When is Reverse Osmosis Right for Boiler Pre-Treatment

GE Infrastructure
Water & Process Technologies

RO Benefits

- Reduced fuel costs through lower heat loss / increased boiler cycles
- Reduced boiler system chemical treatment costs
- Improved operation & Steam Purity
- Reduced risk
- Improved condensate corrosion control
- Reduced external treatment costs; particularly if previously using cold or hot lime softening, ion exchange and / or re-generable DI
- Remove / reduce hazardous acid and caustic chemicals
- Extended ion exchange resin life

What to consider when looking at RO for boiler pretreatment

- Cycles of concentration
- Size of plant – steam production
- FW Quality
  - Make-up alkalinity, Dissolved mineral breakdown
- % FW make up - % hot condensate return
- Pressure deaerator or FW tank?
- Feed water piping and pump construction
- Is there a use for RO reject (cooling tower MU)
- Chemical Program types
  - Separates, all-in-ones, powders, liquids, etc.

Questions to help you qualify feasibility of replacing demins with RO/EDI

1. Is the customer concerned with handling acid and caustic?
2. What is the conductivity of the influent water? The higher the dissolved solids in the influent water, the greater the potential benefits.
3. How much acid and caustic are used and what is the cost?
4. What is the cost of power?
5. Can the plant effectively use the RO reject water? Or will the increase in water consumption and waste volume be an issue?
6. Is this a new installation or is the customer considering replacement of or renovating an existing demineralizer system?

ASME GUIDELINES

Table 1 - Watertube Boiler with Superheater/Turbine

All Pressures: FW dissolved oxygen < 7 ppb (with DA)

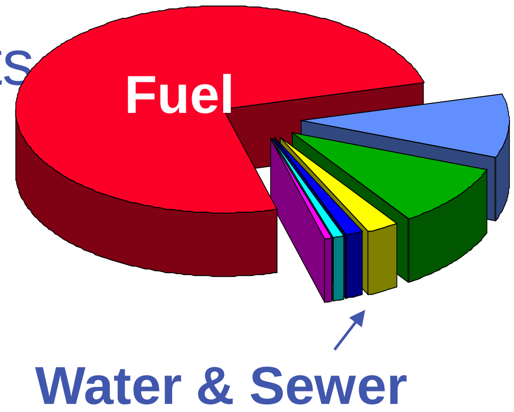
Feedwater pH: 8.3 - 10.0 (0- 900 psig) / pH 8.8 - 9.6 (> 901 psig)

	Boiler Feedwater			Boiler Water		
Drum Pressure (psig)	Iron (ppm Fe)	Copper (ppm Cu)	Total Hardness (ppm $CaCO_3$)	Silica (ppm SiO_2)	Total alkalinity (ppm $CaCO_3$)	Specific Conductance (µmhos/cm) (Unneutralized)
0 to 300	0.100	0.050	0.300	150	350	3500
300 to 450	0.050	0.025	0.300	90	300	3000
451 to 600	0.030	0.020	0.200	40	250	2500
601 to 750	0.025	0.020	0.200	30	200	2000
751 to 900	0.020	0.015	0.100	20	150	1500
901 to 1,000	0.020	0.015	0.050	8	100	1000
1,001 to 1,500	0.010	0.010	0.000	2	-	150
1,501 to 2,000	0.010	0.010	0.000	1	-	100

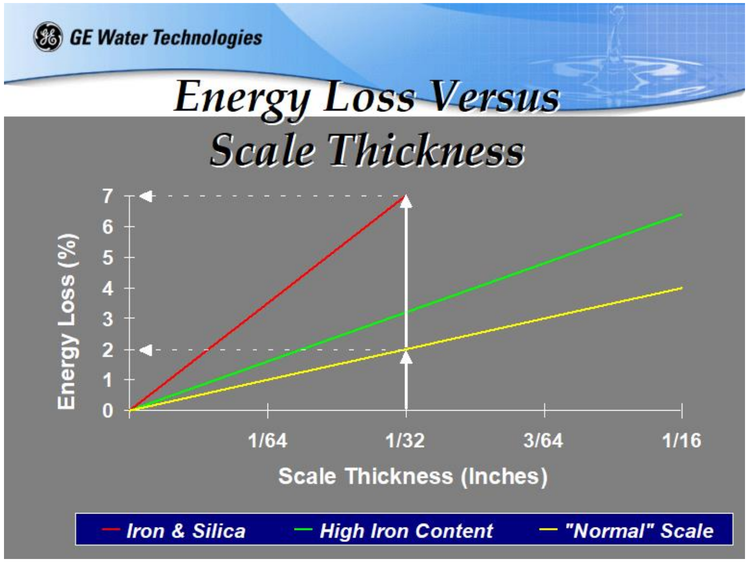
Note: All limits are expressed “less than” the value specified (e.g., < 0.100 ppm)

Impact of feedwater quality on boiler operational efficiency

- Fuel-to-steam efficiency
  - o Fuel is 70 – 80% of boiler operating costs
  - o Water & Sewer costs 3 – 5%
  - o But - Feedwater quality has **enormous** impact on boiler efficiency & fuel costs



- Reliability and availability
  - o Industry statistics – Tube failures due to waterside mechanisms are the leading cause of unscheduled Boiler outages



Impact of feedwater quality on boiler operational efficiency

- Steam purity
  - **Steam purity is a <u>direct function</u> of boiler water dissolved solids content**
  - Superheater and turbine reliability
  - High-purity processes
    - ✓ Semiconductors
    - ✓ Pharmaceuticals
    - ✓ Catalytic hydrocarbon / chemical processes
    - ✓ Food and beverage processing/sterilization
    - ✓ Comfort humidification
    - ✓ Medical and research steam sterilization processes

Boiler feedwater quality considerations

Boiler pressure and superheater/turbine steam purity requirements generally define pretreatment and feedwater quality requirements.

In general –

> Softened or single pass RO-quality make-up < **600** psig

> Generally demineralized or RO/EDI make-up > **900** psi

Resin Based Pretreatment Performance

System	Typical Effluent Quality	Typical Boiler Operating Pressure (psig)
Softener	0.2-1.0 ppm hardness (no TDS reduction)	0 to 600
Dealkalizer	50 to 90% alkalinity reduction (no TDS reduction)	0 to 600
Standard two-bed demineralizer	<10 µmho <200 ppb silica	400 to 900
Two-bed demineralizer with counterflow regeneration	<5 µmho <50 ppb silica	900 to 1,200
Two-bed demineralizer with mixed bed polisher	<0.1 µmho <10 ppb silica	1,200+

Benefits for the Customer Conversion from Softened to RO Makeup

- Improved steam purity & safety
  - Improved purity of products/processes contacted by steam
  - Reduced steam contamination
  - Enhanced regulatory compliance
- Improved steam equipment reliability, efficiency & longevity
  - Improved safety - Reduced chance of catastrophic failure
  - Improved turbine efficiency
  - Improved steam heat transfer efficiency
- Reduced total cost of operation (must qualify carefully)
  - Improved steam system heat transfer efficiency
  - Improved boiler thermal efficiency
  - Reduced chemical treatment costs
  - Reduced regenerant costs

Questions to help you qualify feasibility of pursuing RO conversions from NaZ

1. RO will generally reduce our overall boiler chemical revenue by a factor of 60-80% .
   Is customer looking to reduce chemical?
2. Is there a <u>significant</u> operational or efficiency issue that can be solved by higher purity FW?
3. Does the plant <u>lack</u> blowdown heat recovery equipment (or is it inoperable)?
4. Is there competitive pressure or a bid that is compelling you to consider RO as a solution?
5. Are current average cycles of concentration < 10?

Technical considerations in conversions from Na Zeolite to Reverse Osmosis Makeup

- RO permeate carbon dioxide considerations & reduction strategies
  - Corrosivity of RO permeate
  - Alloy considerations
  - Preferred methods of pH adjustment

- Consider boiler feed pump alloys
- Selection of oxygen scavenger
- Internal treatment program considerations
- Condensate corrosion discussion & pH control range

Zeolite Softening & Dealkalization

Advantages

- Inexpensive – Capital & operating costs
- Simple-to-operate
- Durable
- Safe & inexpensive sodium chloride regenerant

Limitations

- No reduction in total dissolved solids (TDS)
- FW quality can limit boiler cycles
- Not suitable for high-pressure boiler operation (> 900 psig)
- No silica reduction
- No alkalinity reduction without dealkalizer

Resin-based demineralization

Advantages

- Reduction in all dissolved solids
- Enables high cycles operation
- Suitable for high-pressure boilers
- Can tailor to specific purity needs
- Excellent silica rejection
- Excellent alkalinity/CO2 rejection

Limitations

- Strong acid/caustic required for regeneration
- Caustic costs high & variable
- Limited anion resin life
- Silica and sodium leakage
- Manpower intensive
- Operating costs directly proportional to TDS

Reverse Osmosis

Advantages

- Rejection of all dissolved solids
- Operating costs not directly dependant on TDS
- Enables high cycle boiler operation
- Requires no chemical regenerants (acid/caustic)
- Not labor intensive
- Versatile pairings with resin-based systems
- Ideal for mobile applications

Limitations

- RO alone not suitable for HP boiler feedwater > 1000 psig with turbine
- Higher electrical costs than resin-based systems (high-pressure pumps)
- Generates significant reject stream (typically 20 – 30% of input stream)
- Does not reject $CO2_{(g)}$

Potential membrane solutions for Boiler systems

1. RO in front of existing demineralizers

2. RO to replace or augment softeners

3. RO/EDI to replace resin-based demineralizer
   - Mixed-bed quality train

4. Ultrafiltration in front of demin. or RO to replace traditional filtration/clarification

Key input variables for modeling & analysis

Economic

- ✓ TDS of influent water
- ✓ Capital equipment costs (RO)
- ✓ Caustic costs
- ✓ Electrical power rates
- ✓ Influent water costs
- ✓ Sewerage costs
  - Volume or Vol/TDS-basis?
  - **Can plant reuse RO reject?**
  - Credits or incentives for reuse
- ✓ Regenerant neutralization costs
- ✓ Differential labor costs

Environmental

- ✓ Reduction of acid/caustic inventory
- ✓ Personnel safety - chemical exposure
- ✓ Water scarcity issues
- ✓ Discharge/permitting issues

This can be a critical factor because direct sewerage of the RO reject stream may be costly

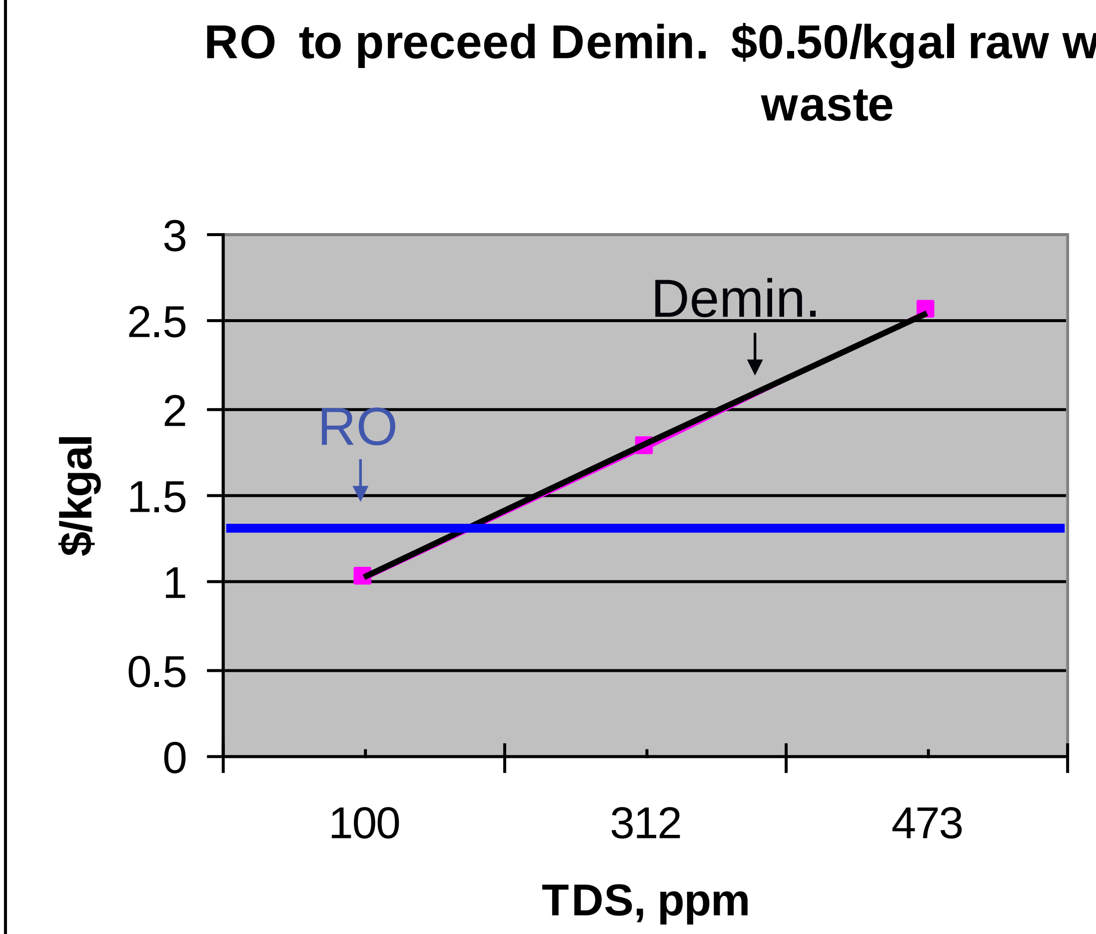
Case 1 - Potential Benefits in the Addition of RO ahead of Demineralizer

- Reduced acid & caustic regenerant costs
  - 90 – 95% reduction in regenerant usage is typical
- Reduced operator labor
- Reduced high TDS regenerant neutralization discharge
- Extended ion exchange resin life
  - 40 – 50% extension in resin life typical
  - Greatly reduced regen. cycles & reduced iron/organic fouling
- Improved feedwater & steam quality
  - Sodium & silica slippage & breaks significantly reduced

RO Preceding Demineralizer

Example with relatively inexpensive water and sewerage

RO cost justified above approx. 200 ppm TDS

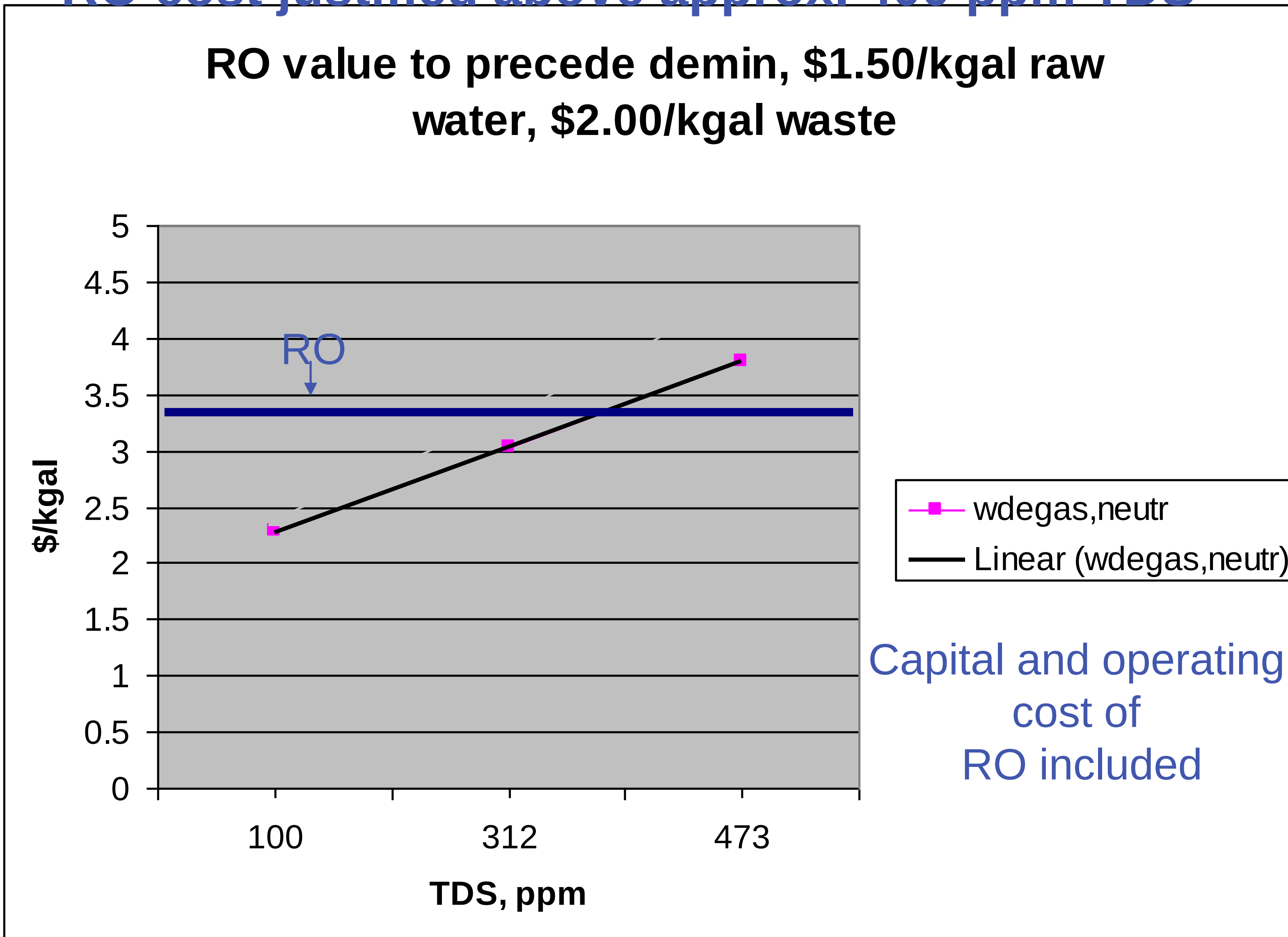


Capital and operating cost of RO included

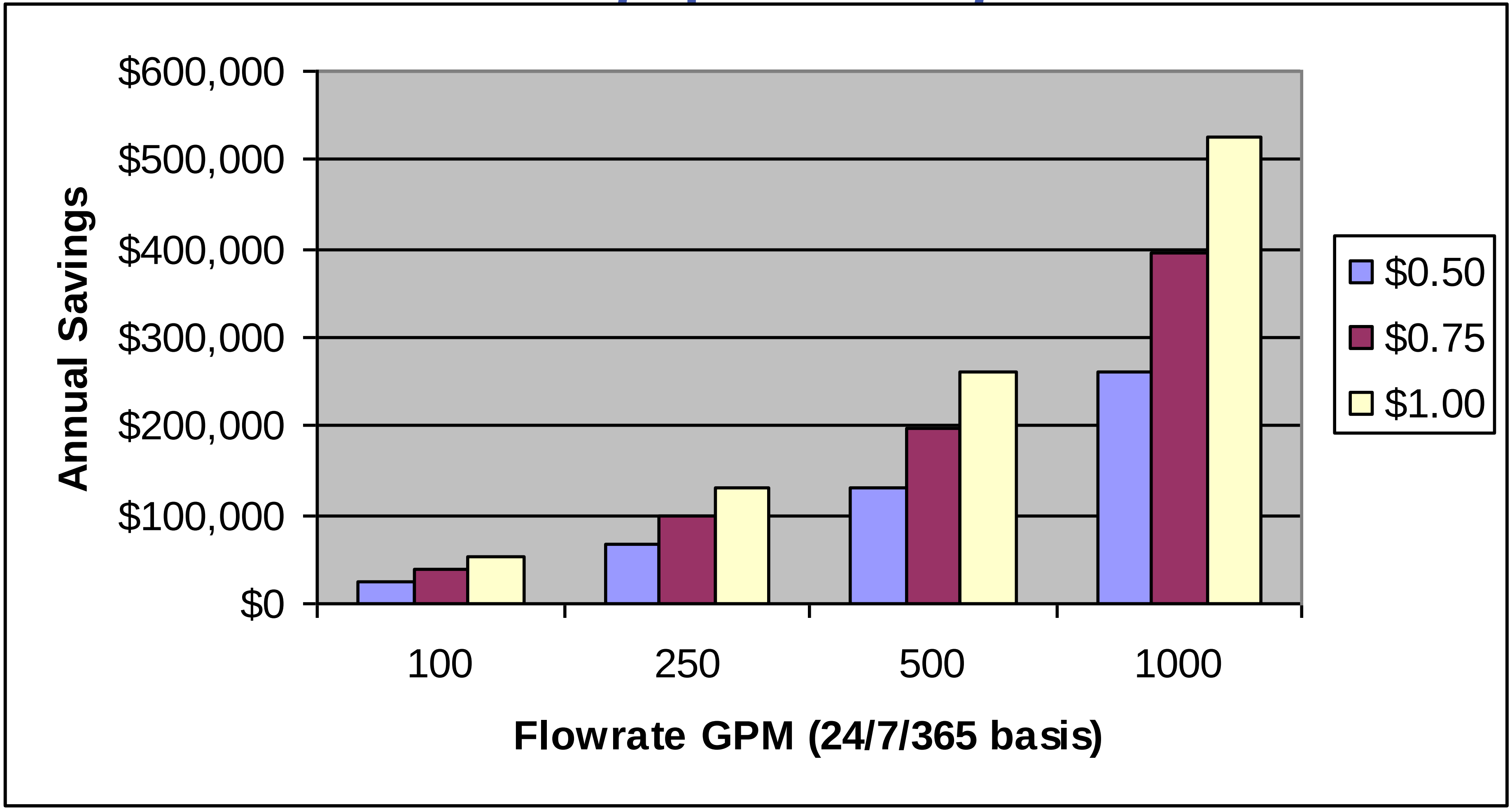
RO Preceding Demineralizer

Example with more expensive water and sewerage

RO cost justified above approx. 400 ppm TDS

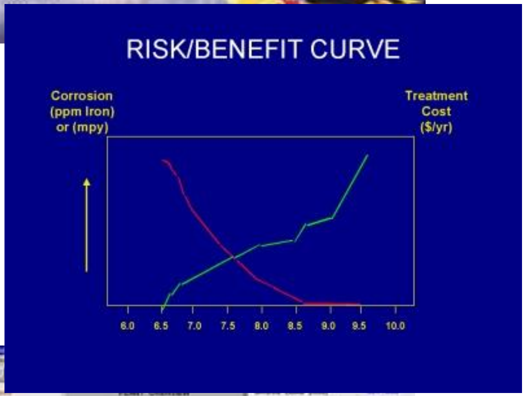


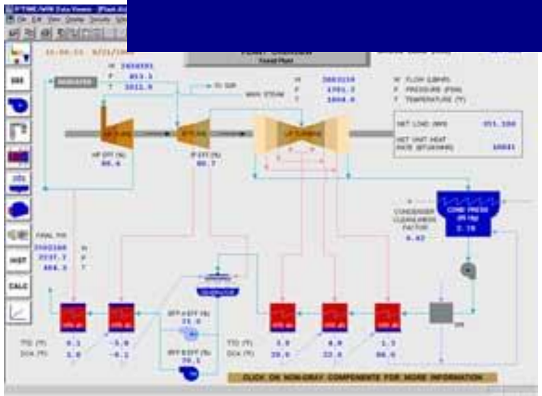
Case 1 Summary - RO in front of Demineralizer Annual cost savings based on water production and savings per 1000 gallons



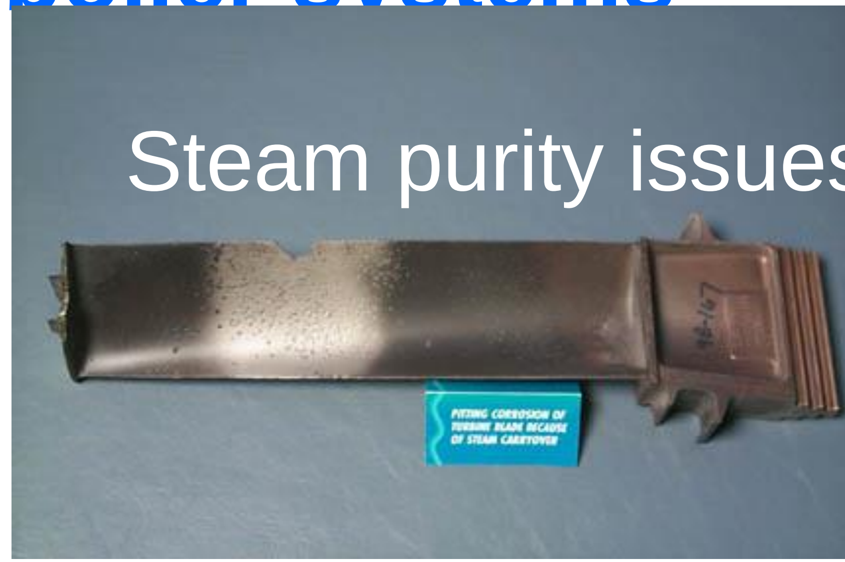
Case 2 - Potential Benefits
Conversion from Softened to RO make-up

- **Improved steam purity**
  > Process/Turbine
- **Improved condensate corrosion control**
  > High-alkalinity waters
- **Minimizes operating and maintenance expenses**
  > Boiler waterside and steamside failures
- **Maintains optimal thermal performance**
  > Boiler and steam heat transfer efficiency
- **Reduced chemical treatment costs**
  > Higher cycles operation – less wastage
  > Lower steam system treatment requirements





Typical Problems encountered in Softened water boiler systems



A look at fuel and water savings when increasing boiler cycles noting a natural cost of $8 per decatherm.

CCR Bankbook Program - Pharma

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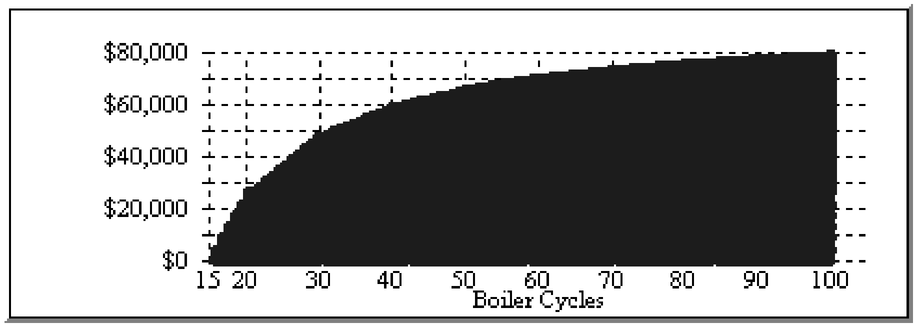
CCR Opportunity: Increasing Boiler Cycles

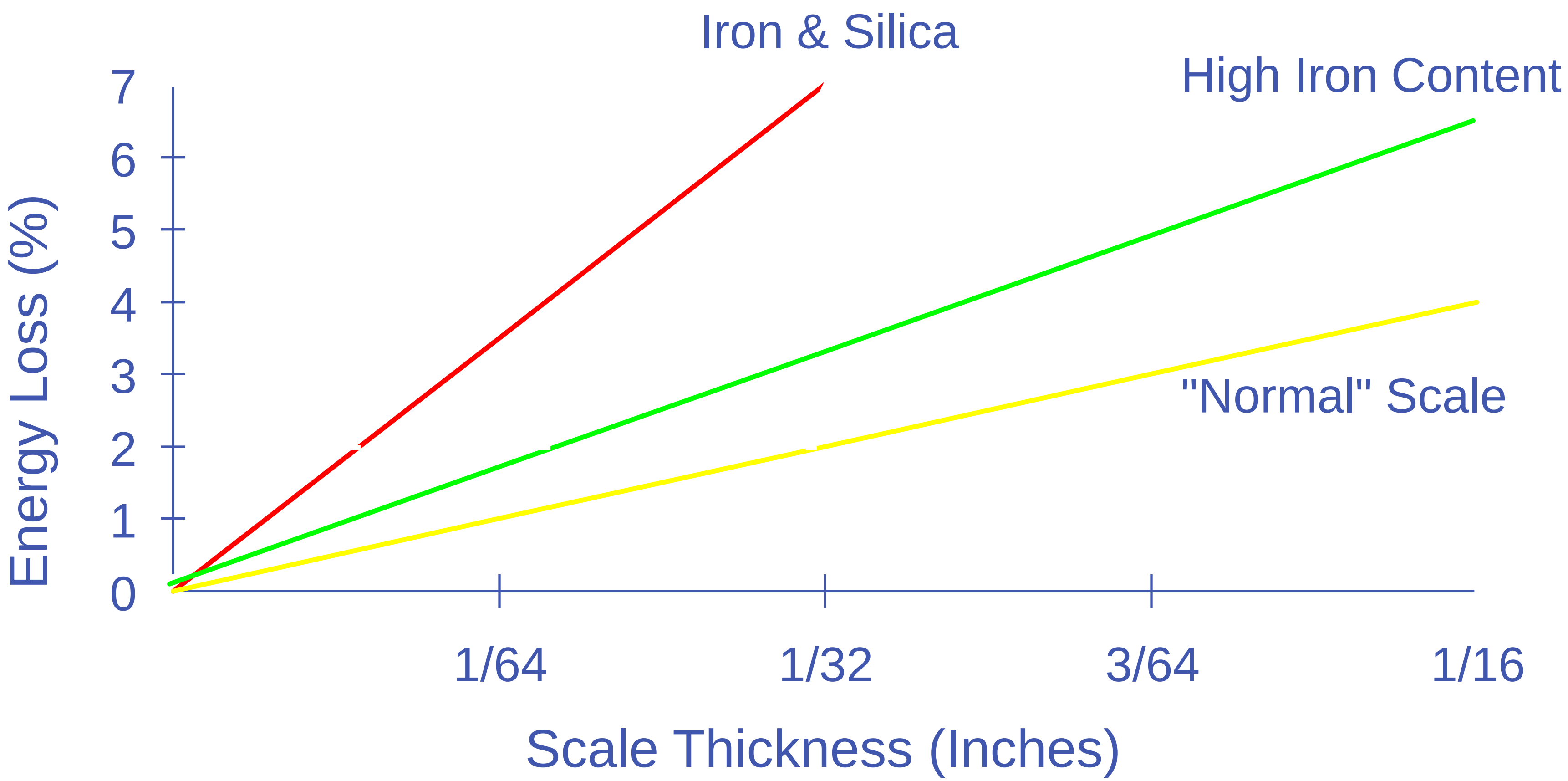
Increase cycles from 15 to 100
Total Savings: $78,912 per year

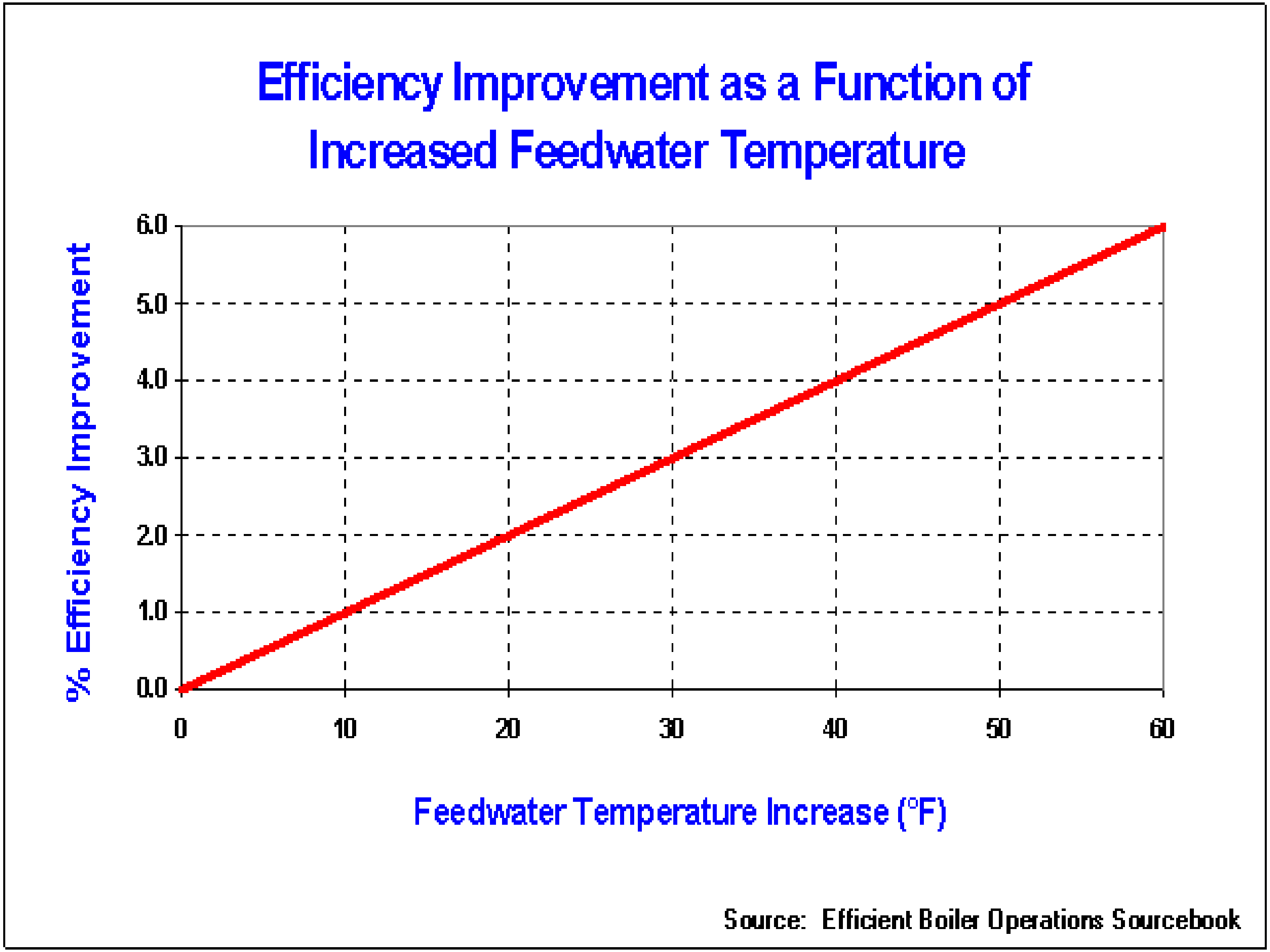
Savings as a Function of Increased Boiler Cycles:



FW Cycles	Makeup (MM gal/yr)	Blowdown (MM gal/yr)	Fuel (mcf/yr)	Makeup Cost ($/yr)	Sewer Cost ($/yr)	Fuel Cost ($/yr)	Total Cost ($/yr)	Total Savings ($/yr)
15	9.38	3.13	479,616	$18,756	$6,252	$3,836,929	$3,861,938	$0
20	8.56	2.30	477,004	$17,111	$4,607	$3,816,033	$3,837,751	$24,186
30	7.76	1.51	474,482	$15,523	$3,018	$3,795,858	$3,814,399	$47,539
40	7.37	1.12	473,254	$14,749	$2,244	$3,786,029	$3,803,022	$58,916
50	7.15	0.89	472,526	$14,291	$1,786	$3,780,212	$3,796,289	$65,649
60	6.99	0.74	472,046	$13,988	$1,484	$3,776,367	$3,791,838	$70,100
70	6.89	0.63	471,705	$13,773	$1,269	$3,773,636	$3,788,678	$73,260
80	6.81	0.55	471,450	$13,612	$1,108	$3,771,597	$3,786,317	$75,621
90	6.74	0.49	471,252	$13,488	$983	$3,770,015	$3,784,487	$77,451
100	6.69	0.44	471,094	$13,388	$884	$3,768,754	$3,783,026	$78,912

Potential Energy Loss Versus Waterside Scale Thickness





Efficiency Improvement as a Function of Increased Feedwater Temperature
% Efficiency Improvement
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
10
20
30
40
50
60
Feedwater Temperature Increase (°F)
Source: Efficient Boiler Operations Sourcebook

Saving Water & Energy
is a Big Win in Every Way,
and the creative use of Membrane solutions for Boilers can help you to make it happen at your facility!