Cost Effective Treatment of Produced Water Using Co-Produced Energy Sources for Small Producers

Presented by Liangxiong Li

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RPSEA Program Review Meeting, Midland, TX, Feb. 3, 2010.

1. OVERVIEW

- **RPSEA Contract: #07123-05**
  - **RPSEA** *project manager: Charlotte Schroeder and* James Pappas *(Houston)*
- **Timeline**
  - *Project start date: August, 2008*
  - *Expected project end date: July, 2011*
  - *Percent complete: ~50%*
- **Budget/Total Project Funding**
  - *RPSEA: $409,506*
  - *Cost share: $683,163*
  - *Total budget: $1,103,706*
- **Project Goal**
  - Develop and demonstrate a thermal-based desalination process for produced water purification at wellhead by using co-produced geothermal energy or solar energy.

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2. SCOPE & APPROACH

Development and demonstration of a low-temperature distillation unit by using co-produced energy sources for produced water purification at wellhead**. Project includes two phases:**

- **Phase 1 (FY08-09):** Development of a Co-Sited Produced Water Purification Technology that Can be Deployed at Wellhead, Including Process Design and Equipment Procurement. (COMPLETE)
- **Phase 2 (FY09-10):** Pilot Test of Produced Water Purification at Wellhead . (ON-GOING)

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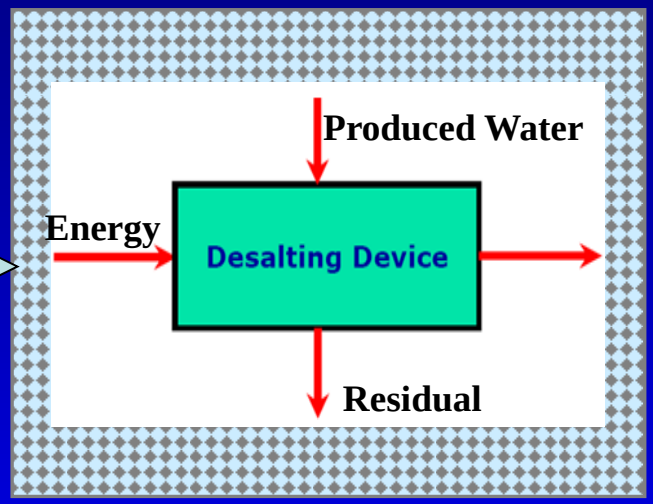
2.1 Background of Produced Water

Quality

Economic Efficiency

Quantity

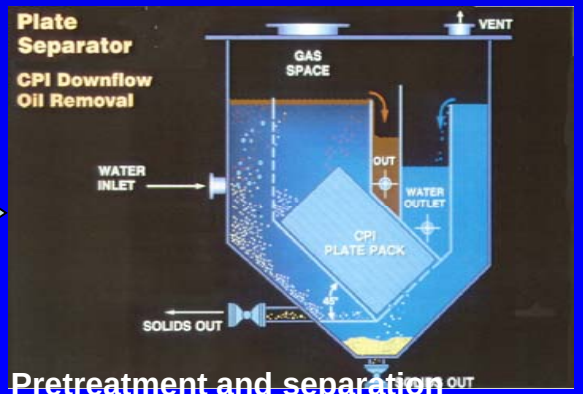
Wellhead Separation



Clean water

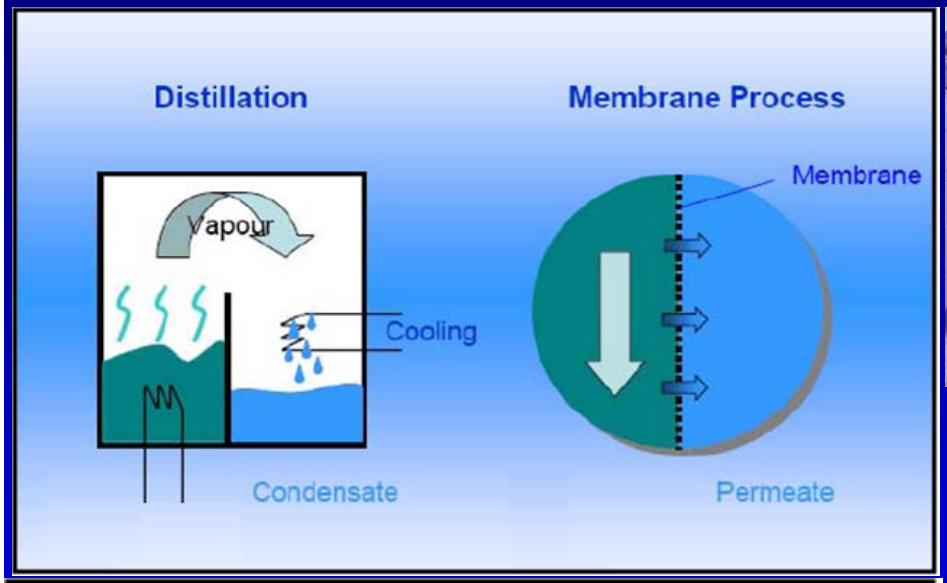
(Beneficial uses)

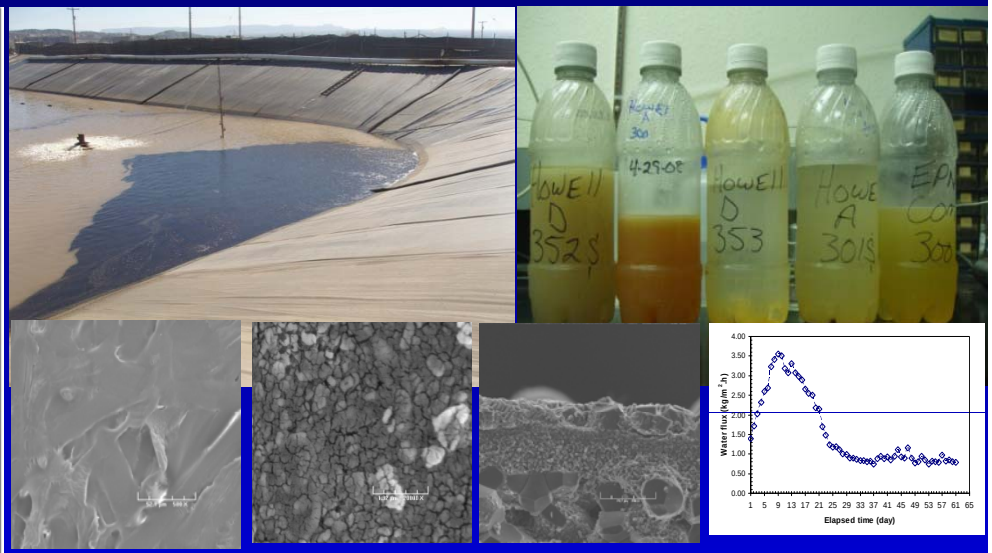
Disposal – reduced volume
Concentrated brine for drilling fluid

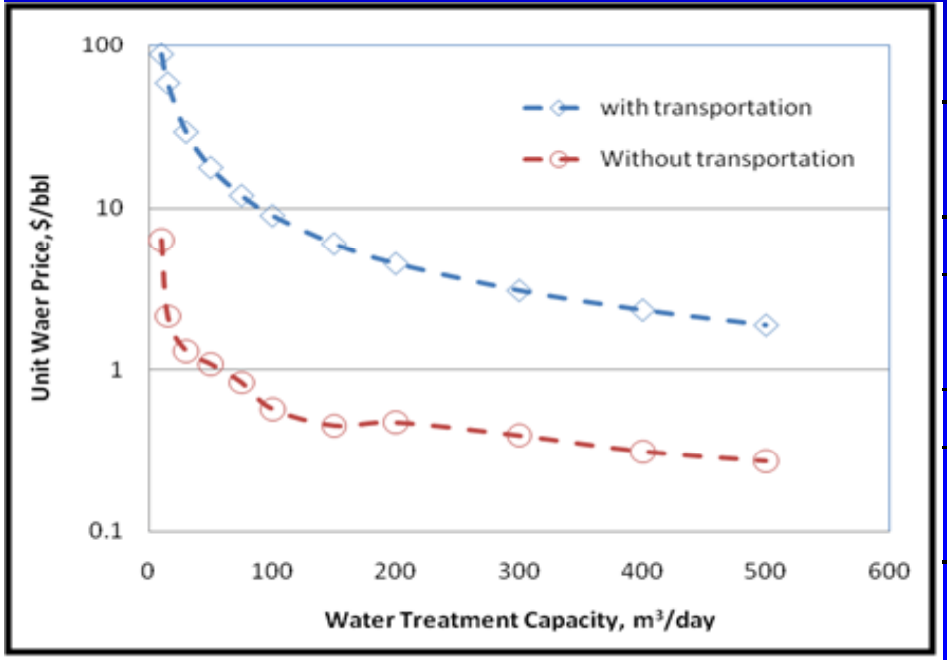


Pretreatment and separation

2.2 Technical Approach





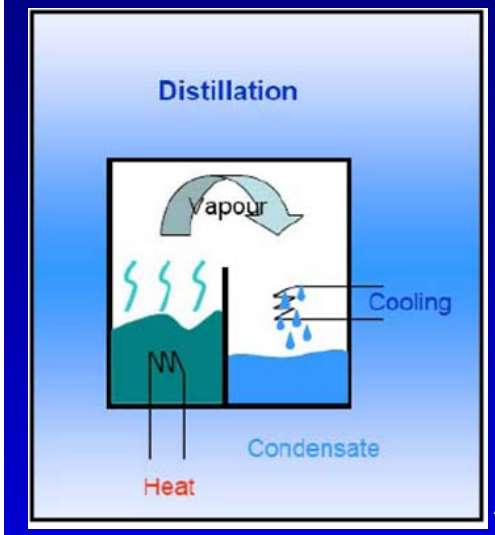


Percent Distribution of Cost Factors

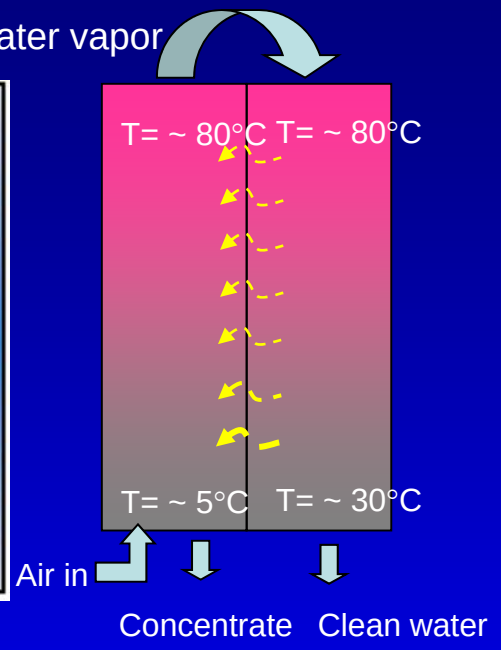
	Produced Water (%)	Seawater (%)	Brackish water (%)
Pretreatment	36	17	10
RO membrane replacement	12	6	7
Fixed costs	20	27	54
Electric power and maintanence	32	50	20

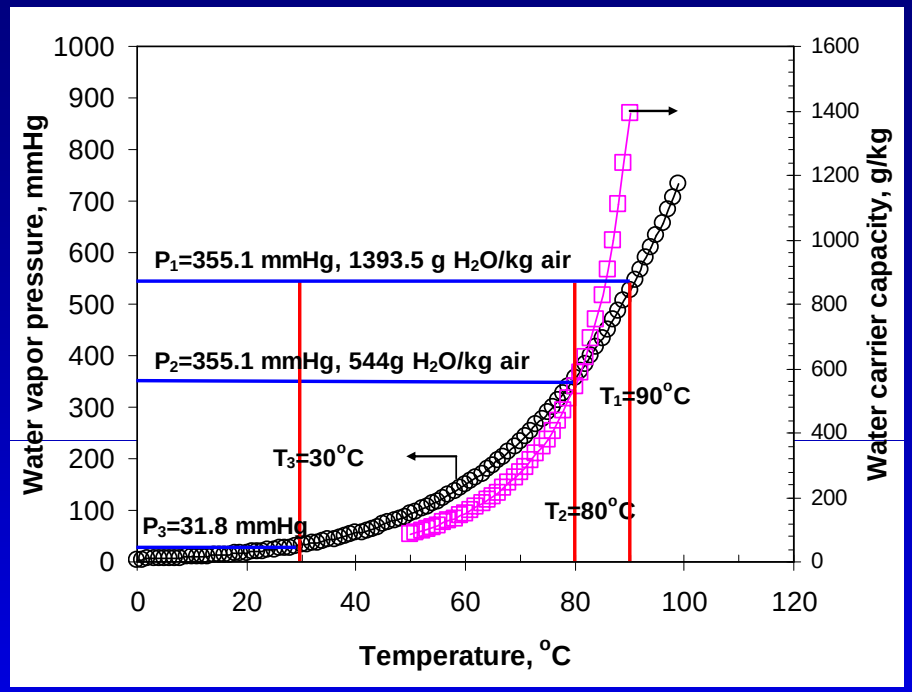
Younos, 2005.

2.3 Desalination Mechanism



Beckman et al., 2006, 2008



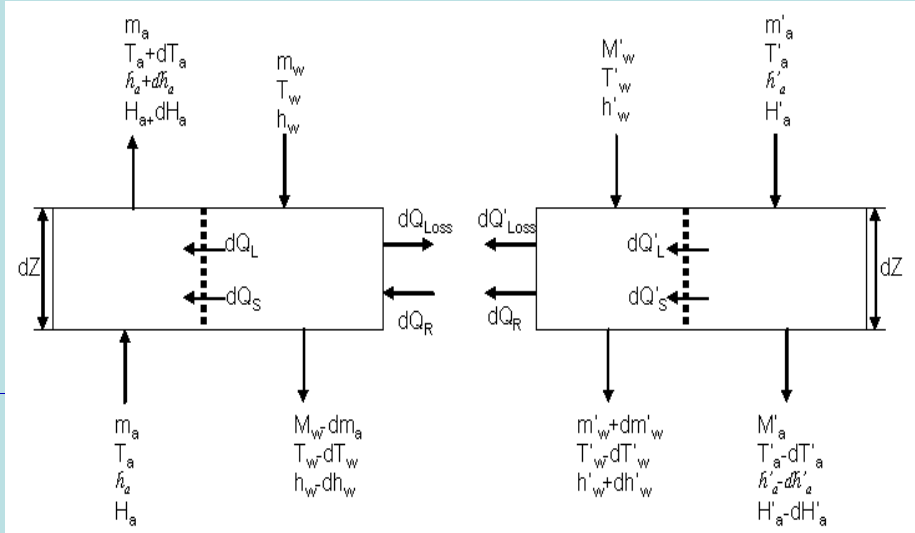


Component	San Juan Basin (), mg/L	Permian Basin (Oilfield), mg/L	Typical Seawater, mg/L
Bicarbonate ( )	5870.3	1538.1	107
Hydrogen sulfide ( )	65	22.5	N/A
Chloride ( )	2389.5	130636	19352.9
Sulfate ( )	24.1	4594.1	2412.4
Sodium ( )	4169.3	80421.2	10783.8
Potassium ( )	35	398.6	399.1
Magnesium ( )	19	894.1	1283.7
Calcium (	11	4395.5	412.1
Strontium ( )	6.3	88.9	7.9
Iron ( )	0.65	65.3	15.5
Total Dissolved Solids ()	12590.2	223054.3	34774.4

Benefits of proposed process:

- No/simple screening pretreatment
- Tolerant to changes in intake water quality and volume
- Deployment of co-produced energy and lower carbon footprint
- Removing salt and organics simultaneously

2.4 Process Optimization



Energy balance

$$m_a h_a + dQ_s + dQ_L = (h_a + dh_a)\cdot m_a$$

$$m_w h_w + dQ_R = (m_w - dm_w)(h_w - dh_w) + dQ_L + dQ_S + dQ_{Loss}$$

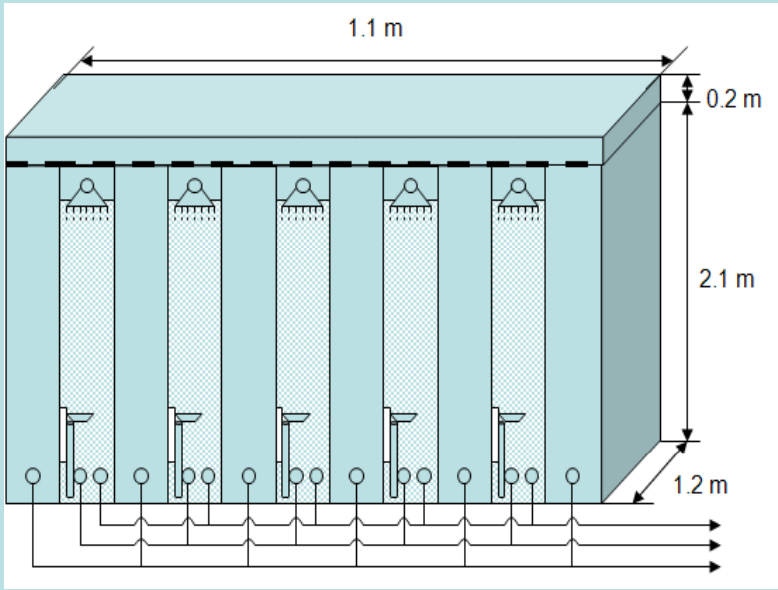
Mass balance

$$m_a = m_a^{'}$$

$$\frac{dH}{dZ} = \frac{LK}{m_a}[H^{sat}(T_w) - H_{(a)}]$$

$$\frac{dT_a}{dZ} = \frac{(T_w - T_a)}{(C_{pa} + HC_{p,s}^{sat})}\left(\frac{L\alpha_{LA}}{m_a} + \frac{C_{p,s}^{sat}dH}{dZ}\right)$$

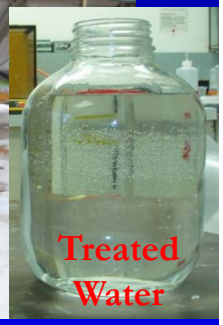
$$\frac{dT_w}{dz} = \frac{m_a}{M_w c_{pw}}(c_{p,s}^{sat}T_w + \lambda - C_{pw}T_w)\frac{dH}{dz} + \frac{bk_{Loss}(T_w - T_{Env}) - ck(T_w^{'} - T_w)}{M_w c_{pw}}$$



Thin Film Distillation

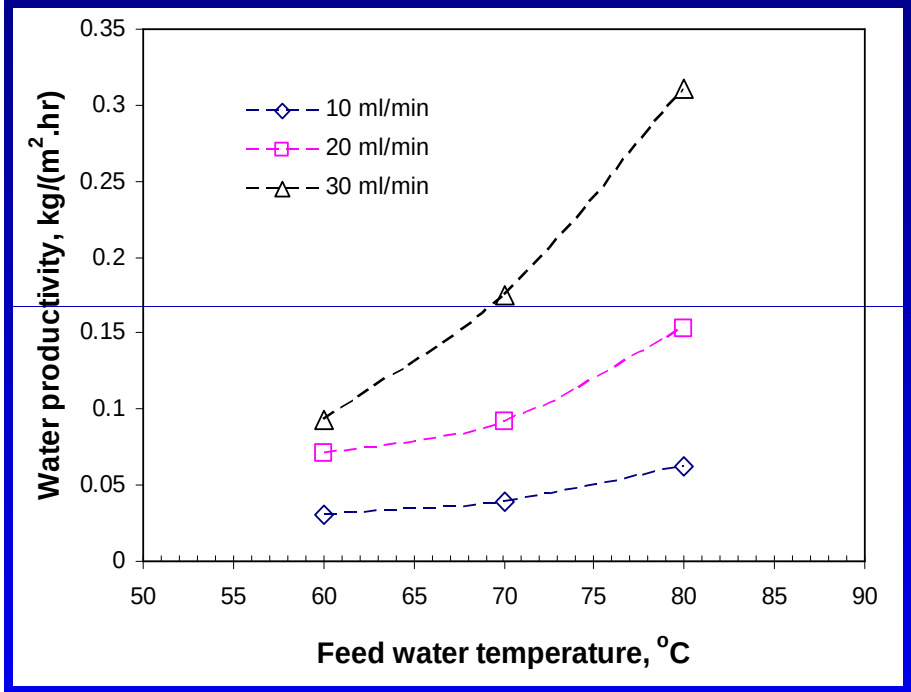
3. CURRENT STATUS

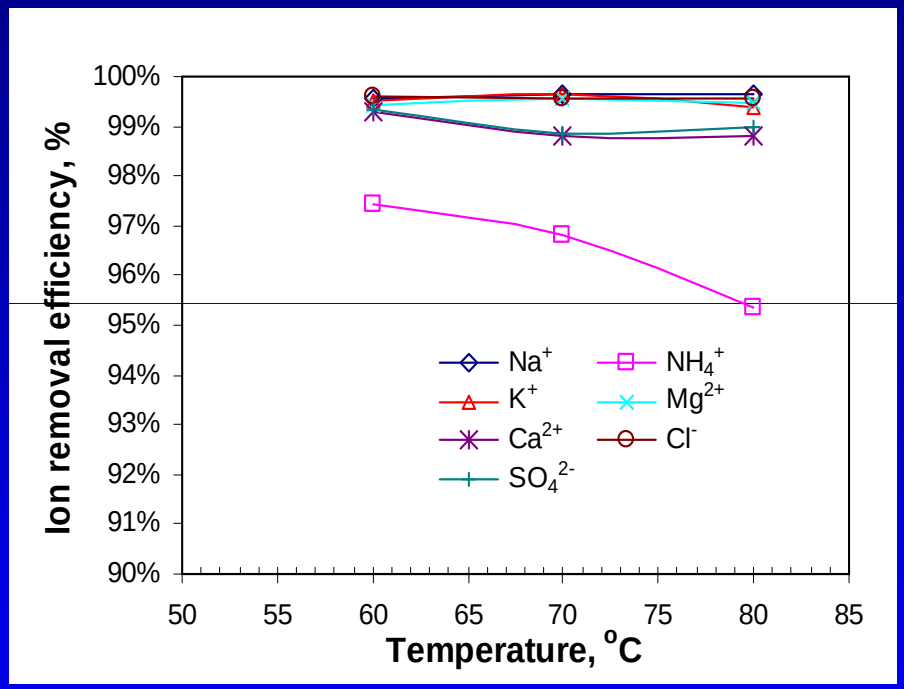
3.1 Laboratory Setup of Process Optimization



Composition	Feed water	Purified water	Removal efficiency, %
Total dissolved solid (TDS), mg/L	19756.0	76.35	99.6
Total suspended particulates, mg/L (0.22μm < dia.< 100μm)	99.6	Undetectable	100%
Total organic carbon (TOC), mg/L	470.2	17.83	96.2%

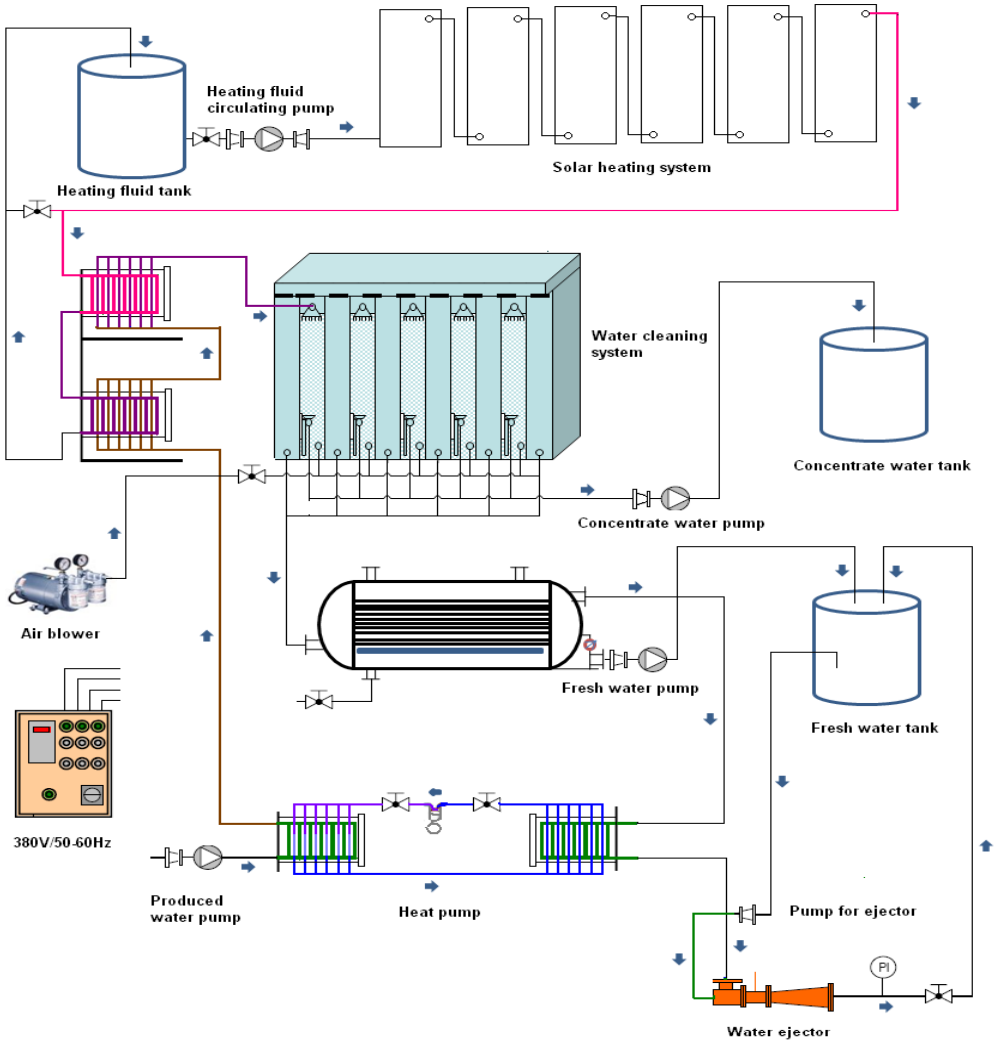
3.2 Effects of Operating Parameters on Performance

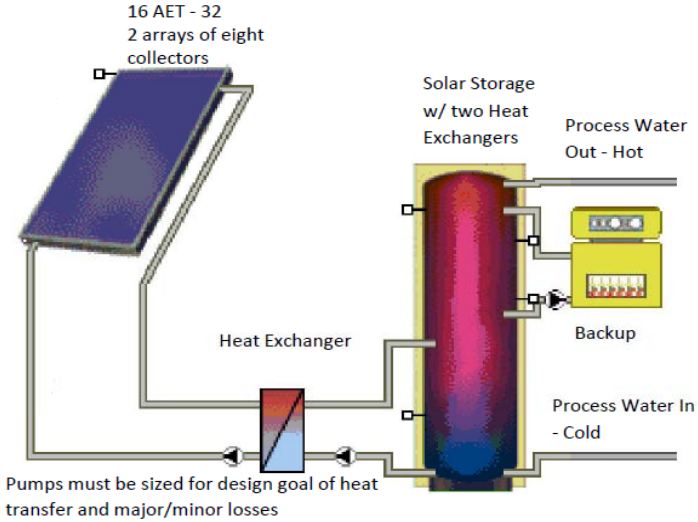


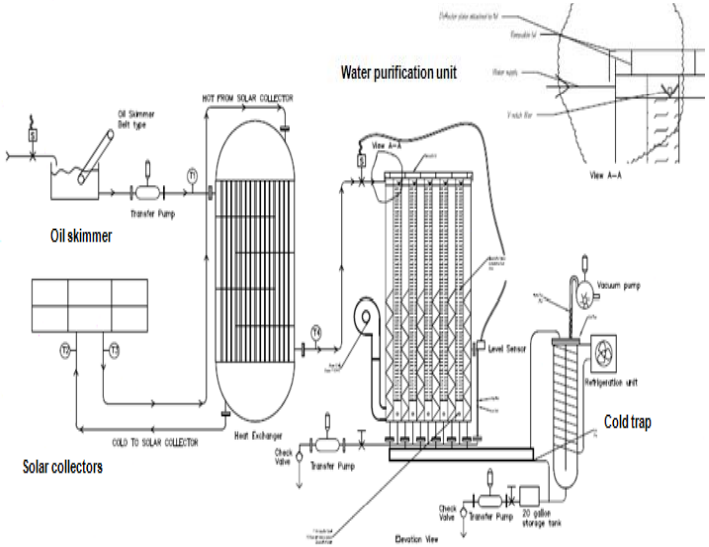


1. Increasing temperature increases water production significantly
2. Ion/organic removal efficiency remain nearly stable at increasing temperature.
3. The feed water chemistry has little influence on separation performance

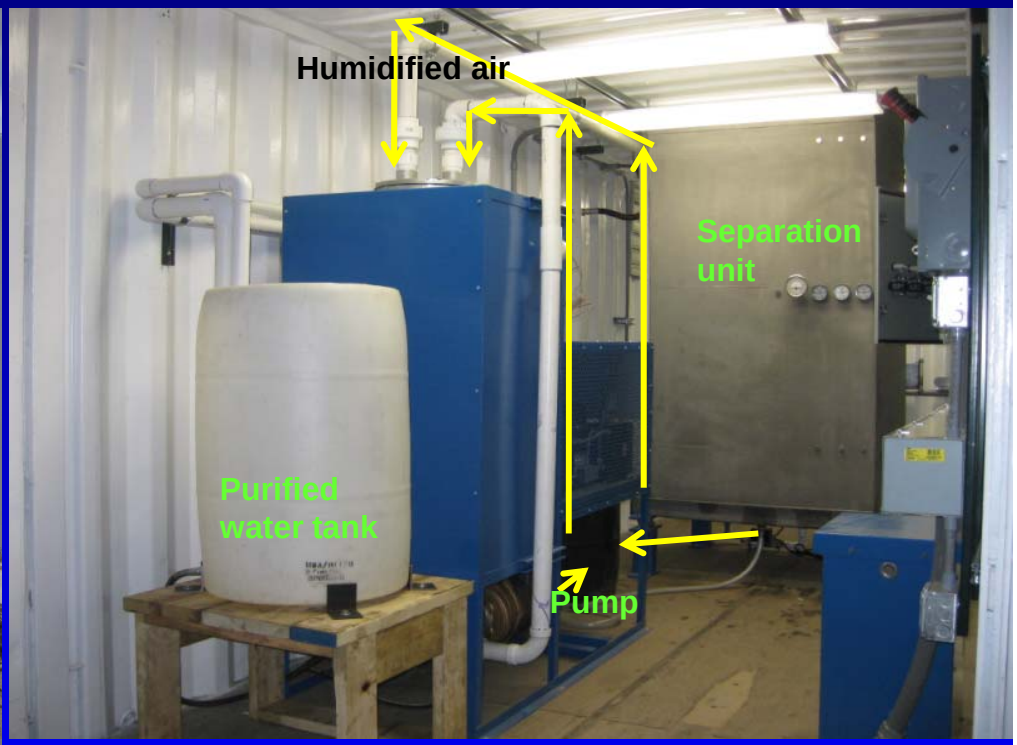
3.3 Prototype Design and Manufacture







3.4 Construction of Prototype



Moving container

Separation unit

Process monitoring

3.5 Economic Analysis & Benefits

Technology	Energy deployed	Unit capital cost, $/m^3/d	Unit energy cost	Unit chemical cost, $/bbl	Water cost	References
RO membrane	Electricity	924	$0.13/bbl	0.03	$0.16/bbl	Ettouney et al., 2002 Hansen et al., 1994 Rowe et al., 1995 J. Beckman, 2008 ALTELA, Inc.
HDP	Natural gas	264	$0.89/bbl	N/A	$1.04/bbl	
HDP	Waste heat	264	$0.002/bbl	N/A	$0.14/bbl	

Options	Estimated cost ($/bbl)
Evaporation pits	0.01-0.8
Water hauling	1.0-5.5
Disposal well	0.05-2.65
Freeze-thaw	2.65-5.0
Electrodialysis	0.02-0.64

Jackson and Myers, 2003; J. Veil, 2004

Energy Consumption Analysis:

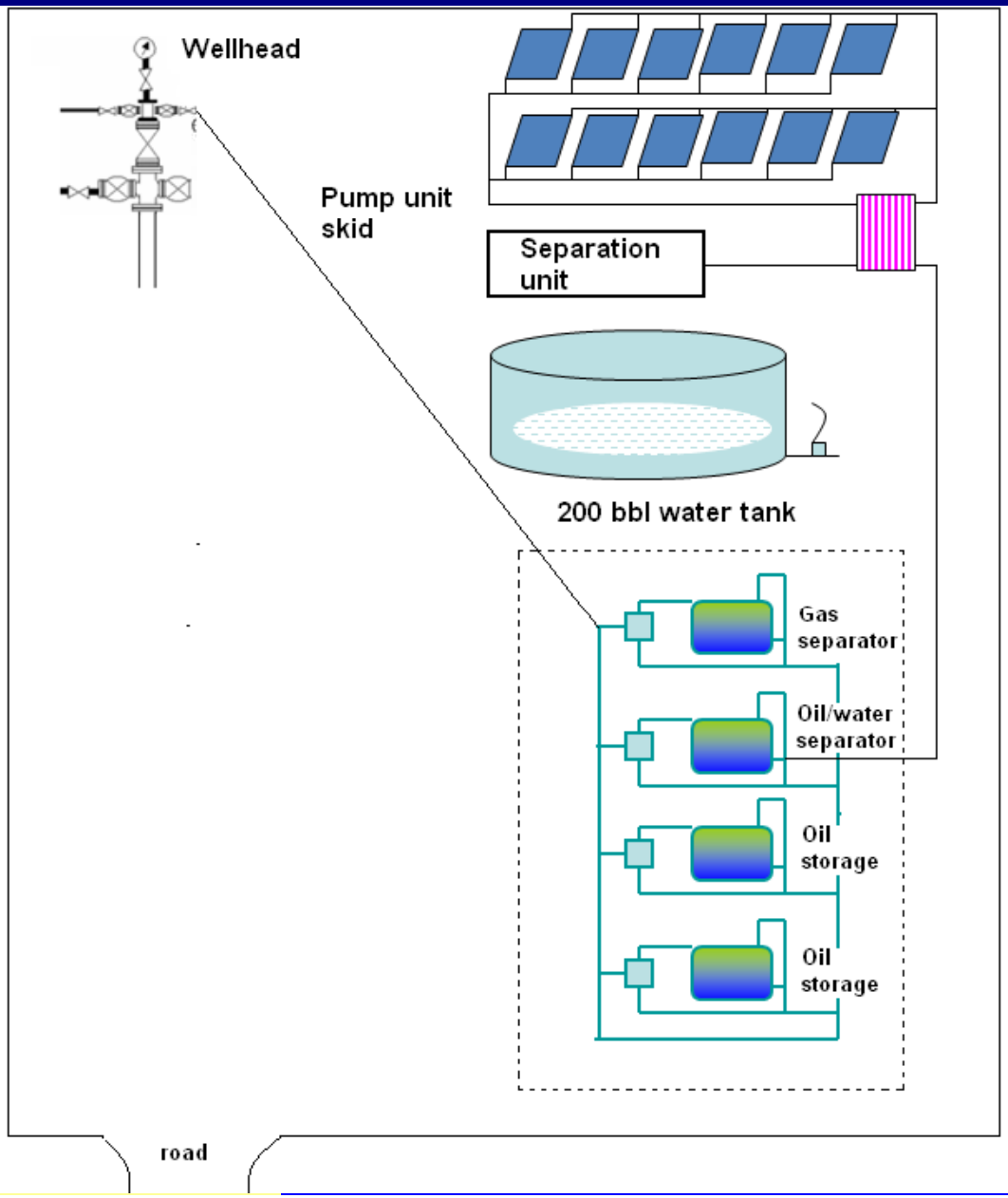
Theoretical minimum energy: 0.7 KWh/m^3

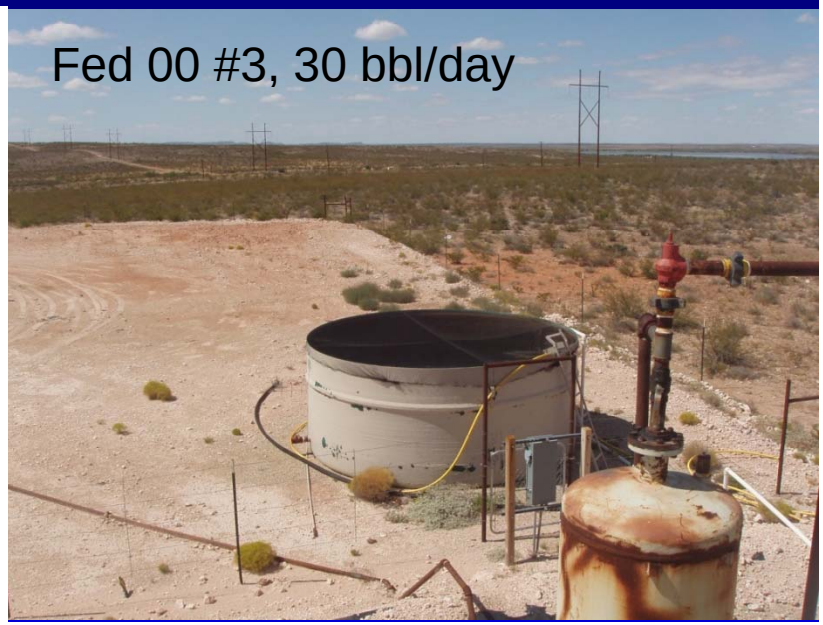
Current sea water RO: 3.0 KWh/m^3

Thermal process: 2.65 KWh/m^3 for pumps
40 KWh/m^3 for thermal distillation

Projected Economics:
Capital cost for the 20 bbl/day capacity: $15,000
Energy cost: $0.7-0.9/bbl

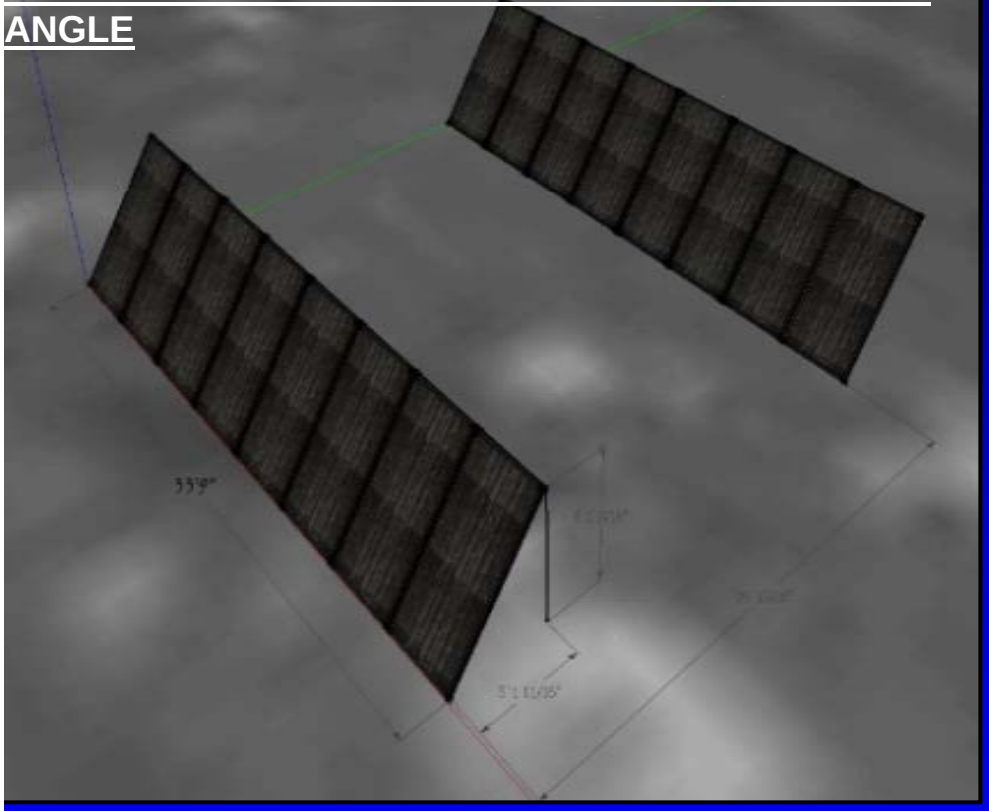
4. FIELD DEPLOYMENT

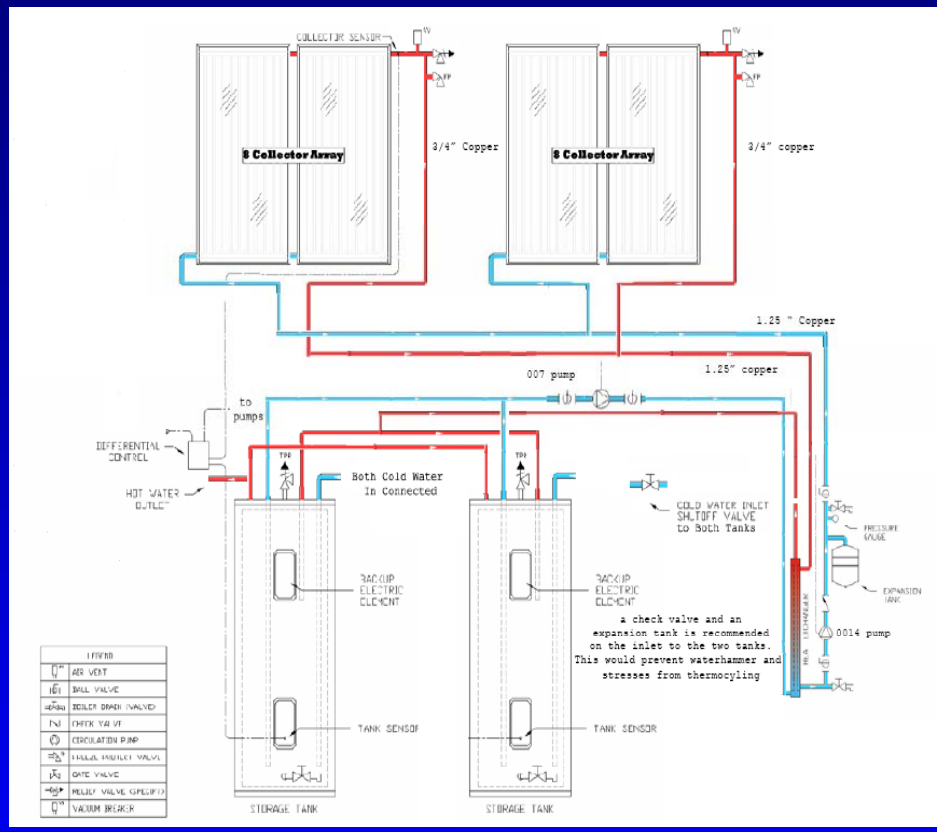




4.1 Deployment of Solar Energy

ARRAY OF 16 SOLAR COLLECTORS WITH 50 ° TILT ANGLE





HEAT INPUT REQUIRED FOR SOLAR HEATING- Solar company method

630 gallons/day or 15 bbls

(15 * 42 gallons) X 8.34 lbs/gallon X (75) degree change in fahrenheit divided by 78% (Efficiency)

= 500 KBTU

- Evacuated tubes and flat plate solar collectors were considered, however glycol based solar collectors were chosen due to budget constraints.

4.2 Field Facility & Equipment

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CONCLUSION/PLANS (Phase I)

- Distillation is more robust to feed water quality and is more attractive in challenge locations, such as wellhead comparing to membrane process.

- Thin film based distillation process can purify produced water to substantial quality that suitable for irrigation and other beneficial uses:
  - High purity water (TDS=76 mg/l, TOC=17.8 mg/l) was achieved with feed produced water containing TDS of 2.0×10^4 mg/l and TOC of 470 mg/l.
  - The water productivity of bench scale demonstration ranges from 48 to 311 ml/(m^2.h). Recovery varies from 8% to 30% when the feed water temperature ranges from 60 ° C to 80 °C.

- A 20 bbl/day prototype was designed, manufactured, and tested at New Mexico Tech. The capital cost for the unit is estimated at $15,000.

- Co-produced geothermal heat is abundant at wellhead. It is possible to desalinate produced water at wellhead by using co-produced geothermal energy.

Future Work and Suggestions

- Field deployment for prototype installation is scheduled at Fed 003 well.
- Distillate quality and quantity will be monitored for prolonged operating time (1 year)
- Integration of solar heating and co-produced geothermal will be evaluated for driving the desalination process.
- Treating produced water at wellhead by deploying solar energy or co-produced geothermal energy could be an economic method for desalting produced water.
- Economic evaluation based on the capital cost, lifetime of each operation, maintenance and operation costs will be carried out.

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TRANSFER OF KNOWLEDGE

PUBLICATIONS in leading journals

1. S. Muraleedaaran, X. Li, L. Li, and R. Lee, “Is Reverse Osmosis Effective for Produced Water Purification: Viability and Economic Analysis,” SPE 115952. This paper was prepared for presentation at the 2009 SPE Western Regional Meeting Held in San Jose, California, USA, 24-26 March 2009.

2. L. Li, and R. Lee, “Purification of Produced Water by Ceramic Membranes: Material Screening, Process Design and Economics,” Separation Science and Technology, 44(15), 3455-3484, 2009.

3. X. Li, Master thesis, “Experimental Analysis of Produced Water Desalination by a Humidification-Dehumidification ,” 2009.

4. X. Li, S. Muraleedaaran, L. Li, and R. Lee, “A Humidification Dehumidification Process for Produced Water Purification,” Desalination, in printing, 2010.