


**THERMOENERGY™**

**Flash Vacuum Distillation**  
**A More Effective Evaporative Method**  
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Executive Vice-President

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- Water treatment since 1984
- High TDS and metal industrial process waters
- Recovery of water and process chemistry for reuse or recycle
- First ZLD system in US
- 85+ systems sold
- High performance and reliability over many years
- 48,000 manufacturing and engineering facility
- Worcester, Massachusetts

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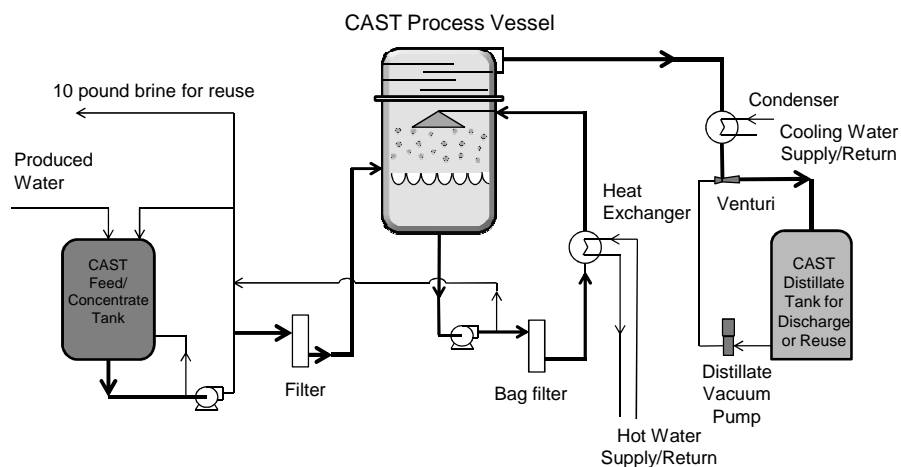
### Recovering Produced Water Critical Issues

- Water Quality Requirements (need for fresh water)
- Choice of Technology
  - Above 35,000 mg/l TDS evaporative systems
  - MVR, atmospheric, humidification/dehumidification, thin film technologies
- Prevention of scaling/salting of treatment systems as solubility limits are approached
- Brine recovery and reuse
- Energy consumption

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### CAST Flash Vacuum Distillation Process Flow Diagram



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CAST Vacuum Technology Advantages	THERMOENERGY™
<p><b>Flash Distillation and Vacuum Evaporation with a Vapor/Liquid Separation system</b></p>	
<ul style="list-style-type: none"> <li>⌚ Lower Boiling Temperature, typically 100-140°F. Facilitates use of lower cost engineering plastics, reducing overall cost of manufacturing and customer installed cost.</li> <li>⌚ High flow forced flash distillation allows for reduced carry over (high quality distillate water)</li> <li>⌚ Elimination of fugitive discharges. RCRA permit exemption from USEPA</li> </ul>	
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CAST Advantages (continued)	THERMOENERGY™
<ul style="list-style-type: none"> <li>⌚ External, commercially available plate and frame heat exchangers</li> <li>⌚ Low temperature &amp; high flow rate and large heat exchanger surface area allow for use of low temperature heat sources, such as hot water, low pressure steam or waste heat</li> <li>⌚ High flow rate used to produce the necessary spray also produces high shear forces, low temperature differentials and low surface film temperatures in the external plate and frame heat exchangers</li> </ul>	
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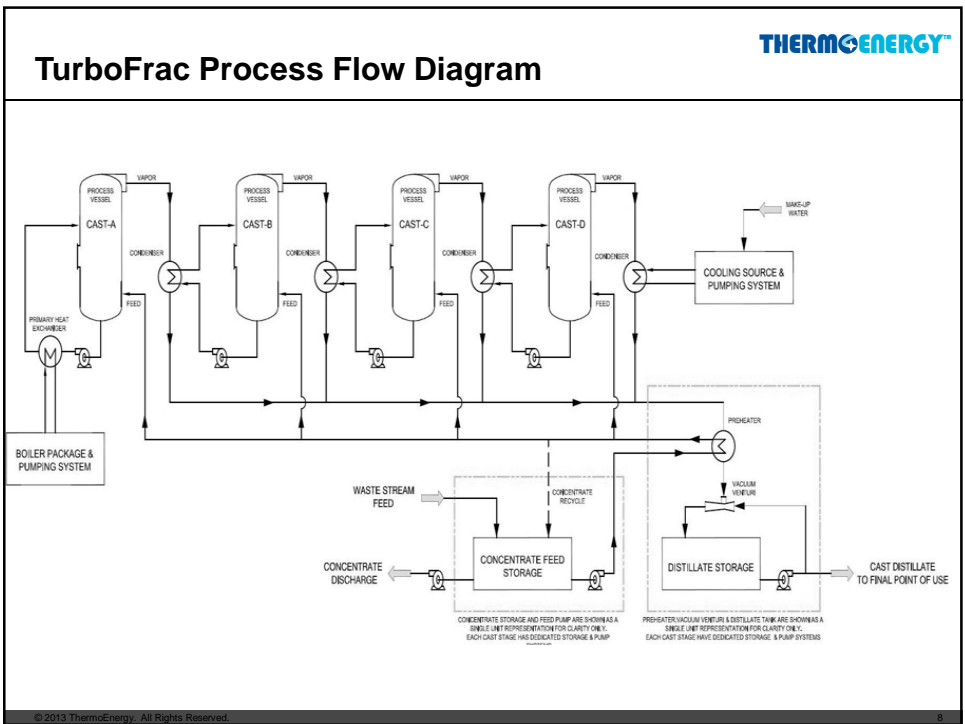
## TurboFrac 4000

- ⦿ 4000 BBL/day to 100,000 BBL/day systems
- ⦿ Can process higher influent TDS (> 150,000 mg/l) than other evaporation methods
- ⦿ Energy Efficient multiple effect design
- ⦿ 60-90% water recovery
- ⦿ Compact
- ⦿ Ease of operation and maintenance
- ⦿ Production of 10lb brine with pretreatment

ThermoEnergy Staged CAST System

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**65 BBL/Day Pilot System**



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**Superior Distillate Qualities**

Parameter	Unit	Pilot Test 1 Feed Water	Pilot Test 1 Distillate	Pilot Test 2 Feed Water	Pilot Test 2 Distillate
<b>pH</b>	Unit	6.8	5.4	7.68	7.63
<b>TDS</b>	Mg/l	250,000	120	105,000	36
<b>Sulfate</b>	Mg/l	1,313	4	2,190	28
<b>Ca Hardness</b>	Mg/l as CaCO <sub>3</sub>	7,820	54	3,500	6.40
<b>Chloride</b>	Mg/l	124,000	91	76,200	16.2
<b>Magnesium</b>	Mg/l			630	1.2
<b>Sodium</b>	Mg/l			40,000	5.7
<b>Iron</b>	Mg/l			13	ND
<b>Total Hardness</b>	Mg/l			11,300	20.9

Water Recovery was 70%. Run time 7 hours. Sample size 900 gallons

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### 10 Pound Brine for Reuse

Parameter	Unit	Feed Water	Concentrate
Chloride	Mg/l	76,200	293,000
Total hardness	Mg/l	11,300	32,100
Specific Gravity	G/l	1.06	1.228
Sulfate	Mg/l	2,190	9,920
Calcium	Mg/l	3,500	9,900
Iron	Mg/l	13	7
Magnesium	Mg/l	630	1,800
Sodium	Mg/l	40,000	78,000
TDS	Mg/l	105,000	300,000

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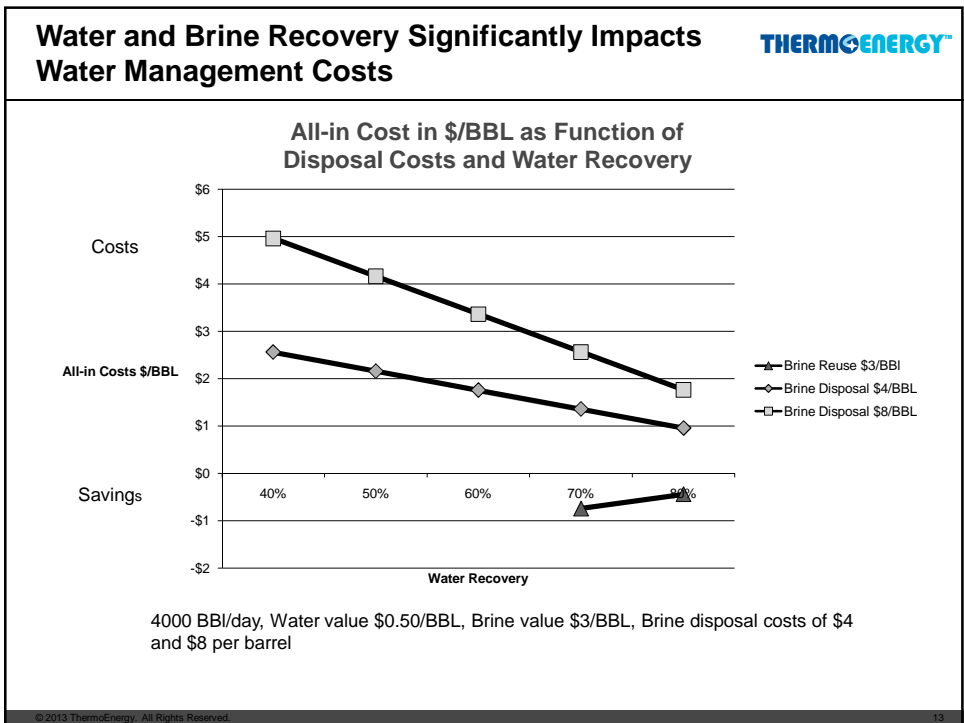
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### Energy Efficiency at a Low Capital Cost (4000 BPD)

	TurboFrac	MVR
Power (Kw/hr)	433	1026
Heat (Mbtu/hr)	12	
Energy Consumption (Kwh/bbl intake)	37.9	42.7
Capital Cost (\$/bbl) (5 yr amortization)	\$0.74	\$1.00
Operating Cost per barrel (based on 100,000 mg/l)	\$0.69	\$0.74
All-in Per Barrel Cost	\$1.43	1.74

Assumptions: 60% Recovery of water, \$0.12/Kwh, \$4.50 Mbtu/hr, 4,000 BBLs/day produced water. H<sub>2</sub>S and metals add \$0.09/bbl

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- ### Competitive Advantage - TurboFrac vs. MVR
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- Higher water recovery (60-90%)
  - Recovery of a 10 pound brine (10.22 pound brine)
  - TurboFrac has a 20-25% cost advantage over MVRs
  - CAST use of FRP and engineering alloys eliminates the chloride corrosion issues and allows CAST® systems to operate at lower pHs.
  - MVRs operate at higher temperatures and therefore generally can't use fiberglass (FRP) or engineering plastics.
  - MVRs typically limit TDS concentrations to <150,000 mg/l due to the increase in boiling temperature associated with higher salt concentrations. Additionally, as the boiling temperature increases, efficiency significantly decreases with MVRs.
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**Summary** **THERMOENERGY™**

- ⌚ CAST flash vacuum technology platform is proven, versatile, and simple to operate and maintain.
- ⌚ CAST Technology can treat difficult wastewaters containing high TDS. ThermoEnergy systems have a long operating history with low maintenance costs
- ⌚ Compared to other distillation systems CAST is superior in terms of costs and performance

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Turning Wastewater into Revenue

Questions?

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