GENERAL:

The Brine Concentrator has been designed and supplied by Swenson Process Equipment, Inc. for TransAlta Generation LLC, Centralia, Washington. The system concentrates a feed stream that contains primarily calcium sulfate. The feed originates from a wet scrubber, and the concentrated brine is pumped to a pugmill for mixing and disposal with flyash. This manual describes the function and operation of individual components and the system overall. The control and monitoring of the system is by programmable logic controller (PLC). A PLC user manual has been provided to describe system control functions.

PROCESS DESCRIPTION:

NOTE: All temperatures flow rates, and concentrations are approximate. Process parameters vary with feed composition, feed temperature, heat losses to atmosphere, cleanliness of piping and vessels, and many other factors.

CALCIUM SULFATE AND ITS PROPERTIES

Calcium sulfate is the predominant chemical compound present in the feed to the brine concentrator.

It is useful to understand that calcium sulfate exists in different forms as a solid. There are actually six forms but for this discussion three are described. These three are gypsum, hemi hydrate, and anhydrite. The properties and behavior of these forms are somewhat different one from the other.

Gypsum occurs in nature. Gypsum crystals contain calcium sulfate with two molecules of water. It is formed at low temperatures. The next form is the hemi hydrate of calcium sulfate. The hemi hydrate contains half a molecule of water. It is formed when gypsum in solution is heated and concentrated in a medium temperature range. The hemi hydrate can revert back to gypsum at certain temperature conditions. The third form of calcium sulfate crystals is the anhydrite which has no water associated. This form is stable and cannot revert back to either hemi hydrate or gypsum.

The feed to the brine concentrator system contains gypsum. As the feed is heated and concentration takes place the solids will be the hemi hydrate. If the design temperature is exceeded during operation it is possible to form the anhydrite.

It is desirable to maintain operation at design conditions to help prevent scale deposits.

Another property of calcium sulfate is that it is inversely soluble. Most salts become more soluble as the temperature of the solution is increased but calcium sulfate becomes less soluble. The reason this is so important is that the heat transfer surfaces are hotter than the bulk process liquor. As the liquor is heated by these surfaces the
calcium sulfate tends to precipitate and has a tendency to deposit on the surfaces.

**BRINE CONCENTRATOR SYSTEM**

The primary purpose of the brine concentrator system is to reduce the volume of the liquid effluent from the plant off gas scrubber system. Evaporating water from the feed stream and recovering it as a very clean water stream for reuse accomplish the volume reduction.

**CRYSTALLIZATION IN THE BRINE CONCENTRATOR**

The TransAlta brine concentrator has been designed as a forced circulation crystallizer. As evaporation removes water from the process the calcium sulfate that is in solution precipitates or crystallizes to a solid phase. If there are a lot of solid calcium sulfate particles already present in the liquor the precipitation takes place on these particles causing them to grow larger in size. If there are no particles, the precipitation will take place on the hot heat transfer surfaces. It is common in crystallization processes to design the process such that a crystal particle inventory is maintained in the crystallizer. The TransAlta system includes provisions for adding solid calcium sulfate at startup and for controlling the amount of solids inventory during operation. In crystallization, introduction of solids prior to operation is referred to as “seeding” the system.

**FEED CHEMICAL TREATMENT**

The feed is expected to have calcium carbonate present in addition to the calcium sulfate. This compound forms scale readily. To prevent the scale formation sulfuric acid is added to the feed tank to react with the calcium carbonate. The reaction destroys the calcium carbonate forming calcium sulfate and carbon dioxide. To effectively convert the calcium carbonate to calcium sulfate the pH needs to be in the range of 5 to 6 or perhaps a little lower. The feed tank is sized to provide some time for the reaction to take place and for the pH to be stabilized enough that good pH control is possible.

There also is provision for the addition of anti-scale compounds. These help prevent the solids that precipitate from depositing on heat transfer surfaces. The use of anti-scale may not be necessary. Actual feed composition and the resulting behavior of the process liquor will determine if the anti-scale is needed.

**FEED PRE-HEATERS**

Two feed pre-heaters are provided. One pre-heater is used at low operating rate and both are used for full capacity operation. Hot distillate from the evaporation process is used to heat the feed. The pre-heaters consist of a series of plates where the distillate flows on one side of a plate while the feed flows on the other side. The heat is transferred from the distillate to the feed. The system is designed for steady operation at either half of maximum rate or at full design rate. Heat transfer performance in the
pre-heaters is improved if both the distillate and feed flow rapidly with a lot of turbulence. Also, the feed contains some solids that are swept out at high flow rate but could settle at too low flow.
GAS STRIPPER (FEED DEAERATOR)

The feed stream contains dissolved air and the carbon dioxide formed during the acid treatment step in the feed tank. The gas stripper is provided to remove these gasses. The solubility of the gasses decreases as the feed is heated. The feed is sprayed on top of an 8 ft. deep bed of packing in the vessel. Steam is injected into the bottom of the vessel. The feed flows down as the steam and gasses flow upward. The feed flows over the surface of the packing such that there is a large surface of liquid exposed to the vapor and gas flow. The feed temperature increases as it flows down the packing. This allows the gas to evolve from the liquid. Some excess steam is used to assure that the gasses are swept out of the vessel to the maximum extent possible.

VAPOR BODY

The vapor body has several functions. The first is to provide for the separation of the vapor generated by the evaporation process from the process liquor. It also provides for the removal of entrained liquid drops from the vapor stream before the vapor leaves the vessel. The vapor body is sized to provide volume and residence time for the dynamics of crystal formation. Finally the vessel provides a constant and sufficient liquid head for operation of the circulation pump.

HEATING ELEMENT

The heating element is a horizontal, two-pass, shell and tube heat exchanger. The process liquor is pumped from the vapor body and through the inside of the tubes. Steam flows into the shell side where it heats the outside of the tubes. As the steam gives up its heat it condenses to water that is referred to as distillate.

The heating element is designed for high tube velocities and low temperature increase of the liquor.

The high tube velocities help reduce scale formation. The low temperature rise makes it possible to prevent boiling within the tubes. Boiling at the inside tube surfaces would lead to solids deposits.

COMPRESSOR

The compressor provides the energy for operation of the system. The electrical energy that drives the motor is converted to mechanical energy that rotates the motor and compressor. The mechanical energy is converted to heat energy as the temperature and pressure of the vapor flowing through the compressor is increased.

The vapor or steam that leaves the vapor body flows into the suction side of the compressor. The temperature of the steam exiting the compressor is sufficient for operating the heating element. The vapor from the vapor body is about 195° F and
leaves the compressor at about 232° F. The liquor temperature in the vapor body is about 210° F.

**VARIABLE FREQUENCY COMPRESSOR DRIVE**

The variable frequency drive varies the compressor motor speed. Changing the speed changes the evaporation rate for the system because at low speed there is less energy input. Variable frequency speed control has a number of advantages over other types of equipment that could be used for speed control. A process advantage is that variable frequency provides a greater range of speed control than other methods. Variable frequency provides high torque and high efficiency at low speed. Therefore it results in power consumption saving over other types of speed control.

The speed control is the operator’s primary system control adjustment. Speed is increased to increase operating rate and decreased to decrease rate.

**HYDROCYCLONE**

The hydrocyclone is a device that is designed to separate solid particles out of a liquid stream. The hydrocyclone is a tall cone shaped vessel where liquid feed that contains solids enters the vessel near the top tangentially. The flow pattern is such that the liquid flows circumferentially around the inside of the vessel walls. The flow is then split such that a part flows up the center and out of the vessel at the top and the other part flows along the perimeter down and out of the bottom. The heavier solids particles tend to flow to the walls due to centrifugal force while the lighter liquid is forced to the middle of the unit. The flow out of the top is called the overflow and the flow out of the bottom is the underflow. At the feed entry point there is a device called a “vortex finder” that prevents the feed from flowing directly to the overflow outlet. At the bottom the outlet is a removable section that is called the “apex”. The apex restricts the flow out the bottom forcing more flow out of the overflow. The size (diameter) of both of these parts changes the performance characteristics of the hydro cyclone. Engineers have selected the apex and vortex finder sizes during the design phase for the brine concentrator system based on assumptions of particle size distribution and content of solids in the feed to the hydrocyclone. Sometimes it is necessary to modify the hydrocyclone performance when actual system performance characteristics become known. Usually an apex size change is all that is necessary to optimize performance. An engineering study of performance is needed to specify changes.

The hydrocyclone is used to help control the solids inventory in the vapor body. If the solids inventory is less than specified for operation the product flow will be from the overflow of the hydro cyclone to retain solids in the brine concentrator. If the solids are too high or at the correct amount the product flow will be from the hydro cyclone bypass line.

Based on the feed chemistry provided for design, the hydro cyclone does not need to
be used to control solids during normal operation. The natural solids concentration should be sufficient for operation.
CONCENTRATE TANK, PUMP, AND PIPING SYSTEM

The concentrate is designed for the startup situation when solids need to be added to the vapor body as crystal seed. The seed must be calcium sulfate as gypsum or plaster of paris. Piping is provided that allows the contents of the concentrate tank to be pumped back to the vapor body.

In normal operation the concentrate tank receives the brine that includes suspended solids. A mixer is provided on the tank to keep the solids from settling.

Periodically the product is pumped from the tank to the pug mill where it is mixed with fly ash for disposal. This is a batch process that pumps the product out at a high rate to prevent solids from settling as would happen if the flow rate were slow. Following transfer of a batch of product the piping must be flushed with water to prevent settling of solids and plugging of the piping.

OPERATOR TRAINING AND SAFETY

Safety is everyone’s responsibility. The brine concentrator system has been designed and fabricated in accordance with design standards including those of OSHA to provide equipment that can be operated safely. Potential hazards cannot be completely eliminated. Trained personnel can avoid these hazards. Access to the equipment and operation should be restricted to trained and authorized personnel.

The following safety items should be considered by the plant supervisors prior to commissioning and operation:

- Personnel should be trained to understand the safe operation of the equipment and to recognize and avoid potential hazards.
- Provide safety glasses, safety shoes, chemical resistant boots, goggles, coats or aprons, gloves for handling chemicals, and any other types of items for personnel protection. Provide training and implement rules.
- Operating procedures and lockout procedures should be implemented for safe access to equipment when cleaning or maintenance activities are necessary.
- Provide instructions and training in the use of safety showers, eye washes, and getting emergency assistance.
- Provide training for working with acid and other chemicals.
- Implement vessel entry procedures. These should consider training, vessel entry permits, entry procedures, watch requirements, air flow in and out of the vessel, and other items.