

# ***Copper Corrosion & Agglomeration in APS Water Cooling System***

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for the U.S. Department of Energy



# ***Out Line***

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- **Background**
- **Corrosion Products**
- **Parameters that Affect Corrosion & Agglomeration**
- **Objective & Approach**
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# ***Background***

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The surplus X-ray, produced at APS, Argonne is absorbed by various copper absorbers. The function of low conductivity water system is to water cool various critical components, such as electromagnets, absorbers etc.

## Issue:

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- **The water used in APS water cooling system is almost pure, contains trace amount of impurity (ionic / particulates / gaseous).**
- **APS Water cooling system contains components consist of massive amount of copper tubing. Additionally, copper mesh has been installed inside the water carrying copper tubes to improve heat conductivity.**
- **Since 1997 the water cooling system has been encountering a severe agglomeration of copper compounds (corrosion products) which clogs the system, resulting in a drop in flow rate. This drop in flow rate has resulted in insufficient cooling leading to system shut down in a few occasions.**
- **Routine maintenance is required to avoid this situation. These maintenance are very expensive and results in undesired downtime.**

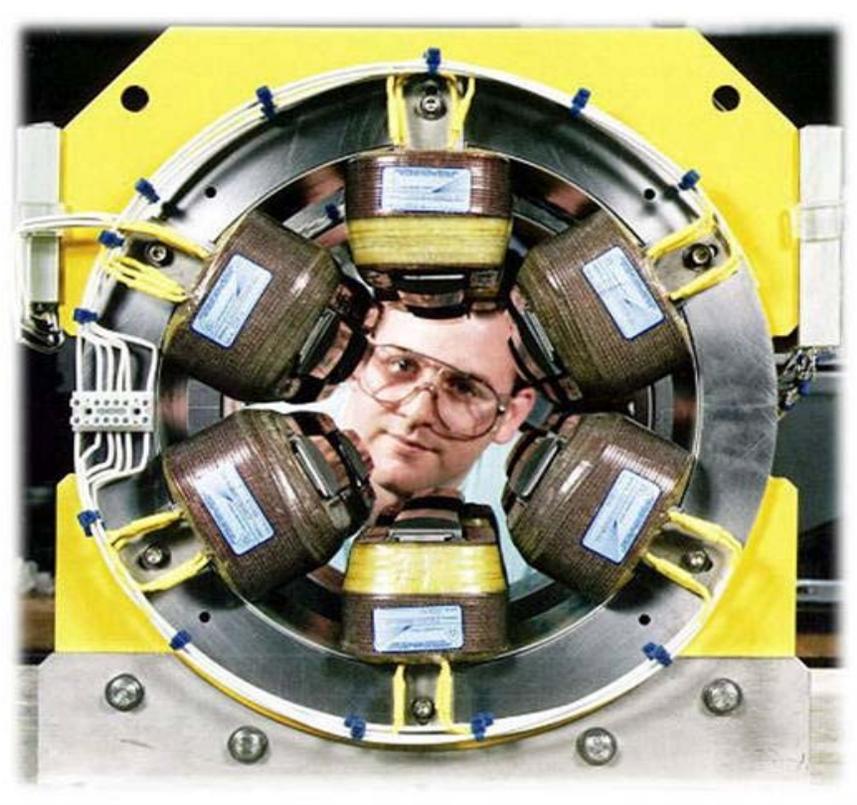
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# *Drop in flow occurs due to:*

- Corrosion  
&
- Agglomeration

# Magnets are the principal source of Corrosion:

- Function:
  - Control the direction of electron beam
  - Focus / defocus electron beam
- Consist of a lot of water cooled copper tubing for carrying current



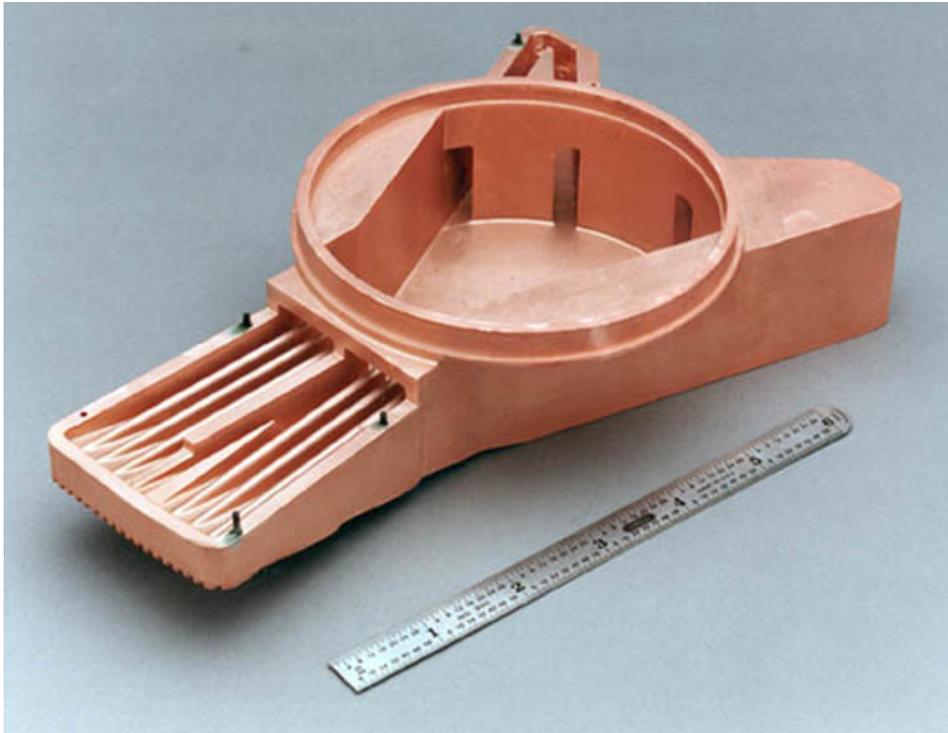


## Magnets in one sector

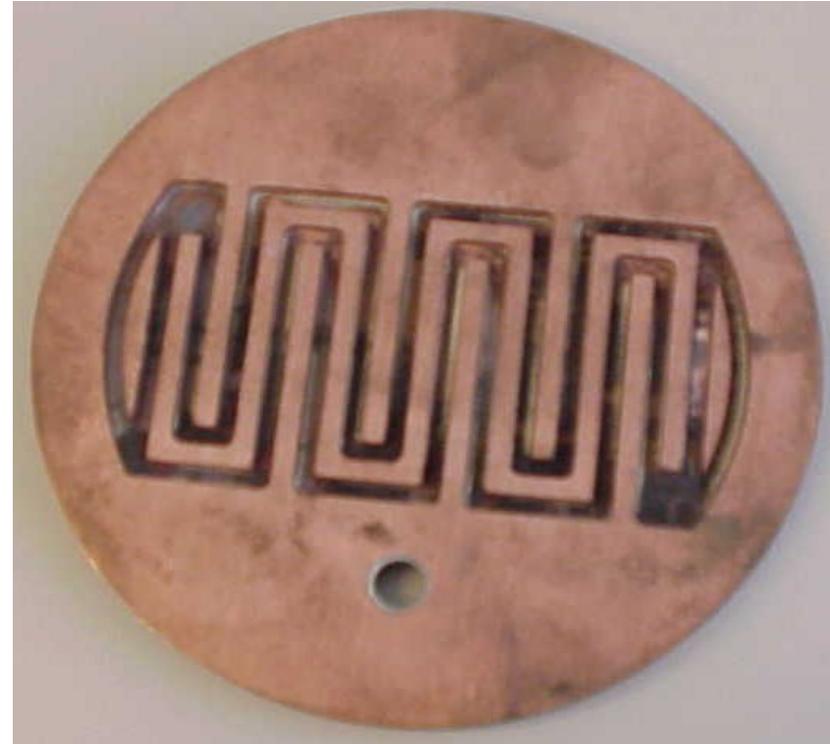
\* Note: There are 40 sectors in the ring

# Components where Clogging Takes Place:

- Copper Absorbers
- Copper tubes with copper mesh
- Griswold Valve



**Crotch Absorber Before Clogging**



**Beam Stop After Clogging**

# Corrosion Products

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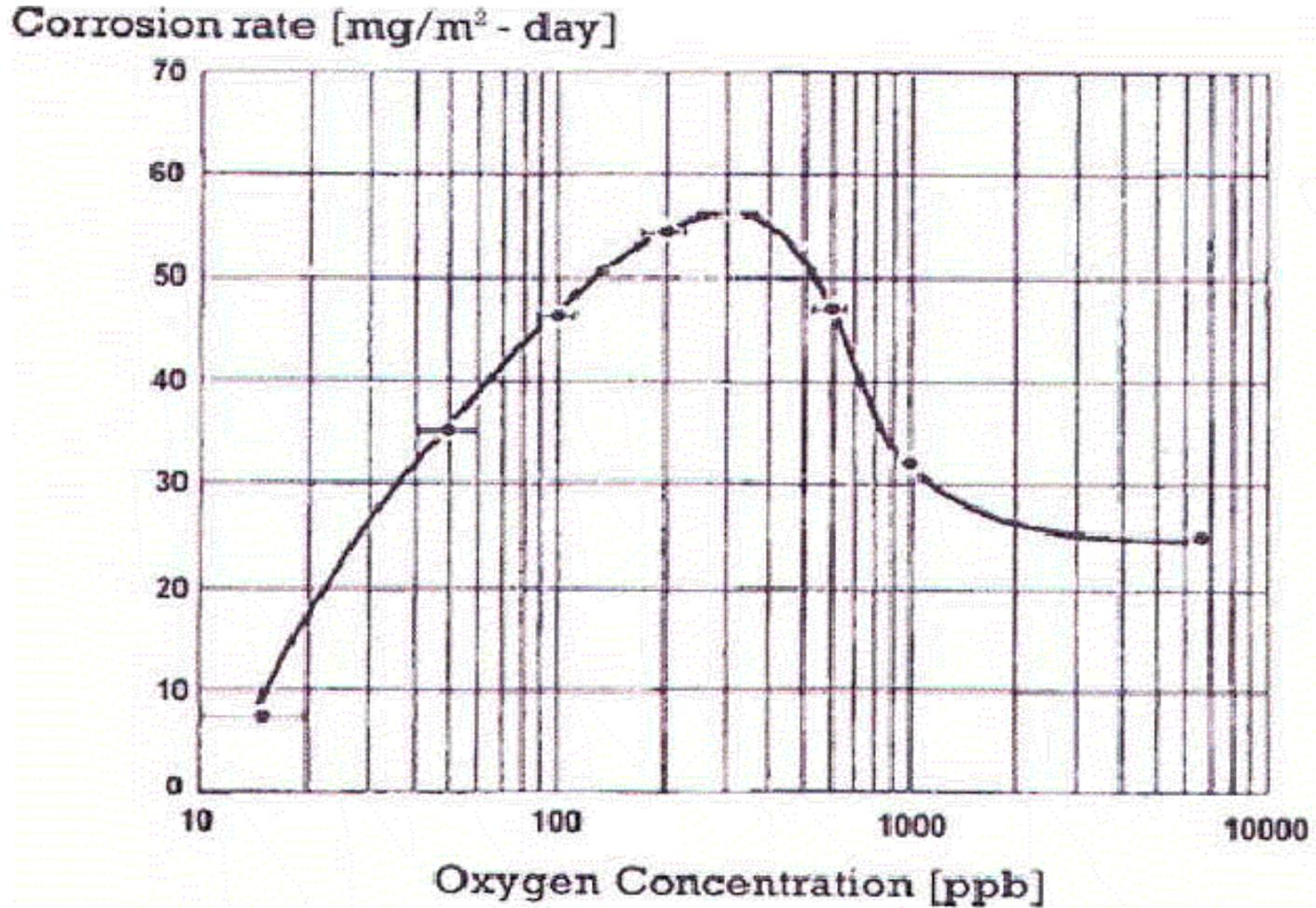
- Corrosion Products:  $\text{Cu}^+$ ,  $\text{Cu}^{++}$ , Cu-Oxides, Hydroxides (might be).
  - *$\text{Cu}^+$ ,  $\text{Cu}^{++}$  - Soluble in water*
  - *Cu-Oxides, Hydroxides – Insoluble, forms a protective layer on the component surface that prevents any further corrosion.*
  - *$\text{Cu}^+$  forms at low Oxygen level*
  - *$\text{Cu}^{++}$  forms at high Oxygen level*

# Parameters that Affect Corrosion & Agglomeration

- Dissolved Oxygen
- pH
- Temperature
- Resistivity
- Geometry

**\* The above parameters are inter-dependent also.**

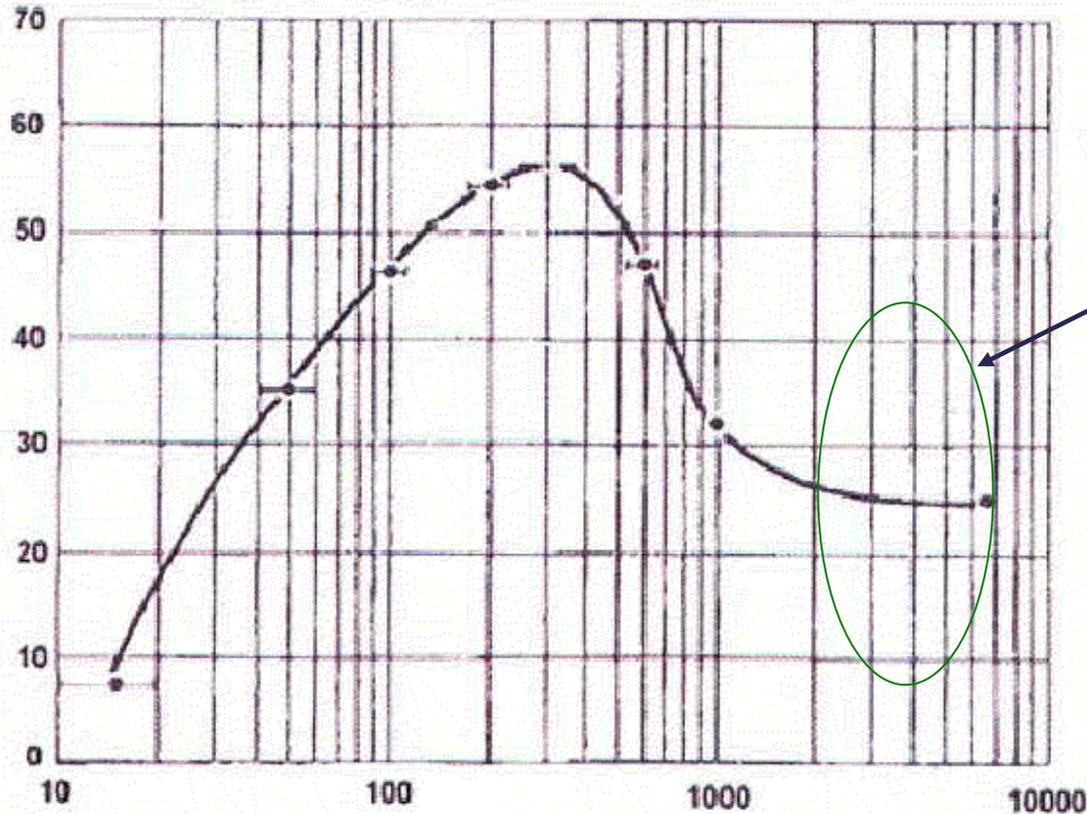
# Copper Corrosion vs Dissolved Oxygen:



Corrosion rate vs. DO.

# Goal for Future Plan:

Corrosion rate [ $\text{mg}/\text{m}^2 \cdot \text{day}$ ]



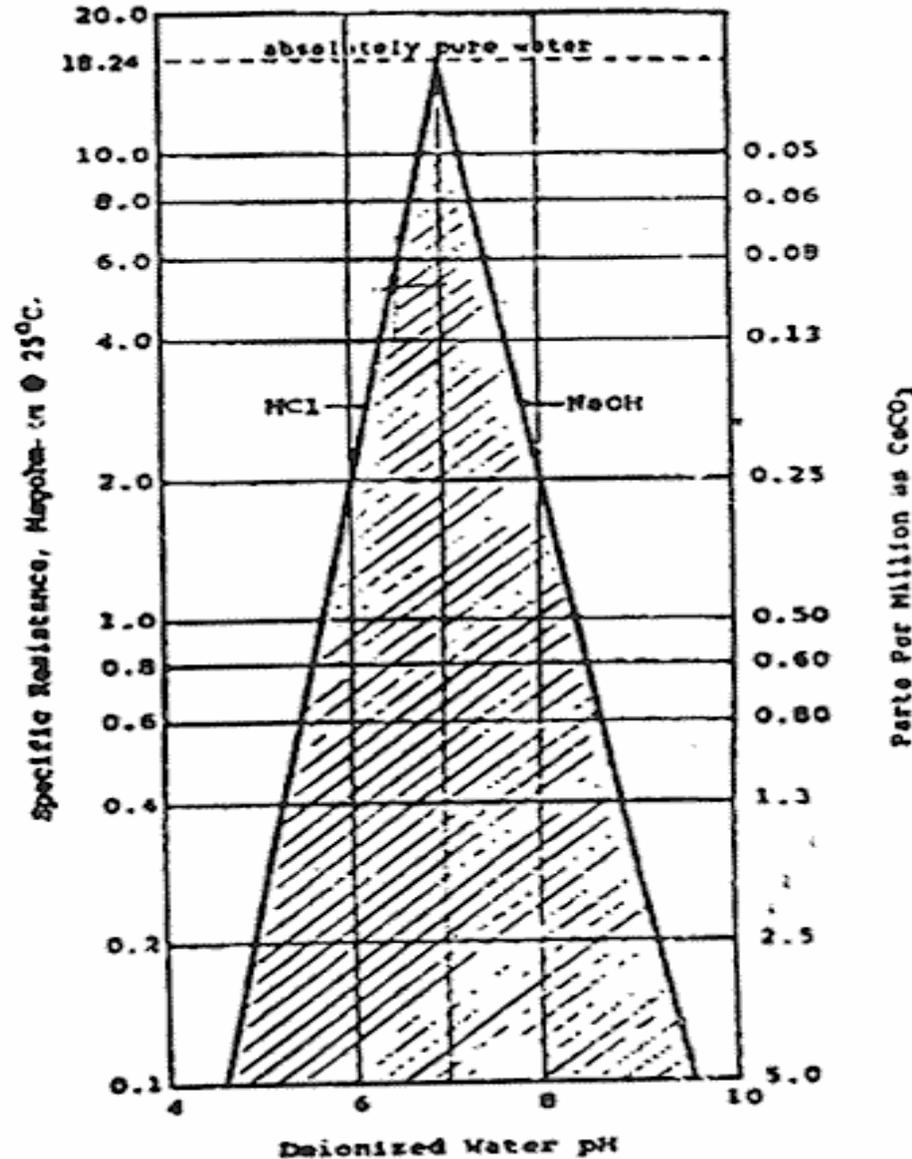
Planned  
Operating  
Region, nowc  
(High Oxygen Water  
Chemistry)

Oxygen Concentration [ppb]

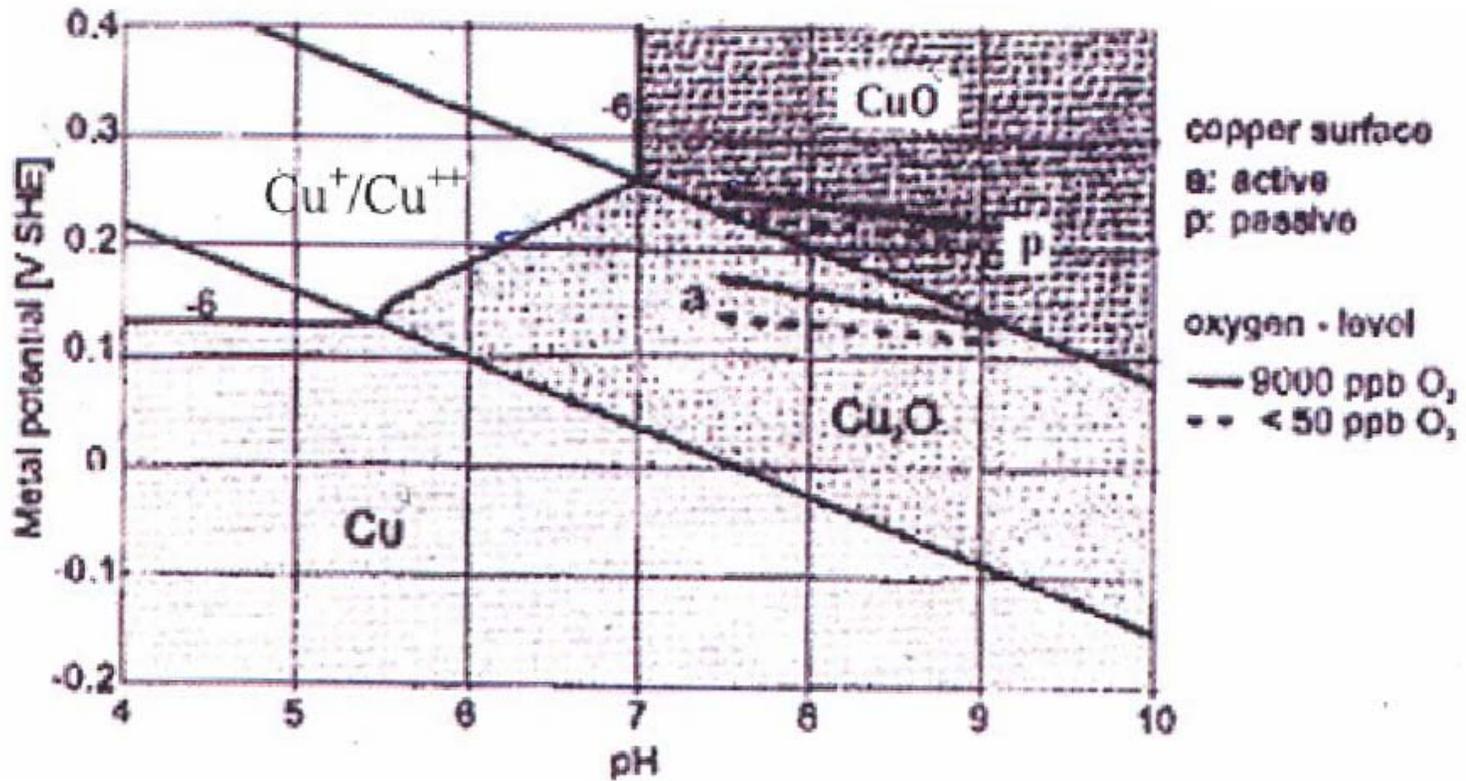
Corrosion rate vs. DO.

# Resistivity Limits of DI Water:

\* Due to operating constraint specific resistivity cannot be less than 5 Mohm-cm



# E-pH Diagram for Copper:



Pourbaix diagram for Copper

\*  $E = E_0 - (RT/ZF) \ln (\text{Activity of products} / \text{Activity of reactants})$

# Objective & Approach

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**Objective:** Establish a mechanism of clogging due to corrosion and to determine a solution to the issue.

**Approach:**

- Literature Survey
- Experimental Set up & Planning
- Experiments
  - Aeration of water (with out samples)
    - Determine the effect on DO and pH
  - Determine the effect of various parameters on agglomeration (with samples)
  - Determine the effect of various parameters on corrosion (with samples)
- Analysis
  - Mechanism
    - *SEM*
    - *XRD*

# P&ID Diagram of the Experimental Set-Up

