

## CHAPTER 4

### RESULTS AND DISCUSSION

#### Static Test

In comparative study of scale inhibitor effectiveness, the static flash test was the one of method to accept and prove the active of inhibitors. Under a stimulating condition, many samples were added into the glass bottles which lacked of air, so that the concentration of  $\text{CO}_2$ ,  $\text{HCO}_3^-$  and  $\text{CO}_3^{2-}$  did not change and were constant the time during experimental. However, the test was limited by low friction and local superheating which both parameters were the critical function of scale deposition. Therefore, the experiment was compensated by control higher pH and alkalinity over operating condition.

#### Calcium Carbonate Stabilizer

For water condition, 350 ppm total hardness and 300 ppm total alkalinity were as  $\text{CaCO}_3$ , this condition resulted in pH 8.6. The experimental proved that the inhibitor (PBTC, SHMP, HEDP, and PC) could protect the system from scale deposition, as shown in Fig. 4.1.

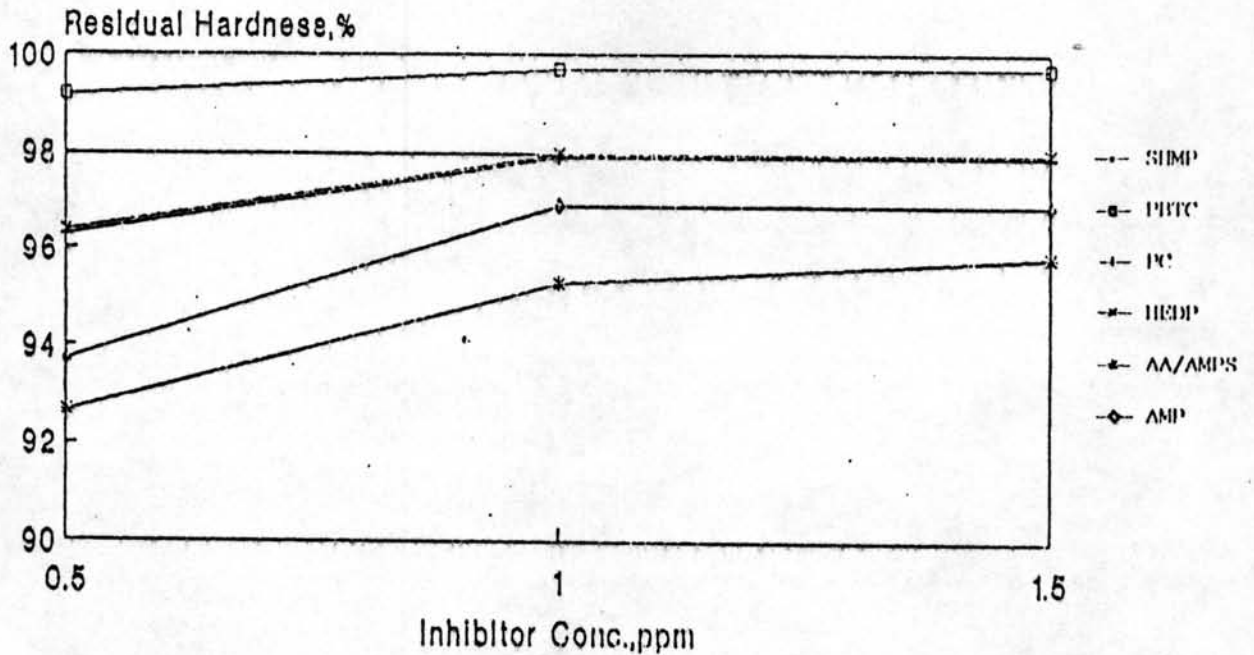


Fig. 4.1 Static Test Condition 330 ppm TH, 300 ppm TA, pH 8.6, 40° C.

The results of critical condition (higher total hardness and total alkalinity concentration) were shown in Fig. 4.2- 4.3 and higher pH were shown Fig. 4.4-4.5 however, the inhibitor (HEDP and SHMP) were more effective than the others in the critical condition.

For water condition with 530 ppm total hardness and 450 ppm total alkalinity as  $\text{CaCO}_3$ , pH 8.6, temperature 60° C, the results were shown in Fig. 4.6. It presented that HEDP and SHMP were highly effectiveness. Furthermore, for more aggressive water condition with pH 9.1, the effectiveness was slightly decreased. When the pH condition of water was adjusted to 10.1, the effectiveness of all inhibitors was low to protect the scale deposition.

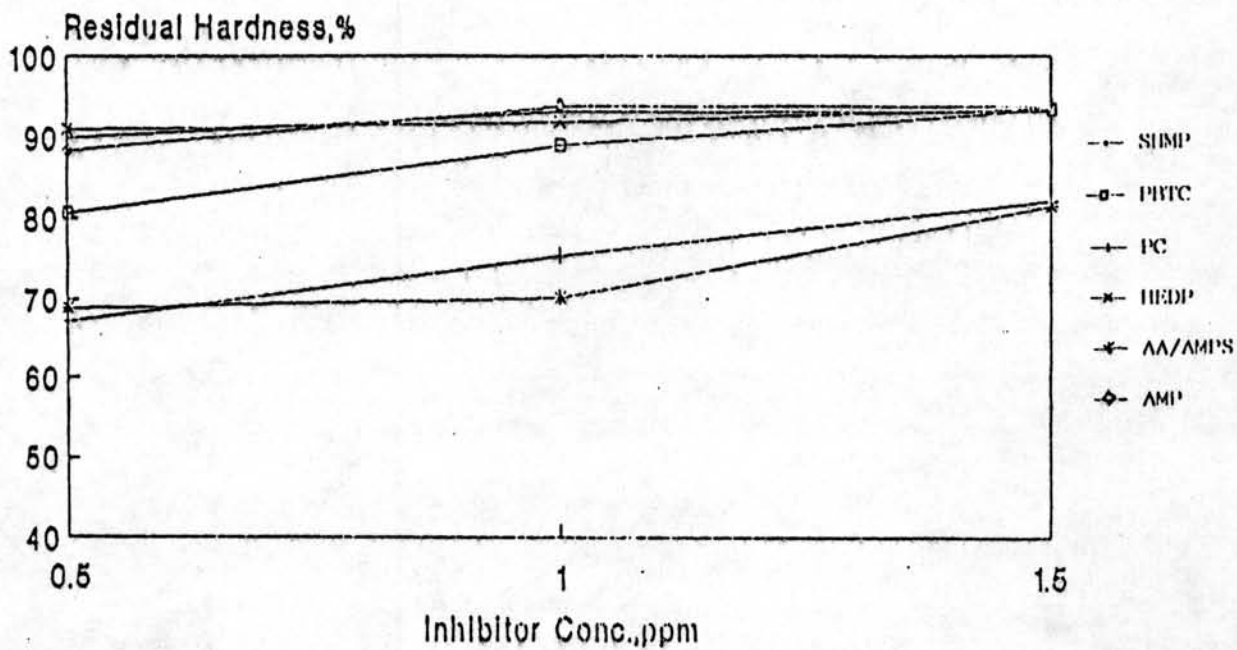


Fig. 4.2 Static Test Condition 540 ppm TH, 450 ppm TA,  
pH 8.6, 40° C.

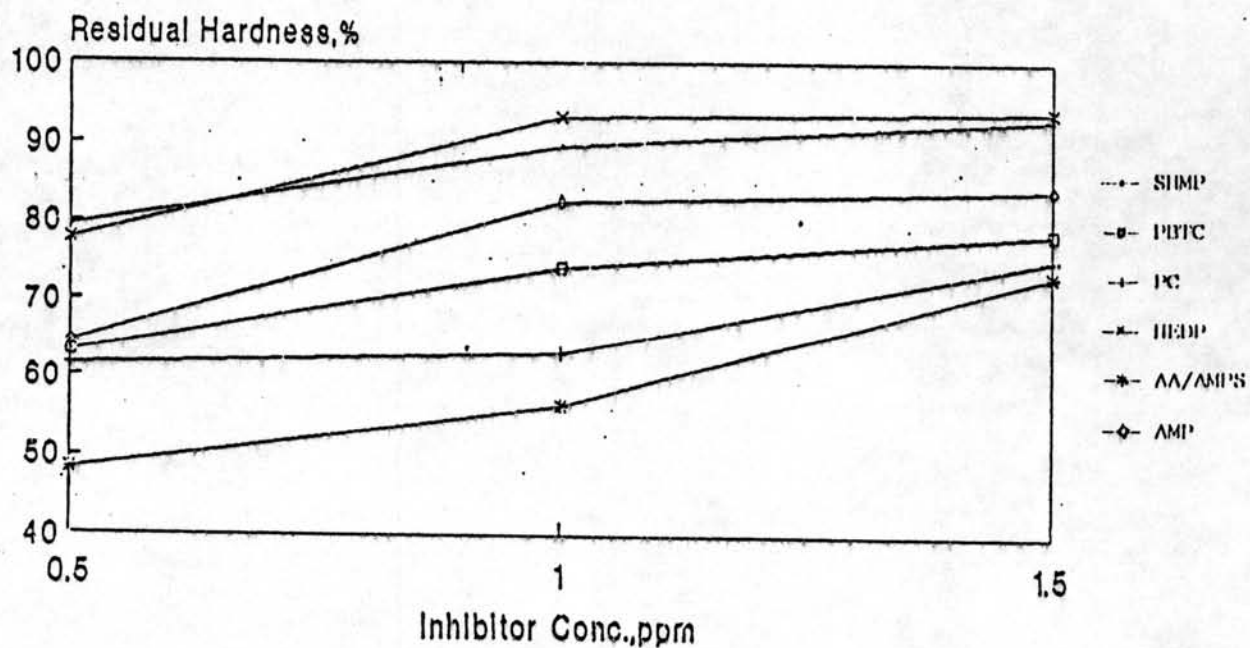


Fig. 4.3 Static Test Condition 700 ppm TH, 450 ppm TA,  
pH 8.6, 40° C.

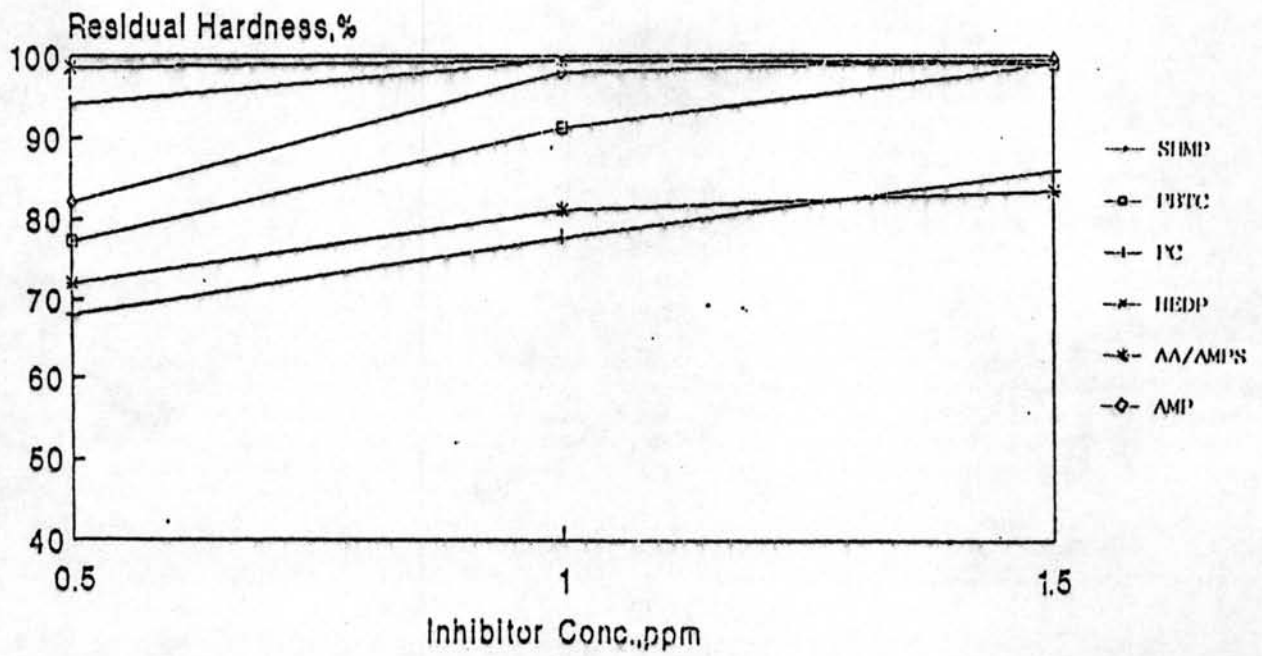


Fig. 4.4 Static Test Condition 350 ppm TH, 300 ppm TA, pH 9.1, 40° C.

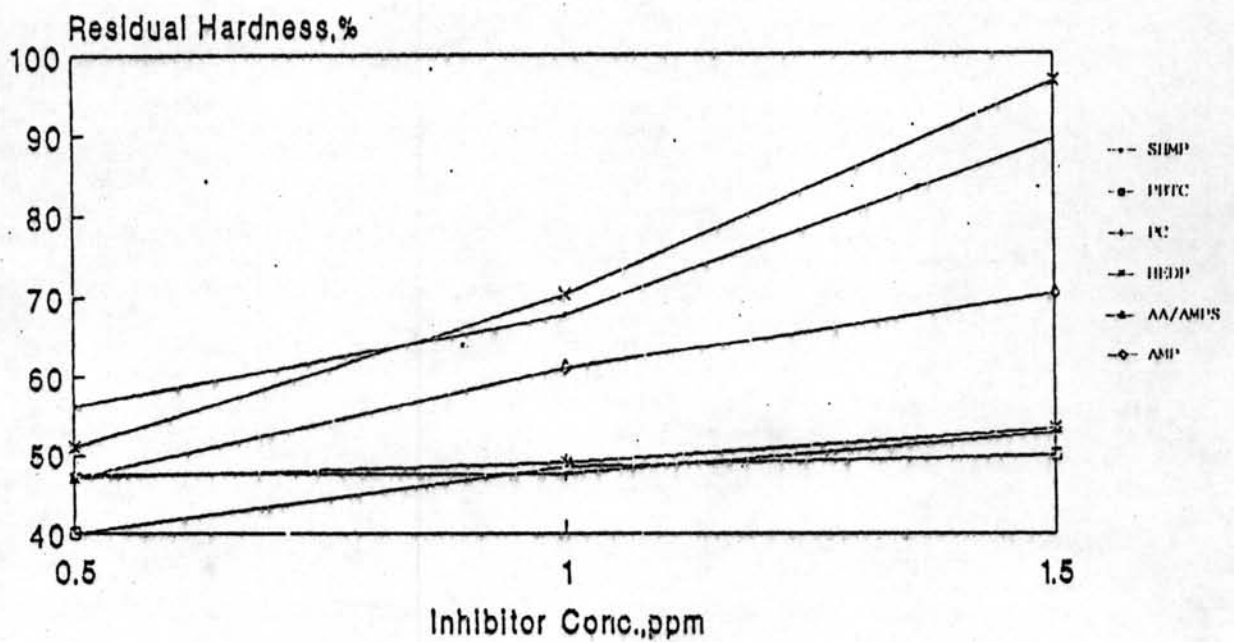


Fig. 4.5 Static Test Condition 360 ppm TH, 300 ppm TA, pH 9.6, 40° C.

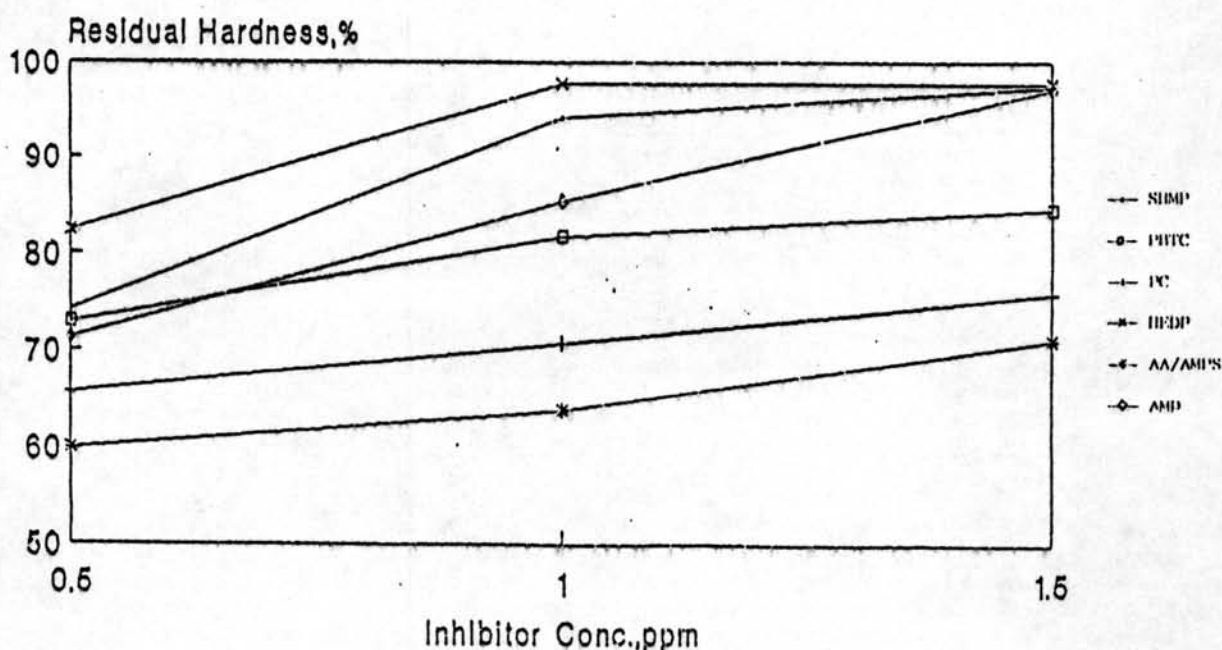


Fig. 4.6 Static Test Condition 530 ppm TH, 450 ppm TA, pH 8.6, 60° C.

For 360 ppm total hardness and 300 ppm total alkalinity as  $\text{CaCO}_3$ , pH 9.1, temperature 80° C, the results see Fig. 4.7, 4.9 showed that HEDP and SHMP were still highly effective. When the water condition was increased (total hardness, total alkalinity and pH), as shown in Fig. 4.8 and 4.10, all inhibitors were lower effective.

Therefore, it could be concluded that SHMP and HEDP were the suitable inhibitors for protecting the scale deposition in a power plant cooling system. As for the cost consideration, SHMP was cheaper than HEDP, thus SHMP was reasonably chosen for an actual work.



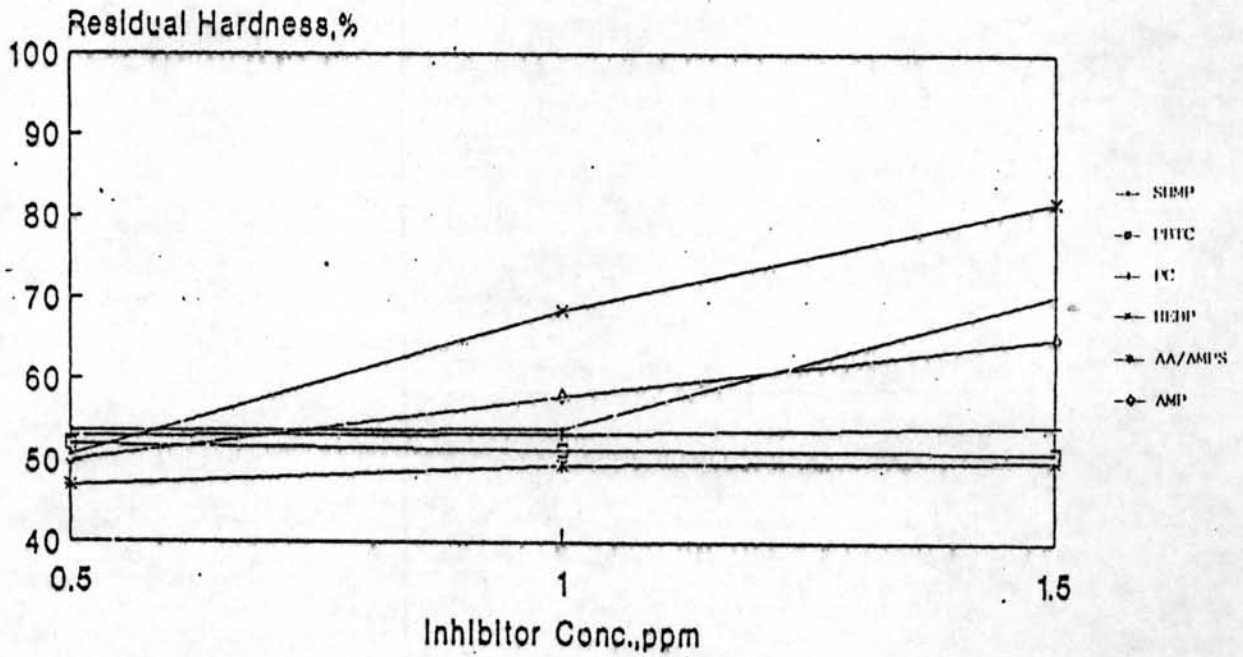


Fig. 4.7 Static Test Condition 530 ppm TH, 450 ppm TA,  
pH 9.1, 60° C.

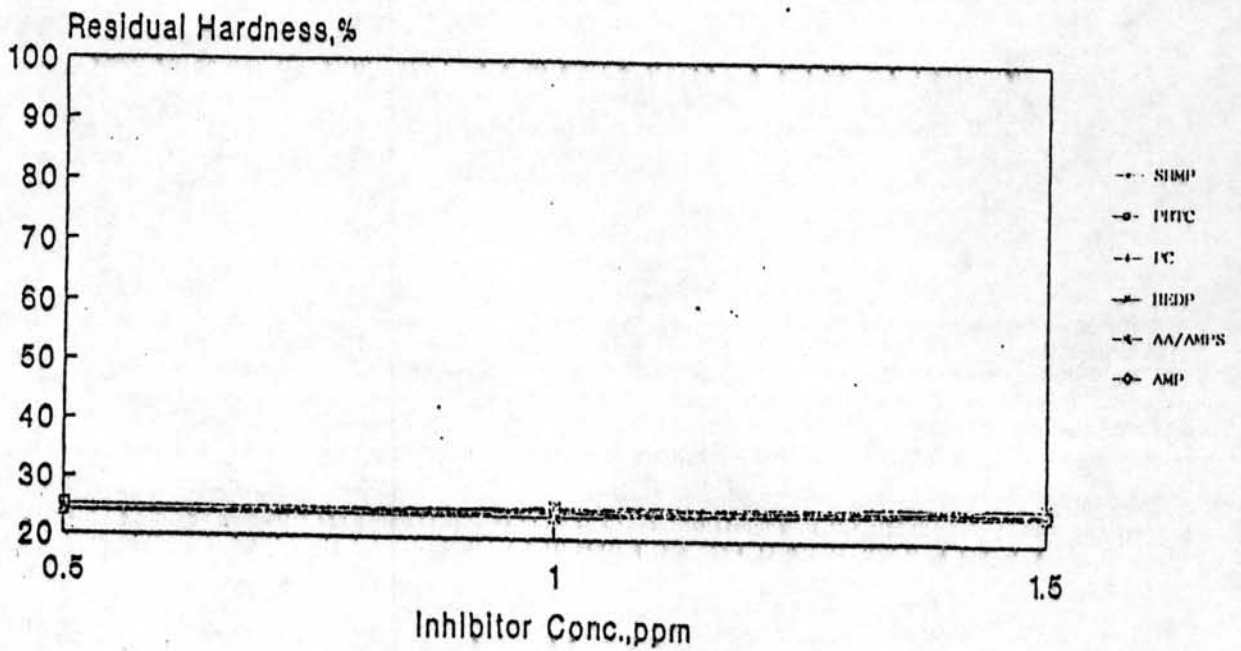


Fig. 4.8 Static Test Condition 530 ppm TH, 450 ppm TA,  
pH 10.1, 60° C.

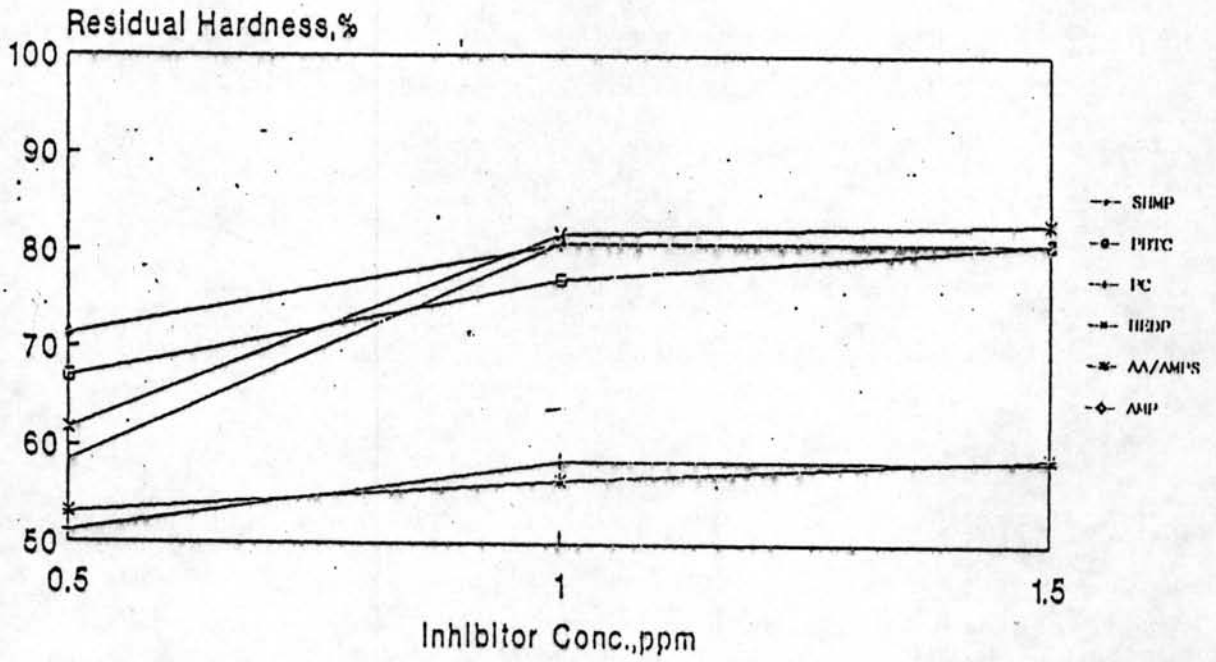


Fig. 4.9 Static Test Condition 360 ppm TH, 300 ppm TA, pH 9.1, 80° C.

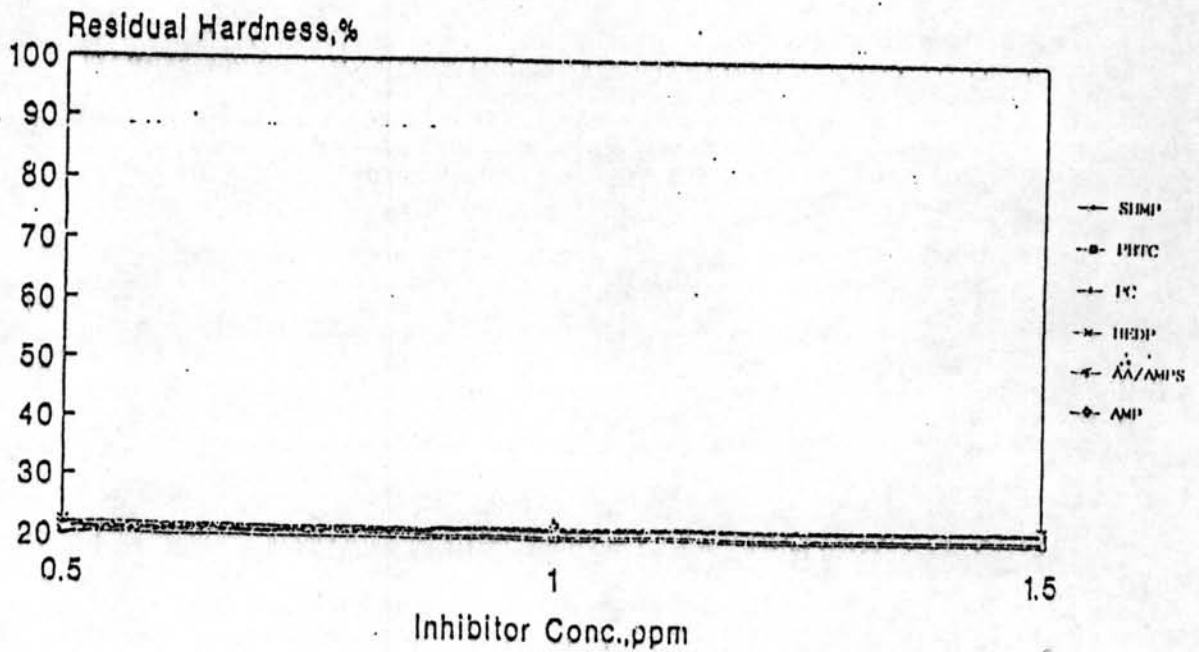


Fig. 4.10 Static Test Condition 540 ppm TH, 450 ppm TA, pH 10.1, 80° C.

### Calcium Phosphate Stabilizer

The limitation on the phosphaste treatment program was the formation of calcium phosphate ( $\text{Ca}_3(\text{PO}_4)_2$ ) scale deposition. The program therefore had to supply the calcium phosphate stabilizer for dispersing the calcium phosphate precipitate and antiscale deposition. The chemicals that were active to be dispersant were polymer, co-polymer and ter-polymer. The dispersant for this experimental was chosen as follow:

- Acrylic-2-Acrylamido-2-Methyl Propyl Sulfonic acid co-polymer (AA/AMPS), 39% Active Ingredient.
- Phosphono-Phosphino-maleic acid co-polymer (PPMC), 40 %, Active Ingredient.
- Polycarboxylate (Sodium Salt), (PC), 45 %, Active Ingredient.

The result presented that AA/AMPS co-polymer was more effective in scale protection than PPMC and Polycarboxylate. The effective curves were shown in Fig. 4.11 and 4.12.



300 ppm Calcium, 300 ppm TA, 15 ppm PO<sub>4</sub>  
pH 8.9, 60°C, 40 hrs.

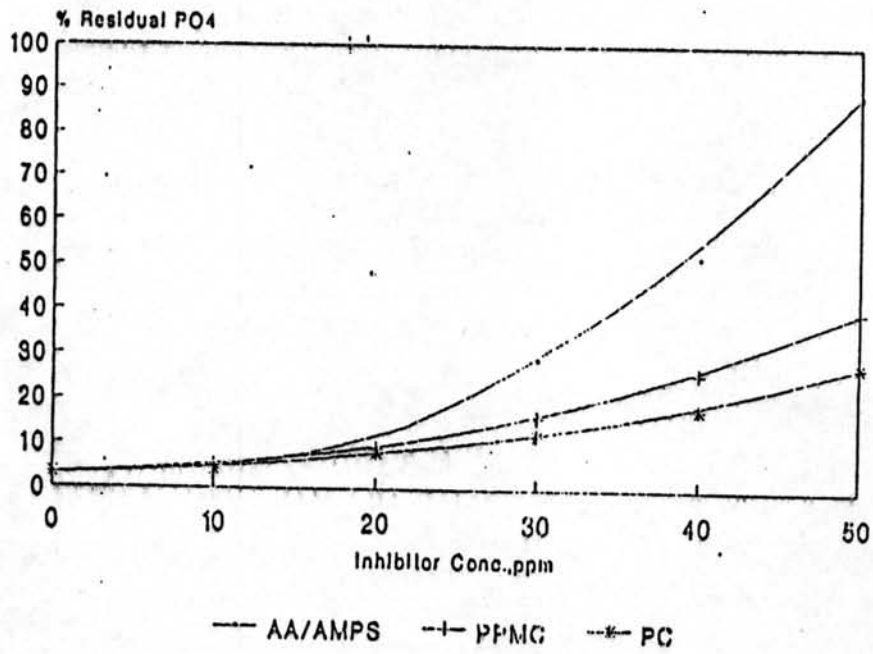


Fig. 4.11 Calcium Phosphate Static Test

250 ppm Calcium, 250 ppm TA, 10 ppm PO<sub>4</sub>  
pH 8.7, 60°C, 40 hrs.

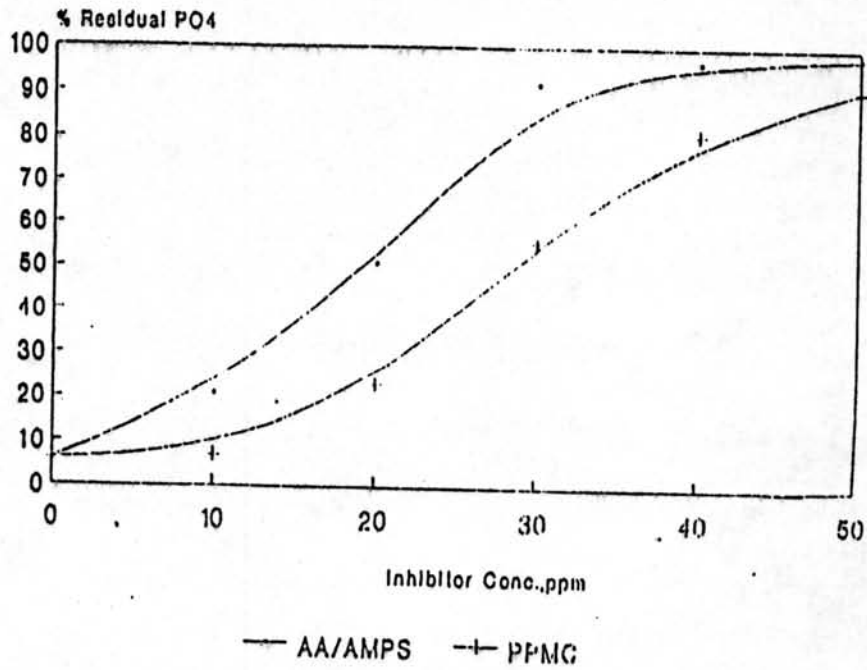


Fig. 4.12 Calcium Phosphate Static Test

## Model on Cooling Tower System

The static test was done by simulating the water just like as the plant condition in EGAT. Sodium hexametaphosphate was chosen to inhibit the calcium carbonate scale because it was high efficiency and low price. However, the SHMP was used as scale inhibitor since 1970, but its effect couldn't apply to control calciumphosphate scale, especially beyond highly cycle of concentration. The calcium phosphate scale was mainly the problem which consequently affected many problems, such as being unable to control highly cycle of concentration, pH adjustment. These conditions caused scale and corrosion problem. The problem was thus deleted if the calciumphosphate scale was inhibited, and the experiment of calcium phosphate stabilizer showed that AA/AMPS-co-polymer was inhibited the calcium phosphate scale completely.

With all controlled conditions, it formed that Sodium hexameta phosphate + Acrylic-2-Acrylamido-2-Methyl propyl sulfonic acid co-polymer (SHMP + AA/AMPS) were suitable to apply as inhibitors.

The simulation on the cooling tower system at Mae Moh Power Plant included the following 3 experiments; Test No.1 used old treatment program of Mae Moh Power Plant, test No.2 used SHMP and PPMC co-polymer and test No.3 used SHMP and AA/AMPS co-polymer. The conditions of the experiments were shown in Table 4.1.

Table 4.1 Condition of model cooling tower system

System volume	20	l
Recirculation rate	5	l/min
Different temperature	10 <sup>o</sup>	C
Evaporation loss	5.17	l/hr
Cycle of concentration	6	
Bleed off + Drift loss	1.03	l/hr
Make-up water	6.2	l/hr

Each experiment took one month period. Water quality during the test (average) was shown in Table 4.2. The results of all tests were carried out at the same cycle of concentration which was controlled about 6.

The results were shown in Table 4.3, Fig. 4.13 to 4.34 that test No.1, used the old treatment program, had the highest corrosion rate of mild steel (17.05 mpy) and couldn't control scale deposition. The LPR probe and aluminium brass heat exchanger tubes were fouled with calcium phosphate scale. The test No.2, using SHMP and PPMC co-polymer, also had high corrosion rate of mild steel (5.16 mpy) and couldn't control scale deposition either. The calcium phosphate scale deposition on cooling tower, was found at the LPR probe and aluminium brass heat exchanger tubes. The best results were shown

Table 4.2 Results of water analysis in Model Cooling Tower System

PARAMETERS	Test 1	Test 2	Test 3
pH	8.6±0.6%	8.8±1.3%	8.6±0.7
Conductivity (us/cm)	1593±19%	1457±27%	1570±26%
Turbidity (ppm as Kaolin)	1.2±41%	1.0±41%	2.2±65%
Total Alkalinity (ppm as CaCO <sub>3</sub> )	209±10%	266±15%	228±%12
Total Hardness (ppm as CaCO <sub>3</sub> )	551±8%	477±16%	543±21%
Calcium Hardness (ppm as CaCO <sub>3</sub> )	285±9%	292±8%	276±12
Inorganic Phosphate (ppm PO <sub>4</sub> )	3.1±23%	8.0±28%	13.8±19%
Organic Phosphate (ppm PO <sub>4</sub> )	2.3±17%	-	-
ppm Inhibitor (product basis)	34±17%	-	-
H/E Temp. diff.,C	9.25±5%	7.0±7%	9.4±7%
Cycle of conc. (Calculate from Silica)	6.0±8%	6.2±8%	6.2±4%

Table 4.3 Results of corrosion and deposit in Model Cooling Tower System

PARAMETERS	Test 1	Test 2	Test 3
1. Coupon test piece.			
1.1 Mild steel			
- Corrosion rate (mpy)	17.05	5.16	2.46
- Deposit	corrosion product (Fig. 4.18)	corrosion product (Fig. 4.25)	corrosion product (Fig. 4.31)
- Corrosion type	under deposit	under deposit	under deposit
1.2 Copper/Nickel			
- Corrosion rate (mpy)	N.D.	0.008	N.D.
2. LPR-probe (on-line monitoring)			
2.1 Corrosion rate	6.34±36%	2.17±89%	2.62±42%
2.2 Deposit	corrosion product (Fig. 4.17)	corrosion product (Fig. 4.24)	corrosion product (Fig. 4.34)
2.3 Scale	Scale $\text{Ca}_3(\text{PO}_4)_2$ (Fig. 4.17)	Scale $\text{Ca}_3(\text{PO}_4)_2$ (Fig. 4.23)	Scale $\text{Ca}_3(\text{PO}_4)_2$ (Fig. 4.33)



Table 4.3 Continued

PARAMETERS	Test 1	Test 2	Test 3
3. Aluminium brass heat exchanger tube			
3.1 Scale	hard scale Most composition Ca and PO <sub>4</sub> (Fig.4.15, 4.16)	hard scale Most composition Ca and PO <sub>4</sub> (Fig.4.21, 4.22)	N.D. (Fig. 4.29, 4.30)
3.2 Deposit	hard deposit  (Fig. 4.15, 4.16)	hard deposit  (Fig. 4.21, 4.22)	lignite ash can easy removable (Fig. 4.29, 4.30)
3.3 Corrosion	pitting (Fig. 4.15	N.D. (Fig. 4.21	N.D. (Fig.4.30)

N.D. = Not Detectable

for the test No.3, using SHMP and AA/AMPS co-polymer. It had corrosion rate of mild steel less than 5 mpy (about 2.46 mpy) and no scale deposition on LPR probe and Al/Brass heat exchanger tubes.

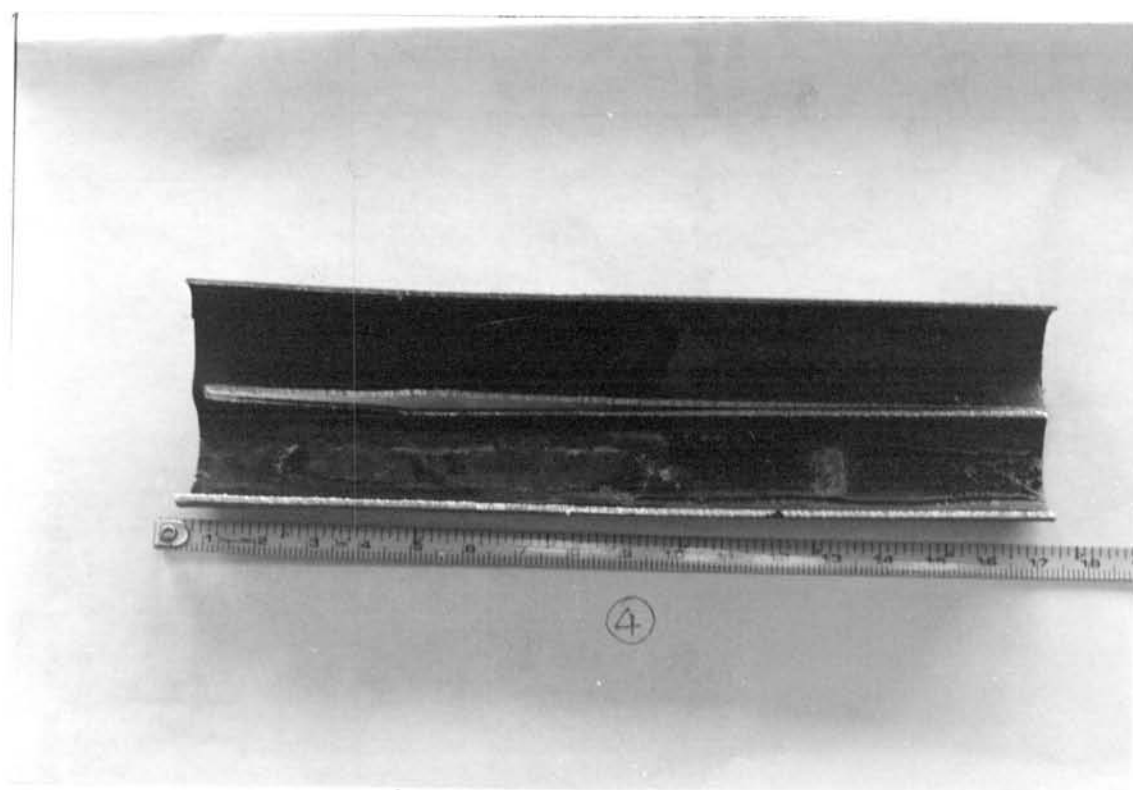


Fig. 4.13 The scale deposition on non treatment program

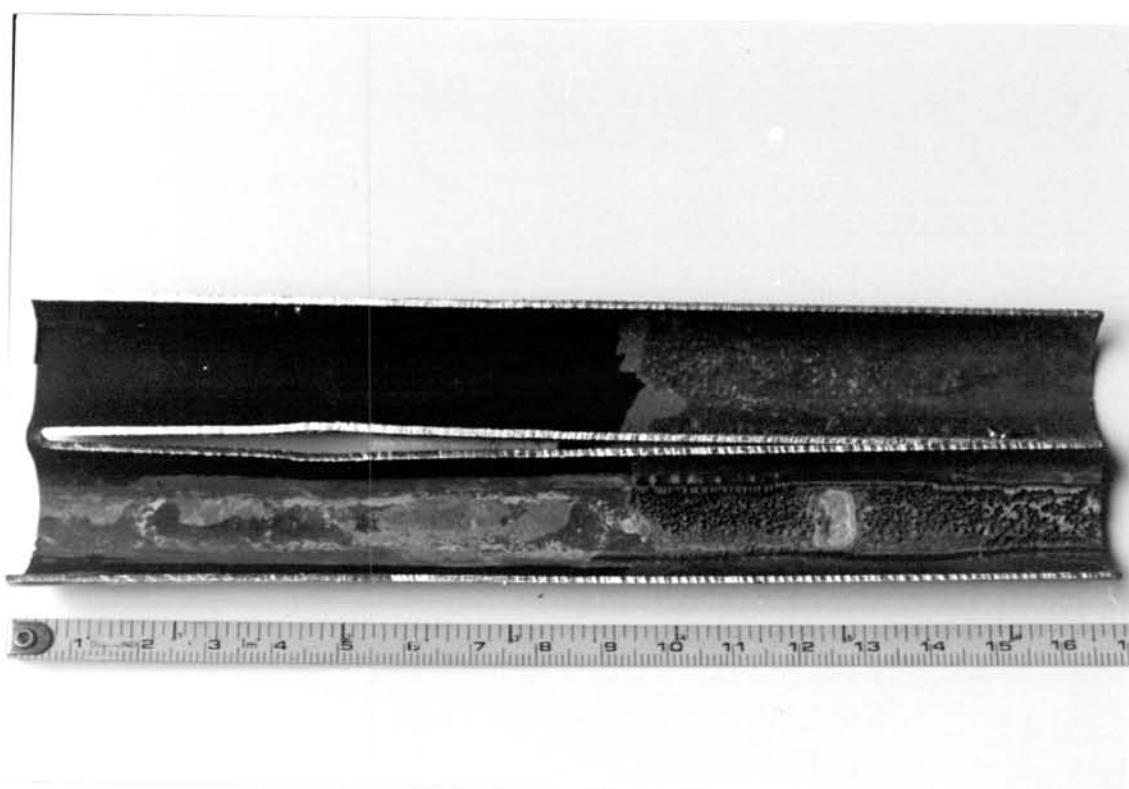


Fig. 4.14 The heat exchanger tube on non treatment program

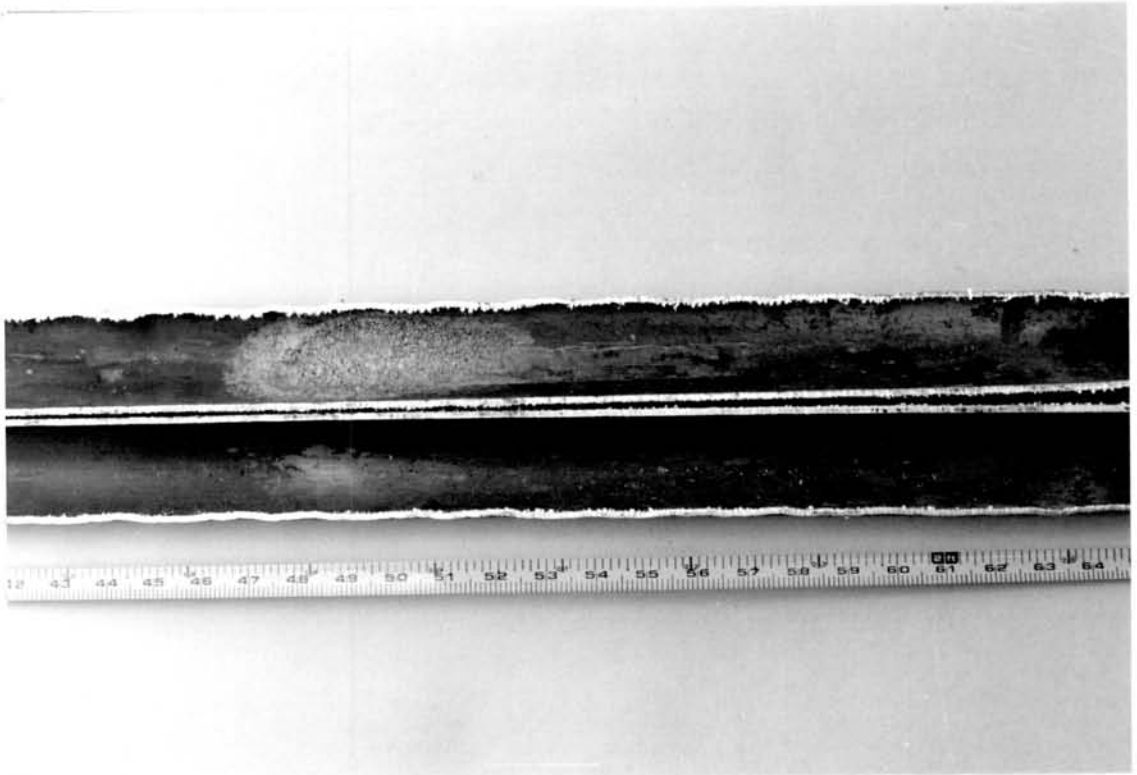


Fig. 4.15 The heat exchanger tube on test No.1

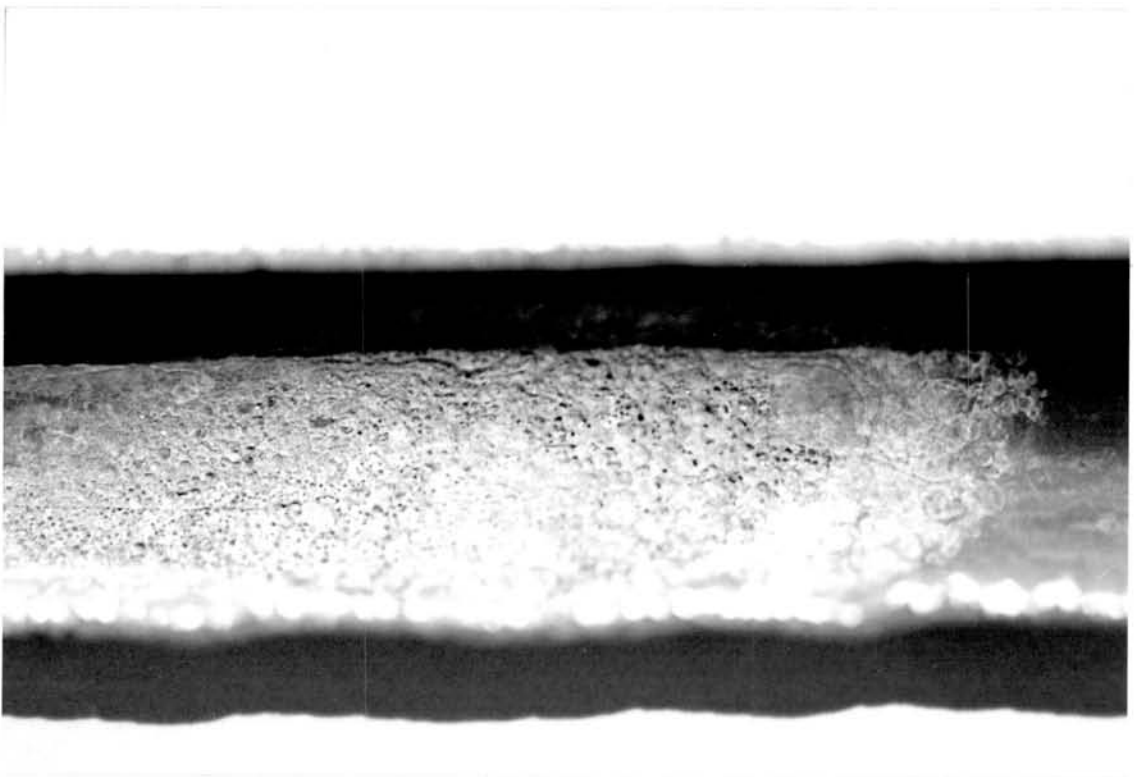


Fig. 4.16 The scale deposition on test No.1

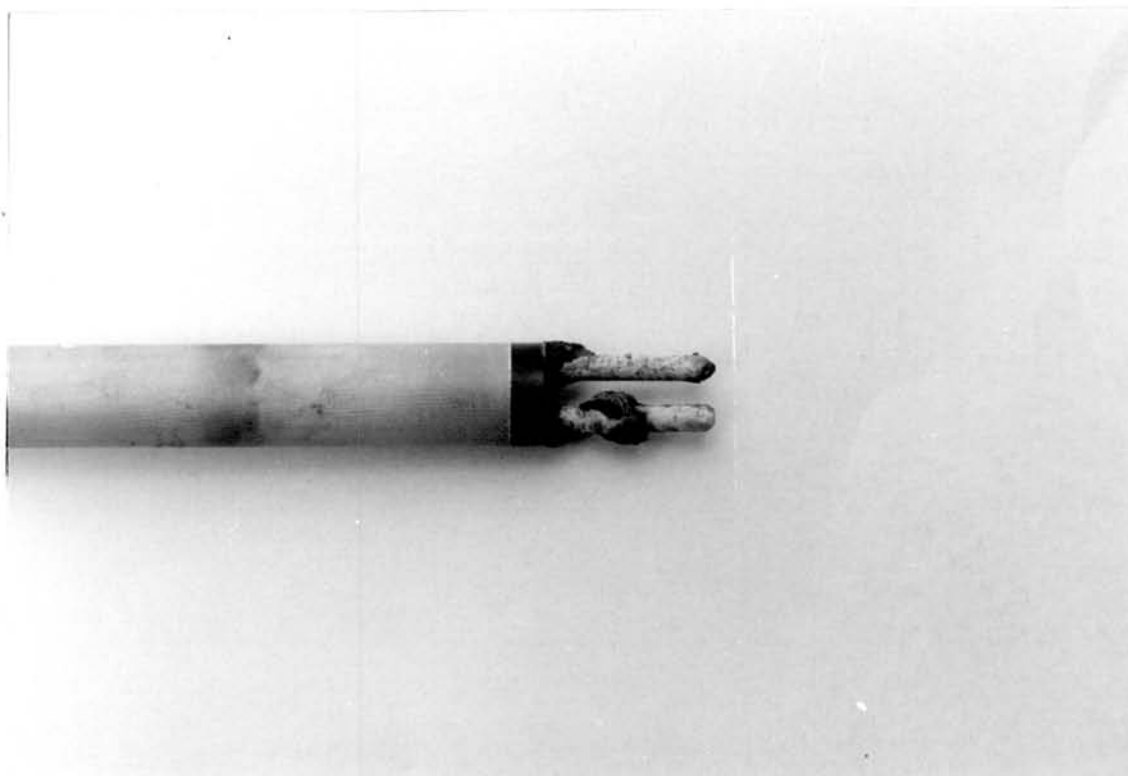


Fig. 4.17 The corrosion meter probe (mild steel) on test No.1.

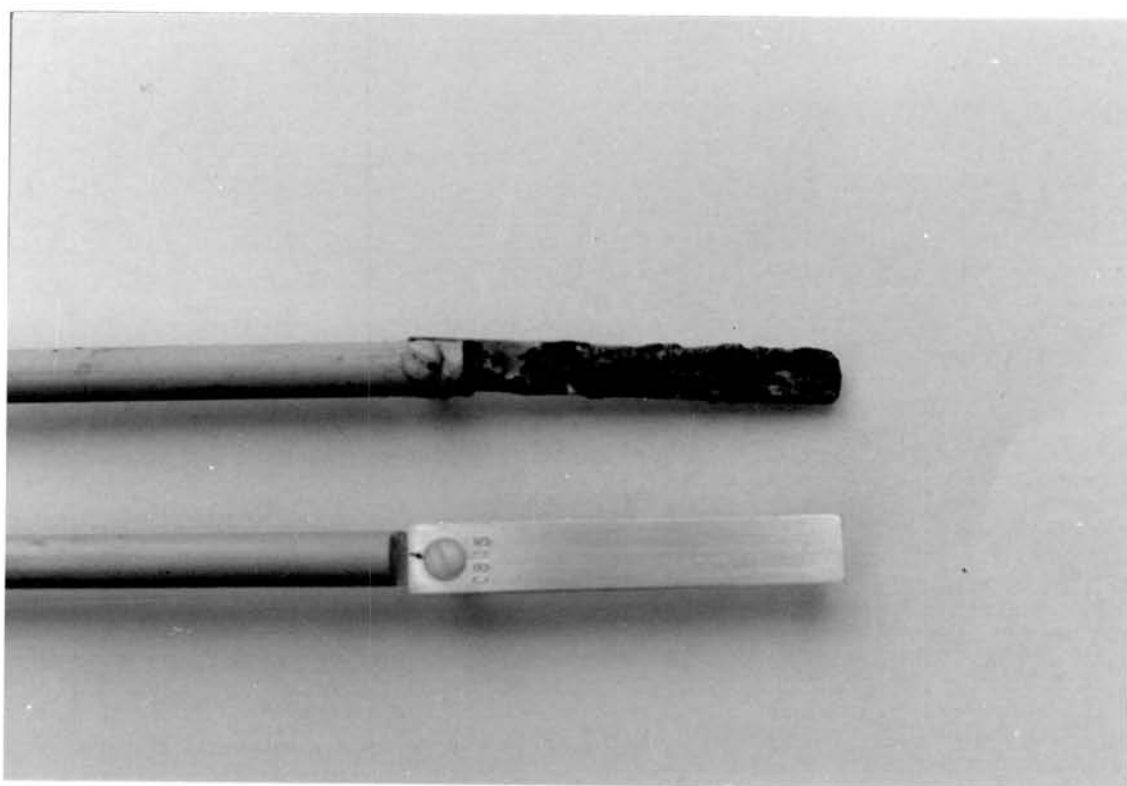


Fig. 4.18 The coupon (mild steel, Cu/Ni) before cleaning on test No.1.

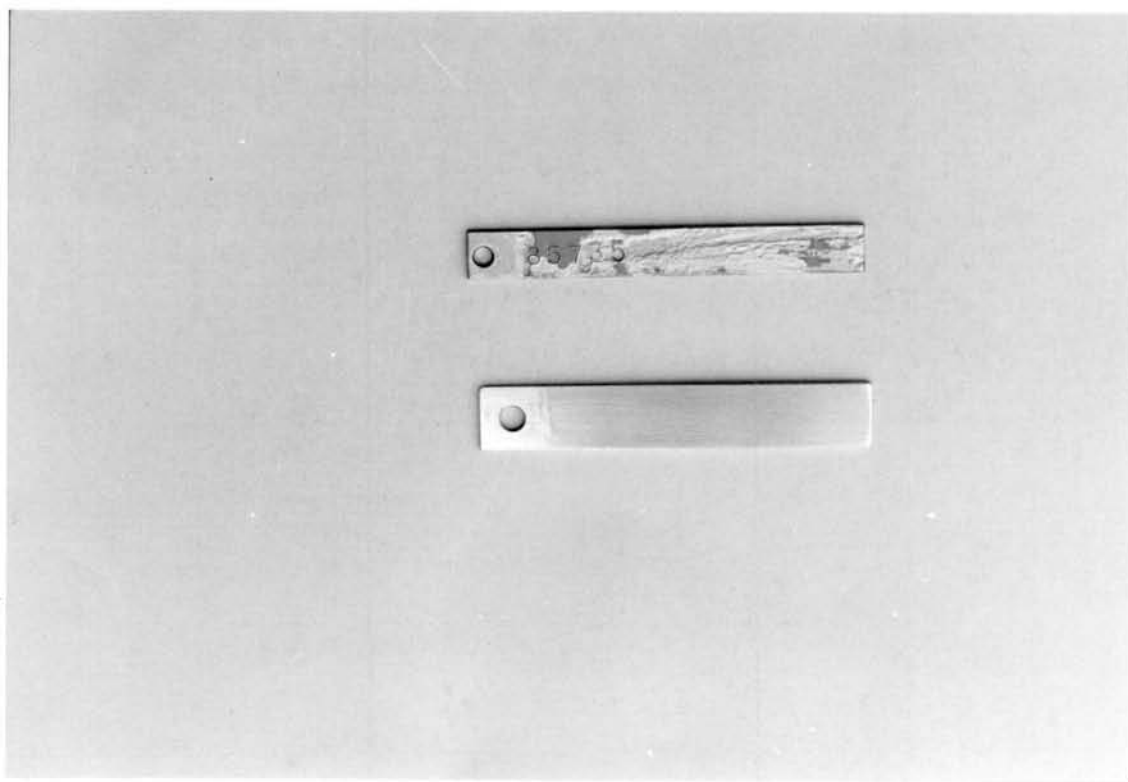


Fig. 4.19 The Coupon (mild steel, Cu/Ni) after cleaning on test No.1.

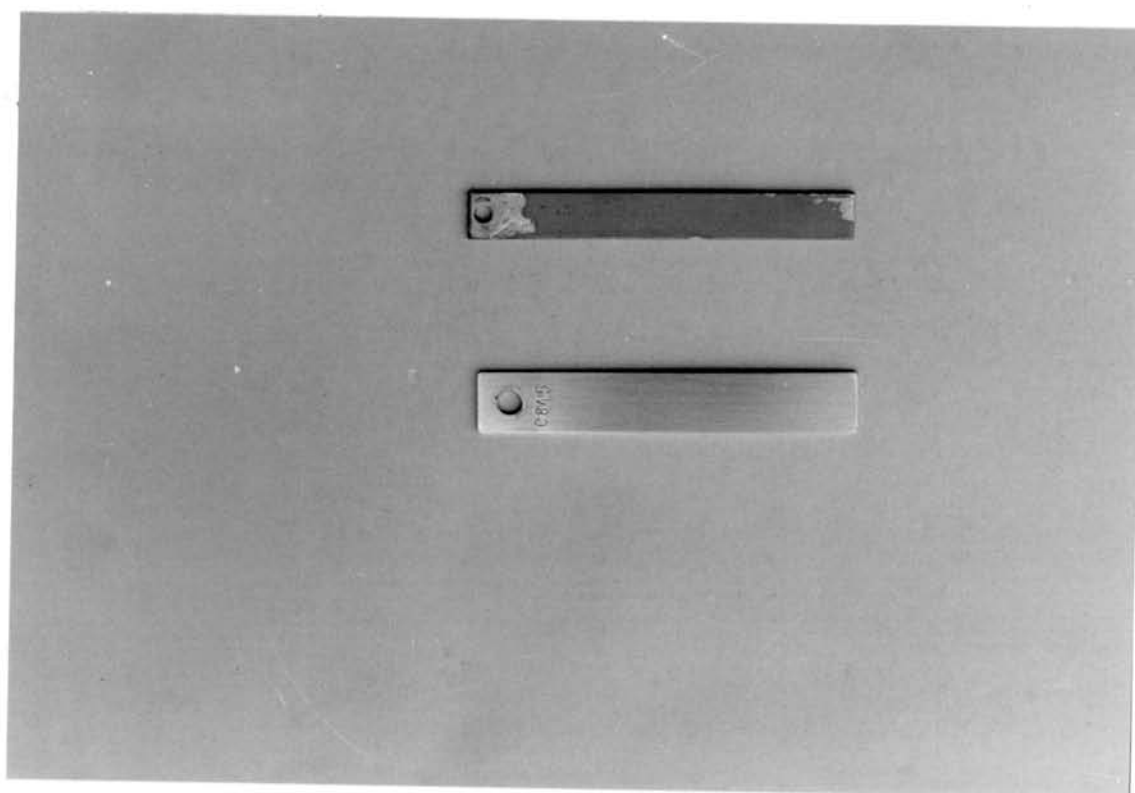


Fig. 4.20 The Coupon (mild steel, Cu/Ni) after cleaning on test No.1.



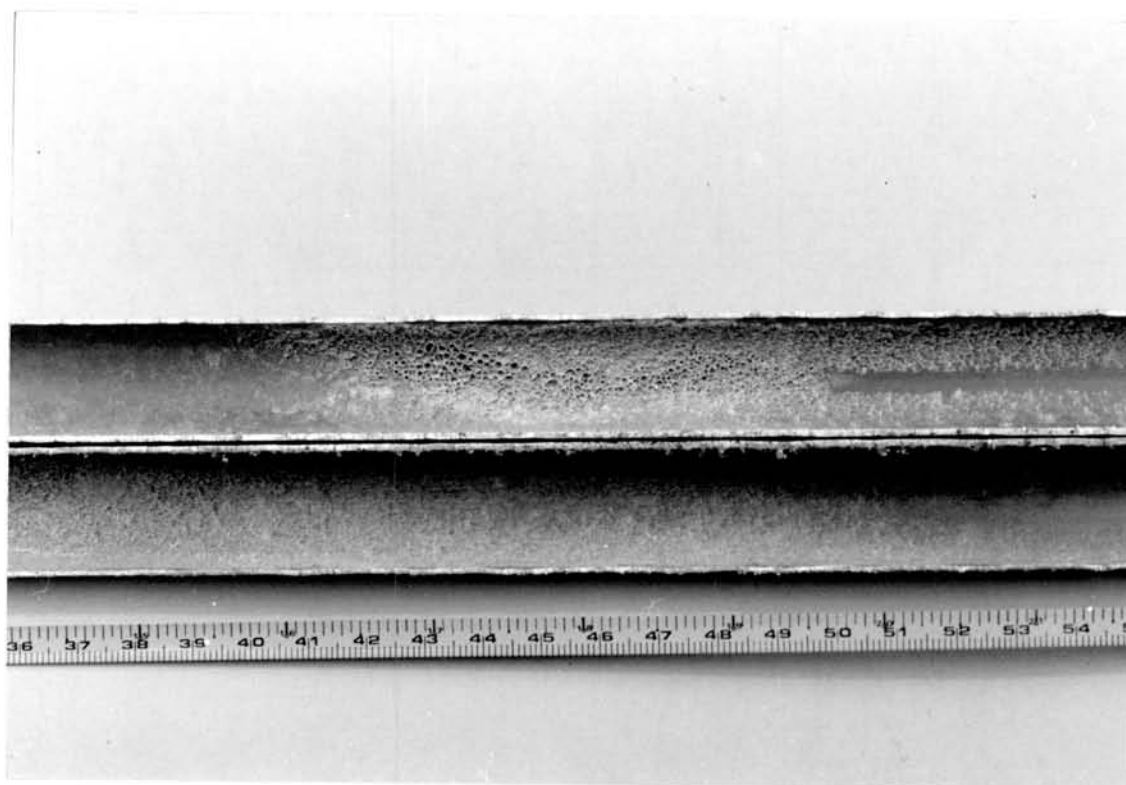


Fig. 4.21 The heat exchanger tube on test No.2 (PPMC).

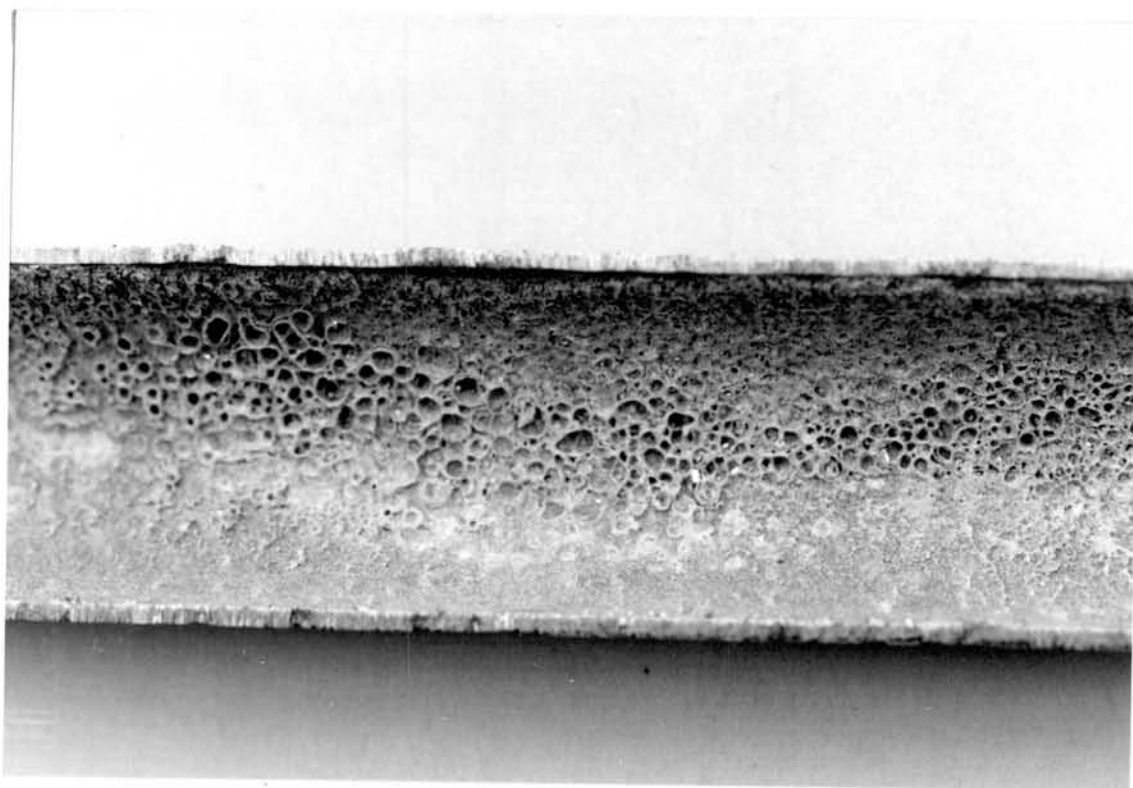


Fig. 4.22 The scale deposit on heat exchanger tube on test No.2 (PPMC).

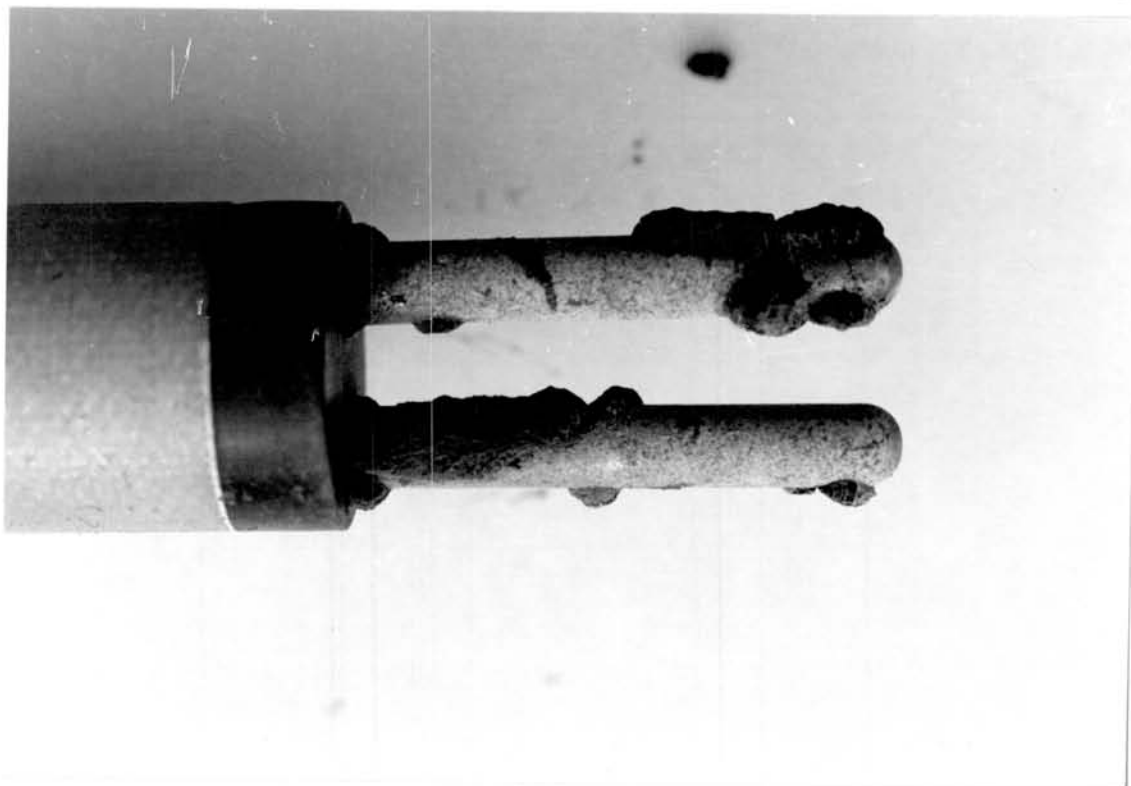


Fig. 4.23 The corrosion meter probe (mild steel)  
on test No.2 (SHMP + PPMC).

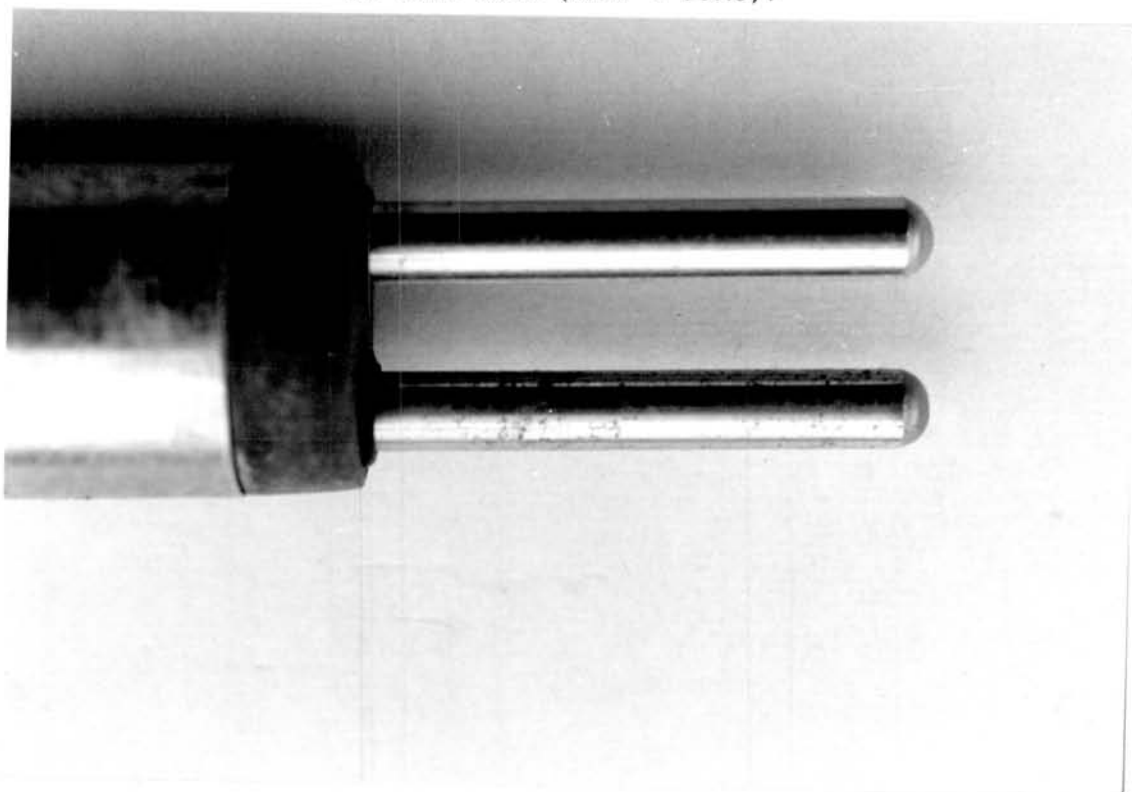


Fig. 4.24 The corrosion meter probe (Cu/Ni) on test No.2  
(SHMP + PPMC)

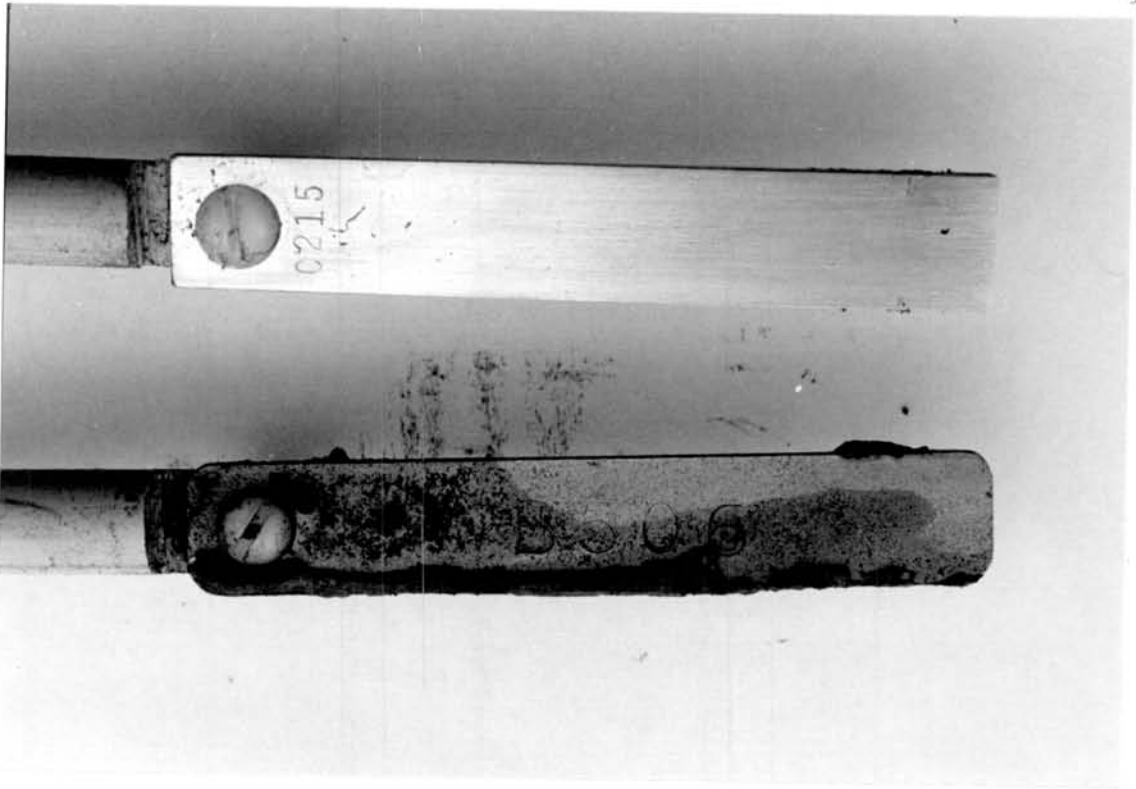


Fig. 4.25 The coupon (Cu/Ni and mild steel) before cleaning on test No.2 (SHMP + PPMC).

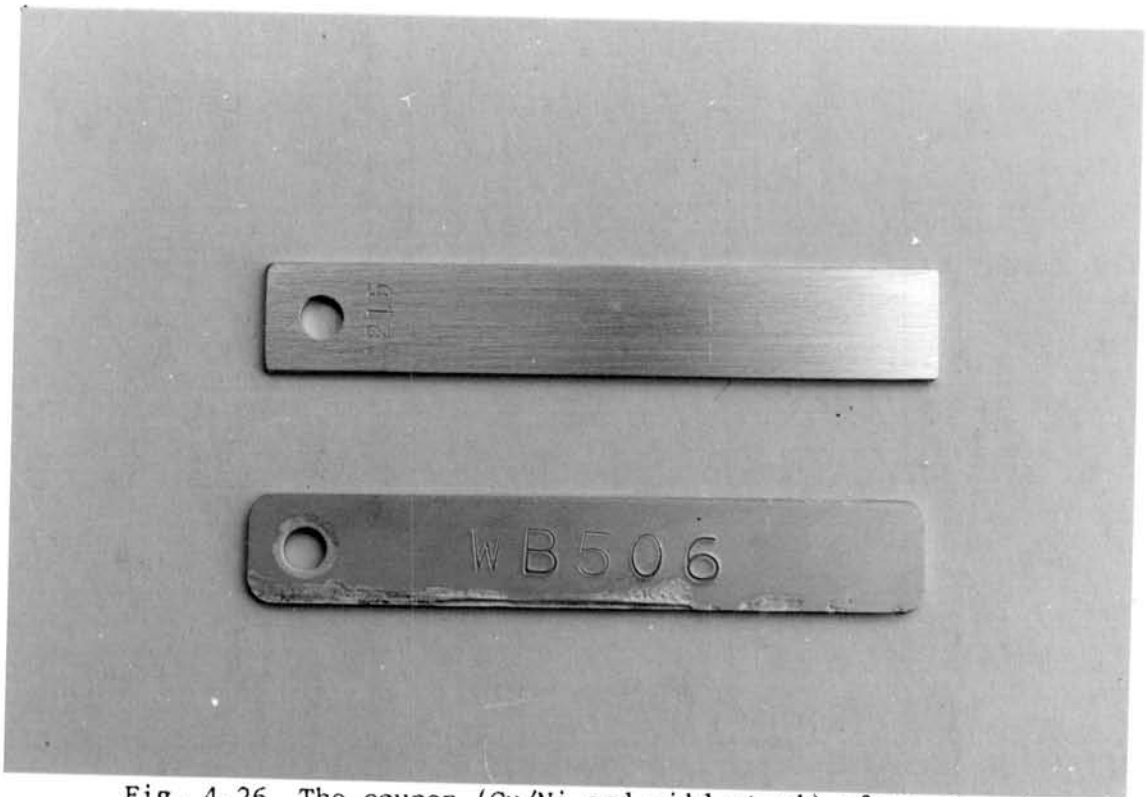


Fig. 4.26 The coupon (Cu/Ni and mild steel) after cleaning on test No.2 (SHMP + PPMC).

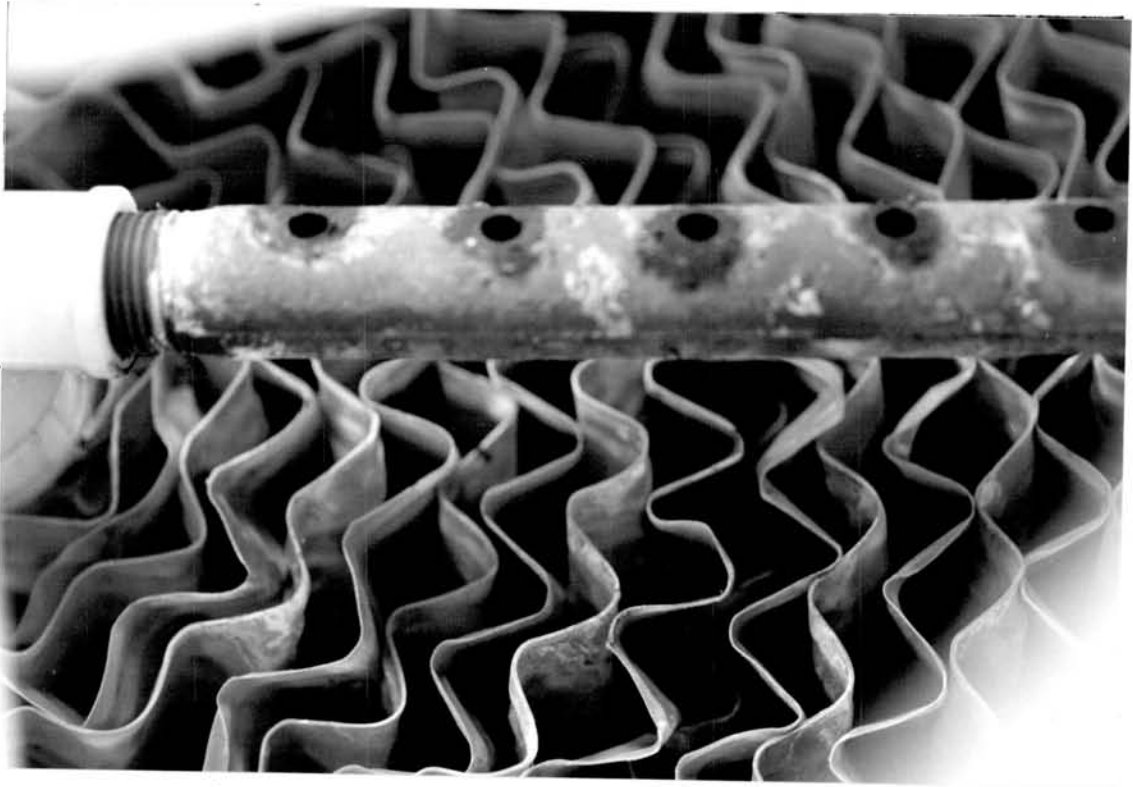


Fig 4.27 The scale deposit on cooling tower on test No.2 (SHMP + PPMC).

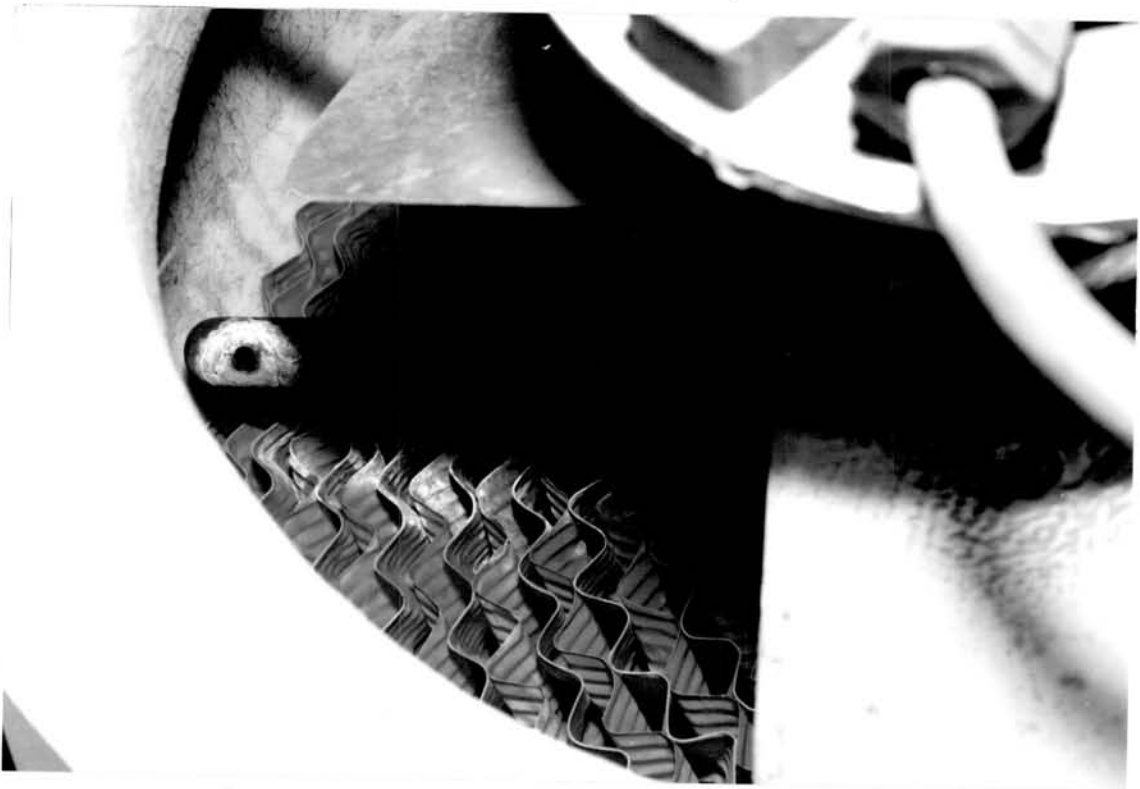


Fig. 4.28 The scale deposit on cooling tower on test No.2

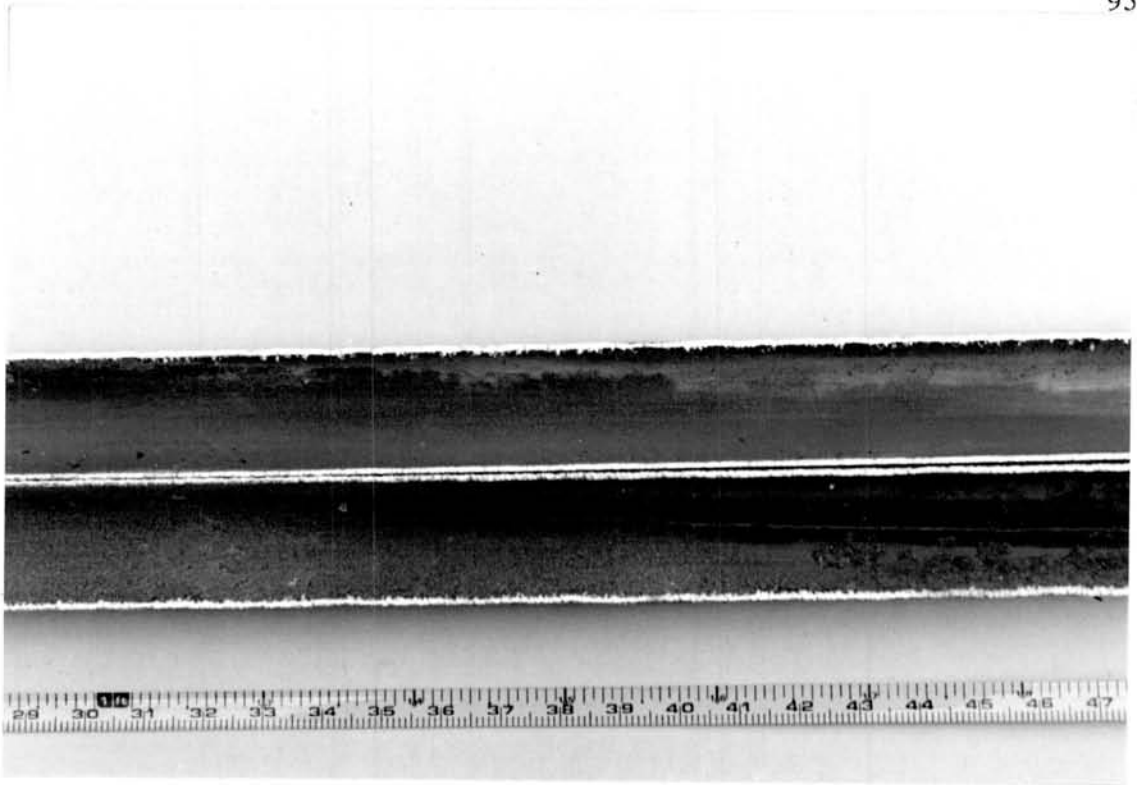


Fig. 4.29 The heat exchanger tube on test No.3 (SHMP + AA/ AMPS).

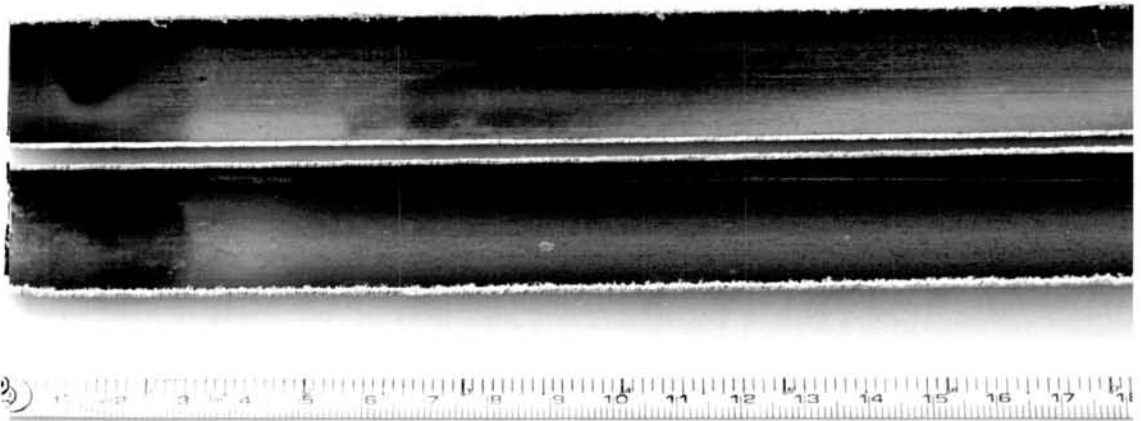


Fig. 4.30 The heat exchanger tube before cleaning  
on test No.3 (SHMP + AA/ AMPS).





Fig. 4.31 The coupon (mild steel) before cleaning  
on test No.3 (SHMP + AA/AMPS).

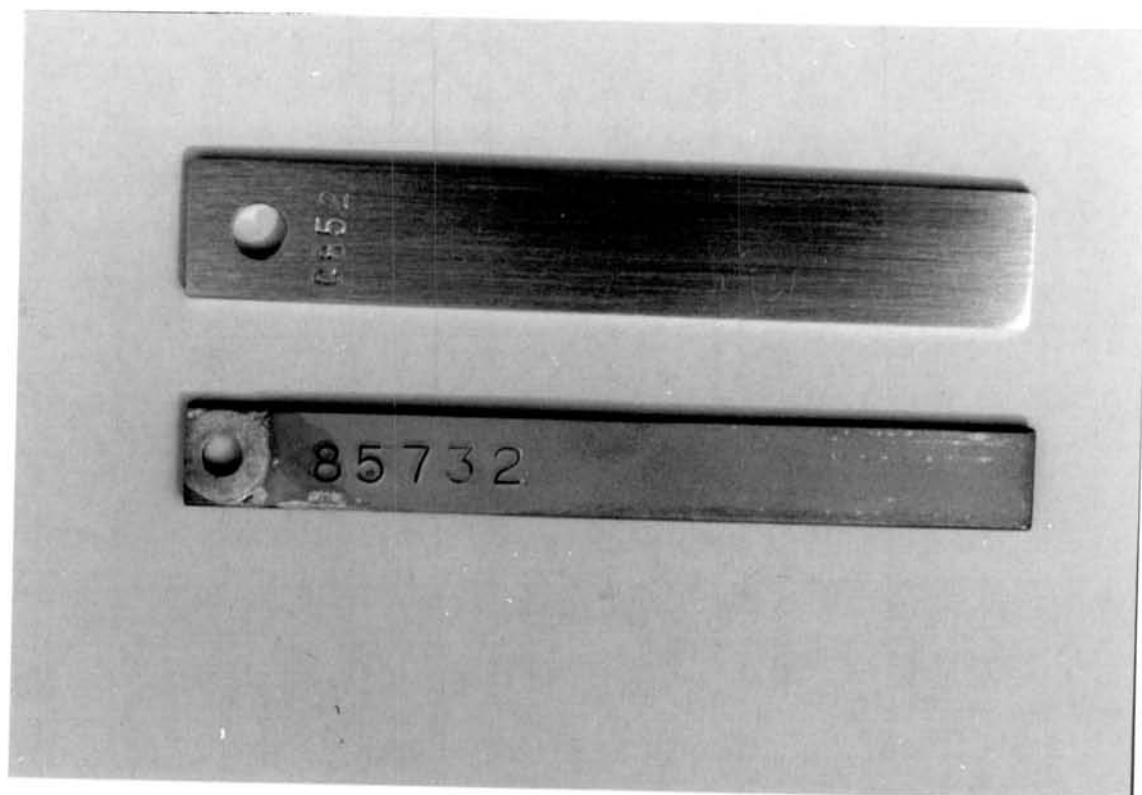


Fig. 4.32 The coupon after cleaning on test No.3 (SHMP + AA/AMPS).

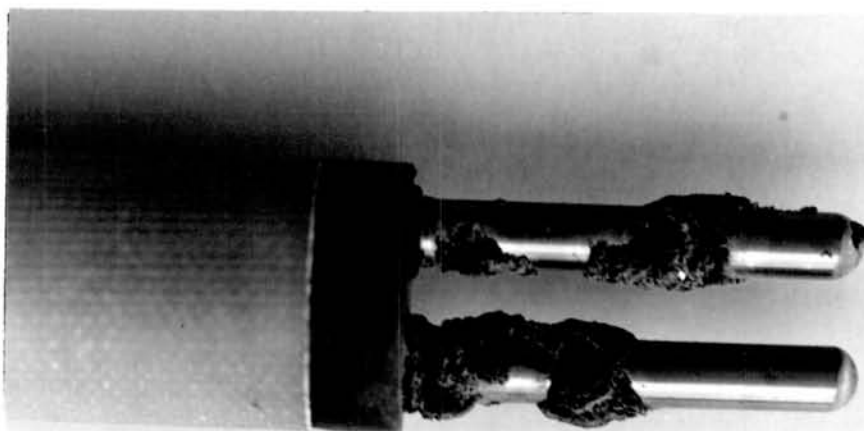


Fig. 4.33 The corrosion meter probe (mild steel) before cleaning on test No.3 (SHMP + AA/AMPS).

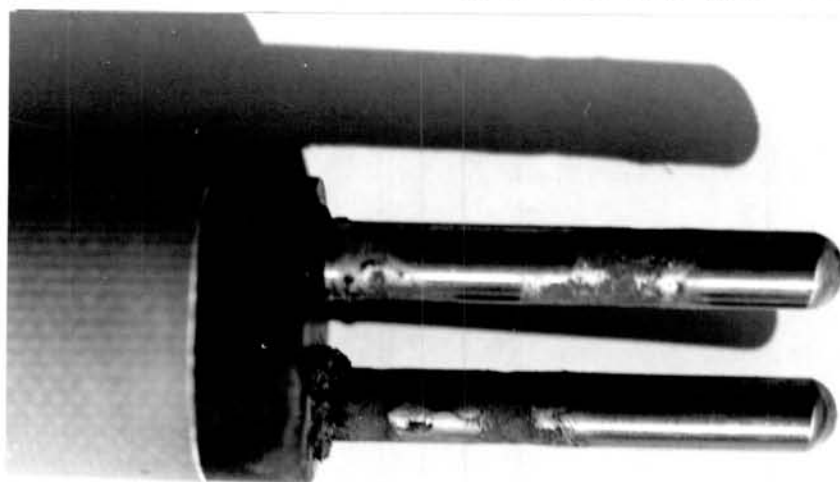


Fig. 4.34 The corrosion meter probe (mild steel) after cleaning on test No.3 (SHMP + AA/AMPS).