Zero Liquid Discharge in Power Plants

December 23, 2016

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Why Zero Liquid Discharge (ZLD) in Power Plants?

Global water challenges

| Availability          | • Growing population and industrial use  
|                      | • Climate change and drought             |
| Quality              | • Increased industrial pollution         
|                      | • Deteriorating water quality            |
| Productivity         | • Pressure to improve operational efficiency 
|                      | • Managing downtime and aging assets     |
| Policy               | • Stricter regulation on discharge/withdrawal 
|                      | • Water reuse incentives and policy mandates |

Zero discharge of liquids is now in many cases mandatory for industry & Power Plants

ZLD systems enable reuse of waste water and minimization of discharges
Drivers for Zero Liquid Discharge

- Tightening national & local environmental discharge limits
  - Tighter limitations on heavy metal discharge limits
  - Stricter limitations on selenium, mercury, arsenic, nitrate
  - Physical/chemical precipitation & biological process unable to reduce
    - Total dissolved solids (TDS)
    - Specific contaminants (including chlorides, sulfates, boron)
  - Co-mingling of waste streams may not be permitted

- Treat & discharge may not be permitted or unable to meet limits

- “Future Proofing”
  - Long term environmental risks minimized due to elimination of discharge
  - Enable range of coals to be used

- In some countries ZLD is mandated for new plants
Typical Power Plant Waste Streams Treated by ZLD

- Cooling tower blowdown
- Demineralizer waste
- Process wastewater
- Ash pond blowdown
- Scrubber blowdown
- Plant drains
- FGD Blowdown
- Gasification wastes
- Boiler blowdown
- Reverse osmosis reject
- Electrodialysis reject
ZLD Solutions for CTBG & FGD
ZLD Solutions for CTBD & FGD Wastewater

### Volume Reduction
- **Brine Concentrator Only**
  - Does not achieve full ZLD
  - Used to reduce the volume of waste to storage or disposal
  - BC ideal for high TDS waste streams
  - Achieves high conc. factors of up to 100x
  - Achieves water recoveries of 75%-99%
  - Typically use Seeded slurry technology to allow concentration without scaling of surfaces
  - Typically uses vapor compression reduces energy consumption - either steam (TVR) or mechanical (MVR)
  - Produces high quality distillate for reuse

### ZLD Waste Salt
- **Brine Concentrator + Crystallizer**
  - Produces a soluble crystalline solid salt for landfill disposal
  - Achieves zero liquid discharge
  - Achieves water recoveries of 85%-99%
  - Typically concentrator uses Seed Slurry BC design to allow high concentration without scaling
  - Typically uses steam (TVR) or mechanical (MVR) vapor compression to reduce energy
  - May require pre-treatment including clarification and/or softening depending on feed water chemistry.
  - Produces high quality distillate for reuse

### ZLD SDE
- **Brine Concentrator + SDE**
  - Evaporates highly concentrated waste water from Brine Concentrator to produce dry solids
  - Uses flue gas from boiler to evaporate waste water to produce solid by-product
  - The dried solids are captured in the downstream particulate collection device, such as the electrostatic precipitator (ESP) or fabric filter.
  - Either Inline (Integrated) or Slipstream configuration
  - Simple, cost-effective design.
  - Ability to integrate the SDE system to existing power plants by using a slipstream of the boiler hot flue gas.
  - Recovers high quality distillate for reuse

### ZLD Solidification
- **Brine Concentrator + Solidification**
  - Produces a solid waste suitable for long term disposal
  - Uses a pozzolanic reaction, combining FGD wastewater with fly ash + reagents to produce an "engineered" solid material
  - Produces a stable solid product with:
    - High structural strength able to bear weight (able to supports heavy earth moving equipment), providing long term stability in a land fill
    - low hydraulic permeability (sheds water)
    - non-leachable (reduces landfill leachate contamination).
  - “Reduced Capex and Opex of 30-50% compared to ZLD Waste Salt.

<table>
<thead>
<tr>
<th>Suitable for</th>
<th>- CTBD (depending on storage/disposal options)</th>
<th>Suitable for</th>
<th>- CTBD, FGD</th>
<th>Suitable for</th>
<th>- FGD</th>
<th>Suitable for</th>
<th>– (CTBD), FGD</th>
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</table>
ZLD Technologies
Salt Removal and Recovery in Brine Wastewaters

- ZLD typically requires thermal or evaporative technologies to achieve solids and max recovery of water
- Evaporation is generally expensive and has high power requirement
- Pre-concentration enables reduction in size/capacity and therefore capex and opex of evaporator and crystallizer units
- ZLD systems integrate both conventional and membrane systems to pre-concentrate wastewater prior to thermal systems
ZLD Brine Concentrator

- Used to reduce the volume of waste (to reduce size of downstream equipment, e.g., crystallizers)
- Seeded and unseeded designs
- **Seeded slurry** technology allows concentration without scaling of surfaces
- **Vapor compression** reduces energy consumption,
  - either using steam (TVR) or mechanical (MVR)
- Ideal for high TDS waste streams
- 2 - 275 m$^3$/hr evaporation per unit
- 13 - 26 kWh/m$^3$ specific power consumption
- Recoveries of 75%-99% (CF=4x-100x)
- Produces high quality distillate for reuse
ZLD Brine Crystallizer

- Used to produce a crystalline solid, typically a Mixed Salt (Pure Salts depend on chemistry)
- Evaporates highly concentrated waste water (eg Brine Concentrator blowdown) to produce dry solids
- Typically forced circulation
- **Vapor compression** reduces energy consumption,
  - either using steam (TVR) or mechanical (MVR)
- Ideal for waste waters >60,000 ppm
- Solids are harvested from the crystallizer by filter press, centrifuge or dryer
- 0.5 - 115 m³/hr of evaporation per unit
- 32 to 65 kWh/m³ specific power consumption
- Recoveries of 65%-85%
- Produce high quality distillate for reuse

Modularized Mixed Salt Crystallizer
ZLD Spray Dryer Evaporator (SDE)

- Evaporates highly concentrated waste water from Brine Concentrator to produce dry solids
- Uses flue gas from boiler to evaporate waste water to produce solid by-product.
- The dried solids are captured in the downstream particulate collection device, such as the electrostatic precipitator (ESP) or fabric filter.
- Either Inline (Integrated) or Slipstream configuration
- Simple, cost-effective design.
- Lime conditioning offers acid gas capture co-benefit and mitigates downstream corrosion.
- Ability to integrate the SDE system to existing power plants by using a slipstream of the boiler hot flue gas.
ZLD Solidification

- Produces a solid waste suitable for long term disposal
- Uses a pozzolanic reaction, combining FGD wastewater with fly ash and reagents to produce an “engineered” solid material.
- Produces a stable product with
  - High structural strength able to bear weight (able to supports heavy earth moving equipment), providing long term stability in a land fill
  - Low hydraulic permeability (sheds water)
  - Non-leachable (reduces landfill leachate contamination).
- “Engineered” solid material was established following collaboration with a leading landfill engineer & operator.
- Reduced Capex and Opex of 30-50%.
Sox Control - Challenges
Challenges in Sox Control

- Limited space availability for FGDs in existing power stations
- Limitations in logistics for lime/limestone and gypsum storage and conveying systems in boiler area

List of Equipment for a Wet FGD in a 660 MWe TPS

1. Sox Absorber
2. Gas-Gas Heat Exchanger
3. Booster Fan
4. Recycle Pumps
5. Oxy-Blowers
6. Dewatering Area (Building)
7. Limestone Area (Building)
8. Electrical Building
9. Limestone Silos and Conveyor
10. Gypsum Conveyor
11. Belt Filter
12. Hydro-cyclones
13. Pumping Systems

Solution
- Install FGD behind the Chimney area
- Water Recycling – ZLD system can be located away from Boiler area
Foot Print

Approx. 145m x 115 m is required for Wet FGD system in a typical 660 MW TPS.
Case Studies
Mt Piper Power Station, Australia

- 1400 MW Coal Fired Power Plant
- 2x 700 MW units

**Challenge:**
Limits on supply water & waste water discharge

**Solution:**
Integrated ZLD system into original power plant design to recover waste water for reuse in Cooling Tower

**ZLD system**
- Treats 7000 m³/d of CTBD, Ash Washdown & Demin’ waste streams
- Streams segregated via dedicated ponds for SS settling before Brine Concentration
- ZLD combined feed TDS = 2250 mg/l
- 2x 50% ZLD Seeded Slurry Brine Concentrators
- Achieve 98% recovery of <10 mg/L TDS water for reuse
- Power consumption <22 kW/m³ of feed
Zepak Adamów Power Station, Poland

- **2738 MW coal fired power plant**

- **Challenge:**
  Waste water could no longer be discharged into old mine shafts

- **Solution:**
  ZLD selected vs RO & EDR, due to high scaling nature of waste water (Sr, Ba) and increasing TDS of waste water reservoir

**ZLD system**

- Treats 7000 m³/d of CTBD, Ash Washdown & Demin’ waste streams
- Streams segregated via dedicated ponds for SS settling before Brine Concentration
- ZLD combined feed TDS = 2250 mg/l
- 2x 50% ZLD Seeded Slurry Brine Concentrators
- Achieve 98% recovery of <10 mg/L TDS water for reuse
- Power consumption <22 kW/m³ of feed
**Orlando Utilities Commission, USA**

- Coal fired & Combined Cycle power plant
- 4x power generation units (2x coal, 2x gas)

**Challenge:**
New regulations limited availability of make-up water and increased waste water discharge guidelines. OUC also required low energy consumption and >95% reliability

**Solution:**
ZLD system to treat CTBD to recover water for reuse in CT and produce waste salt for off-site disposal

**ZLD system**
- Treats 11000 m$^3$/d of CTDB
- Feed = 3600 mg/L TDS
- Original 1986 ZLD system
  - 1x 3200 m$^3$/d Evaporator, 2x 140 m$^3$/d Crystallizers
- Today 11000 m$^3$/d ZLD system;
  - 4x Evaporators; 3200 m$^3$/d, 2700 m$^3$/d, 2x 1600 m$^3$/d, 4x 140 m$^3$/d Crystallizers
- Achieves 99% recovery
AES Ironwood Power Plant, USA

• **700MW CCGT Power Plant**

• **Challenge:**
  To re-use CTBD for supply to demineralizer (EDI) plant & CT make-up

• **Solution:**
  A fully integrated water/waste water system with simplified design incorporating ZLD

**ZLD system**

• Treats 1100 m$^3$/d of CTBD

• Feed = xx mg/l TDS

• 1x 1100 m$^3$/d Brine Concentrator + 1x 100 m$^3$/d Crystallizer

• Achieves 97% recovery

• Crystallizer solids produced are dewatered and sent to landfill.

• Optimized recirculating CT treatment program with 15x cycles

• Simplified treatment system with few unit operations, but flexible enough to accommodate chemistry variations in the make-up water
Experience
Extensive Design Database
Currently Operating Brine Concentrator Systems

Based on more than 40 years experience
### Power Industry Experience

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<tr>
<th>Location</th>
<th>Startup</th>
<th>m³/hr</th>
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<td>318</td>
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<tr>
<td>Utah</td>
<td>1974</td>
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### FGD Installations

<table>
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<th>Location</th>
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<th>m³/hr</th>
<th>MW</th>
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<td>2017</td>
<td>68</td>
<td>1760</td>
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*SDE-based solutions

### Proven Reliability & Performance

- Huntington, UT
  - Installed 1974
  - Operated for 30 years
  - New Thermal Products
  - Unit installed in 2005

- San Juan, NM
  - Installed 1974
  - Still Operating

- Pawnee Station, CO
  - Installed 1980
  - Still Operating

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More than 65 power installations over 40 years
Advantages of GE Zero Liquid Discharge

- **Environmental & Regulatory Compliance**
  - Reduced environmental discharge
  - Minimized long term environmental risks due to elimination of discharge

- **“Future Proof”**
  - Avoid future treat & discharge limits when discharge limits tighten
  - Ability to use wide range of coal fuels

- **Reduced Long Term Risk**
  - Sustainable long term management of solid residuals

- **Recover water for reuse**
  - Reduced operating costs
Experience
>40 years,
>275 ZLD
installations,
>65 power plant
installations

Expertise
process & waste
water expertise to
understand &
develop solution

Comprehensive
BAT Portfolio
integrated solutions
from pretreatment
to advanced
treatment

Proven designs
extensive knowledge
base

Proven performance
robust designs, full
process guarantee

Demonstrated
reliability
operating plants
>30 years old

Modularization
reduced field
installation costs

Schedule certainty
experienced
project team

Partnering
collaborative
approach to
achieving best for
client outcomes

Why GE?

Delivering outcomes for our clients through certainty of performance