CHAPTER III

E X P E R I M E N T A L

EXPERIMENTAL

(A) General

Samples of standard metals and alloys can be used for carrying out the experiments in different waters and in conditions of differing variables.

For the purpose of present investigation, mild steel has been chosen for assessing the impact of various waters on the extent of corrosion. The mild steel used for the experimental work conformed with the IS-1079, 10 S.W.G. standards. It was taken in the form of sheets manufactured by the steel authority of India Ltd., The chemical composition of the mild steel sample was as follows:

C	.. .	0.09 %
S	....	0.03 %
Mn	....	0.31 %
Si	....	0.03 %
P	....	Traces
Fe	....	Remainder

(B) Preparation of Specimen:

A number of rectangular specimen of definite size was cut out from the specified sheet of mild steel, by shearing machine and the edges were ground properly to ensure uniformity. In keeping with the norms prescribed by Protevin (113), edges of the specimen were taken care of. The size and shape of the specimen yielded low edge area ratio and made to have a reasonably large area. The rectangular specimens were pickled in a bath of concentrated HCl containing 20 g/l of Sb_2O_3 and 1 g/l of $SnCl_2$ to remove any mil-scale adhering the metal surface. They were burnished first lengthwise followed by breadth wise, with IS grit 60, 80, 100, 120, 180 and 240 untill the surface assumed a smooth and even look. They were polished well to free them from pits and scratches and then degreased with acetone by swabbing with cotton. The specimens were weighed accurately.

The following specifications for the mild steel samples were maintained:

Length	.....	5.092 cms
Width	.....	2.954 cms
Thickness	.....	0.300 cms
Diameter of the hole	..	0.400 cms

Shape	.....	Rectangular
Density	.....	7.8 g/cm^3

(C) Waters selected for the study:

Waters from different 'Plants' of the G.S.F.C., Baroda were specially picked up for the study.

I Cooling water Ammonia Plant

II Cooling Water Caprolactam Plant

III Cooling Water Urea Plant

IV Cooling Water Ammonium Sulphate Plant

V Makeup Water

All the waters were analysed for the following:

1. pH
2. Total dissolved solids in p.p.m.
3. P.Alkalinity in p.p.m.
4. M.Alkalinity in p.p.m.
5. Total Alkalinity in p.p.m.
6. Total Hardness in p.p.m.
7. Calcium Hardness in p.p.m.
8. Chloride in p.p.m.
9. Phosphate in p.p.m.
10. Sulphate in p.p.m.

11. Ammonical Nitrogen in p.p.m.
12. Total Nitrogen in p.p.m.
13. Turbidity in p.p.m.
14. Nitrate in p.p.m.
15. Conductivity in micromhos

The various waters from different 'plants' of the G.S.F.C. (courtsey) were collected and stored for the general study of the impact of the inhibitors, since the waters used, in the plants would vary in their characteristics every day as no standardization of waters before putting them to the use as cooling waters, is normally done. Hence, the 'stored' waters will atleast ensure the identical analysis of waters treated and studied under this investigation. The purpose of a direct comparison and evaluation of the impact of the various inhibitors under identical conditions thus has been well served.

However, the storing capacity, as well as the 'estimate' for'once storing' being low, after studying three inhibitors, a fresh lot of water was required to be stored. Thus, three different collections of waters from different plants at different time of the year were made over the span of about twenty months. Each collection has been fully analysed. They were designated as:

C I Benzotriazole
Corobit-EPA-529
Aquacid-105 (H.E.D.P.)

C II Diammonium hydrogen orthophosphate

CIII Aquacid-105 (H.E.D.P.)+ Diammonium hydrogen orthophosphate

Waters : their analyses are given accordingly.

Table 18

(C) ANALYSIS : COOLING WATER AMMONIA PLANT : I

Characteristics	Results
pH	7.39
Total dissolved solids p.p.m.	827
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	100
Total Alkalinity as $CaCO_3$ p.p.m.	100
Total Hardness as $CaCO_3$ p.p.m.	280
Calcium Hardness p.p.m.	110
Chloride as $Cl^{'}$ p.p.m.	94
Phosphate as $PO_4^{''}$ p.p.m.	4.1
Sulphate as $SO_4^{''}$ p.p.m.	640
Ammonical Nitrogen p.p.m.	14
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	8
Nitrate as $NO_3^{'}$ p.p.m.	106
Conductivity in micromhos	1445

Table 19

(C) ANALYSIS : COOLING WATER CAPROLACTAM PLANT : I

Characteristics	Results
pH	8.07
Total dissolved solids p.p.m.	1140
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	150
Total Alkalinity as $CaCO_3$ p.p.m.	150
Total Hardness as $CaCO_3$ p.p.m.	920
Calcium Hardness p.p.m.	450
Chloride as $Cl^{'}$ p.p.m.	190
Phosphate as $PO_4^{'''}$ p.p.m.	62
Sulphate as $SO_4^{''}$ p.p.m.	238
Ammonical Nitrogen p.p.m.	8
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	23
Nitrate as $NO_3^{'}$ p.p.m.	Not analysed
Conductivity micromhos	1445

Table 20

(C) ANALYSIS : COOLING WATER UREA PLANT : I

Characteristics	Results
pH	7.55
Total dissolved solids p.p.m.	1760
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	92
Total Alkalinity as $CaCO_3$ p.p.m.	92
Total Hardness as $CaCO_3$ p.p.m.	492
Calcium Hardness p.p.m.	228
Chloride as $Cl^{'}$ p.p.m.	121
Phosphate as $PO_4^{'''}$ p.p.m.	7
Sulphate as $SO_4^{''}$ p.p.m.	490
Ammonical Nitrogen p.p.m.	56
Total Nitrogen p.p.m.	127
Turbidity p.p.m.	230
Nitrate as $NO_3^{'}$ p.p.m.	221
Conductivity micromhos	2248

Table 21

(C) ANALYSIS : COOLING WATER AMMONIUM SULPHATE PLANT:I

Characteristics	Results
pH	7.23
Total dissolved solids p.p.m.	746
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	24
Total Alkalinity as $CaCO_3$ p.p.m.	24
Total Hardness as $CaCO_3$ p.p.m.	170
Calcium Hardness as p.p.m.	88
Chloride as $Cl^{'}$ p.p.m.	43
Phosphate as $PO_4^{'''}$ p.p.m.	1
Sulphate as $SO_4^{''}$ p.p.m.	190
Ammonical Nitrogen p.p.m.	25
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	13
Nitrate as $NO_3^{'}$ p.p.m.	182
Conductivity micromhos	964

Table 22

(C) ANALYSIS : MAKEUP WATER : I

Characteristics	Results
pH	7.7
Total dissolved solids p.p.m.	372
P.Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	212
Total Alkalinity as $CaCO_3$ p.p.m.	212
Total Hardness as $CaCO_3$ p.p.m.	152
Calcium Hardness p.p.m.	64
Chloride as Cl' p.p.m.	41
Phosphate as PO_4''' p.p.m.	Traces
Sulphate as SO_4'' p.p.m.	Traces
Ammonical Nitrogen p.p.m.	14
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	10
Nitrate as NO_3' p.p.m.	Traces
Conductivity micromhos	458

Table 23

(C) ANALYSIS : COOLING WATER AMMONIA PLANT : II

Characteristics	Results
pH	7.07
Total dissolved solids p.p.m.	602
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	68
Total Alkalinity as $CaCO_3$ p.p.m.	68
Total Hardness as $CaCO_3$ p.p.m.	208
Calcium Hardness p.p.m.	84
Chloride as Cl' p.p.m.	86
Phosphate as PO_4''' p.p.m.	5
Sulphate as SO_4'' p.p.m.	108
Ammonical Nitrogen p.p.m.	6
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	6
Nitrate as NO_3' p.p.m.	Not analysed
Conductivity micromhos	1050

Table 24

(C) ANALYSIS : COOLING WATER CAPROLACTAM PLANT : II

Characteristics	Results
pH	6.96
Total dissolved solids p.p.m.	1234
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	16
Total Alkalinity as $CaCO_3$ p.p.m.	16
Total Hardness as $CaCO_3$ p.p.m.	344
Calcium Hardness p.p.m.	160
Chloride as Cl' p.p.m.	110
Phosphate as PO_4''' p.p.m.	8
Sulphate as SO_4'' p.p.m.	314
Ammonical Nitrogen p.p.m.	Traces
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	10
Nitrate as NO_3' p.p.m.	Not analysed
Conductivity micromhos	1490

Table 25

(C) ANALYSIS : COOLING WATER UREA PLANT : II

Characteristics	Results
pH	8.10
Total dissolved solids p.p.m.	1878
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	750
Total Alkalinity as $CaCO_3$ p.p.m.	750
Total Hardness as $CaCO_3$ p.p.m.	104
Calcium Hardness p.p.m.	50
Chloride as $Cl^{'}$ p.p.m.	55
Phosphate as $PO_4^{'''}$ p.p.m.	1.5
Sulphate as $SO_4^{''}$ p.p.m.	588
Ammonical Nitrogen p.p.m.	533
Total Nitrogen p.p.m	Not analysed
Turbidity [illegible] p.p.m.	964
Nitrate as $NO_3^{'}$ p.p.m.	Not analysed
Conductivity micromhos	7700

Table 26

(C) ANALYSIS: COOLING WATER AMMONIUM SULPHATE PLANT :II

Characteristics	Results
pH	7.47
Total dissolved solids p.p.m.	448
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	62
Total Alkalinity as $CaCO_3$ p.p.m.	62
Total Hardness as $CaCO_3$ p.p.m.	152
Calcium Hardness p.p.m.	60
Chloride as Cl' p.p.m.	32
Phosphate as PO_4''' p.p.m.	Traces
Sulphate as SO_4'' p.p.m.	86
Ammonical Nitrogen p.p.m.	Traces
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	Less than 5
Nitrate as NO_3' p.p.m.	Not analysed
Conductivity micromhos	780

Table 27

(C) ANALYSIS : MAKEUP WATER : II

Characteristics	Results
pH	7.73
Total dissolved solids p.p.m.	268
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p .p.m.	412
Total Alkalinity as $CaCO_3$ p.p.m.	412
Total Hardness as $CaCO_3$ p.p.m.	70
Calcium Hardness as $CaCO_3$ p.p.m.	26
Chloride as Cl' p.p.m.	40
Phosphate as PO_4''' p.p.m.	Traces
Sulphate as SO_4'' p.p.m.	6
Ammonical Nitrogen p.p.m.	Traces
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	9
Nitrate as NO_3' p.p.m.	Not analysed
Conductivity micromhos	610

Table 28

(C) ANALYSIS : COOLING WATER AMMONIA PLANT : III

Characteristics	Results
pH	7.76
Total dissolved solids p.p.m.	932
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	420
Total Alkalinity as $CaCO_3$ p.p.m.	420
Total Hardness as $CaCO_3$ p.p.m.	280
Calcium Hardness p.p.m.	100
Chloride as $Cl^{'}$ p.p.m.	160
Phosphate as $PO_4^{'''}$ p.p.m.	2
Sulphate as $SO_4^{''}$ p.p.m.	56
Ammonical Nitrogen p.p.m.	5
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	6
Nitrate as $NO_3^{'}$ p.p.m.	Not analysed
Conductivity micromhos	1000

Table 29

(C) ANALYSIS : COOLING WATER CAPROLACTAM PLANT: III

Characteristics	Results
pH	7.29
Total dissolved solids p.p.m.	1280
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	120
Total Alkalinity as $CaCO_3$ p.p.m.	120
Total Hardness as $CaCO_3$ p.p.m.	925
Calcium Hardness p.p.m.	457
Chloride as $Cl^{'}$ p.p.m.	227
Phosphate as $PO_4^{'''}$ p.p.m.	66
Sulphate as $SO_4^{''}$ p.p.m.	246
Ammonical Nitrogen p.p.m.	6
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	20
Nitrate as $NO_3^{'}$ p.p.m.	Not analysed
Conductivity micromhos	2000

Table 30

(C) ANALYSIS : COOLING WATER UREA PLANT : III

Characteristics	Results
pH	6.70
Total dissolved solids p.p.m.	1274
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	90
Total Alkalinity as $CaCO_3$ p.p.m.	90
Total Hardness as $CaCO_3$ p.p.m.	390
Calcium Hardness p.p.m.	190
Chloride as $Cl^{'}$ p.p.m.	200
Phosphate as $PO_4^{'''}$ p.p.m.	5
Sulphate as $SO_4^{''}$ p.p.m.	328
Ammonical Nitrogen p.p.m.	17
Total Nitrogen p.p.m.	112
Turbidity p.p.m.	96
Nitrate as $NO_3^{'}$ p.p.m.	Not analysed
Conductivity micromhos	2300

Table 31

(C) ANALYSIS : COOLING WATER AMMONIUM SULPHATE PLANT :III

Characteristics	Results
pH	8.37
Total dissolved solids p.p.m.	510
P. Alkalinity as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	220
Total Alkalinity as $CaCO_3$ p.p.m.	220
Total Hardness as $CaCO_3$ p.p.m.	196
Calcium Hardness p.p.m.	88
Chloride as $Cl^{'}$ p.p.m.	55
Phosphate as $PO_4^{'''}$ p.p.m.	1
Sulphate as $SO_4^{''}$ p.p.m.	18
Ammonical Nitrogen p.p.m.	Traces
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	Not analysed
Nitrate as $NO_3^{'}$ p.p.m.	Not analysed
Conductivity micromhos	900

Table 32

(C) ANALYSIS : MAKEUP WATER : III

Characteristics	Results
pH	7.7
Total dissolved solids p.p.m.	372
P. Alkanility as $CaCO_3$ p.p.m.	Nil
M. Alkalinity as $CaCO_3$ p.p.m.	212
Total Alkalinity as $CaCO_3$ p.p.m.	212
Total Hardness as $CaCO_3$ p.p.m.	152
Calcium Hardness p.p.m.	64
Chloride as Cl' p p.m.	41
Phosphate as PO_4''' p.p.m.	Traces
Sulphate as SO_4'' p.p.m.	Traces
Ammonical Nitrogen p.p.m.	14
Total Nitrogen p.p.m.	Not analysed
Turbidity p.p.m.	10
Nitrate as NO_3' p.p.m.	Traces
Conductivity micromhos	458

(D) Inhibitors selected for the study:

I - Benzotriazole (Gharda Chemicals Private Limited, Dombivali) in concentrations (% Wt/Vol.) of 0.1, 0.2, 0.5, 1 and 2.

II - Corobit EPA-529 (Ashok Industries, Worli, Bombay-400 018) in concentrations (% Vol/Vol.) of 0.1, 0.2, 0.5, 1, 2 and 5.

III - Aquacid-105 (H.E.D.P.) (Aquapharm Chemical Co., Pune-411 026) in concentrations (% Vol/Vol) of 0.1, 0.2, 0.5, 1, 2 and 5.

IV - Diammonium hydrogen orthophosphate GR Grade (Sarabhai M. Chemicals, Baroda) in concentrations (% Wt/Vol) of 0.1, 0.2, 0.5, 1 and 2.

V - Mixture of Aquacid - 105 (% Vol / Vol). Diammonium hydrogen orthophosphate (% Wt/Vol.) in combination of 0.1 + 0.1, 0.1 + 0.5, 0.1 + 1, 5 + 0.1, 5 + 0.5 and 5 + 1.

(E) Procedure:

The weight loss method was employed. The general procedure was the same for all waters taken for study.

The water was taken in a corning glass beaker of 250 ml. capacity. Water was filled up to 2 cms below the brim. Each specimen was suspended 1.0 cm below water level and 1.0 cm above the bottom of beaker maintaining the same depth. The volume of the water for all the experiments was 230 ml. Only one specimen was immersed in each beaker. For blank as well as for concentrations of the waters containing inhibitors, the pH and conductivity were measured first. The condition of experiment was stagnant. Experiments were performed in triplicate, however, only mean values of the results have been recorded. The beakers were kept in a double walled asbestos frame thermostatically controlled cupboard with an automatic arrangement for regulating temperature. Inside the cupboard, the lamps were covered with proper system in order to avoid any effect of light. The temperature was kept at 35°C $\pm$ 1°C. A few ml of distilled water were added every alternate day to compensate for the losses due to evaporation. On conclusion of experiments, the coupons were removed from the beakers. Simple visual observations with a magnifying glass (X 6) were made. Then they were cleaned mechanically using nylon bristle brush using scouring agent vim. They were then washed with water, immersed in acetone and dried with Rosella brand tissue

paper and weighed. Thus weight loss was determined. Corrosion rate in mils per year and percentage inhibitor efficiency were calculated.

$$\text{Mils per year (mpy)} = \frac{\text{Weight loss in miligram x 534}}{\text{A x D x T}}$$

A = Exposed surface Area (in^2)

D = Density of exposed metal (g/cm^3)

T = Time in hour

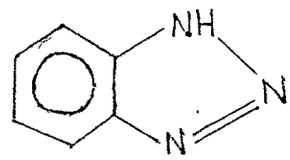
$$\text{\% Inhibitor Efficiency} = \frac{\text{Corrosion rate uninhibited} - \text{Corrosion rate inhibited}}{\text{Corrosion rate uninhibited}} \times 100$$

(F) OBSERVATIONS AND RESULTS

F.I. - BENZOTRIAZOLE

BENZOTRIAZOLE

Structure :



Formula : $C_6H_5N_3$

Molecular weight	: 119.12
Appearance	: Off white to light yellow powder
Specific gravity (100°C/25°C)	: 1.19
Assay	: 98.0 % Min.
Moisture	: 0.5 % Max.
Ash	: 0.5 % Max.

Table 33

COOLING WATER AMMONIA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : Stagnant

Inhibitor : Benzotriazole

% inhibitor Wt/Vol	Corrosion rate (Mpy) No. of days exposure				pH Initial	pH After Exposure (No.of days)				Conductivity m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	1.41	1.14	1.80	2.77	7.39	8.26	7.62	8.40	8.33	1445	-	-	-	-
0.1	0.084	0.031	0.023	0.024	7.19	5.50	4.95	6.61	7.24	1365	94.04	97.28	98.72	99.13
0.2	0.092	0.030	0.031	0.014	7.03	5.99	5.91	6.90	7.20	1365	93.48	97.37	98.28	99.49
0.5	0.078	0.039	0.033	0.018	6.71	5.82	5.67	6.57	6.88	1365	94.47	96.58	98.17	99.35
1	0.075	0.043	0.153	0.109	6.52	5.80	5.58	6.43	6.70	1365	94.68	96.23	91.50	96.06
2	0.139	0.063	0.015	0.005	6.30	5.69	5.42	6.23	6.52	1365	90.14	94.47	99.17	99.82

Table 34

COOLING WATER CAPROLACTAM PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : Stagnant

Inhibitor : Benzotriazole

% inhibitor Wt/Vol	Corrosion rate (Mpy) No. of days exposure				pH Initial	pH After Exposure (No. of days)				Conductivity m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.61	4.19	3.06	2.76	8.07	8.36	7.94	7.73	7.09	1445	-	-	-	-
0.1	2.53	2.48	2.30	2.44	7.13	7.59	7.72	7.88	8.07	1445	29.92	40.81	24.84	11.59
0.2	2.49	2.39	2.08	1.97	6.91	7.32	7.38	7.52	7.67	1445	31.02	42.96	32.03	28.62
0.5	1.73	1.73	1.51	1.25	6.76	6.96	6.97	7.12	7.22	1445	52.08	58.71	50.65	54.71
1	1.43	1.35	1.18	0.86	6.67	6.70	6.71	6.81	6.85	1445	60.39	67.78	61.44	68.84
2	1.34	1.06	0.81	0.61	6.44	6.50	6.48	6.54	6.60	1445	62.88	74.70	73.52	77.90

Table 35

COOLING WATER UREA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : Stagnant

Inhibitor : Benzotriazole

% Inhibitor Wt/Vol	Corrosion rate (Mpy) No.of days Exposure				pH Initial After Exposure (No. of days)					Conductivity m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	6.56	4.89	5.35	4.04	7.55	8.37	8.25	8.14	7.12	2248	-	-	-	-
0.1	2.25	2.41	2.45	2.91	7.18	7.56	7.62	7.69	7.68	2248	65.70	50.72	54.21	27.97
0.2	2.32	2.10	2.31	2.22	6.95	7.31	7.39	7.53	7.48	2248	64.63	57.06	56.82	45.05
0.5	1.91	1.74	1.72	1.61	6.73	6.96	7.04	7.30	7.20	2248	70.88	64.42	67.85	60.15
1	1.74	1.50	1.09	1.01	6.47	6.71	6.81	7.02	6.97	2248	73.48	69.33	79.63	75.00
2	1.75	1.28	0.66	0.53	6.30	6.47	6.58	6.76	6.72	2248	73.32	73.82	87.66	86.88

Table 36

COOLING WATER AMMONIUM SULPHATE PLANT

Material: Mild Steel IS 1079 — Quantity of C.W : 230 ml

Exposed Surface Area : 6.33 in^2 — Temperature : 35°C ± 1°C

Density : 7.8 g/cm^3 — Condition : Stagnant

Inhibitor : Benzotriazole

% Inhibitor Wt/Vol.	Corrosion rate (Mpy) No. of days exposure				pH Initial	pH After Exposure (No. of days)				Conductivity m.mhos	% Inhibitor Efficiency No. of days (Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.61	4.81	4.41	4.06	7.23	8.17	7.41	8.01	7.55	964	-	-	-	-
0.1	2.00	2.40	1.98	2.13	6.83	6.36	6.25	7.15	7.00	964	64.35	50.10	55.10	47.54
0.2	1.88	1.80	1.53	1.67	6.72	6.17	6.06	6.89	6.68	964	66.49	62.58	65.31	58.87
0.5	1.98	1.71	1.16	1.16	6.17	5.96	5.58	6.62	6.40	964	64.71	64.45	73.70	71.43
1	2.31	2.01	1.10	0.55	6.02	5.82	5.56	6.37	6.10	964	58.82	58.21	75.06	86.45
2	2.04	1.82	1.22	0.61	5.92	5.70	5.45	6.24	5.95	964	63.64	62.16	72.34	84.98

Table 37

MAKEUP WATER

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Benzotriazole

% Inhi-bitor Wt/Vol	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.40	4.04	3.46	3.75	7.70	8.30	8.30	8.40	8.48	458	-	-	-	-
0.1	2.49	1.89	2.87	2.99	7.26	7.82	7.93	7.99	8.29	458	53.89	53.22	17.05	20.27
0.2	2.59	1.98	2.30	2.68	7.22	7.52	7.63	7.78	8.02	458	52.04	50.99	33.53	28.53
0.5	1.60	1.20	1.43	1.48	6.95	7.10	7.20	7.26	7.42	458	70.37	70.30	58.67	60.57
1	1.01	0.60	0.59	0.53	6.87	6.83	6.91	6.97	7.06	458	81.30	85.15	82.95	85.87
2	0.66	0.28	0.18	0.11	6.62	6.63	6.68	6.67	6.83	458	87.78	93.07	94.80	97.07

F- II - COROBIT EPA - 529

COROBIT EPA - 529

High Molecular Weight complex organoamine phosphonate + Dispersing Agent

Appearance	: Light yellow clear liquid
Specific Gravity	: 1.27
pH	: 10
Organophosphonate	: 25 % Active Content
Sequestering value	: 300 mg of Calcium / gm

Table 38

COOLING WATER AMMONIA PLANT

Material : Mild Steel IS 1079

Exposed Surface area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Corobit EPA-529

% Inhibitor Vol/Vol.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	1.41	1.14	1.80	2.77	7.39	8.26	7.62	8.40	8.33	1445	-	-	-	-
0.1	Nil	0.024	0.034	0.063	7.87	7.81	8.20	8.05	7.91	1767	100	97.89	98.11	97.73
0.2	0.084	0.022	0.019	0.010	8.10	8.08	8.29	8.28	8.07	2088	94.04	98.07	98.94	99.64
0.5	0.088	0.037	0.017	0.023	8.49	8.71	8.74	8.77	8.84	3332	93.76	96.75	99.06	99.17
1	0.070	0.073	0.276	0.011	8.76	8.81	8.73	9.02	9.04	6424	95.04	93.60	84.67	99.60
2	0.405	0.401	0.708	0.715	9.07	9.24	9.00	9.09	9.29	8833	71.28	64.82	60.67	74.19
5	0.676	1.12	2.390	3.670	9.64	9.78	9.36	8.99	9.45	16863	52.06	1.75	N*	N*

N* - Negative

Table 39

COOLING WATER CAPROLACTAM PLANT

Material : Mild Steel IS 1079 | Quantity of C.W. : 230 ml

Exposed Surface Area : 6.33 in^2 | Temperature : 35°C ± 1°C

Density : 7.8 g/cm^3 | Condition : stagnant

Inhibitor : Corobit EPA-529

% Inhibitor Vol/Vol	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.61	4.19	3.06	2.76	8.07	8.36	7.94	7.73	7.09	1445	-	-	-	-
0.1	0.93	0.78	0.51	0.42	7.53	8.41	8.35	8.48	8.59	1767	74.24	81.38	83.33	84.78
0.2	1.19	0.81	0.55	0.50	7.54	8.49	8.47	8.52	8.66	1887	67.04	80.67	82.03	81.88
0.5	3.20	3.31	3.88	3.36	7.99	8.88	8.62	8.87	9.04	3132	11.33	21.00	N*	N*
1	2.24	1.87	3.70	4.09	8.73	8.80	8.86	9.10	9.12	4818	37.95	55.37	N*	N*
2	2.33	1.74	2.14	4.25	9.48	9.06	8.92	9.15	9.38	8833	35.46	58.47	30.07	N*
5	2.26	1.65	3.41	2.66	10.07	9.60	9.30	9.57	9.58	15257	37.40	60.62	N*	3.62

* Negative

Table 40

COOLING WATER UREA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Corobit EPA-529

% Inhibitor Vol/Vol	Corrosion rate (Mpy)				pH					Conductivity m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	6.56	4.89	5.35	4.04	7.55	8.37	8.25	8.14	7.12	2248	-	-	-	-
0.1	1.41	0.92	0.74	0.59	7.43	8.17	8.13	8.03	8.13	2329	78.51	81.19	85.98	85.40
0.2	1.74	1.11	0.69	0.54	7.44	8.24	8.23	8.10	8.17	2570	73.48	77.30	87.10	86.63
0.5	2.48	2.34	1.04	0.62	7.62	8.42	8.45	8.30	8.43	3854	62.20	52.15	80.56	84.65
1	2.05	1.77	3.20	3.84	8.09	8.43	8.53	8.81	8.99	5300	68.75	63.80	40.19	04.97
2	1.76	1.37	1.62	3.92	8.62	8.62	8.60	8.93	9.33	8833	73.17	71.98	69.72	01.97
5	1.94	1,26	1.40	6.48	9.41	9.17	8.99	8.85	10.15	16060	70.43	74.23	73.83	N*

* Negative

Table 41

COOLING WATER AMMONIUM SULPHATE PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1 °C

Condition : stagnant

Inhibitor : Corobit EPA-529

% Inhibitor Vol/Vol	Corrosion rate (Mpy)				pH					Conductivity m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.61	4.81	4.41	4.06	7.23	8.17	7.41	8.01	7.55	964	-	-	-	-
0.1	1.66	1.18	0.81	0.45	7.29	7.96	8.09	8.04	7.52	1365	70.41	75.47	81.63	88.92
0.2	2.30	1.22	0.89	0.46	7.37	8.22	8.22	8.25	8.04	1847	59.00	74.64	79.82	88.67
0.5	2.79	2.84	2.79	2.63	8.47	8.39	8.67	8.85	8.77	3132	50.27	40.96	36.73	35.22
1	2.03	1.62	2.30	2.45	9.08	8.63	8.61	9.05	8.94	4818	63.81	66.32	47.85	39.66
2	2.07	1.65	1.72	2.14	9.76	9.14	8.79	8.85	9.22	8030	63.10	65.70	61.00	47.29
5	2.37	1.48	1.54	2.55	10.29	9.77	9.34	9.44	9.45	17666	57.75	69.23	65.08	37.19

Table 42

MAKEUP WATER

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Corobit EPA-529

% Inhibitor Vol/Vol.	Corrosion rate (Mpy)				pH					Conductivity m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.40	4.04	3.46	3.75	7.70	8.30	8.30	8.40	8.48	458	-	-	-	-
0.1	2.32	1.65	1.15	2.51	7.78	8.78	8.86	9.04	8.77	843	57.04	59.16	66.76	33.07
0.2	3.50	2.95	4.41	3.28	8.30	8.70	8.77	8.95	8.82	1325	35.19	26.98	N*	12.53
0.5	2.99	2.75	4.53	2.47	9.02	9.11	8.92	9.01	8.89	2529	44.63	31.93	N*	34.13
1	2.63	2.24	2.72	2.28	9.52	9.12	9.10	9.15	9.00	4256	51.30	44.55	21.39	39.20
2	3.28	2.01	2.75	2.93	10.00	9.35	9.02	9.30	9.16	8030	39.26	50.25	20.52	21.87
5	2.45	2.49	2.90	3.85	10.38	9.71	9.26	9.49	9.56	13651	54.63	38.37	16.18	N*

* N - Negative

pH Aquacid - 105 (Blank)	0.33
Density	1.330 g/cm^3/28.8°C
pH Corobit EPA-529 (Blank)	10.40
Density	1.284 g/cm^3/28.5°C

BENZOTRIAZOLE

D.M. Water (Blank) pH	6.4
0.1 % Wt/Vol. Benzotriazole	5.5
0.2 % " "	5.42
0.5 % " "	5.36
1 % " "	5.35
2 % " "	5.30

F - III AQUACID - 105 (H. E. D. P.)

AQUACID-105

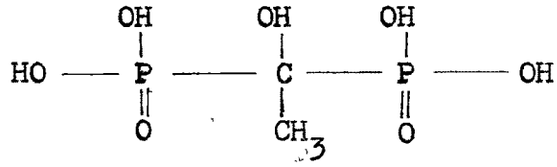
1)	Name	1-Hydroxy Ethylidene-1-1-Diphosphonic acid
2)	Abbrevation	HEDP
3)	Structure	
4)	Mol.Wt.	206
5)	Commercial Form	Liquid
6)	Colour	Colourless to pale yellow
7)	Active content	49 - 51 %
8)	Sequestration value (mg of Ca as $CaCO_3$ per gm sequestrant)	395 - 410
9)	pH (1 % Soln.)	Less than 2
10)	Specific Gravity	1.33 - 1.37
11)	Solubility	Soluble in water Phosphoric acid, ethylene glycol, most aqueous acids and bases
12)	Chlorine stability	Contains no Nitrogen

Table 43

COOLING WATER AMMONIA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Aquacid-105 (H.E.D.P.)

% Inhibitor Vol/Vol.	Corrosion rate (Mpy)				pH					Conduc-tivity m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	1.41	1.14	1.80	2.77	7.39	8.26	7.62	8.40	8.33	1445	-	-	-	-
0.1	9.18	3.97	2.34	1.68	2.74	5.20	5.92	6.98	7.36	1927	N*	N*	N*	39.35
0.2	14.42	7.41	4.10	2.21	2.20	4.06	4.68	5.57	6.09	2489	N*	N*	N*	20.22
0.5	38.55	19.03	10.23	5.54	1.83	3.39	3.56	5.24	5.53	4818	N*	N*	N*	N*
1	74.79	36.92	14.32	7.86	1.63	3.22	3.16	4.65	2.75	8432	N*	N*	N*	N*
2	149 .09	70.17	24.39	13.01	1.42	2.81	2.70	3.43	2.18	13250	N*	N*	N*	N*
5	281.35	109.90	65.32	24.58	1.18	2.18	1.72	2.35	2.04	24090	N*	N*	N*	N*

N* - Negative

Table 44

COOLING WATER CAPROLACTAM PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : Stagnant

Inhibitor : Aquacid-105 (H.E.D.P.)

% Inhibitor Vol/Vol	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.61	4.19	3.06	2.76	8.07	8.36	7.94	7.73	7.09	1445	-	-	-	-
0.1	10.08	8.01	5.23	3.62	2.52	4.94	6.51	6.89	7.28	2811	N*	N*	N*	N*
0.2	17.23	10.37	5.46	3.78	2.41	4.78	5.35	5.56	6.23	3573	N*	N*	N*	N*
0.5	40.70	21.56	11.43	6.18	2.15	3.67	4.74	5.26	4.84	7629	N*	N*	N*	N*
1	76.17	39.37	20.02	10.50	1.97	3.22	3.76	4.53	4.63	10841	N*	N*	N*	N*
2	146.97	73.53	37.65	19.61	1.83	3.09	3.49	3.72	3.86	15659	N*	N*	N*	N*
5	273.64	103.69	51.11	29.72	1.66	2.61	2.70	2.55	2.45	32522	N*	N*	N*	N*

N* - Negative

Table 45

COOLING WATER UREA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Aquacid-105 (H.E.D.P.)

% Inhibitor Vol/Vol.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	6.56	4.89	5.35	4.04	7.55	8.37	8.25	8.14	7.12	2248	-	-	-	-
0.1	8.41	3.30	1.85	0.87	2.28	4.97	5.53	6.37	6.69	3553	N*	32.52	65.42	78.47
0.2	17.11	8.45	4.66	2.97	2.14	4.68	6.05	6.76	7.20	4015	N*	N*	12.90	26.49
0.5	36.24	19.53	9.94	5.66	1.70	3.40	4.65	5.68	6.29	8030	N*	N*	N*	N*
1	69.94	38.46	18.77	10.17	1.45	3.29	4.01	4.68	5.15	12045	N*	N*	N*	N*
2	127.23	37.91	25.84	14.04	1.32	2.86	3.04	2.73	2.73	16863	N*	N*	N*	N*
5	244.24	105.53	48.60	23.42	1.09	2.39	2.35	2.62	2.47	32120	N*	N*	N*	N*

N* - Negative

Table 46

COOLING WATER AMMONIUM SULPHATE PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Aquacid-105 (H.E.D.P.)

% Inhibitor Vol/Vol.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No.of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.61	4.81	4.41	4.06	7.23	8.17	7.41	8.01	7.55	964	-	-	-	-
0.1	10.95	7.36	5.60	4.05	2.29	4.90	6.13	6.96	7.41	2570	N*	N*	N*	0.25
0.2	19.85	10.09	5.64	4.18	2.12	4.03	5.16	6.04	7.05	3614	N*	N*	N*	N*
0.5	44.43	21.97	11.18	6.15	1.85	3.59	4.31	4.74	5.13	6826	N*	N*	N*	N*
1	81.66	51.81	20.29	10.45	1.59	3.57	3.57	4.17	4.88	11242	N*	N*	N*	N*
2	158.02	77.54	37.45	19.74	1.42	3.33	3.39	3.43	4.13	17666	N*	N*	N*	N*
5	251.17	108.85	51.33	25.34	1.20	2.67	2.50	1.97	2.20	32923	N*	N*	N*	N*

N* - Negative

Table 47

MAKEUP WATER

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g /cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor :Aquacid-105 (H.E.D.P.)

% Inhibitor Vol/Vol.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.40	4.04	3.46	3.75	7.70	8.30	8.30	8.40	8.48	458	-	-	-	-
0.1	7.04	3.91	1.83	1.20	2.59	5.44	5.40	5.70	6.40	964	N*	3.22	47.11	68.00
0.2	17.12	9.49	5.54	4.22	2.41	5.38	5.88	6.49	7.06	3011	N*	N*	N*	N*
0.5	43.98	21.62	10.66	5.61	2.19	4.19	4.60	4.85	5.65	6023	N*	N*	N*	N*
1	84.45	38.27	19.92	10.64	2.01	3.56	3.89	4.27	4.88	9636	N*	N*	N*	N*
2	158.97	72.50	37.60	20.13	1.83	3.34	3.47	3.73	4.25	16060	N*	N*	N*	N*
5	248.61	85.92	49.70	22.75	1.70	2.76	2.67	2.20	2.43	27302	N*	N*	N*	N*

N* - Negative

F-IV DI AMMONIUM HYDROGEN ORTHOPHOSPHATE (DAP)

DI AMMONIUM HYDROGEN ORTHOPHOSPHATE

Formula	$(NH_4)_2\ HPO_4$
Mol. Wt.	132.06
Make	Sarabhai M. Chemicals
Assay	98.0 -102.0%
pH on 5 % aqueous soln.	7.9 - 8.2
Insoluble matter	Max. 0.003 %
Chloride Cl'	Max. 0.0003%
Sulphate SO_4''	Max. 0.002 %
Nitrate (NO_3)	Max. 0.001 %
Arsenic (AS)	0.00005 %
Iron (Fe)	Max. 0.0005 %
Heavy Metal as (pb)	Max. 0.0005 %
Potassium (K)	Max. 0.01 %
Sodium (Na)	Max. 0.01 %

Table 48

COOLING WATER AMMONIA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Di ammonium Hydrogen Orthophosphate

% Inhibitor Wt/Vol.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.80	3.43	3.25	2.84	7.07	8.08	7.23	7.79	7.52	1050	-	-	-	-
0.1	0.67	1.22	0.90	1.03	7.81	7.42	7.31	6.70	6.67	2480	82.36	64.43	72.31	63.73
0.2	2.47	2.13	2.27	0.69	7.91	7.57	7.49	6.68	6.19	4000	35.00	37.90	30.15	75.70
0.5	1.35	0.23	0.33	0.13	8.02	7.47	7.38	6.58	6.17	7800	64.47	93.29	89.85	95.42
1	0.18	0.14	0.66	0.25	8.18	7.47	7.38	6.81	6.30	13100	95.26	95.92	79.69	91.19
2	0.23	0.13	0.035	0.030	8.36	7.64	7.40	7.00	6.80	22400	93.95	96.21	98.92	98.94

Table 49

COOLING WATER CAPROLACTAM PLANT

Material : Mild Steel IS 1079

Exposed Surface Area: 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Diammonium hydrogen orthophosphate

% Inhibitor Wt/Vol.	Corrosion rate (Mpy)				pH					Conductivity in m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.74	2.62	5.16	3.97	6.96	8.30	7.37	7.88	7.58	1490	-	-	-	-
0.1	0.28	0.47	1.24	0.93	7.60	7.58	7.31	6.46	6.14	2700	92.51	82.06	75.97	76.57
0.2	2.52	1.73	1.65	1.13	7.86	7.66	7.28	6.09	6.34	4000	32.62	33.97	68.02	71.54
0.5	2.40	0.54	1.04	0.37	8.17	7.52	7.44	6.19	5.99	7700	35.83	79.39	79.84	90.68
1	0.18	0.077	0.20	*0.007	8.34	7.61	7.45	6.35	5.99	12600	95.19	97.06	96.12	W*
2	0.20	0.081	0.28	*0.008	8.52	7.52	7.48	6.87	6.02	21500	94.65	96.91	94.57	W*

* % Wt. gain

W* Wt. gain

Table 50

COOLING WATER UREA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Diammonium hydrogen Orthophosphate

% Inhibitor Wt/Vol.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	0.24	0.14	0.060	0.028	8.10	7.65	6.20	6.45	6.33	7700	-	-	-	-
0.1	0.21	0.071	0.057	0.012	8.12	7.63	7.03	6.36	6.56	8800	12.5	49-29	5.00	57.14
0.2	0.22	0.074	0.043	0.016	8.14	7.68	7.18	6.31	6.47	9900	8.33	47.14	28.33	42.86
0.5	0.17	0.078	0.39	0.018	8.27	7.64	7.28	6.69	6.37	12600	29.17	44.29	N*	35.71
1	0.19	0.087	0,31	0.014	8.41	7.64	7.44	6.82	6.54	17500	20.83	37.86	N*	50.00
2	0.30	0.059	0.31	0.021	8.50	7.67	7.41	6.87	6.74	25600	N*	57.86	N*	25.00

N* = Negative

Table 51

COOLING WATER AMMONIUM SULPHATE PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Diammonium Hydrogen Orthophosphate

% Inhibitor Wt/Vol	Corrosion rate (Mpy)				pH					Conductivity in m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	2.96	2.67	2.34	2.33	7.47	8.85	8.41	8.36	8.29	780	-	-	-	-
0.1	2.02	1.44	1.41	0.90	7.98	8.00	8.04	6.44	6.58	2100	31.76	46.07	39.74	61.37
0.2	0.93	0.70	1.03	0.086	8.04	7.83	7.67	6.43	6.19	3700	68.58	73.78	55.98	96.31
0.5	0.081	0.11	0.53	0.049	8.31	7.70	7.56	6.79	6.14	7550	97.26	95.88	77.35	97.90
1	0.062	0.096	0.31	*0.093	8.39	7.69	7.54	7.05	6.33	12700	97.91	96.40	86.75	W*
2	0.088	0.070	0.12	*0.037	8.51	7.79	7.56	7.22	6.18	22100	97.03	97.38	94.87	W *

* % Wt. gain

W * Wt. gain

Table 52

MAKEUP WATER

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Diammonium Hydrogen Orthophosphate

% Inhibitor Wt/Vol.	Corrosion rate (Mpy)				pH					Conductivity in m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.15	2.63	1.58	1.72	7.73	8.87	8.73	8.38	8.58	610	-	-	-	-
0.1	2.68	2.42	1.50	1.09	7.98	8.12	7.50	6.96	6.33	2050	14.92	7.98	5.06	36.63
0.2	1.56	0.61	0.95	0.41	8.02	7.84	7.49	6.59	6.25	3500	50.48	76.81	39.87	76.16
0.5	0.43	0.17	0.14	0.17	8.18	7.67	7.47	7.31	6.14	7450	86.35	93.54	91.14	90.12
1	0.095	0.097	0.041	0.22	8.32	7.67	7.43	7.23	6.69	12600	96.98	96.31	97.41	87.21
2	0.15	0.12	0.34	0.024	8.46	7.62	7.46	7.21	7.03	22000	95.24	95.44	97.85	98.60

F - V AQUACID-105 + DAP

Table 53

COOLING WATER AMMONIA PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Aquacid-105 (H.E.D.P.) + Diammonium hydrogen orthophosphate

% Inhibitor %W/V Aq. +W/V DAP.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Condctivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	3.26	3.37	1.89	2.62	7.76	8.79	8.88	7.69	6.98	1000	-	-	-	-
0.1+0.1	8.27	3.08	1.67	1.18	6.31	7.19	7.07	6.48	6.09	2250	N*	8.61	11.64	54.96
0.1+0.5	5.39	3.07	1.52	0.90	7.29	7.37	7.05	6.27	5.99	7400	N*	8.90	30.16	65.65
0.1+1	7.24	3.73	1.70	1.09	7.64	7.46	7.17	6.68	6.16	12500	N*	N*	10.05	58.40
5+0.1	206.25	109.11	32.32	26.19	1.28	2.13	2.10	2.13	2.31	26100	N*	N*	N*	N*
5+0.5	150.12	99.36	41.27	33.46	1.44	2.39	2.23	2.39	3.26	22700	N*	N*	N*	N*
5+1.0	173.05	86.70	35.55	22.05	1.68	2.59	2.48	2.61	2.89	20700	N*	N*	N*	N*

N* - Negative

Table 54

COOLING WATER CAPTROLACTAM PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Aquacid-105 (H.E.D.P.) + Diammonium hydrogen orthophosphate

% Inhibitor %V/V Aq.+ %W/V DAP	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	6.69	5.17	3.66	3.23	7.29	8.43	8.50	7.12	8.54	2000	-	-	-	-
0.1+0.1	6.17	2.73	1.31	0.58	5.90	6.70	6.83	6.70	6.93	3000	7.77	47.20	64.21	82.04
0.1+0.5	8.21	2.08	1.08	0.48	7.12	7.31	6.90	6.86	6.75	7900	N*	59.77	70.49	85.14
0.1+1	11.35	4.18	1.12	1.09	7.52	7.38	7.09	6.88	6.74	13500	N*	19.15	69.40	66.25
5+0.1	189.71	111.43	52.66	20.25	1.25	2.30	2.11	2.20	2.25	27500	N*	N*	N*	N*
5+0.5	204.42	81.48	51.27	23.40	1.38	2.57	2.27	2.35	2.62	24000	N*	N*	N*	N*
5 + 1	221.38	85.90	50.89	27.15	1.65	2.66	2.48	2.64	3.21	22000	N*	N*	N*	N*

N* - Negative

Table 55

COOLING WATER UREA PLANT

Material : Mild Steel IS-1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor: Aquacid-105 (H.E.D.P.)+Diammonium hydrogen Orthophosphate

% Inhibitor %V/V Aq+ %W/V DAP	Corrosion rate (Mpy)				pH					Conduct-ivity in m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	6.55	1.36	3.27	3.57	6.70	8.37	8.03	8.34	6.82	2300				
0.1+0.1	4.81	1.46	0.81	0.61	5.20	6.32	6.34	6.57	6.46	3600	26.56	N*	75.22	82.91
0.1+0.5	4.89	1.80	0.77	0.65	7.13	7.08	6.85	6.56	5.87	8300	25.34	N*	76.45	81.79
0.1+1	4.19	1.72	1.17	0.59	7.37	7.15	6.69	6.25	6.06	13900	36.03	N*	64.22	83.47
5.0+0.1	196.12	86.74	42.48	29.77	1.35	2.08	2.10	2.08	2.16	25900	N*	N*	N*	N*
5+0.5	205.11	74.30	46.49	31.44	1.50	2.25	2.26	2.23	2.90	22000	N*	N*	N*	N*
5+1	175.19	59.81	41.22	26.79	1.70	2.53	2.52	2.45	2.68	20900	N*	N*	N*	N*

N* - Negative

Table 56

COOLING WATER AMMONIUM SULPHATE PLANT

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W. : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Aquacid-105 (H.E.D.P.) + Diammonium hydrogen orthophosphate

% Inhibitor %V/V Aq+ %W/V DAP	Corrosion rate (Mpy)				pH					Conductivity in m.mhos	% Inhibitor Efficiency			
	No. of days Exposure				Initial	After Exposure (No. of days)					No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	4.94	3.59	2.73	2.24	8.37	8.79	8.16	7.92	7.72	900	-	-	-	-
0.1+0.1	7.01	3.38	1.85	1.73	6.62	7.22	7.21	6.66	6.51	2300	N*	5.85	32.23	22.77
0.1+0.5	5.93	4.05	2.66	1.72	7.45	7.46	7.26	6.77	6.43	7900	N*	N*	2.56	23.21
0.1+1	5.90	3.82	3.33	1.78	7.68	7.48	7.13	7.01	6.82	13800	N*	N*	N*	20.54
5+0.1	168.98	105.86	45.41	22.47	1.36	2.15	2.09	2.12	2.21	29900	N*	N*	N*	N*
5+0.5	178.17	101.23	49.30	24.58	1.52	2.32	2.23	2.31	2.74	23400	N*	N*	N*	N*
5+1	171.65	84.38	42.52	21.83	1.80	2.70	2.53	2.54	2.79	21500	N*	N*	N*	N*

N* - Negative

Table 57

MAKEUP WATER

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35° ± 1°C

Condition : stagnant

Inhibitor - Aquacid-105 (H.E.D.P.) + Diammonium hydrogen orthophosphate

% Inhibitor %V/V Aq.+ %W/V DAP.	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
	3	7	15	30		3	7	15	30		3	7	15	30
Blank	5.40	4.04	3.46	3.75	7.70	8.30	8.30	8.40	8.48	458	-	-	-	-
0.1+0.1	6.62	2.96	1.91	1.19	6.30	7.08	7.04	7.16	7.03	2030	N*	26.73	44.80	68.27
0.1+0.5	7.40	2.24	3.58	1.26	7.10	7.30	6.97	7.10	6.75	7500	N*	44.55	N*	66.40
0.1+1	9.01	4.53	1.80	4.69	7.40	7.32	7.16	6.84	7.02	13700	N*	N*	47.98	N*
5+0.1	243.83	104.67	49.79	21.28	1.00	2.61	2.48	2.19	2.23	29000	N*	N*	N*	N*
5+0.5	215.36	83.58	53.75	24.87	1.20	2.85	2.70	2.38	2.56	24900	N*	N*	N*	N*
5+1	225.93	80.72	49.13	31.11	1.45	3.03	2.96	2.61	3.03	22400	N*	N*	N*	N*

N* - Negative

(G) EFFECT OF SURFACE TREATMENT ON INHIBITOR EFFICIENCY WITH 2% Wt./Vol. EBNZOTRIAZOLE

(G) Effect of 2% Wt/Vol Benzotriazole on surface treatment

Here the specifications of specimen, experimental procedure and experimental conditions were the same as those of the previous experiments. But the water used was synthetic cooling water prepared in laboratory. Two sets of different surface finish specimens were taken, one burnished with IS grit 60 only (rough surface) and the other burnished with IS grit 60, 80, 100, 120, 240 (smooth surface). The concentration of Benzotriazole was 2 % Wt/Vol. The pH change measurements, visual observations, corrosion rate calculation and inhibitor efficiency derivations were done after 3, 7, 15 and 30 days.

Composition of Synthetic Cooling Water

pH	9.56
$NaHCO_3$	220 mg/l
Na_2SO_4	240 mg/l
NaCl	231 mg/l
NaOH	20 mg/l
$CaCO_3$	305 mg/l
Na_2SiO_3	87 mg/l
Conductivity	1600 micromhos

Table 58

SYNTHETIC COOLING WATER

Material : Mild Steel IS 1079

Exposed Surface Area : 6.33 in^2

Density : 7.8 g/cm^3

Quantity of C.W : 230 ml

Temperature : 35°C ± 1°C

Condition : stagnant

Inhibitor : Benzotriazole

Size of Grit	% Wt/Vol Benzotriazole	Corrosion rate (Mpy) No. of days Exposure				pH Initial	pH After Exposure (No. of days)				Conductivity in m.mhos	% Inhibitor Efficiency No. of days Exposure			
		3	7	15	30		3	7	15	30		3	7	15	30
60	Blank	4.18	3.71	2.39	2.58	9.56	9.20	9.01	8.91	8.88	1600	-	-	-	-
60	2	1.25	0.75	0.49	0.18	6.76	6.89	7.00	7.11	7.29	1410	70.0	79.78	79.50	93.02
240	Blank	3.37	3.53	3.14	3.00	9.56	9.20	8.89	8.89	8.86	1600	-	-	-	-
240	2	1.16	0.51	0.29	0.16	6.76	6.89	7.00	7.10	7.27	1410	66.00	85.55	90.76	94.67

(H) ANODIC POLARIZATION STUDY

(H) ANODIC POLARIZATION

The experiments have been carried out using Potentiodyne Analyser M-4100.

The test assembly consists of five naked polarization cell with two platinum auxilary electrodes, mild steel test electrode (A = 8.53 Cm^2), thermometer pocket, luggin probe for making contact between reference saturated calomel electrode and test electrode. The tip of the luggin probe was kept at 1 mm. distance from test electrode to avoid IR drop. The polarization cell contained 900 ml of the corrodent i.e. water. Steady state potential were measured with the help of philips DC - micro volt meter. As soon as the steady state potential was achieved, the graph was obtained automatically at a speed of 2V/hr. Now with the help of polarization curves of various concentrations of the inhibitor and blank water, shift in potential with respect to blank was recorded.

The polarization potential shift in anodic or cathodic direction with respect to blank water, decides the nature of the inhibitor in terms of anodic or cathodic inhibitor.

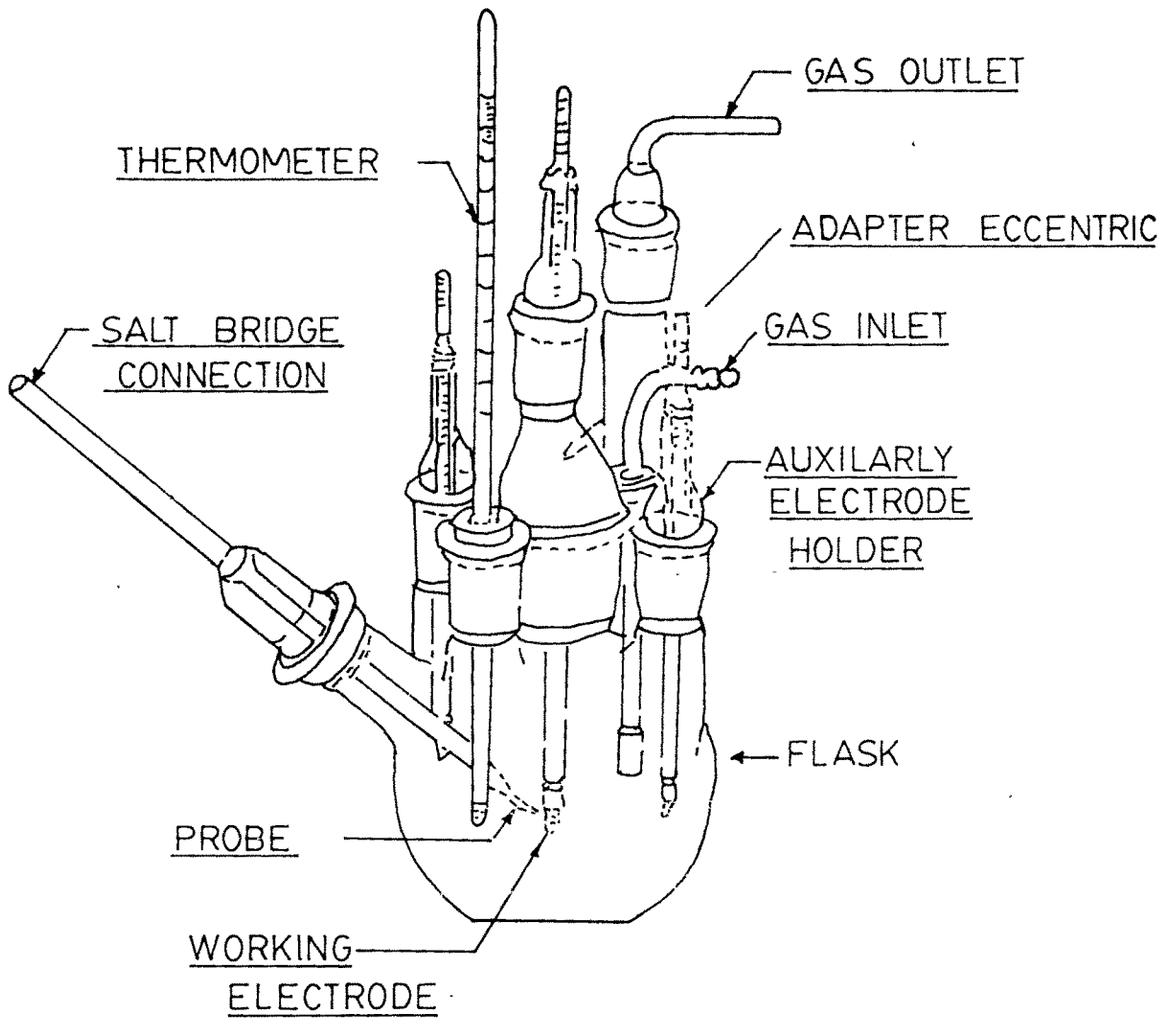
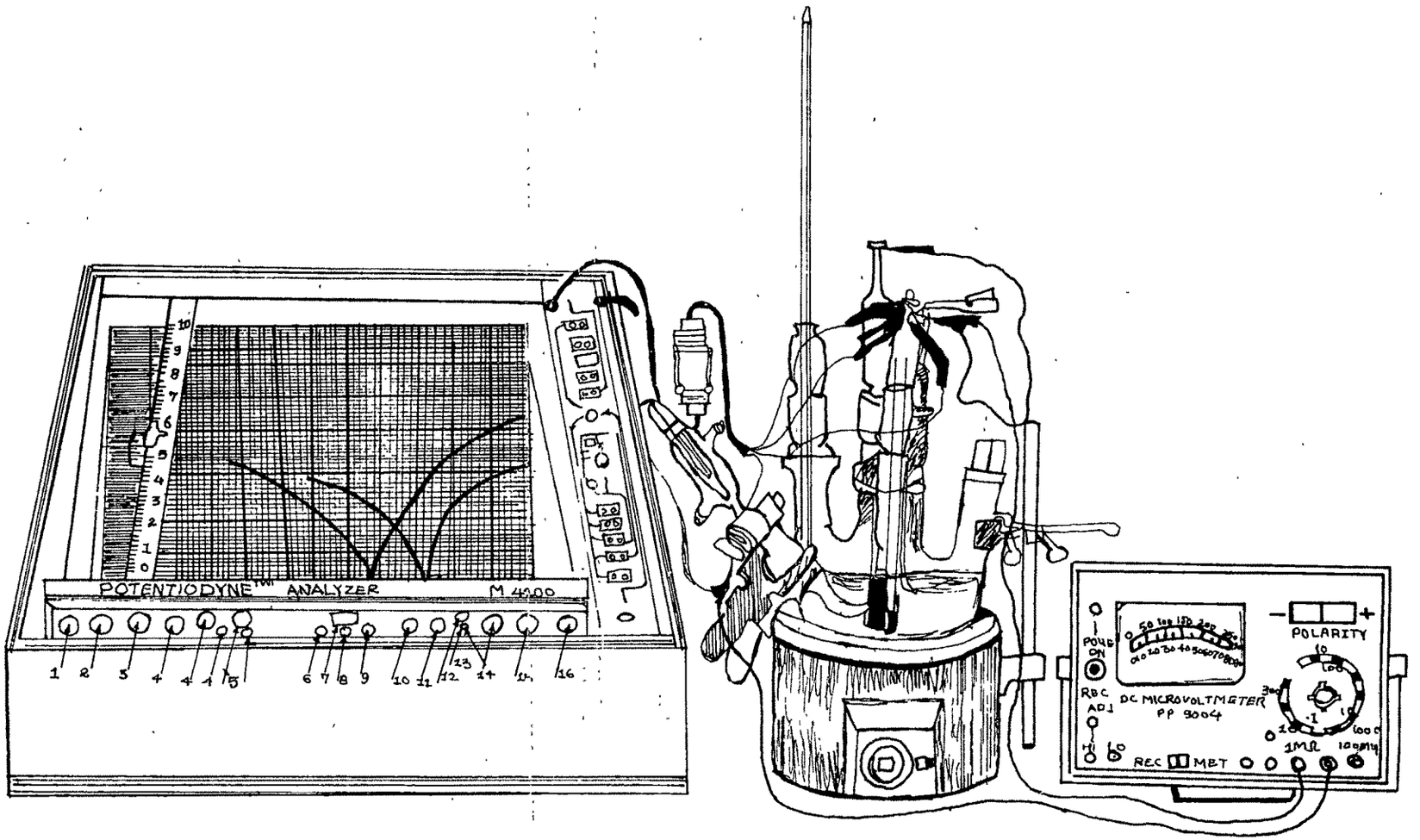


FIGURE - 11

STANDARD POLARIZATION CELL (114)
SCHEMATIC DIAGRAM.



1. VOLTAGE SCALE POSITION CONTROL
2 VOLTAGE SCALE SENSITIVITY CONTROL
3 VOLTAGE SWEEP GENERATOR CONTROL.
4. VOLTAGE LIMITS
5 HORIZONTAL AXIS SELECTOR SWITCH.
6. POWER.
7 CURRENT POLARITY METER
8 SWEEP DIRECTION COMMAND
9 PEN LIFT
10. OPERATE
11. CURRENT SCALE SELECTOR
12 VOLTAGE SCALE EXPANSION.
13 RECORDER COORDINATE CHECK
14 OFFSET VOLTAGE CONTROL
15 CURRENT SCALE SENSITIVITY
16 CURRENT AXIS POSITION CONTROL

FIG. 12 POTENTIODYNE ANALYZER.

Table 59

(H) I : BENZOTRIAZOLE INHIBITOR

% Concentration Wt/Vol	Shift in potential mv	Direction
0.1	480	Anodic
2	520	Anodic

(H) II : COROBIT EPA - 529

% Concentration Vol/Vol	Shift in potential mv	Direction
0.1	120	Cathodic
5	180	Cathodic

(H) III : AQUACID-105 (H.E.D.P.)

% Concentration Vol/Vol	Shift in potential mv	Direction
0.1	-	Mix.
0.2	160	Anodic
5	260	Anodic

(H) IV : DIAMMONIUM HYDROGEN ORTHOPHOSPHATE (DAP)

% Concentration Wt/Vol	Shift in potential mv	Direction
0.1	40	Cathodic
2	250	Cathodic

(H) V : AQUACID-105 (H.E.D.P.) + DIAMMONIUM HYDROGEN ORTHOPHOSPHATE (DAP).

% Concentration Vol/Vol + Wt/Vol	Shift in potential mv	Direction
0.1 + 0.1	100	Cathodic
0.1 + 0.5	110	Cathodic
0.1 + 1	130	Cathodic
5 + 1	170	Anodic

(I) NON HEAT TRANSFER LOOP METHOD

(I) Non-Heat Transfer Loop Method:

Carefully prepared and weighed metal coupons were installed in contact with flowing cooling water for a measured length of time. After removal from the system, these coupons were examined, cleaned and reweighed. The corrosivity and fouling characteristics of the water were determined from the difference in weight, the depth and distribution of pits, and the weight and characteristics of the foreign matter on the coupons.

Waters investigated by this method were:

(i) Ammonia Plant Cooling Water
(ii) Caprolactam Plant Cooling Water

Coupon loop connections were made in inlet, outlet and makeup water bypass line in both the plants. Four coupons were inserted in each loop. The flow velocity in each line was kept 1.5 ft/Sec. The temperature of the inlet, outlet and makeup water varied with seasonal weather conditions.

Temperature °C

Ammonia Plant		Caprolactam Plant	
Inlet	40° ± 1°C	Inlet	36° ± 1°C
Outlet	35° ± 1°C	Outlet	33° ± 1°C
Makeup Water	31° ± 1°C	Makeup Water	31° ± 1°C

The coupons were cut from single sheet of mild steel conforming to IS 1079 in sizes of 102 mm x 13 mm x 3 mm. A hole of 4 mm size was drilled near upper edge. All sharp edges on the coupons specimen were debured by using emry belt. For the hole, oversize drill was used. The mill scales were removed with inhibited hydrochloric acid containing 20 g/l Sb_2O_3 and 1 g/l $SnCl_2$ and burnished with IS grit 60, 80, 100, 120. The coupons were degreased with acetone by swabbing with cotton. The clean and dry specimens were weighed accurately on analytical balance and kept in dessicator until taken out for the study.

The phenolic rod (152 mm long) having two holes each at two ends, one for attaching coupon and the other for attaching drilled pipe plug, was used. Four coupons in each loop were seperately attached with phenolic rod, using an insulating washer to preclude any contact of coupon with screw and nut assembly. For added protection the specimen was attached to the holder using a screw and nut of the same metal composition as the coupon. The holder and coupon assembly were installed in a bypass piping arrangement. The adjusted flow of water was 1.5 ft/sec.

After one month exposure, the specimens were removed and visual observations for scaling and fouling were carried out. The exposed specimens were weighed alongwith the rust

and scale; thereafter the specimens were derusted by mechanical abrasion and weighed again. The exposed specimens were finally pickeled with concentrated hydrochloric acid containing 20 g/l Sb_2O_3 and 1 g/l $SnCl_2$, washed with water, cleaned with acetone, dried with rosella brand tissue papers and weighed. A weighed blank coupon of the same material was subjected to the identical cleaning procedure used for the test specimens and reweighed to determine blank correction factor to be applied to the coupon weight loss. In the case of pitting, size, shape, number and distribution of the pits were also determined and recorded. " Protected", " Moderate localized", "Moderate Pitting" or "Severe Pitting" were the observed recordings, as the case may be, for the well cleaned and accurately weighed coupons.

The average weight loss of four coupons were taken for calculating the corrosion rate. The study was carried out for twelve months. Average water analysis after month's exposure was recorded and Langelier index was calculated for corrosive and scale forming nature of water.

For scale and corrosion products, the results as expressed are :

(A) Gain or loss during installation g/day

(B) Loose scale and corrosion products g/day

(C) Tight scale and Corrosion products g/day

(D) Actual weight loss of insert g/day

(E) Total scale and corrosion products g/day

Calculations

$$\text{Corrosion rate (Mpy)} = \frac{W \times 534}{A \times \rho \times T}$$

A = Exposed Surface Area (in^2)

ρ = Density of Exposed metal (g/cm^3)

T = Time in hour

W = Weight in Miligram

$$\text{Mdd} = \frac{\text{Mpy} \times \rho}{1.437}$$

($Mg/dm^2/day$)

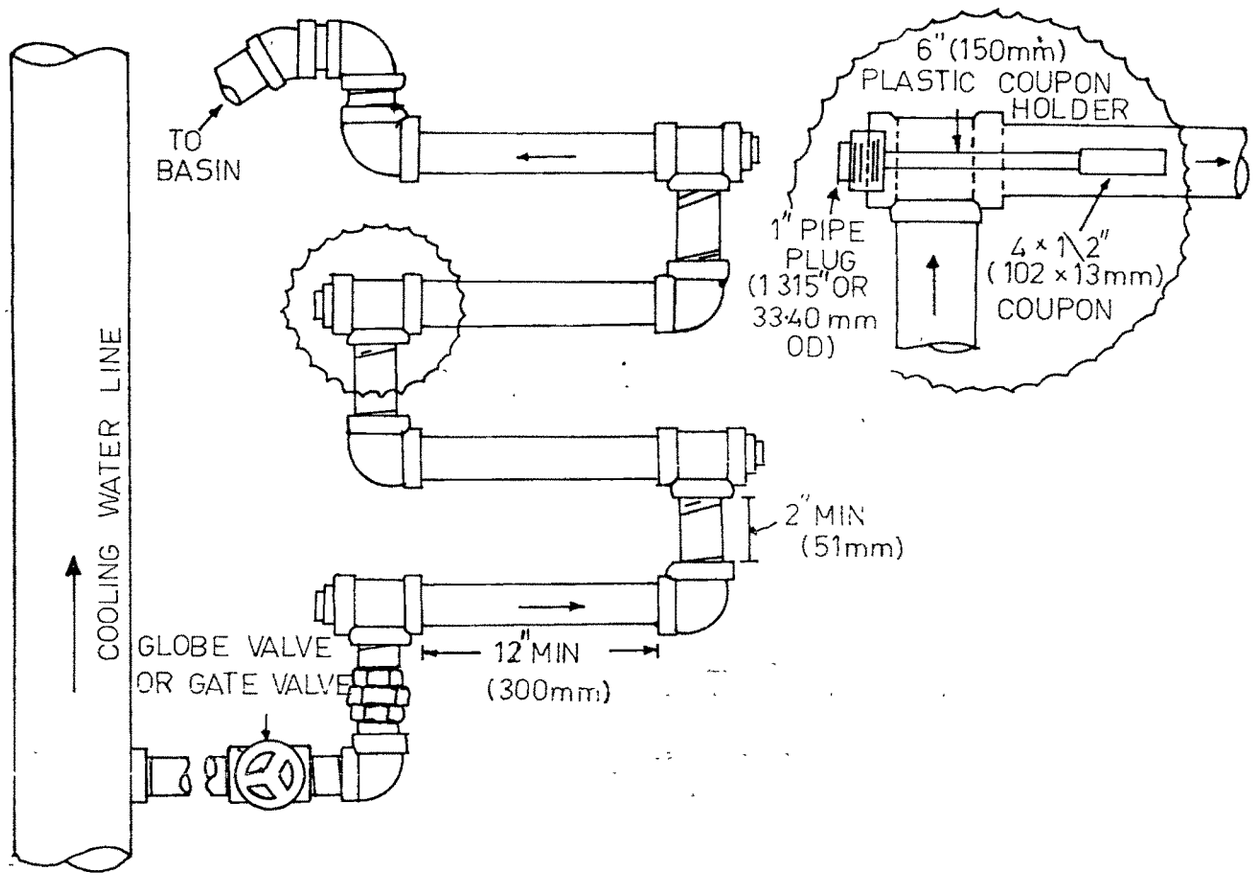


FIG. 13 NON HEAT TRANSFER LOOP.

CHEMICAL TREATMENT OF COOLING WATER - CAPROLACTAM PLANT

Circulation rate	: 5200 M^3/ hr
Sodium Hexameta Phosphate	: 5 kg/day
or	
E.D.T.A.	: 5 kg/day
Zinc sulphate	: 1 kg / day
Santobrite	: 10 kg/week
Quat-2C	: 1 kg/day
Chlorine	: 4 hrs. in a day
Polyacryloamide	: 1 kg/day
Sulphuric acid	: To maintain pH 7 (40 kg/hr.)

AMMONIA PLANT COOLING WATER

Circulation rate	: 9200 M^3/hr
Sodium Hexameta Phosphate	: 100 kg/day
Zinc Sulphate	: 20 kg/day
Polyacryloamide	: 10 kg/day
Chlorine	: Continuous
Sulphuric acid	: to maintain pH 7

Table 60

MAKEUP WATER AMMONIA PLANT

Month	Hardness (p.p.m) / Chloride (p.p.m)	Alkalinity(p.p.m.) / Chloride+Sulphate (p.p.m)	epm(Chloride + Sulphate) / epm (M-Alkalinity)
1	3.45	4.08	0.660
2	3.70	4.12	0.847
3	4.07	3.98	0.814
4	3.10	3.88	0.643
5	4.17	4.38	0.691
6	1.73	5.37	0.540
7	3.25	4.47	0.360
8	3.20	5.71	0.450
9	3.13	3.07	1.150
10	3.72	4.73	0.570
11	4.96	5.03	0.700
12	3.65	3.88	0.700

Table 61

AMMONIA PLANT COOLING TOWER LANGELIER INDEX

Month	Makeup	Cooling Water Ammonia Plant
1	+ 0.500	+ 0.200
2	+ 0.700	+ 0.600
3	+ 0.800	+ 0.600
4	+ 0.400	0.0
5	+ 0.600	- 1.00
6	+ 0.650	- 0.500
7	+ 0.900	+ 0.300
8	+ 0.800	+ 1.00
9	+ 0.650	+ 0.200
10	+ 0.850	+ 0.100
11	+ 0.650	- 0.900
12	+ 0.700	0.0

Calculations : Confidence level

AMMONIA PLANT MAKEUP WATER CORROSION RATE IN Mpy

(8.63, 9.42, 9.91, 11.62, 12.02, 12.43)

(5.83, 6.55, 6.78, 7.34, 7.42, 8.12)

(9.91 + 11.62) / 2 = 10.77 median

(6.78 + 7.34) / 2 = 7.06 median

12.43 - 8.63 = 3.80

8.12 - 5.83 = 2.29

for 99 %

Confidence interval = range x confidence factor

= 3.80 x 0.33 = 1.25

= 2.29 x 0.33 = 0.76

The corrosion rate is reported as :

10.77 - 1.25 = 9.52 Mpy
7.06 - 0.76 = 6.30 Mpy > Average 7.91 mpy

i.e. 7.91 mpy corrosion rate with a confidence level of 99 % (99 out of 100 coupons will fall in this range)

for 95 %

3.80 x 0.23 = 0.87

2.29 x 0.23 = 0.53

The corrosion rate is reported as :

10.77 - 0.87 = 9.90
7.06 - 0.53 = 6.53 > Average 8.22 mpy

i.e. 8.22 mpy corrosion rate with a confidence level of 95% (95 out of 100 coupons will fall within this range).

AMMONIA PLANT (NON HEAT TRANSFER LOOP)

Confidence level of 99 % i.e. 99 samples out of 100 samples will fall in this range.

MAKEUP WATER

Total Hardness as $CaCO_3$ p.p.m.	: 142
Hardness / Chloride	: 3.02
Total Alkalinity as $CaCO_3$ p.p.m.	: 195.89
Alkalinity /Chloride + Sulphate	: 4.01
pH	: 8.07

AMMONIA PLANT COOLING WATER

Total Hardness as $CaCO_3$ p.p.m.	: 229.65
Total Alkalinity as $CaCO_3$ p.p.m.	: 65.58
pH	: 7.39

99 % CONFIDENCE LEVEL OF CORROSION RATE

Makeup	: 7.91 mpy
Inlet to cooling tower	: 10.59 mpy
Outlet of cooling tower	: 5.42 mpy

Table 62

MAKEUP WATER CAPROLACTAM PLANT

Month	Hardness (p.p.m.) / Chloride (p.p.m.)	Alkalinity (p.p.m.) / Chloride+Sulphate (p.p.m.)	epm(Chloride+Sulphate) / epm (M-Alkalinity)
1	2.53	3.65	0.814
2	3.05	3.75	0.710
3	3.51	4.29	0.608
4	3.67	4.64	0.562
5	4.12	4.02	0.773
6	3.58	4.29	0.611
7	4.90	4.85	0.567
8	3.38	5.03	0.550
9	3.23	5.07	0.510
10	3.15	4.24	0.740
11	3.0	3.92	0.690
12	3.72	4.74	0.570

Table 63

CAPROLACTAM PLANT COOLING TOWER

LANGELIER INDEX

Month	Makeup	Cooling water Caprolactam plant
1	+ 0.700	0.0
2	+ 0.700	- 1.700
3	+ 0.600	- 0.700
4	+ 0.800	0.0
5	+ 0.800	- 1.100
6	+ 0.700	+ 0.200
7	+ 0.600	- 0.300
8	+ 0.750	+ 0.190
9	+ 0.750	+ 0.800
10	+ 0.780	+ 0.600
11	+ 0.300	- 0.700
12	+ 0.950	+ 0.270

CAPROLACTAM PLANT NON HEAT TRANSFER LOOP

Makeup	99 % confidence level
Total Hardness as $CaCO_3$ p.p.m. ..	150.34
Total Alkalinity as $CaCO_3$ p.p.m. ..	224.04
Hardness / Chloride ..	3.03
Alkalinity / Chloride + Sulphate ..	4.15
pH ..	8.01

CAPROLACTAM PLANT COOLING WATER

Total Hardness as $CaCO_3$ p.p.m. ..	397.04
Total Alkalinity as $CaCO_3$ p.p.m. ..	63.75
pH ..	7.13

CORROSION RATE (99% Confidence level)

Makeup ..	8.07 mpy
Inlet to cooling Tower ..	14.01 mpy
Outlet of cooling Tower ..	5.14 mpy

Table 64

AMMONIA PLANT COOLING TOWER

Month	Type of Water	Gain during installation g/day	Loss during installation g/day	Loose Scale and Corrosion products g/day	Tight Scale and Corrosion products g/day	Total Scale &Corrosion products g/day	Actual weight loss g/day
1.	Makeup	0.00584	-	0.01784	0.00325	0.02109	0.01525
	Inlet	0.00964	-	0.04047	0.01097	0.05144	0.04179
	Outlet	0.00630	-	0.02514	0.00627	0.03141	0.02511
2.	Makeup	0.00891	-	0.02264	0.00332	0.02596	0.01761
	Inlet	0.01498	-	0.04390	0.00851	0.05349	0.03752
	Outlet	0.01734	-	0.05128	0.00482	0.05610	0.03875
3.	Makeup	0.00829	-	0.02233	0.00559	0.02793	0.01964
	Inlet	0.01452	-	0.04085	0.00493	0.04579	0.03126
	Outlet	-	0.00764	0.03114	0.00207	0.03315	0.04085
4.	Makeup	0.00901	-	0.02139	0.00278	0.02418	0.01516
	Inlet	0.00202	-	0.01485	0.00841	0.02326	0.02183
	Outlet	0.00249	-	0.01855	0.00396	0.02252	0.02002
5.	Makeup	0.00793	-	0.01914	0.00193	0.02107	0.01314
	Inlet	-	0.00114	0.01010	0.00591	0.01600	0.01714
	Outlet	-	0.00153	0.00712	0.00158	0.00870	0.00944
6.	Makeup	0.01116	-	0.02363	0.00108	0.02470	0.01355
	Inlet	-	0.02561	0.00430	0.00108	0.00538	0.03100
	Outlet	-	0.01603	0.00420	0.00086	0.00506	0.02108
7.	Makeup	0.01200	-	0.02883	0.00310	0.03194	0.01995
	Inlet	-	0.00024	0.00277	0.00355	0.00633	0.00727
	Outlet	-	0.00055	0.00620	0.00304	0.00924	0.00910
8.	Makeup	0.00760	-	0.02547	0.00420	0.02968	0.02210
	Inlet	0.00076	-	0.00410	0.00284	0.00690	0.00065
	Outlet	0.00190	-	0.01010	0.00300	0.01320	0.01100

Table 65

CAPROLACTAM PLANT COOLING TOWER

Month	Type of Water	Gain during installation g/day	Loos during installation g/day	Loose Scale & Corrosion products g/day	Tight Scale & Corrosion products g/day	Total Scale & Corrosion products g/day
1.	Makeup	0.01186	-	0.02349	0.00089	0.02742
	Inlet	-	0.03624	0.02594	0.00180	0.02775
	Outlet	-	0.00792	0.02567	0.00185	0.02752
2.	Makeup	0.01072	-	0.01963	0.00186	0.02149
	Inlet	0.01528	-	0.02803	0.00178	0.02982
	Outlet	0.01160	-	0.03076	0.00136	0.03212
3.	Makeup	0.01638	-	0.03502	0.00143	0.03646
	Inlet	0.00823	-	0.01912	0.00168	0.02081
	Outlet	0.01658	-	0.03553	0.00198	0.03751
4.	Makeup	0.01851	-	0.04064	0.00232	0.04296
	Inlet	0.01483	-	0.02831	0.00200	0.03031
	Outlet	0.01539	-	0.02918	0.00181	0.03099
5.	Makeup	0.01607	-	0.03430	0.00109	0.03539
	Inlet	-	0.00473	0.00424	0.00177	0.00602
	Outlet	-	0.00223	0.00394	0.00096	0.00491
6.	Makeup	0.01299	-	0.02607	0.00205	0.02812
	Inlet	0.00096	-	0.01363	0.00198	0.01562
	Outlet	0.00195	-	0.01147	0.00111	0.01258
7.	Makeup	0.01209	-	0.02802	0.00100	0.02905
	Inlet	-	0.00380	0.00491	0.00095	0.00586
	Outlet	0.00118	-	0.00640	0.00080	0.00720
8.	Makeup	0.00900	-	0.02905	0.00109	0.02124
	Inlet	0.00631	-	0.01667	0.00150	0.01818
	Outlet	0.00431	-	0.01045	0.00110	0.01108

Table 66

AMMONIA PLANT COOLING TOWER

Month	Name of the sample	pH	T.D.S p.p.m.	P.Alkalinity p.p.m.	M.Alkalinity p.p.m.	T.Alkalinity p.p.m.	Total Hardness p.p.m.	Silica p.p.m.	Cl^{-} p.p.m.	$PO_4^{'''}$ p.p.m.
1.	Makeup	8.1	375	Nil	200	200	145	24	42	NA
	Cooling water	7.8	1252	5	84	89	326	NA	112	2.7
2.	Makeup	8.2	315	Nil	214	214	148	24	40	NA
	Cooling water	8.1	676	8	134	142	222	NA	69	5
3.	Makeup	8.3	337	Nil	215	215	175	21	43	NA
	Cooling Water	8.0	820	6	153	159	309	NA	87	10
4.	Makeup	8.1	358	Nil	225	225	158	16	51	NA
	Cooling Water	7.7	792	1	89	90	243	NA	89	4
5.	Makeup	8.0	292	Nil	219	219	171	18	41	NA
	Cooling Water	6.9	925	Nil	44	44	280	NA	137	6
6.	Makeup	7.95	328	Nil	290	290	78	21	45	NA
	Cooling Water	6.7	994	3	116	119	241	NA	112	5
7.	Makeup	8.10	372	Nil	264	264	169	18	52	NA
	Cooling Water	7.6	821	11	217	228	271	NA	173	6
8.	Makeup	8.0	362	Nil	354	354	173	23	54	NA
	Cooling Water	8.1	890	36	310	346	288	NA	170	4
9.	Makeup	8.15	361	Nil	221	221	172	19	55	NA
	Cooling Water	7.7	828	Nil	121	121	156	NA	148	5

Table 67

CAPROLACTAM PLANT COOLING TOWER

Month	Name of the sample	pH	T.D.S p.p.m.	P-Alkalinity p.p.m.	M-Alkalinity p.p.m.	T.Alkalinity p.p.m.	Total Hardness p.p.m.	Silica p.p.m.	Cl' p.p.m.	PO_4''' p.p.m.
1.	Makeup	8.1	366	Nil	252	252	144	20	57	NA
	Cooling Water	7.6	939	4	74	78	432	4	185	4
2.	Makeup	8.1	447	4	247	251	177	26	58	NA
	Cooling Water	6.7	919	3	34	37	494	7	208	4
3.	Makeup	8.1	327	Nil	193	193	137	24	39	NA
	Cooling Water	7.1	944	Nil	49	49	401	6	180	2
4.	Makeup	8.2	313	Nil	209	209	143	25	39	NA
	Cooling Water	7.6	847	5	91	96	366	9	189	4
5.	Makeup	8.3	347	Nil	213	213	177	25	43	NA
	Cooling Water	6.8	848	Nil	47	47	374	7	172	4
6.	Makeup	8.1	307	Nil	223	223	161	16	45	NA
	Cooling Water	7.6	958	5	121	126	383	4	190	3.8
7.	Makeup	8.0	316	Nil	228	228	196	22	40	NA
	Cooling Water	7.5	872	Nil	57	57	358	4	70	3
8.	Makeup	8.05	355	Nil	297	297	169	20	50	NA
	Cooling Water	7.79	1031	Nil	72	72	415	4	116	3
9.	Makeup	8.05	367	Nil	309	309	171	21	53	NA
	Cooling Water	7.90	1026	2	98	100	453	4	113	3