

MEMORANDUM

To H.E. Pawson

Date January 15, 1974

From A. Cheng

Ref. Fe

Subject The Utilization of Mine Water in Arsenic Suppression

A preliminary survey was conducted to investigate the effect of mixing waste solutions and mine water in hope that mine water could be utilized to dilute the arsenic content and to supply part of the ferrous iron for arsenic suppression. After reviewing the results and the experimental procedure of that survey, it was found that some modification should be taken to improve the survey. The following changes were made: good agitation was provided to mix the solutions thoroughly, product solutions were filtered twice to ensure that only soluble arsenic was under determination. The filtrate from the waste solution was used to carry the survey so as to know what is the maximum suppression effect of the mine water on the soluble arsenic. The filtering process removed most solids which at this point would complicate the interpretation of data relating to soluble arsenic depression.

The dilution tests were run for this apparent variable to see what effect the mixing of waste solutions and mine water in different volume ratio had on reduction of arsenic. The results indicated that the optimum volume ratio fell into one to two of waste solution to mine water. However, the dilution ratio is only an apparent variable. A closer control of the process will have to study the true variables, among which the most obvious are pH of the #8 Agitator Discharge, pH of the resultant solution, the iron content of the mine water and other unknown variables. Some of the operational variables were also discussed, such as, agitation time, operational stability of the precipitate, pH of the resultant solution and iron content of mine water.

It was found that the net depression was affected by agitation time, but it reaches equilibrium quickly. The precipitate was operationally stable. A study of the precipitate stability in the tailing pond was done. Distilled water was added to the mixture with agitation to model the consequences of the mixture entering the tailing pond. The distilled water was used to bring the pH of the unfiltered mixtures down so as to see how the pH affected the precipitate in the tailing pond. It was chosen as it does not contribute any unknown effects so as to simplify the model and as the solution in the tailing pond is very low in iron content. It was found that the stability of the precipitate depended on the concentration of the unreacted iron and the pH in the resultant mixture.

If the precipitate cannot be stabilized or be separated before going to the tailing pond, the method cannot be encouraged.

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EXPERIMENTAL PROCEDURE:

The waste solutions were filtered and then mixed with the mine water with a good agitation. The resultant solutions were filtered twice to ensure that only soluble arsenic was determined by the tests.

The following mine waters were used for this survey.

<u>DENOTED BY</u>	<u>DATE</u>	<u>pH</u>	<u>As. (p.p.m.)</u>	<u>Fe. p.p.m.</u>
MW1	Dec. 7,/73	7.5	2.05	19.5
MW2	Dec. 17/73	7.6	1.86	34.0
MW3	Dec. 27/73	7.8	2.34	27.0

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(A)

DILUTION TEST:

This set of tests was conducted to see what effect mixing different waste solutions with mine water in different volume ratios had on the reduction of soluble arsenic. The bulk of the data is related to the #8 and #5 agitator discharge as these are the most prominent waste solutions but some tests were also run on those solutions which enter the #8 and #5 agitator to see if they would yield more favourable depressions. The results are expressed in terms of total and net As. depression. They are defined as follows:

$$\text{Total As. depression} = \frac{\text{As. content of waste solution} - \text{As. content of resultant solution}}{\text{As. content of waste solution}}$$

$$\text{Net As. depression by mine water} = \frac{\text{As. content of ideal mixture} - \text{As. content of resultant solution}}{\text{As. content of ideal mixture}}$$

$$\text{As. content of ideal mixture} = \frac{(\text{Vol.}) \text{ w.s.} \times (\text{As.}) \text{ w.s.} + (\text{Vol.}) \text{ m.w.} \times (\text{As.}) \text{ m.w.}}{(\text{Vol}) \text{ w.s.} + (\text{Vol}) \text{ m.w.}}$$

The dilution test data are presented in the tables below

TABLE 1

1. #11 thickener O'flow (D.W.T.O.) with MW1 (19.5 F₂)

Agitation time: 3 minutes

<u>MIXTURE COMPOSITION</u>	<u>PH</u>	<u>As. (ppm)</u>	<u>Total As. Depression</u> %	<u>Net As. Depress.</u> %
D.W.T.O.	3.6	103.8		
D.W.T.O. + lime	10.9	35.9	65.6	15.4
1 part D.W.T.O. + lime + 1 part mine water	10.3	17.6	83.68	83.0 7.25
1 part D.W.T.O. + lime + 2.5 parts mine water	9.4	9.3	91.04	91.3 20.66

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TABLE 2

2. #6 Thickener O'Flow (M.W.T.O.) with MW1 (19.5 Fe)

Agitation Time: 3 minutes

MIXTURE COMPOSITION	PH	As. p.p.m.	Total As. Depression %	Net As. Depress. %
M.W.T.O.	6.2	39.58		
M.W.T.O. + lime	11.3	12.10	69.43 71.2	
1 part M.W.T.O. + lime + 1 part mine water	10.9	6.92	82.52 82.5	1.56
1 part M.W.T.O. + lime + 2.5 parts mine water	10.2	5.05	87.17 87.2	-2.55

TABLE 3

3. Carbon Plant Thickener O'Flow (C.P.T.P.) with MW1 (19.5 Fe)

Agitation time: 3 minutes

C.P.T.O.	6.1	794.6		
C.P.T.O. + lime	10.2	91.5	88.48	
1 part C.P.T.O. + lime + 1 part mine water	9.9	63.84	91.97	-33.62
1 part C.P.T.O. + lime + 2.5 part mine water	9.5	45.22	94.31	-63.79

TABLE 4

4. Dust Treatment Barren Solution (D.T.B.) with MW1 (19.5 Fe)

Agitation time: 3 minutes

D.T.B. + lime	9.4	758.10	32.14	
D.T.B.	8.2	1117.2		
1 part D.T.B. + lime + 1 part mine water	9.2	473.48	57.61	-24.58

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TABLE 4 cont'd

<u>MIXTURE COMPOSITION</u>	<u>PH</u>	<u>As. p.p.m.</u>	<u>Total As. Depression %</u>	<u>Net As. Depress %</u>
1 part D.T.B. + lime + 2.5 part mine water	9.2	289.40	74.10	-32.71

TABLE 5 (a)

5. #8 Agitator Discharge

(a) #8 Agitator Discharge of November 27, 1973 with MW1 (19.5 Fe)
Agitation time: 3 minutes

<u>#8 A.D.</u>	<u>PH</u>	<u>As. (ppm)</u>	<u>Total As. Depression %</u>	<u>Net As. Depression %</u>
<u>Mine Water</u>				
#8 A.D. only	12.0	12.98		
1/1	11.5	4.95	61.87	41.70
1/2	11.3	3.51	72.72 72.96	49.78
1/5	10.5	2.93	77.43	36.98

TABLE 5 (b)

(b) #8 Agitator Discharge of December 8, 1973 with MW1 (19.5 Fe)
Agitation time: 3 minutes

#8 A.D. only	12.0	15.59	63.00	33.00
2/1	11.8	6.97	55.29	37.90
1/1	11.5	4.47	71.33	50.58
1/2	11.1	3.59	76.97	47.69
1/4	10.7	2.71	82.62	47.05

TABLE 5 (c)

(c) #8 Agitator Discharge of December 14, 1973 with MW2 (34 Fe)
Agitation time: 3 minutes

#8 A.D. only	11.8	6.85		
2/1	11.7	3.44	49.74 49.78	33.62
1/1	11.5	1.21	82.37 82.34	65.72

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TABLE 5 (c) cont'd

#8 A.D. Mine Water	PH	As. (ppm)	Total As. Depression %	Net As. Depression %
1/2	11.3	1.21	82.37 82.34	<u>65.72</u>
1/4	10.6	1.20	82.48	58.01

TABLE 5 (d)

(d) #8 Agitator Discharge of January 5, 1974 with MW3 (27 Fe)

Agitation time: 5 minutes

#8 A.D. only	11.9	15.2		
2/1	11.55	7.45	51.0 4	31.2
1/1	11.4	3.62	76.2	58.6
1/2	10.85	2.23	85.5 85.3	<u>66.4</u>
1/4	10.3	2.87	80.9 81.1	64.7

TABLE 6 (a)

6. #5 Agitator Discharge

(a) #5 A.D. of December 10, 1973 with MW1 (19.5 Fe)

Agitation time: 3 minutes

#5 A.D. Mine Water	PH	As. (ppm)	Total As. Depression %	Net As. Depression %
#5 A.D. Only	12.0	10.27		
2/1	11.8	8.99	12.46	-17.06
1/1	11.7	8.40	18.21	-31.56
1/2	11.4	4.97	51.61	+ 2.36
1/4	10.8	3.96	61.44	+ 2.32

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TABLE 6(b)

(b) #5 Agitator Discharge of December 15, 1973 with MW2 (34 Fe)
Agitation time = 3 minutes

#5 A.D. Mine Water	pH	As. (ppm)	Total As. Depression %	Net As. Depression %
#5 A.D. only	12.0	2.66		
2/1	--	0.90	66.17	60.17
1/1	11.8	1.12?	57.89	50.44
1/2	11.6	0.64	75.94	71.68
1/4	11.3	0.96	63.16 63.91	57.52

TABLE 6(c)

(c) #5 Agitator Discharge of January 3, 1974 with MW3 (27 Fe)
Agitation time = 5 minutes

#5 A.D. only	12.1	4.79		
2/1	11.95	1.54	6.78 67.8	61.1
1/1	11.62	0.64	86.6	82.0
1/2	11.3	0.27	96.00 94.4	91.4
1/4	10.9	0.27	96.0 94.4	89.3

Note the results of the tests on the individual solutions (D.W.T.O., M.W.T.O., D.T.B., C.P.T.O.) were not encouraging. Dilution of #8 and #5 with mine water showed that the optimal ratio is mixing 1 part of #8 or #5 Agitator Discharge with 2 parts of mine water. At these ratios, the depression of arsenic is as much as 66.4% net for #8 and 91.4% net for #5. As Figure 1 and Figure 2 of depression versus dilution indicates, dilution ratio up to 1/5 does not adversely affect depression by too great a factor.

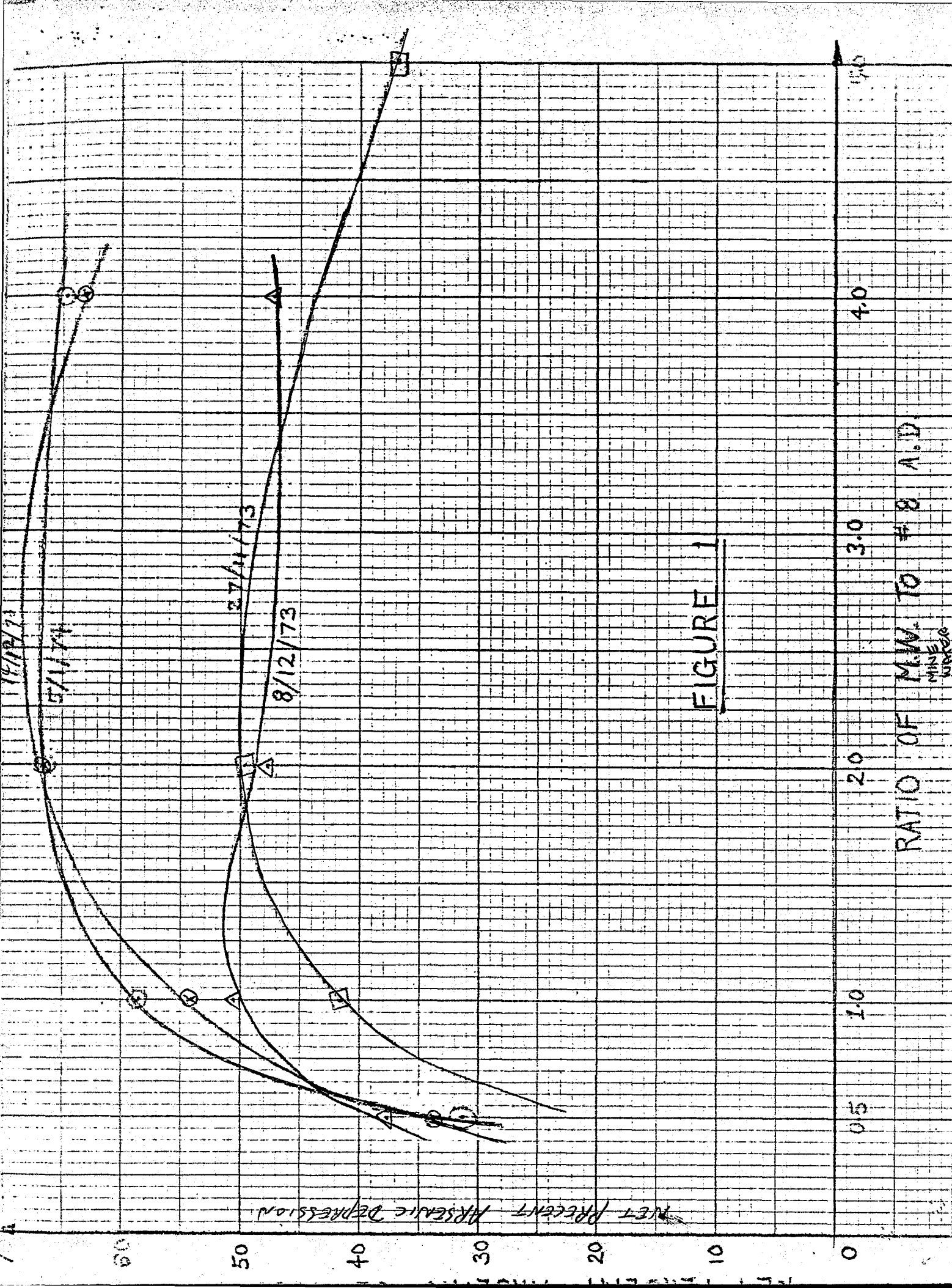
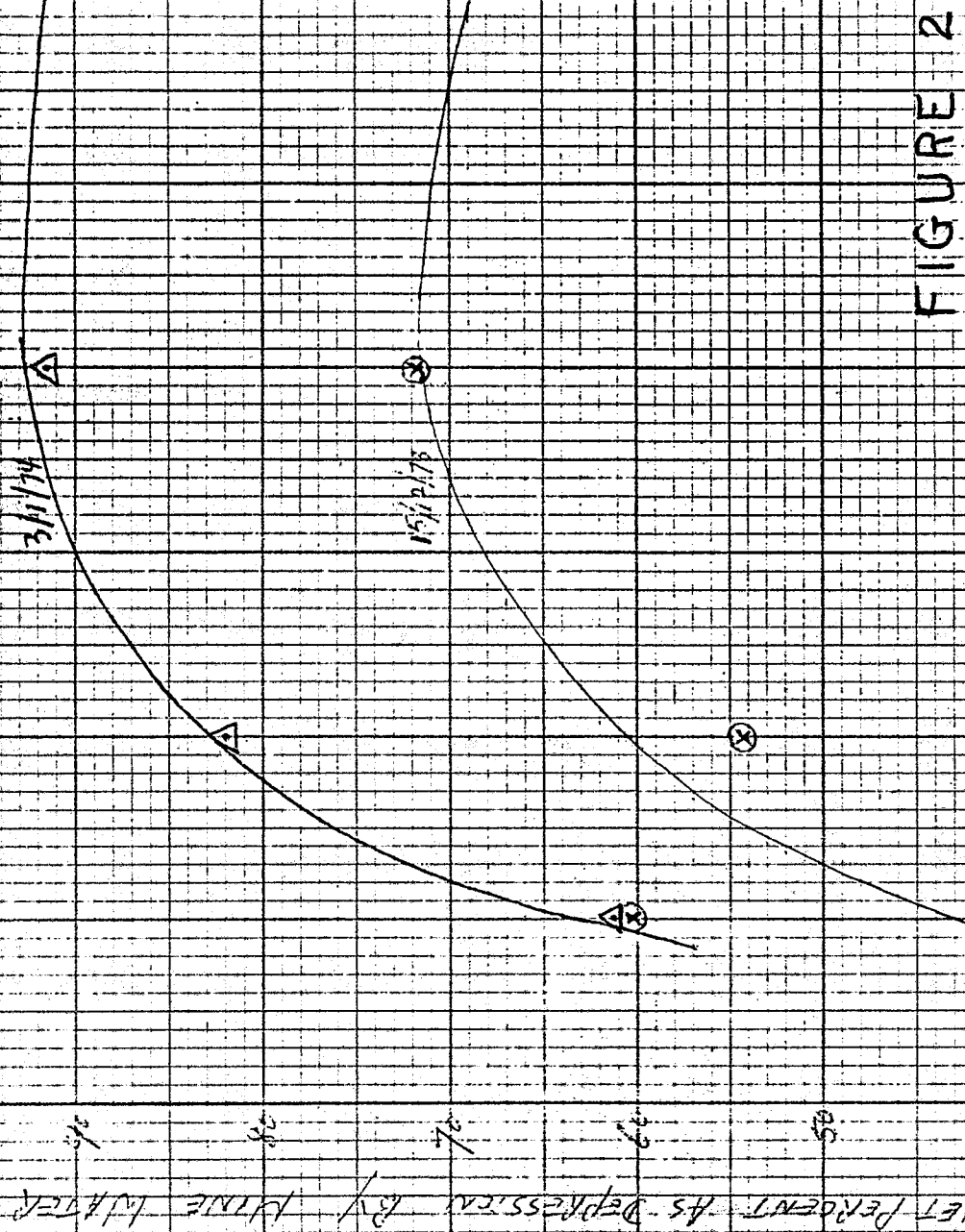


FIGURE 1



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(B) Operation Variables

(a) Agitation Time:

Iron content of mine water is suspected to be one of the factors which contributes to the suppression of soluble arsenic in waste solutions. As it was found that the iron present in the mine water is in the form of minute solid particles, agitation time is expected to be a variable for the reaction of solid with liquid.

Equal volume mixing was used to carry out the test.

TABLE 7

Test 1

#8 Agitator Discharge of December 24, 1973 (As. = 15.16 ppm) with MW2.

<u>Agitation Time (min.)</u>	<u>As. (ppm)</u>	<u>Net As. Depression</u>
1	5.21	38.78
5	4.20	50.65
25	3.19	62.51
50	4.52	46.89

TABLE 8

Test 2

#8 Agitator Discharge of January 5, 1974 (As. = 15.2 ppm) with MW3

1	4.73	46.0
5	3.62	58.6
20	4.20	52.0
40	4.31	50.9

Figure 3 indicates that the net As. suppression rises rapidly within the first 5 to 10 minutes of agitation and does not change further. The best agitation time is about 5 minutes.

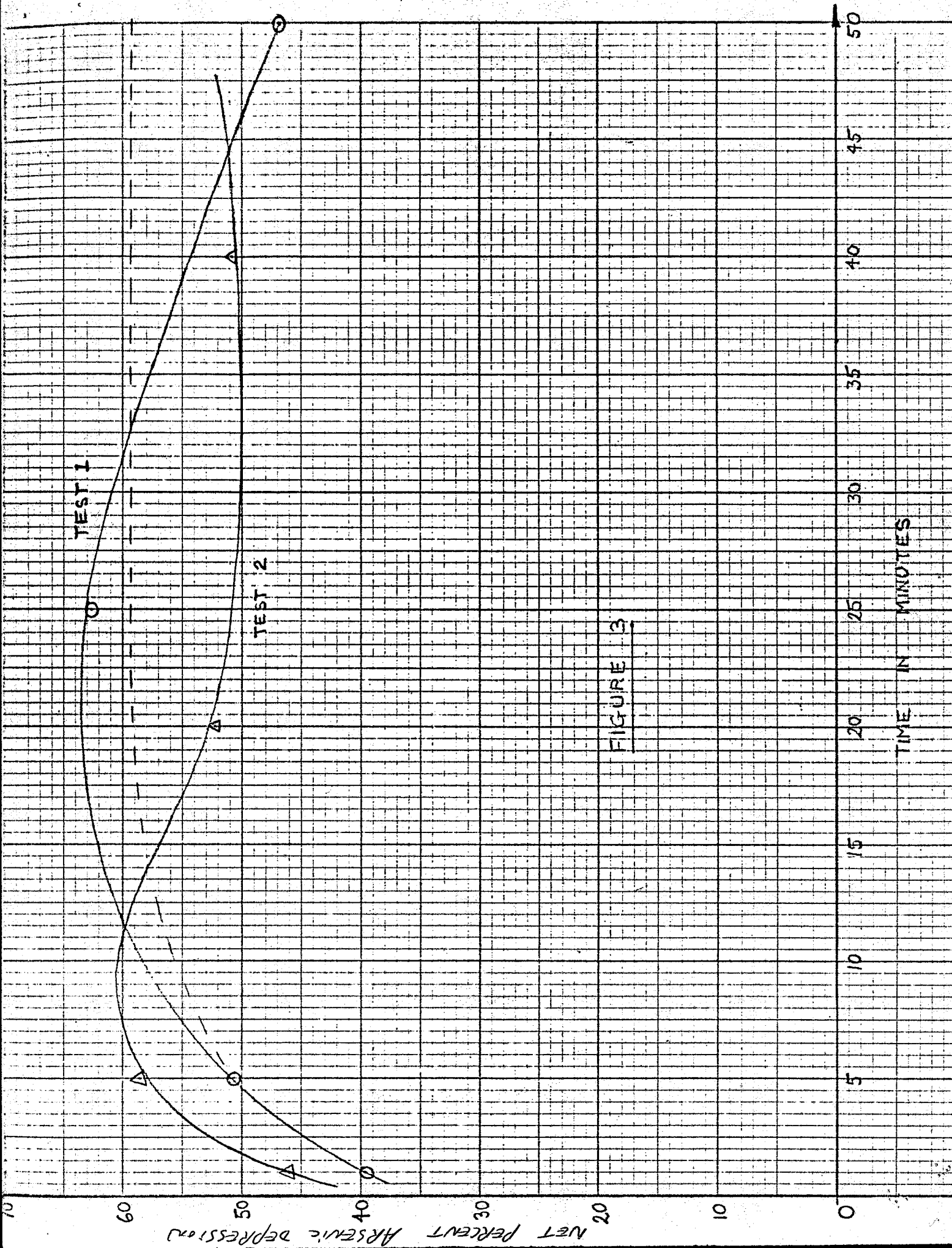


FIGURE 3

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(b) Operation Stability

Table 9 shows the stability of mine water and waste solution mixtures when subjected to physical agitation separated by a period of rest

TABLE 9

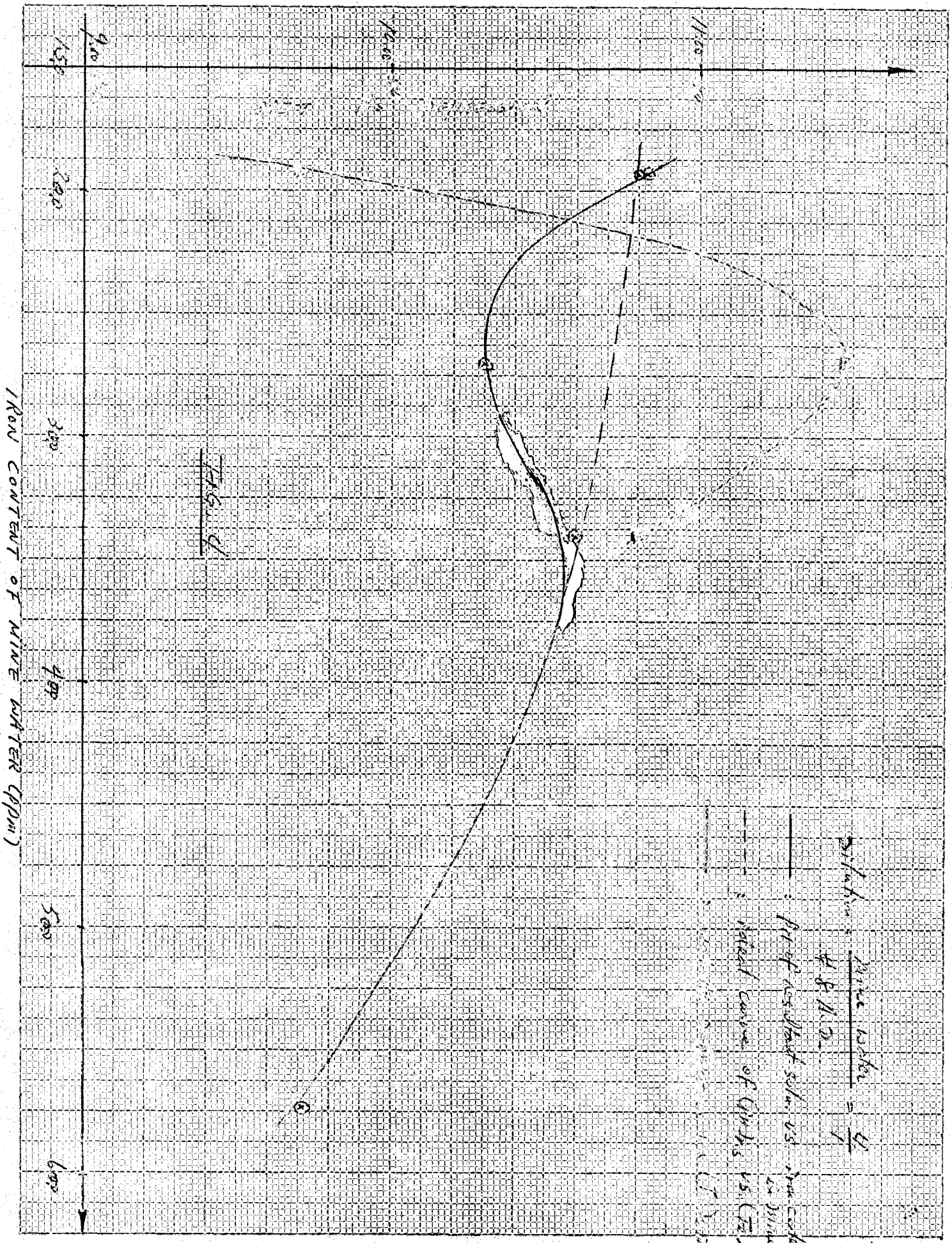
Equal Vol. Mixture	1st Agitation Time	As. Content	Rest Time	2nd Agitation Time	As. Content
#8 A.D. of Dec. 14/73 with MW2	3 min.	1.998	15 min.	2 min.	1.768
#8 A.D. of Jan. 5/74 with MW3	5 min.	3.62 ppm (58.6% net As. Dep.)	17 hrs.	5 min.	4.2 p.p.m. (72.4% Tot. Dep.) (52.0% Net Dep.)
#8 A.D. of Jan. 5/74 with MW3	5 min.	3.62 ppm (58.6% net As. Dep.)	17 hrs.	5 min.	4.62 ppm (69.7% Tot. Dep.) (46.7% Net Dep.)

The data shows that after a sufficient total agitating time (25 min.) more agitation and sitting time tend to be slightly unfavourable for arsenic depression due probably to concentration of soluble arsenic content due to evaporation of test samples overnight.

(c) PH of the Resultant Solution and the Iron Content of Mine Water

The pH of the resultant solution and the iron content of mine water are believed to be the most important variable affecting the maximum net arsenic depression. An indirect result was found and was shown in Figure 4 (the pH of #8 Agitator Discharge was assumed to be the same since it only varies from 11.8 - 12.0.) At the fixed dilution ratio ($\frac{1}{4}$), the lower the pH of the resultant solution, the higher the net As. depression. The rough trend is pH decreasing with the increasing of iron content of mine water; it means that, the net depression might increase with the increasing of iron content in mine water. Figure 4 also has a distinct maximum net arsenic suppression which coincided exactly with the local minimum in the pH curve. The significance of this is worth investigating in order to closely control the process if it is adapted.

PH



$$\text{definition} = \frac{\text{pH value}}{4.8 \text{ H.O.}} = \frac{4}{1}$$

— : pH of acidified soln. vs iron content
 --- : Natural curve of (pH) vs (Fe) in water

IRON CONTENT OF NINE WATER (ppm)

Fig. 4

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(C) Stability of Precipitate

Consider the stability of the precipitate after the mixture is pumped out to the tailing pond. The pH of the incoming mixture will fall to that of the tailing pond (around pH = 10.2).

To model this, an equal volume mixture prepared by agitating for 5 minutes, was allowed to stand for 20 minutes, and then was re-agitated for 1 more minute with distilled water added simultaneously. This 1 minute re-agitation simulated all the motion the flow undergoes after exit of the agitator.

TABLE 10

Vol	Vol. Dist. H ₂ O	PH	As. (ppm)	Net As.	% of As.
	Vol. #8 A.D.	—	—	Depress.	Precipit. Redissolv.
<u>Set 1</u>					
#8 A.D. December 14, 1973 + MW2	0	11.5	2.00	54.12	0
#8 A.D. December 14, 1973 + MW2	2.50	11.1	1.71	11.86	78.09
<u>Set 2</u>					
#8 A.D. December 24, 1973 + MW2	0	11.4	4.20	50.65	0
#8 A.D. December 24, 1973 + MW2	2.94	10.8	3.95	0	Almost completely redissolv.

TABLE 11

Test 1 Relationship between % precipitate redissolved and pH

Set 3

#8 A.D. January 5, 1974 + MW3	0	11.4	3.62	58.6	0
#8 A.D. January 5, 1974 + MW3	1	11.26	3.03	48.08	17.99
#8 A.D. January 5, 1974 + MW3	2	11.12	3.35	23.52	59.88
#8 A.D. January 5, 1974 + MW3	3	11.04	2.29	34.57	41.04

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TABLE 11 (cont'd)

Set 3 (cont'd)

	<u>Vol. Dist. H₂O</u> <u>Vol. #8 A.D.</u>	<u>PH</u>	<u>As. (ppm)</u>	<u>Net As.</u> <u>Depress.</u>	<u>% of As.</u> <u>Precip.</u> <u>Redissol.</u>
#8 A.D. of January 5/74 + MW3	4	10.95	2.61	10.64	81.98
#8 A.D. of January 5/74	5	10.8	2.21	11.60	80.21

The Figure 5 showed precipitate instability. The precipitate will dissolve back according to the pH. However, combining 1 part of #8 agitator discharge with 4 parts of mine water, which also brings down the pH to 10.8, did not make the precipitate unstable. This is probably due to an equilibrium existing between reacted and unreacted iron content in the solution. From this, one concludes that the characteristics of the solution in the tailing pond will be an important factor affecting the stability of the precipitate - especially its iron content and pH. Since the iron content in the tailing pond is very low (1.5 ppm), the stability of the precipitate will behave according to the graph (Figure 4).

% of PRECIPITATE REDISSOLVED

pH of the resultant solution

11.5

11.0

10.8

1.5

2.5

3.5

4.5

5.5

6.5

7.5

100

90

40

20

10

5

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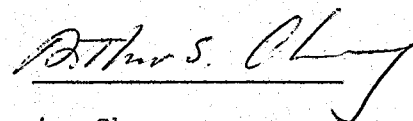
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(D) RECOMMENDATIONS:

The main problem associated with the mine water method for suppression of arsenic in waste solutions is the stability of this precipitate. Stabilization or elimination of the precipitate going to the tailing pond is the challenge to be faced. One solution to this problem is to pump the resultant solution to a thickener; the overflow from the thickener to go to the tailing pond, and the underflow should go underground. If the stability of the precipitate was affected only by the pH, the process can be improved by using high dilution ratio of mine water to #8 Agitator Discharge (to adjust the pH to that of the tailing pond) since high dilution ratio lowers the net suppression of arsenic only slightly.

However, it seems that the stability depends also on the unreacted iron concentration in the surrounding solution so that the precipitate will redissolve upon the lowering of iron content in the solution of the tailing pond. (only 1.5 ppm). This would necessitate further study of the stability of the precipitate upon mixing with large amount of tailing pond solution. (which is inaccessible until spring due to the frozen outlet.)



A. Cheng
Mill Engineer