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LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

A PLANT OPERATING SCHEDULE AND PRODUCTION RATE FOR NUCLEAR CHEMICAL MINING OF COPPER

by

R. Mallon and J. Cramer

July 24, 1973

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SUBJECT A PLANT OPERATING SCHEDULE AND PRODUCTION RATE FOR

NAME *RDM*
R. Walton & J. Cramer

NUCLEAR CHEMICAL MINING OF COPPER

DATE July 24, 1973

I. INTRODUCTION

The economic feasibility of in-situ copper mining with nuclear explosives is currently being studied by this Laboratory and Kennecott Copper Corporation. This note describes a proposed plant operating schedule and two case studies of variations in annual copper production. J. Agarwal of Kennecott¹ has stated that, for favorable economics, the variation in annual production should be kept to a minimum. There are three principal reasons for variation in output:

1. The necessity to shutdown the plant during the blasting of a new set of chimneys.
2. The below-normal output during reentry of a newly blasted set of chimneys.
3. The variation of copper production during the life of the chimney.

The operating schedule proposed in this note is an attempt to minimize the year-to-year variation in copper production. This schedule is the best of many which were analyzed. Time estimates of each necessary step in establishing a new set of chimneys and placing it in service are included.

II. DRILLING AND EMPLACEMENT PROCEDURE

The drilling and emplacement of explosives for blasting several chimneys which are far apart can proceed at the same time, and the detonations can be spaced by a few minutes. However, because of vulnerability of explosive assemblies to damage by the effects of nearby explosions, simultaneous emplacement with sequential detonation cannot be used for chimneys in close proximity. In order to blast chimneys which are close together, it is necessary to emplace and detonate each explosive before starting emplacement of the next explosive. Most of the time required in preparation for blasting a chimney is used in drilling the emplacement hole. We propose to speed-up field operations by drilling these holes while the plant is in operation. Those holes not initially used are to be protected against collapse by filling with wet sand. The sand can be easily removed by using a small, highly-mobile workover rig when the hole is to be used. This procedure has not been previously used. The problem of the hole being partially closed-off by a differential shift of subsurface layers can probably be overcome by drilling larger holes than are actually required. This approach must be balanced against the increased vulnerability of the larger hole to collapse-type failure. Presently, a detailed analytical study is underway to establish the feasibility of the proposed procedure.

In establishing a row of adjacent chimneys, the pattern of collapse of rock into a blasted cavity may be affected by the presence of an adjacent chimney. In order to provide for symmetry of the collapse, we propose that the sequence of blasting be such that each new cavity have adjacent chimneys on both sides, or on neither side.

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III. PROPOSED OPERATING SCHEDULE**A. Preparation for Blasting**

The arrangement of chimneys was described in a previous note². Each set is a straight row of 10 chimneys. For the description to follow, these chimneys are sequentially numbered from 1 to 10. Before shutting down the plant for blasting a row of chimneys, the emplacement holes for the explosives are drilled. Explosives are placed in holes 1, 5, and 9, and are stemmed. The remaining holes are filled with wet sand. The plant is then shutdown and all equipment is placed in a shock-resistant condition, specifically:

1. All pipes carrying liquids are drained.
2. All long pipe runs are disconnected at topographic discontinuities, such as creeks or arroyos.
3. All heavy piping-system components, such as valves and pumps are disconnected.
4. Shock vulnerable equipment is removed from the spill region.
5. The LIX plants, if located in the spill region, are removed.

For planning purposes, we estimate that the time required for the above 5 steps is 2 days.

B. Blasting Procedure

After completion of the preparation described above, explosives 1, 5, and 9 are sequentially detonated. Next, holes 3 and 7 are washed free of sand, dimensionally checked, and the explosives are placed and stemmed. These explosives are then sequentially detonated. We estimate that the elapsed time between detonation of explosives 1, 5, 9 and explosives 3, 7 is 10 days. The next group of explosives is 4, 8 and the final group is 2, 6, 10.

Since the explosives are fired in 4 groups with 10 days between each group, the total time during which detonations occur is 30 days. We estimate that 3 days are required to reconnect the pipes, reinstall valves, pumps, and LIX plants, and repair minor damage. These 3 days, plus 30 days for blasting plus 2 days for making the plant shock-resistant results in the plant being shutdown for a total of 35 days. Immediately after the plant is returned to production, only 10 chimneys will be in service. Leaching in the newly blasted chimneys cannot begin until reentry procedures are complete.

C. Chimney Reentry

For estimating the time required for reentry, we assume that one drill-rig is available for each chimney, so that reentry drilling can proceed simultaneously on all newly blasted chimneys. The piping required for leach liquor circulation has been described previously². The total time required for drilling

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and setting pipe for all the required flow lines is estimated to be 130 days. In addition, we allow an average of 5 days for late arrival of the drill-rigs used for reentry. Thus, we estimate that leaching of new chimneys will begin 135 days after the final detonation.

IV. COMPUTATION OF OUTPUT

The computation of annual copper production is performed for two different rates of flow of leach liquor to the LIX plant. For the first case, the flow from each chimney is held constant at 540 gpm throughout the life of the chimney and the LIX processing is started at the same time that leaching is started. These assumptions and all other parameters used in the calculation are the same as those used previously². Figure 1 shows the variation of copper concentration in the leach liquor in a chimney. If separate LIX plants are provided for each chimney, the concentration shown on Figure 1 is the concentration in the LIX feed. If a LIX plant receives flow from several chimneys of different ages, the LIX plant feed concentration will be the weighted average of the concentrations in the chimneys from which the LIX plant is supplied. The copper production rate per chimney is derived from the curve on Figure 1. The copper produced from a chimney during a selected time interval is obtained by multiplying the flow rate to LIX by the area under the curve during that time interval. The copper produced by 10 chimneys of the same age during each of the 6 leaching years is shown below.

10 Chimney Production - Constant Flow To LIX

<u>Year</u>	<u>Flow to LIX - gpm per Chimney</u>	<u>Production - KT of Copper</u>
1	540	16.8
2	540	37.0
3	540	28.4
4	540	25.2
5	540	20.4
6	540	15.0

For this computation, the first year starts on the day of the last detonation. During the first year, the first 135 days are lost from leaching operation of the new chimneys because of reentry operations. During the third year, the last 32 days are lost because of shutdown operations and blasting of the next row of chimneys. Since year one for each row of chimneys was defined to start on the day of the last detonation, the first 3 days of the fourth year are lost for plant restart operations. Finally, during the sixth year, 32 days are again lost during plant shutdown and blasting. The total number of days during which leaching is in progress in each chimney is 1988.

Figure 2 shows a chart of the plant-operations schedule. The operation of each row of chimneys is indicated. Each year's copper production is also shown. It is seen that the annual production varies with a 3 year cycle after full production is reached. The minimum of this cycle is 42.0 kilotons per year, and the

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maximum is 57.4 kilotons per year. The average annual production during the 3 year cycle is 47.6 kilotons.

In the second case, the year-to-year variation in production is eliminated by varying the flow rate to the LIX plant. The table below illustrates how the flow rate from each chimney to the LIX plant can be varied to accomplish this. The flow rate is constant during each leaching year. The schedule of plant operations is exactly as shown on Figure 2 and the number of days lost from each leaching year is as described previously.

10 Chimney Production - Varied Flow to LIX

<u>Year</u>	<u>Flow to LIX - gpm per Chimney</u>	<u>Production - KT of Copper</u>
1	390	14.2
2	210	27.1
3	280	32.6
4	540	33.4
5	540	20.5
6	540	15.0

Figure 3 shows the variation of copper concentration in the leach liquor in a chimney when the LIX flow rate varies as described. By adding the production from two rows of chimneys which differ in age by three years, the total annual production is found to be 47.6 kilotons every year after full production is reached. This is equal to the average annual production in the first case in which constant LIX flow rate is used.

The plant production rate can be adjusted to meet variations in market demand for copper. This can be accomplished by changing the rate of flow from the chimneys to LIX. If, because of low demand, the plant operates at a low flow rate and low output, the concentration of copper in the leach liquor in the chimneys will increase, and this additional copper can be withdrawn at a later time. Conversely, the plant output can be increased for a limited time by increasing the rate of flow of leach liquor to LIX and thereby reducing the concentration in the leach liquor in the chimneys.

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1. Agarwal, J.C., Kennecott Copper Corporation, personal communication, June 21, 1973.
2. Mallon, R.G., "Conceptual Design of Underground and Wellhead Equipment for Nuclear Chemical Mining of Copper, ENN 73-115, June 19, 1973.

FIGURE 1
Variation of Copper Concentration
Constant LIX Flow

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FIGURE 2

OPERATION SCHEDULE

Annual
Production-
KT of Copper

Year	Operation	Row Number						Production KT of Copper				
0	Plant Construction, Blast Row 1	1	2	3	4	5	6	0				
1	Reenter Row 1							16.8				
2								37.0				
3	Blast Row 2							28.4				
4	Reenter Row 2							42.0				
5								57.4				
6	Blast Row 3							43.4				
7	Reenter Row 3							42.0				
8								57.4				
9	Blast Row 4							43.4				
10	Reenter Row 4							42.0				
11								57.4				
12								43.4				
13								42.0				
14								57.4				
15								43.4				
16								42.0				

Legend

Blasting + Reentry

Leaching

Shutdown

Legend

- Blasting + Reentry
- Leaching
- Shutdown

FIGURE 3

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