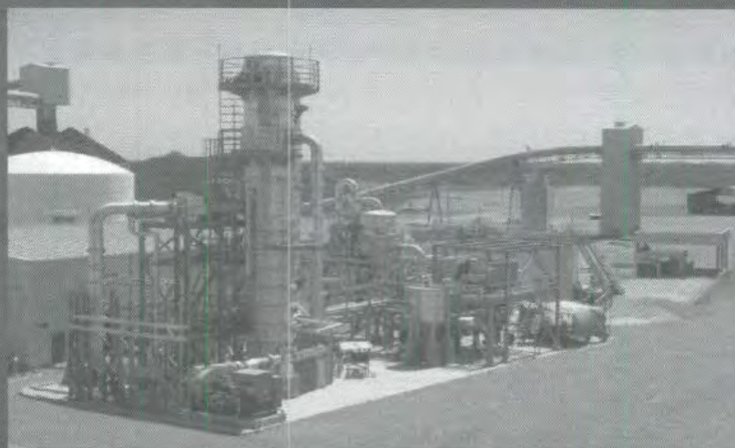
INTERNATIONAL WATER CONFERENCE®

November 17-21, 2013
Hilton at the Walt Disney Resort
Orlando, FL

Thermal Zero Liquid Discharge

Presented by: *J. Michael Marlett, P.E., P.Eng*
Aquatech International Corp., Hartland, WI

Evaporation Systems



International Water Conference
November 20th, 2013

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Puerto Rico

Agenda

- Chemistry
- Evaporator Types
- Energy Supply Alternatives
- Mist Elimination
- Evaporator Impacts
- Miscellaneous
- Evaporator Examples
- Top 10 Lists

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Definitions

Evaporation – The removal of a solvent by converting it from a liquid to a vapor

BPE – Boiling Point Elevation

The difference between the temperature that a solution boils compared to water at that same pressure.

Viscosity – resistance to flow. → inhibitor to heat transfer

Solubility Limit – The point where the addition of a solute to a solvent causes precipitation of a solid.

Economy – The amount of distillate produced per pound of steam (aka Gain Output Ratio)

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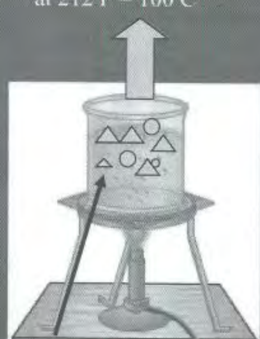
Separation by Vaporization

Water changes phase at 212 F = 100 C



Suspended and Dissolved Solids Accumulate in the Beaker

- Approximate vaporizing temperature of some salts dissolved in water:
  - Sodium Chloride 752 F = 400 C
  - Calcium Chloride 856 F = 457 C
  - Calcium Sulfate 620 F = 326 C
  - Potassium Chloride 800 F = 426 C
  - All other dissolved salts > 500 F = 278 C
- Since solution temperatures within the evaporator do not exceed the vaporizing point of the dissolved solids, only pure water vapor and other volatiles will be driven from the contaminated solution

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Cons for Evaporation

- It's expensive
- It's expensive from CAPEX
  - Brine Concentrator
    - Capacity 500-600 GPM
    - Cost $5-8 MM
  - Crystallizer
    - Capacity 20-30 GPM
    - Cost $2-3 MM

Cons for Evaporation

- It's expensive from OPEX
  - Falling Film Evaporator
    - Capacity 550 GPM
    - Power 4700 HP (3500 KW)
      - 106 KW/1000 Gallons
  - Crystallizer
    - Capacity 26 GPM
    - Power 720 HP (537 KW)
      - 344 KW/1000 Gallons

Pros for Evaporation

- It works
- It provides higher quality distillate than RO.
- It allows ZLD operation

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The Business

$$Q = U A \Delta T$$

Q – Heat Transferred
U – Heat Transfer Coefficient
A – Area
ΔT – Driving Force

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The Business

$Q = U\ A\ \Delta T$

Q – Capacity

U – Chemistry

A – Capital

ΔT – Cash Flow

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Q - Energy

What it is

- Lbs/hr evaporation
- Lbs/hr * (Latent Heat + Sensible Heat)

What it is not

- Lbs/hr feed
- Lbs/hr discharge

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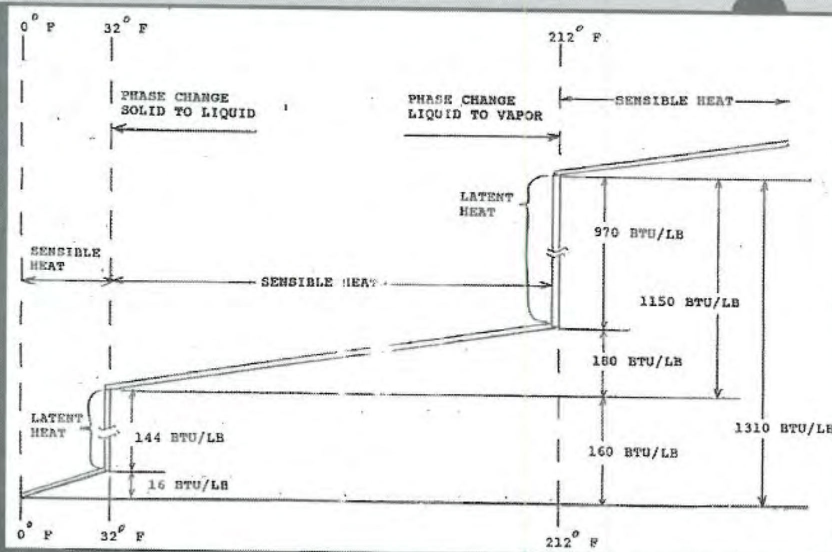
Sensible vs. Latent Heat



© Phil Flash.

5:1 ratio always take more energy to do phase change than just heat up water.

U – Heat Transfer

How easy is it to transfer heat?

What are the resistances
- Scaling – physically attaches chem bond calcium sulfate silica
- Fouling – O&G – can wash off.
- Physical Properties

How can we improve that
- Pretreatment – hardness, silica O&G – remove
- Equipment – type of evap.
- Operation – seeded slurry – circ CaSO4 seed

Heat Transfer Coefficient

- Inverse of Heat Transfer Resistance

$$U = 1 / R$$

- Resistance comes from several factors

$$R = 1/U = 1/h_o + x/k^*D_L + D_o/D_i/h_i$$

  - $1/h_o$ is the outside film coefficient ← generally steam film
  - x/k^*D_L is the resistance due to tube wall ← depends on material used & thickness.
  - $D_o/D_i/h_i$ is the inside film coefficient ← brine circulating
- Scaling Resistance
  - Adds an extra x/k^*D_L term to the resistance equation

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D_o - outside diameter
D_i - inside diameter.
D_L - length.

A – Area

HOW MUCH DO WE NEED

What type of Evaporator is best – thin film 2X heat transfer coeff = less area

What are the materials – titanium, SS 2507, SS 2205, SS 316, SS 304, carbon steel. ($ increasing)

What is my U

What is my ΔT

What is the scaling potential of my brine

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non scaling service → plate & frame (such as caustic soda)

shell & tube – forced circ (tube full of liquid) ← used w/ lots of solids

thin film – least area & $ footprint etc...

brine conc vs. thin film.

ΔT- How much do I need

- What is my Energy Source
  - Steam
  - Thermocompressor ← steam
  - Mechanical Compressor ← mechanical pump
  - Multiple Effect
- What is the impact on the brine
  - Increased scaling
  - Equipment design considerations

essentially same.

side
shell - steam
tube - brine

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Questions to be answered

- How much evaporation do I need
  - What is my ultimate goal
- What is the chemistry of my feed
- What am I going to do with the distillate
- What am I going to do with the concentrate
- What do I want to use for an energy source
- What is my physical limitation
- What are my key decision points
  - OPEX
  - CAPEX
  - Ease of Operation
  - Flexibility
- All of the above

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Physical Properties

- Chemistry
  - What makes up the feed
- What are the final physical properties
  - Viscosity
  - Latent Heat
  - Solubility
  - Heat of concentration (dilution)
  - Boiling Point Elevation

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Chemistry

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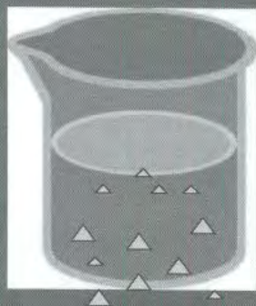
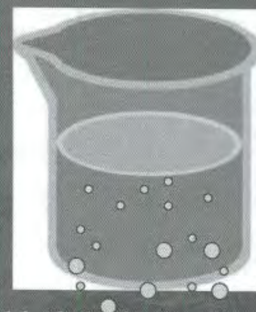
Dissolved vs. Suspended Solids



Suspended solids mixed with water.

Visible cloudiness

CAN BE FILTERED



Soluble Salts ionized in water.

May not be visible

CANNOT BE FILTERED

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Key Components

- Calcium
- Sodium
- Magnesium
- Chlorides
- Sulfates
- Silica
- Ammonia
- Boron (for FGD)

not separating organics } not distilling.

← look only at inorganics.

may or may not end up in distillate.

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Calcium

- Highly soluble with chlorides
  - Increases Boiling Point Elevation
  - Increases corrosion
- Highly scaling
  - Calcium Carbonate
  - Calcium Sulfate
- Calcium Carbonate and Calcium Sulfate solubility decreases with increasing temperature

inversely soluble
hotter less soluble

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Sodium

- Beneficial when it is in sufficient quantity to remove chlorides
- NaCl crystallizes at 28%. by weight.
- This limits the chloride concentration in the brine
  - Reduces corrosion potential
  - Allows less exotic materials
  - Reduces BPE

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Calcium Sulfate

- Detrimental when forming $CaSO_4$ — scaling potential @ certain conc.
- Beneficial in sufficient quantities for seeding purposes.
- Required for coprecipitation with silica
- Low Solubility
- Low impact on BPE

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Sodium Sulfate

- Solubility ~28%
- Issue with combination with NaCl to form glauberite

doesn't allow $CaSO_4$ to attach to seed...

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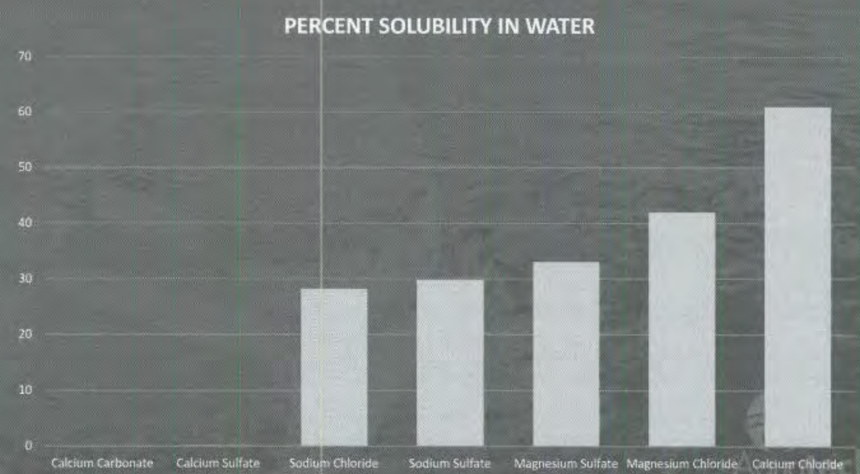
Solubilities



remove by softening first to get rid of.

Silica — nasty — thermal fracture to create fissures then wash or HF acid but could damage tubes

- Silica
  - Scales Heat Transfer surface
  - Difficult to clean
- Solubility
  - 150-200 ppm at pH 7
  - Solubility increases with increasing pH
- Precipitation
  - Co-precipitates with almost anything

Ammonia & Boron

- Consider the sources of Ammonia and Boron.
- Ammonia and Boron can be volatilized in an evaporator - they carryover with vapor.
- Amount volatilized is dependent upon a complex equilibrium.

  $NH_3 + H^+ \rightleftharpoons NH_4^+$ $H_2BO_3^- + H^+ \rightleftharpoons H_3BO_3$
- Equilibrium is a strong function of pH.

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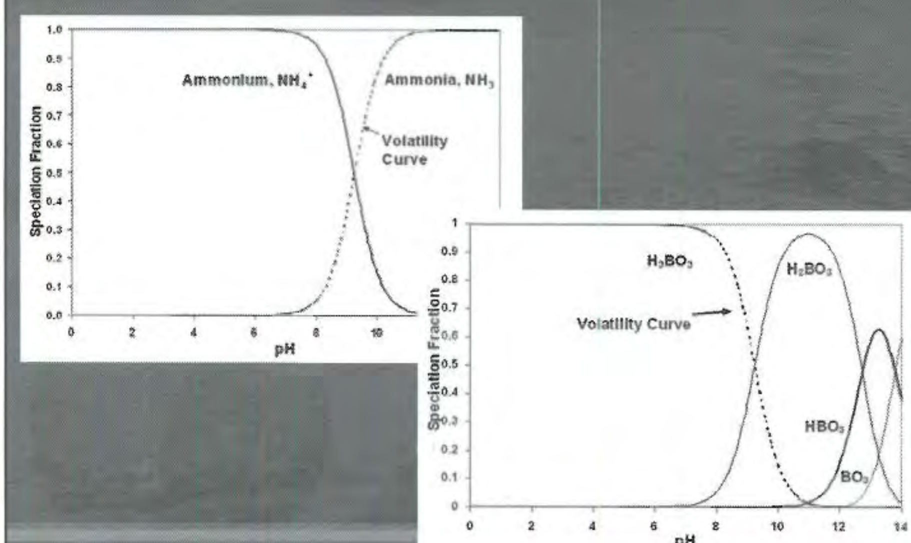
← inhibitors in nuclear reactors in 1960's.

Ammonia & Boron



use boron selective membrane.

Bob Gold's Paper

Oil & Grease, BOD, COD

- Fouls the heat transfer surface
- May contaminate distillate
- May limit percentage evaporation

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Other Components

- Nitrates
  - Prevalent in Municipally treated water
  - Highly Soluble
  - Large Addition to BPE
- Buffering Acids
  - Used mostly in FGD systems
  - Impact on pH
- pH

dibasic acids? add caustic to raise pH to neutral

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Evaporator Types

- Type
  - Tubular
  - Plate
  - Continuous
  - Batch

  } generic types
- Falling Film – Seeded and Non-Seeded — tubular
  - Vertical Tube Falling Film
  - Horizontal
- Forced Circulation – Crystallizers
- Submerged Tube
- Rising Film
- Natural Circulation
- Wiped Film — more mechanical for very viscous liquids.

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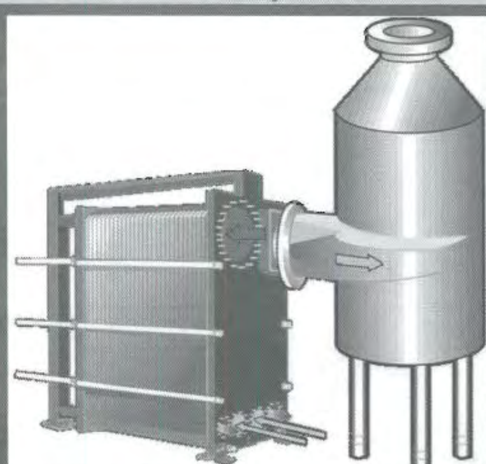
Plate Evaporator



- Plate evaporator from Alfa Laval

- Compact
- Materials include 316, 6% Mo, Ni, Ti
- Less area
- Not suitable for use suspended solids

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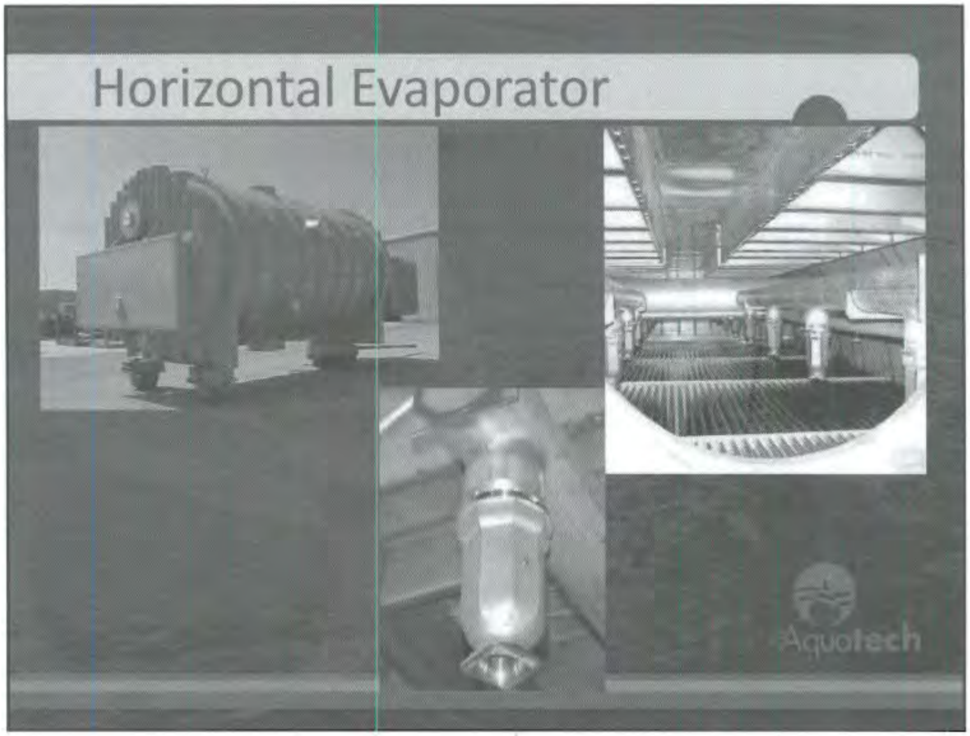
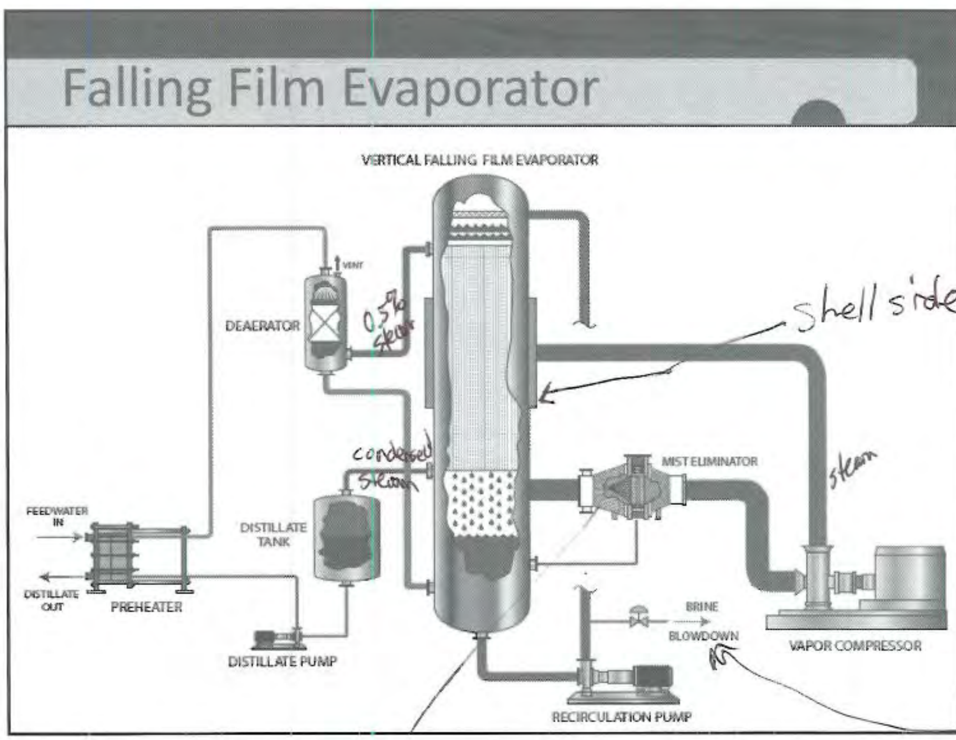
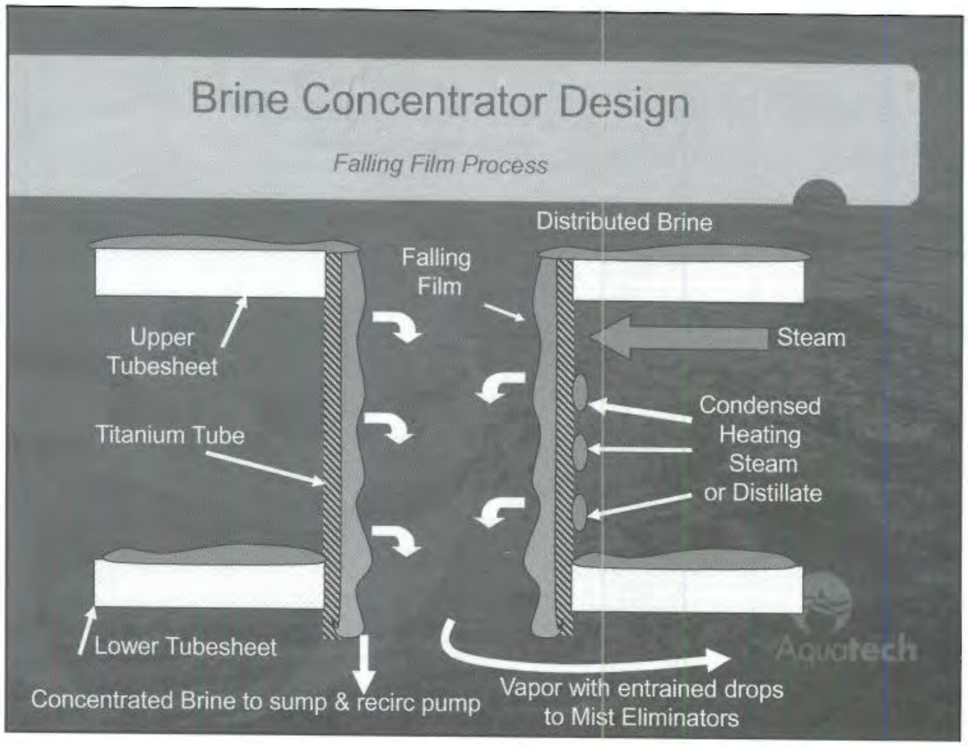


brine sprayer



Cheveron plates.

have to add steam heat to system w/ brine conc. because too much loss of heat here


Brine Concentrator Design
Falling Film Process
Distributed Brine
Falling Film
Upper Tubesheet
Steam
Titanium Tube
Condensed Heating Steam or Distillate
Lower Tubesheet
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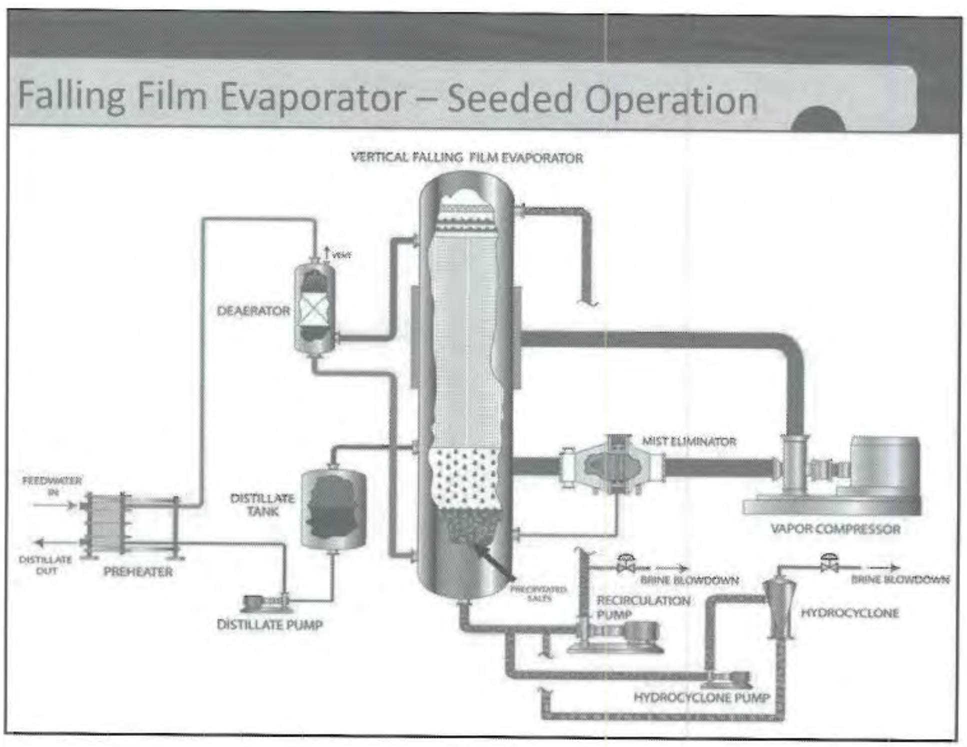
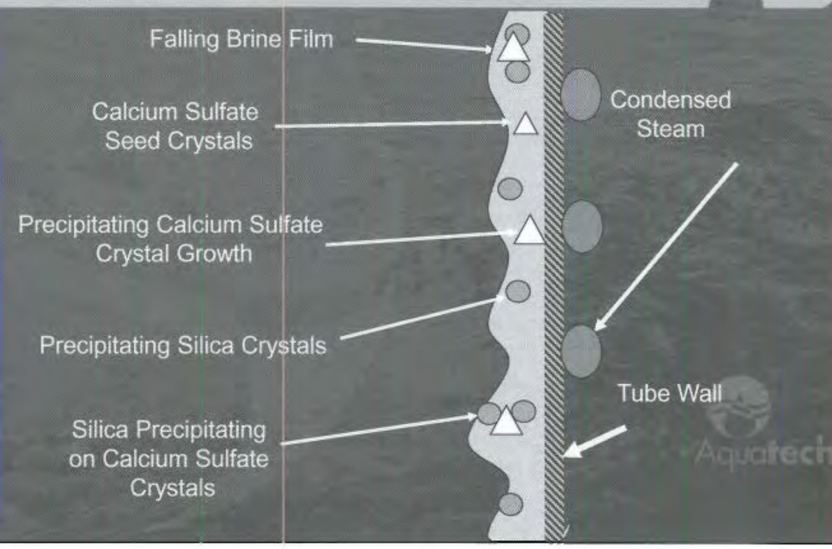
Concentrated Brine to sump & recirc pump
Vapor with entrained drops to Mist Eliminators


Falling Film Evaporator – Seeded Operation
VERTICAL FALLING FILM EVAPORATOR
VENT
DEAERATOR
MIST ELIMINATOR
FEEDWATER IN
DISTILLATE TANK
VAPOR COMPRESSOR
DISTILLATE OUT
PREHEATER
BRINE BLOWDOWN
BRINE BLOWDOWN
PRECIPITATED SALTS
RECIRCULATION PUMP
HYDROCYCLONE
DISTILLATE PUMP
HYDROCYCLONE PUMP

Brine Concentrator Design

Seeded Slurry Process



Design Criteria(Evaporator)

- Capacity
- Chemistry
  - Ion Ratios (Ca/SO_4, Mg/SO_4, Na/SO_4, Na/Cl) silica/$CaSO_4$
- Area
- Materials
- Energy Source
- Discharge Limitations
- Customer Expectations

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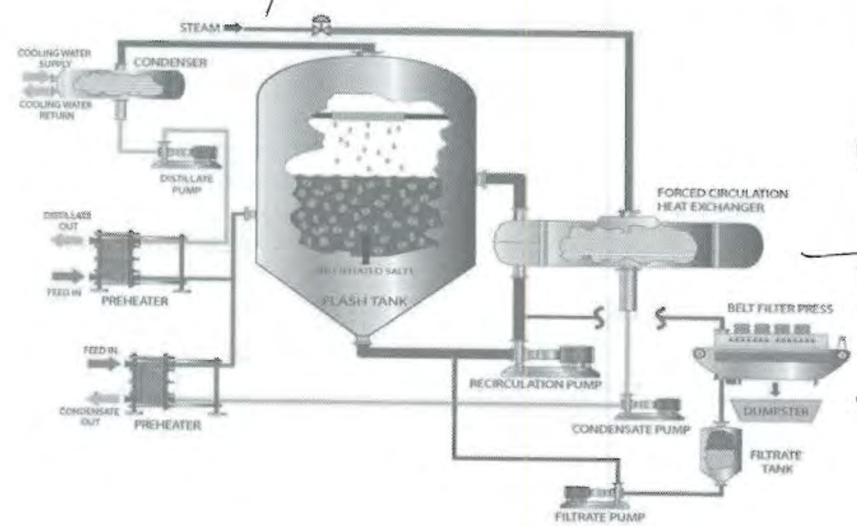
could easily put ~~steam~~ in a thermocompressor or vapor compressor instead of steam.

Forced Circulation Crystallizer (aka evaporator)



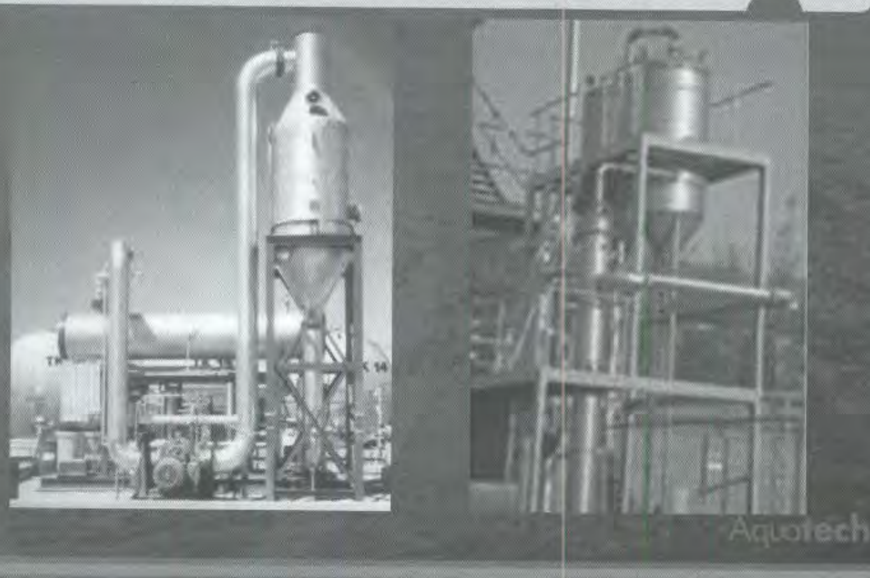
heat feed above boiling pt.

brine temp ΔT incoming to outgoing 2-6°F only.

or spray dryer or centrifuge. 10-20% SS 20% TDS NaCl.

multi effect system atm pressure or under vacuum.

FC Evaporator Arrangements



Queen Creek, Az

Design Criteria(Crystallizer)

- Capacity
- Chemistry
- Area
- Circulation Flow
- Flash Tank Size
- Materials
- Energy Source
- Solids Removal Devices

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Crystallizer – Important Design Parameters

- Crystal Formation
  - Predominantly NaCl and Na_2SO_4
  - $CaSO_4$ least soluble
  - NaCl and $NaSO_4$ solubility is depressed by presence of Mg salts

also drags pH down + have to add chem (NaOH) to bring pH back [illegible]

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Crystallizer – Important Design Parameters

- Cycling of Mg, Ca, and Nitrates
  - Impact on boiling point elevation/compressor
  - Salts such as $NaNO_3$, $MgCl_2$, $MgNO_3$, $CaCl_2$ remain soluble and removed with moisture in cake
  - Increased brine slurry chloride concentration
  - Purge stream sometimes required
- Cycling of Organics
  - High solubility
  - High concentrations can impact boiling point elevation, viscosity, and foaming tendency

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15-20% moisture in salt cake max.

organics can cause

Foaming
Viscosity
ability to sep. solids
- BPE

Crystallizer – Important Design Parameters

- Suspended Solids Concentration
  - Limited to 20 % suspended solids to maintain high HTCs (Heat Transfer Coefficients)
- Suppressed Boiling
  - No boiling or concentration change over the heating surface for scale control

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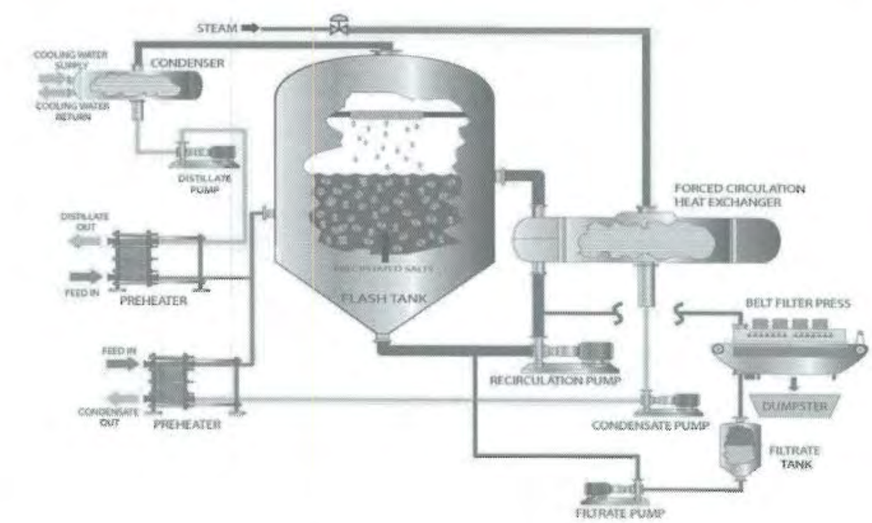
Energy Supply Alternatives

- Steam
- Multiple Effect
- Mechanical Vapor Compression
- Thermal Vapor Compression

} so much more energy efficient than multiple effect w/ steam only!

Steam Driven Evaporator



Steam

- Why Steam
  - Equipment is less expensive
  - It's forgiving
  - It compensates for errors
- Why not steam
  - It's expensive for operation
  - It requires cooling water for heat rejection

allows make equip smaller & less $ than ~~Heat~~ vapor compressor.

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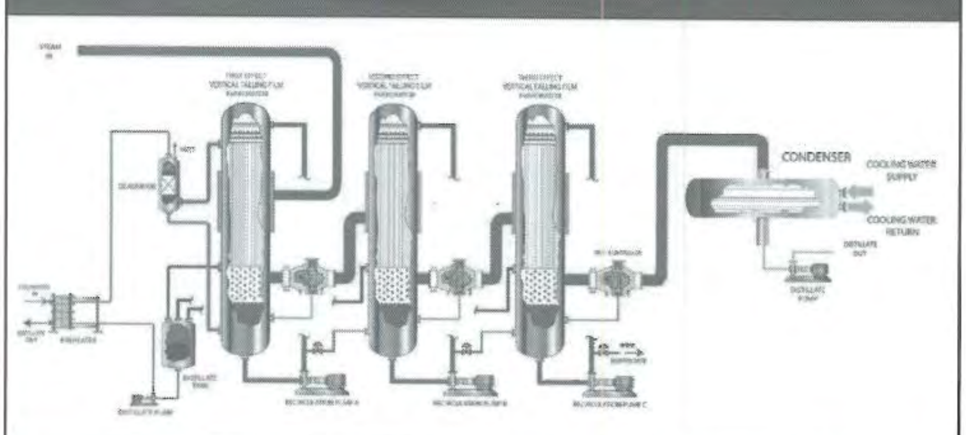
Multiple Effect Evaporation



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5 psig
sump atm.

10 psia

5 psia.

Use 2° effect as condenser.

Multiple Effect

Multiple Effect

- Why Multiple Effect
  - Reduces steam consumption
    - Evaporation/# Effects = Steam usage
  - Reduces cooling water usage
  - Can make weaker effects from less costly materials
- Why not Multiple Effect
  - It still uses steam and cooling water
  - It has more rotating equipment
  - CAPEX is higher

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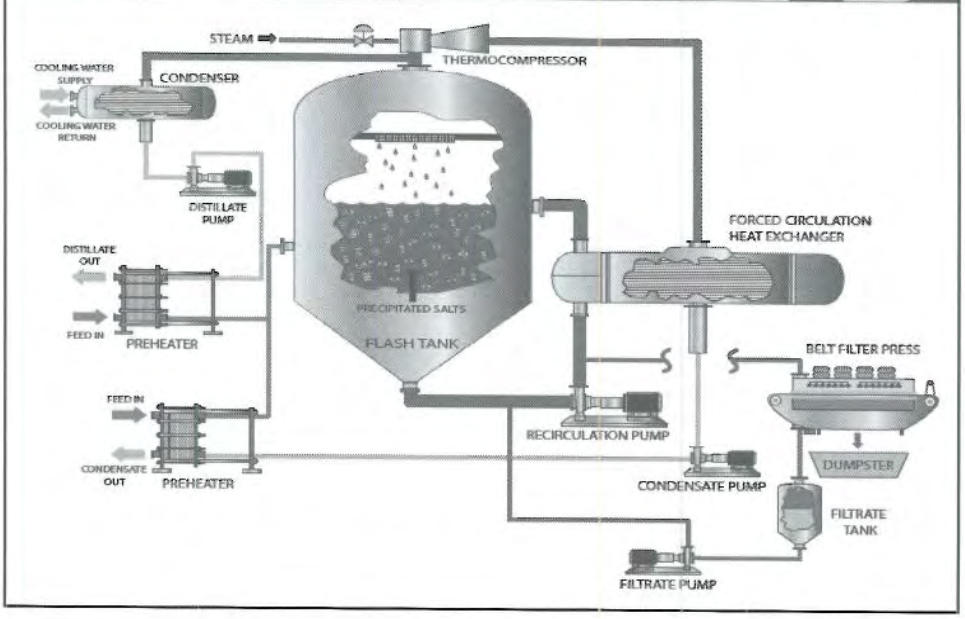
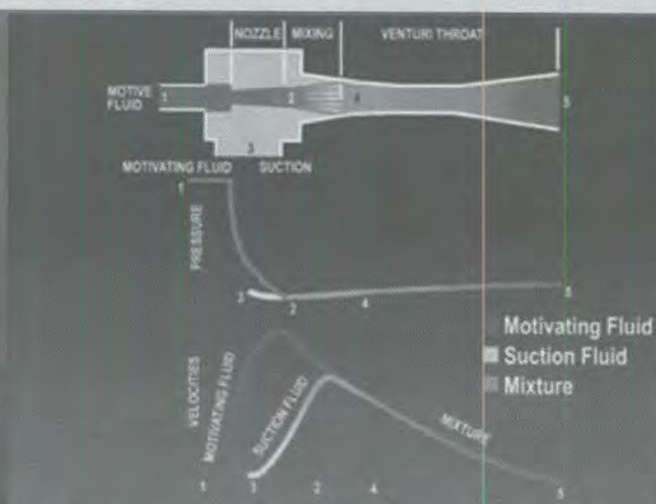
Thermocompressor



Thermocompressor



Fluid Flow Model of a Steam Jet Ejector

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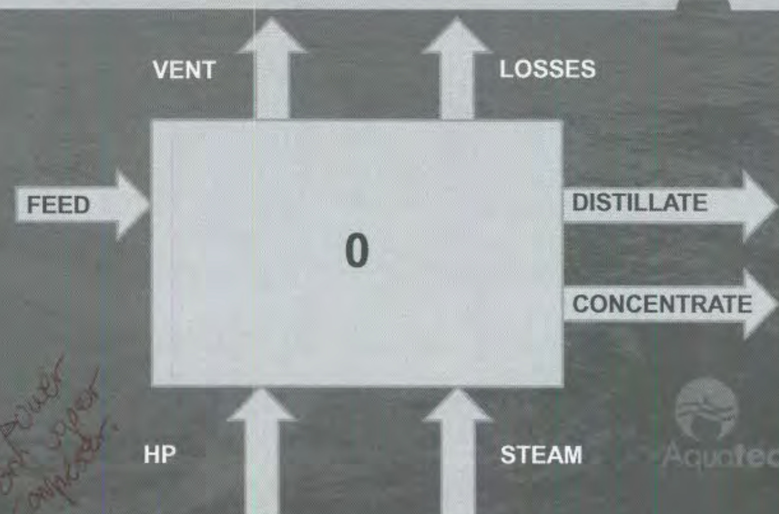
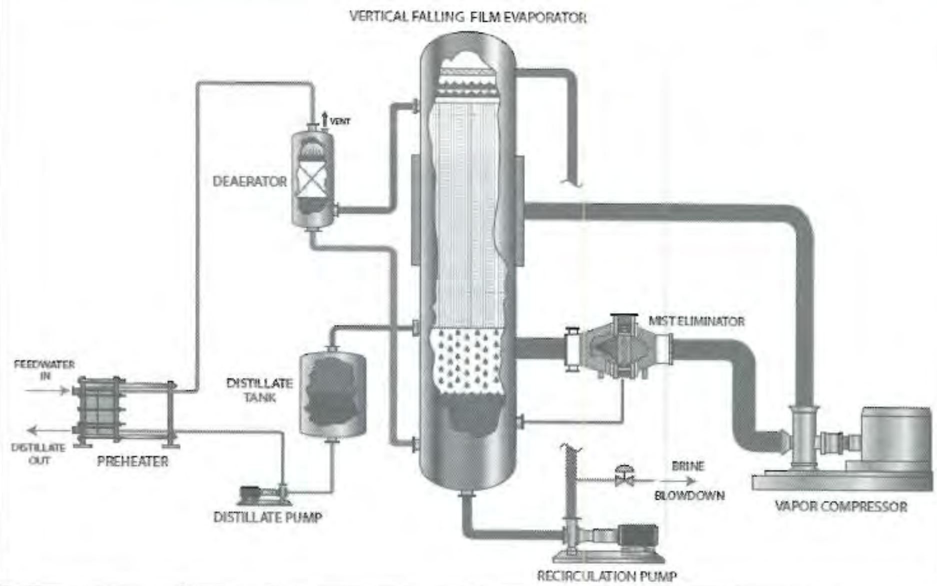
Thermocompressor

- Why a Thermocompressor
  - Reduces steam usage
  - Reduces cooling water usage
  - Can achieve the same economy with less equipment (Less CAPEX
- Why not a Thermocompressor
  - It still uses high pressure steam
  - It uses cooling water
  - It has limited capability to adjust to errors in design chemistries

Energy Supply Alternatives – Mechanical Vapor Compression

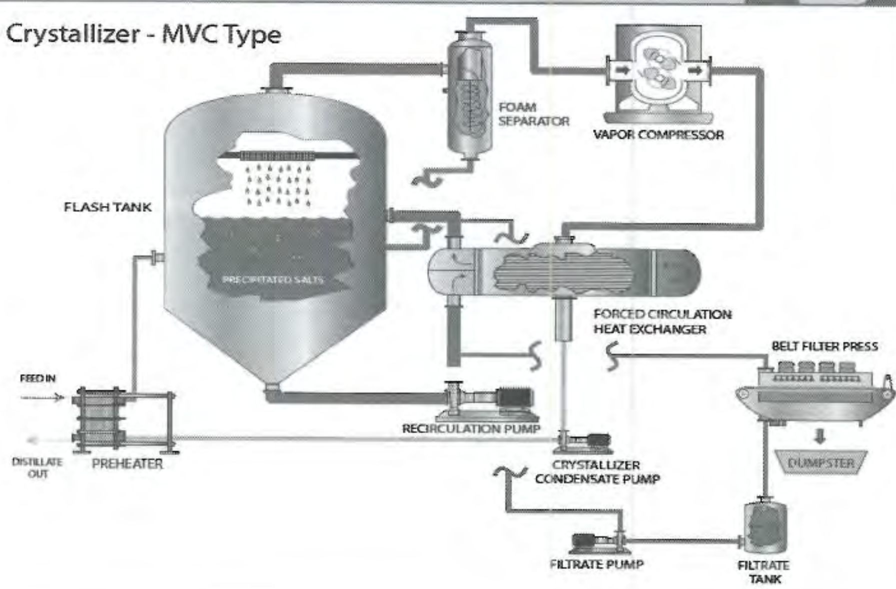


Mechanical Vapor Compressor

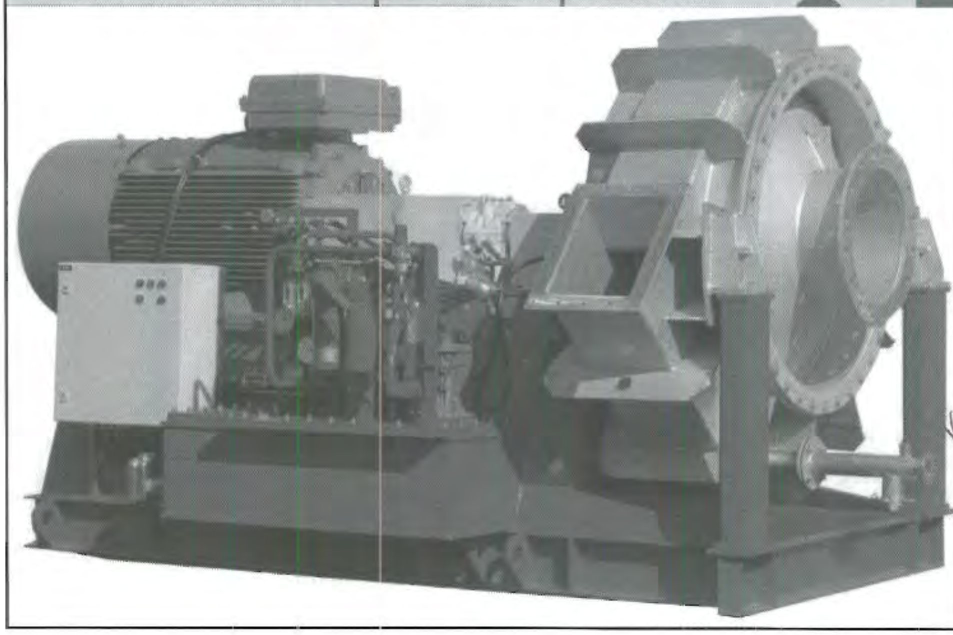


Forced Circulation Crystallizer

Crystallizer - MVC Type

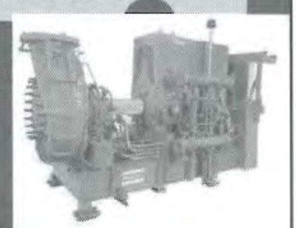


Mechanical Vapor Compressor



Kansas City Power & Light
1200 horsepower

Single Stage Centrifugal Compressor



- High Speed (12,000 - 24,000 rpm)
- IGV for capacity control and 50% turndown
- Pressurized lubrication system
- Standard instrumentation
  Vibration, current draw, system temperatures
- Polytropic efficiency, 70% - 75%
- Casing – Cast Iron
- Impeller titanium
- Limited flexibility of arrangement of nozzles
- Requires dry suction

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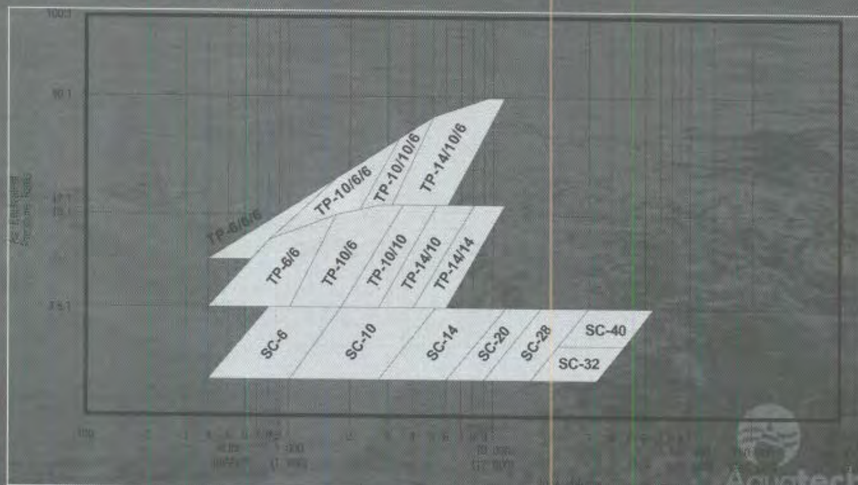
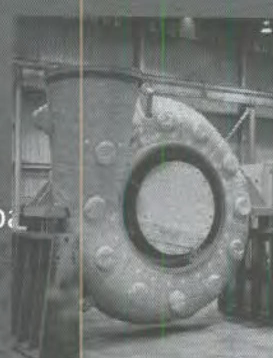
Operating Range – Compressor

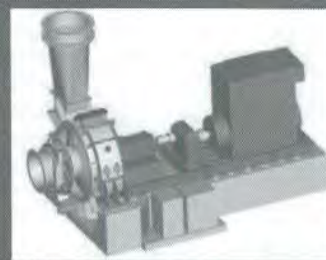


D-Style Single Stage

- Inlet Volume
  - 1,000 - 260,000 CFM
- Pressure
  - Vacuum -250 psig (17 ba



Centrifugal Fan



- Low Speed (1500 - 4400 rpm)
- Casing – 316 SST or Duplex
- Impeller Duplex
- Pressurized lubrication system
- Significant flexibility of arrangement of nozzles
- IGV for capacity control and 50% turndown
- Standard instrumentation
  - Vibration, current draw, system temperatures
- Robust design for foam carryover
- Polytropic efficiency, 70% - 75%

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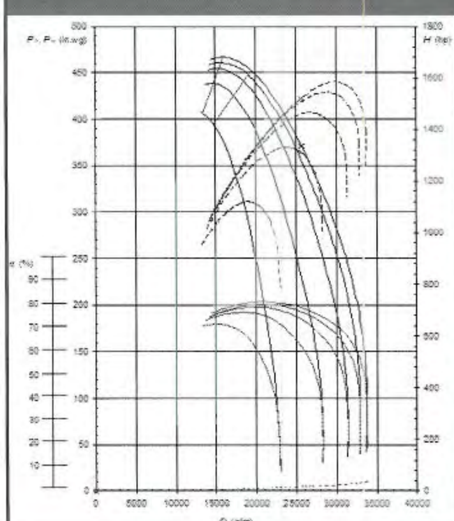
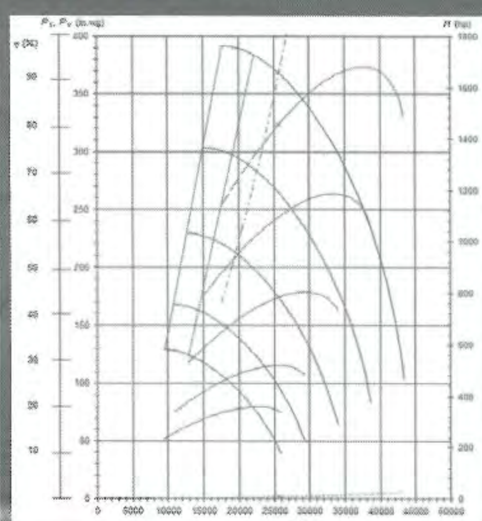
Centrifugal Fan

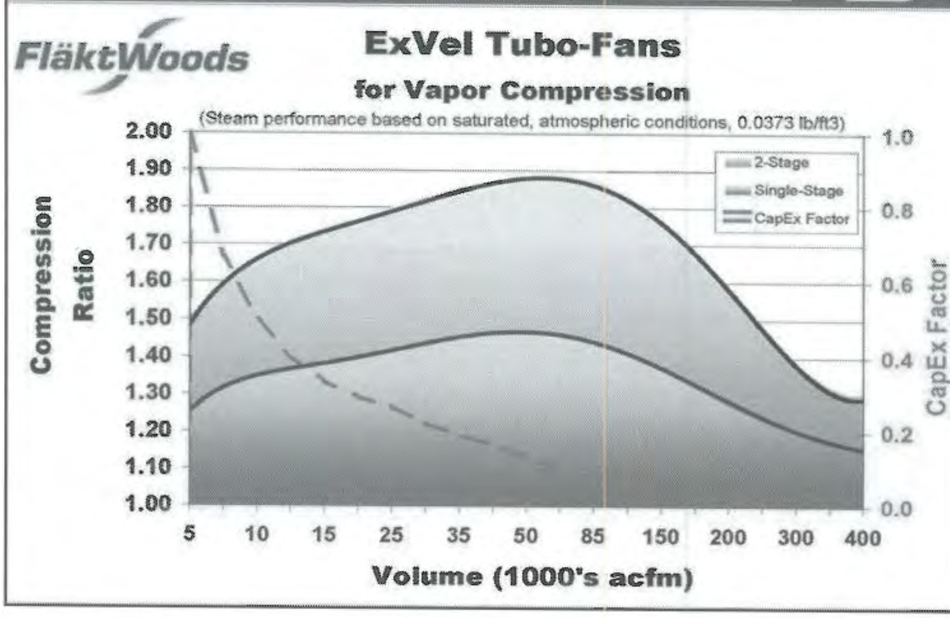
INLET GUIDE VANE CONTROL



VFD CONTROL

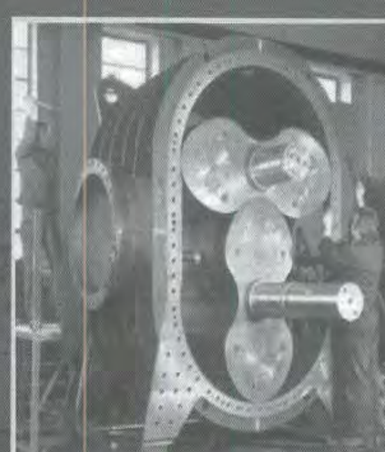


Centrifugal Fan

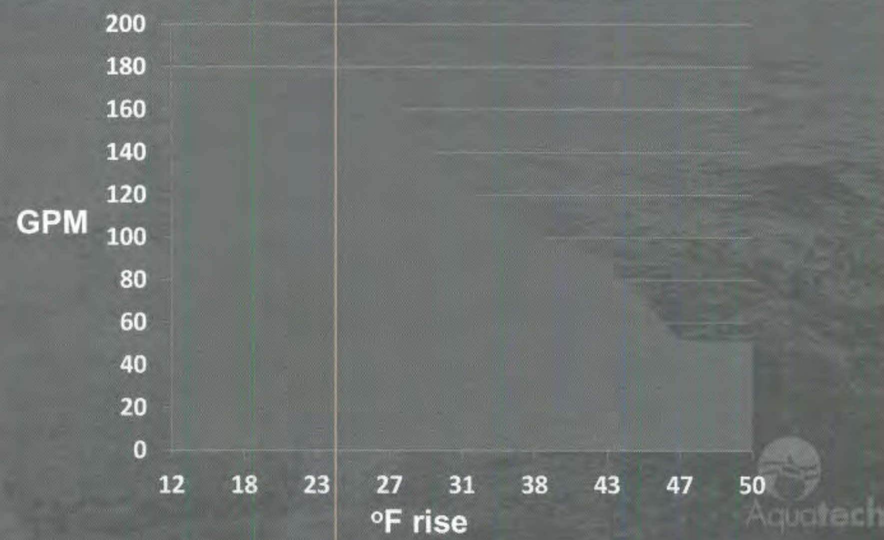


Positive Displacement Blower

- Rotary Blower
  - Constant volume machine
  - Tight rotor clearances
  - Sensitive to foam carry-over or water slugs
  - Water injection required to limit thermal expansion
  - Cast iron, ductile iron construction
  - Capacity control by VFD or vapor recycle



Operating Range – PD Blower



Mechanical Vapor Compressor

- Why a Mechanical Vapor Compressor
  - Eliminates steam usage
  - Eliminates cooling water usage ←
  - Most energy efficient
- Why not a Mechanical Vapor Compressor
  - It has limited capability to adjust to errors in design chemistries
  - Limited delta T.
  - Expensive (CAPEX)
  - Rotating Equipment

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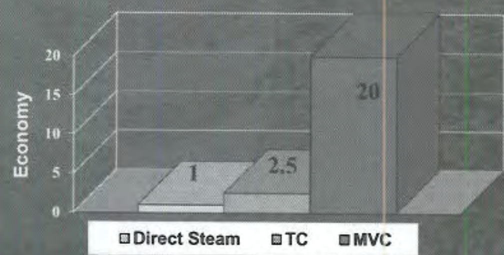
Energy Economy Comparison

- Direct Steam (boiler or vent from BC)
- Thermocompressor (TC)
- Mechanical Vapor Compressor (MVC)

most $ efficient from OPEX perspective.



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Types of Mist Eliminators

- Knock Out Drums
- Cyclonic
- Wire Mesh
- Chevrons
- Vapor Washer

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Knock Out Drums

- A large tank
- Based on vapor velocity
- Removal of particles larger than 100 micron
- Solids handling capability high

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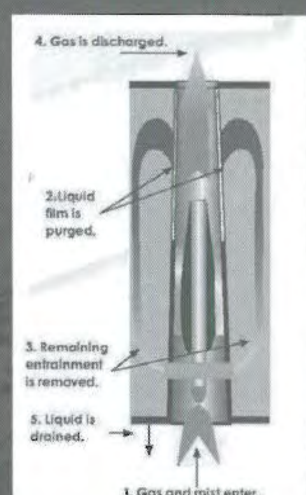
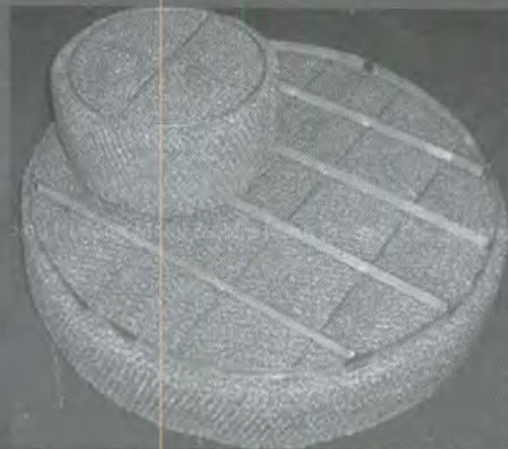
Cyclones

- Separation based on centrifugal force
- Pressure drop 8" – 14" WC
- Removal size 7-10 micron
- Solids handling capability high



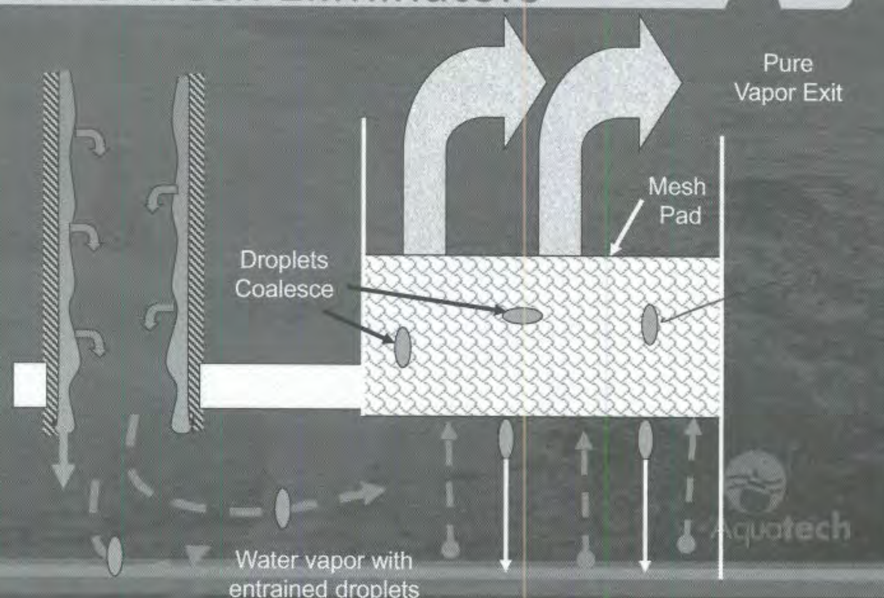
Wire Mesh Eliminators

- Based on impaction
- Pressure drop ~1" WC
- Removal size 3-10 micron
- Solids handling capability low



probably most efficient but also most prone to plugging.

Wire Mesh Eliminators



droplets can dry & they'll have solids in them

Wire Mesh Eliminators

clogged w/solids (white)

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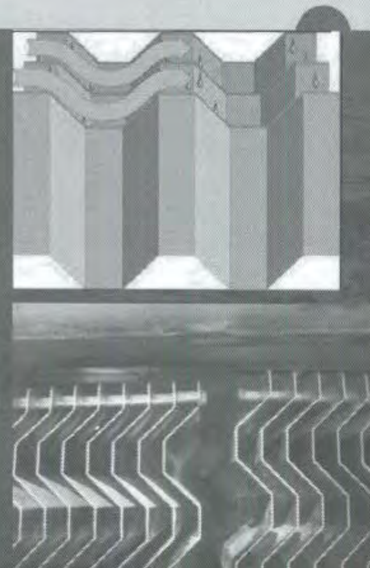
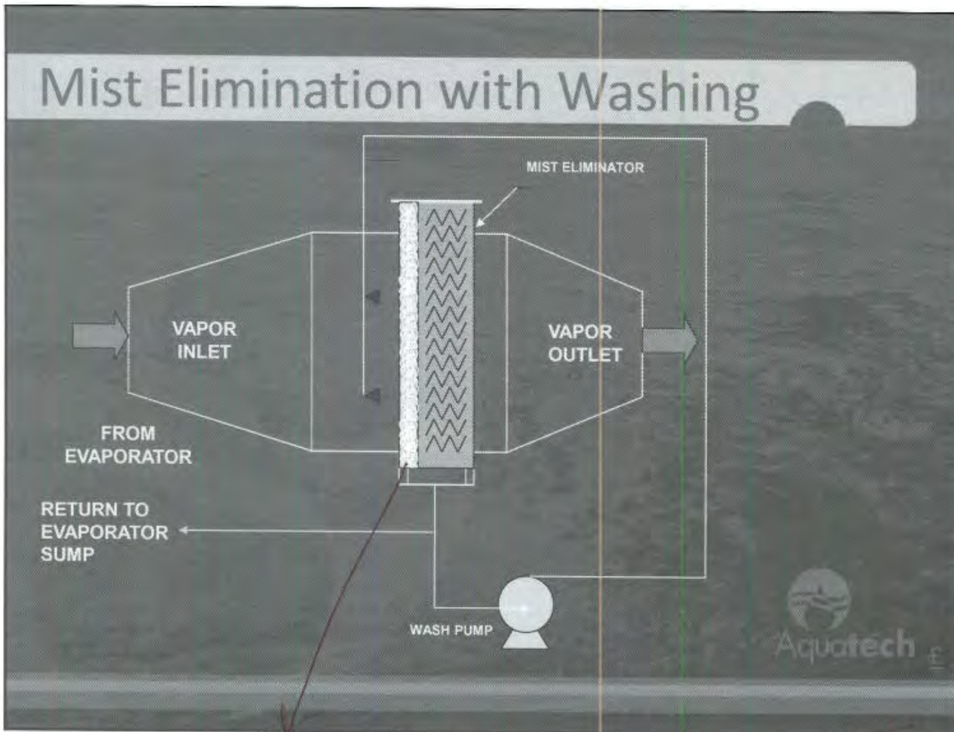
Chevrons

- Based on impaction
- Pressure drop ~0.4-3.5" WC
- Removal size 3-10 micron
- Solids handling capability high



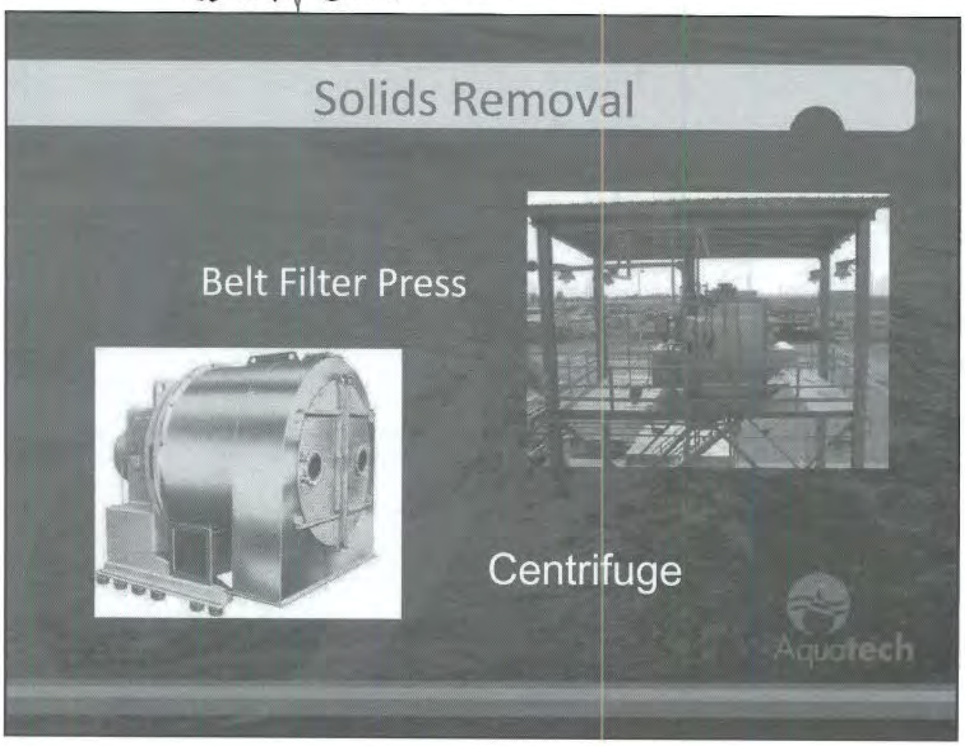
not as efficient as mesh but can add more stages/passes.



this is for highly purified distillate.

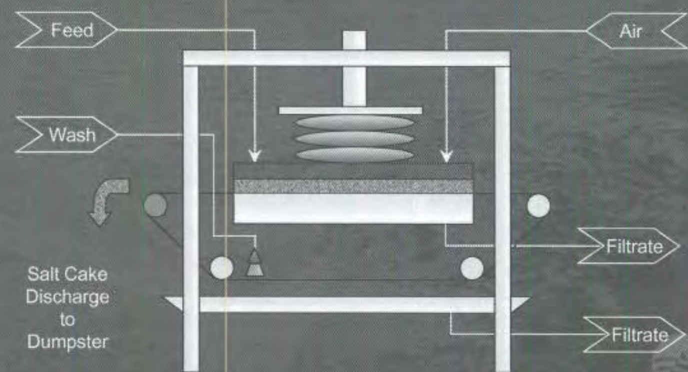
~~[illegible]~~ intermittent washing for less purified distillate.

agglomerator (wire mesh) usually cont. washed.



Belt Filter Press

Automated Belt Filter Press



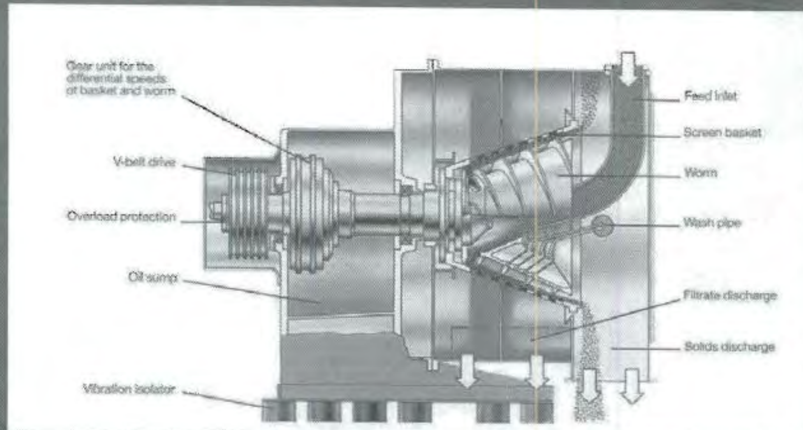
< 1 ton/hr.

Belt Filter Press

- **Dewatering Device- Belt Filter Press**
  - Available materials
    - Inconel 625
    - 6 Moly SST
    - 316 SST
  - 78 micron high temperature nylon belt
  - Batchwise operation
  - PLC automated operation
  - Typical moisture content 10-20%

Centrifuge

- **Centrifuge - Basket/Worm-Screw Type**



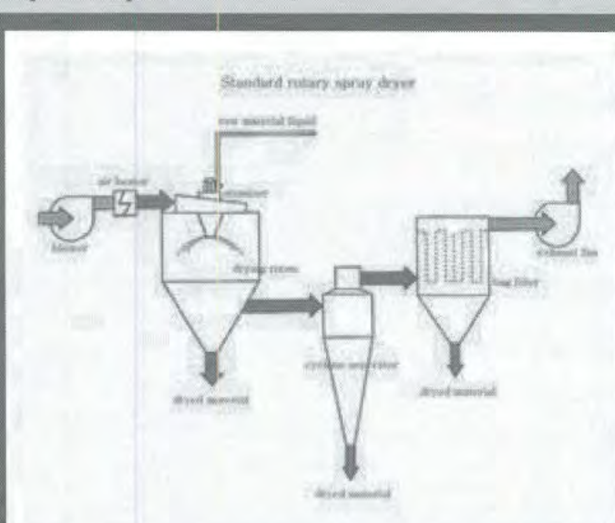
Centrifuge

- **Dewatering Device- Centrifuge**
  - **Available Materials**
    - **316 SST**
    - **6% Mo SST**
    - **Duplex**
    - **Hasteloy**
  - **Pressure Lubricated**
  - **Continuous operation**
  - **Minimum slurry feed concentration is 10%**
  - **Low cake discharge moisture, approximately 5%**

Spray Dryer

- **Spray Drier**

Spray Dryer



Spray Dryer

- Dewatering Device- Spray Dryer
  - Wetted parts are 316L SST
  - Liquid distribution by high speed wheel or fluidizing nozzle
  - Dries both dissolved and suspended solids.
  - High energy usage
  - May use multiple energy sources
    - Steam
    - Electricity
    - Gas
    - Waste Heat
  - Low solids moisture, <1%

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EVAPORATOR ISSUES

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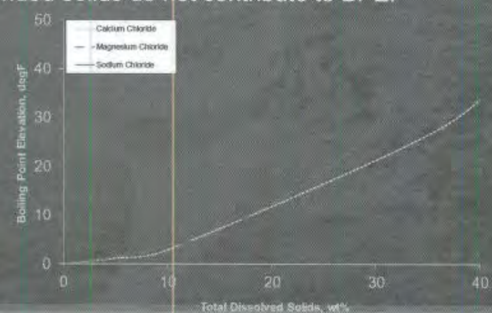
Boiling Point Elevation

- Solutions containing dissolved solids boil at a higher temperature than pure water at the same pressure.
- The difference in boiling temperature between a solution and pure water is called boiling point elevation (BPE).
- In general, the BPE of a solution rises as the solution TDS concentration increases.
- Suspended solids do not contribute to BPE.



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Scaling

- Scaling is the precipitation of insoluble salts and consequent adhesion to vessel surfaces.
- The most insoluble ions are the most likely to scale.
- The most common scales are:
  - Calcium Carbonate $CaCO_3$
  - Calcium Sulfate $CaSO_4$
  - Silica SiO_2
  - Or combinations of them

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Scaling Control

- Calcium Carbonate
  - Reduce pH
- Silica
  - Increase pH

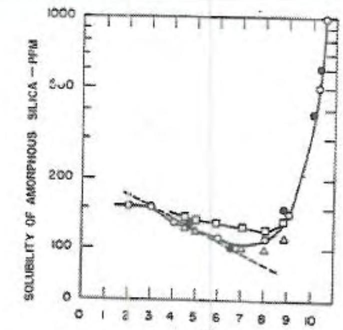

Figure 1.6. Solubility of amorphous silica versus pH: O, Alexander, 25°C; ●, Cherkinskii and Knyaz'kova (160) 19°C; Baumann, 20°C; Baumann, 30°C; Dashed line from Cherkinskii equation: $\log C_M = -2.44 - 0.053\,(pH)$.

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Scaling Control

Mechanisms of scale control

* Threshold
* Crystal growth
* Crystal distortion
* Dispersancy

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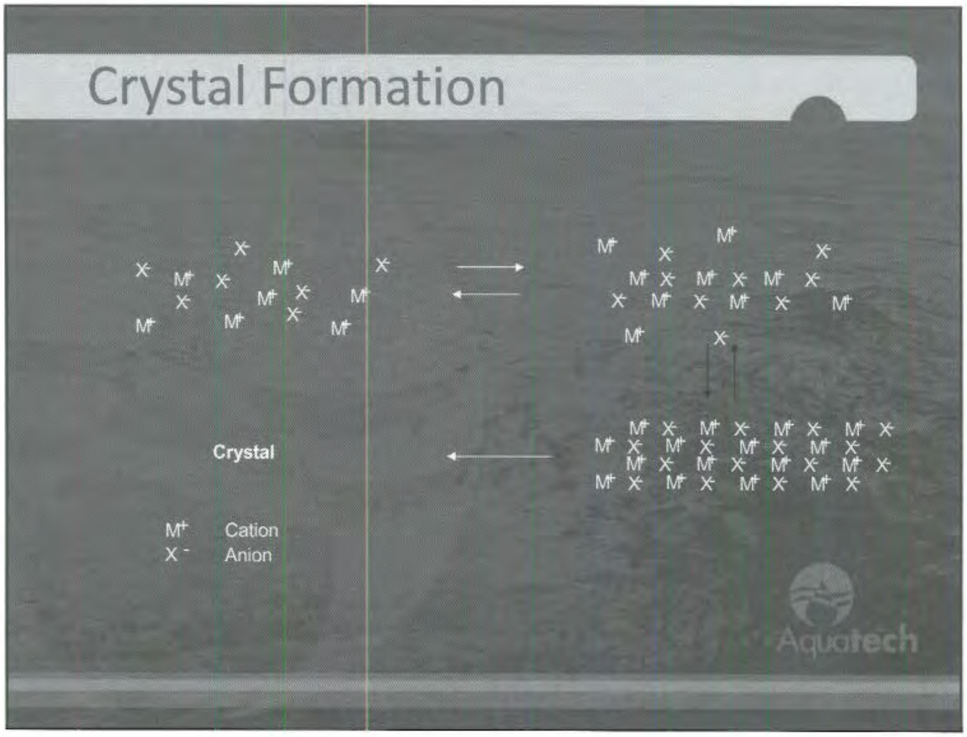
Crystal Formation
Crystal
M+ Cation
X - Anion
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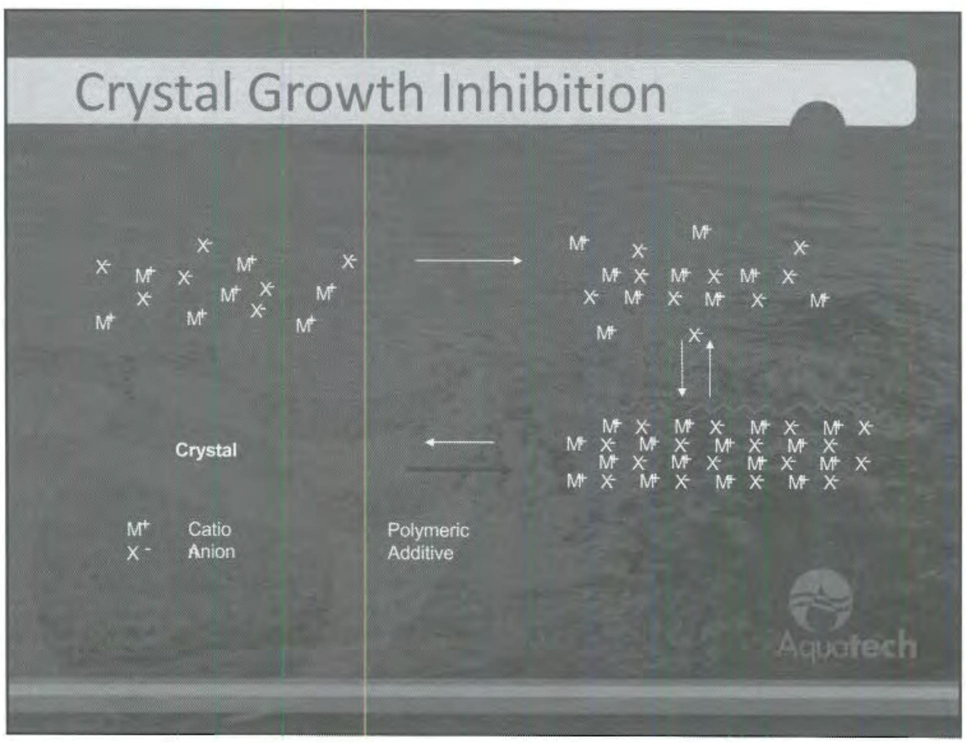
Crystal Growth Inhibition
Crystal
M+ Catio
X - Anion
Polymeric
Additive
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Crystal Distortion

(i) Crystal Lattice

Hard scale

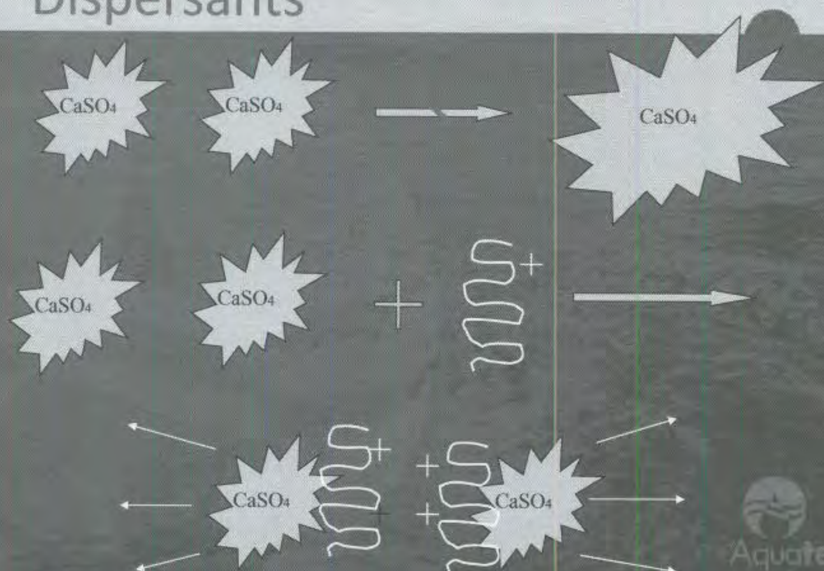
Good adherence to surfaces

(ii) Distorted Crystal Lattice

Soft scale

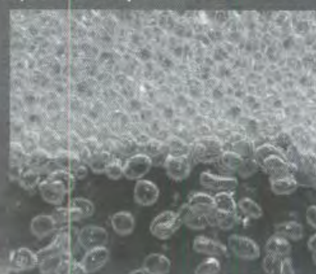
Less adherent to surfaces

Dispersants



Evaporator Foaming

- Cause
  - Organic Compounds and Surfactants that increase surface tension and stabilize the liquid-vapor interface
- Consequences
  - Foam carry-over with pure vapor
  - High conductivity distillate
  - Harmful to vapor compressor



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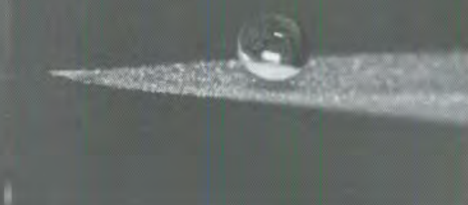
Examples of Surface Tension



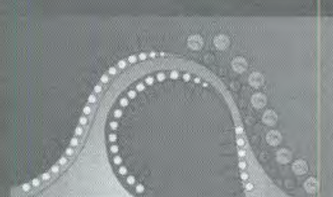
Surface Tension

- Surface tension is defined as the force along a line of unit length where the force is parallel to the surface but perpendicular to the line.
- Surface tension is caused by the attraction between the molecules of the liquid by various intermolecular forces

Foaming Solution

Anti-Foam Agent

– Compounds that change the surface tension to stabilize the liquid-vapor interface or destabilize the liquid-vapor interface of the foam bubble



- Concept
- Because of their spreading properties and due to their low surface tension, silicone fluids can enter into the foam lamella and displace the foam stabilizing surfactants from the liquid-air interface. The foam lamellas are thereby destabilized and burst, which lets the foam collapse.

Rules of Thumb

- It is always best to run a crystallizer using steam
- Concentration factors of >10 result in no steam usage for vapor compression.
- High ratios of Ca to SO_4 (>0.55) are usually bad for crystallizers.
- Steam flow (#/h) = Evaporation (#/H)/# Effects
- Cooling water (GPM) = 10% Steam Flow (#/h)

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unfortunately most $

Troubleshooting

- Evaporation is low
  - Insufficient delta T
  - Scaled heat transfer surface
  - Insufficient circulation
  - Physical properties changed and the BPE is too high
- The antifoam isn't working
  - Chemistry has changed
  - Too much antifoam is being added
  - Not enough antifoam is being added
- I have too much concentrate
  - The feed concentration is too high
- Mechanical Vapor Compression
  - Too much steam is being used
    - Evaporator is too clean and the compressor isn't inputting enough energy
    - The feed preheater is scaled
  - The compressor is surging
    - Insufficient vapor flow to the compressor

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SIZING AN EVAPORATION SYSTEM

What do we need to know

- What are the customer expectations
- What is the feed flowrate
- What is the feed chemistry
  - What streams are being fed to the system
- What are the limits on discharges
- Are there limitations on utilities
- Are there limits on budgets

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Industrial Concentration & Desalination

EVAPORATOR AND CRYSTALLIZER QUESTIONNAIRE

Customer: ______ Date: ______

Address: Street ______

City ______ State ______ Zip Code ______

Country ______

Contact ______ Title ______

Telephone ______ Fax ______ Email ______

Description of Project ______

Funded? ☐ Yes ☐ No

Process Purpose

☐ Waste Minimization ☐ Water Recovery/Reuse

☐ Environmental Compliance ☐ Product Recovery

Other ______

Reason for Equipment Purchase:

☐ New ☐ Upgrade

☐ Expansion ☐ Replacement

Method of Disposal

☐ ZLD/Landfill ☐ Sewer/POTW

☐ Truck Offsite ☐ Inject underground

☐ Reuse Other ______

Origin of Stream to be evaporated ______

Description of Stream ______

Please specify quantity and unit of measure for the following characteristics of the feed stream.

Temperature:	Pressure:	Flow Rate:	Frequency:
Design: ______	Design: ______	Design: ______	Hours/Day ______
Minimum: ______	Minimum: ______	Minimum: ______	Days/Week ______
Maximum: ______	Maximum: ______	Maximum: ______	Weeks/Year ______

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Industrial Concentration & Desalination

Raw Water Analysis ☐ mg/L as ion or substance ☐ mg/L as $CaCO_3$

Na^+ ______	Cl^- ______	SiO_2 ______
K^+ ______	SO_4^{-2} ______	CO_2 ______
Ca^{+2} ______	HCO_3^- ______	NH_3 ______
Mg^{+2} ______	CO_3^{-2} ______	H_2S ______
Fe^{+2} ______	PO_4^{-3} ______	TDS ______
Fe^{+3} ______	NO_3^- ______	TSS ______
Mn^{+2} ______	F^- ______	pH ______
Ba^{+2} ______	S^{-2} ______	m-Alkalinity ______
Sr^{+2} ______	SO_3^{-2} ______	p-Alkalinity ______
NH_4^+ ______		Turbidity ______

Other Feed Stream Characteristics BOD: COD TOC

Other Information of Feed Stream

Distillate Purity Requirements

TDS ______ VOC ______ Temp ______

pH ______ Conductivity ______

Other Ions of interest ______

Is a sample (minimum 1 gallon) of the feed available for bench scale testing? ☐ Yes ☐ No

What is the desired concentration to be achieved? wt% solids ☐ zero liquid discharge

End use of the product? ☐ waste ☐ sale ☐ further processing ______

End use of the recovered water (distillate)? ☐ waste ☐ sale ☐ recycle to process

Electric power available: Quantity ______ KW Volts ______ Phase ______

Frequency ______ Cost ______ /KWH

Steam available: Quantity ______ Pressure ______ Temperature ______ Cost ______ /1000 #

Waste heat available: Quantity ______ Temperature In ______ Temperature Out ______

Cooling water available: Quantity ______ Temperature In ______ Temperature Out ______

Natural Gas available: Quantity ______ Pressure ______

Other information or concerns ______

Evaluating the Offer

- What is the equipment cost?
- What is the operating cost?
- What are the materials?
- How easy is it to install?
- What is the area?
- What is the circulation rate?
- Has the vendor evaporated this brine before?
- How has he handled problems?
- What is the vendor's operating experience?
- Do I have enough power?
- Do I have enough steam?
- Do I have enough water?
- Can I get it in the building?

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FINAL RULE

- THE SOUR TASTE OF POOR SELECTION LINGERS LONG AFTER THE SWEET TASTE OF LOW PRICE HAS BEEN FORGOTTEN

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FINAL FINAL RULE

- GARBAGE IN = GARBAGE OUT.

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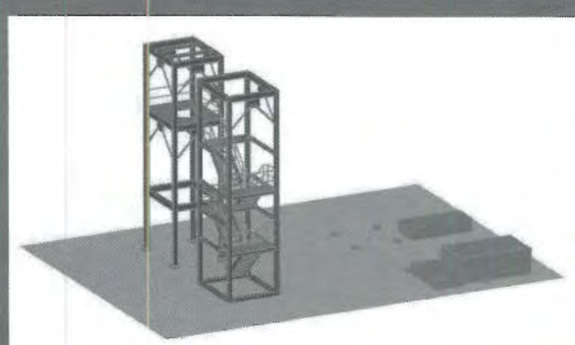
Interesting Projects

Shoe-horn
Small amount
of room.

Site Assembly

Structural Module #2 Located at Site



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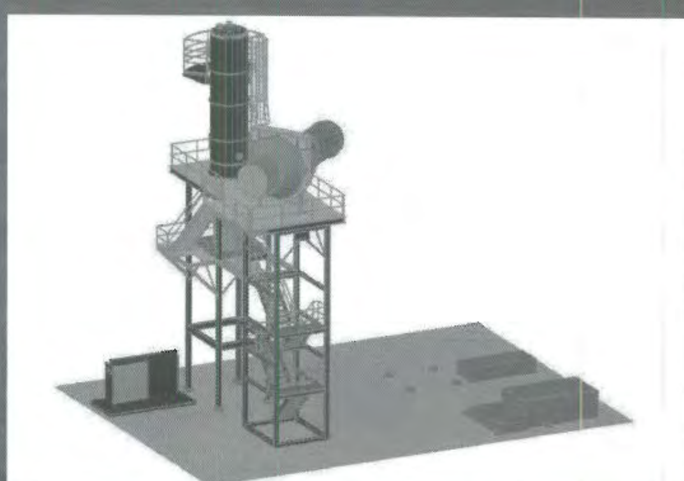
Site Assembly

Site Structural Steel, Handrail and Stair Installed

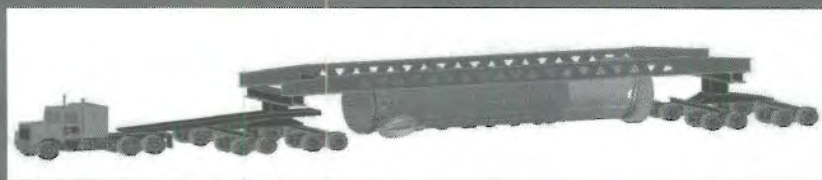
Site Assembly



Deaerator, Mist Eliminator, Distillate Tank, and Misc. Skids Installed

Evaporator Shipments

Lower Half of Evaporator



Upper Half of Evaporator

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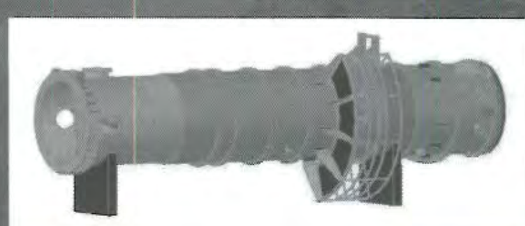
Evaporator Lower Half Preparation

Lower Half of Evaporator Insulated in Staging Area

Lower Half of Evaporator - Platform and Supports Installed.



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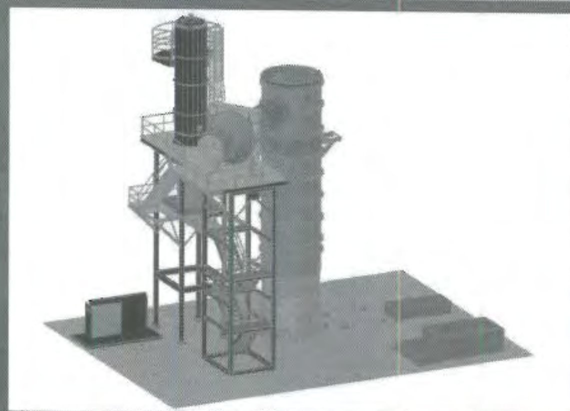
Evaporator Lower Half Installation

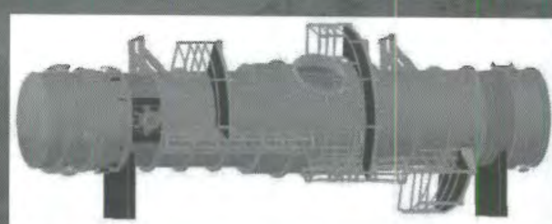
Lower Half of Evaporator Located on Site



Evaporator Upper Half Preparation

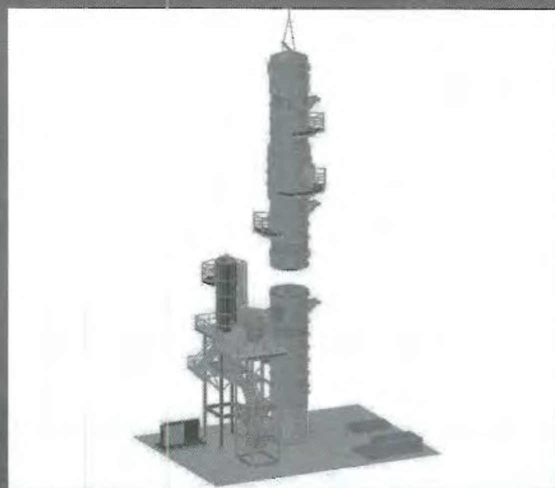
Upper Half of Evaporator Insulated in Staging Area.

Upper Half of Evaporator - Platform , Ladders and Supports Installed



Evaporator Upper Half Installation

Upper Half of Evaporator Mounted to Lower Half of Evaporator



Equipment Installation

Compressor, Hydrocyclone, Recirculation Pumps and Ducting Installed

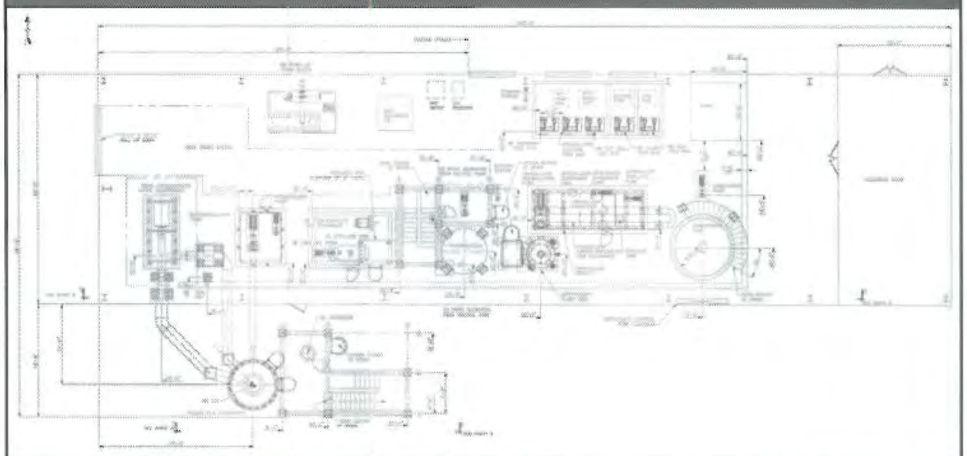
Equipment and Ducting Installed

Suction and Discharge Ducting and Piping Installed

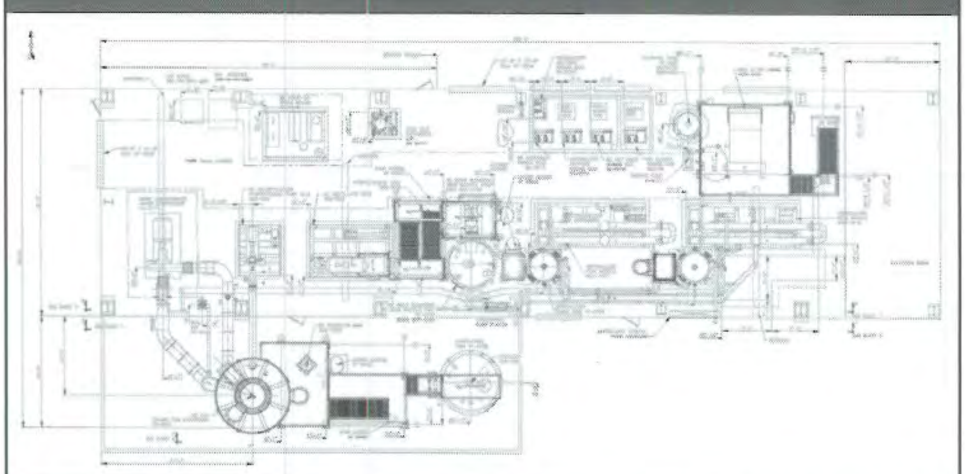
Interesting Project

- Scope
  - BC
  - FC
  - Boiler
- Location
  - Indoors in new building
- Purpose
  - Waste Minimization
- Change
  - Double Evaporation in FC
  - Purpose
    - ZLD
- Challenge
  - Use existing boiler
  - Fit within existing building
  - Integrate with existing equipment
  - Don't interrupt production of original equipment

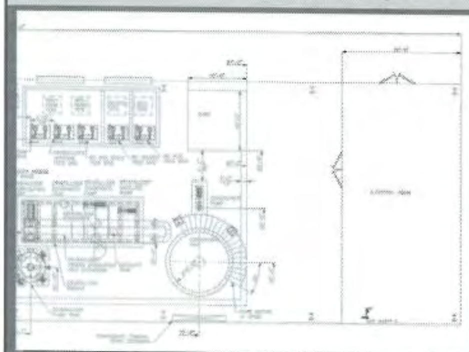
Original Design

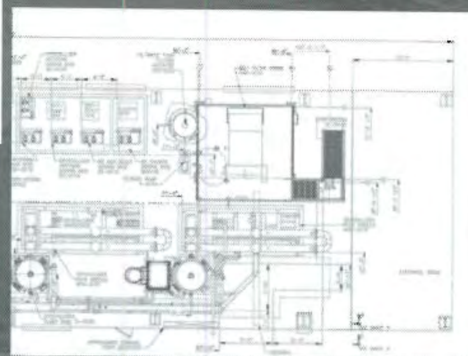


Modified Design



Comparison





Contact

- Mike Marlett

- Marlettm @ Aquatech.com
- 262+369-4039

Top 10 of what we don't want to hear

- TDS will range from 0 – 45,000 mg/l
- Design the system for 100 GPM max feed but we will normally have 10 GPM.
- Give me an evaporator for 100 GPM feed.
- It has to be cheap but high quality.
- I want the latest technology but it has to have 15 years of proven service
- Can you hold the price for 2 years?
- Don't worry about the specifications. We'll work that out after the order.
- I know this is a new system but I need all the drawings in 2 weeks.
- It's exactly like the last one with just a few small changes.
- I don't know the chemistry or flow, just give me a price for an evaporator.

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Top 10 (What the Supplier Needs)

1. What's the chemistry
2. What's the evaporation rate
3. What's being done with the water
4. Are there space issues
5. Are there specifications
6. When do you need the proposal
7. When does the plant need to be operating
8. What energy limitations do you have
9. Where is it going
10. Do you have special concerns?

And last but not least

11. How much money do you have?

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