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GOVERNMENT OF INDIA
ATOMIC ENERGY COMMISSION

REPORT ON THE STUDIES ON THE CORROSION BEHAVIOUR OF THE CONSTRUCTIONAL MATERIALS FOR THE GATE COOLING SYSTEM

by

N. S. D. Elayathu and J. Balachandra
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BHABHA ATOMIC RESEARCH CENTRE
BOMBAY, INDIA
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INIS Subject Category : E30

Descriptors

TROMBAY R-5 REACTOR

REACTOR MATERIALS

REACTOR COOLING SYSTEMS

STAINLESS STEEL - 304

CARBON STEELS

LEAD

ALUMINIUM

NEOPRENE

PERSPEX

POTASSIUM COMPOUNDS

BORATES

AQUEOUS SOLUTIONS

CORROSION

REPORT ON THE STUDIES ON THE CORROSION BEHAVIOUR OF THE CONSTRUCTIONAL MATERIALS FOR THE GATE COOLING SYSTEM

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1. INTRODUCTION

The Gate Cooling System for the proposed 100 MW Reactor is understood to be a laminated gate designed to operate with 50% KBO_2 solution within the temperature limits 30°C and 50°C. The laminated gate system consists of a set of beam hole gates in parellel connections. (A schematic diagram of the Gate Cooling System is appended). The materials chosen for the construction of the system are S.S. 304 L (ASTM 240-69), lead (ASTM B-29), aluminum (as Boral) for the gates and neoprene tubes for flexible connections Carbon Steel (ASTM A 302 Grade B) is being considered as a candidate material in place of S.S. and perspex also is expected to be used in the construction of some components.

Instances have been reported of the failures of component parts like nuts and studs on the pressure vessels in some operating P.W.R.s and the cause traced to be due to increased corrosion by borate concentration from the primary coolant.[1] Hence it becomes significant to study the corrosion behaviour of these materials in KBO_2 solution. Hence coupons of these materials have been exposed to 50% KBO_2 solution at 45°C and their corrosion behaviour evaluated by periodic observations after definite periods of exposure. The nature and extent of attack were evaluated from weight change studies and metallographic observations in each case.

2. EXPERIMENTAL

Rectangular coupons, 5 cms x 2.5 cms x 0.2 cms were cut from plates of carbon steel, S.S. 304 L (hot rolled), lead, Al-2S, neoprene and perspex sheets. The metallic coupons were polished on successive grades of water-proof abrasive papers, washed thoroughly in distilled water, degreased in acetone and dried in warm air. Neoprene and perspex coupons were washed throughly in distilled water and dried in warm air. After noting the surface area of the coupons in each case, they were weighed accurately on a semimicro balance. The weighed coupons were suspended by means of glass hooks in 50% KBO_2 solution (prepared by dissolving the weighed amount of pure KBO_2 in double distilled water) in an Erlenmeyer flask and kept heated under reflux at 45° ± 2°C. The pH of the Solution was measured at intervals and adjusted to the original value by addition of KOH, whenever a change of more than ± 0.1 unit was noted. The specimenswere withdrawn after periodic intervals, cleaned ultrasonically in distilled water, dried in warm air and weighed. From the weight change data the corrosion rate was calculated in each case. The specimens were then examined metallographically at different magnifications to assess the nature and extent of sub-surface attacks, if any.

3. RESULTS AND DISCUSSION

The data on weight changes of the different materials are presented in Tables I and II and figures 1-5. The corrosion behaviour as revealed from weight changes in the initial periods of exposure (presented in table I) is uniform dissolution in the case of all the metallic materials and steady gain in weight in the case of perspex and neoprene, obviously due to absorption of water. However, this rate of absorption of water by neoprene and perspex decreases rapidly on continued exposure and fall to very low values after 50 days of exposure. The stainless steel coupons show at first slow dissolutions, but after about a month of exposure they gain in weight obviously due to the small film build up which offsets the dissolution. However the weight gains remain very low showing that it is not significantly affected on continued exposure.

(Weight gain 0.035 mdd after 29 days' exposure)
(Weight gain 0.045 mdd after 50 days' exposure)

Carbon steel coupons show dissolutions throughout, but the weight losses are very unsteady, indicating dissolution and corrosion product film build up and the poor protective nature of the film formed. On exposure over 100 days it shows small weight gains but the behaviour is not very reliable.

Aluminim-2S shows steady dissolution but the rates are not very high during initial periods of exposure. But on continued exposure above 50 days there is accelerated dissolution and hence is not satisfactory for use over extended period of time.

Lead specimens are steadily dissolved away at very high rates (46-52 mdd). Obviously it cannot form any protective film and it hence undergoes steady dissolution.

Microscopic examinations reveal that stainless steel, perspex and neoprene are not attacked significantly. Carbon steel suffers uniform dissolution and a non-uniform corrosion product film builds up. The photo micrographs at different magnifications reveal that lead and aluminim suffer localised attacks. However carbon steel coupons show no indications of any sub-surface attack.

4. CONCLUSION

From the experimental observations it may be concluded that of the several constructional materials proposed to be used in the construction of the Gate Cooling System, it is desirable to avoid carbon steel, lead and aluminim as their corrosion behaviour in the borate solution is not satisfactory.

ACKNOWLEDGEMENT

The authors wish to thank Dr. V.K. Moorthy, Head, Metallurgy Division for his keen interest throughout the course of this investigation. They are also indebted to Shri Kargathra, T.V. of R.E.D. for the drawings and details furnished regarding the Gate Cooling System and to Shri C.K. Subrahmaniam of Reactor Engineering Division for his keen interest and providing the materials. The assistance of Shri V.P. Joshi, Scientific Assistant is acknowledged.

REFERENCE

1. Nuclear Safety, 13 (3), 237 (May/June 1972).

Table 1

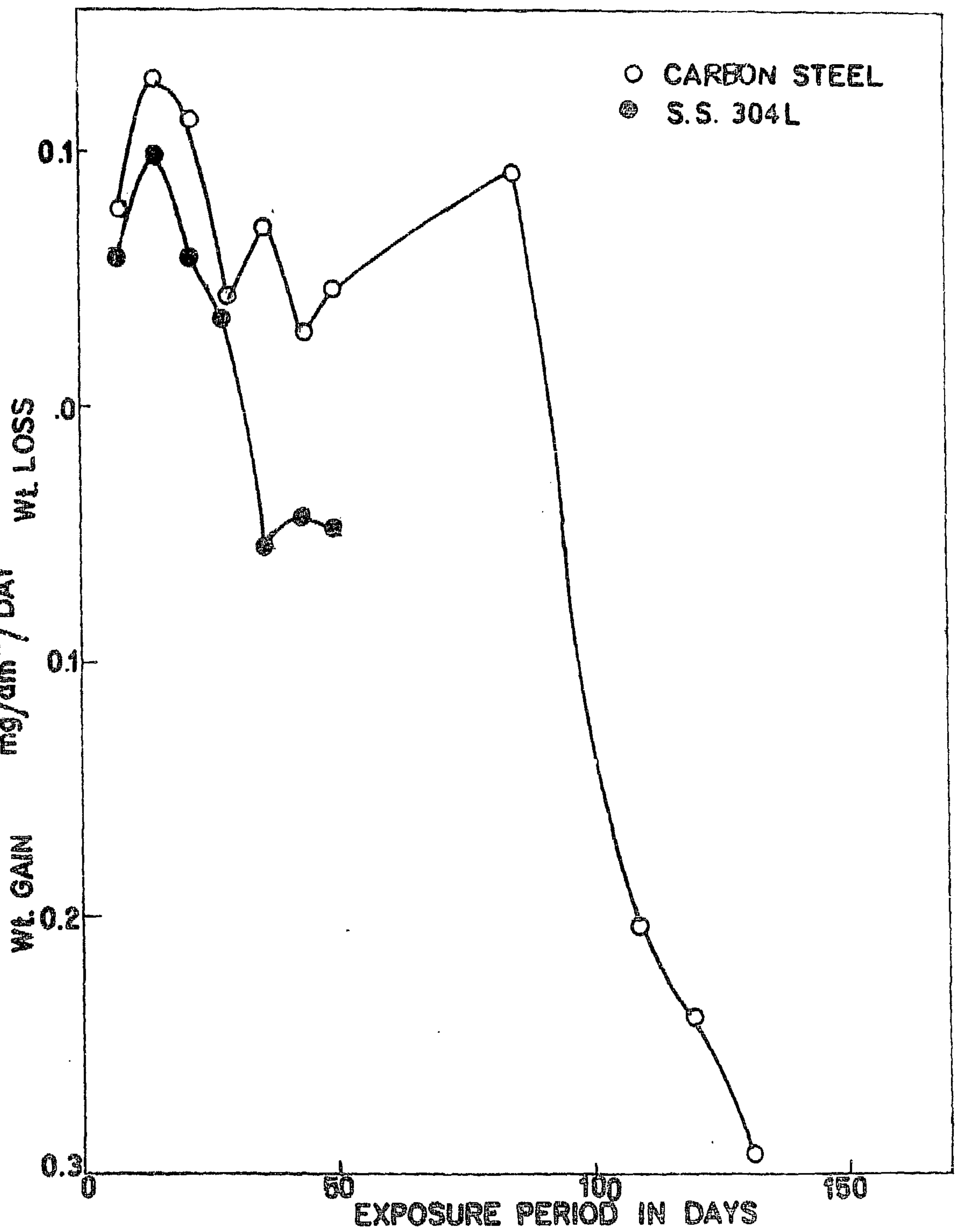
Material	Weight Change in mgms/ dm² per day after exposure periods of 8 days	15 days	22 days	29 days	36 days	44 days	50 days
S. S. 304 L	0. 059 (WL)	0. 093 (WG)	0. [illegible] (WL)	0. 035 (WL)	0. 097 (WG)	0. 042 (WG)	0. 045 (WG)
Carbon steel	0. 077 (WL)	0. 129 (WL)	0. 112(WL)	0. 044 (WL)	0. 071 (WL)	0. 03 (WL)	0. 046 (WL)
Aluminium -2S	3. 455 (WL)	3. 657 (WL)	3. 509 (WL)	3. 438 (WL)	3. 461 (WL)	3. 447 (WL)	3. 434 (WL)
Lead	50. 24 (WL)	46. 54 (WL)	46. 83 (WL)	45. 28 (WL)	47. 55 (WL)	48. 39 (WL)	47. 61 (WL)
Perspex	15. 33 (WG)	7. 77 (WG)	4. 686 (WG)	3. 659 (WG)	2. 429 (WG)	1. 888(WG)	1. 609(WG)
Neoprene	22. 85 (WG)	15. 21 (WG)	11. 69 (WG)	10. 34 (WG)	8. 145 (WG)	7. 148(WG)	6. 688(WG)

WL = Weight Loss WG = Weight Gain

Table II

Material	Weight change in mgms/ dm^2 / day after exposure periods of 15 days	36 days	50 days	85 days	120 days	176 days
S. S. 304 L	0. 093 (WL)	0. 057 (WG)	0. 045 (WG)	—	—	—
Carbon steel	0. 129 (WL)	0. 071 (WL)	0. 046 (WL)	0. 093 (WL)	0. 239 (WG)	0. 302 (WG)
Lead	46. 54 (WL)	47. 55 (WL)	47. 61 (WL)	51. 55 (WL)	48. 14 (WL)	46. 41 (WL)
Aluminium 2S	5. 657 (WL)	3. 461 (WL)	3. 434 (WL)	5. 629 (WL)	15. 52 (WL)	27. 67 (WL)
Neoprene	15. 21 (WG)	8. 145 (WG)	6. 688 WG)	—	—	—
Perspex	7. 77 (WG)	2. 429 (WG)	1. 609 (WG)	0. 625 (WG)	0. 147 (WG)	0. 062 (WG)

WL = Weight loss WG = Weight gain.



CARBON STEEL
S.S. 304L
0.1
.0
0.1
0.2
0.3
Wt. LOSS
mg/dm2/DAY
Wt. GAIN
0
50
100
150
EXPOSURE PERIOD IN DAYS

FIG. 1.

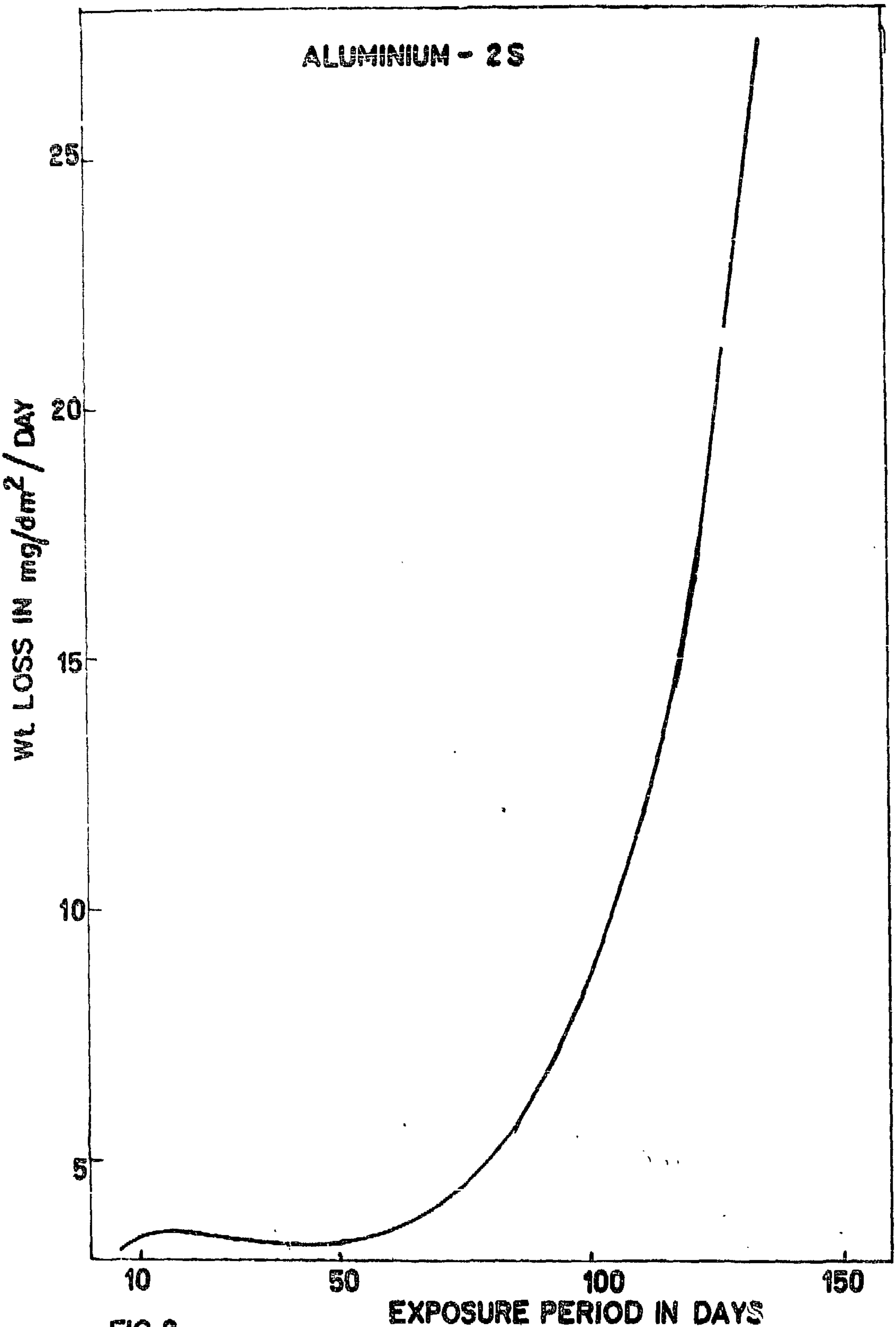

ALUMINIUM - 2S
WL LOSS IN mg/dm² / DAY
25
20
15
10
5
10
50
100
150
EXPOSURE PERIOD IN DAYS

FIG. 2.

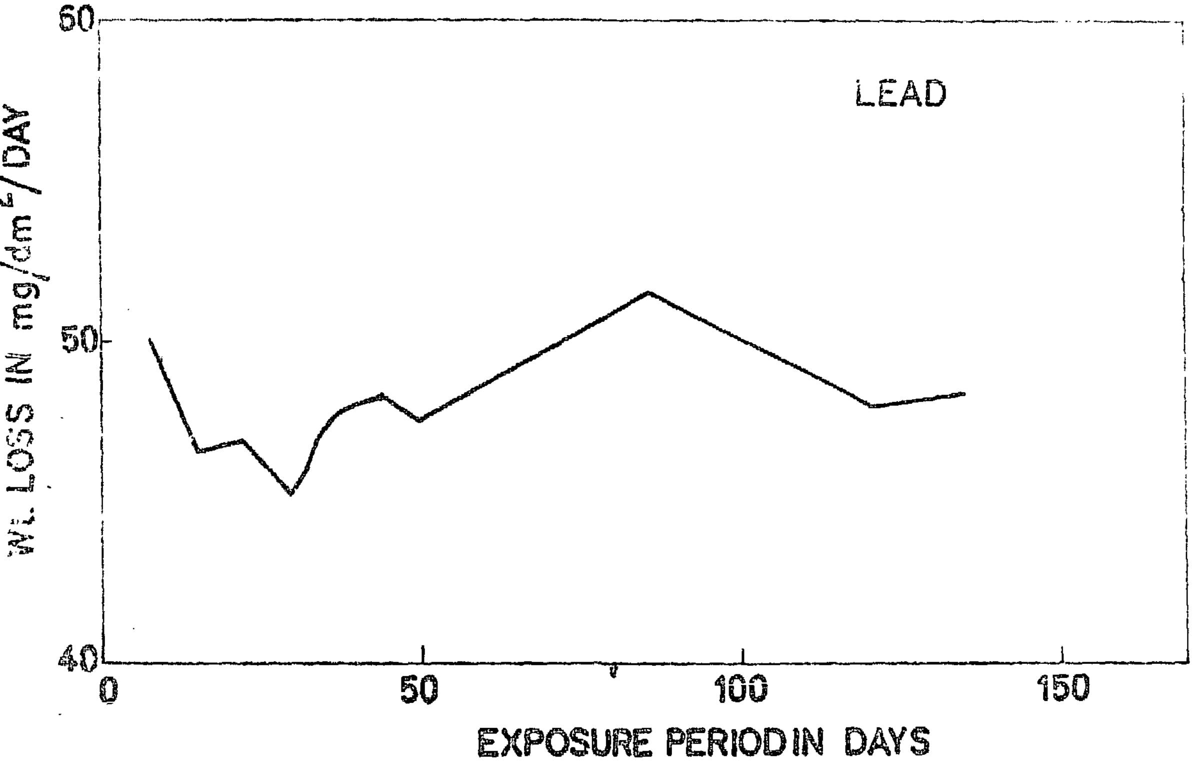

60
50
40
0
50
100
150
LEAD
WT. LOSS IN mg/dm2/DAY
EXPOSURE PERIOD IN DAYS

FIG. 3

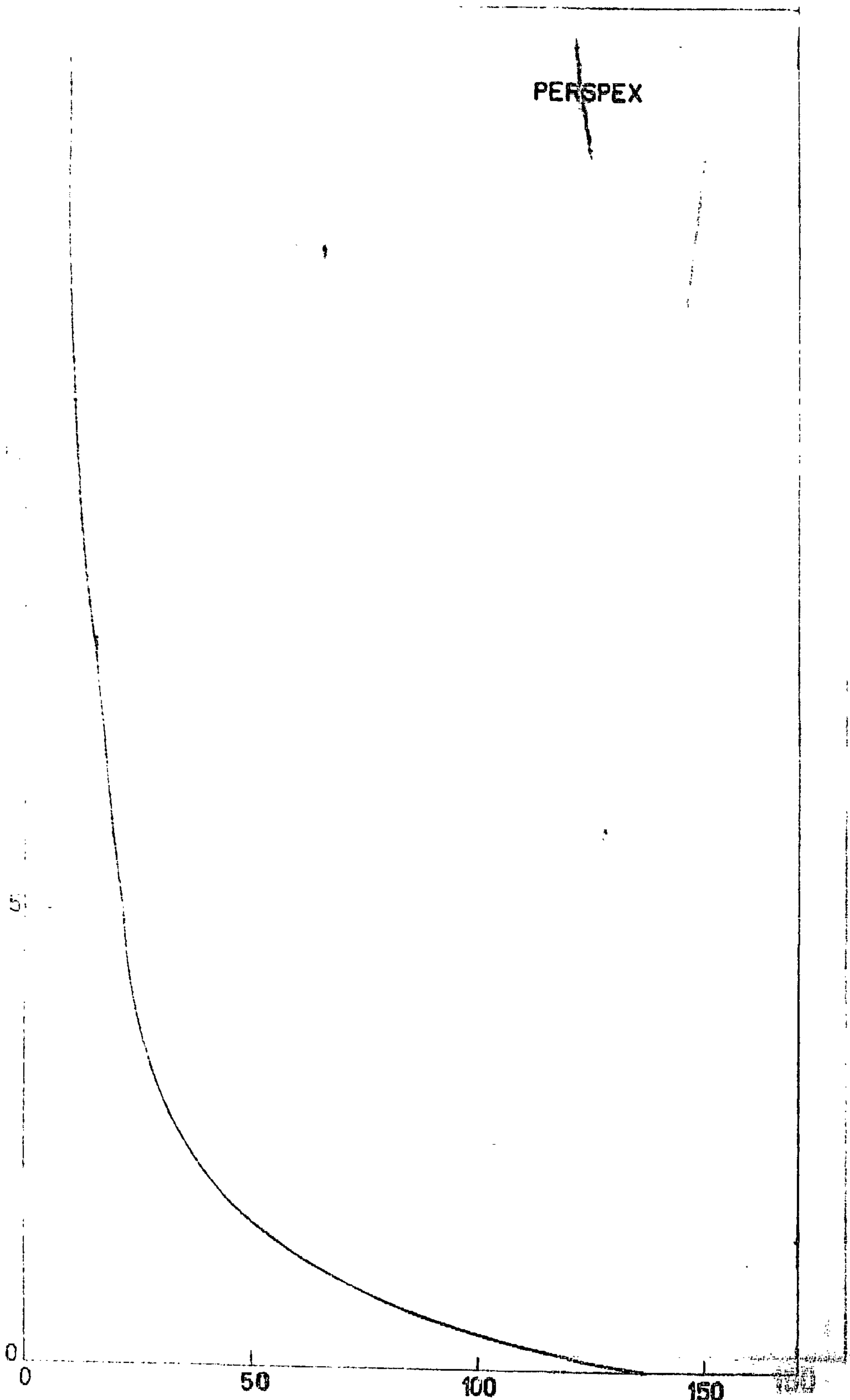


FIG. 4.

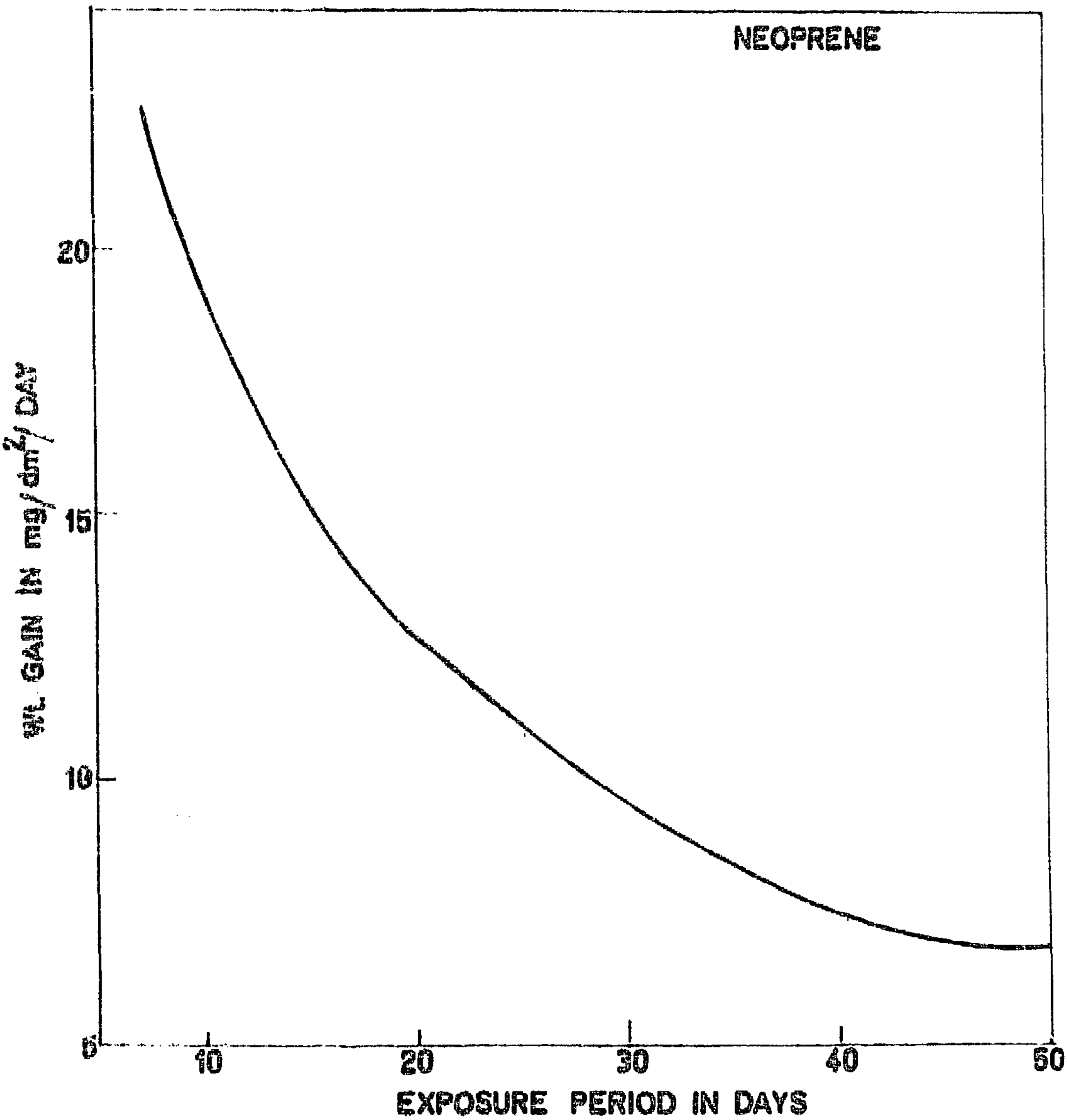
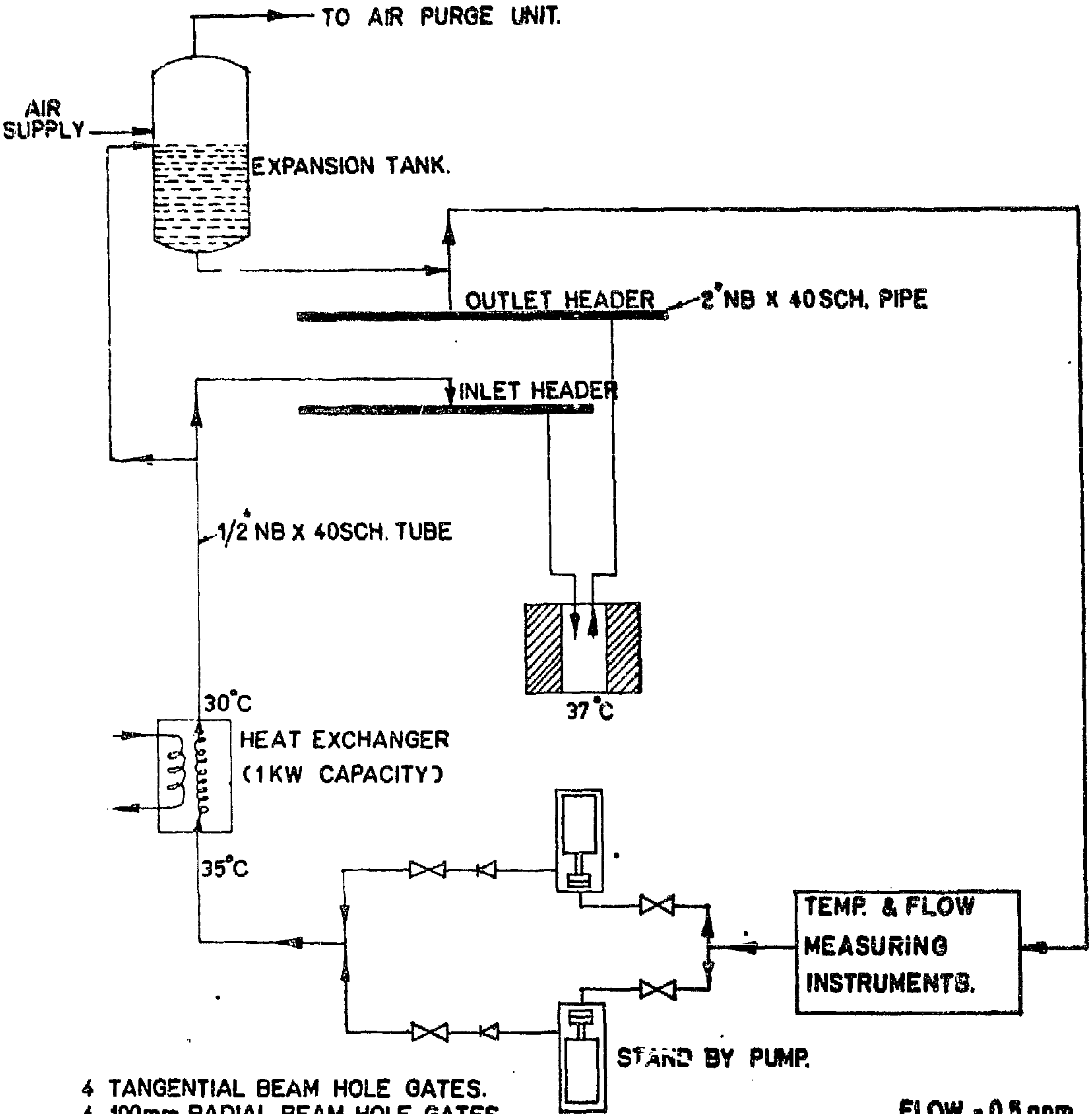

NEOPRENE
20
15
10
5
10
20
30
40
50
EXPOSURE PERIOD IN DAYS
Wt. GAIN IN mg/dm²/ DAY

FIG. 5.

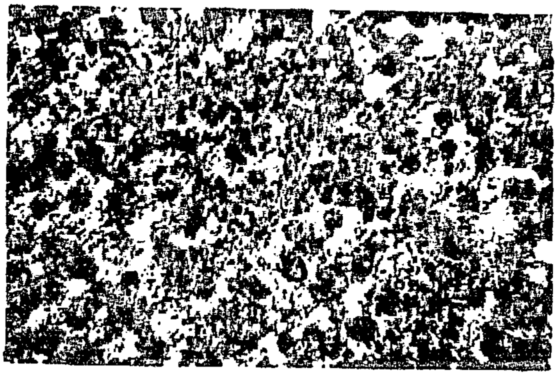


4 TANGENTIAL BEAM HOLE GATES.
4 100mm RADIAL BEAM HOLE GATES.
2 300mm RADIAL BEAM HOLE GATES.
2 COLD SOURSE BEAM HOLE GATES (300mm)
1 HOT SOURSE BEAM HOLE GATES (300mm)
2 —Do— (100mm)
2 THROUGH TUBE BEAM HOLE GATES.
17 GATES IN PARALLEL CONNECTIONS.

GATE COOLING SYSTEM SCHEMATIC DIAGRAM

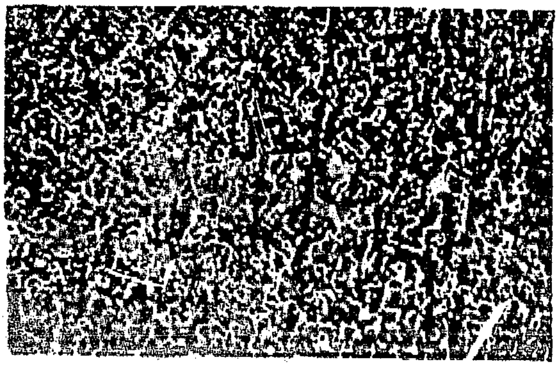
ALUMINIUM

(Cross Section)
Magnification: 50 X



(Surface-pitted)
Magnification: 50 X

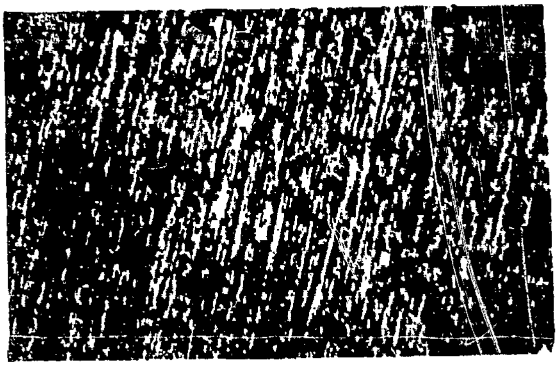
LEAD



(SURFACE)
Magnification: 50 X

CARBON STEEL

SURFACE



(136 days exposed)
Magnification: 50 X

(136 days exposed)
Magnification: 575 X

MICROSTRUCTURE

(Unexposed)
Magnification: 575 X