

**EROSION & CORROSION
&
GEOTHERMAL HEAT PUMPS**

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**EROSION & CORROSION
&
GEOTHERMAL HEAT PUMPS**

Applies to:

OPEN & CLOSED LOOPS Both

Emphasis on:

OPEN & STANDING COLUMN

Earth Coupling

**EROSION & CORROSION
&
GEOTHERMAL HEAT PUMPS**

**Examples
Measuring
Avoiding**

**AVOIDING
EROSION & CORROSION**

**Avoid High Velocity Liquids
Avoid Reducing Liquids
Avoid Dissimilar Metals
Avoid Electrolysis**

**INHIBITING
EROSION & CORROSION**

**Low Velocity Liquids
Oxidizing Liquids
Dielectrics w/ Dissimilar Metals
Good Electrical Bonding
NO 115 volt devices**

**EROSION & CORROSION
&
GEOTHERMAL HEAT PUMPS**

**Erosion & Corrosion
Examples
Measuring
Avoiding**

EROSION & CORROSION

MECHANICAL
CHEMICAL
GALVANIC
ELECTROLYTIC

ANY ONE ACTION CAN MAKE
THE OTHER(S) WORSE....A
SPIRALING DEGRADATION

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EROSION & CORROSION

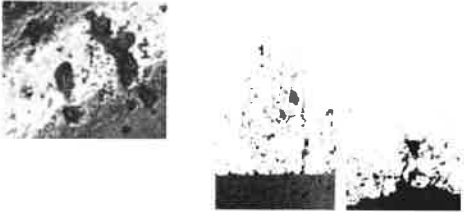
MECHANICAL

MECHANICAL
LIQUID
Velocity
Turbulence
PARTICALS

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EROSION & CORROSION

MECHANICAL



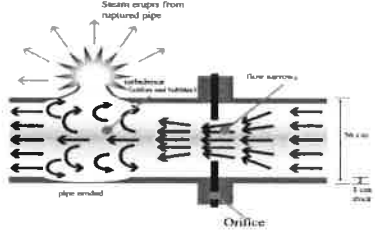
STAINLESS STEEL
PITTING CORROSION
IN SEA WATER

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EROSION & CORROSION

MECHANICAL

Figure 2:
Erosion/Corrosion induced Rupture downstream of Orifice

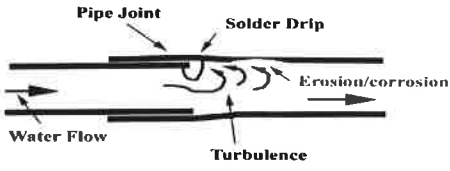


Steam escapes from ruptured pipe
Erosion/corrosion and rupture
Flow arrows
100 ft
100 ft
Orifice
pipe section

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EROSION & CORROSION

MECHANICAL



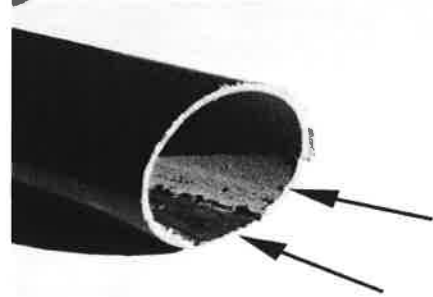
Pipe Joint
Solder Drip
Erosion/corrosion
Water Flow
Turbulence

CREVICE CORROSION

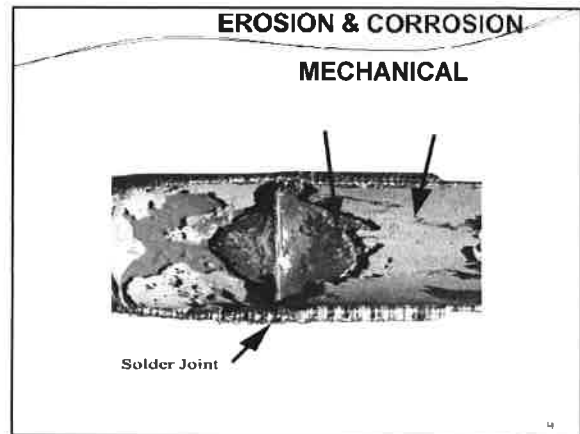
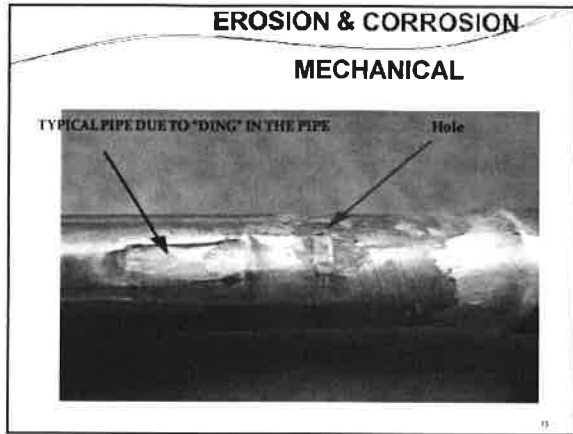
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EROSION & CORROSION

MECHANICAL



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EROSION & CORROSION
MECHANICAL
EROSION & CORROSION
MECHANICAL
PARTICLES
Grit
Foreign Material

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EROSION & CORROSION
MECHANICAL
EROSION & CORROSION
MECHANICAL
< 800 - 400 Micron
> 20 - 40 Mesh
Grit Tolerance Will Vary with
HX Type - Check with
Manufacturer

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EROSION & CORROSION
MECHANICAL
CHEMICAL
GALVANIC
ELECTROLYTIC

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EROSION & CORROSION
CHEMICAL
An Oxide Layer Protects both
Copper-Nickel, Stainless Steel &
Even Iron
The Oxide Layer for Cu-Ni
& SS does not Spall-off &
Protects those Metals
(Iron Rust Does NOT have Integrity)

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EROSION & CORROSION

CHEMICAL

An Oxide Layer Protects

EROSION & CORROSION

CHEMICAL

Copper-Nickel (& Stainless Steel)

Form Protective Oxide Layer

Within 4-6 weeks from exposure to Sea Water and other Oxidizing Water.

(Acid waters are oxidizing)

EROSION & CORROSION

CHEMICAL Protective Oxide Layer

For Copper-Nickel Alloy –SEA WATER

EROSION & CORROSION

Copper-Nickel Hull

Foil after 20 Years of Service, Vancouver

Vancouver, B.C.

Hull given a light spray wash prior to photos

Photos Courtesy:
Chris Cowland, 2005

EROSION & CORROSION

CHEMICAL –

COPPER- NICKEL Alloy Resistance to Localized Corrosion

Chloride Pitting	Very Good
Crevice Corrosion	Very Good
Chloride Stress Corrosion	Excellent
Sulphide Stress Corrosion	Excellent
Hydrogen Embrittlement	Excellent

EROSION & CORROSION

CHEMICAL –

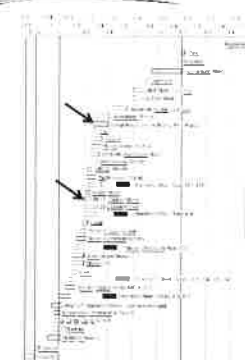
	Cu-Ni 90/10	S.Steel
Chloride Pitting	Very Good	Poor
Crevice Corrosion	Very Good	Poor
Chloride Stress Corrosion	Excellent	Poor
Sulphide Stress Corrosion	Excellent	unk
Hydrogen Embrittlement	Excellent	unk

EROSION & CORROSION

**MECHANICAL
CHEMICAL
GALVANIC
ELECTROLYTIC**

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EROSION & CORROSION



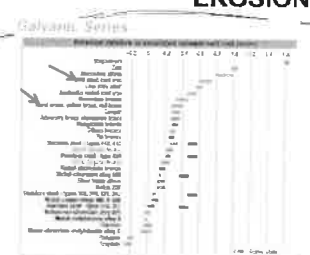
GALVANIC

The Further Apart
the Greater the
Galvanic Activity

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EROSION & CORROSION

GALVANIC




**STEEL (MILD) -
0.65 VOLTS INTO
A BRASS FITTING
-0.35 VOLTS &
CONDUCTIVE
WATER**

**= A DC VOLTAGE THAT WILL PLATE
AWAY THE STEEL - THE STEEL
BECOMES THE SACRIFICIAL ANODE**

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EROSION & CORROSION

GALVANIC Failure



Tape
Waterproofs on
OUTSIDE


Steel into Brass
Fitting - NO
Dielectric on
INSIDE

**BURIED PIPE NEEDS
"DIELECTRIC" OR DRY
FITTINGS on OUTSIDE
and INSIDE**

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**EROSION & CORROSION
ELECTROLYTIC EROSION**

- 2nd Law of Thermodynamics
"Everything in Our Universe Seeks a
Lower Energy Potential"



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EROSION & CORROSION

**MECHANICAL
CHEMICAL
GALVANIC
ELECTROLYTIC**

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**EROSION & CORROSION
ELECTROLYTIC**

A VOLTAGE DIFFERENTIAL

**EROSION & CORROSION
ELECTROLYTIC**

13,600 Volt Power Lines

Then Why Aren't these Birds DEAD!

**EROSION & CORROSION
ELECTROLYTIC**

The VOLTAGE DIFFERENTIAL To GROUND IS 13,600 -!
ALL POSITIVE CHARGES WANT to GO to GROUND/EARTH POTENTIAL

**EROSION & CORROSION
EXAMPLES**

How Do I Get 115 volts for a Pump, Control, etc?

ELECTRICAL EARTH BOND

EARTH BOND - National Electric Code 1999

- "shall be grounded...(when) located in a wet or damp location and not isolated" -section 250-110(2)
- "...non-current-carrying metal parts of equipment and enclosures...shall be grounded regardless of voltage." - section 250-112(a)(1)
- "The (grounding) connection shall be made by bonding the equipment grounding conductor to the grounding electrode conductor" - section 250-130(a), (b)

**EROSION & CORROSION
EXAMPLES**

ELECTROLYTIC EROSION

- AC Power is Converted to DC
- By Copper Oxide On Pipe

PIPE EROSION DUE TO ELECTROLYSIS - LONG ISLAND 4

**EROSION & CORROSION
ELECTROLYTIC EXAMPLES**

• AC Power is Converted to DC Power by
Copper Oxide

BUILDING AC
(+) Charge

EARTH POTENTIAL (-)
HALF WAVE DC
(-) Charge

Cu Pipe
w/ Oxide

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ELECTROLYSIS

CAN CREATE TUBULENT SITES by OFF PLATING

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**EROSION & CORROSION
MECHANICAL**

EROSION & CORROSION

- MECHANICAL
- CHEMICAL
- ELECTROLYTIC

ALL HAVE SHARP CORNERED EDGES
CREATED by the MECHANICAL,
CHEMICAL or ELECTROLYTIC ACTION

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**EROSION & CORROSION
MECHANICAL**

ALL HAVE SHARP CORNERED EDGES
CREATED by the MECHANICAL,
CONSTRUCTION/FABRICATION

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**EROSION & CORROSION
&
GEOTHERMAL HEAT PUMPS**

**Erosion & Corrosion
Examples
Measuring
Avoiding**

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**EROSION & CORROSION
EXAMPLES**

**ELECTROLYTIC
EROSION**

- PIPE EROSION DUE TO
ELECTROLYSIS -
LONG ISLAND
Note Location

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EROSION & CORROSION
EXAMPLES

ELECTROLYSIS EROSION – LONG ISLAND NY

Electric Utility Transformer - Ground Mount

1.8 amps

GEO HEAT PUMP PIPING BECAME THE ELECTRICAL GROUND FOR THREE HOUSES

ALL ELECTRIC GROUNDS WERE NOT EXISTING- not deep enough in moist earth or dissolved

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EROSION & CORROSION
MEASURING

Amp probe on pipe

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EROSION & CORROSION
MEASURING

**THREE HOUSES
ELECTRICAL RETURN
THROUGH THE WELL OF
THE GEOTHERMAL HEAT
PUMP HOUSE**

=

PIPE "CORROSION"

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EROSION & CORROSION
EXAMPLES

**ELECTROLYTIC
EROSION**

- PIPE EROSION DUE TO ELECTROLYSIS - Cape Cod
Note Location

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EROSION & CORROSION
EXAMPLES

ELECTROLYSIS EROSION – CAPE COD MA

Electric Utility Transformer - Pole Mount

Temp Wires 126 Ω

ALL HOUSE ELECTRIC GROUNDS WERE NOT DEEP ENOUGH IN DRY SAND to REACH WATER TABLE -20 ft

GEO HEAT PUMP BECAME THE ELECTRICAL GROUND PATH FOR A SMALL 115 VOLT HOT WATER CIRCULATOR

LOCAL CODE REQUIRED 30 ft ELECTRICAL GROUND ROD - LOW BID ELECTRICIAN PUT IN THREE 10 ft RODS !!

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EROSION & CORROSION

TEMPORARY WIRE GROUNDING

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**EROSION & CORROSION
MEASURING**

**ELECTRICAL RETURN FOR A
115 VAC HOT WATER
CIRCULATOR THROUGH THE
WELL OF THE GEOTHERMAL
HEAT PUMP**

=

**Pipe & Heat Exchanger
"CORROSION"**

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**EROSION & CORROSION
&
GEOTHERMAL HEAT PUMPS**

**Erosion
Corrosion
Examples
Measuring
Avoiding**

43

**EROSION & CORROSION
MEASURING CHEMICAL**

CONDUCTIVITY & TDS (TOTAL DISSOLVED SOLIDS)
Seimans (S) or
Micromho/centimeter ($\mu\text{mho/cm}$)

Distilled Water	0
Typical Well Water	100 - 500
Brackish	1,000 - 5,000
Sea Water	30,000 - 50,000

**TOTAL DISSOLVED SOLIDS (TDS) is
Approximately 1/2 of the
CONDUCTIVITY Value**

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**EROSION & CORROSION
MEASURING CHEMICAL**

LANGOLIER Stability Index (LSI)
A Good Measure of SCALING Possibility (CaCO_3)
A POOR Measure of Corrosion

LSI < 0.0 Removes Scale, Possible Corrosion
LSI = 0.0 No Scale, No Corrosion
LSI > 0.0 Scaling May Occur

-2.0 to -0.5	If Unprotected Corrosion
0.05 to 0.0	Slight Possibility of Unprotected Corrosion
0.00	Balanced LSI, but Pitting can occur
+0.0 to +0.50	Slight Scaling & Corrosion
+0.5 to + 2.0	Scaling

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**EROSION & CORROSION
MEASURING**

Measure Leakage

**DIGITAL
VOLT
METER**
297mV

**>300 mV POSSIBLE ELECTROLYSIS
>500 mV FOR SURE
AC or DC**

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**EROSION & CORROSION
MEASURING**

0.29 volts

**HEAT PUMP
FRAME**

**METAL INTO
WATER
STREAM**

Pete's Port

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EROSION & CORROSION
&
GEOHERMAL HEAT PUMPS

Erosion
Corrosion
Examples
Measuring
Avoiding

EROSION & CORROSION
AVOIDING
Copper-Nickel (& Stainless Steel)
Form Protective Oxide Layer
Within 4-6 weeks from exposure to
OXIDIZING water.

OXIDIZING water is typically
Acid (pH < 7.0), sea water, non-reducing
water.

EROSION & CORROSION
CHEMICAL LOST PROTECTION

Increasing probability of premature failure in seawater by impingement attack

~8-9 fps

EROSION & CORROSION
AVOIDING
MECHANICAL
Low Velocity

VELOCITY IS < 5.0 fps

Re is less than 2,500 = No NOISE

EROSION & CORROSION
AVOIDING
MECHANICAL

Keep Liquid Velocity LOW

< 6 gpm 3/4" pipe
< 12 gpm 1" pipe
< 20 gpm 1 1/4" pipe
< 30 gpm 1 1/2" pipe

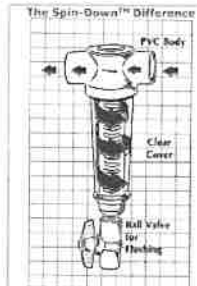
VELOCITY IS < 5.0 fps
Re is less than 2,500 = No NOISE

AVOIDING
EROSION - Mechanical
Heat Exchanger Requirements
Typical 800 microns (μ)

Microns	Approx Mesh
800	20
600	30
400	40
No Smaller.....	

**EROSION & CORROSION
AVOIDING**

MECHANICAL



**Particulate Control
Spin Down Filters**

**EROSION & CORROSION
AVOIDING**

Copper-Nickel (& Stainless Steel)
Can LOSE their Protective Oxide Layer in
a REDUCING Environment

REDUCING water Scavenges Oxygen
Smells = H₂S, Rotting Vegetation, Dead Fish
Both Cu-Ni & SS are not oxide protected when
exposed to REDUCING Agents

Request ReDox Measurement of Water &
Heat Transfer Liquids

**EROSION & CORROSION
AVOIDING**

GALVANIC-

Use Dielectric Fittings

Water Proof all Dissimilar Meets
(on outside if buried)

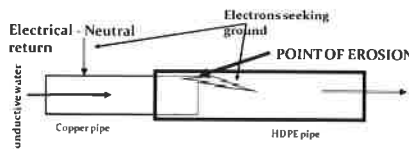
**EROSION & CORROSION
AVOIDING**

ELECTROLYTIC

Verify No Electrical Earth Leakage

Check for Current Flow in Piping

ELECTROLYSIS
CAN CORRODE & DESTROY PIPE & HX



- Poor Intended Electric Earth Ground, with neutral return
- 115 vac Traced to WS Heat Pump - (hot neutral)
- Conductive Water - Lower Resistance than the Intended Ground

**ALL THREE MUST EXIST FOR ELECTROLYTIC
CORROSION TO OCCUR**

**INHIBITING
EROSION & CORROSION**

Low Velocity Liquids
Oxidizing Liquids
Dielectrics w/ Dissimilar Metals
Good Electrical Bonding
NO 115 volt devices