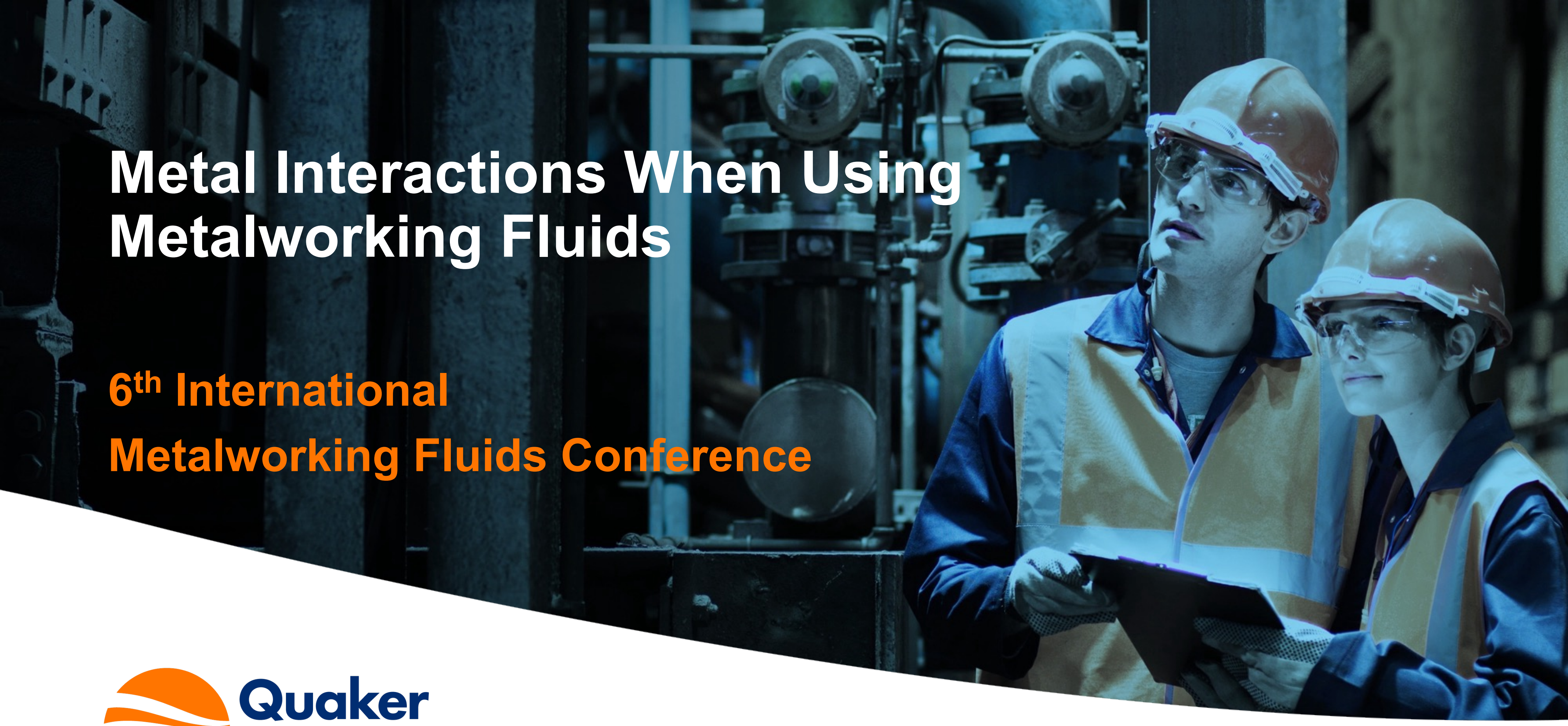


Metal Interactions When Using Metalworking Fluids

6th International Metalworking Fluids Conference

Quaker Houghton™
Forward Together™

John Burke CMFS, FSTLE

Introduction

Understanding the effect of various metals

Understanding particle size concerns

Corrective actions

General Theory

During metal machining processes, very reactive metal ions are exposed to the coolant or cutting oil.

These metal ions are continuously released into the coolant as long as the chips remain in the system.

These reactive metal ions have a destabilizing effect on the cutting fluid.

Why Fluids Fail

Three Basic Water Reducible MRF Formulations

Emulsifiable Oil (Soluble Oil)	**Oil + Anionic Soap + Rust Preventative + Coupling Agent + Biocide + Buffer**
Semi-Synthetic	**Oil + Synthetic Component + Anionic Soap + Coupling Agent + Rust Preventative + Buffer + Biocide**
Synthetic	**Synthetic Component + Fatty Acid + Anionic Wetting Agent + Rust Preventative + Buffer + Biocide**

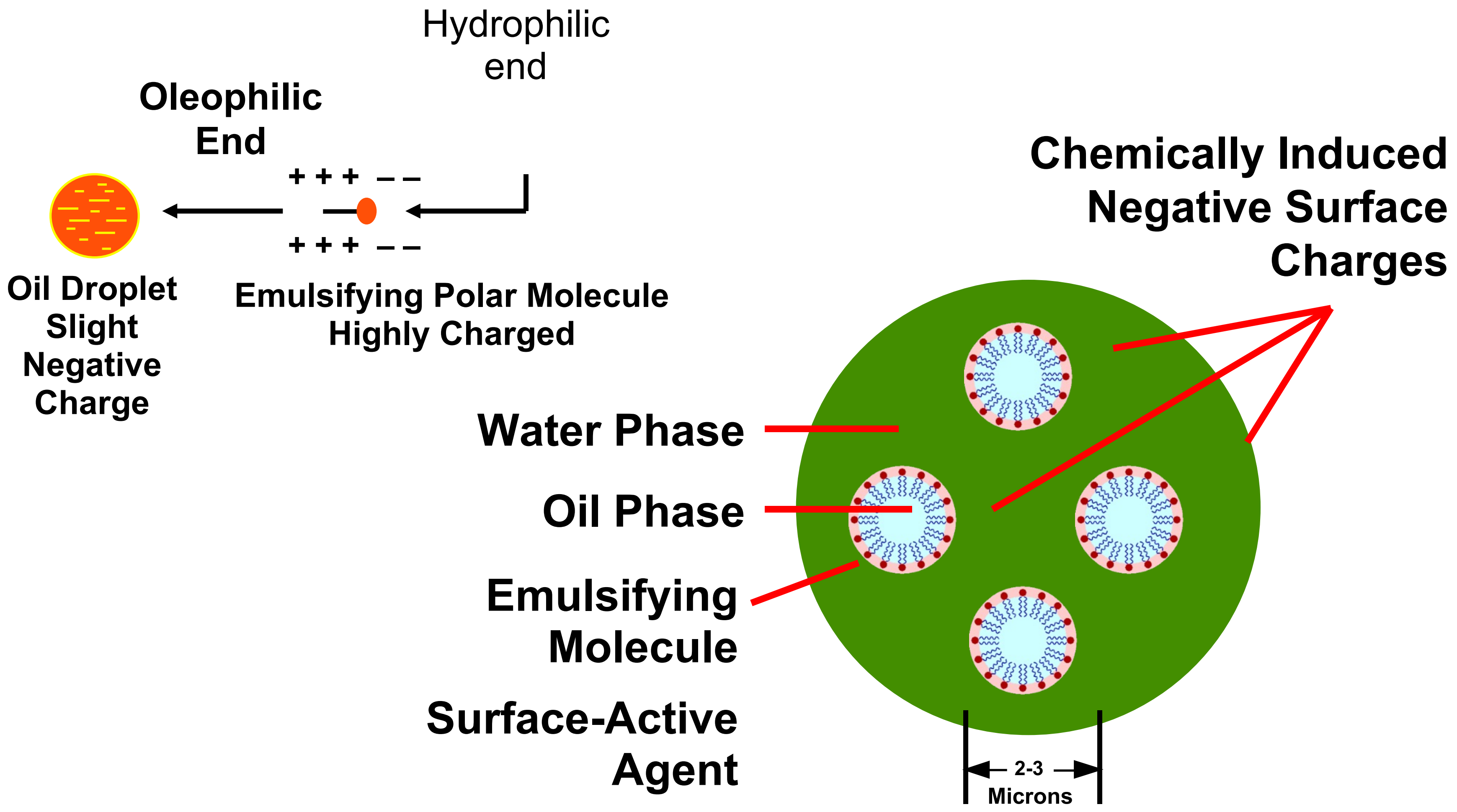
Why Fluids F

Highlighted areas
Are negatively charged

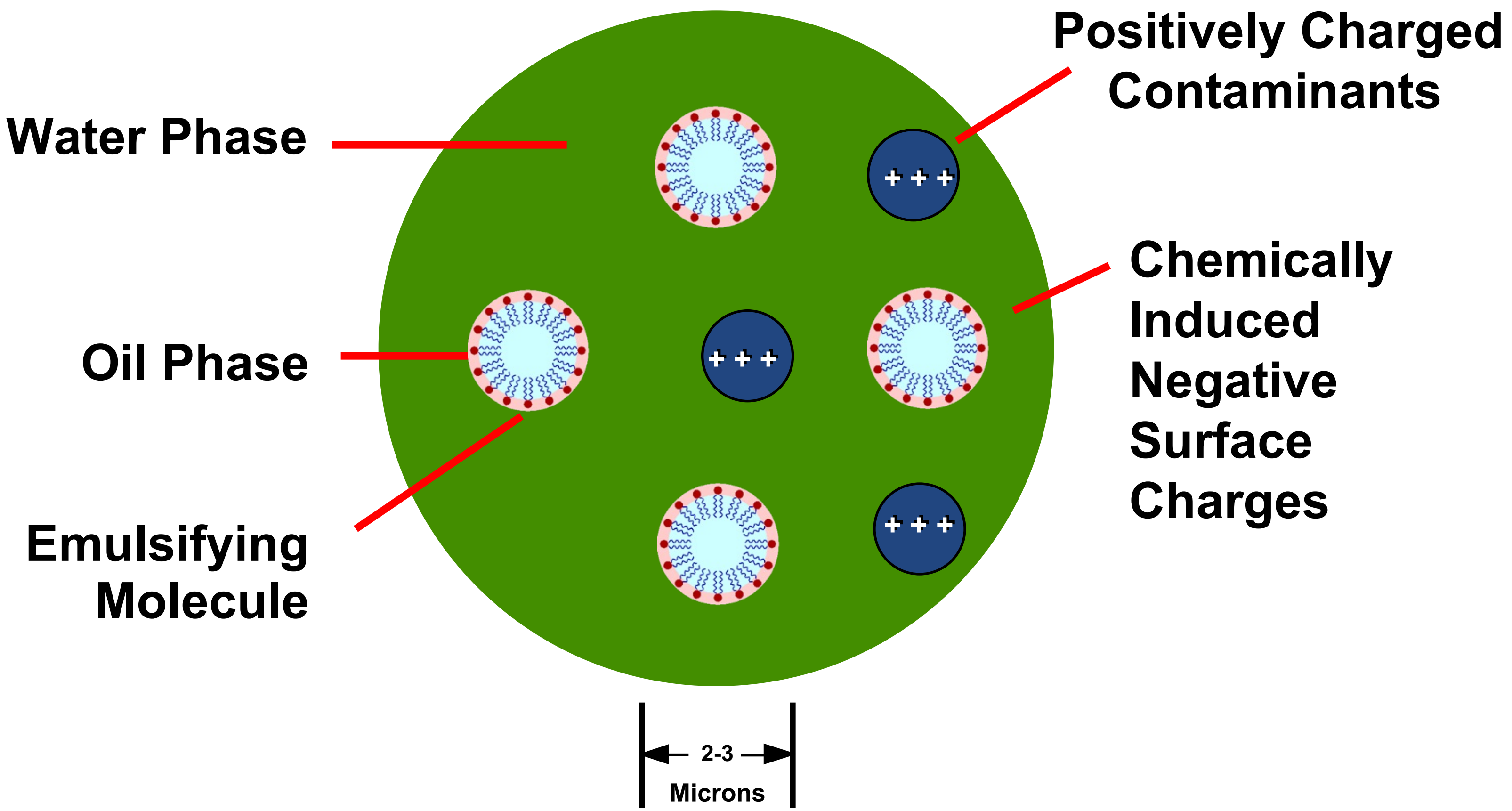
Three Basic Water Reducible MRF Formulations

Emulsifiable Oil (Soluble Oil)	***Oil*** **+ Anionic Soap + Rust Preventative +** ***Coupling Agent*** **+** ***Biocide*** **+** ***Buffer***
Semi-Synthetic	***Oil*** **+** ***Synthetic Component*** **+ Anionic Soap +** ***Coupling Agent*** **+ Rust Preventative +** ***Buffer*** **+** ***Biocide***
Synthetic	***Synthetic Component*** **+ Fatty Acid + Anionic Wetting Agent + Rust Preventative +** ***Buffer*** **+** ***Biocide***

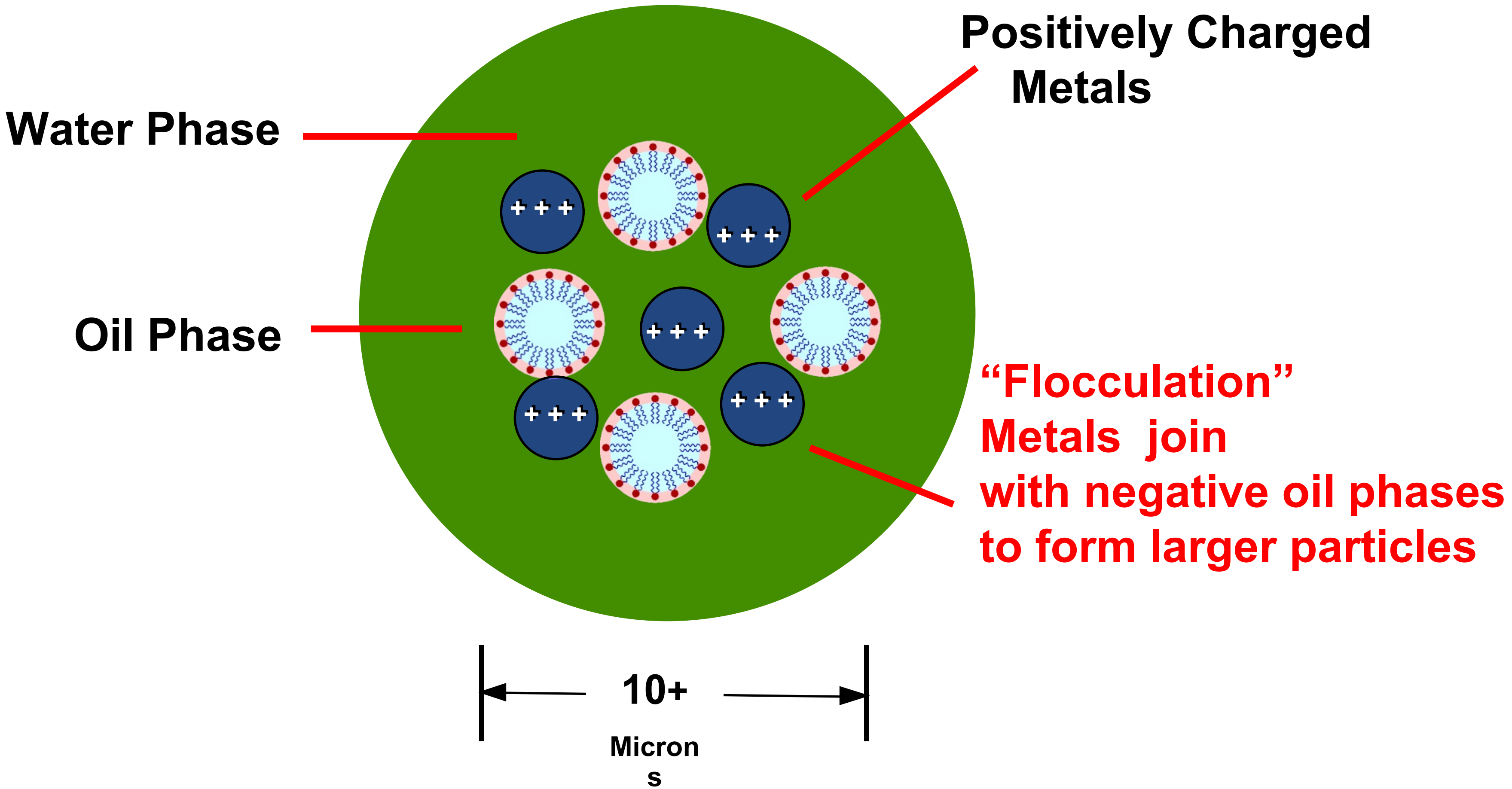
Typical Emulsified Oil MWF Schematic



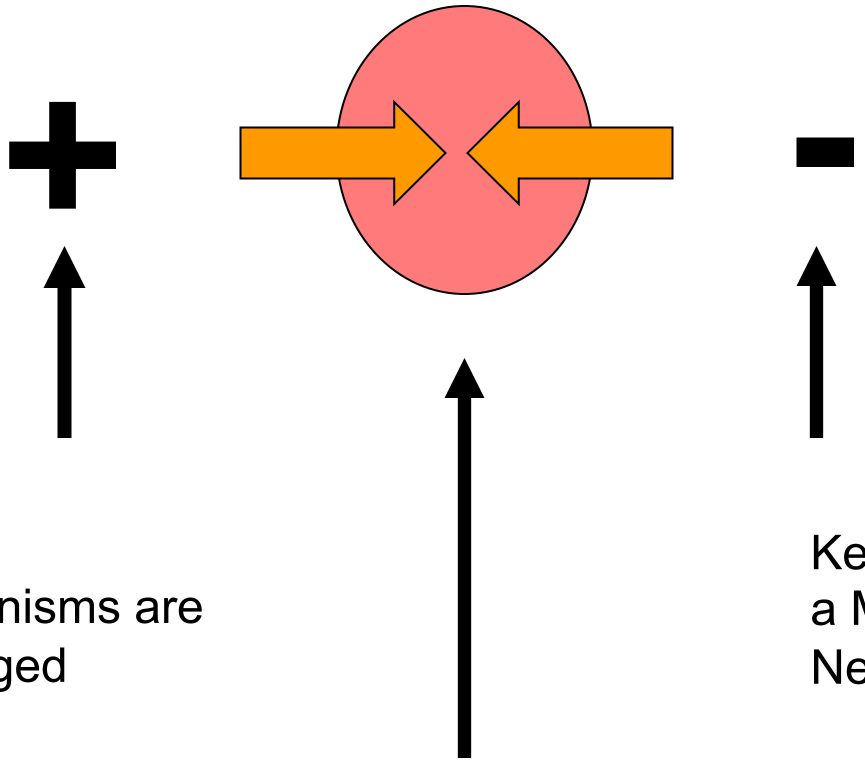
Typical Emulsified Oil MWF Schematic
On the Road to Failure



Typical Emulsified Oil MWF Schematic



It's All About Plusses and Minuses



One Group of
Failures Mechanisms are
Positively Charged

Key Components of
a MRF are
Negatively Charged

When the two Groups come together
MRF failure begins

Metal Basics

For example Aluminum Oxide

Al_2^{+++} O_3^{--}

Cation
Positive
Charge

Anion
Negative
Charge

Metal Basics

Many anions to choose from in a coolant

Availability determines observed failure

Al^{+++} $(SO_4)^{3\,-\,-}$

Al^{+++} $(Cl_3)^{-\,-\,-}$

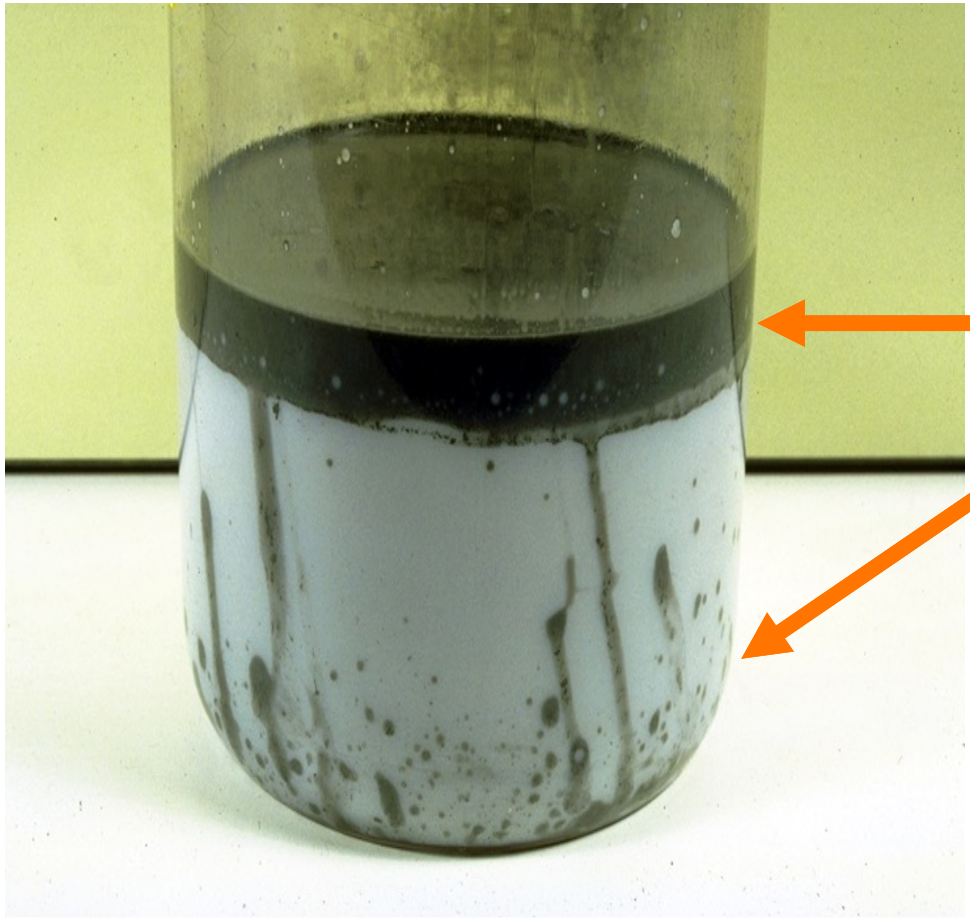
Cation
Positive
Charge

Anion
Negative
Charge

Cast Iron Grinding Experiment

Cast Iron Grinding Experiment

Cast Iron Grinding Experiment



Coolant split after 15 minutes of intense grinding

Metal Failure Mechanisms

1. Type of metal being machined

Most Destructive:	Cast or Ductile Iron	Fe^{+++}
	Certain Grades of Aluminum	Al^{+++}
	Magnesium	Mg^{++}
Mildly Destructive:	AISI/SAE 1020, 4140, 8620	
	Brass	
	Lead	
	Copper	
Least Destructive:	Stainless Steel	
	Ultra-Alloys Such as Incoloy	
Key Words:	Type of metal being cut	

Metal Failure Mechanisms

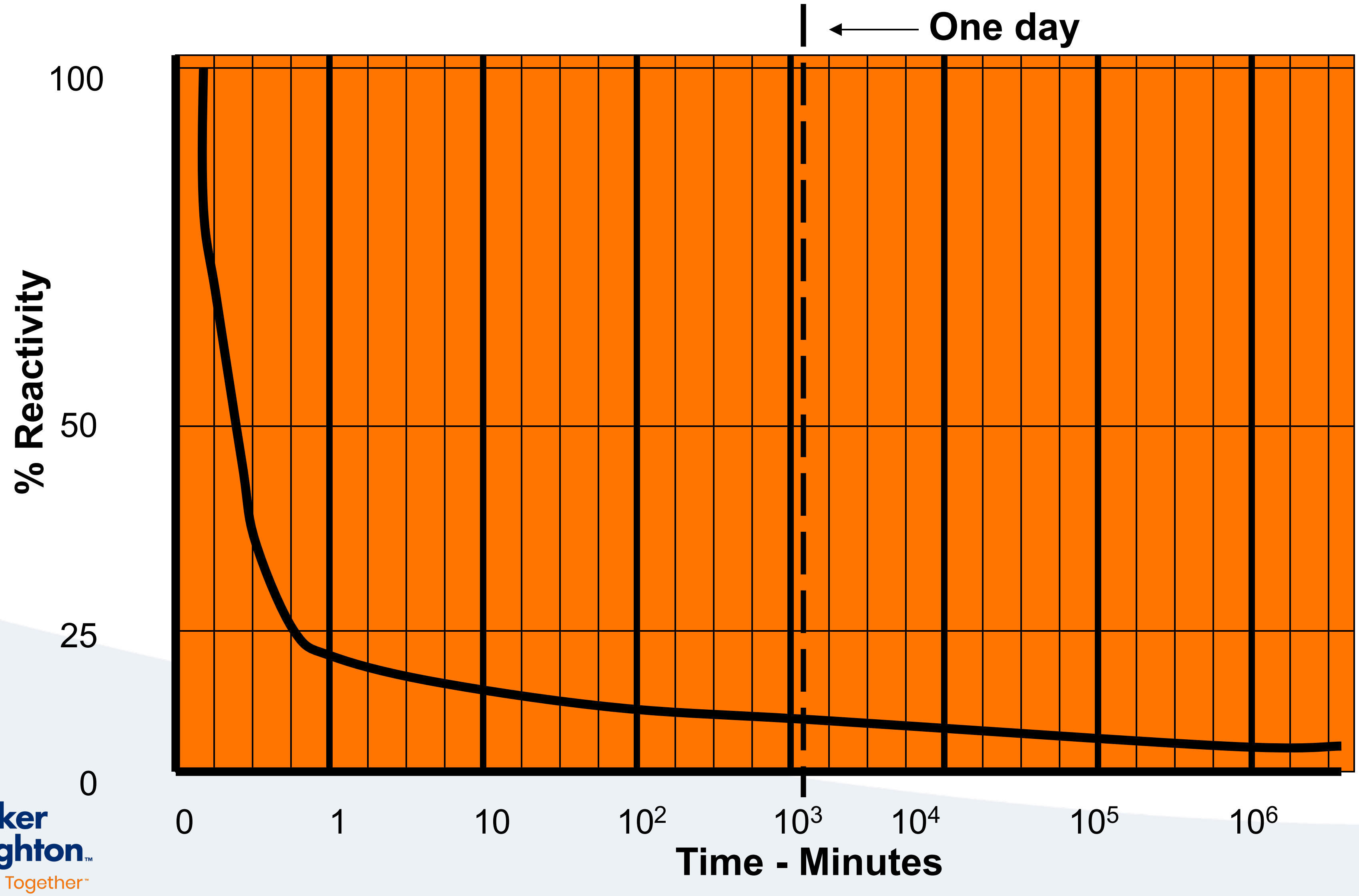
The Battle of the Cations

	Potassium	K^{+}
	Sodium	Na^{+}
	Calcium	Ca^{++}
1	Lead	Pb^{++}
1	Zinc	Zn^{++}
1	Magnesium	Mg^{++}
1	Nickel	Ni^{+++}
1	Iron Ferrous	Fe^{++}
1	Iron Ferric	Fe^{+++}
1	Aluminum	Al^{+++}
1	Titanium	Ti^{++++}

- Typical cations found in metals being machined.

Metal Surface Reactivity vs. Time

Classic Logarithmic Decay



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Particle Size Failure Mechanisms

2. Size and rate of metal being machined (in relation to volume of coolant)

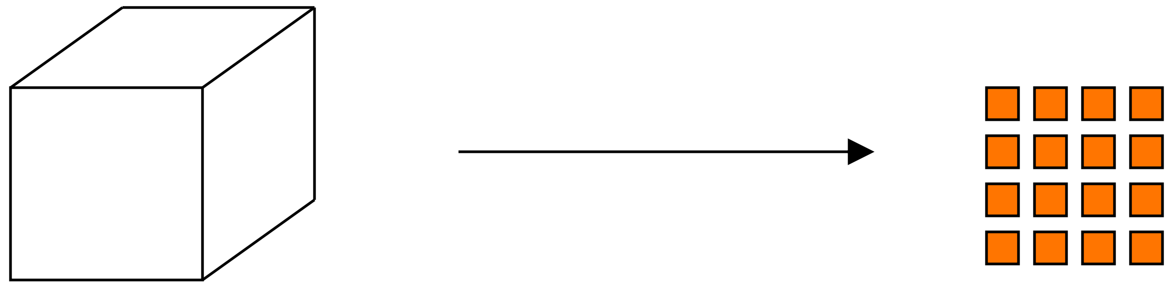
Most Destructive:	**Grinding, polishing, ball grinding**
Mildly Destructive:	**Sawing, CBN grinding, milling**
Least Destructive:	**Single point turning**
Key Words:	**Size and rate of chips cut; Volume of fluid surface area of metal removed / volume of fluid**

Particle Size Failure Mechanisms

Machining generates a lot of surface area

Grind 1 square foot of steel into 50-micron cubes

6 square feet　　becomes　　35,720 square feet



1’ x 1’ x 6 sides　　50-micron cubes

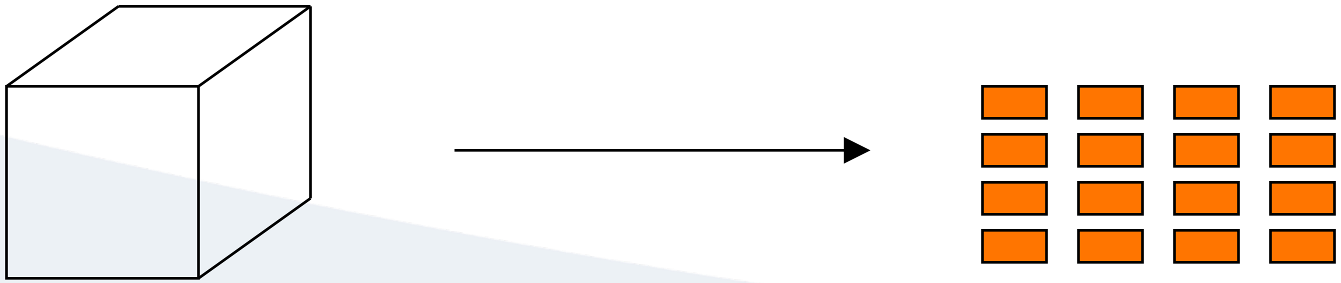
Filtration Example

- 15,000-gallon system
  - SAE 1015
  - Fine grinding of copper
    - 1,000 Total suspended solids
    - 210 mg/L < 8 micron
    - 168 mg/L < 0.45 micron
    - 120 mg/L < 0.2 micron
  - Over time dirt built up linearly while surface area of dirt built up exponentially.
  - Once coolant hit these dirt levels, failure occurred in 4 days.

Chip Surface Area

Depth of cut	=	0.005”
Length of chip	=	1”
Width of chip	=	1/16”

6 square feet **becomes** **5,208 square feet**



1’ x 1’ x 6 sides **1.00” x 0.0625” x 0.005” slabs**

Chip Cutting vs. Grinding

Reducing a 1’ x 1’ x 1’ cube into small particles

35,720 ft^2 Grinding

5,208 ft^2 Chip Cutting

=

6.85 times more surface area from grinding

Plus the heat energy = more rubbing in grinding

Chips Are Not All Alike

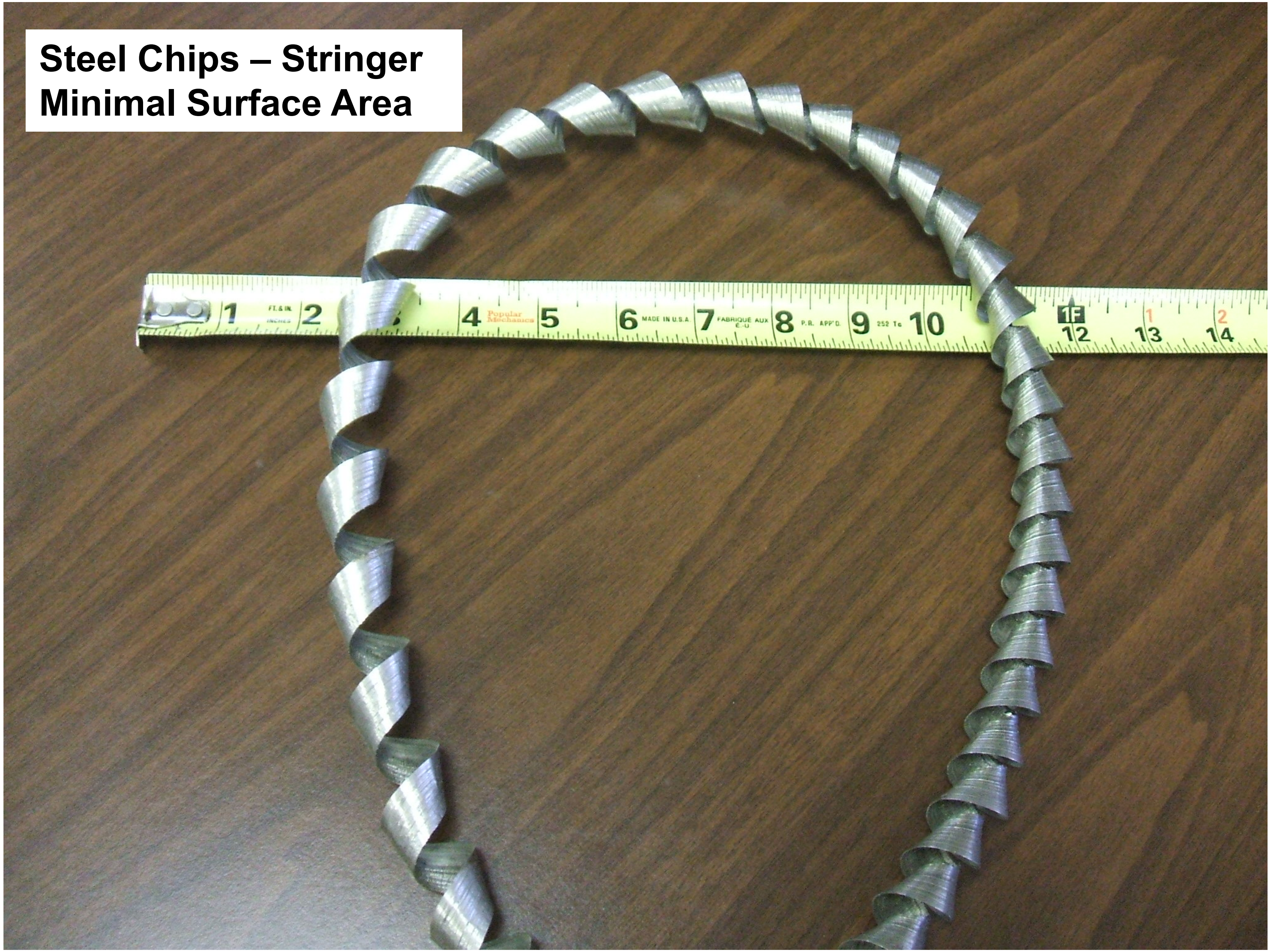
Different metal alloys form different chips

- Soft alloys tend to produce longer chips
- Longer chips have less surface area per pound of metal removed

Grinding can produce chips well below 1.0 micron in size

Aluminum Chips Minimal Surface Area

Steel Chips – Stringer
Minimal Surface Area



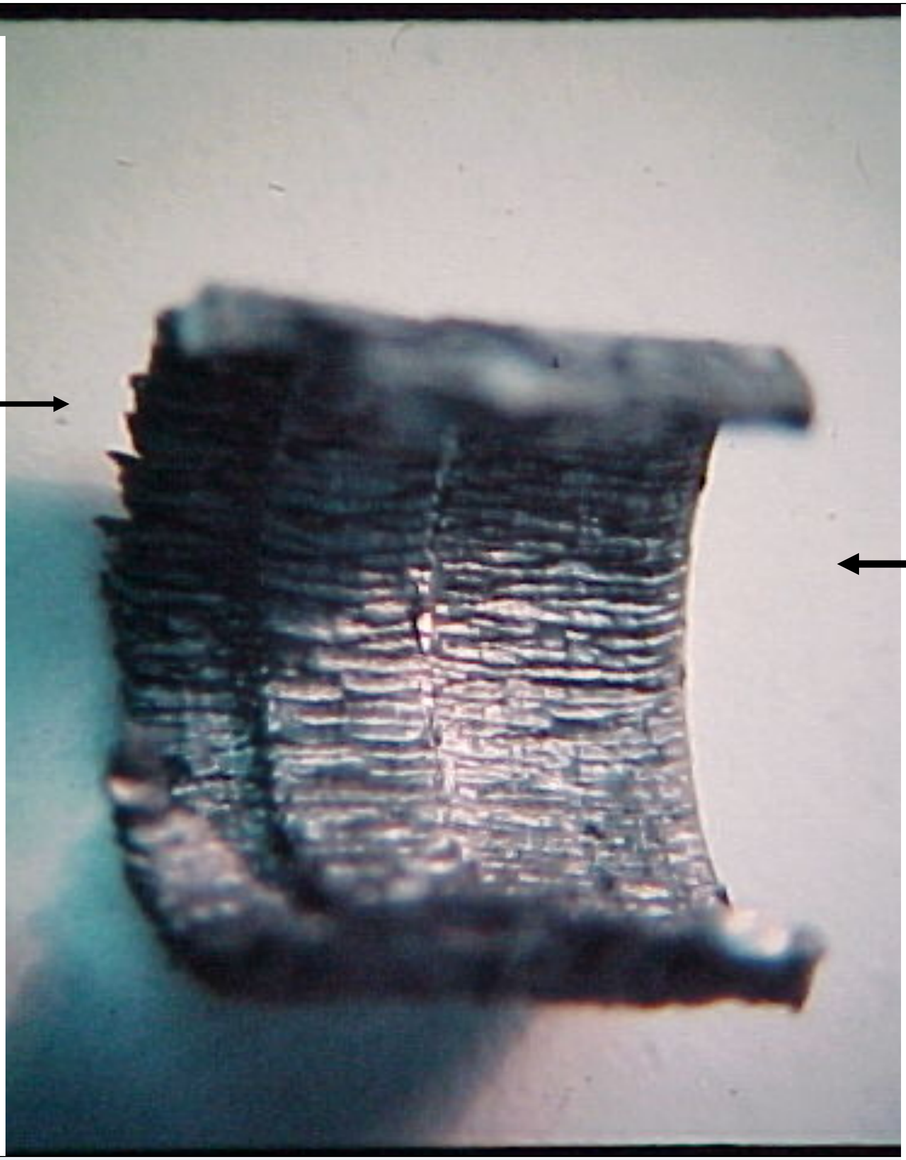

Brass Chips – Stringer
More Surface Area

Aluminum Chips - More Surface Area

Aluminum Chips - Progressive Gain in Surface Area

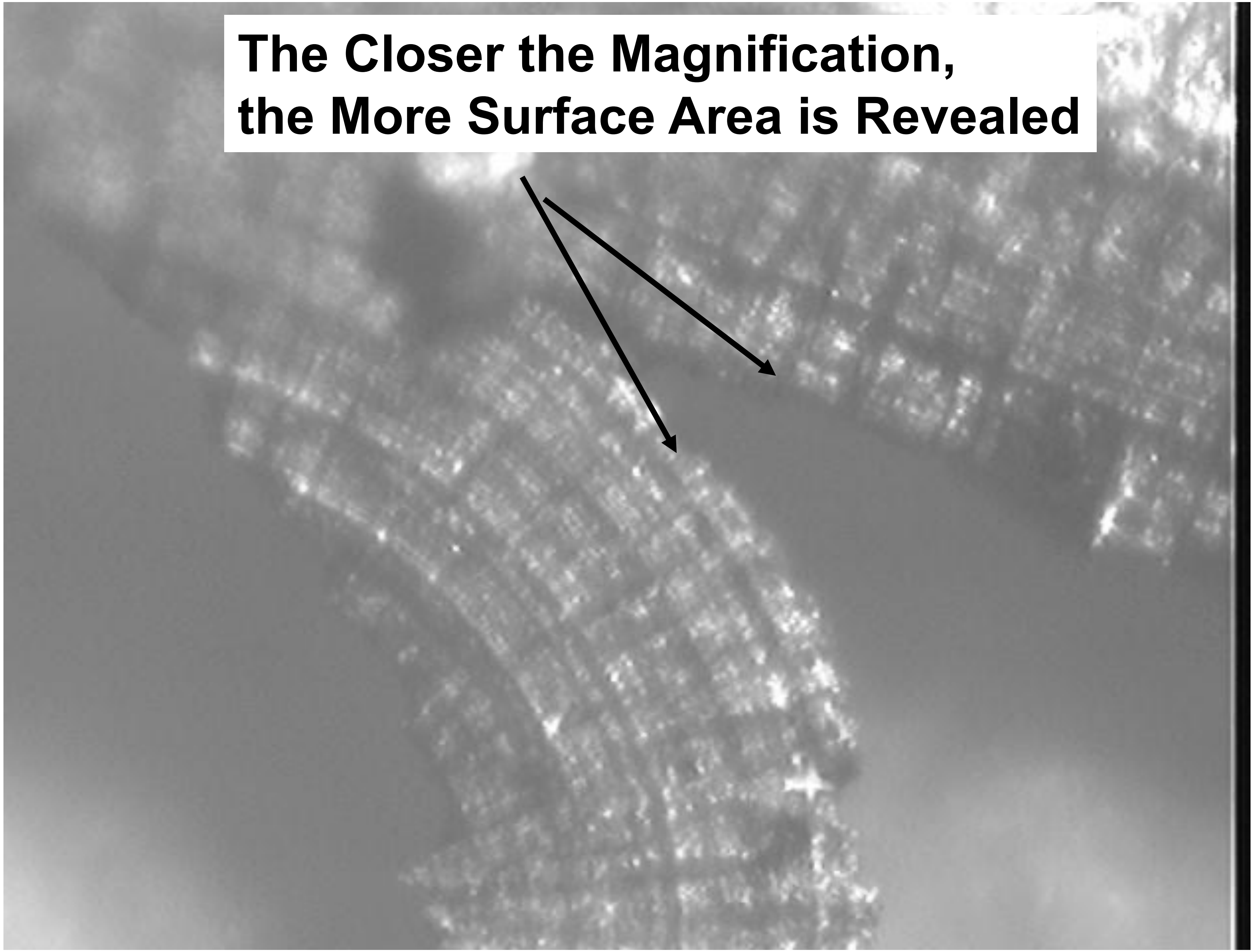
More reactive per kilogram of metal removed

Total Surface Area is Very Large



Additional Surface Area

Almost 2X Surface Area


The Closer the Magnification,
the More Surface Area is Revealed

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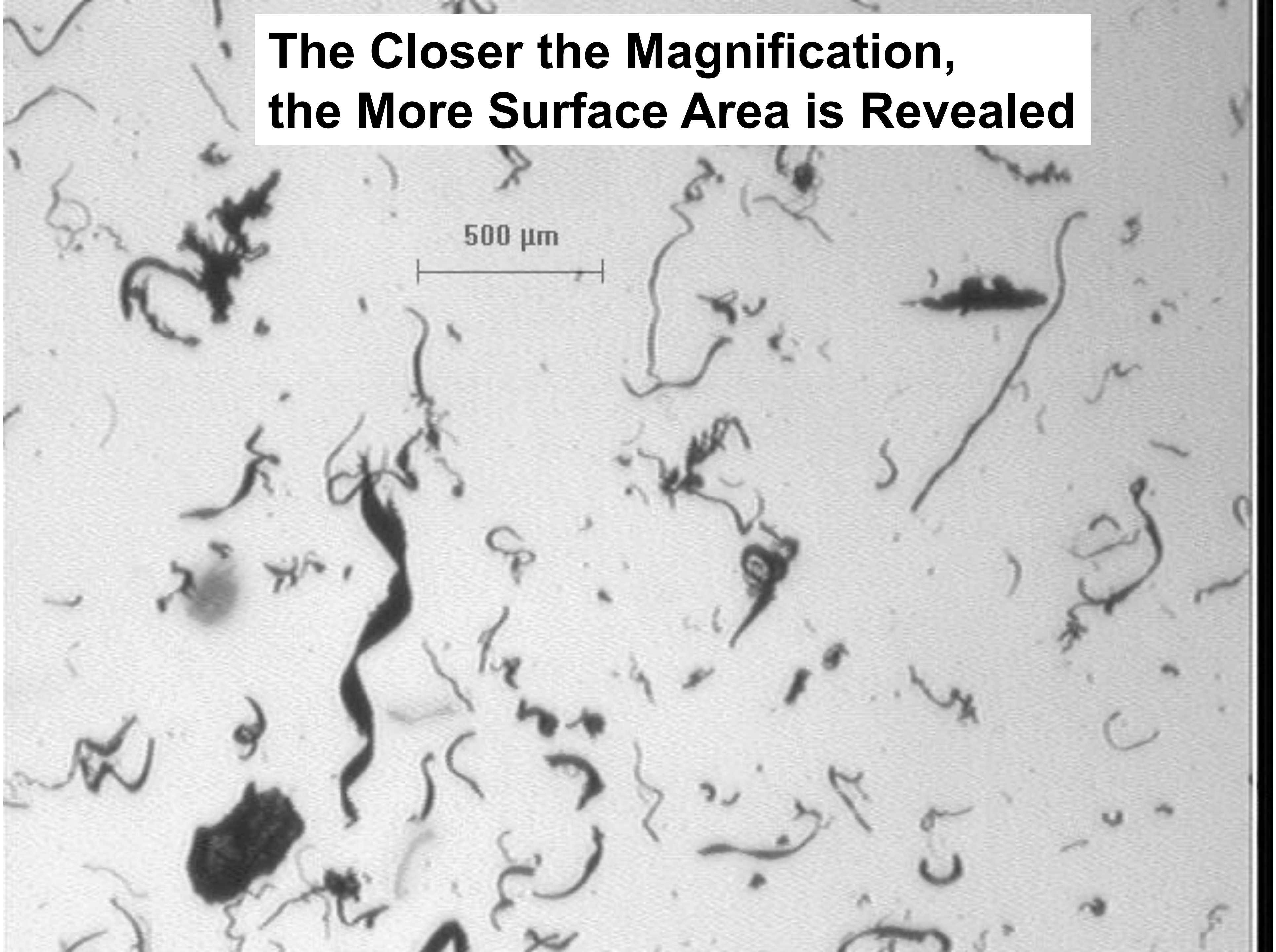

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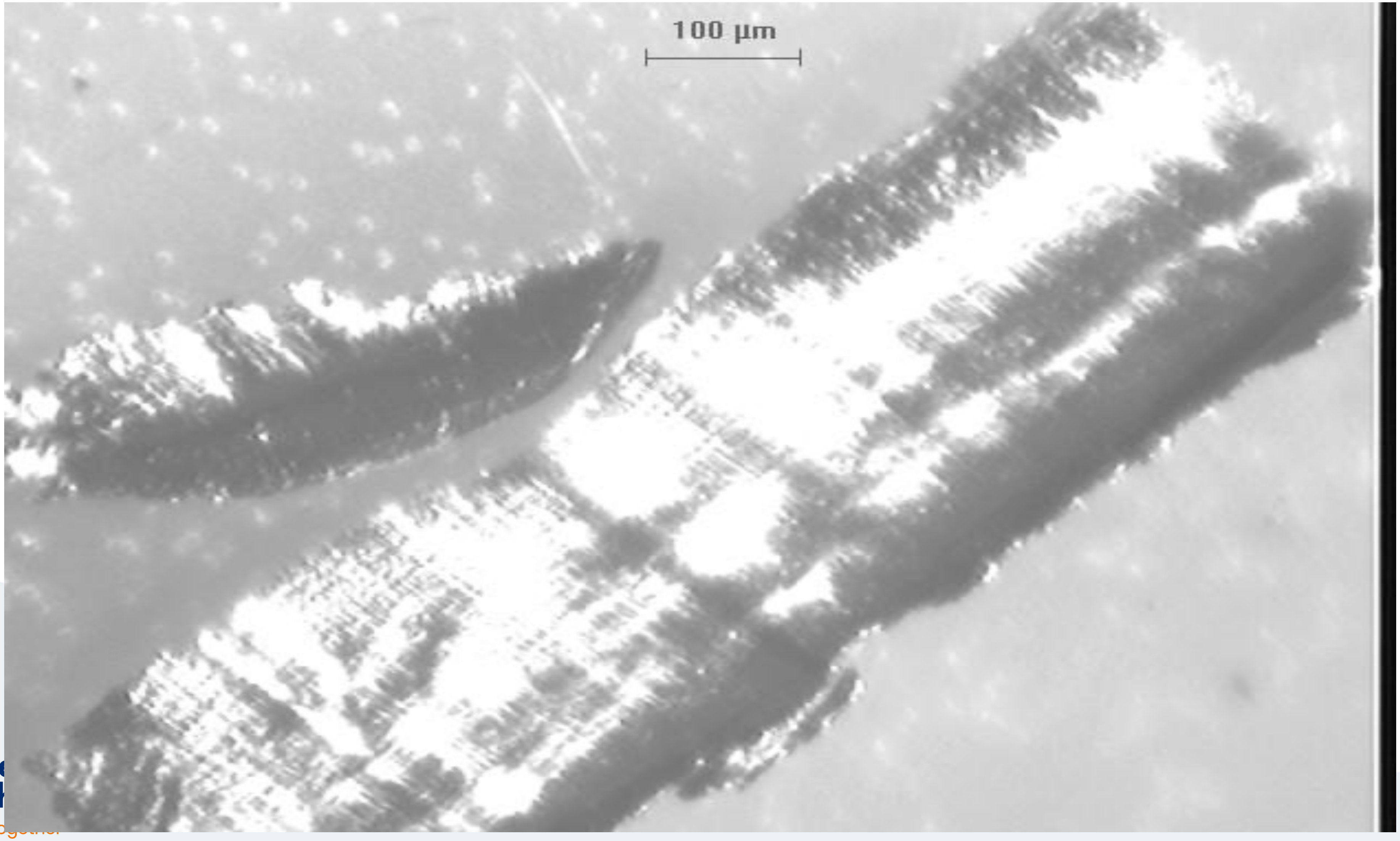
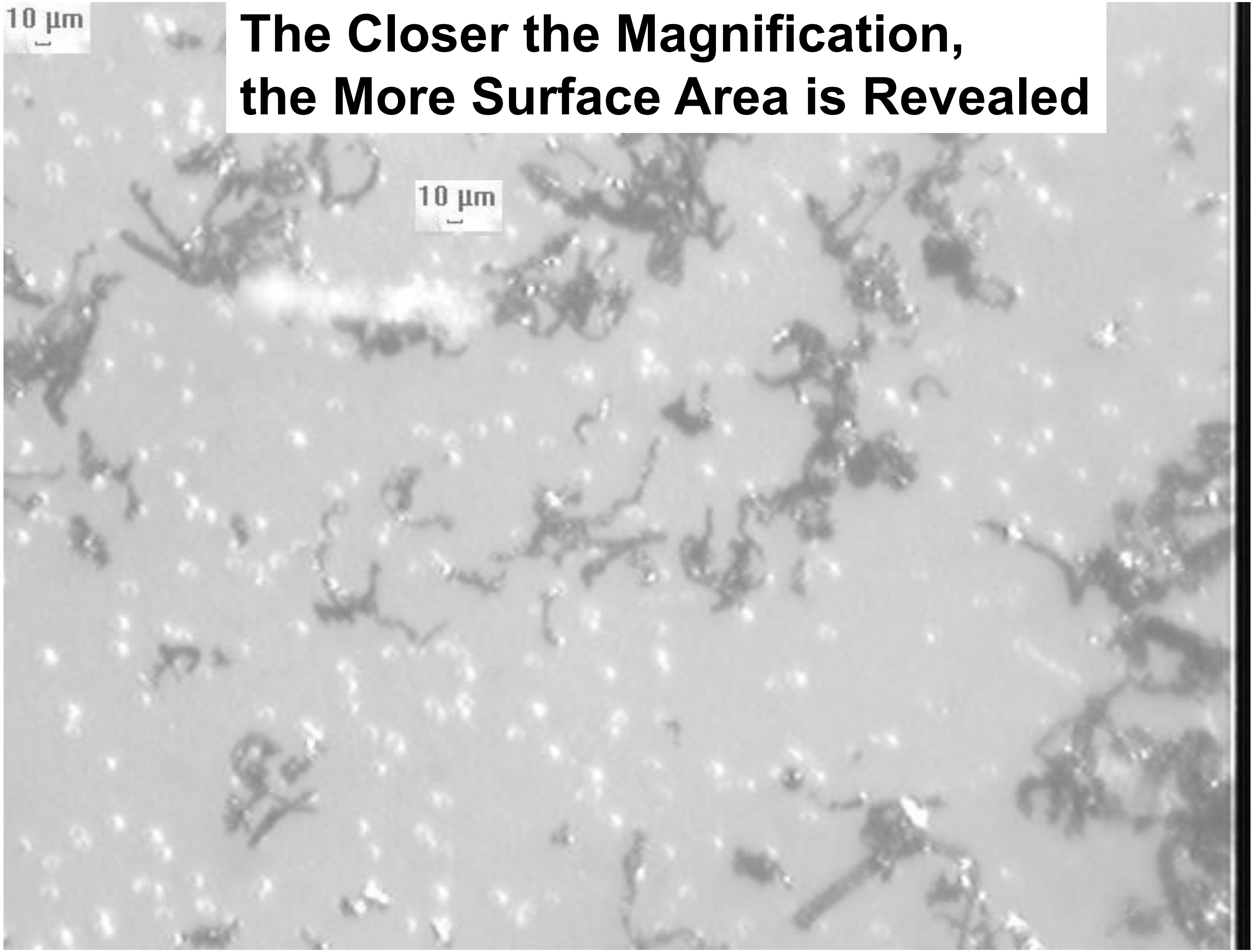
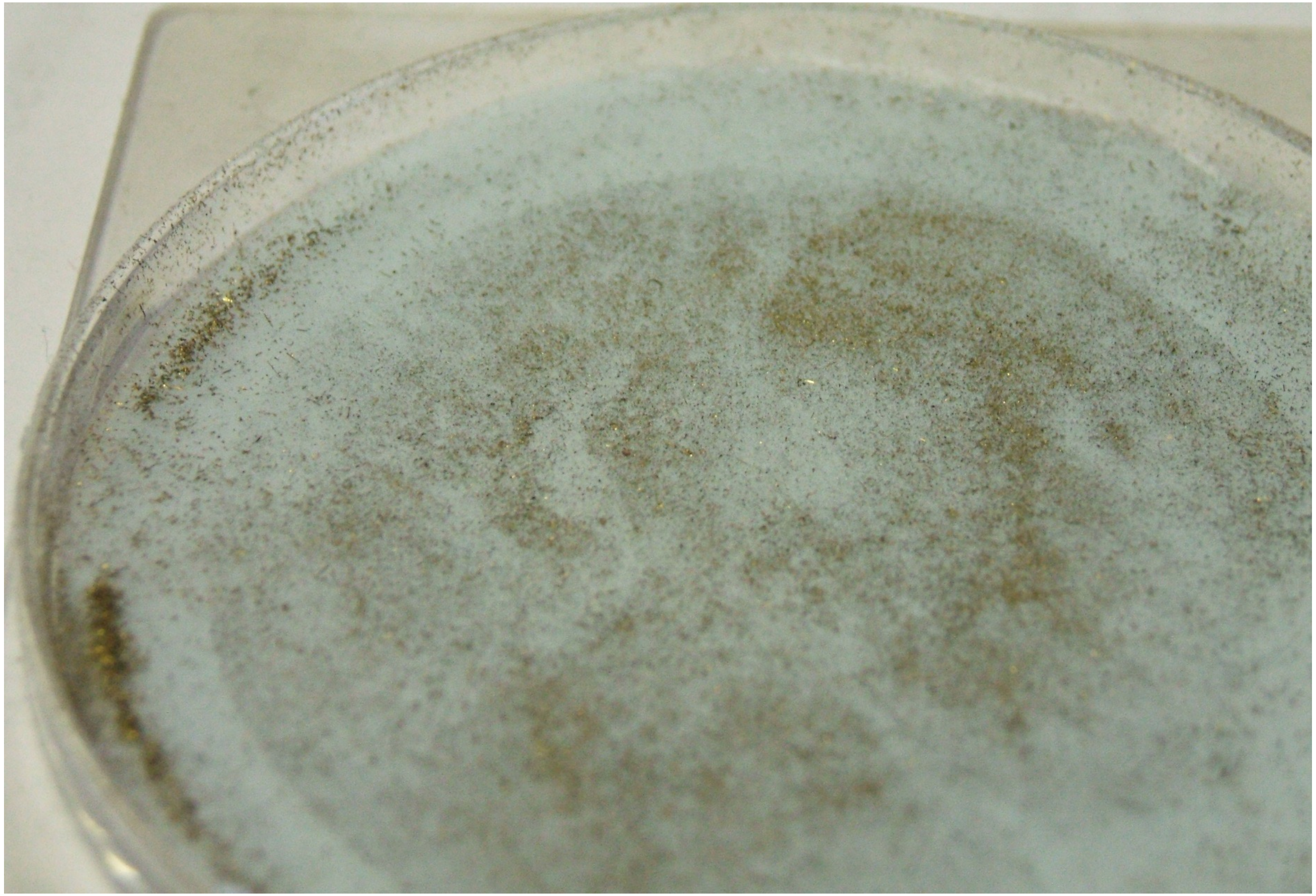


The Closer the Magnification, the More Surface Area is Revealed




Small Brass Chips – Maximum Surface Area
The amount of surface area is almost incalculable

Small Brass Chips - Maximum Surface Area



Fresh Cut Chips Left in Piles Continue to React

Time left to react.

Weight or density of chips

Several corrosion cell reactions take place

Piles of Chips

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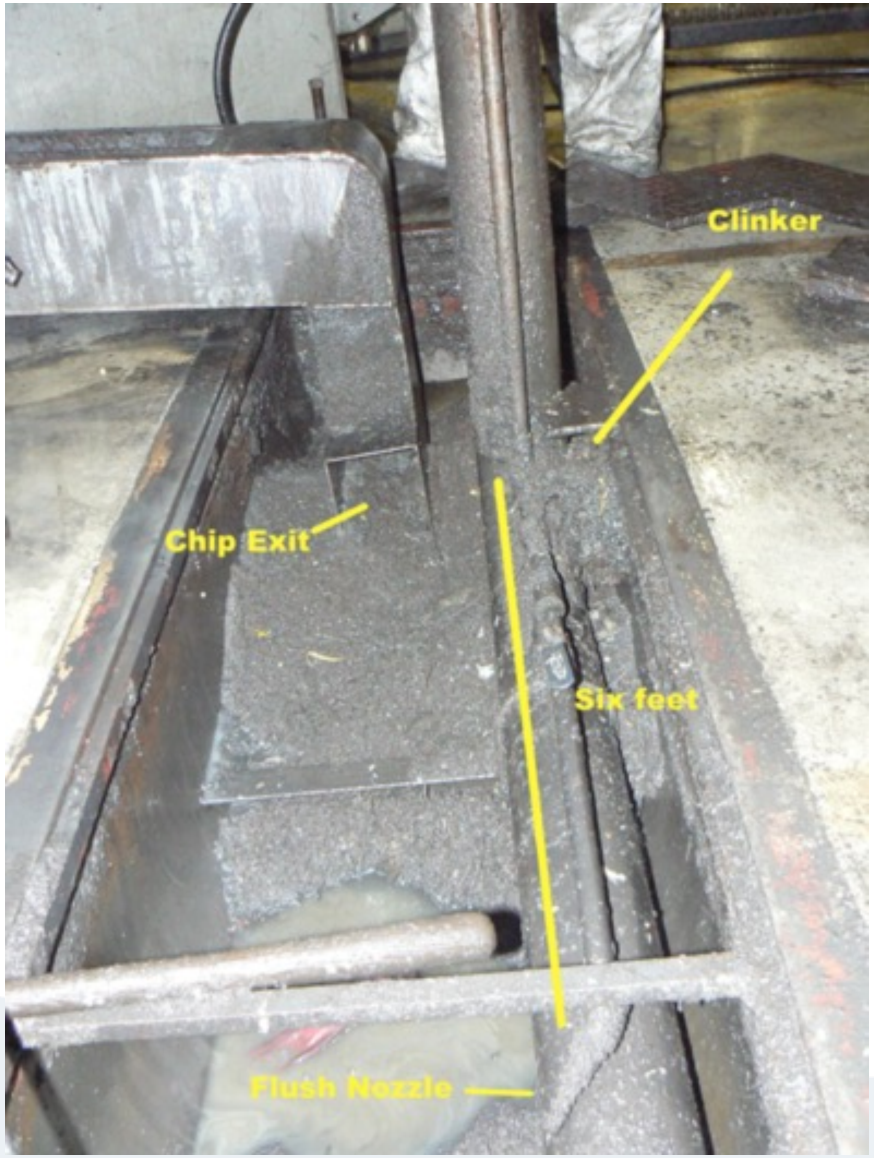
Piles of Chips

Other times you have to pull trench covers to see these chips



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The Beginning of an Electrolytic Corrosion Cell

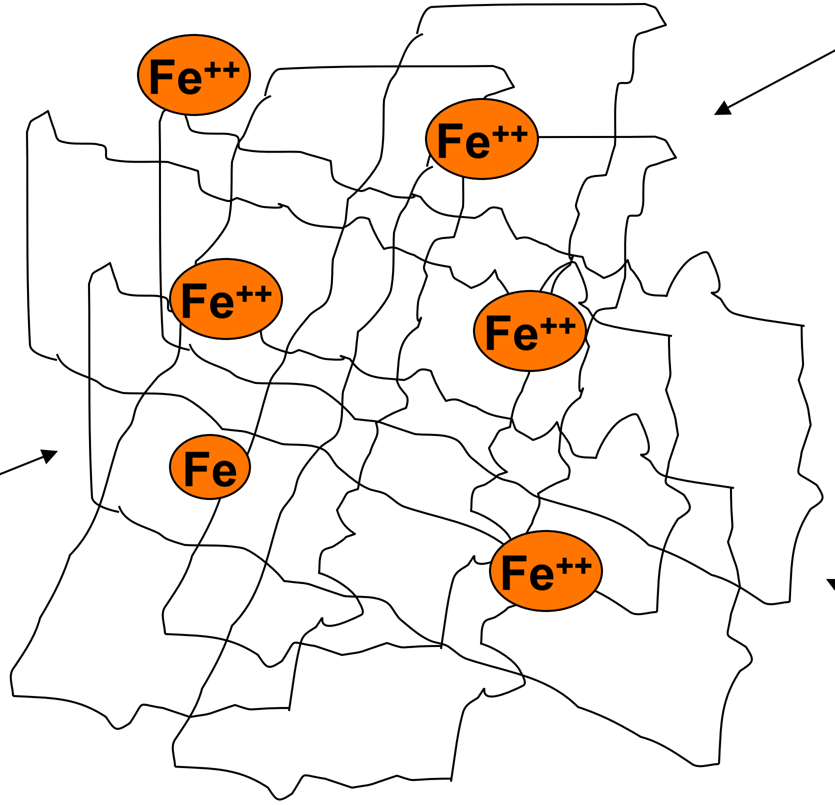
Electrolytic Cell Reaction

Chip on Chips or Swarf on Swarf

Weight

Fresh metal ions are released

Conductive Solution (Electrolyte)



Warm and Dark
Bacteria
M.I.C

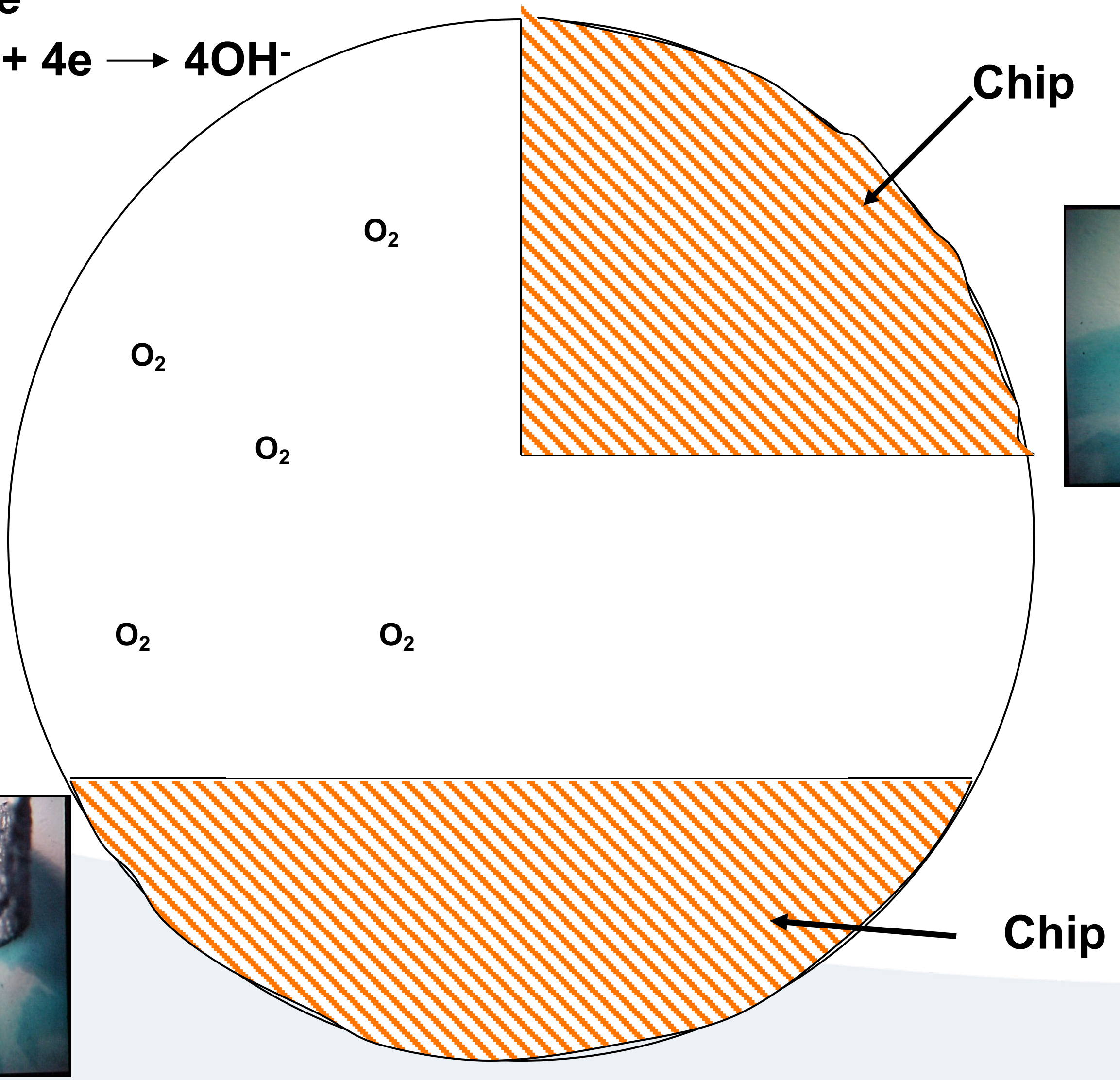
Inconsistent Contact Points

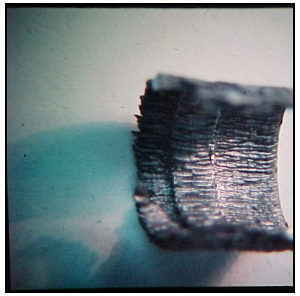
Heat is Generated
Reactions Speed Up

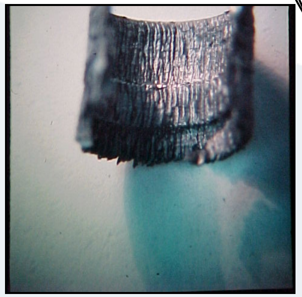
Crevice Corrosion and MWF Failure

Oxidation $M \longrightarrow M^{+} + e$

Reduction $O_2 = 2H_2O + 4e \longrightarrow 4OH^{-}$



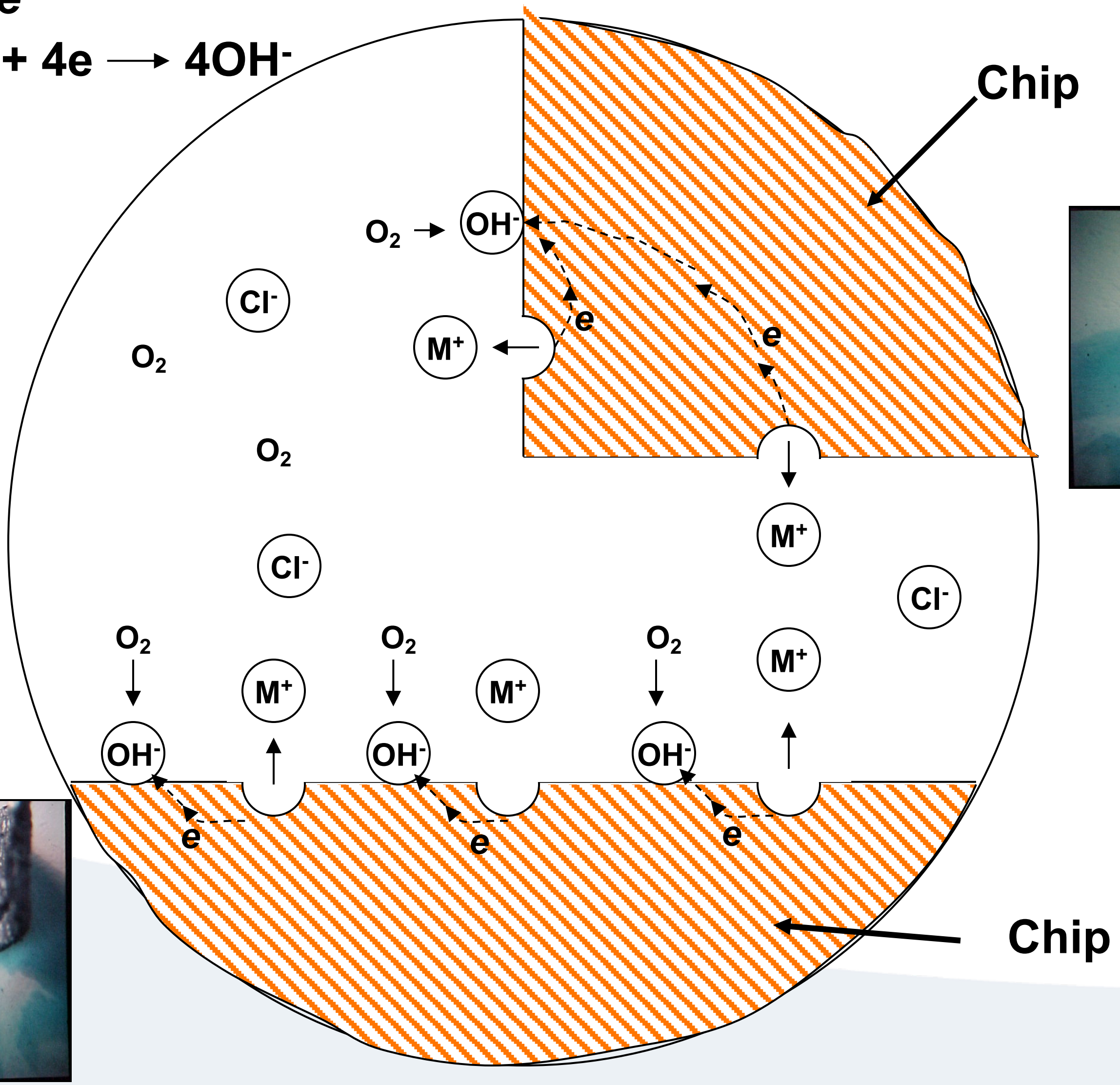


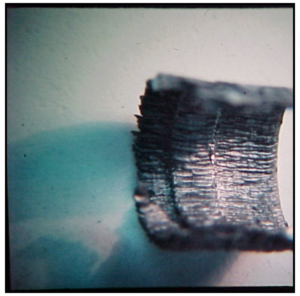


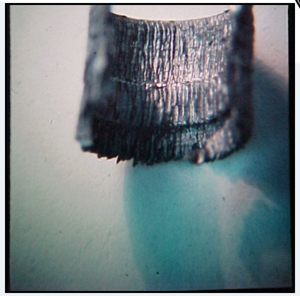
Crevice Corrosion and MWF Failure

Oxidation M ⟶ $M^+ + e$

Reduction $O_2 = 2H_2O + 4e \longrightarrow 4OH^-$







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Crevice Corrosion and MWF Failure

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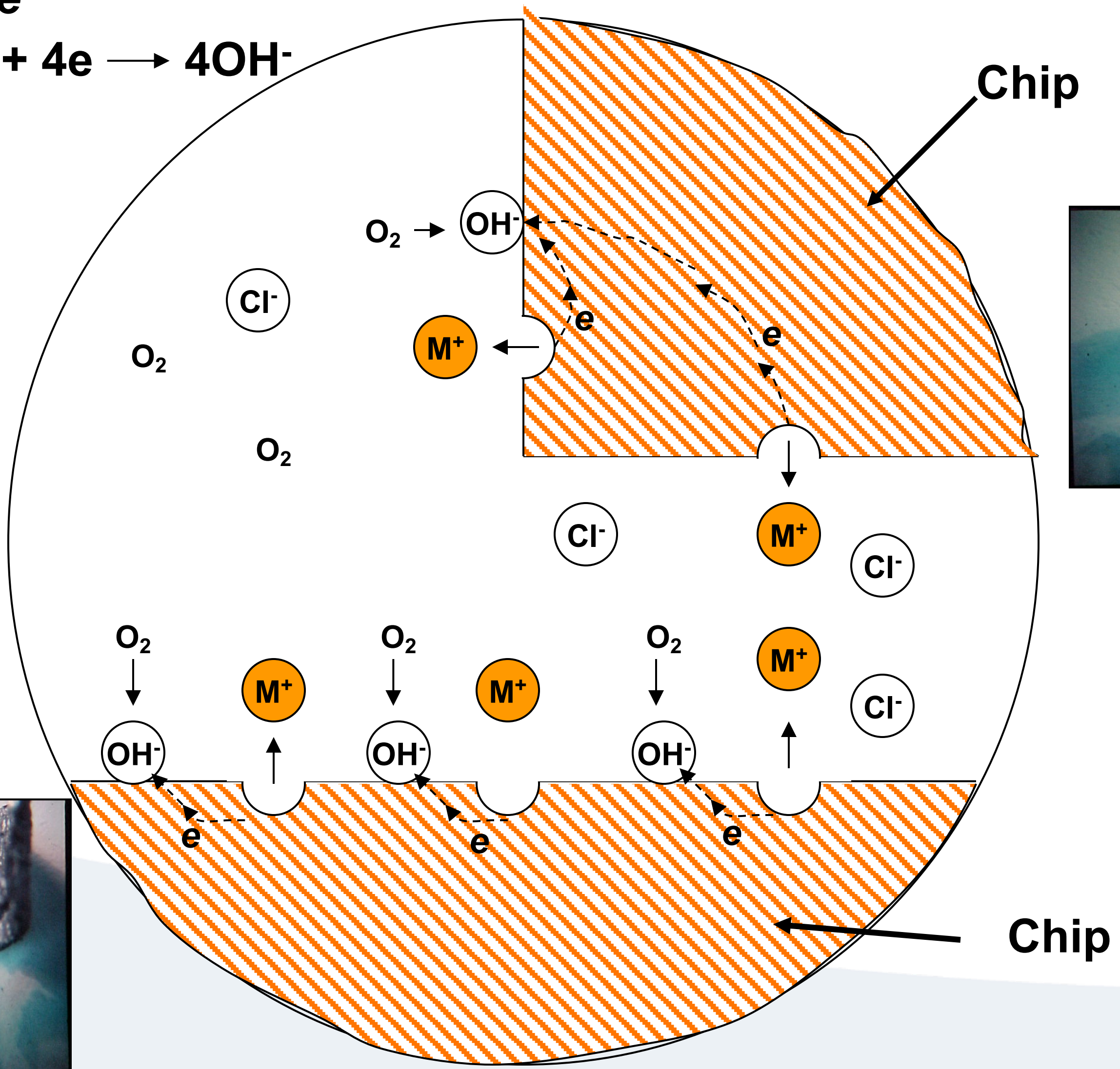

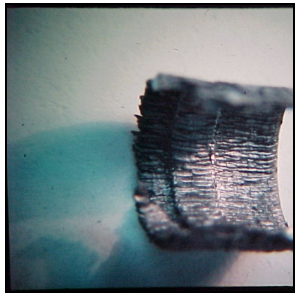

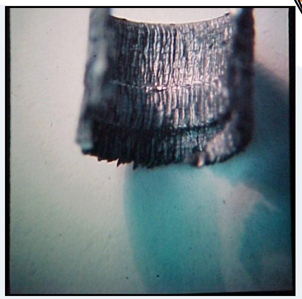

Hexavalent Chromium Reaction

Raising Temperature of high chromium alloys above 675ºC can create Cr (VI).

Confirmed by California South Coast Air Quality Management District in 2019.

Currently in rule making process as Proposed Rule 1435.

Half Life of Cr (VI) to Cr (III) is approximately 14 hours.

Quench Tanks (containing a metalworking fluid) is considered a point source.

Affects many heat treat operations in Southern California.

Stay tuned

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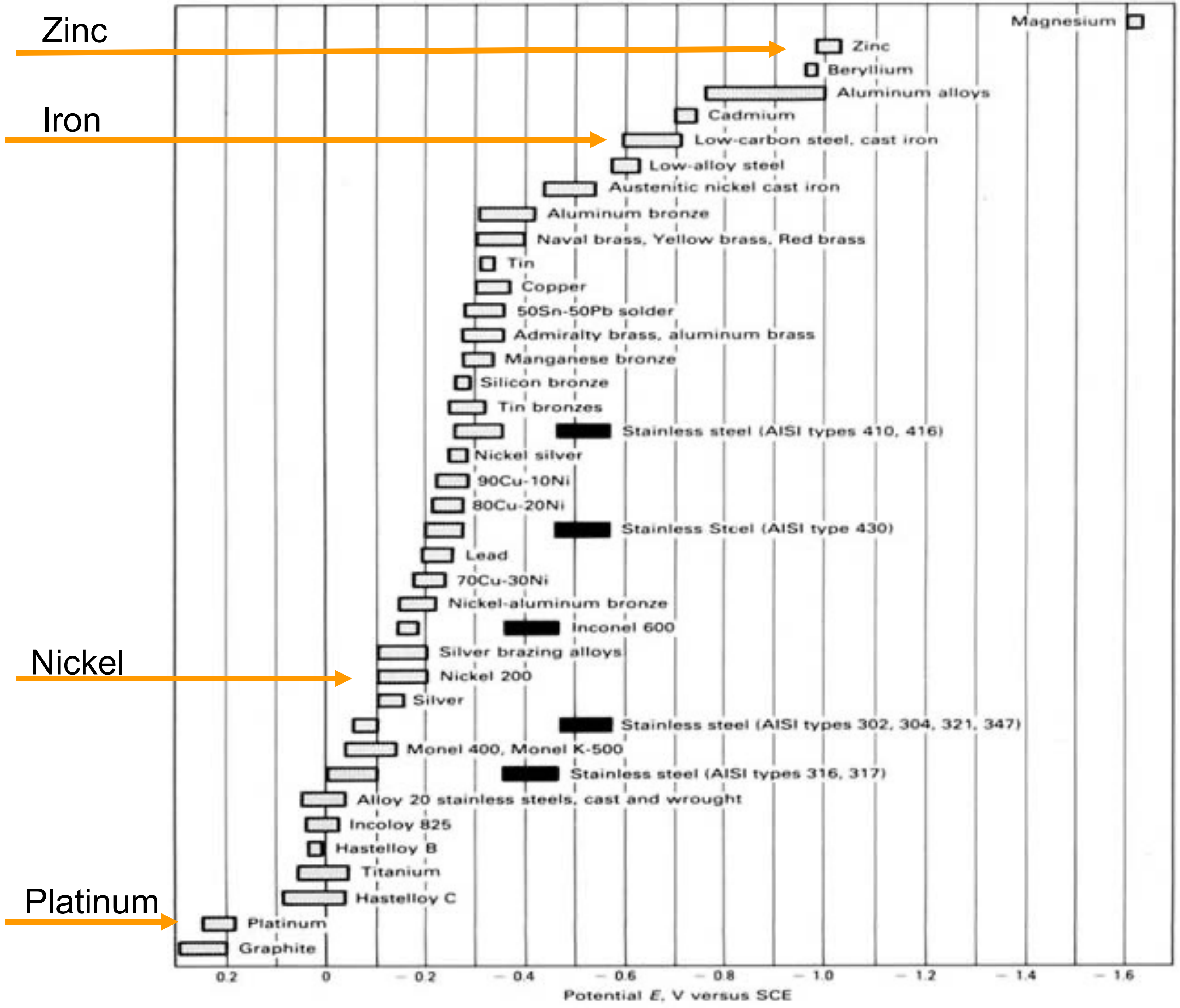
The Corrosion Cell Increases With the Weight and Depth of the Chips

Increasing Corrosion

Increasing Depth

Chips actually welding together


Zinc
Iron
Nickel
Platinum
Magnesium
Zinc
Beryllium
Aluminum alloys
Cadmium
Low-carbon steel, cast iron
Low-alloy steel
Austenitic nickel cast iron
Aluminum bronze
Naval brass, Yellow brass, Red brass
Tin
Copper
50Sn-50Pb solder
Admiralty brass, aluminum brass
Manganese bronze
Silicon bronze
Tin bronzes
Stainless steel (AISI types 410, 416)
Nickel silver
90Cu-10Ni
80Cu-20Ni
Stainless Steel (AISI type 430)
Lead
70Cu-30Ni
Nickel-aluminum bronze
Inconel 600
Silver brazing alloys
Nickel 200
Silver
Stainless steel (AISI types 302, 304, 321, 347)
Monel 400, Monel K-500
Stainless steel (AISI types 316, 317)
Alloy 20 stainless steels, cast and wrought
Incoloy 825
Hastelloy B
Titanium
Hastelloy C
Platinum
Graphite
0.2
0
− 0.2
− 0.4
− 0.6
− 0.8
− 1.0
− 1.2
− 1.4
− 1.6
Potential E, V versus SCE

Certain Metal Alloys Are More Reactive Than Other Alloys

Iron is more reactive than nickel

Mixing metals presents additional problems

- Galvanic cell reactions

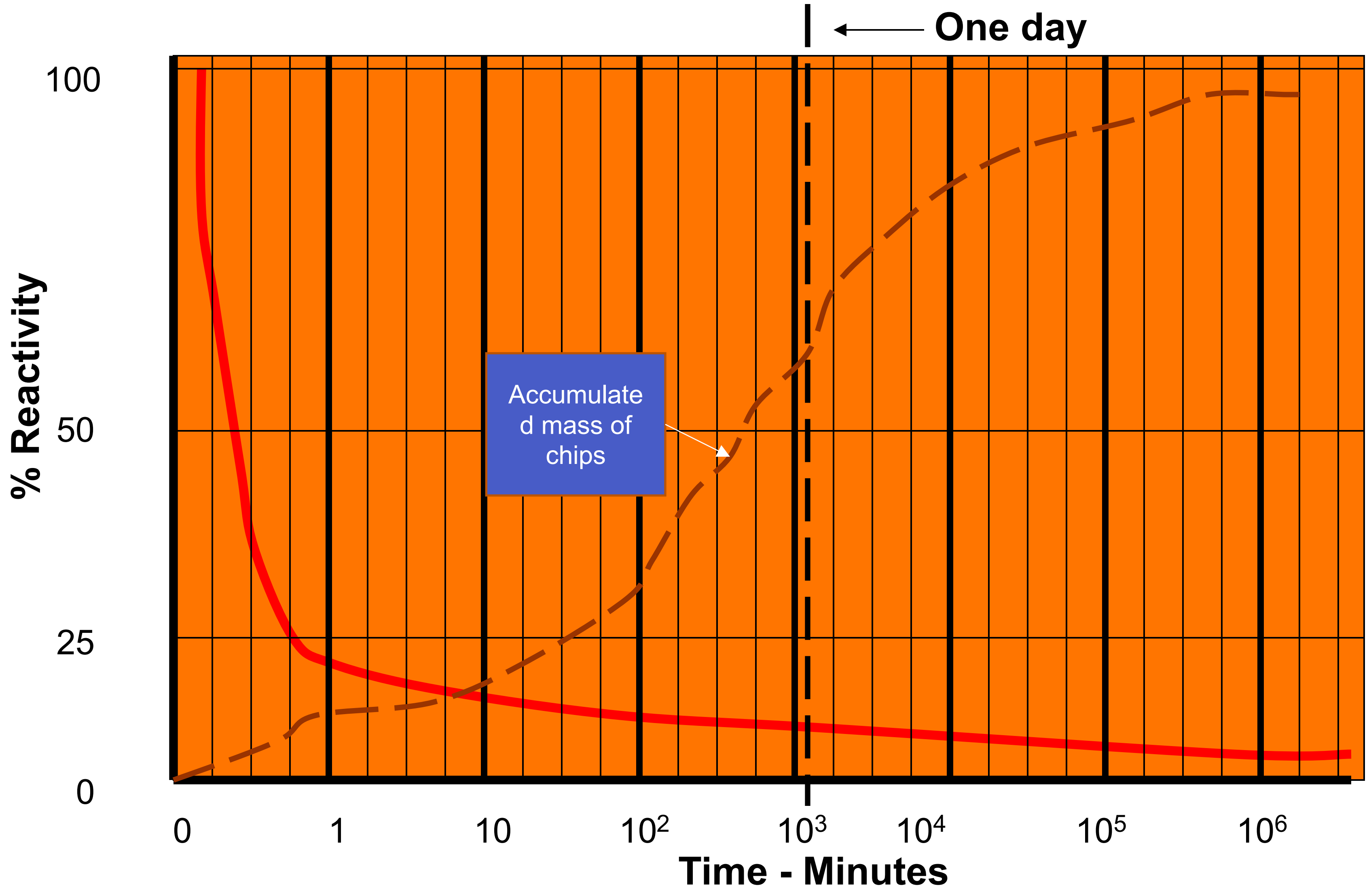
Therefore

Three primary metal failure reactions take place

1. Fresh metal ions exposed during machining
2. Metal ions released in piles of chips and swarf
3. Certain metals are more reactive than others

Metal Surface Reactivity vs. Time

Classic Logarithmic Decay



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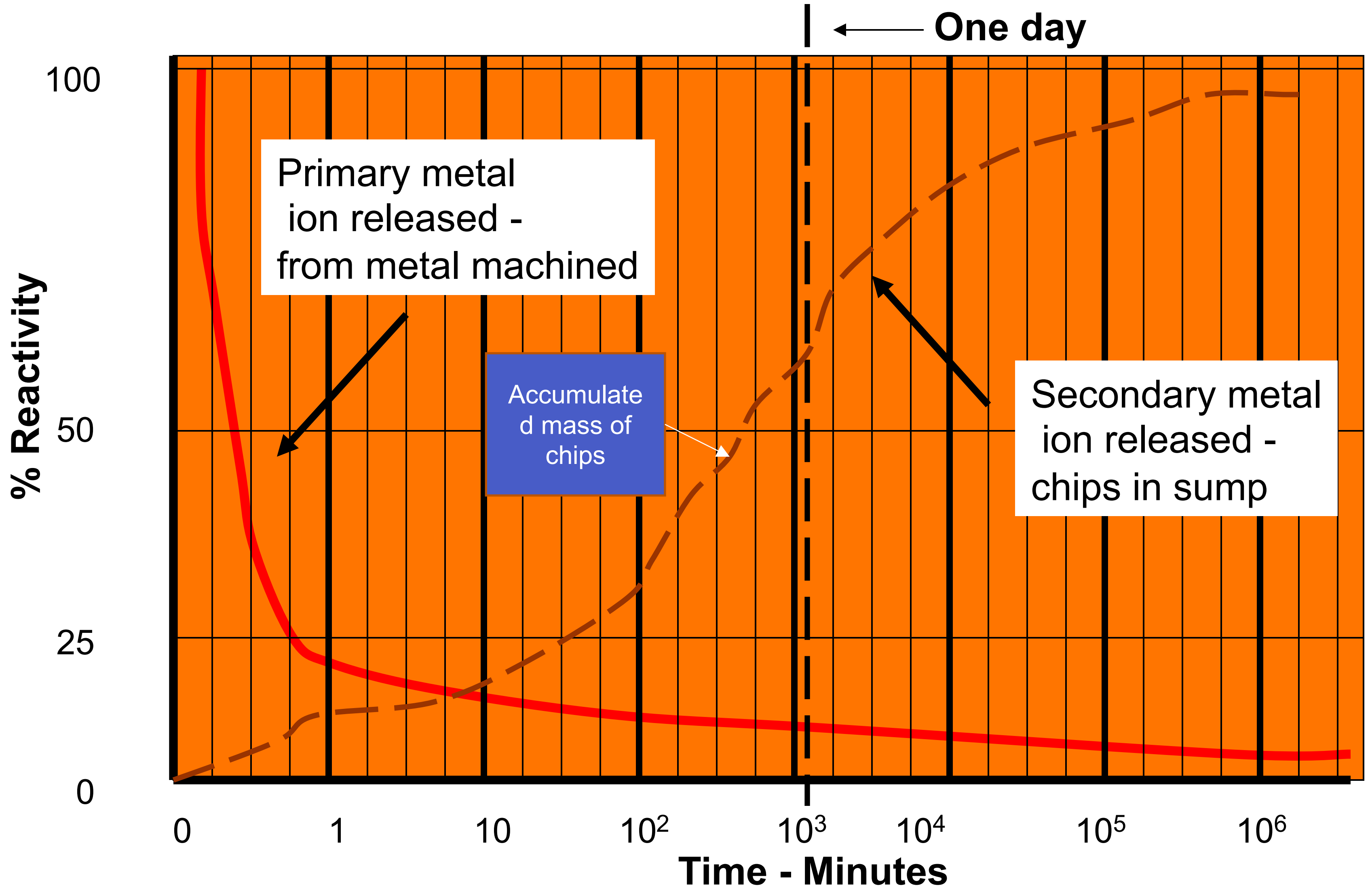


The Summary of the Metal Chip Failure Mechanisms

1. Small chips are more reactive than large chips

Single point turning vs. grinding

2. Certain metals are more reactive than other metals

Cast iron vs. stainless steel

3. Length of time the chips are in the system

Minutes to days

4. Chip density increases reaction rate

Densely packed chips can actually smolder

The Summary of the Metal Chip Failure Mechanisms

5. Volume of coolant to chip load

Too small of a sump worsens the effects of the reaction

6. Heat accelerates the reaction

Grinding puts in maximum energy, increasing reactivity, and generates small chips

7. System "turns" play a role in coolant stability

Less turn rate = more issues

Corrective Actions

Get chips out of the coolant as fast as possible

Filter fluids well

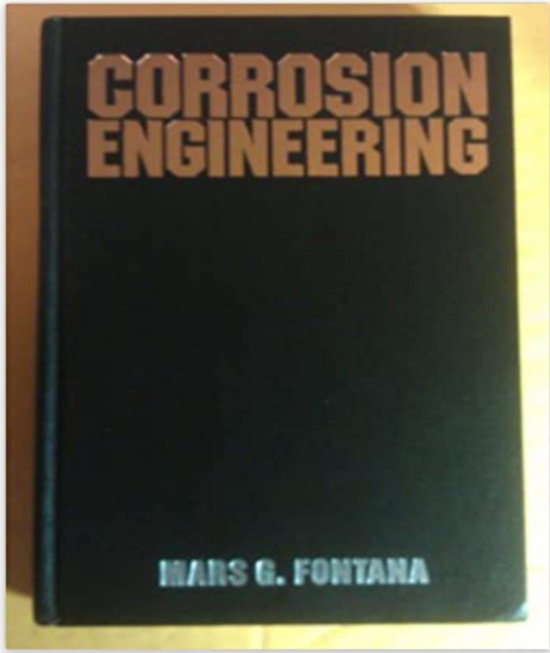
Increase sump volume if possible

Look for dead spots

Change metal alloys (likely not possible)

Don’t mix metals

Recommended Textbook



Corrosion Engineering 3rd Edition
by Mars G. Fontana (Author)

Thank You!

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