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Name: **James Gregory Moore**
"Gymnast Brass" No. 1
Work:
Trailing Fire Windows (4-4)
Status: **Toward Drop**
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TAC CONSTRUCTION MATERIALS LTD

RESEARCH REPORT

CONFIDENTIAL

SERIAL NO : 1194 TITLE : Pressure Pipes
PROJECT NO : 527 SUBJECT : Release of Asbestos
REPORT NO : 3 Fibre into water

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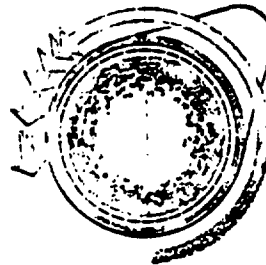
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ABRASION RESISTANCE

Tests simulating long-term conditions helped evaluate the abrasion resistance of Flartran pipe. These tests were made with water containing large amounts of silt, sand and gravel placed in the pipe and rotated axially for nearly three million revolutions. Some of the test results are presented in the table below.

TEST MATERIAL	PERCENT THICKNESS LOSS—GROSS
Steel Pipe	1.1
Cast Iron	1.8
Cast Iron—Bearing Metal Steel	18.9
Cast Iron—Cast Iron Steel	20.9
Cast Iron—Cast Iron Steel	20.9

NOTE: THE PERCENT THICKNESS LOSS IS 1/10 OF THE PERCENT OF THE ORIGINAL THICKNESS OF THE PIPE.



TABLES AND FIGURES

TABLE I Percentage Fibre in Filtered Residue

TABLE II Fibre Release from Pipeline

TABLE III Removal of Calcium from Pipeline

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FIGURE I Calcium Level in water with time at pH6

FIGURE II Calcium Level in water with time at pH5

FIGURE III Calcium Level in water with time at pH4

FIGURE IV Calcium Level in water with time at pH3

FIGURE V Summary of Calcium Level with time at pH3 - pH6

FIGURE VI Fibre Release into water v. pH

FIGURE VII Average Fibre Release into water v. pH

FIGURE VIII Rate of Release of Residue into water v pH

FIGURE IX Average of the considered best values for fibre release into water v. pH

FIGURE X Average of the considered best values for fibre release into water v. reciprocal rate of calcium removal

FIGURE XI Expected Half-Life of Pipes v. pH

OBJECTIVE

As a result of the possible hazard to health caused by the release of asbestos fibres from asbestos-cement pipes carrying drinking water, the object of the project was to establish the level of fibre release into water flowing through asbestos-cement pressure pipes as the water was made increasingly more chemically aggressive.

SUMMARY

Since the last report (Serial Number 1018) the pipeline corrosion test rig has been operated using water which was first reduced in unit steps of pH value from pH5 to pH3 and then raised again to pH6 in unit steps. The filtered residue from each run has been analysed for chrysotile asbestos by x-ray diffraction spectroscopy and atomic absorption spectroscopy with the assistance of TBA, Rochdale and TAN Asbestos Fibre Laboratory. The results from the two analyses have been taken to indicate the possible range of fibre concentrations in the water. The results are listed in Tables 1 to 5 and they show:-

1. An increase in fibre release as the pH of the water was progressively decreased from pH6 to pH3.
2. An approximately constant level of fibre release as the pH of the water was progressively raised from pH3 to pH6.

CONCLUSIONS

1. The fibre release for runs at pH6 to pH3 increases by a factor of 5 to 10 approximately for each unit decrease in pH value.
2. Fibre release remains approximately at the pH3 level as the pH value of the water is again increased from pH3 to pH6.
3. The background level of fibre release for clean pipes carrying water at pH7 is extrapolated to be less than 10^{-5} g/water/100ft of 4" diameter pipe.
4. Once a pipe has been attacked by water of a low pH value there will still be an appreciable release of fibre even when the water is made less aggressive.

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COMPARISON OF TWO RESULTS FROM X-RAY DIFFRACTION
AND ATOMIC ABSORPTION SPECTROSCOPY

Two methods were used to estimate the amount of chrysotile in the residue collected by filtration. Detailed descriptions of the procedures for x-ray diffraction and atomic absorption spectroscopy are contained in Report No. 2 (Serial No. 1016). The essential difference between the two techniques is that x-ray diffraction provides a direct measure of the chrysotile from its crystal structure whereas atomic absorption spectroscopy is used to measure a secondary standard, the magnesium content. As there are other materials present in the ashed residue which contain magnesium some account must be made of these when relating the magnesium content to chrysotile assuming 2% magnesium in the fibre. The magnesium resulting from the ashing of the filter membrane was deducted from the total magnesium content. These magnesium contents are given in Table I. A further correction was made for magnesium arising from the amosite fibre and cementitious residue assuming that the residue on the filter membrane had the same proportions of cement and fibre as the original pipe. This is obviously only approximately true for most cases. These corrected values for the chrysotile contents from atomic absorption spectroscopy are compared with the results from x-ray diffraction in Table I.

The results for the percentage of chrysotile in the residue from both methods of analysis show a general increase in both the proportion of fibre in the residue and also an actual increase in the amount of fibre in the residue as the pH of the water in the pipeline was reduced (Table I & II). This was the expected result from visual examination of the residue in the filter membrane, which became more fibrous as the pH was reduced to pH2 and pH3. Also infra red spectra of small samples of residue showed the presence of substantial amounts of fibre.

Even though the results from AAS and x-ray diffraction show the same trends, the corrected values from AAS in all but two cases were higher than the equivalent determination by x-ray diffraction.

The discrepancy between the results is thought to be due to the intrinsic differences between the two methods and partly due to experimental errors. As an approximation the two levels have been taken as upper and lower limits.

Ca. v

At pH6 the level of chrysotile in the residue was below the detectable limit by X-ray diffraction in three cases representing a release of the order of 10-6 g/gal/100ft of pipe.

REMOVAL OF CALCIUM INTO PIPELINE WATER

The extent of the build up of calcium ions in the pipeline water was measured by analysing samples of water taken at regular intervals during the course of each run. The results are shown in Figures I-V. There is a rapid initial increase in the first hours of the run after which the rate of increase is approximately linear over the time of each run. Thus the attack on the cement matrix is not limited to any extent by the increase in hardness of the circulating water for runs of the order of 200 hours as adopted for the present series of experiments.

The source of the calcium was from free lime in the cement and also from the breakdown of calcium silicate compounds in the cement matrix. The free lime tends to be removed preferentially and the destruction of the main cement matrix follows more slowly.

An approximation of the rate of removal of calcium ion was made by taking the calcium level after 100 hours and dividing by the time. (See Table III)

THE EXTENT OF FIBRE RELEASE

(a) Decreasing pH Value

The results are presented in Table II for the amount of chrysotile released into the pipeline water at each pH value calculated from X-ray and AAS data. They are expressed as weight of fibre in μg per gallon of water for 100ft of 4" diameter pipe. The same results are shown graphically in Figures VI and VII.

They show an increase in the quantity of fibre released as the acidity of the water is increased which is approximately equivalent to a 5-10 times increase for each pH unit decrease. This result is at variance to that found by Johns-Manville who established no significant increase in fibre release even at pH2. This is possibly explained by the choice of acids used in the two experiments. TAC used hydrochloric

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2.

5. Measurement of the calcium release provides an indication of the expected life-time of the pipe for a range of operating conditions.
6. The results confirm that grey pipes may be used in waters with a pH value of 6.0 or more. (Appendix A)

RECOMMENDATIONS

1. The initial run at pH7 should be repeated for a longer period of several weeks, because of the low rate of attack. (see p.5)
2. A series of runs should be made using sulphuric acid instead of hydrochloric acid as the neutralising acid, commencing at pH7 and ending at pH3. (see p.4/5)

6.

detection by x-ray diffraction. (after runs of one week duration) showed the pipe bore to be free from loose material.

(b) Increasing pH Value

It is evident from the results shown in Table 2 and in Figures VI and VII that once a pipe has been exposed to water at a low pH value of 3, then there is a continuing high release of fibre even when the pH of the water is again raised. The values of the fibre release at pH4, pH5 and pH6 for the runs carried out after the pipe had been exposed to water at pH3 are of the same order as for attack at pH3.

This would seem to be due to the formation of a fibrous mat on the inside of the pipe as the cement is removed due to attack by the acidic water. Even though the water is made less chemically aggressive, the mechanical action of the water is sufficient to remove substantial quantities of fibre.

An examination was made of the bore of the pipes after the final run at pH6. The inner bore of the pipe was covered with a fibrous mat about 1.5mm in depth. Chemical analysis showed this to contain only about 1% of cement.

It is apparent that the pipe matrix must be broken down to a considerable extent before there is massive release of fibre. However, once the pipe has been attacked by aggressive water which forms the soluble reaction products, there will be a continuing release of fibre even when less aggressive water is passed through the pipeline.

APPENDIX AExpected Life-Time of Pipes

A measurement of the rate of removal of calcium into the water provides a means of estimating the life time of the pipes. In this it must be assumed that all the calcium arises mainly from the breakdown of calcium silicate compounds in the cement matrix.

The results for the rate of breakdown of the cement and the time to remove half the lime from the cement of the pipes are shown in Table III. The time to destroy half the cement was chosen as this was thought to give an indication of the expected useful lifetime of the pipes.

The total cement content of the pipeline was calculated, assuming a 20% water content and a parity weight of 95 lb for a 4 metre length of 4" Class "C" pipe, leading to a dry weight of 76 lb. The cement content of the pipe is approximately 85% giving a parity weight of cement of 64.6 lb. The actual figure used in calculation 62.5 lb was the mean of this figure and a value of 60.4 lb provided by Cost Control Department. This leads to a total cement content for the length of the pipe work (18.4km) of 130690 gm.

Figure XY shows a plot of the time to remove half the cement of the pipes against pH for uncoated pipes. This shows that below a value of about pH 6.0 the attack on the pipes begins to become appreciable which is in agreement with the present policy of not recommending uncoated pipes for use with waters having a pH value of less than 6.0.

The useful lifetimes of the pipe shown for pH 7 and 8 are probably low as the measurements were made on fresh pipes and most of the calcium removed would be from free lime rather than from a breakdown of the cement matrix.

TABLE 1

Percentage Fibers in Filtered Residues

PH	Weight of residue (a)	% Mg in Residue (b)	% Chrysotile in Residue AAS (c)	% Chrysotile in Residue XRD
6	12.6	2.2	6.7	Less than 0.1
6	32.5	1.2	2.5	Less than 0.1
6	8.4	0.9	1.3	Less than 0.1
6	33.2	0.56	1.6	0.2
5	57.5	2.3	7.1	7.1
5	46.5	1.4	3.4	4.5
5	61.2	2.2	6.7	5.5
5	28.4	1.7	4.6	3.7
5	46.7	2.9	9.7	13.8
4	75.7	1.5	3.8	0.6
4	305	15.0	60.5	18.3
4	76.8	5.8	21.9	3.8
4	56.8	8.3	32.4	10.0
3	187.3	12.8	51.3	17.4
3	306.1	15.7	63.5	1.4
3	560.7	15.0	60.5	8.0
4	1002	-	-	5.5
4	730	15.0	60.5	49
3	444	14.4	58.0	23
3	1113	16.2	65.6	16
6	905	17.7	71.9	35
6	828	15.4	62.2	65

(a) Allowance made for not filtering the whole of the contents of the pipeline.

(b) Magnesium content corrected for magnesium in the filter membrane (80 g/membrane).

(c) Allowance made for magnesium contained in the residue not attributable to chrysotile.

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TABLE II
Fibre Release from Pipelines

pH	Duration of Run (hrs)	Quantity of Water Passed (gallons)	Fibre in Residue (µg)		Fibre Release (µg/gal/100 ft pipe)	
			AAS	KED	AAS	KED
6	166.5	2.00×10^6	844	Less than 10	7×10^{-4}	Less than 8.0×10^{-5}
6	191.5	2.30×10^6	813	33	5.8×10^{-4}	2.4×10^{-5}
6	194	2.33×10^6	109	11	7.7×10^{-5}	7.8×10^{-6}
6	195	2.34×10^6	531	66	3.8×10^{-4}	4.7×10^{-5}
5	43	5.16×10^5	4083	4083	1.3×10^{-2}	1.3×10^{-2}
5	97.5	1.17×10^6	1581	2093	2.2×10^{-3}	3.0×10^{-3}
5	341.5	4.10×10^6	4100	3366	1.7×10^{-3}	1.4×10^{-3}
5	193.5	2.35×10^6	1306	1090	9.2×10^{-4}	7.4×10^{-4}
5	218.5	2.62×10^6	4530	6445	2.9×10^{-3}	4.1×10^{-3}
4	212	2.34×10^6	2877	454	1.9×10^{-3}	3.0×10^{-4}
4	163.5	1.96×10^6	184,525	55,815	1.6×10^{-1}	4.7×10^{-2}
4	214	2.57×10^6	16,819	2,918	1.1×10^{-2}	1.9×10^{-3}
4	94	1.13×10^6	11,923	3,680	1.7×10^{-2}	5.4×10^{-3}
3	155.5	2.00×10^6	96,085	32,590	7.9×10^{-2}	2.7×10^{-2}
3	161	1.93×10^6	194,373	4,285	1.7×10^{-1}	3.7×10^{-3}
3	162	1.94×10^6	339,224	44,856	2.9×10^{-1}	3.8×10^{-2}
4	238.5	2.89×10^6	-	55,110	-	3.2×10^{-2}
4	162.5	1.95×10^6	441,650	357,700	3.7×10^{-1}	3.0×10^{-1}
5	165.5	1.98×10^6	257,520	102,120	2.1×10^{-1}	8.5×10^{-2}
5	166	1.99×10^6	729,015	178,080	6.1×10^{-1}	1.5×10^{-1}
6	187.5	2.23×10^6	650,695	316,750	4.8×10^{-1}	2.3×10^{-1}
6	121	1.44×10^6	312,006	538,200	6.1×10^{-1}	6.1×10^{-1}

TABLE III
Removal of Calcium From Pipelines

pH	Calcium Released after 100 hrs (ppm)	Rate of removal of Calcium ppm/hr	Rate of removal of cement gm/hr	Hours to Remove half cement of pipe
8	87	0.87	0.38	19.6
8	67	0.67	0.38	19.6
8	78	0.78	0.34	22.2
7	88	0.88	0.38	19.7
7	92	0.92	0.40	18.8
7	88	0.88	0.38	19.7
6	176	1.76	0.76	9.8
6	133	1.33	0.57	13.1
6	135	1.34	0.58	12.9
6	124	1.24	0.53	14.1
5	222	2.22	0.96	7.8
5	238	2.38	1.03	7.2
5	240	2.40	1.03	7.2
5	195	1.95	0.84	8.9
4	225	2.25	0.97	7.7
4	290	2.90	1.25	6.0
4	326	3.26	1.41	5.2
3	810	8.10	3.49	2.1
3	990	9.90	4.27	1.7

acid to regulate the acidity whereas JW used sulphuric acid. The hydrochloric acid was chosen because the reaction products are soluble in water and there was no possibility of the chemical attack being slowed down by the formation of a reaction product of low solubility. It was therefore to be expected that hydrochloric acid would be more severe than sulphuric acid.

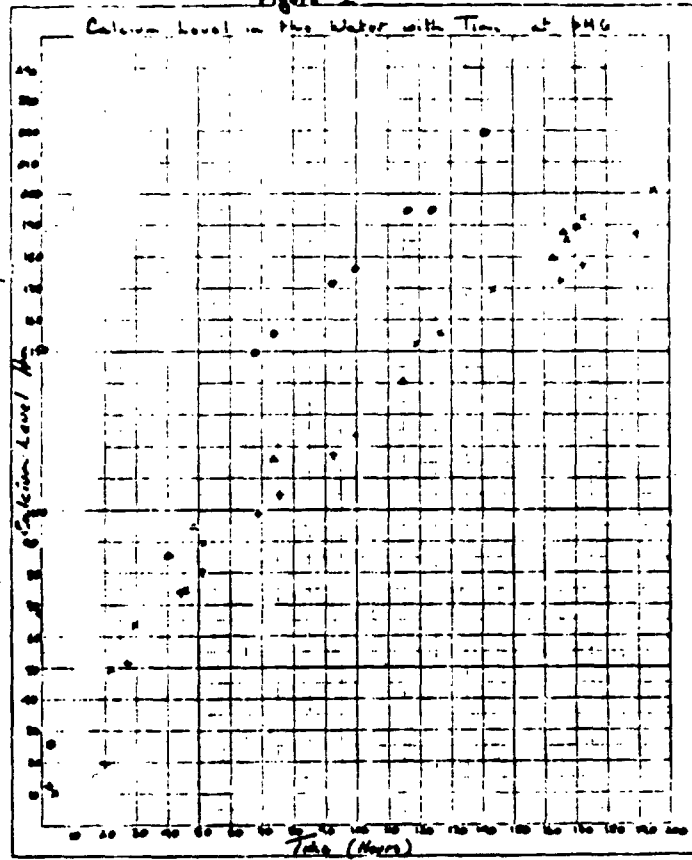
A further rationalisation of the results has been carried out by considering the rate of build-up of residue in the water and also the agreement of the AAS and X-ray results. Figure VIII is a graph of rate of release of residue (i.e. the residue collected divided by the length of time for the run) against pH. Any values which lie far from the main line of the graph were rejected for both AAS and X-ray results. Also any X-ray values which were more than five times smaller than the equivalent AAS value were ignored. The average values for the fibre release at each pH value after these omissions are shown in Figure IX.

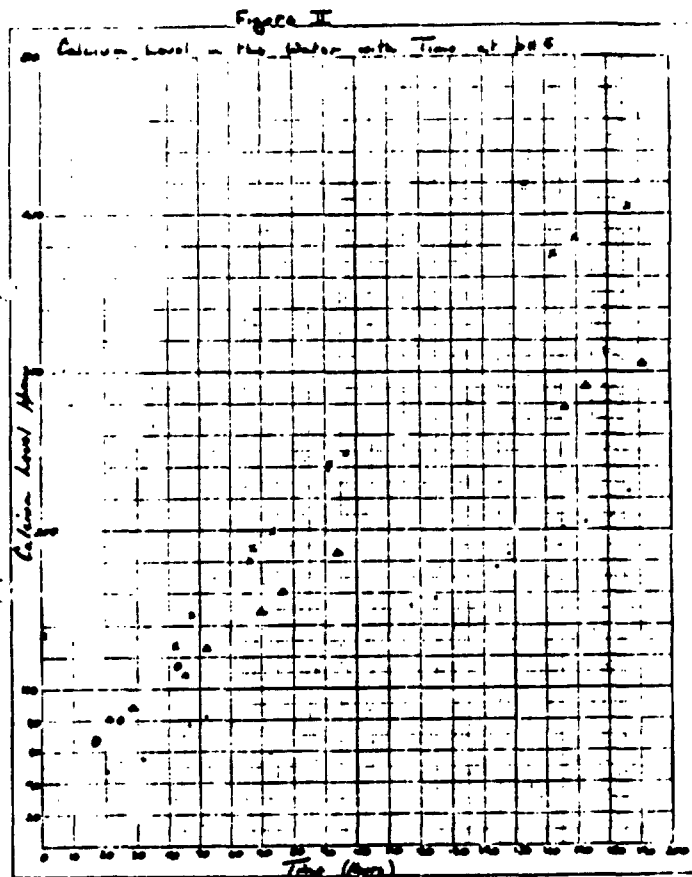
Figure I shows a plot of the average log fibre release (taking into account the corrections shown in Figure IX) against the average reciprocal of the rate of calcium release for pH values from 3-8. As explained in the previous report, the fibre release at pH7 and pH8 was high because the pipes were fresh and the major proportion of the fibre was the result of mechanical action of the water rather than chemical attack on the pipes. However, if the graph for the pH values 3-6 is extrapolated back to points corresponding to the rates of calcium release at pH7 and pH8 this results in a value for fibre release of the order of 10^{-3} mg/100ft of 4" pipes which would be the expected value for clean pipes. It is likely that the true value lies below this figure as the rates of calcium removal at pH7 and pH8 are probably higher than would be the case for pipes which had been used for some time. The present values were established with fresh pipes.

Values for the fibre release below a value of 10^{-3} mg/gal/100ft of 4" pipes would yield fibre content in the filtered residue below the detection limit of the analytical techniques for runs of the present length. In order to establish the actual release at pH6 and above, it would be necessary to carry out prolonged runs lasting several weeks. This would be carried out once a background level of zero

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Figure I





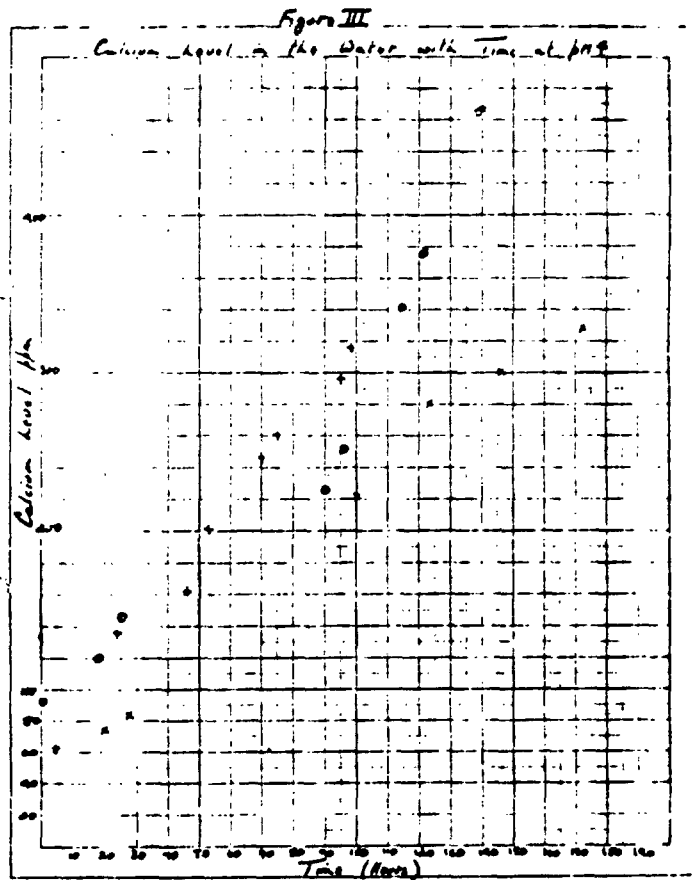


Figure V

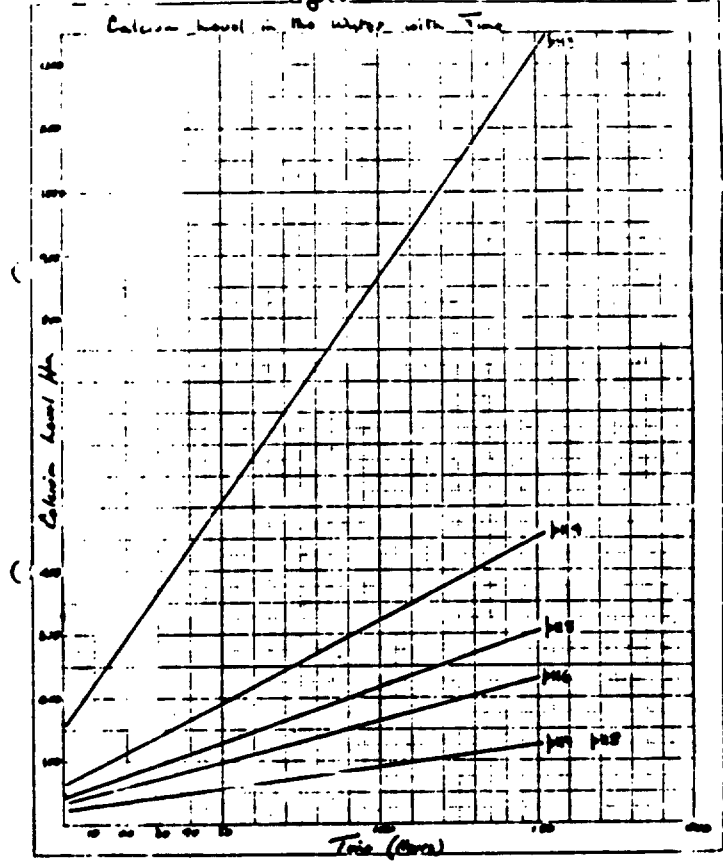
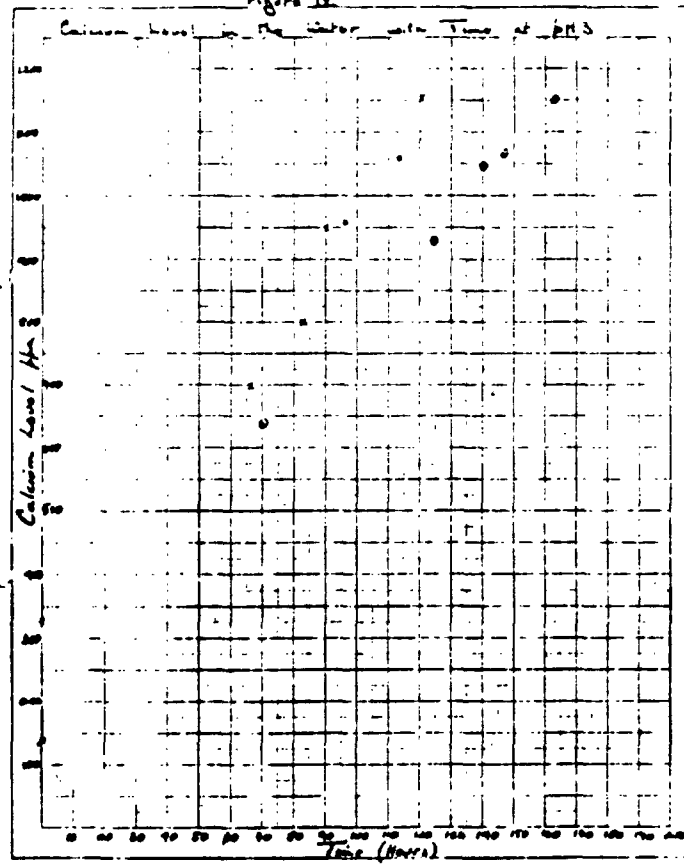
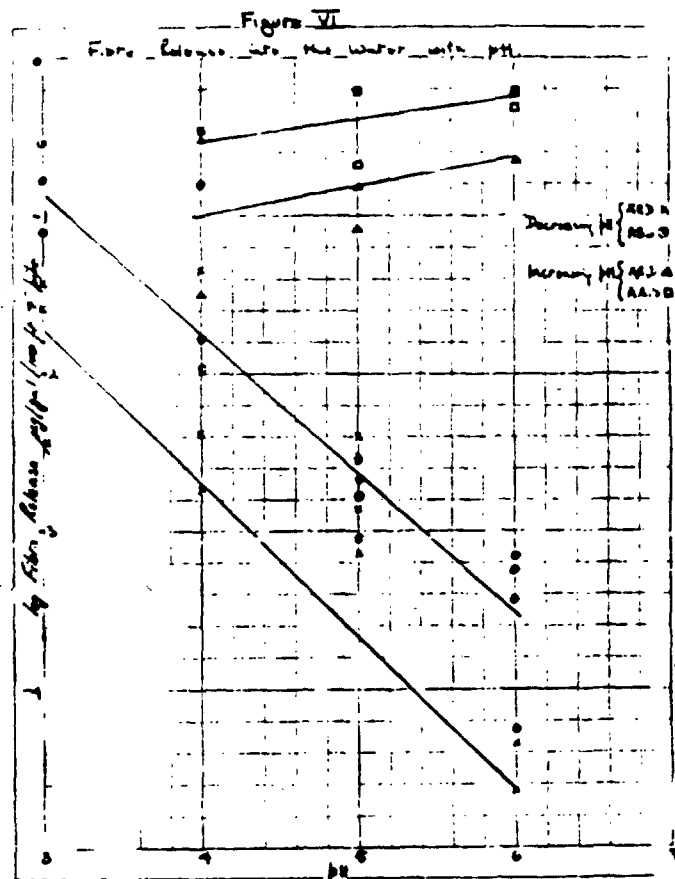


Figure IV



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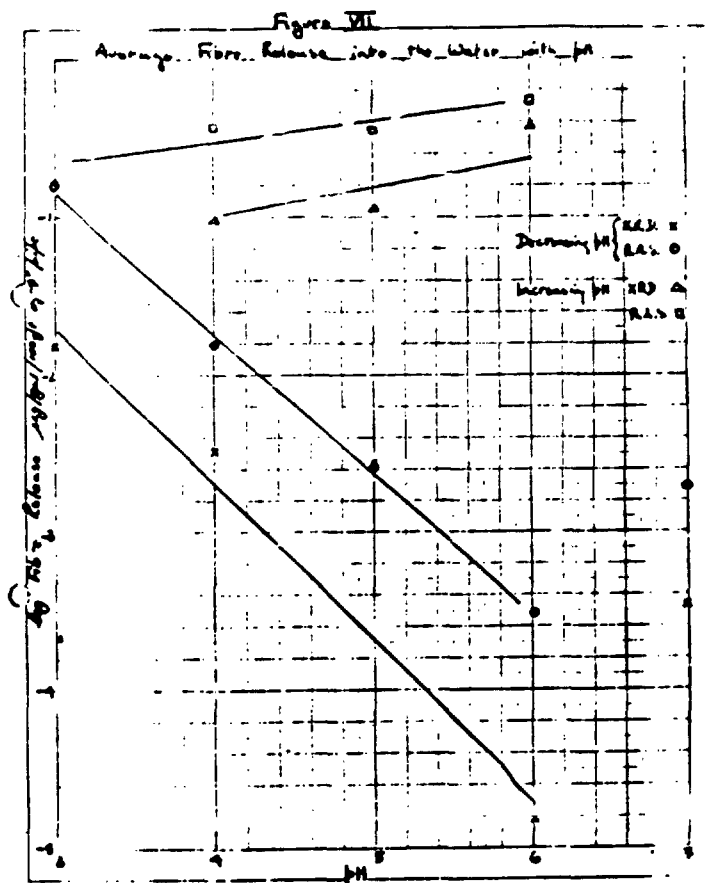
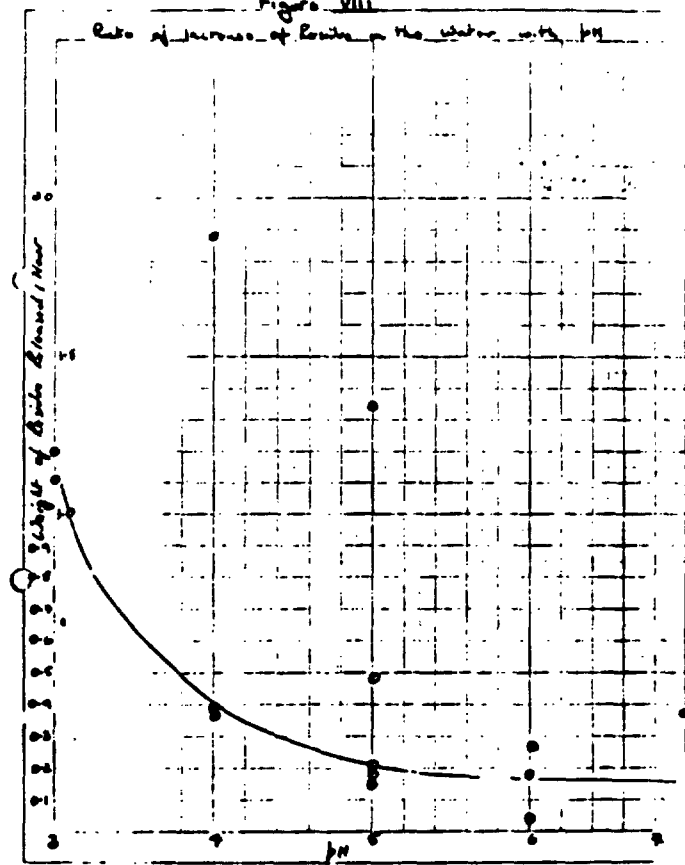


Figure VIII



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Figure II
Average Considered Best Values of Fibre Release into Water vs pH.

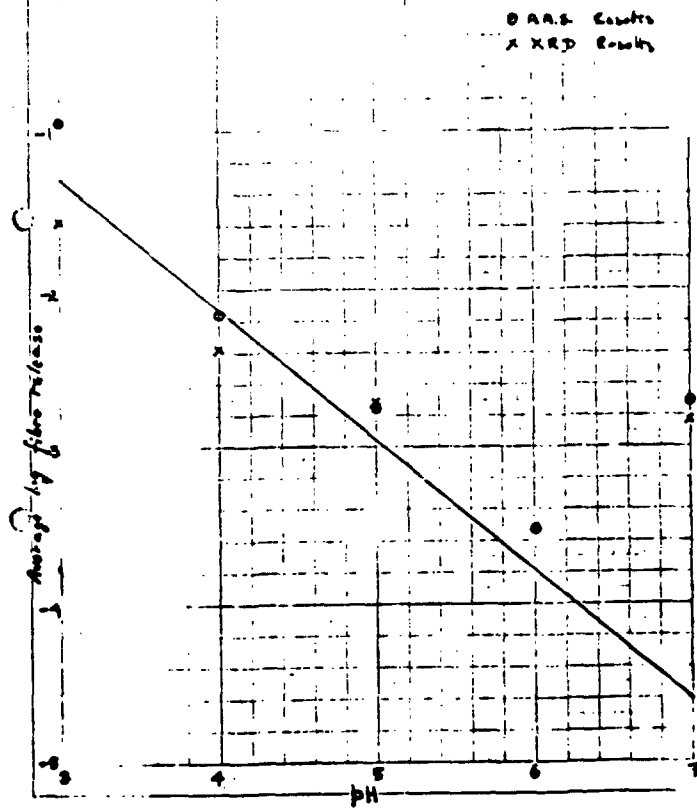


Figure X
Average Considered Best Values for Fibre Release & Reciprocal Rate of Calcium Removal

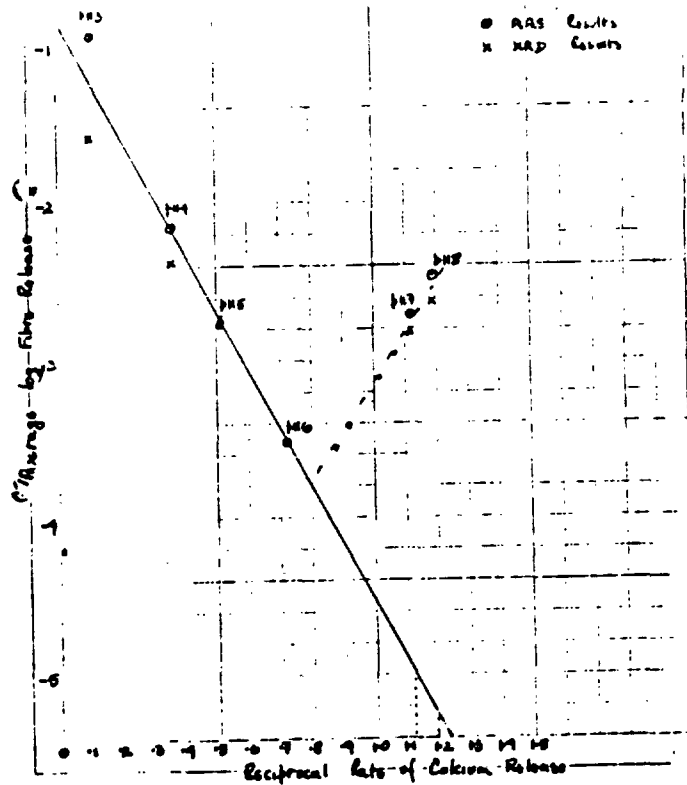


Figure II
Expected Mill. rate of Abs. against pH

