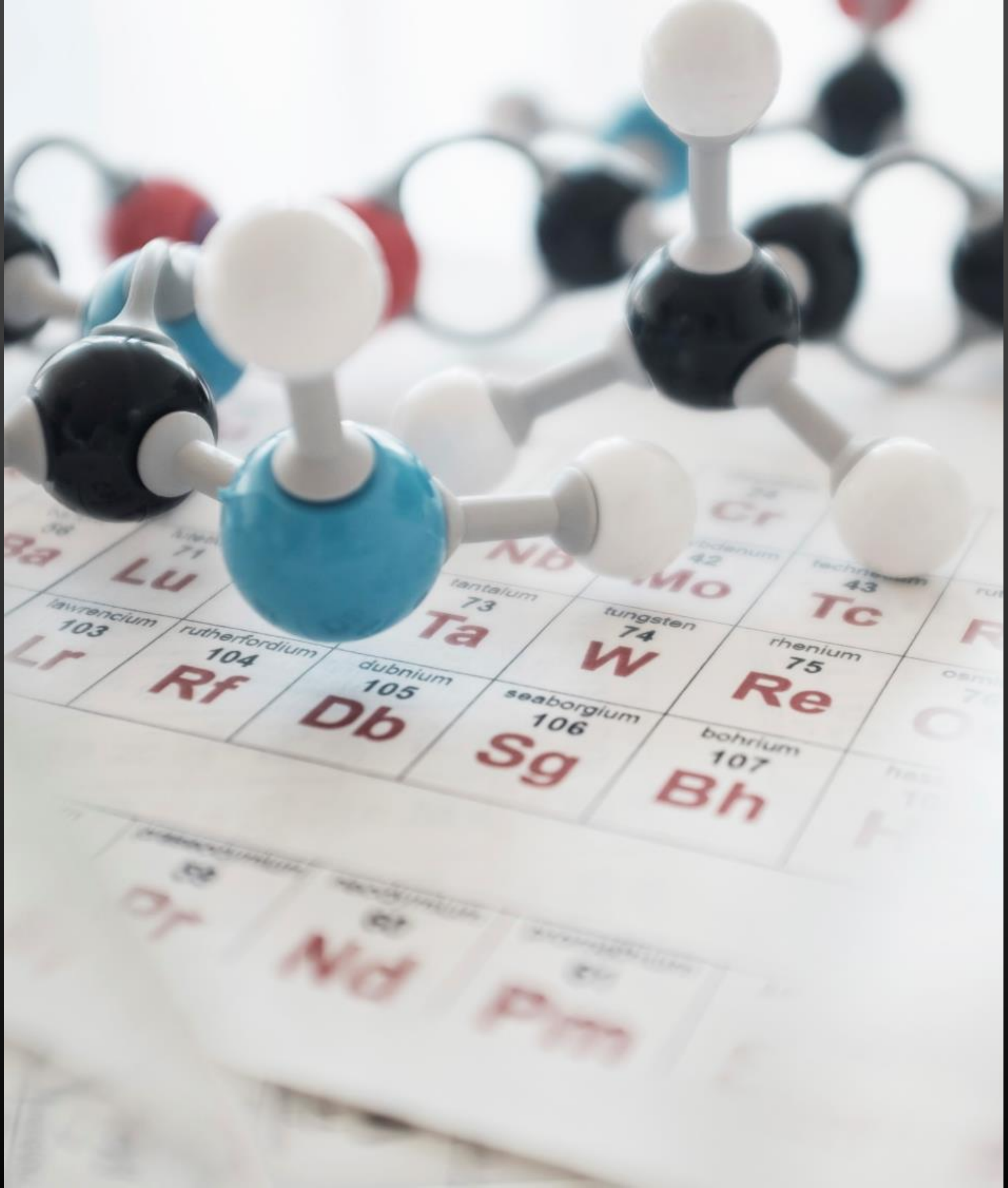
Reverse Osmosis in a Steam Boiler Plant

Brigham Young University Idaho (BYU-I)

Water and Energy Systems Technology (WEST)



Reverse Osmosis Efficiencies

- **Outline**
  - Operational Challenges
  - Operational Lessons Learned
  - Water Savings
  - Energy Savings
  - Applications to your Plant
  - Questions

Operational Questions\Challenges

- **Water Pressure and Volume**
  - Do we have enough water?

- **Location**
  - How much space is needed?
  - Does it need to be close to the water source?
  - Where in the process do we put it?

- **New to RO**
  - How do we run it?
  - When do we know to change membranes?
  - Should we use a clean in place machine?
  - Will it be worth it?

Operational Lessons Learned

- **Water Pressure and Volume**
  - We did not have enough water to feed both the boiler and chilled water facilities
  - A booster pump was installed on the main water line in the facility to maintain 80 psi

Operational Lessons Learned

- **Location**
  - RO units do take up space and need to be serviced.
  - Make sure you can remove the membranes when required.
  - You will need to have access to a drain for the waste.
  - We chose a low traffic area.
  - It is installed after the softeners and carbon filter.

Operational Lessons Learned

- **New to RO**
  - Be aware of the prefilters and membrane life.
  - Get operational training.
  - Reassure the operators that it will be different to operate and not to revert back to old plant operations.
  - Know how to check the membrane life through differential pressures and permeate quality
  - We opted not to use a Clean in Place Machine.

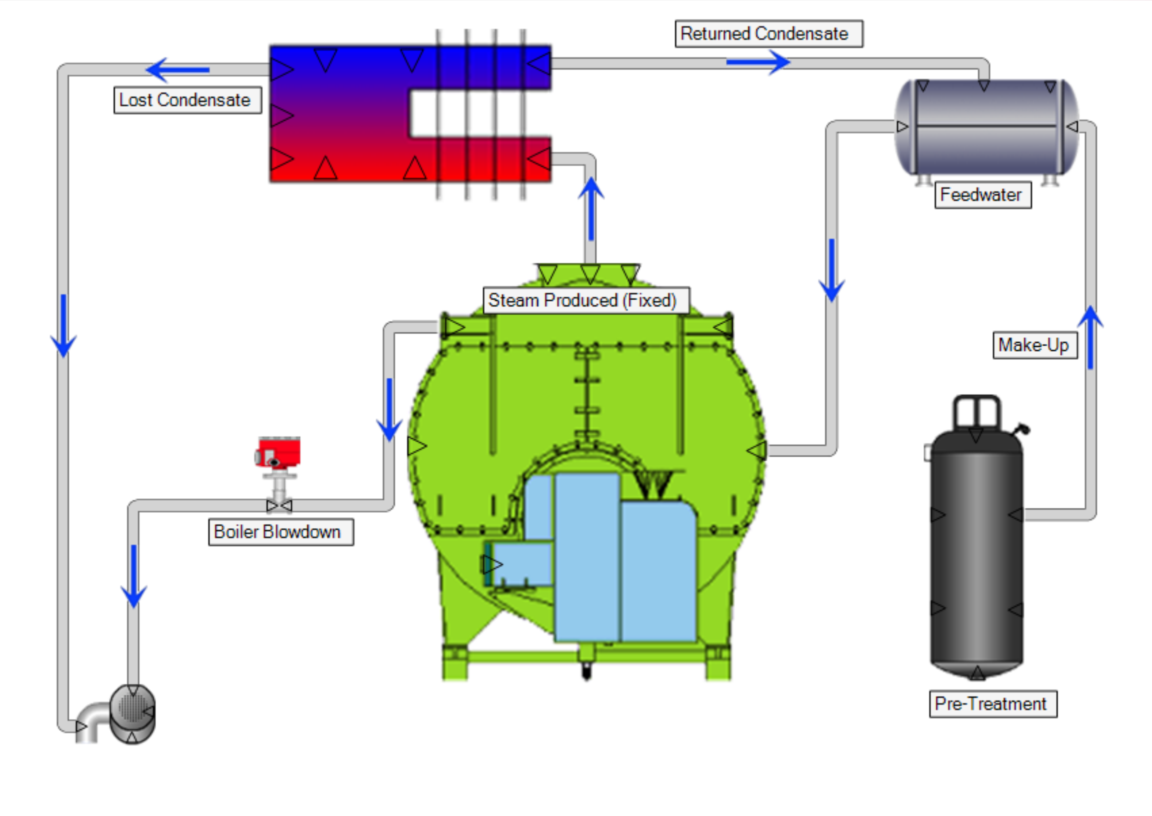
Water & Energy Savings

- **Savings Methods**
- Water & Energy Savings + Chemical Savings
  - Water savings will always result in reduced chemical expenditures
  - Reduced water, energy and chemical usage saves money!
  - This presentation covers specifically a reserse osmosis pre-treatment system and % condensate return – other options may be important for your consideration

- Boiler Efficiency
  - Burner Optimization (F/A Ratio)
  - Scale Protection
- System Losses
  - Survey Systems for Leaks
  - Steam Trap Survey
  - Percent Condensate Return
- Blowdown Reduction
  - Maximize Percent Condensate Return
  - Improve Feedwater Quality
    - Dealkalizers, Steam Degaisifier, Reverse Osmosis
- Economizers
  - Capture Energy from Combustion and Return this to the Feedwater
- Blowdown Heat Recovery
  - Return Energy Lost through Blowdown to Feedwater

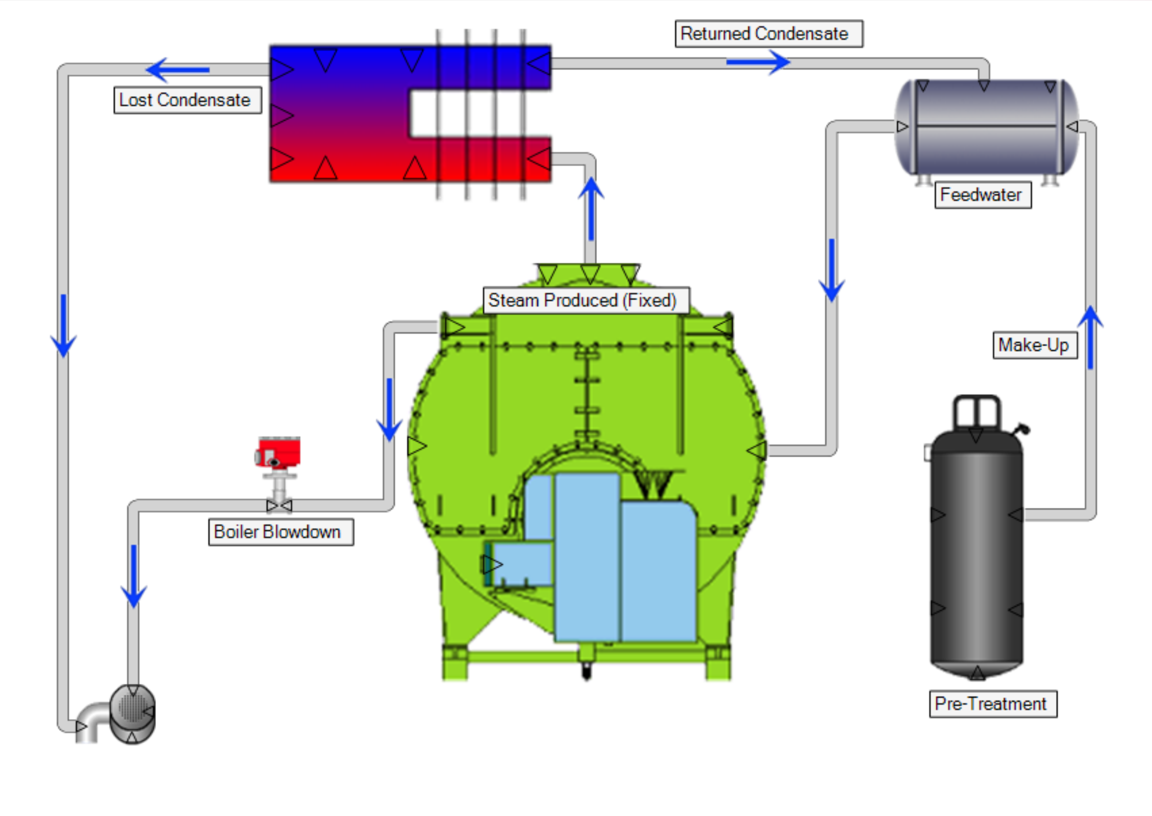
Water & Energy Savings

- **Water**
- Increased Cycles of Concentration (CoC)
  - Steam Production is set by the process
  - Losses can be managed by process improvement
- How?
  - Pre-Treatment (Reverse Osmosis)
  - Recovering steam and condensate
  - Boiler System Mass Balance
    - $Blowdown = \frac{S}{CoC - 1}$
    - $Feedwater = \mathrm{BD} + \mathrm{S} = C_R + MU$
    - $CoC = \frac{MU}{BD} = \frac{S}{B} + 1$
      - S: Steam Production (lb/hr)
      - CoC: Cycles of Concentration
      - BD: Boiler blowdown (lb/hr)
      - C_R: Condensate Return (lb/hr)
      - MU: Pretreatment make-up (lb/hr)



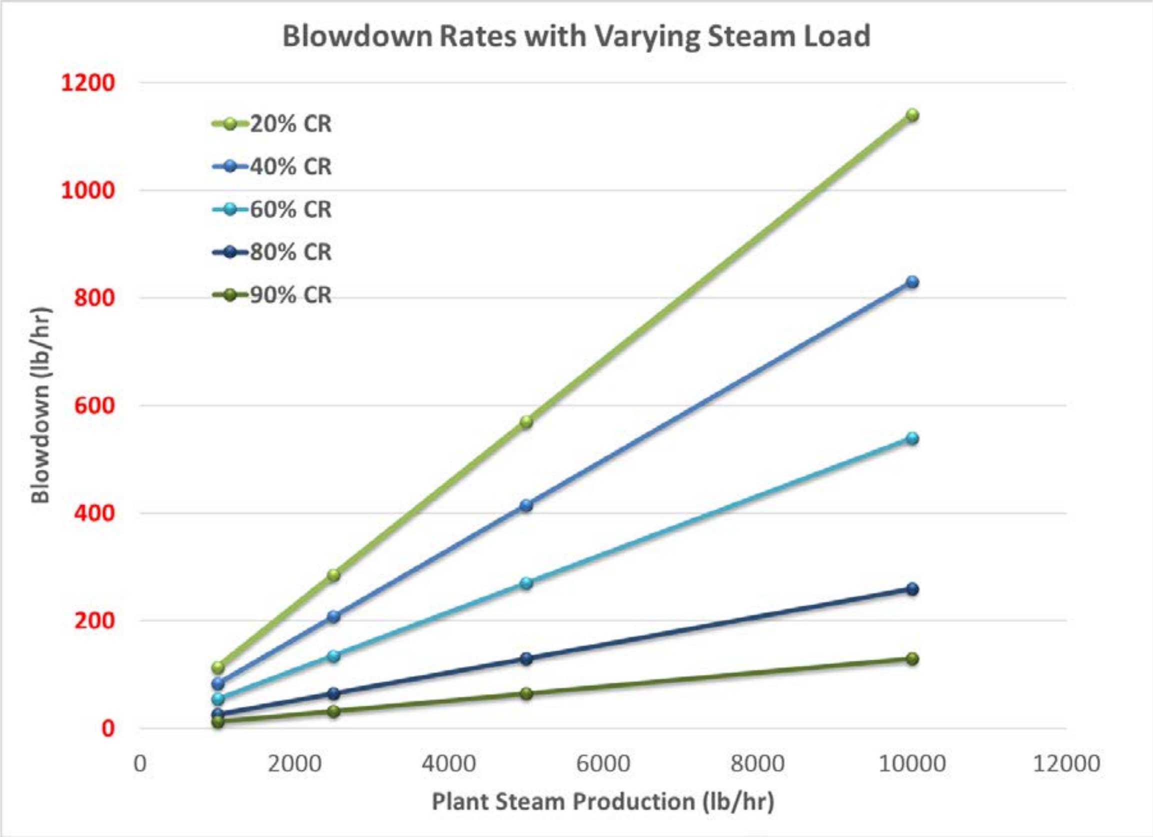
Water & Energy Savings

- **Energy**
- Increased Cycles of Concentration (CoC)
- How?
  - A pound of water in a 110-psi boiler is 344°F and contains 411 BTU
  - A pound of condensate at 180°F contains 148 BTU
  - By reducing blowdown and lost condensate CoC increase and energy losses decrease
  - One cubic foot of natural gas contains about 900 BTU
  - By reducing blowdown and optimizing condensate return, significant fuel savings can be realized

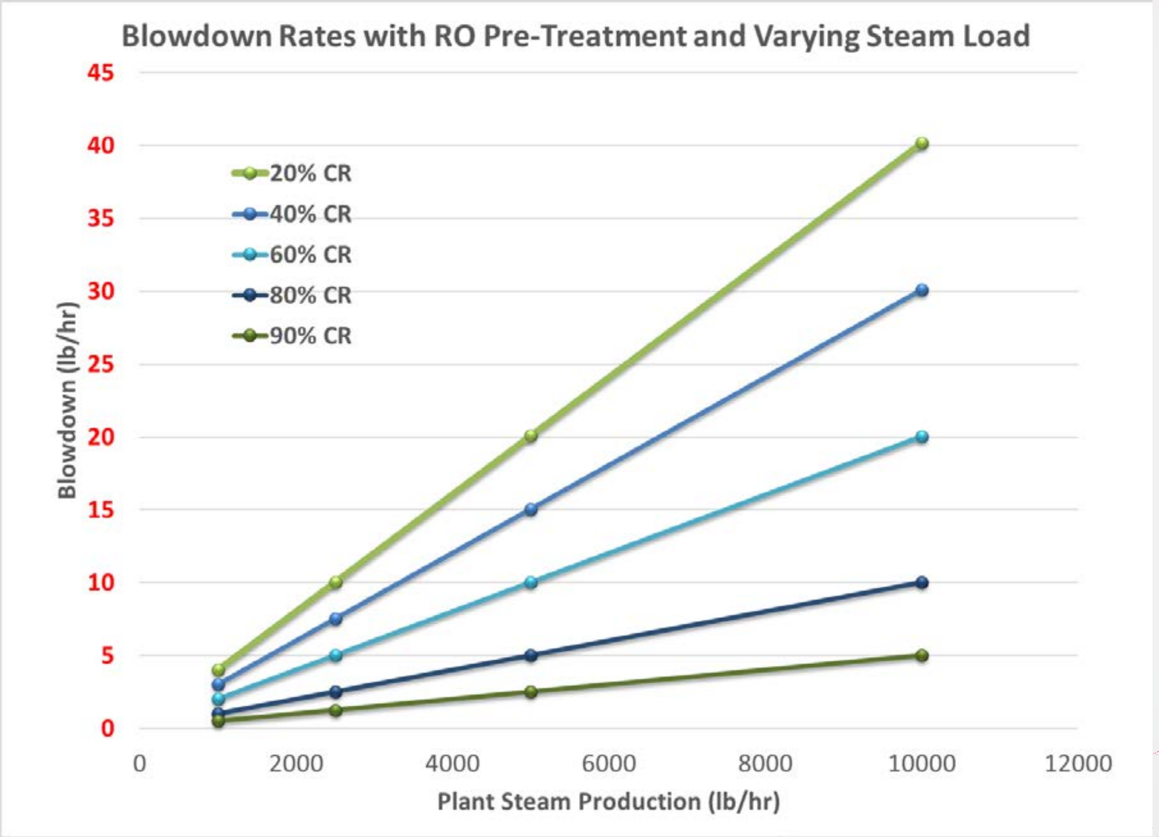


Blowdown Reduction

- **Boiler Plant without RO**
  - **Shown with varying average steam loads**

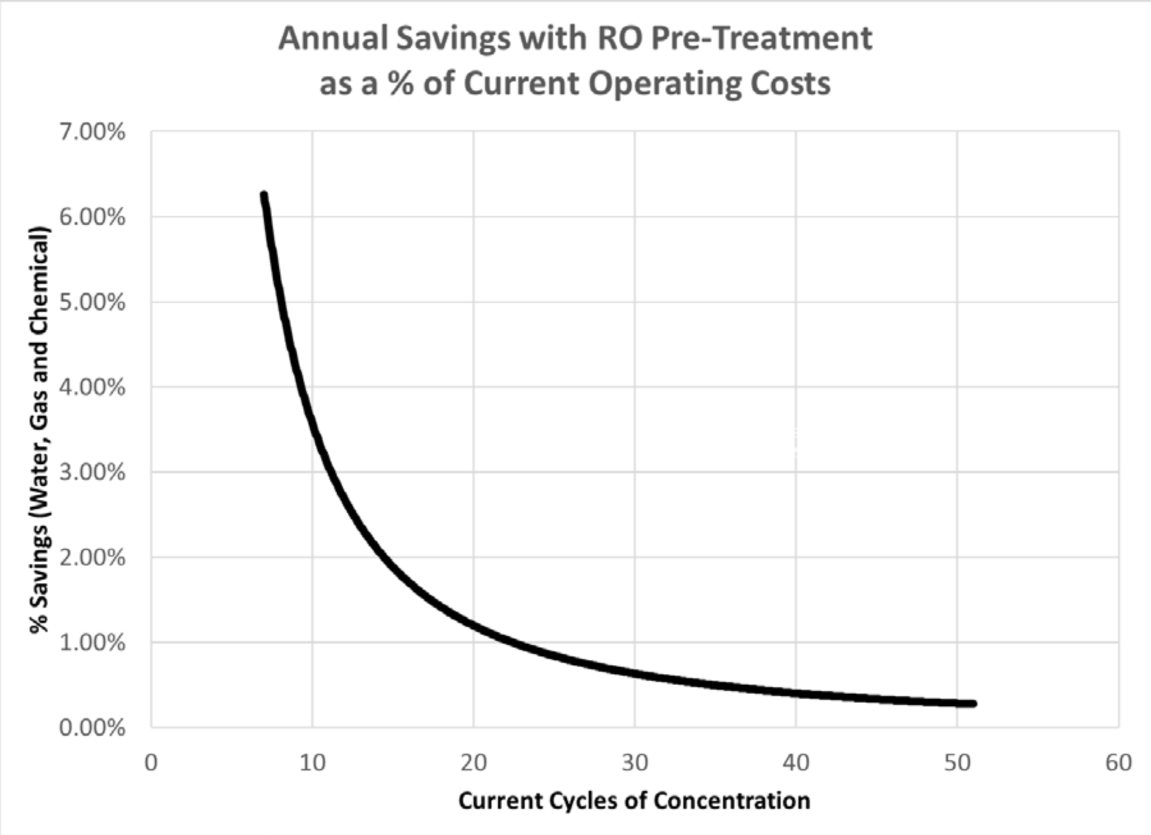


- **Boiler Plant with RO Pre-Treatment**



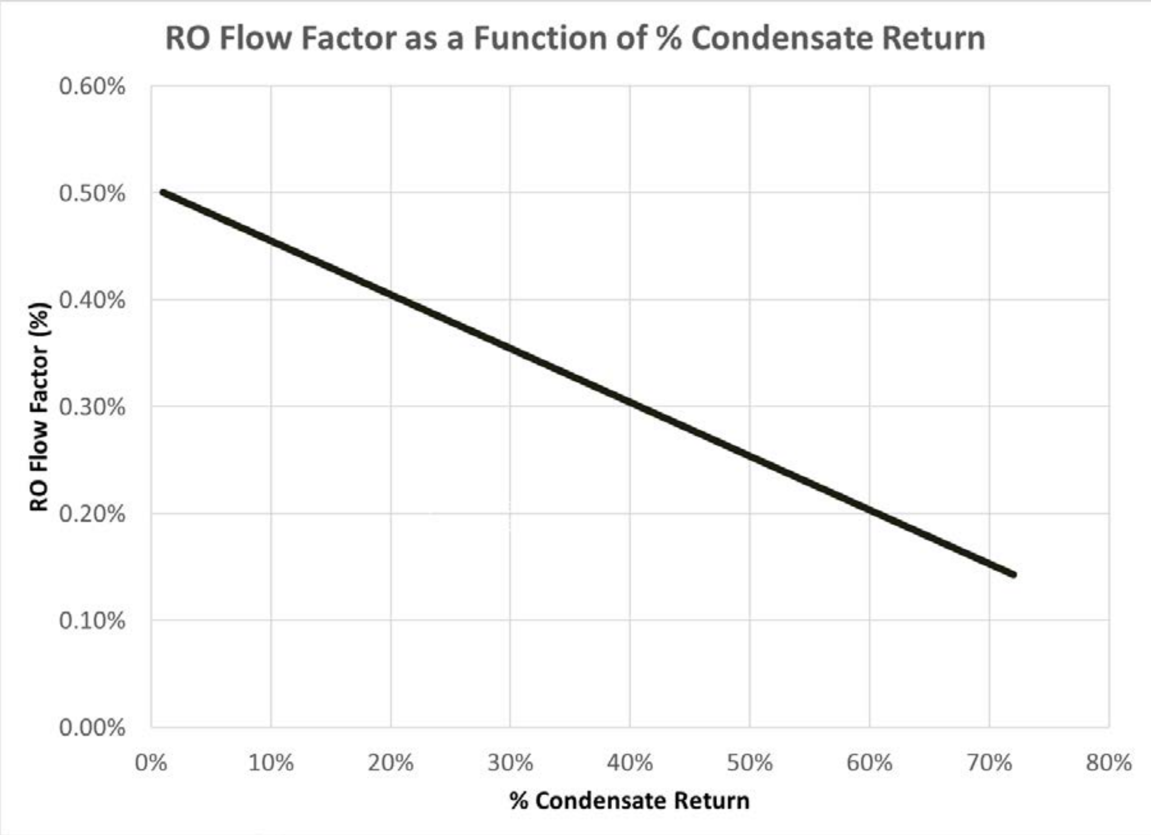
Savings Potential

- **Water + Energy + Chemical**
- Pre-Treating your water with RO will result in savings in energy, water and chemical!!
- Predicting your savings
  - $Savings = D_o \times 1.3452(C_o)^{-1.576}$
  - D_o = Current expenses for Gas, Water and Chemical
  - C_o = Current cycles of concentration in boiler
- Example
  - I produce an average of 18,000 lb/hr of steam in my boiler plant and I operate at 12.0 cycles of concentration.
  - I spend $1,153,800 each year on gas, water and chemical in this plant
  - My Savings with RO Pre-Treatment are
    - $1{,}153{,}800 \times 1.3452 \times (12)^{-1.576} = \$30{,}912.05$



Savings Potential

- **Sizing your Reverse Osmosis System**
- A RO system is sized primarily by the product flow rate and the quality of RO feedwater
  - Additional features may increase the cost, but this example will help you size the RO required for your plant
- Determine the RO Size
  - $\text{RO Permeate Flow} = S * [(-0.005 \times P_{CR}) + 0.0051)]$
  - S = Current steam production (lb/hr)
  - P_{CR} = Current plant % condensate return
- Example
  - I produce an average of 18,000 lb/hr of steam in my boiler plant and I normally return 70% of my steam as condensate
  - My RO will need to provide a pure water flow rate of:
    - $18{,}000 \times ((-0.005 \times 0.65) + 0.0051) = 28.8\ GPM$



*Includes 2.5 safety factor on RO size, but does not provide redundancy

Summary

- Predicted vs. Actual
- BYU-Idaho Predicted Savings and RO Size
  - BYU-Idaho produced an average of 20,547 lb/hr of steam and operated at 15 cycles of concentration with an annual gas, water and chemical expenditure of $1,296,000.
    - Savings Equation: $Savings = D_o \times 1.3452(C_o)^{-1.576}$
      - $Savings = 1{,}296{,}000 \times 1.3452(15)^{-1.576} = \$\mathbf{24,427}\ \$/\boldsymbol{year}$
    - RO Payback is less than 3 years.
    - RO Sizing: $\text{RO Permeate Flow} = S * [(-0.005 \times P_{CR}) + 0.0051)]$
      - $\text{RO Permeate Flow} = 20{,}547 \times [(-0.005 \times 0.70) + 0.0051)] = \mathbf{32.9}\ \boldsymbol{GPM}$ (@ 0% Condensate Return Size would Be 105 GPM)
- BYU-Idaho Actual Savings and RO Size
  - 80% reduction on blow down from 3 times a day to 3 times a week
  - For the past three years we are averaging a 48% reduction in cost with an annual saving of $26,900
  - The BYU-Idaho RO system is designed to produce 100GPM which covers the operating condition of a 0% condensate return

Thank You