Steam Purity Considerations For New Turbines

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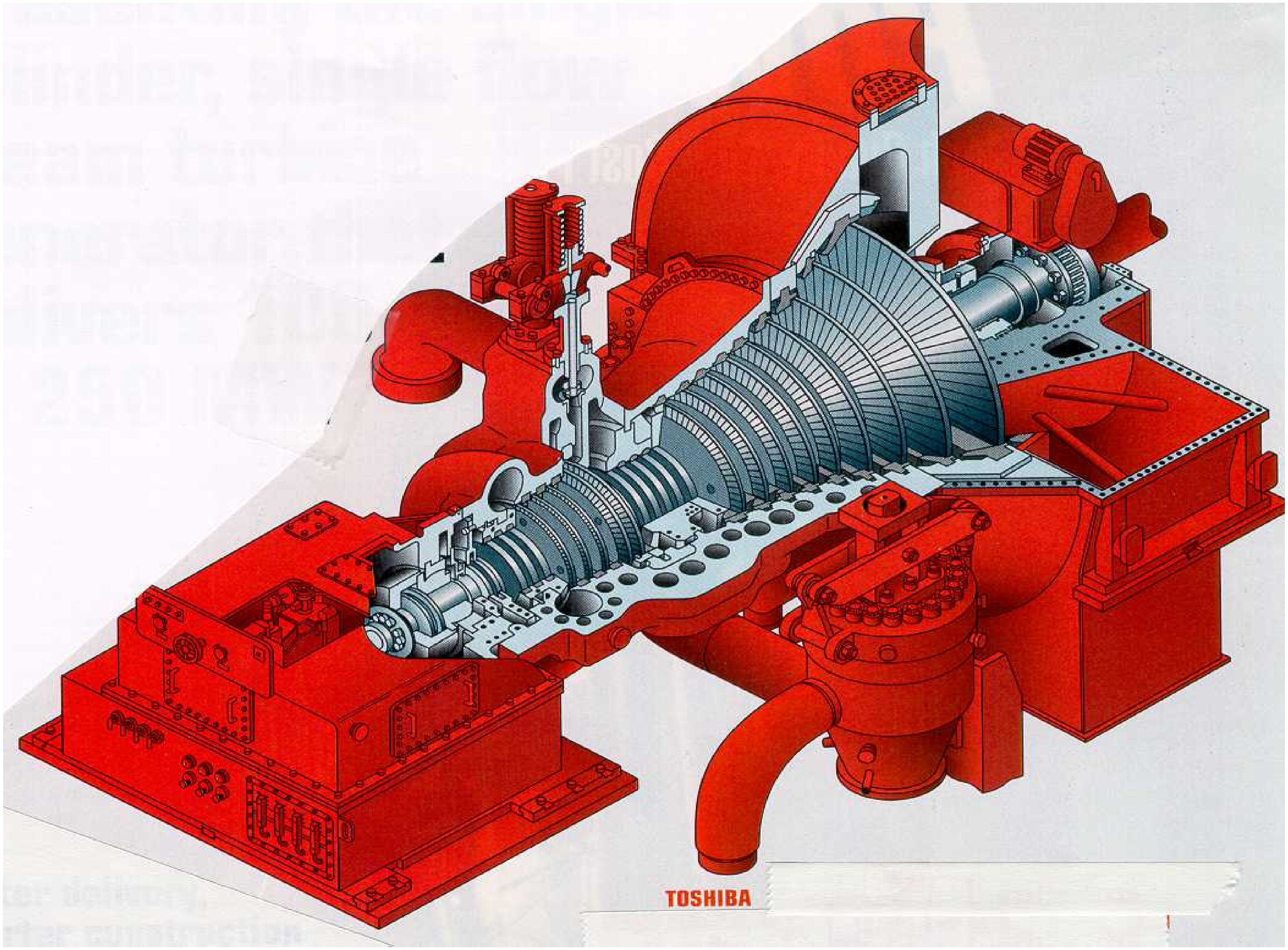

"Ideal" Steam

- Dry (steam "quality")
- pH ~ 9.0 (neutralizing amines)
- Otherwise just gaseous H_20

"Real World" Steam

"Potential" Bad Actors:

- Suspended solids
  - Metallic particles
- "Dissolved" solids
  - Na, Cl, SO_4, etc.
- Gases
  - CO_2, oxygen
- Vapourized silica
- "Organics"

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Potential Impact of Poor Steam Purity

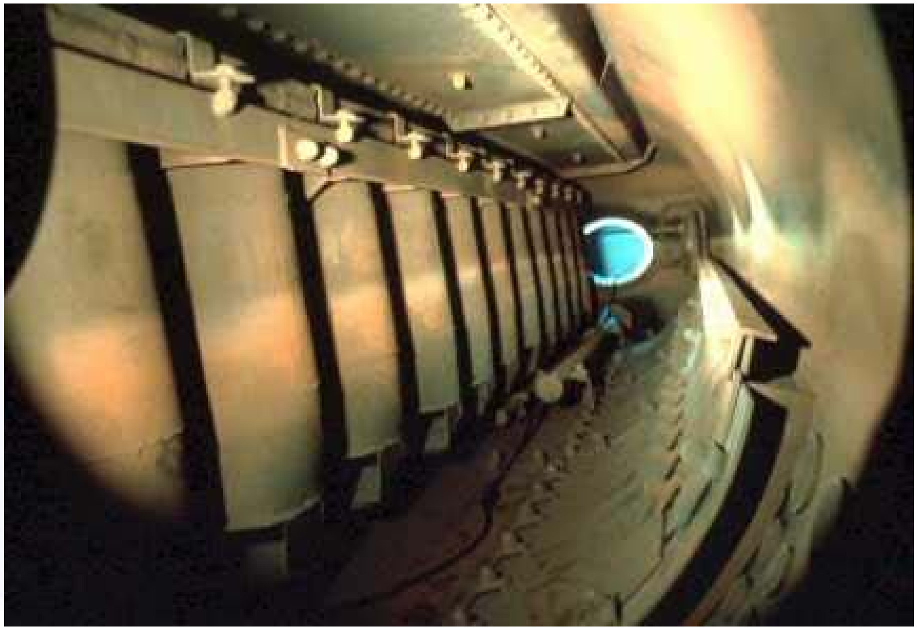
- Deposition on turbine blades
- Corrosion fatigue of blades, discs
- Particle erosion
- Wear of thrust bearing as stage pressure increases
- Sticking valve stems
- Plugging of seals

Potential Sources/Causes of Contamination

- Boiler carryover
- Attemperating water
- Silica vaporization
- Vaporization of organic compounds

Boiler Carryover

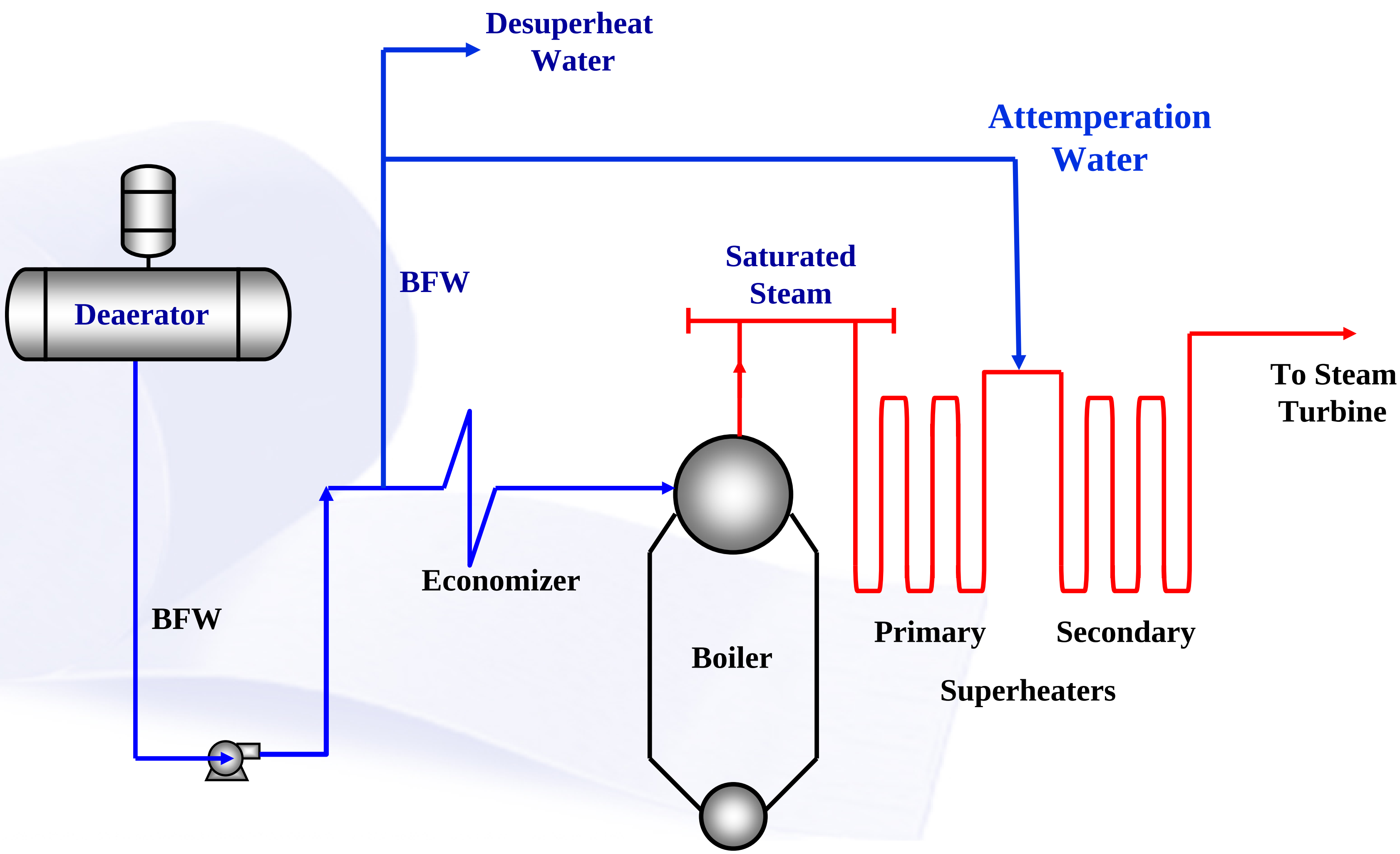
- Boiler manufacturers steam purity guarantees typically based a maximum percent carryover for a given pressure, e.g. 0.05 – 0.1%
- Amount of impurities present (e.g. sodium) will depend on the quality of the boiler water



Attemperating Water

- Boiler feedwater
- Mill condensate
- Condensed steam ("sweetwater condenser")

Feedwater for Attemperation



Feedwater for Attemperation

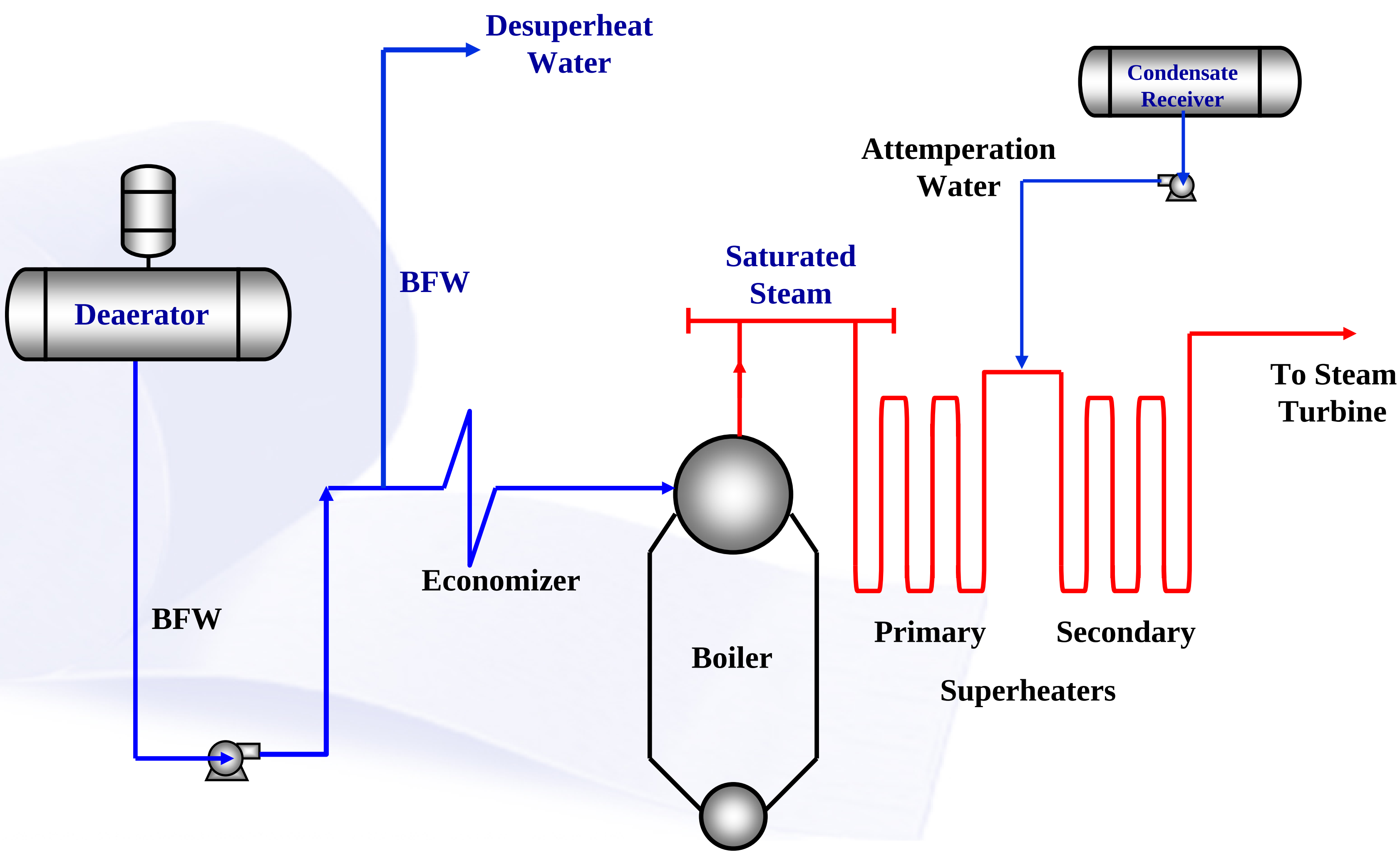
- Convenient, “low cost” source, but …
- Subject to “normal” levels of FW impurities
  - Demineralizer leakage
  - Condensate polisher leakage
- Subject to FW quality excursions
  - Condensate contamination
  - Demineralizer / polisher regenerant
- Impurities in FW used for attemperating is the most common cause of industrial turbine fouling

Feedwater for Attemperation

If you must …

- Optimize demineralizer performance to reduce [Na] leakage
- Operate [cation] condensate polishers in the amine cycle
- Only feed volatile treatment chemicals before the take-off point
- Monitor FW quality closely
  - conductivity, Na

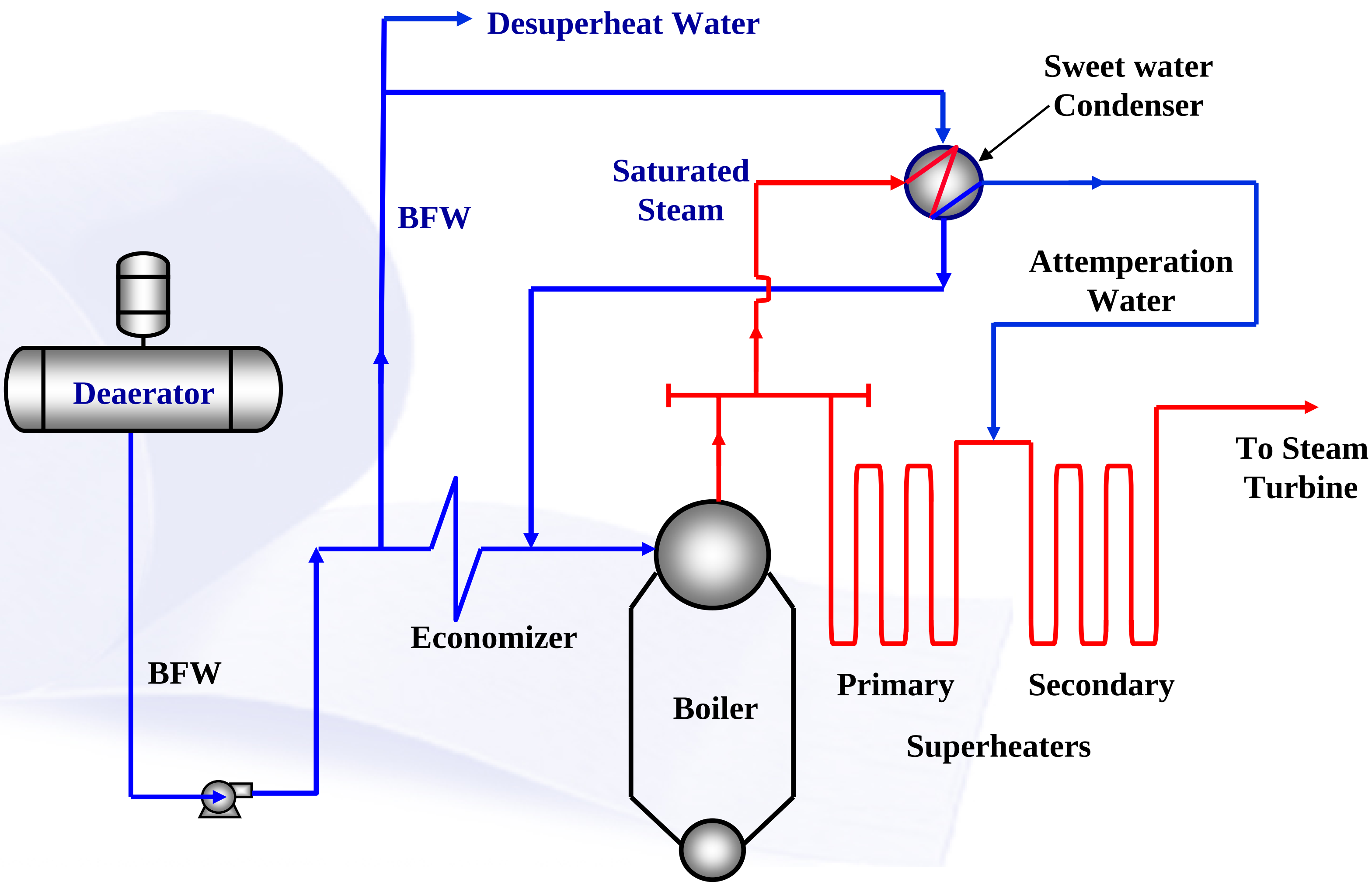
Mill Condensate for Attemperation



Mill Condensate for Attemperation

- Requires a high pressure pump
- Ideally a high purity, low risk condensate
  - Otherwise subject to potential condensate contaminants/risks

Sweetwater Condenser for Attemperation



Sweetwater Condenser for Attemperation

- The ideal source
- Highest [initial] cost
- Expensive add on
- Common on most new higher pressure installations

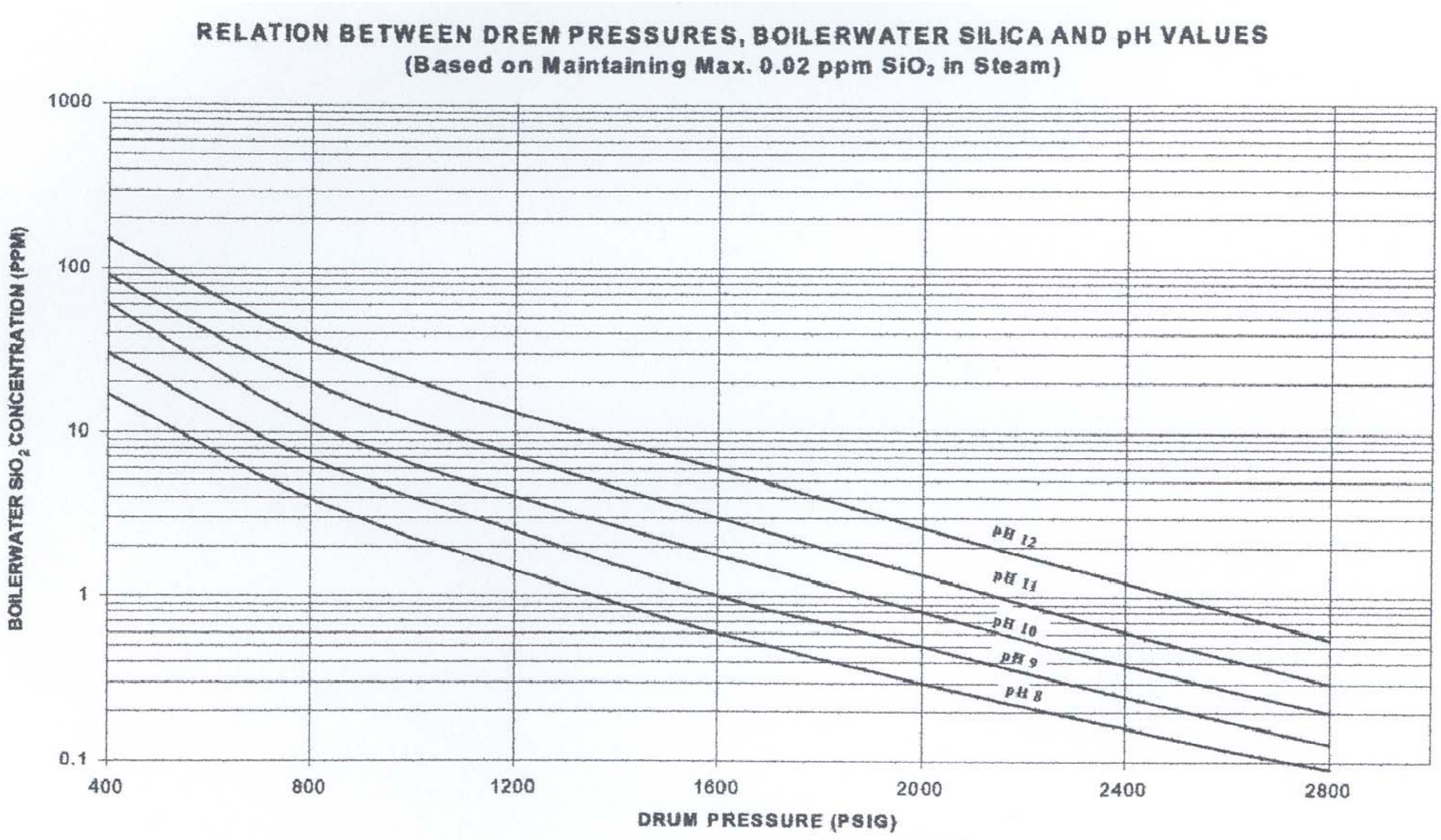
Potential Sources/Causes of Contamination

- Boiler carryover
- Attemperating water
- Silica vaporization
- Organic compound breakdown products

Silica Vaporization

- Silica will partially vaporize at boiler pressures above about 400 psig
- Independent of boiler carryover
- Amount in steam dependent on temperature (pressure), silica concentration and pH
- Not a superheater issue, but definitely a turbine issue
- Generally not a problem if < 20 ppb in the steam

Boiler Water Silica Limits



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Vaporization of Organic Compounds

- All organics will experience some thermal decomposition (to lower molecular weight compounds) at increasing boiler temperatures/pressures
  - Natural organics from make-up water
  - Organic treatment chemicals
  - Process contaminants
  - Ion exchange resin

Vaporization of Organics Compounds

- Potential for adverse impact on steam turbines is subject to continuing debate

Typical Turbine Manufacturer Steam Purity Limits

Sodium	5 - 20 ppb
Silica	10 - 20 ppb
Chloride, sulfate	3 – 15 ppb
Cation Conductivity	0.1 – 0.3 µS/cm

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Why Measure Sodium?

- Sodium is the primary cation in the boiler water (or feedwater)
- Easily detected at ppb levels
- Reliable continuous analyzers available
- Can ratio to TDS using the boiler water Na/TDS ratio
- Indirectly detects all present anions

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Typical Continuous Sodium analyzer

Cation Conductivity

So what is “Cation Conductivity” anyway?

Conductivity Definitions

- **Specific Conductivity (SC):**
  - An indirect measurement of all dissolved solids in the steam based on electrical conductance
  - Neutralizing amines are the major contributor to the conductivity of steam/condensate in a high purity system
  - Typically 3 – 5 µS/cm at pH 9.0

Conductivity Definitions

- **Cation Conductivity (CC):**
  - Sample is first "conditioned" by passing through an hydrogen form cation resin column
    - Converts all cations (Na^+, $NH_4^{+\,*}$) to hydrogen (H^+) ions
    - All anions (sulfate, chloride, phosphate, organics, CO_2) become acids
    - Typically baseline levels of 0.2 – 2.0 µS/cm
      - Essentially all due to organics

* Representing ammonia and amines

Conductivity Definitions

- **Cation Conductivity (CC):**
  - Benefits:
    - Eliminates background conductivity caused by amines, which can “mask” contamination
    - Significantly “amplifies” the impact of all anions on the resulting conductivity reading …the acids formed are 4 – 5 times more conductive than their neutral salts

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Conductivity Definitions

- **Cation Conductivity (CC):**
  - Limitations:
    - Is still an indirect measure of multiple anions
      - known high risk anions (chloride, sulfate)
      - low [or unclear] risk anions (CO_2, organics)
    - Results in a “new” background conductivity
    - Does not detect caustic!

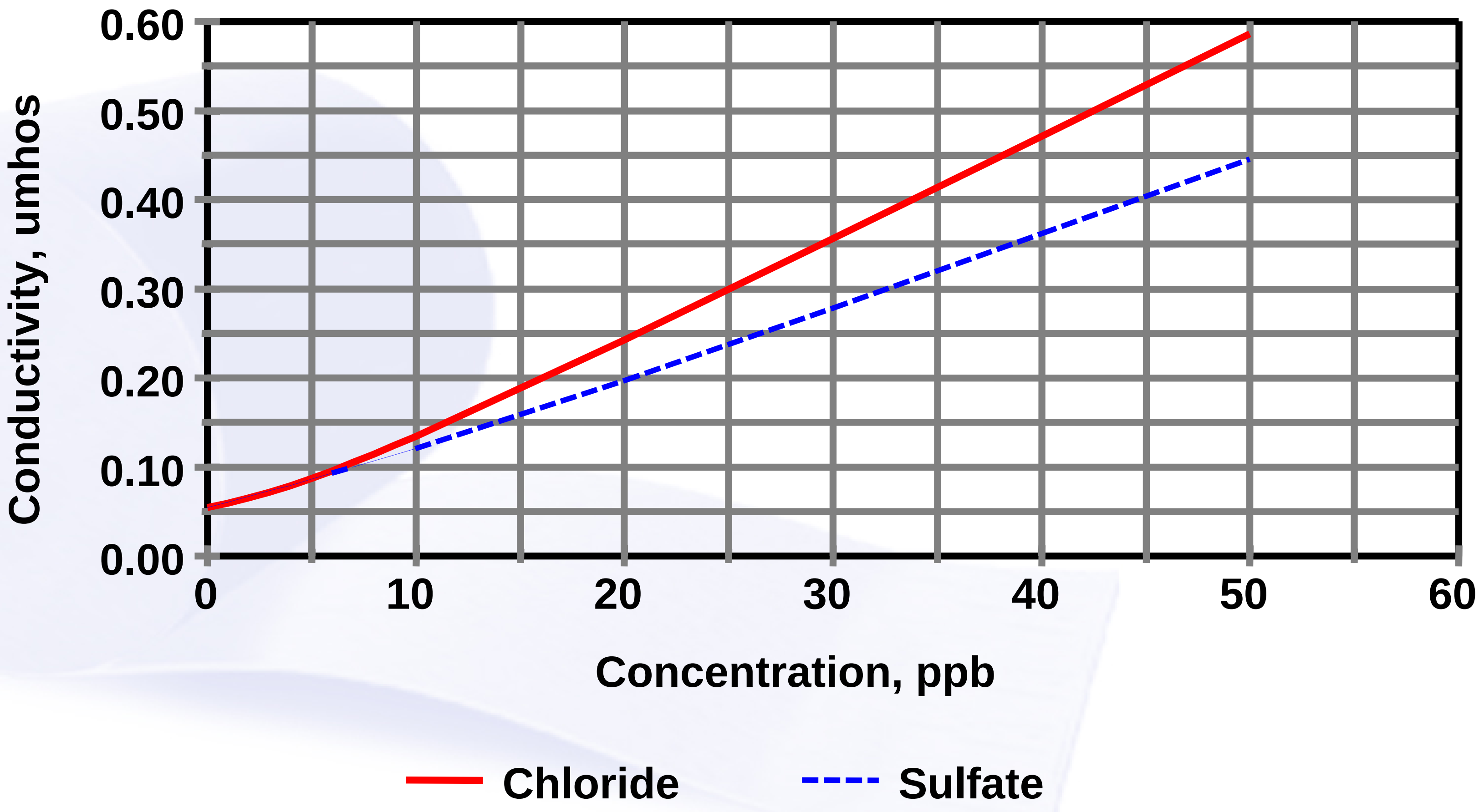
$$NaOH + R\text{-}H \rightarrow R\text{-}Na + H_2O$$

Conductivity Definitions

- **“Degassed” Cation Conductivity (CC):**
  - Sample is heated after the resin column to remove dissolved gases (CO_2) that contribute to [undegassed] cation conductivity
  - Sometime used following cation conductivity in order to eliminate the impact of and/or estimate the concentration of CO_2
  - More common in the utilities industry

Cation Conductivity

Chloride and Sulfate



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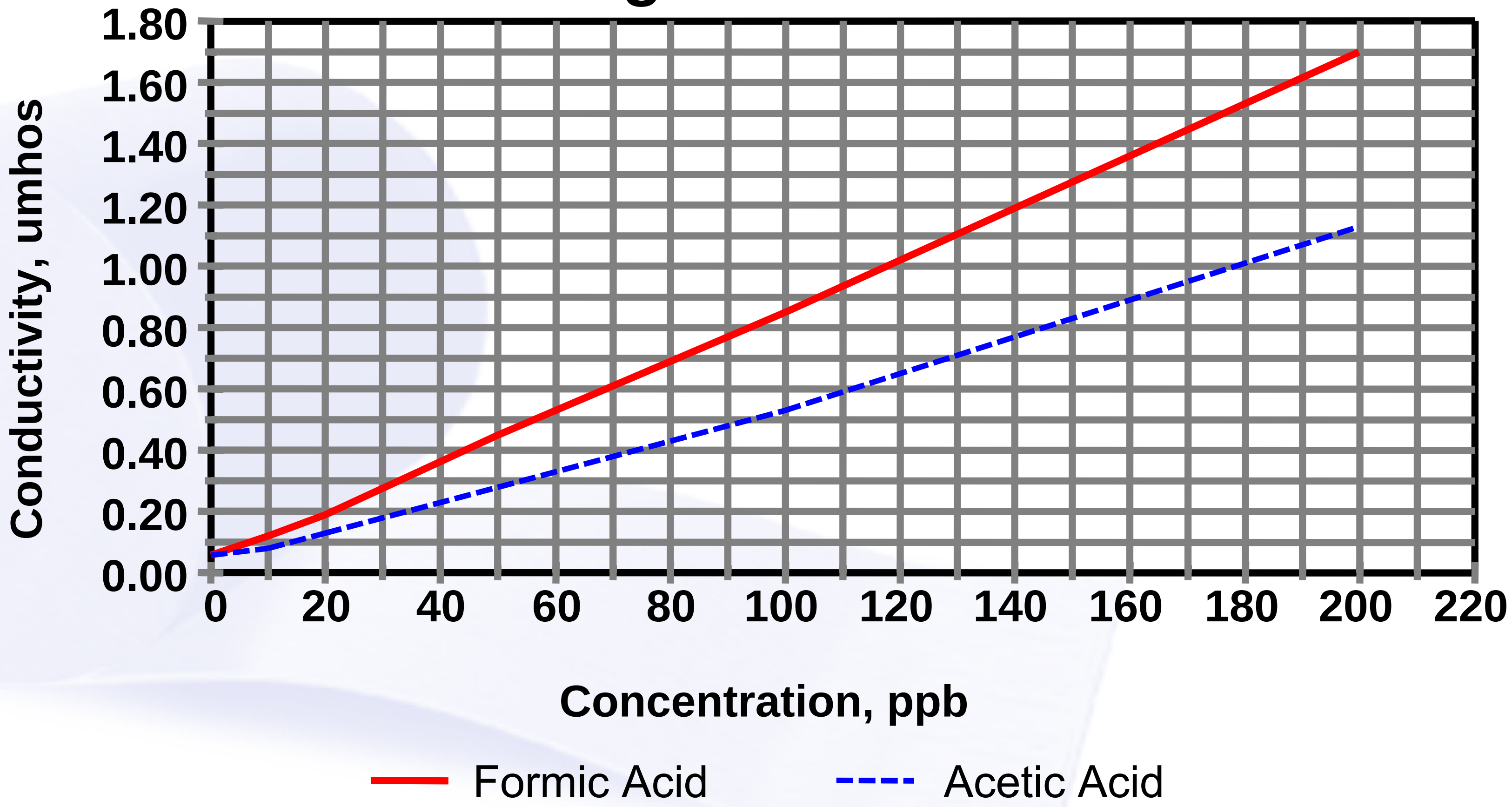
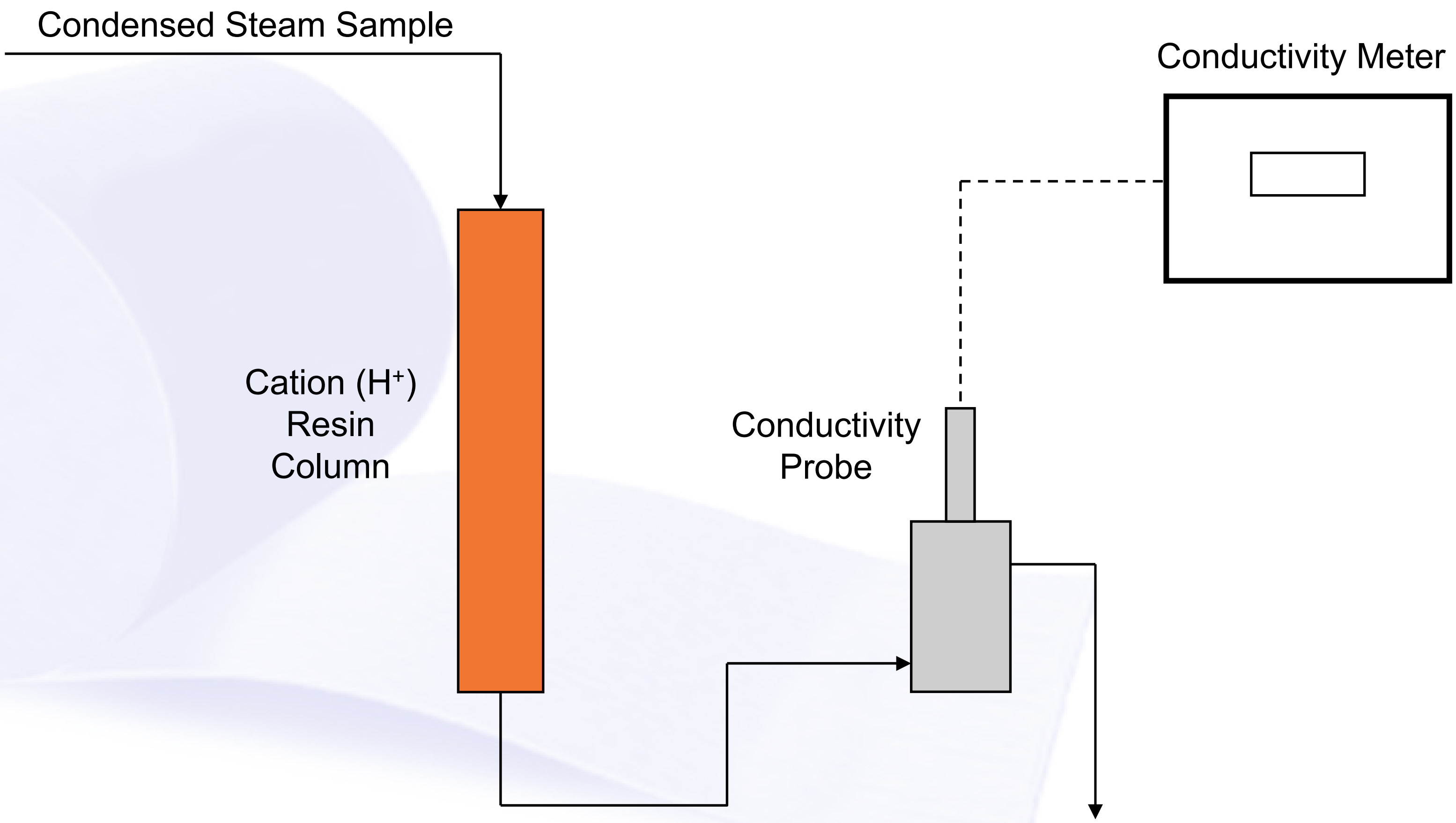
Cation Conductivity

Organic Acids



Cation Conductivity Measurement



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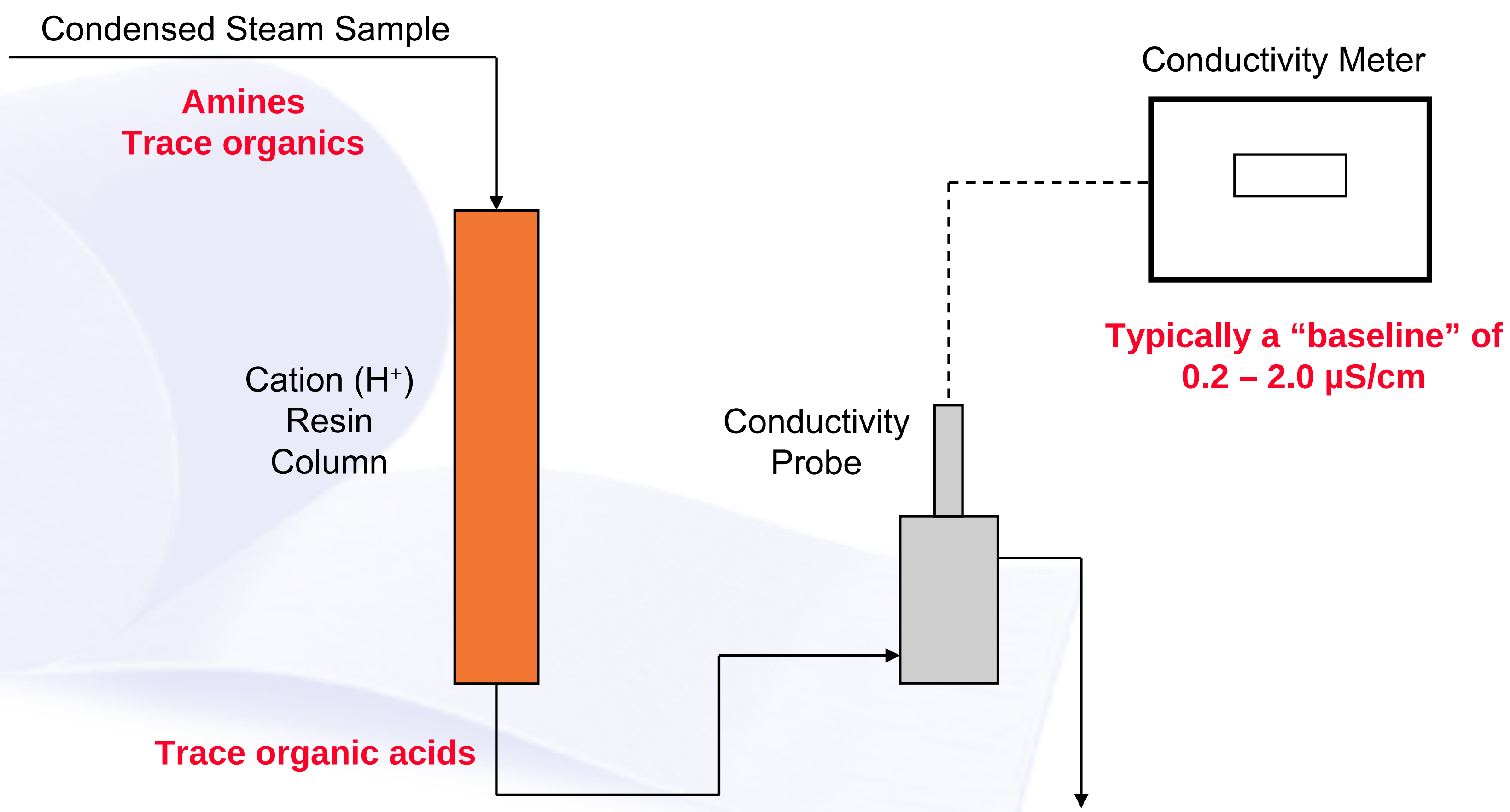
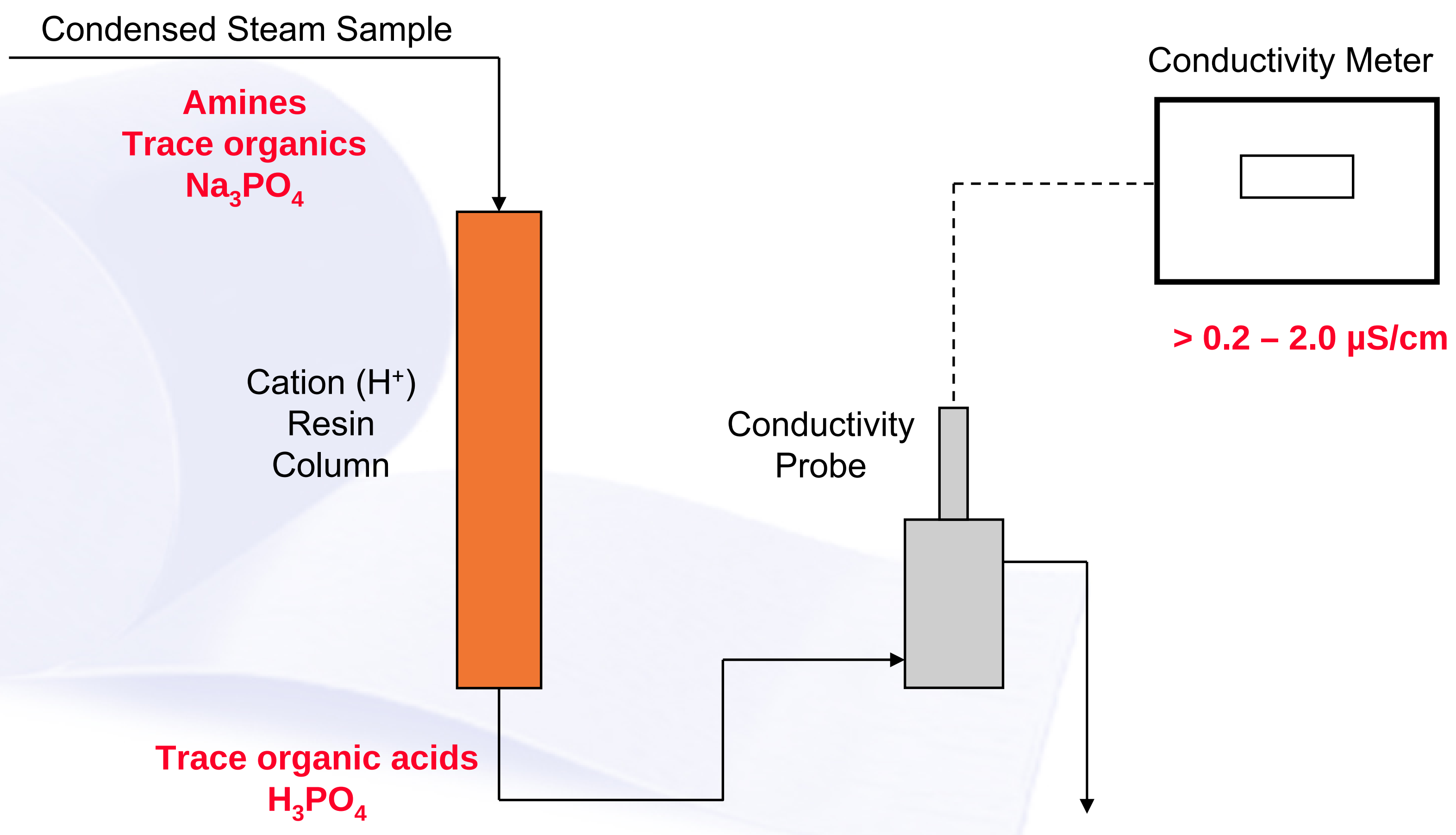
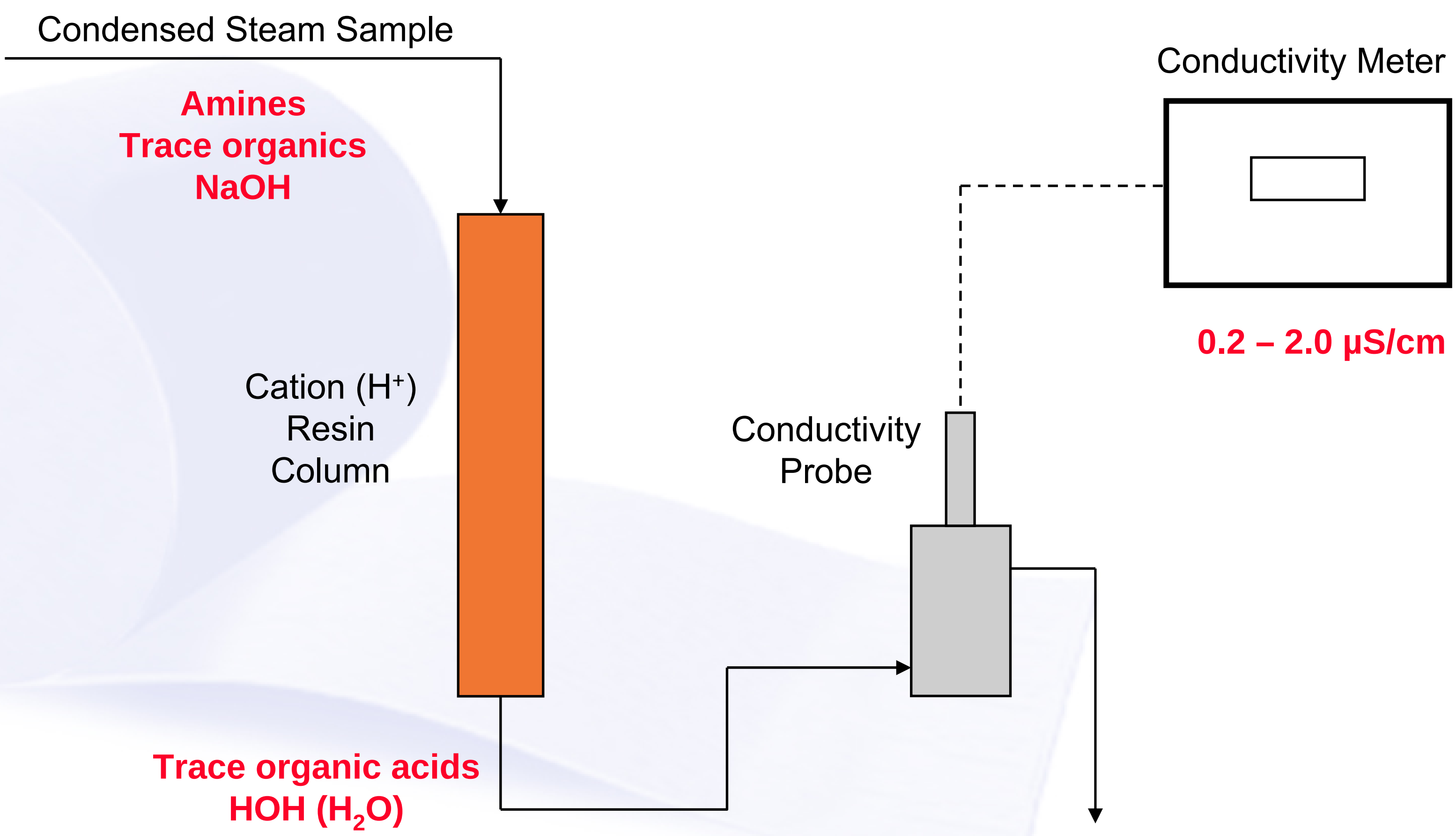


Cation Conductivity Measurement



Cation Conductivity Measurement



The Dilemma …

Typical “real world” steam cation conductivity levels in industrial systems

= 0.2 – 2.0 μS/cm

Turbine manufacturers specifications:

= 0.1 – 0.3 μS/cm

= Potential warranty conflict!!!

Industry Experience

- Strong evidence that the typical levels of background organics in "industrial" systems do <u>not</u> pose a risk to steam turbines
- Cation conductivity is <u>not</u> the best method to monitor steam purity in industrial systems

Industry Experience

- 20 plant study conducted in 2001 by GE Water & Process Technologies:
  - 31 turbines, 900 – 2850 psig steam
  - Wide range of pretreatment and chemical treatment
  - **Cation conductivities:**
    - **Range: 0.19 – 1.9 µS/cm**
    - **Average: 0.72 µS/cm**
    - **Only one plant met the turbine manufacturers limit**

Industry Experience

- **Not a single turbine problem attributed to chemistry**

Industry Experience

- 120 MW combined cycle cogen plant
  - Commissioned in 1989
  - 44 MW 1330 psig GE steam turbine
  - IP Steam exported/condensate returned from a host tire manufacturing plant
  - City water/demineralized make-up
  - Mixed bed condensate polishing
  - Coordinated treatment, neutralizing amines, DEHA

Industry Experience

- 120 MW combined cycle cogen plant
  - Cation conductivity consistently 2 – 5 µS/cm
  - Over 17 years of steady operation (to 2006), the steam turbine is still in excellent condition

The Bottom Line …

Organic acids:

- Are present at low levels in all industrial systems
- Are responsible for most of the “background” steam cation conductivity
- Are effectively neutralized in the turbine environment by normal amine treatment
- Despite contributing to cation conductivity, have not been shown to cause corrosion in boilers or steam turbines

Steam Purity Best Practices
(for modern steam turbines)

- Sweetwater condenser for attemperating water
  - Much lower risk compared to other sources
- Continuously monitor steam <u>sodium</u>
  - Turbine inlet as a minimum
  - Proper steam sampling (ASTM D-1066)

Steam Purity Best Practices
(for modern steam turbines)

- Cation conductivity can still be a useful tool, **but …**
  - Recognize the limitations
  - Establish normal baseline for each system
  - Is not sufficient on it’s own
- Detailed excursion response procedures

Questions?