

Flow accelerated corrosion in cooper-nickel 90-10 in sea water

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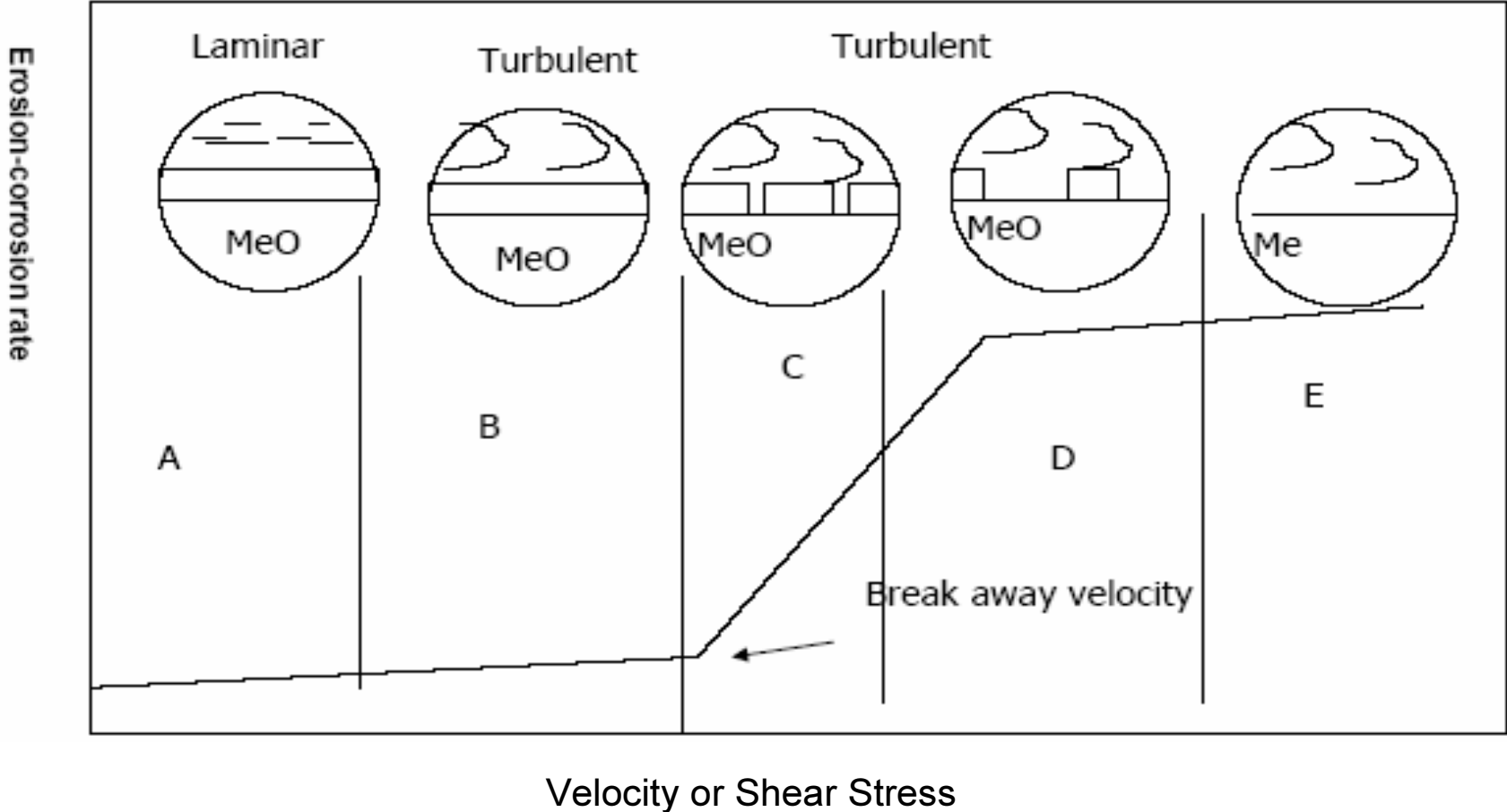
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Introduction

- The flow accelerated corrosion may occur partly by mechanical processes and partly by electrochemical process or it may occur entirely by electrochemical process. The rate of corrosion is strongly influenced by the velocity and geometry of the flow system

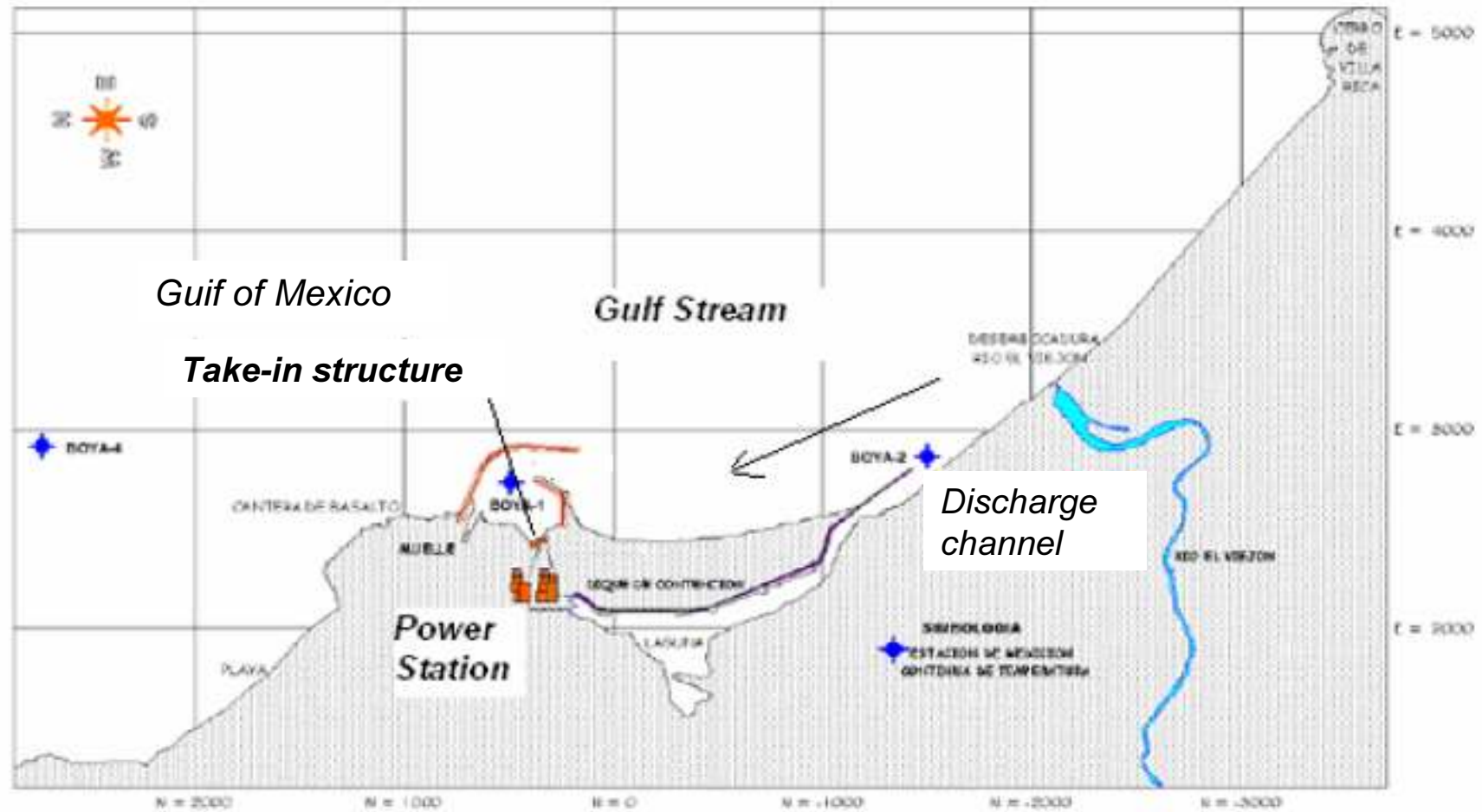
Effect of Velocity



The important parameters affecting the behaviors are:

- Dissolved Sulfide.
- Hydrodynamic Conditions.
- Oxidation products of dissolved sulfides.
- Exposure time
- Pre-exposure to low concentrations of extraneous ions.
- Effect of chloride and other pollutants' such as ammonia.
- Effect of "sensitized" microstructures (e.g. Iron rich second phases precipitates in grain boundaries in Cu-Ni alloys by heated around 600o C)

Environmental condition



Enviromental conditions

- Water temperature in the Gulf of Mexico varies from 19.50C(67.10F)to31.50C (88.70F); the design temperature used for the service water system is 32.20C (900F)
- Mesh of 9.5 mm square.
- the presence of small fishes and barnacles
- organic matter in decomposition, and the present of Sulfides and also amines is possible.
- biocides are applying including hypochlorite's, bromides and quaternary amines.



Case 1. Tee's

- Tee of 8X16X24 inches presented loss of thickness
- Tee of 24x24x24 presented a leak in the union of the two fluxes. In this case, the leak was repaired with a stick wood and with a welded patched



Case 2 medium Pipes

- This pipe presents a leak, caused by damage that reach the total thickness
- "The Balance of plant" velocity was of 2.19 m/s.
- **15.5 cm diameter pipe**



Case 3 small pipes

- Those pipes presents damage in the elbows and in strain lines after the gaps of bad weld unions



- b) Square elbow of $\frac{3}{4}$ inches (1.8 cm diameter pipes and elbows.
 - c) Details of the damage I a elbow.
 - d) General view of the damage.
- Flow 0.06 m³ per minute



Microstructures

- All microstructures present alpha copper grains with precipitations in grain boundaries of iron carbides, magnesium sulfides, and silicates

Flow Rate Velocities

Table 3 Maximum Flow Velocities m/s

Alloy	Typical maximum Flow Velocity, m/s
90-10 Cu-Ni	3.5
70-30 Cu-Ni	4.0

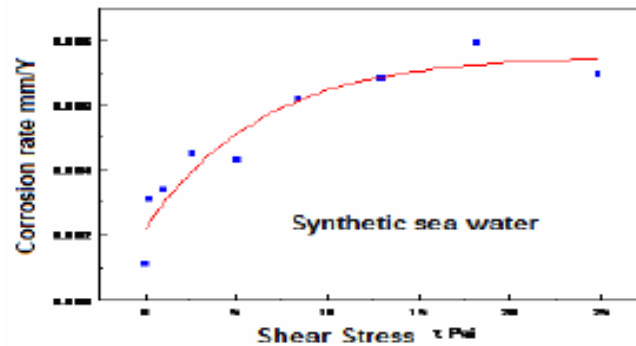
"Balance of plant Velocities" are below the maximum Flow Velocities

Effects of flow rate

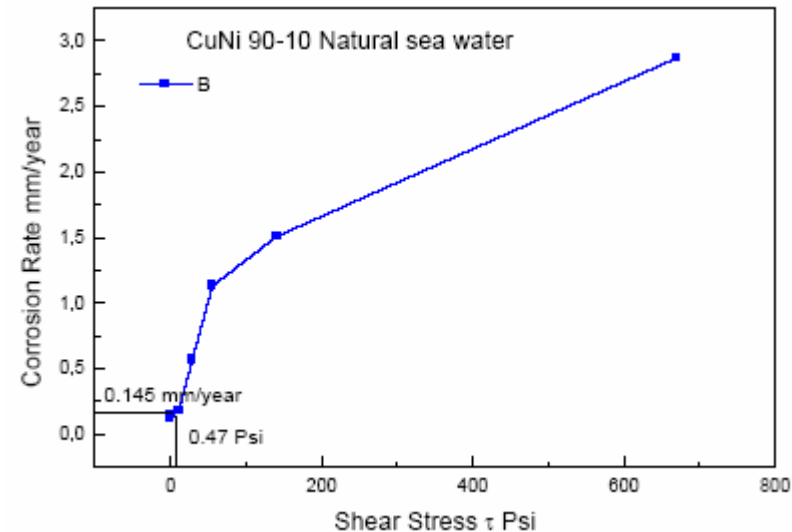


rpm	Ω rad/s	Re cilindro	τ kg/ms ² (Pa)	τ , psi	Corrosion rate mm/year
0	0	0	0	0	0.115
84	8.70	69.21	9889.63	1.434	0.145
204	21.36	168.73	77780.20	11.28	0.181
306	32.04	253.10	197900.28	28.70	0.5644
408	42.72	337.47	383536.78	55.62	1.132
612	64.08	506.20	974575.80	141.350	1.511
1209	126.60	995.35	4615383.73	669.404	2.877

Effects of flow rate

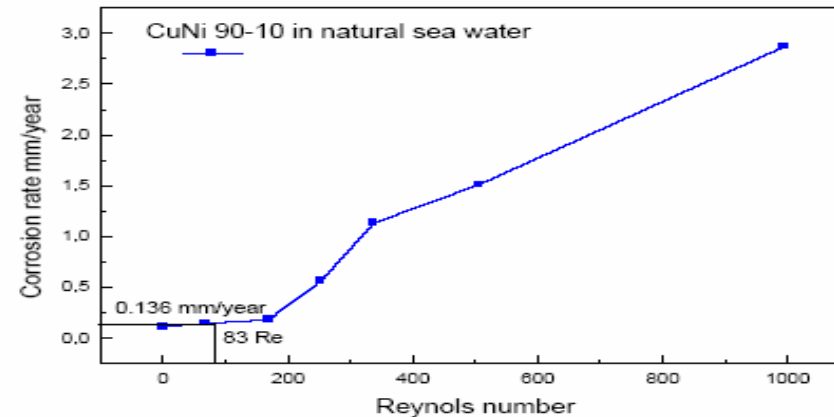


The natural sea water are more aggressive that synthetic sea water



- Modeling of Corrosion Acceleration by Shear Mechanism in the Tee. 0.15 mm per year

Effects of flow rate



Modeling of Corrosion Acceleration by Convective Mass Transfer using the mass transference coefficient K of the Tee, 0.136 mm per year.

Both model not could explain the loss of material of 0.2 inches in 1.5 year (3.38 mm per year)

ANSYS calculus of flow rate

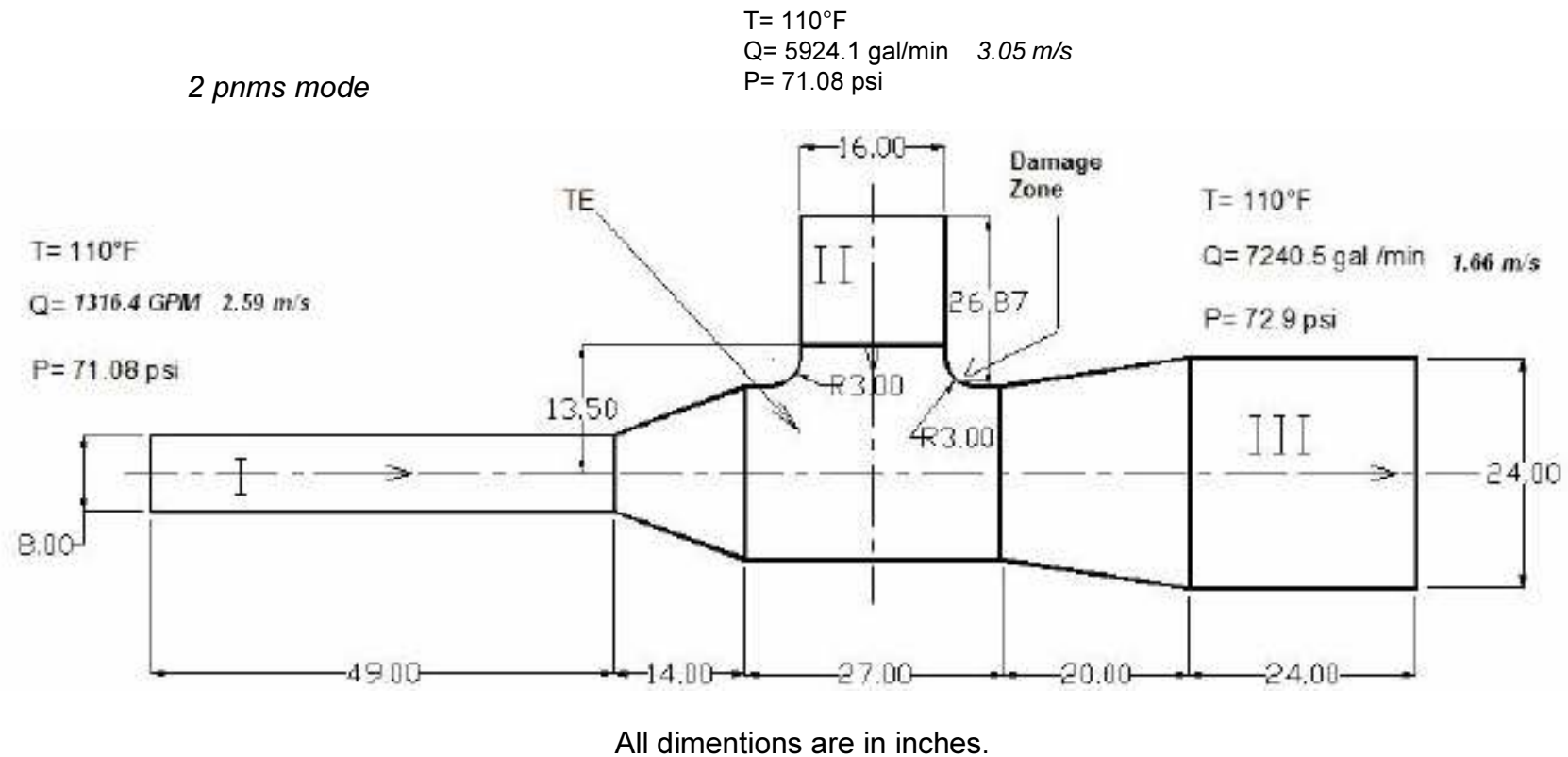
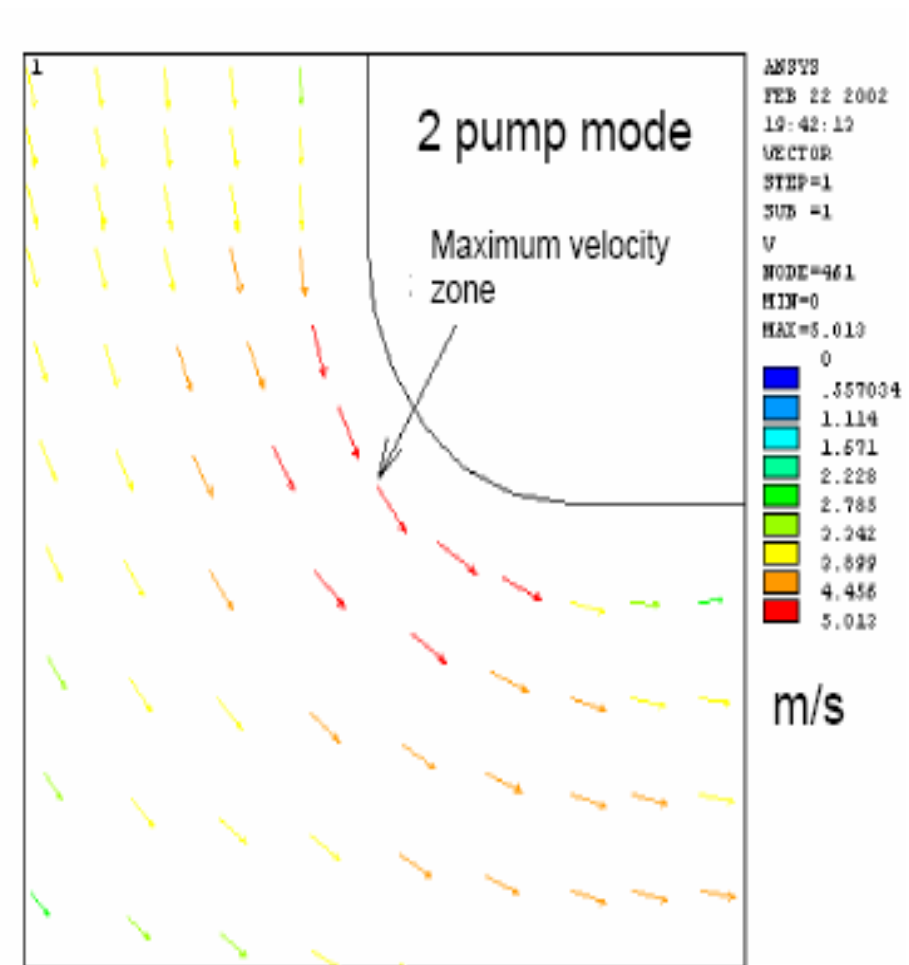
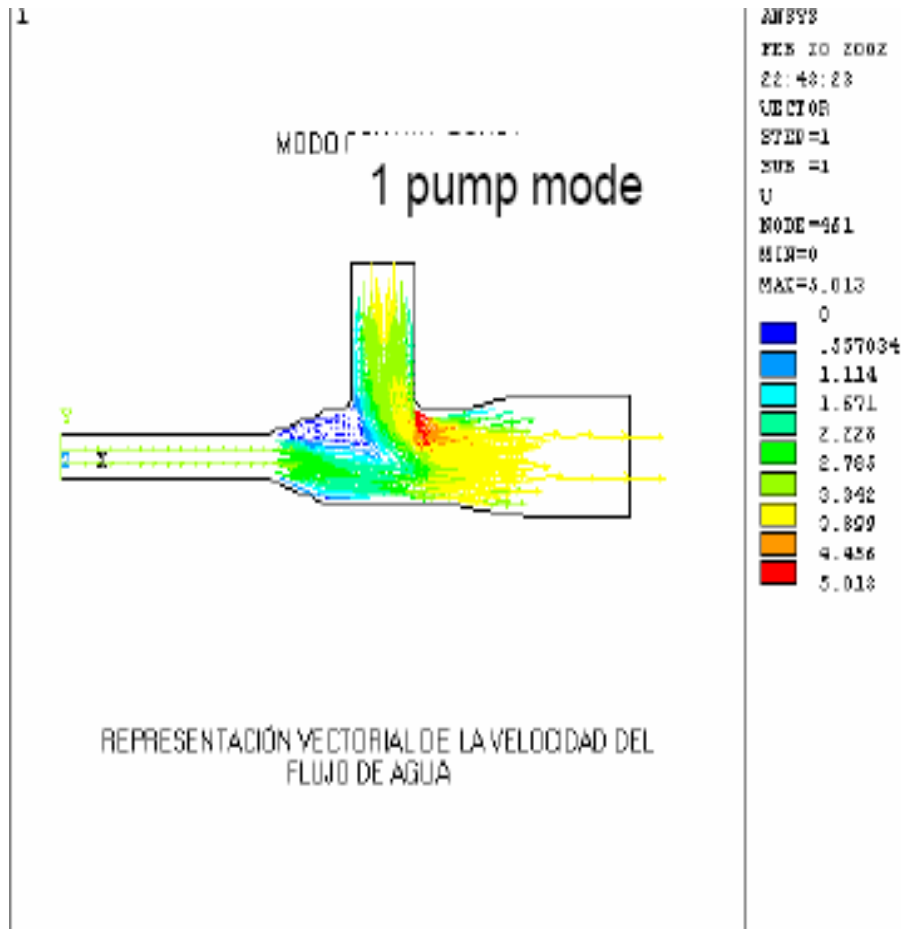
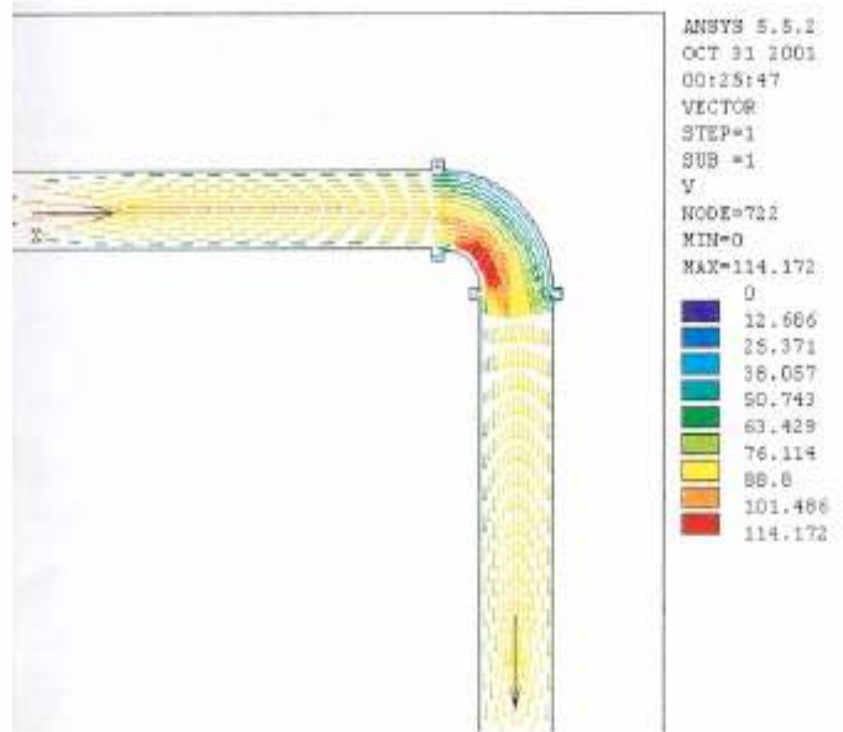


Figure 3. Dimension and conditions of the 8x16x24 tee



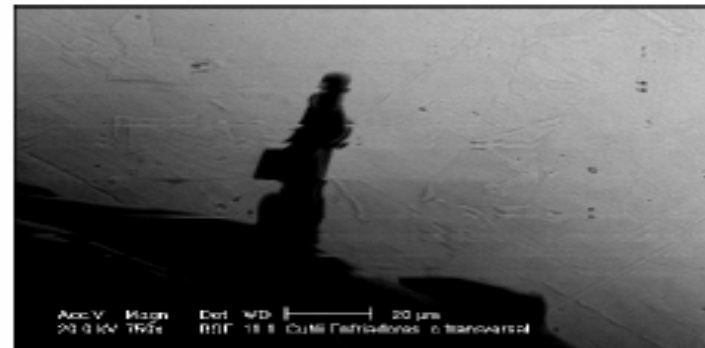
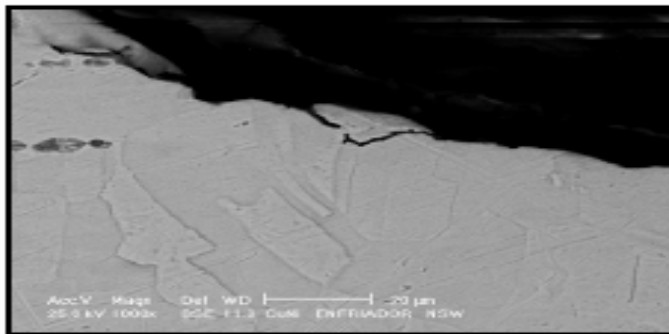
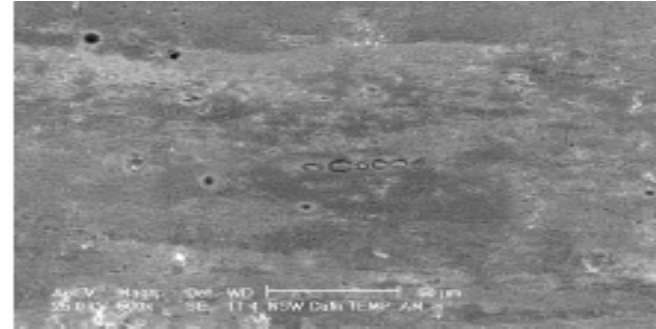
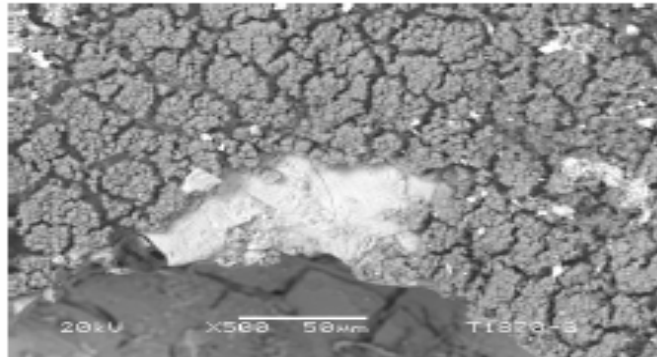
The flow velocity exceed the maximum designed flow rate in the zone of the damage



Figures 8. a) 1.8 cm diameter pipe and elbow flow profile with a 0.06 m³ per minute with a good union and b) The same pipe and elbow with a bad union with a gap of 3 mm. Velocities are in inches per second.

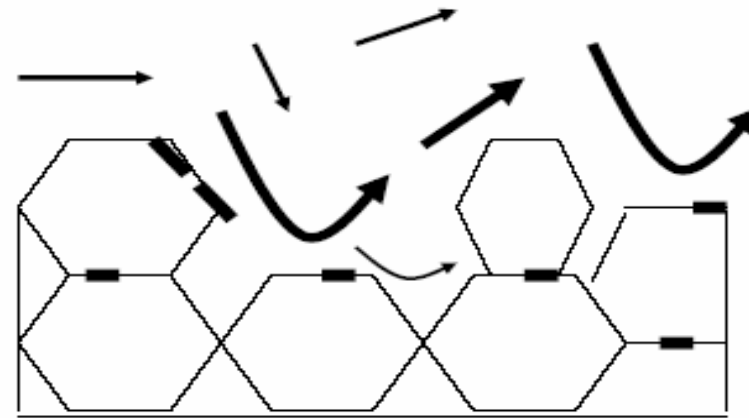
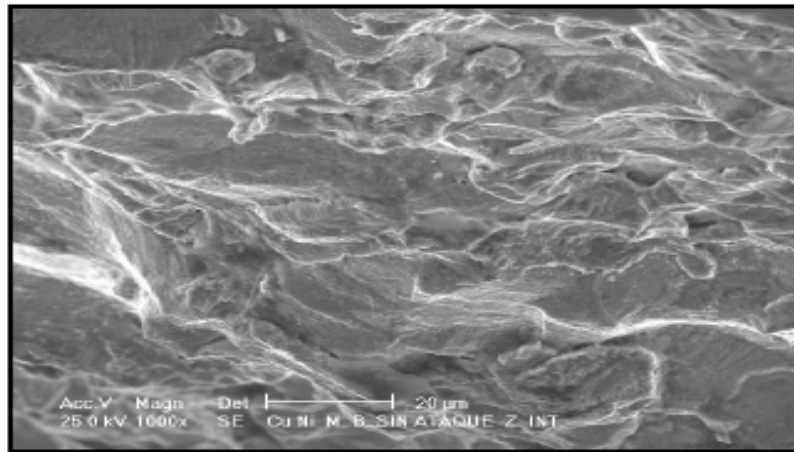
The changes in the profile flow is in agree with the geometry of the real damage in the elbows

Failure Analyses and mechanism



Figures 9. a) CuNi retired from the Tee, showing a porous layer and IGA in the bare metal. b) Polished CuNi after 24 hours in natural sea water showing attack around the precipitates. c) Intergranular attack surrounding a grain. d) IGA penetrating and loss of completed grains

Failure Analyses and mechanism



cavities produces microvortex and mechanical damage

This also explain way the model of the corrosion accelerated by flow not work so well in this case, due to the nature intergranular of this attack. There is a part of the loss of materials that are related with the loss of completed grains.

Small pipelines are connected to more big pipelines and a suction effects that could accelerate the flow in this small pipelines. Provisional's flow meters were installed ant this hypothesis was confirmed

Failure Analyses and mechanism

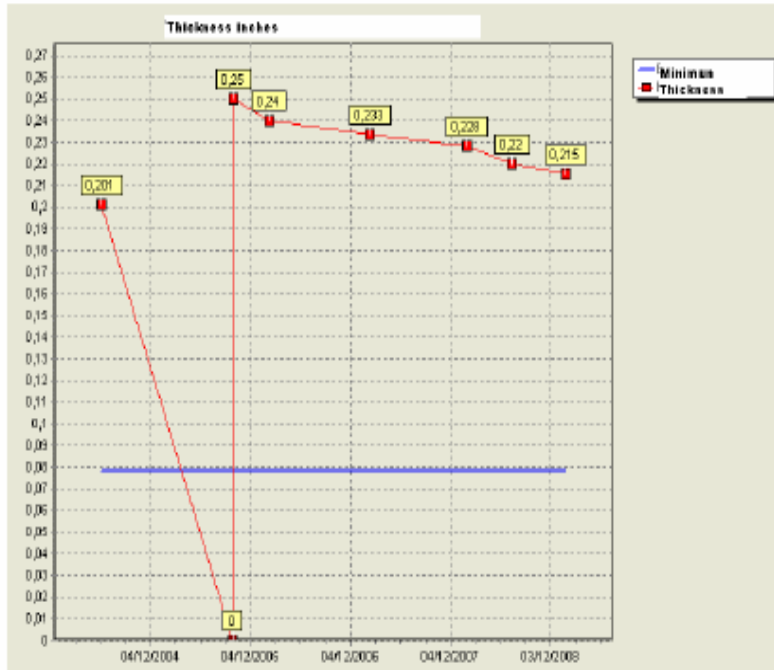
Table 4. Chemical analyses of the natural sea water in the service water system.

Sea Water	Ca mg/l	Free Cl mg/l	Cl	Cu ²⁺	Fe	K+	Mg ²⁺	Mn ²⁺	N/NO3	Na ⁺	Ammoniac Nitrogen	SO ₄ ²⁻	pH	Zn	S ²⁻
In Site ININ	432 411	<0.02	21566 20200	<0.125 0.031	<0.25 0.12	405 434	1322 1261	<0.1 <0.1	<7.17	10940 11364	<0.54	2803 2800	8.10 8.03	<0.05	N.D.

The Power plant not has available sulfides detections chemical techniques. The National Nuclear Research Institute (ININ) carried out the analyses, but due to the distance the water samples arrived one day after and it was not possible to detect the sulfides after this time

Solutions of the problem

- **The power station including the Service Water System in the FAC program**
- **the use of CHECWORK software to detect the more sensitive sites to the FAC and operational experience.**
- **the use of UT and other volumetric not destructive test NDT to surveillance the thickness of the pipes**
- **more resistant materials like the ALX65**



Thickness of a 18" Tee. UT test

Loss of thickness

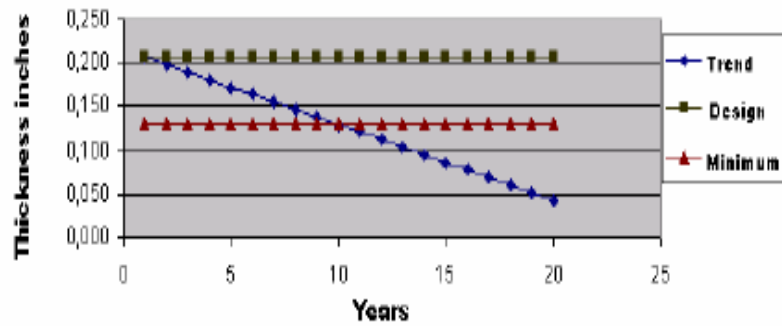


Figure 11.18" Tee thickness prediction and service life of a Tee

Update



ALX65 valve with a Leak after 9 months in service

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