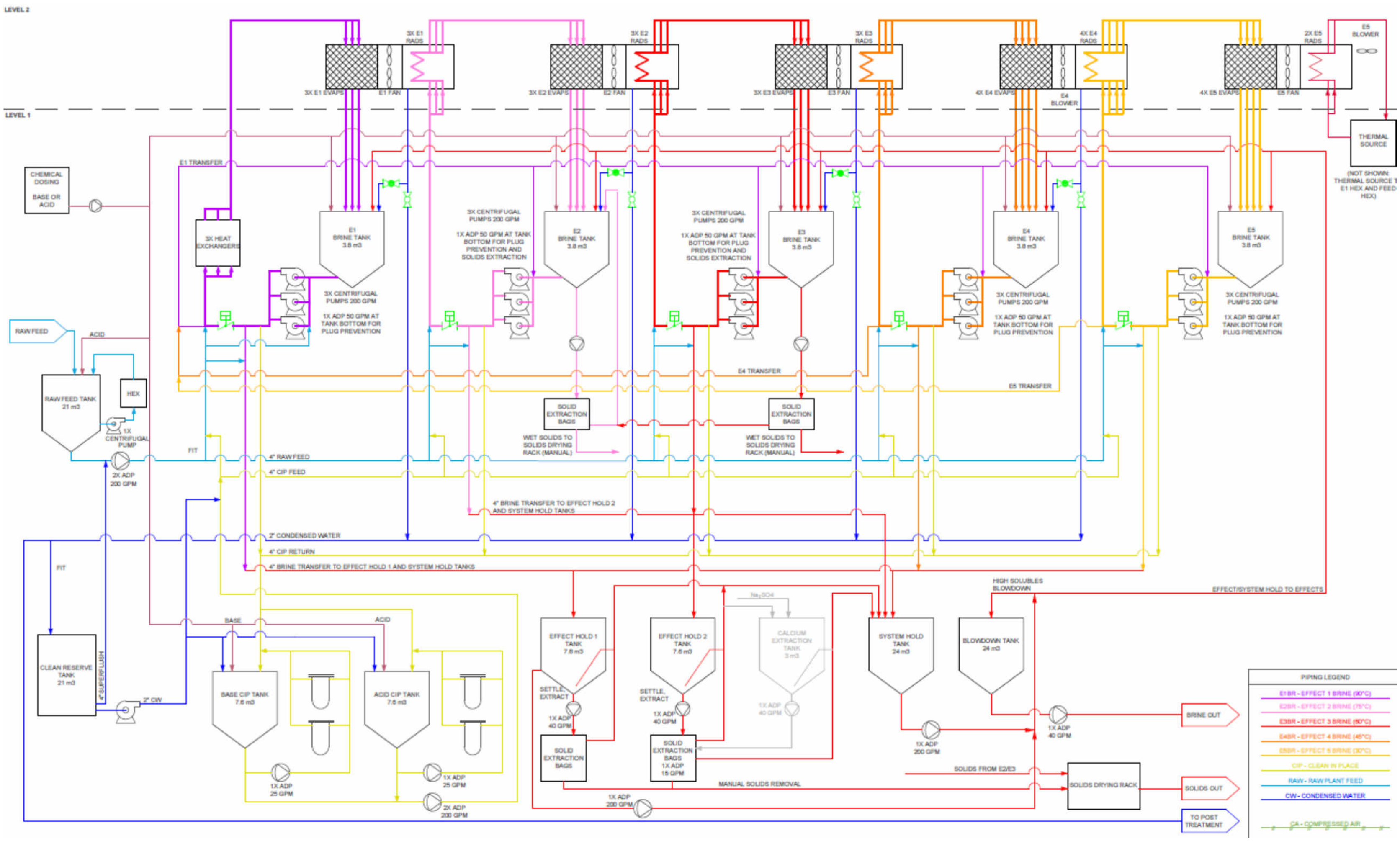



**Figure 5 – SaltMaker Process Flow Diagram**

#### *2.1.4 Post-Treatment*

Distilled water from the SaltMaker unit needs to be treated mainly for volatiles such as ammonia and nitrite (resulting from ammonia oxidation). The proposed chain is a chemical oxidation of nitrite with sulfamic acid followed by a reverse osmosis filtration step.

##### *2.1.4.1 Nitrite Removal*

The overall reaction between nitrite and sulfamic acid is presented below:

$NaNO_2 + H_3NSO_3 \rightarrow N_2 + NaHSO_4 + H_2O$

This reaction leads to the formation of nitrogen as the final product of nitrite removal.

Distilled water from the two SaltMaker units is stored in two 21 $m^3$ tanks. Sulfamic acid is then added in batch mode to remove nitrite (one reactor is treated while the second one stores distilled water). Acid dosage is controlled by a pH sensor. An optimum pH of 2-3 needs to be reached for effective nitrite removal. The reaction time is about 1-2 minutes in the reactor. The pH of the water from the nitrite removal tank is then adjusted to 4.5 using caustic soda prior to the reverse osmosis process.

##### *2.1.4.2 Ammonia Removal by Reverse Osmosis*

Reverse osmosis (RO) is a water purification technology that uses a semi-permeable membrane to remove ions and molecules. In RO, an applied pressure is used to overcome osmotic pressure. Normally, water to be treated with RO has to be pretreated for suspended solids, bacteria, and scaling compound. In the present case, as the water comes from an evaporation process, it should be easy to pre-treat. A recovery of 96% is expected.

The RO system operates at variable recovery based on the conductivity (salt and ammonia content) of the permeate. If the permeate conductivity is too high, the RO will lower recovery by opening the concentrate valve, allowing more water to flow to the concentrate stream and less water to be directed to the product stream.

Filtration is done at low pH (approximately 5.5) to promote the ammonium form which is best retained by the RO step.

The flowsheet for the RO process is presented in Figure 7.

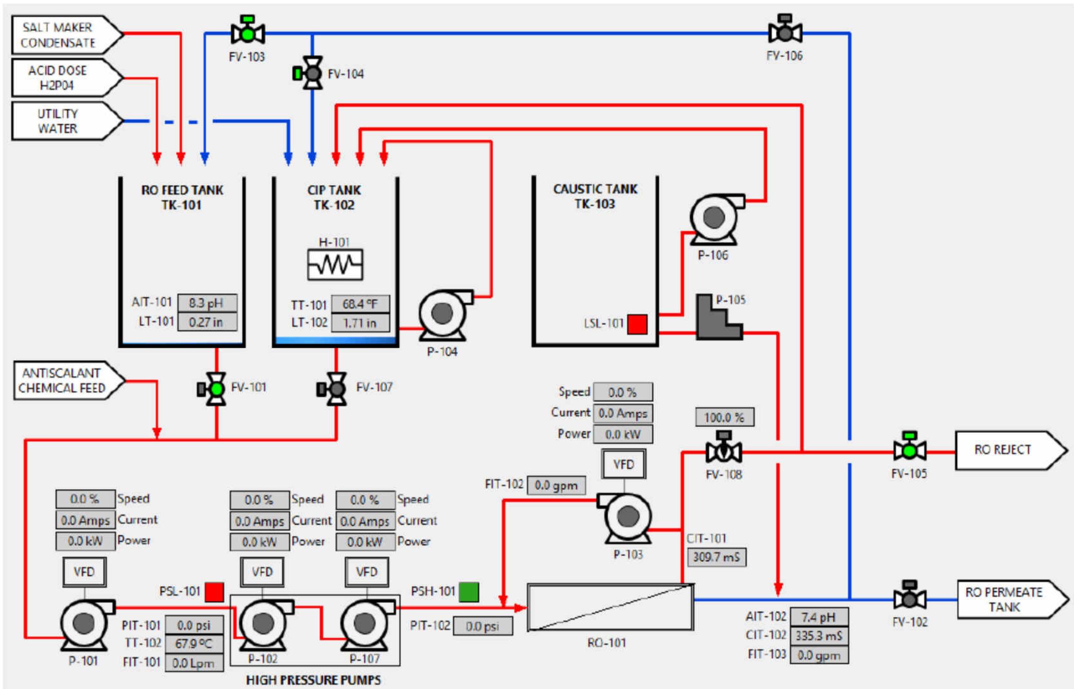



**Figure 6 – Reverse Osmosis Process Flow Diagram**

### *2.1.5 RO Brine Treatment for Ammonia*

Brine from the RO process contains a high concentration of ammonia. In order to prevent a build-up of ammonia in the process, this compound is oxidized with calcium hypochlorite in a 7.6 m$^3$ tank (this reaction is also commonly called 'breakpoint chlorination'). Two tanks are available for brine storage (one in ammonia destruction mode; the second in brine storage mode). The treatment is done manually in batch mode by the operator. The pH is adjusted to alkaline values. The required quantity of calcium hypochlorite is determined by the operator on the basis of the ammonia analysis obtained with a colorimetric test kit. Calcium hypochlorite is added directly in solid form. The retention time is also determined by the operator and is typically around 10 minutes.

The overall reaction leading to the release of nitrogen and nitrate as a final product is presented below:

$NH_4^+ + 1.5\ HOCl \rightarrow 0.5\ N_2 + 1.5\ H_2O + 2.5\ H^+ + 1.5\ Cl^-$
$NH_4^+ + 4\ HOCl \rightarrow NO_3^- + H_2O + 6\ H^+ + 4\ Cl^-$

Treated water is recirculated back to the SaltMaker units.

### *2.1.6 Salt Bagging System*

Salt slurry is discharged into a big bag rack. Loading of each big bag is controlled by load cells. An automatic valve discharges the slurry into a big bag until it is full. Once the bag is full, another big bag is positioned to be filled. The big bag is left to drain of free water until it only contains solid salts. Free water (high salinity leachate) is recycled to the SaltMaker unit for further treatment. Figures 8 and 9 present the concept for the salt bagging system.

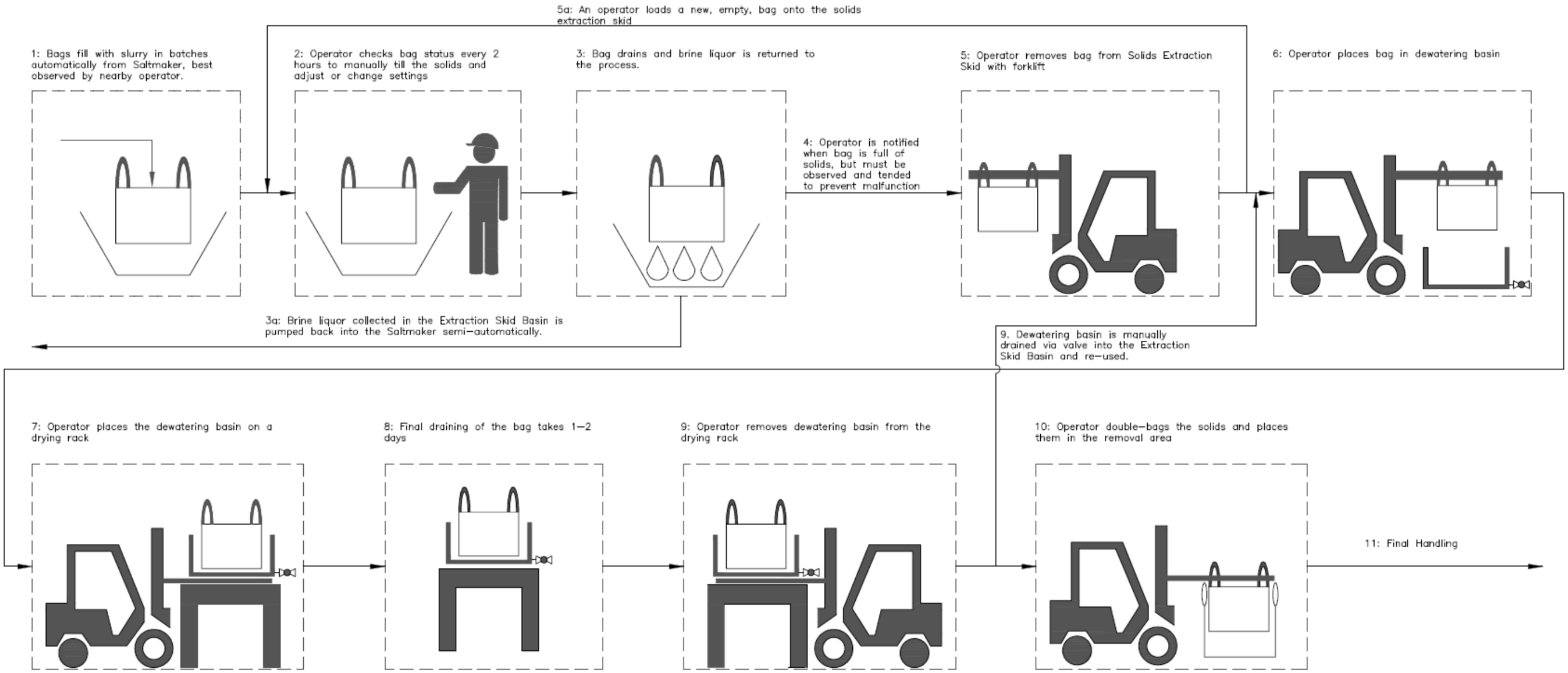



**Figure 7 – Salt Bagging Concept**

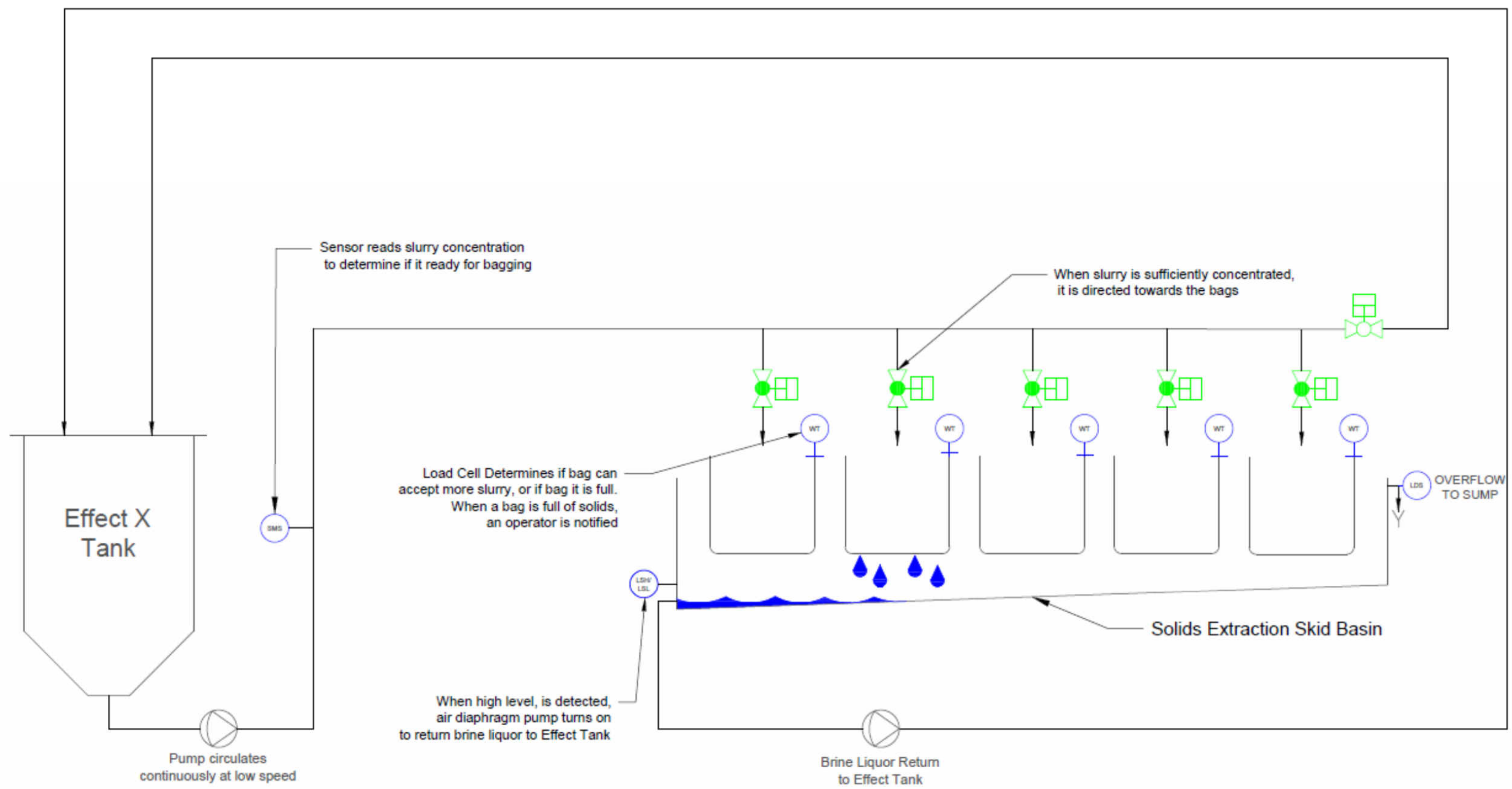



**Figure 8 – Salt Bagging Flow Diagram**

### *2.1.7 Blowdown Management*

The salt is mainly composed of Ca, Na and Cl. Underground water also contains a non-negligible amount of nitrate which do not precipitate during the salt production step. Therefore, the nitrate is recirculated in the SaltMaker where it accumulates. Overly high concentrations of nitrate leads to an increase in the viscosity of the water to be treated, causing the efficiency of the Saltmaker to decrease significantly. To prevent a nitrate build-up, approximately 1% of the feed flow should be removed. This corresponds to a volume of approximately 1.2 $m^3$ per day. During operation, a volume of 10 $m^3$ is be removed periodically and stored in a blowdown tank.

The blowdown solution is stored in tote tanks and sea cans. Once a year, the sea cans are sent back south whereby the totes are dealt with by a subcontractor who disposes of the solution according to regulations.

### *2.1.8 Water Heater*

Three water heaters are to be used to heat water to approximately 80$^{o}$C (first effect of the SaltMaker unit). Heat plate exchangers are used to transfer heat between the water to be treated and the thermal source. The thermal units are diesel driven.

### *2.1.9 Service Water System*

The service water system is mainly based on reusing distilled water produced within the plant. A 21 $m^3$ clean water reserve tank is be used for storage.

### *2.1.10 Controls*

The SWTP Pump is equipped with a variable frequency drive (VFD) that allows the flow to be modulated.

The SaltMaker system and post-treatment use a variety of sensors and automation hardware to achieve reliable plant operations. Sensors include temperature, pressure, flow, level, conductivity, and pH.

The electrical and control system for the post-treatment consists of a main control panel with multiple alternating current (AC) drives, switch gear, terminal blocks as well as the Programmable Logic Control (PLC) and modules. AC drives allow variable speed on the feed pump, high pressure pumps, and RO recirculation pump. The drives allow the control system to make flow and pressure adjustments to maximize RO recovery and efficiency. The panel houses the Human Machine Interface (HMI), conductivity and pH transmitters for operators. All instrumentation and automation functions are carried out by the PLC based on signals from sensors.

Saltworks standardized on 4-20 mA analogue sensor outputs to minimize signal loss issues. 4-20 mA signals are read by input/output (I/O) modules on the PLC or Remote I/O units.

The SaltMaker and post-treatment use the following types of instruments:

**Pressure:**
These sensors are used to measure pump discharge pressure on main water lines on each effect. Trends in pressure readings can help the operator identify pipe scaling issues. They can also be used to identify pump problems. These pressure sensors use piezoresistive measuring cells (similar to a

strain gauge) to measure pressure being applied on the sensor connector. A built-in transmitter amplifies this signal and converts it into 4-20 mA to communicate with the PLC modules.

For the post-treatment, these sensors are used to measure the pump inlet/discharge pressures. Trends in pressure readings can help the operator identify filter clogging or membrane fouling issues. They can also be used to identify pump problems.

**Level:**
These sensors are used to measure the level on SaltMaker tanks and post-treatment. Different types of sensors are used depending on the fluid and process conditions.

> ***Pressure:*** These sensors use piezoresistive measure cells that are calibrated at high resolution to measure level changes in tanks. They are mounted near the bottom of the tank. Because they measure hydrostatic pressure, they are affected by density changes of the fluid.
>
> ***Ultrasonic:*** These sensors send ultrasonic sound pulses and measure the time it takes for the pulses to reflect and bounce back from the process medium below and return to the sensor. This is translated into a level measurement. These sensors are mounted on top of the tank and do not come into direct contact with process fluids.
>
> ***Radar:*** These sensors send radar pulses and measure the time it takes for the pulses to reflect and bounce back from the process medium below and return to the sensor. This is translated into a level measurement. These sensors are mounted on top of the tank and do not come into direct contact with process fluids. In general, radar has performance and reliability advantages over ultrasonic. Suitability of radar versus ultrasonic sensors depends on actual tank conditions and is outside the scope of this manual.

Level sensor feedback allows for automated level control by filling and transfer of water in process tanks. The system is vital to continuous operation of the SaltMaker. Proper SaltMaker operations produce a unique saw-tooth pattern on main effect tanks, with a slow decrease in tank level due to evaporation and a fast increase in levels due to the transfer of process fluids into the tank. Automated level warnings help operators locate issues before they become serious enough to interrupt operations.

For the post-treatment, level sensor feedback allows for automated level control by filling and transfer of water in process tanks. The system is vital to continuous operation of the Post-Treatment RO. Automated level warnings help operators locate issues before they become serious enough to interrupt operations.

**Conductivity:**
These sensors are used to measure the conductivity of water, which is proportional to the ionic or salt concentration of the water. The SaltMaker deploys two different types of conductivity sensors:

> ***Contacting Conductivity Sensors:*** These sensors employ a potentiometric method. Two or four electrodes are submersed in the sample fluid. The sample fluid completes the electrical circuit. A potential is proportional to the conductivity of the fluid. Saltworks uses this type of sensor to measure a conductivity range from 0-5 mS.
>
> ***Inductive Conductivity Sensors:*** Two coils are wound inside the ring-shaped sensor. One coil drives a magnetic field with a known voltage and induces a current on the second coil. This current is proportional to the conductivity of the measured fluid. This type of sensor is suitable for measuring conductivity in the 5-1000 mS range.

Conductivity sensor signals help operators monitor the concentration of process water in different effects. By tracking an increase in concentration of brine over time, these sensors ensure that the SaltMaker is functioning normally.

For the post-treatment, conductivity sensor signals help operators monitor the concentration of the concentrate and permeate process streams. By tracking conductivity changes over time, these sensors ensure that the Post-Treatment RO is functioning normally.

**pH:**
These sensors contain a potentiometric cell made of pH-sensitive electrodes. Voltage is measured across the electrodes and the signal is amplified and processed into a 4-20 mA signal. pH sensors help monitor the condition of treated and untreated water. They are also used in optional acid and base dosing systems to monitor and control pH to adjust the solubility of the process water to different salts.

**Temperature:**
These sensors measure the temperature of the process streams. The SaltMaker and post-treatment use resistive RTDs (resistance temperature detectors) which are sensors that measure a change in resistance due to a change in temperature. This signal is amplified and processed into a 4-20 mA signal with a transmitter. Temperature differences between the effects provide the main driving force for the humidification-dehumidification (HDH) process. Abnormal temperature differences would indicate problems with heat transfer between one effect and the other. These sensors help operators track temperature across all the effects to confirm normal operations.

**Weight:**
Load cells measure the mass of the salt produced and stored in big bags. This information let the operator know when to replace the big bag.

# 3 OPERATION AND MAINTENANCE

## 3.1 PUMPING

The SaltMaker uses variable speed pumps to circulate saltwater around effects. The pumps are driven by variable speed drives that provide a controlled start-up and shutdown of the plant. The pipes are mounted on a pump skid that includes the pipework and instrumentation necessary to connect to the effect modules and the hot wash system. The drives also vary the speed of the pumps to induce turbulent flows to reduce scaling and fouling. The electrical draw of the VFD pump is monitored for indication of system fouling.

The SaltMaker effect pipework treating high temperature brine, including Effects 1, 2 and 3, and hot washes is made of Schedule 80 CPVC. CPVC can operate reliably at up to 90ºC at low pressures. The pipework on the effect running at the lowest temperature, Effect 4, is made of Schedule 80 PVC, and can operate reliably at up to 60ºC. The pipework on the pump skids includes the pump seal flush and pump shaft wash systems. These systems keep salt crystals from accumulating near the pump seals and the pump shaft, and are crucial for the long-term reliability of the SaltMaker. If salt crystals accumulate, they could wear out the pump seals and cause premature failure of the pump.

The solid extraction auger, or hose pump, is designed to remove slurry that settles at the bottom of the brine cone tank. Depending on the brine chemistry, solids or slurry are extracted from the brine tank into a collection bin. In the case of slurry extraction, solids are extracted and the supernatant liquid is pumped back to the brine tank.

All pumps are regularly inspected by the operator who ensures the pumps continue to operate efficiently and addresses any deficiencies. If the pumps require maintenance, the operator reports the situation and takes appropriate action. Some of the pumps are installed with a standby unit that allows the operator to switch from one pump to the other if necessary. In some situations, it may be necessary to temporarily shut down the SWTP for servicing of the equipment.

A preventative maintenance program, as recommended by the pump supplier, is followed by the Maintenance Crew to ensure that the pumps are always kept in good working order.

## 3.2 REAGENT PREPARATION

Most of the chemicals are supplied in liquid form (and dosed using a dosing skid pump directly into the process) except for the sulfamic acid, calcium hypochlorite, sodium meta-bisulfite and trisodium phosphate which must be prepared manually before dosing.

The solutions made with these products are prepared according to the MSDS provided by the suppliers.

### *3.2.1 Sulfamic Acid Preparation*

Sulfamic acid is added into a sulfamic acid tank according to the MSDS procedure.

### *3.2.2 Calcium Hypochlorite Preparation*

This chemical is dosed directly as a solid into the ammonia destruction reactor. No special preparation is required.

### 3.2.3 Trisodium Phosphate Preparation

This chemical is prepared manually once by operators during commissioning for cleaning. No special preparation is required.

### 3.2.4 Sodium Meta-Bisulfite Preparation

This chemical is only used for membrane preservation during a shutdown or long period of non-treatment. This chemical is prepared manually by the operator if required. No special preparation is required.

## 3.3 REAGENT DOSING

During the daily inspection, the operator monitors the different reagent systems and prepares additional reagent, as required, according to the reagent preparation procedures in place. The water levels in the mixing and distribution tanks are connected to the control system, which ensures sufficient water is supplied to the reagent preparation systems. In the event of a lack of water supply, a low-level alarm occurs to notify the operator.

Preventive maintenance of the mechanical equipment is performed according to the supplier operating manual specifications.

### 3.3.1 Acid/Base Dosing Systems

Depending on process water chemistry, an acid or base dosing system may be integrated into the SaltMaker processes. Acid dosing can be employed to reduce scale formation (e.g. carbonates) or to preferentially keep some compounds dissolved in the brine (e.g. ammonia) by adjusting the pH of the brine between pH 3 – 5. Similarly, base dosing can also be employed to keep compounds dissolved (e.g. hydrogen sulphide) by adjusting brine pH between pH 9 – 10. The acid/base dosing system consists of dosing hardware as well as pH probes installed in the process water line and Effect 1 hot wash tank to continuously measure pH. Should the solution pH fluctuate above or below the operator set-point, acid or base solution is dispensed to the appropriate tank.

### 3.3.2 Antifoam Dosing System

Depending on process water chemistry, brine foaming may occur as the process water is concentrated. Foam may overflow from the tank, leading to a containment breach. To keep foaming under control, an antifoam chemical can be added to the brine tanks. The antifoam system consists of foam detection sensors, dosing hardware, and a timer based on foam detection dosing controls. When antifoam dosing is initiated, compressed air is used to open valves and to power the dosing pump for chemical dispensing into the specific tank.

### 3.3.3 Antiscalant Dosing Method

Antiscalants are added to the concentrated brine to inhibit the formation of calcium scaling in SaltMaker wetted parts. Typically, the operator would add antiscalants once every 48 hours.

### 3.3.4 Biofilm Treatment System

The biofilm treatment system is used to keep biological growth in the heat recovery modules and basins under control. The system includes a treatment solution holding tank, an air-powered pump, air-actuated valves, and a set of nozzles to spray heat recovery modules on all sets in all four effects. This treatment system distributes a disinfectant mixture to kill micro-organisms and keep slime from forming on heat exchanger surfaces and in collection basins.

#### *3.3.5 Sulfamic Acid Dosing*

Sulfamic acid is added in batches to the tank of SaltMaker-treated water until a target pH of 2-3 is reached. This pH is optimized for complete nitrite destruction. The dosing pump is controlled by a pH sensor.

#### *3.3.6 RO Acid Dosing System*

Acid is dosed to the RO pre-conditioner holding tank. The pH set point should nominally be 5.5. If the process water pH is above the post-treatment RO set point, acid dosing to the tank is activated for a set duration. Ample mixing time is provided after each dose. The cycle is repeated if the pH is still high after the mixing time has expired.

#### *3.3.7 RO Caustic Dosing System*

Caustic is dosed to the RO permeate in order to meet the pH discharge permit requirements. The set point is 6.5. The caustic is continuously dosed into an injection quill. There is a static mixer between the quill and the pH probe to ensure mixing.

#### *3.3.8 RO Operation-Cleaning Dosing System*

The clean-in-place (CIP) system is designed to clean fouled RO membranes by circulating a warm caustic solution through the RO system. The CIP system consists of a caustic pump, a CIP tank, a CIP tank mixer, and a CIP tank heater. The caustic pump runs for a predetermined time to ensure that sufficient caustic has been added to the tank. The CIP sequence is as follows:

- The tank is filled with permeate or chlorine-free service water.
- The heater and circulation pump starts.
- Caustic is added to the tank by the caustic pump.
- The heater runs until the temperature set point is achieved.
- The CIP solution displaces residual water in the RO system.
- The CIP solution circulates through the RO for 30 minutes.

The CIP solution pH is continuously monitored to ensure the pH target is maintained. If the pH of the solution drops below a set-point, the caustic pump dispenses caustic solution for a predetermined time and the solution is mixed by the CIP tank mixer. The pH is measured again to ensure fluid is within the pH operating range.

Both the concentrate and permeate return to the CIP tank during circulation. Once the wash timer expires, the CIP solution is discharged. The RO is then rinsed with chlorine-free service water or SaltMaker fresh water.

### 3.4 SOLID EXTRACTION

#### *3.4.1 Salt Extraction System: Screw Augers*

The salt extraction system screw augers are designed to extract suspended or settled solids. The screw augers are located in the brine tanks of Effect 2 and Effect 3, the highest concentration effects. These augers are controlled by a VFD and, therefore, speed can be adjusted by the operator. Auger controls are timer-based with a high-speed and low-speed setting, and have forward and reverse rotation configuration. When saturation limits are exceeded, salt precipitation occurs. The screw augers extract the solids into a mesh bag inside the collection bin. The mesh bag filters the solids from any brine that may be extracted along with the solids. The brine is recycled back to the brine tank for further concentration. The solids captured by mesh bag filters can be disposed of as solid waste.

#### *3.4.2 Salt Extraction System: Brine Extraction Pumps*

The salt extraction system brine extraction pumps are designed to discharge concentrated brine from the base of the Effect 2 and Effect 3 brine tanks. These pumps are designed for pumping fluids near saturation. The pumps serve two purposes:

**Concentration Control**: Once Effect 2 and Effect 3 tanks reach a certain concentration, these pumps discharge some of the brine to maintain a steady concentration of E2 and E3 brine.

**Recirculation and Agitation**: When the salt extraction system is not discharging, the pumps run in recirculation mode to concentrate the tank to the appropriate concentration to discharge or to prevent salt crust formation when the process fluid is near saturation. Additionally, there are vibrators inside the Effect 2 and Effect 3 cone tanks that turn on and off based on a timer, to agitate and break up solids forming in the tank.

### 3.5 ANTI-CRUSTING AND WASH SYSTEM

#### *3.5.1 Crusting Phenomena*

The SaltMaker is designed to concentrate brine up to crystallization. To achieve this, the SaltMaker separates water from brine at relatively low temperatures using waste heat or a low temperature thermos-source. Concentrated brine may crystallize or "scale" in all parts of the process at different rates. The goal is to control the build-up and remove enough solids from the system so that it can maintain reliable operations. The following causes can increase the crusting rate in the plant.

**Low Flow Sections:** Moving flow prevents the accumulation of salt crust due to constant agitation of moving fluids. If there is a low or stagnant flow in a section of a pipe, salt crust is much more likely to stick to the surfaces. This salt attracts other crystals which stick to it and thus, the crust increases in size. Mitigation methods include increasing flow and agitation through these sections. Washes with lower concentration solution help re-dissolve some of this salt crust. Higher flow also helps "loosen" the crust from the surface and carry these crystals back to the tank where they can be managed.

**Changes in Temperature:** The solubility of most solutions increases with an increase in temperature. For example, a solid liquid mixture at 60ºC may become totally dissolved at 80ºC. However, some solutions behave in the opposite manner, meaning that crystals tend to form at higher temperatures. The important takeaway from this is that a change in temperature impacts the rate that salt crust forms in different sections of the plant. The SaltMaker relies on effective heat exchangers to transfer heat from Effect 1 -> 2 -> 3 -> 4. If the temperature of the effects starts drifting away from normal operating conditions, the operator should investigate the cause and apply the washes that target the problem.

**Process Interruptions:** A process interruption would mean a stop in agitation or flow. This can cause salt crust formation very quickly in the system. SaltMaker has a built-in wash sequence that helps keep pipes clean and crust from forming when stopping the system. An emergency stop or power loss would interrupt this wash sequence, allowing salt crusts to form in many areas of the SaltMaker if it was operating at high concentrations prior to the interruption. If there is a power interruption or if it is unsafe to clear the E-stop for a period of more than a few hours, the operator is required to wash the system manually assuming that a pressurized fresh water supply is available. Manual washes prevent many problems with the SaltMaker start-up once power is restored.

**Exposure to Ambient Air:** Ambient air is cooler and drier than the air inside the effects. When a highly concentrated solution is exposed to this air, evaporation and the reduction in temperature cause salt crust to form in the solution. It is therefore important to keep the effects and modules well insulated. Insulation also helps increase the thermal efficiency of the system. Basins of modules need periodic washes to prevent this type of build-up.

To prevent crusting, several cleaning procedures could be used as presented below.

### *3.5.2 Hot Wash System*

The hot wash system is critical for SaltMaker maintenance and operation. It aids in salt crust removal on equipment and ensures longevity of the plant. Hot wash cycles consist of periodically flushing each effect with hot water to remove salt crust build-up, reducing maintenance and keeping wetted parts of equipment operating smoothly. Described below are the different types of SaltMaker hot washes, which include: evaporator basin wash, pipework wash, evaporator packing spray wash, level sensor wash and pump seal flush. All wash cycles, except for the manual cone tank wash, can be initiated by a set timer or manually by the operator. Hot wash frequency varies with water chemistry, but should be kept to a minimum to prevent brine dilution and to limit effect downtime.

**Evaporator Basin Wash**: The evaporator basin wash is a short hot wash used to clean the saltwater pump, piping, the heat recovery radiator, and the evaporator. Once the evaporator wash is initiated (automatically or manually), hot water is sent through the pump and into the piping. This water then flows through the heat exchanger and into the evaporation module. This wash reduces salt build-up with minimal downtime and brine dilution. Normal operation of the SaltMaker resumes immediately after this burst of hot water is sent through the system. When operators suspect a salt build-up problem (e.g. pump loads increase), it is recommended that the operator try this wash first. This wash is enough to help clean pumps and dislodge salt build-up in many cases.

**Pipework Wash**: The pipework hot wash is a thorough wash to clean the saltwater pump, piping, and the heat exchanger in the heat recovery module. Once the pipework wash is initiated (either manually or automatically), compressed air is enter the piping and push the saltwater back into its respective main tank for a user-defined duration. Hot water flows in a closed loop through the piping, pump, heat exchanger, and back to the satellite hot wash tank. The duration of this cycle is set by the operator. Once the hot wash is finished with the first set, it cleans the remaining sets in the effect using the same order of operations described above. For the final set, instead of returning hot wash water back to the satellite tank, the hot wash water is cycled back into the main tank.

**Evaporator Spray Wash**: The evaporator spray hot wash cleans the evaporator fill. Nozzles are mounted inside the evaporator to increase the effectiveness of the spray. Once the evaporator spray wash is initiated, the pump stops, and the valve for the evaporator spray wash opens. The hot water from the evaporator spray wash comes from the main hot wash system. The duration of the evaporator spray wash can be set by the operator.

**Pump Seal Flush & Pump Shaft Wash**: The pump shaft wash is a short, hot wash that sprays water directly onto the pump shaft to prevent salt build-up. Once the pump shaft hot wash is initiated, hot water from the main hot wash system is sprayed onto the pump shaft. Duration is set by the operator. Use this wash when there is visible salt build-up around the shaft between the pump and the motor.

### *3.5.3 Shutdown and Start-up Wash*

Shutdown washes should be performed before plant shutdown to remove concentrated brine from the SaltMaker pipework system to prevent potential salt crystallization and clogging in valves, pumps, or pipework. The shutdown wash sequence is automated. Before shutting down the SaltMaker, confirm that the “Shutdown Wash” control is enabled for each effect, and the system performed the proper washes before shutting down. Before commencing SaltMaker operation after an emergency stop or alarm trip with no shutdown wash, the operator should perform a start-up flush. This wash cycle aids in removing any crystallized salts resulting from concentrated brine remaining in the system. It is important to remove any crystallized salts from the system to protect equipment (e.g. pumps, valves, pipework) and ensure SaltMaker reliability.

### *3.5.4 Chemically Enhanced Hot Wash*

A chemically enhanced hot wash is used in the event that the SaltMaker heat exchanger surface or pipework system becomes crusted with salts. This hot wash involves cycling a chemical solution through the pipework system where the crust has formed; the type of chemical solution used in the hot wash cycle is dependent on the type of crust formation. Manual inspections of heat exchanger surface and evaporator informs the operator of the need of a chemically enhanced hot wash.

### *3.5.5 Effect Swap Cycles*

To prevent salt crust from forming on the evaporation modules of the SaltMaker, Effects 1 and 4 operate at a concentration that inhibits solid salt formation. Effect 2 and Effect 3 operate at higher concentrations, and thus have the potential to build up salt crust which can severely limit the operability of the plant. To reduce salt crust formation, Effects 2 and 3 operate at alternating high and low concentrations by swapping water sources based on a timer. Cycling lower concentration water to a high concentration effect dissolves and removes any crust build up that has formed. The concentration swap mode is fully automated. The operator can adjust the time interval between swaps, or manually trigger a concentration swap between Effects 2 and 3. Use this when Effect 2 or Effect 3 is near saturation, and Effect 2 is showing rapid signs of crusting.

## 3.6 REVERSE OSMOSIS

### *3.6.1 Operating Ranges*

For the safety of the operator and protection of equipment, always operate the system within the operating ranges as specified below.

- Operating temperature range: 35 – 95 ºF (2 - 35ºC)
- Operating pH range: 4.5 to 6 for optimal ammonia removal
- Electrical: 480 V, 3P, 60 Hz. Inlet Specifications
- Post-treatment RO is designed to treat SaltMaker condensed water.

Reverse osmosis (RO) elements are housed in RO pressure vessels and see high operating pressures. Proper care and maintenance is required to keep these pressure vessels in safe operating condition.

### 3.6.2 RO Wash Cycles

The Post-Treatment RO should be cleaned when the normalized flux decreases by more than 10% of the baseline flux.

**Start-up Flush:** This flush happens every time on start-up. The valve from CIP opens. After a delay, the feed pump turns ON. The high pressure pumps turn ON next, and the brine recirculation pump turns ON to increase crossflow. The RO reject valve opens to discharge flush water. The flush is complete after a user-set time has expired. The RO Feed Tank Valve opens and the CIP Tank closes and the plant starts up.

**Shutdown Flush:** This flush happens every time on shutdown. The valve from CIP opens. After a delay, the feed pump turns ON. The high pressure pumps turn ON next, and the brine recirculation pump turns ON to increase crossflow. The RO reject valve opens to discharge flush water. The flush is complete after a user-set time has expired.

**Inactivity Flush:** When this flush setting is enabled, the RO system flushes after a certain period of inactivity of the RO system, based on the set-point. This flush is necessary to preserve the RO membranes. This flush sequence is similar to the Shutdown flush.

**CIP Flush:** This flush is a thorough cleaning process which involves the use of caustic stored in the caustic tank. The flush is meant to be done once every 6 months to 1 year. Before triggering this flush, please make sure that there is enough caustic in the tank for a proper wash.

When this flush is triggered, the caustic pump transfers fluid to the CIP tank. The CIP circulation pump runs to keep the caustic evenly mixed. When this is complete, the CIP inlet valve to fed pump opens, and the feed pumps, high pressure pumps, and the brine re-circulation pump runs in succession. The RO Reject valve closed, and the CIP fluid circulates back into the CIP tank. The wash keeps going until the user-settable timer has expired.

### 3.6.3 RO Membrane and Filter Replacement

When prefiltration loss of pressure is too high, the bag filter needs to be replaced by a new one. A procedure is provided in Appendix B.

When performance is not reached after the cleaning procedure, the RO membrane has to be changed. A procedure is provided in Appendix B.

## 3.7 WATER HEATER

The boilers are operated in automatic mode in the plant. However, preventive maintenance should be done according to the Operation and Maintenance Manual to prevent any malfunction.

## 3.8 OPERATION CHECK

The SaltMaker is fully automated and can be left with minimal supervision after initial start-up. Intelligent controls notifies the user through warnings and alarms if the plant needs operator attention. The following checks should be performed before running the SaltMaker unattended for a few hours (e.g. running overnight):

- Daily checks are recommended to ensure increased uptime and early detection of problems.
- Weekly checks should be done by the operator whether the SaltMaker is in operation or offline.

Setting proper SaltMaker cleaning cycles is essential to the continuous operation of the SaltMaker. If salt crust is encountered in some of the systems and pipework, the operator can manually initiate each wash sequence.

### 3.9 EFFLUENT QUALITY CONTROL

Treated water from the saline water treatment plant will be discharged into CP1.

The operator must conduct regular inspections of the entire operating system to ensure it operates as intended. Any upset condition is reported and corrective actions will be applied accordingly. The operator must also record key process parameters that will allow the process to be optimized and any discrepancies between the process and expected performances to be detected.

The quality of the treated water from the SWTP is monitored on a continuous basis by pH, temperature and conductivity.

Treated water is sampled for water quality periodically (pH, aluminuim, arsenic, boron, cadmium, chloride, copper, chromium, mercury, ammonia, nickel, nitrite, nitrate, phosphorus, lead, selenium, total dissolved solids, thallium, total cyanides and zinc) and sent to a certified laboratory for analysis. Table 1 presents the treatment target. The results generated by the laboratory will be compared with those obtained with the plant instrumentation to detect any deviations. All the probes and instrumentation within the plant will be calibrated and serviced as per the preventative maintenance program.

**Table 1: Treatment objectives[1]**

| Parameter (Total, mg/L) | Maximum Allowable Salt Plant Effluent Concentration |
|---|---|
| Aluminum | 6 |
| Arsenic | 1 |
| Boron | 4 |
| Cadmium | 0.0003 |
| Chloride | 2500 |
| Copper | 0.7 |
| Chromium | 0.003 |
| Mercury | 0.0001 |
| N-NH4 | 35 |
| Nickel | 1.3 |
| N-NO2 | 0.2 |
| N-NO3 | 2 |
| Phosphorous | 0.1 |
| Lead | 0.6 |
| Selenium | 0.0025 |
| TDS | 1400[2] |
| Thallium | 0.003 |
| Total Cyanide | 1.5 |
| Zinc | 1.3 |

[1] Treatment objective values come from geochemical model made by Golder (2017) for a dry climate, taking into account the dilution occurring into CP1 (Ref: 6515-E-132-013-105-DGC-003).
[2] Maximum concentration for the final effluent (ref: Water License No. 2AM-MEL1631)

### 3.10 RECORD KEEPING

Records of the operational and maintenance and sampling procedures must be accessible to assist in the evaluation of the SWTP performance. Details of any maintenance undertaken at the SWTP are also be recorded. The data are saved on a network database.

### 3.11 SAFETY PROCEDURES FOR OPERATORS

Operators working in the SWTP facility must be trained prior to work so that they are aware of the health and safety risks as well as the operational procedures associated with the SWTP. The following are important safety considerations:

- Working with non-treated water requires adequate personal protective equipment (PPE) for operators. This includes wearing steel-toed boots, hard hat, long sleeves and pants, safety glasses with side shields, respirators (when appropriate) and gloves for chemical handling.
- Operators are required to conduct good housekeeping of the working area to minimize the risk of incidents.
- Lock-out/tag-out procedures must apply when servicing equipment.
- The MSDS for reagents used in the SWTP will be readily available for the operator at all times.
- Eyewash stations are located within proximity of reagent systems in the SWTP.

### 3.12 CONTROLLING ACCESS TO THE SWTP

Access to the SWTP are restricted to authorized personnel only. Signs are posted at the SWTP entrance.

## 4 EMERGENCY RESPONSE

### 4.1 FIRE

In case of fire at the SWTP, the on-site emergency response team (ERT) will be notified as per Agnico Eagle's protocol. Instructions from the on-site emergency response team will be followed by all personnel at the SWTP. Further details of fire response are provided in the "*Risk Management & Emergency Response Plan*". The SWTP includes the necessary fire safety protection measures in accordance with the Nunavut and North West Territories Mine Act.

### 4.2 SPILL

Spill kits and the necessary secondary containment are provided within the building of the SWTP. In the event of a spill at the SWTP, the Environment Department will be notified immediately and provide support, as required. In the event of a large spill, the on-site ERT will be notified as per Agnico Eagle's protocol. Instructions from the ERT will be followed by all personnel at the SWTP. A spill kit is available at the SWTP. Further details regarding the site spill response procedure are provided in the "*Spill Contingency Plan"*.

### 4.3 PLANT MALFUNCTION

If there is a major problem or failure in the SWTP, it will be likely due to a problem with crusting or scaling of the systems caused by the malfunction of the pump, inadequate chemical dosage or loss of temperature control.

In the case of an operational upset, the most likely consequence will be a decrease of treated water production. In such an event, the problem will be investigated. In any case, if the treated water quality does not reach an acceptable level to be discharged into CP1, the water will be recycled to the saline pond. Once the problem is resolved and the water quality returns to concentrations within discharge criteria, the valves will be reopened to allow discharge to CP1.

In the event of an emergency, the E-Stop button on the HMI or a physical E-Stop button on the control panel can be pressed. In case of an emergency shutdown or power loss, all systems will shut down immediately and no hot wash is initiated. To restart the plant, the operator must clear the Emergency Alarm and any other process alarms that may have been triggered during the emergency shutdown. After an emergency shutdown, the SaltMaker plant will require a “Pre-Start-up Flush” before starting again. An alternative would be to perform a full manual flush while power is down.

For the reverse osmosis process, a major malfunction could result from an inadequate membrane filtration in which case the membrane must be changed. The RO Post-Treatment Emergency Stop only shuts down the Post-Treatment RO system. The SaltMaker and other ancillary systems will continue to run. To shut down all systems, one of the six SaltMaker Emergency Stops must be engaged.

## Appendix A: Reagent MSDS Sheets

## Appendix B: Saline Treatment plant Operation and Maintenance Manual

## Appendix C: Drawings