TRAVAUX, Proceedings of the 3rd International Congress of ICSOBA , Nice, 17 - 21 September 1973

The "CableTorq" (1) a new thickener design of special value to the alumina industry

K. D. GRUENER*, E. MARTINI* and E. F. PORTER**

Red mud clarification and washing and hydrate thickening is normally done in the Bayer process in continuous thickener. These conventional thickeners have some disadvantages, main of them is the tendency for building up very heavy scalings on the structural rake arms within relative short time (3-12 months). So it is necessary for clean out the thickeners in these short cycles. To reduce cleaning costs and to improve other features of conventional thickeners,Dorr-Oliver has developed a new thickener concept, called CableTorq.

The principle of the CableTorq is the following: The two raking arms are designed as single pipe arms with blades. The torque is brought to the rake arms by a set of cables from the torque arms which are rotating in the clear liquor. The torque arms can be designed as triangular arms because there is no incrustation in the clear liquor. The rake arms are connected to the center shaft or cage by a special hinge, so giving the possibility for self-lifting of the arms. The lift is dependent on the torque; a mechanical lifting device is no longer necessary.

The following features of the CableTorq besides others are important and advantageous for the Alumina industry:

(1) *CableTorq requires lower torque than conventional thickeners.*

(2) *Single pipe rake arm design minimizes scale formation, therefore longer working cycles.*

(3) *Self-lifting rake arms, so no mechanical lifting device necessary.*

About 150 CableTorq thickeners are installed, approx. 50 of them in Alumina plants. Operation results show that the working cycles are at least doubled. They increased to 6-24 months depending on kind of Bauxite and production process. Limitation is no longer given by raking mechanism but by scaling of tank. Furthermore, operation torques are reduced by 30-40% as compared with conventional thickeners.

1. INTRODUCTION

It is the object of this paper to introduce a new concept in the design of continuous thickener mechanisms, which has been demonstrated to be particularly advantageous in the decantation of red mud from the aluminate solutions. Most noteworthy among its

(1) « Dorr-Oliver » and « CableTorq » are trademarks of Dorr-Oliver Inc.

advantages, as compared with the conventional Dorr-type thickener mechanisms in their well-known modifications, is its ability to minimize scale formation on the raking structures to the point where not only can the frequency of shutdowns of red mud thickeners for descaling be cut in half or less, but the cleaning operation itself can be effected in considerably less time than with conventional rakes. In the course of this presentation, we shall discuss many other operational and economic advantages which are obtainable through the application of this new design. But first let us show by a simplified illustration what are the most significant points of difference between this patented new thickener, which our company has named the "CableTorq", and the former conventional red mud thickener.

2. GENERAL DESCRIPTION

Figure 1, presented here for the purpose of comparison, is a schematic side view of a conventional Dorr Thickener of the kind most often used for the settling of red mud. Its raking mechanism consists ot two or more radial trusses A, mostly of triangular cross section, driven through a vertical shaft B by a drivehead C. In an effort to minimize the troublesome effect of scale, the raking blades D are connected to truss arms A by vertical stilts E.

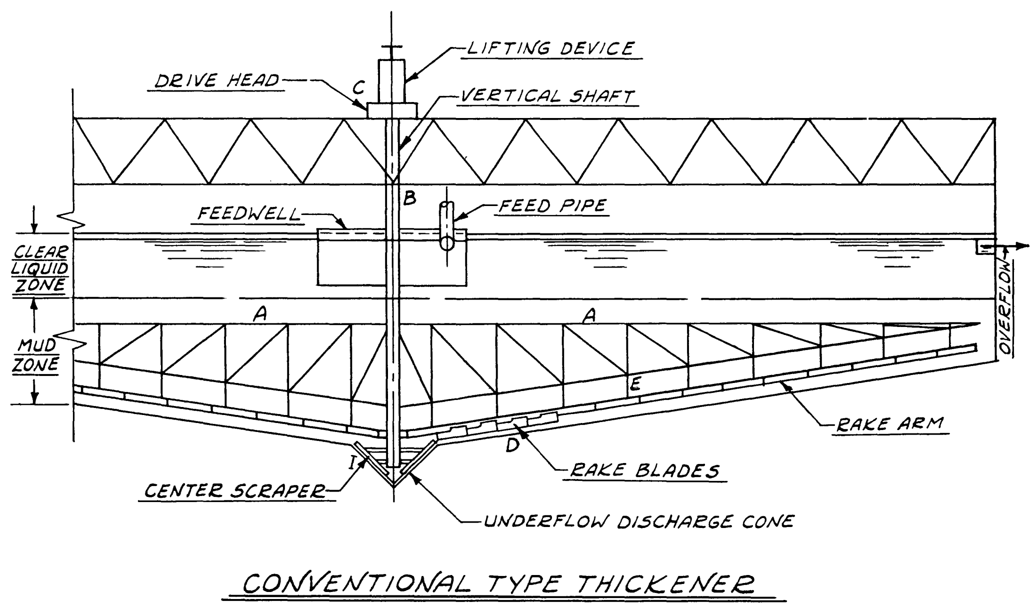


Fig. 1

Figure 2 shows, also schematically, a typical version of the CableTorq Thickener. The outstanding feature of this new device is the fact that the raking elements consist of simple radial pipes A to which the blades B are directly attached. These radial pipe arms are connected by a two-way hinge C to the center shaft D and are supported by cables E from the same center shaft D through any suitable structural part connected to it. Such structural part in this case is the rotating feedwell F. The rake arms are rotated along the bottom of the settling tank by "drag" cables G, connected at their upper end to the extremities of two "torque arms" H, which arms are in turn fixed to vertical center shaft D.

As the name implies, drag cables G simply "drag" the rakes along the tank bottom. Since the rakes are loosely connected to the center shaft by the two-way hinge C, they are

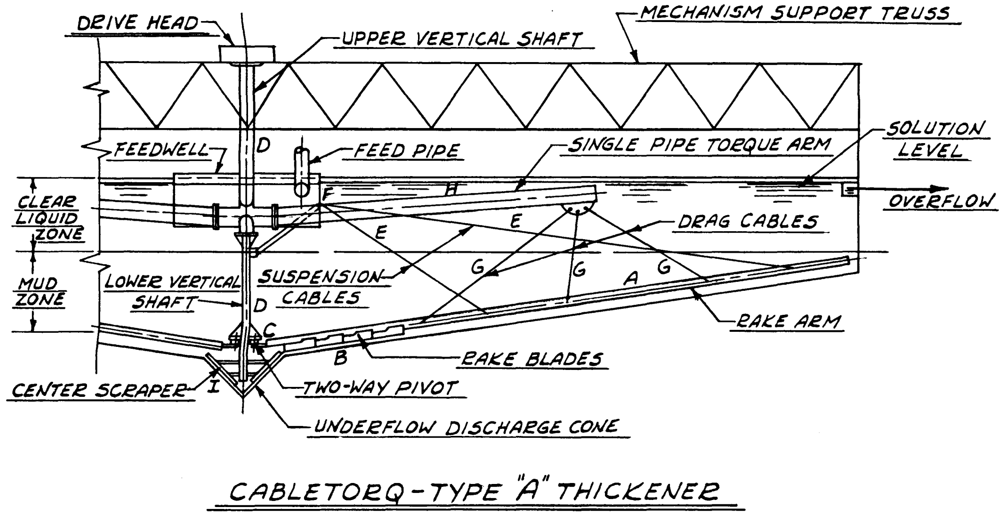


Fig. 2

free to assume whatever vertical and horizontal angular position enables them to offer the least resistance to their movement. Thus, should an obstacle appear along their path, such as a local accumulation of heavy mud, they will simply ride upon it, shaving its top as they go, until the whole accumulation is removed. As to the torque arms H, their function, again as the name implies, is to transmit from the center shaft to the rakes (through the drag cables) the torque required by the rakes to move the red mud. In the design shown in the sketch, used on all centershaft machines, the torque arms consist simply of two radial steel pipes. These arms extend only to about two-thirds of the radius of the tank, and their location is well above the mud zone. It has been found that at the low speed at which these mechanisms are rotated, their presence here does not in the least affect the clarity of the overflow.

3. HISTORY

A few years ago, thickeners applying the principle of the CableTorq were observed by Mr. K. C. Stansmore, Dorr-Oliver Inc. These units were being used successfully by the Union Corporation of South Africa, in several gold extraction plants in the Witwatersrand, to handle thixotropic residual muds. The fact that such residues have many characteristics similar to those which make the sedimentation of red mud so troublesome, induced Dorr-Oliver to negotiate with Union Corporation a Licencing Agreement for the exclusive worldwide use of their "Klopper Thickener", as it was know at the time from the name of the inventor.

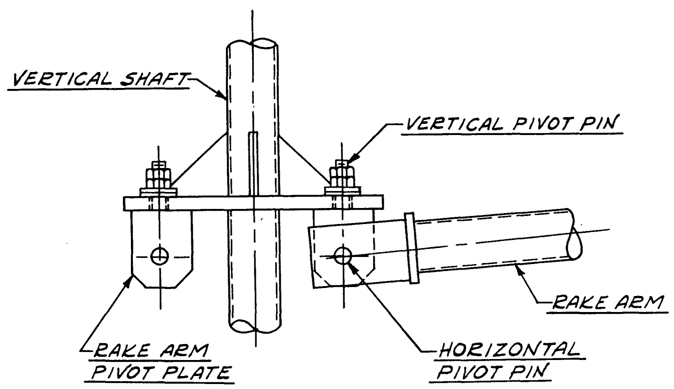
To demonstrate in actual field applications the expected advantages of the new thickener design in the settling of red mud, the cooperation was secured of two major alumina companies with worldwide interests, which agreed to replace the existing rakes with CableTorcq rakes in one of the red mud thickeners in one their respective plants.

After six to nine months of operation of these pilot units, sufficient experimental evidence was collected that thickeners of the new designed could in fact be used with advantage for the handling of red mud, to induce both companies to proceed with additional CableTorq installations.

In each case, further orders were also placed by other plants in their group. In due course, other major alumina companies were induced to try out the new design, and after a suitable operating period, additional CableTorq were specified for plants in these new groups as well. To date about fifty CableTorq Thickeners have been supplied to the Alumina Industry, and these include repeat orders from some of the largest alumina producers, as well as orders from other companies.

4. WHAT MAKES IT WORK

The CableTorq design is based on the fact that each rake arm will always maintain such a position that the torque applied to it through the drag cables counter balances the effective arm weight. Especially noteworthy is the manner in which the principle is applied to the rake arms of the CableTorq, in that the two-way hinge, shown in detail in Figure 3, permits lift of the blades in two planes, but maintains them parallel to the tank bottom, in the optimum attitude for efficient raking.



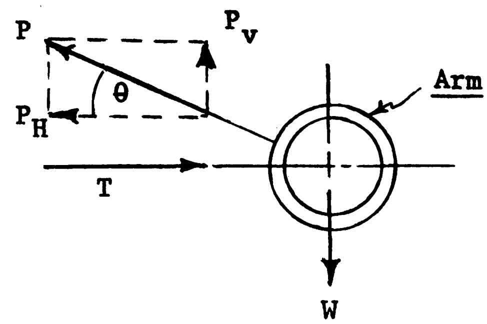
CABLETORQ TWO-WAY HINGE

Fig. 3

This two-way hinge also provides the two degrees of freedom absolutely necessary to permit these drag cables to carry the full torque load under all conditions of rake-arm lift. The drag cables are attached at their upper end to the torque arms, and must pivot about this point of attachment as the rake arms lift. If the drag cables are to carry the full load, they must remain taut, and so the rake arms must move upward in an arc about this pivot point. A single hinge, no matter how inclined, would act to prevent the rake arms lifting along the necessary arc, and so would require that under most conditions of lift either the hinge must carry much of the torque load, which defeats the main purpose of the CableTorq design, or else that the rake-arm structure may bend.

In a simple way, the design theorem can be illustrated by Figure 4. Referring to this figure, the cable tension P will be a function of torque force ($P_H = T$). The magnitude of the vertical component P_V of cable tension P will be determined by the cable angle θ. When P_V exceeds W, the arm will lift until the angle θ is such that $P_V = W$. At this point, the torque demand is reduced, and the tendency is for the arm to move downward again, raking material and reducing the load.

Fig. 4. — Vector Analysis for Rake Arm
— W: Arm Weight.
— P: Cable Tension.
— T: Torque Force.
— P_H: P cos θ.
— P_V: P sin θ



5. VARIANT FORMS

The type of construction schematically shown in Figure 2 is the so-called Type "A". a center-shaft, truss-type machine, used as a rule with tanks not exceeding 100 ft in diameter, With tanks of larger diameter than this, the Type "S" machine with mechanism supported by a center-column is more frequently used, as being more economical. This type of Cable-Torq is illustrated in Figure 5.

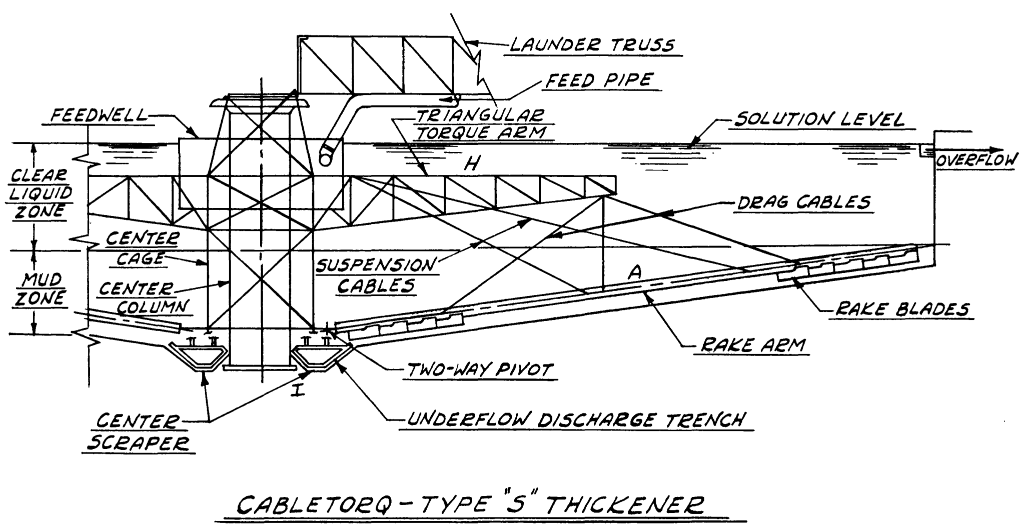


Fig. 5

Apart from the difference in the mechanism supporting means, the only noteworthy difference between the two types is in the construction of the torque arms H, which are of truss, instead of pipe, construction in the Type "S". Here too experience has indicated a minimum of scale formation on these torque arms, as long as they are operated above the mud level.

6. ADVANTAGES OF CABLETORQ

Of the many advantages of CableTorq in the application here considered, the most significant is the greatly reduced amount of scale forming on the raking mechanism, due to the much smaller surface exposed to the scaling action of the aluminate solution, especially in the mud zone. In pratice, this means an increase by two or three times in the duration of continuous runs of the thickener before the rakes become ineffective, and the machine must be shut-down for descaling. It is well known to alumina plant operators what these shut-downs for descaling mean in terms of lost production, maintenance labor costs, damaged equipment and indirectly related problems.

With the advent of the CableTorq, not only has the frequency of required shut-downs been reduced, but the descaling operations themselves can now be performed by fewer men in less time, because of the smaller and simpler structures to be descaled.

A second advantage to be pointed out, again due to the small amount of steel to be moved through the solution and mud in the tank, is the smaller torque to be applied to the CableTorq rakes for equal density of underflow. Or else, with equal torque being applied to the rakes, it is to be expected that a thicker underflow will be obtained with the Cable-Torq. The explanation is not a clearcut one, but it may be found in the fact that the truss-type rake arm of the conventional thickener has to a large extent to plough its way through the highly viscous thixotropic material in the mud zone, whereas the action of the simple CableTorq rake arm is exerted only near the bottom of the mud zone, where the thicker material is found. Also, under certain conditions, masses of thickened material may be carried around by the truss rakes instead of being conveyed to the central outlet, thus allowing thinner mud to flow by simple gravity to the outlet. Such action, known as "island formation", is not likely to occur with the simple pipe arms of the CableTorq, especially in view of their self-lift feature, so only the thickest mud is taken out in this case. The economic significance of even a small percentage increase of percent solids in the thickener underflows in a continuous countercurrent decantation system is illustrated by a calculation example in the next section of this presentation.

The use of self-lifting rake arms in the CableTorq makes it unnecessary to use a mechanical lifting device such as required with all thickeners with fixed rake arms. This is another advantage, the importance of which becomes evident when it is considered that when the rake is lifted by such mechanisms because of the presence of an overload, the center scraper I (Fig. 1 and 5) is also lifted out of its cone or trench just at the time when its action there is more necessary to keep the exit free for the excess mud to be disposed of. In the CableTorq, the cone or trench scraper remains constantly in the place where it is required to be, even when the rake arms are in their maximum lift position. It is important to note also that the rake blades near the center remain close to the floor, continuing to rake the heavier solids accumulated there.

7. VALUE OF THICKER UNDERFLOWS

The economic significance of thicker underflows in a red mud washing system can be calculated in terms of lower soda and alumina losses, and/or less water to evaporate. A computer program (Appendix) has been written at Dorr-Oliver to determine the most economical balance between losses and wash water quantities for any given set of conditions. Figure 6 is a printout showing the total cost of evaporation and of losses under a set of arbitrary but representative conditions. In the first case, the thickener underflows were assumed to be 18% solids, in the second, 20%. Minimum costs are shown for various numbers of thickening stages. Taking seven stages as an example, the cost of losses and evaporations with 18% underflows is \$238.37 per 100 tons red mud solids. That for 20% underflows is \$219.36. The difference is \$19 per 100 tons, or \$0.19 per ton of red mud solids processed. In a plant washing 2,500 tons/day of red mud, the savings amount to \$475 per day or roughly \$160,000 per year.

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// XEQ

          OPTIMUM RED MUD WASH
 CONDITIONS
     TONS SODA IN WASHER FEED PER 100 TONS MUD SOLIDS                 73.
     VALUE OF SODA AND ALUMINA, DOLLARS PER TON SODA                50.00
     THICKENER UNDERFLOWS, ALL STAGES, PERCENT SOLIDS                18.0
     UNIT COST OF EVAPORATING WATER, DOLLARS PER TON WATER           0.50
     EFFICIENCY OF THICKENERS, PERCENT                                80.
 OPTIMUM WASH
     NUMBER OF THICKENING STAGES                                5          6          7
     OPTIMUM GROSS WASH, TONS WATER PER 100 TONS MUD         863.       803.       757.
     NET WASH TO EVAPORATE, TONS                             407.       347.       302.
     COST OF EVAPORATION, DOLLARS                          203.97     173.72     151.03
     SODA LOSS, TONS PER 100 TONS RED MUD SOLIDS             2.78       2.15       1.74
     VALUE OF SODA LOSS, DOLLARS                           139.26     107.97      87.34

     TOTAL COST, EVAPORATION + LOSS                        343.24     281.70     238.37
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          OPTIMUM RED MUD WASH
 CONDITIONS
     TONS SODA IN WASHFR FEED PER 100 TONS MUD SOLIDS                 73.
     VALUE OF SODA AND ALUMINA, DOLLARS PER TON SODA                50.00
     THICKENER UNDERFLOWS, ALL STAGES, PERCENT SOLIDS                20.0
     UNIT COST OF EVAPORATING WATER, DOLLARS PER TON WATER           0.50
     EFFICIENCY OF THICKENERS, PERCENT                                80.
 OPTIMUM WASH
     NUMBER OF THICKENING STAGES                                5          6          7
     OPTIMUM GROSS WASH, TONS WATER PER 100 TONS MUD         784.       726.       683.
     NET WASH TO EVAPORATE, TONS                             384.       326.       283.
     COST OF EVAPORATION, DOLLARS                          192.38     163.08     141.60
     SODA LOSS, TONS PER 100 TONS RED MUD SOLIDS             2.50       1.93       1.55
     VALUE OF SODA LOSS, DOLLARS                           125.09      96.71      77.76

     TOTAL COST, EVAPORATION + LOSS                        317.47     259.79     219.36
```

Fig. 6. — Typical computer printout for calculation of most economical wash conditions

8. CABLETORQ APPLICATIONS FOR ALUMINUM HYDRATE THICKENING

This paper would not be complete without a mention of the fact that more recently thickeners of the CableTorq design have been successfully tried out for the decantation of fine aluminum hydrate. Although red mud and aluminum hydrate have quite different characteristics, both materials are apt to create overload conditions and scale is produced on the raking structures, although for different reasons, in both cases. There is no doubt in our mind that in the future we shall see CableTorqs applied for the handling of hydrate suspensions in ever increasing numbers.

*Dorr-Oliver GmbH
Friedrich-Bergius Strasse, 5, 6200 Wiesbaden (R.F.A.)
**Dorr-Oliver Inc.
Havemeyer Lane, 77, Stamford, Connecticut 06904 (U.S.A.)

APPENDIX

RED MUD WASHING

Dorr-Oliver Inc. Computer Program of Optimum Usage of Wash Water

The costs chargeable to a red mud washing installation are taken as:

1. Value of soda and alumina lost.
2. Cost of evaporating wash water which is not discharged with effluent mud and thus enters process.
3. Costs of operating thickeners, including capital and indirect costs.

The problem is to determine the amount of wash, and the number of thickeners, which will yield the lowest cost. Since the equations turn out to be complicated, the procedure followed will be to determine first the optimum wash quantity for a system having a given number of thickener stages. The value of the soda lost and the evaporation cost, for this optimum will be determined. Then the same procedure will be followed for a system with one more thickener stage. The savings resulting from the added thickener stage can be compared to the costs attributed to it.

Computer Program

The appended program on the two pages which follow, is written in basic Fortran, for an 1130 computer. Its input is a card, Format (5 F 10 . 0, 2I10) giving, in sequence in the field the following values.

Field	*Columns*	*Variable*
1	1-10	Tons Na_2CO_3 in settler underflow
2	11-20	Value of Na_2CO_3, dollars/ton
3	21-30	Percent solids in underflows
4	31-40	Cost of Evaporation, dollars/ton water
5	41-50	Percent efficiency of thickeners
6	51-60	Minimum number of thickener stages
7	61-70	Number of added stages to calculate

Fields 6 and 7 may be left blank, in which case the program will compute values for 5, 6, 7, 8, 9, and 10 stages of thickeners.

Program will terminate when computer reads blank data card.

If data switch O is turned on, computer will pause before reading new data card. This allows operator to change input on the basis of previous output.

Refer to Figure 6 for Computer Printout resulting from this application of the program.

DORR-OLIVER COMPUTER PROGRAM
by E. B. Fitch - July 2, 1968

```
PAGE   1

// JOB     0006

LOG DRIVE    CART SPEC    CART AVAIL   PHY DRIVE
  0000         0006          0006         0000

V2 M11    ACTUAL   8K   CONFIG   8K

// FOR
*NAME CC087
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
*IOCS (CARD,DISK,1132 PRINTER)
C      PROGRAM TO DETERMINE OPTIMUM WASH FOR RED MUD THICKENERS
       DIMENSION G(6),W(6),COST(6),SODA(6),VALUE(6),TOTAL(6),M(6)
       L=3
  300  READ(2,2)A,V,U,C,E,N,J
    2  FORMAT(5F10.0,2I10)
       IF(A)30,30,40
   30  CALL EXIT
   40  WRITE(L,1)
    1  FORMAT(15X,'OPTIMUM RED MUD WASH',/5X,'CONDITIONS')
       IF(N)50,50,60
   50  N=5
   60  IF(J)70,70,80
   70  J=6
   80  WRITE(L,3)A
    3  FORMAT(10X,'TONS SODA IN WASHER FEED PER 100 TONS MUD SOLIDS',12X,
      4F5.0)
       WRITE(L,4)V
    4  FORMAT(10X,'VALUE OF SODA AND ALUMINA, DOLLARS PER TON SODA',13X,F
      45.2)
       WRITE(L,5)U
    5  FORMAT(10X,'THICKENER UNDERFLOWS, ALL STAGES, PERCENT SOLIDS',12X,
      4F5.1)
       WRITE(L,6)C
    6  FORMAT(10X,'UNIT COST OF EVAPORATING WATER, DOLLARS PER TON WATER'
      4,7X,F5.2)
       WRITE(L,7)E
    7  FORMAT(10X,'EFFICIENCY OF THICKENERS, PERCENT',27X,F5.0)
       U=100.0*(100.0-U)/U
       DO 100 I=1,J
       EN=E*N/100.
       ZL=0.0
       Z=1.0
  200  Y=C*U/(V*A)+((Z+1.0)**EN*(1.0-Z*EN)-1.0)/((Z+1.0)**(EN+1.0)-1.0)**
      42
       IF(Y)210,20,220
  210  ZL=Z
       Z=2.0*Z
       GO TO 200
  220  ZU=Z
  230  IF(ZU-ZL-0.001)20,240,240
  240  Z=(ZU+ZL)/2.0
       Y=C*U/(V*A)+((Z+1.0)**EN*(1.0-Z*EN)-1.0)/((Z+1.0)**(EN+1.0)-1.0)**
      42
       IF(Y)250,20,220
  250  ZL=Z
       GO TO 230
   20  ZS=Z
       W(I)=U*ZS
       G(I)=W(I)+U
```

DORR-OLIVER COMPUTER PROGRAM

by E. B. Fitch - July 2, 1968

```
PAGE    2
      COST(I)=W(I)*C
      SODA(I)=A*ZS/((ZS+1.0)**(EN+1.0)-1)
      VALUE(I)=SODA(I)*V
      TOTAL(I)=COST(I)+VALUE(I)
      M(I)=N
      N=N+1
  100 CONTINUE
      WRITE(L,8)
    8 FORMAT(5X,'OPTIMUM WASH')
      WRITE(L,9)(M(I),I=1,J)
    9 FORMAT(10X,'NUMBER OF THICKENING STAGES',23X,6I10)
      WRITE(L,11)(G(I),I=1,J)
   11 FORMAT(10X,'OPTIMUM GROSS WASH, TONS WATER PER 100 TONS MUD',3X,6F
     410.0)
      WRITE(L,12)(W(I),I=1,J)
   12 FORMAT(10X,'NET WASH TO EVAPORATE, TONS',23X,6F10.0)
      WRITE(L,13)(COST(I),I=1,J)
   13 FORMAT(10X,'COST OF EVAPORATION, DOLLARS',22X,6F10.2)
      WRITE(L,14)(SODA(I),I=1,J)
   14 FORMAT(10X,'SODA LOSS, TONS PER 100 TONS RED MUD SOLIDS',7X,6F10.2
     4)
      WRITE(L,15)(VALUE(I),I=1,J)
   15 FORMAT(10X,'VALUE OF SODA LOSS, DOLLARS',23X,6F10.2)
      WRITE(L,16)(TOTAL(I),I=1,J)
   16 FORMAT(/10X,'TOTAL COST, EVAPORATION + LOSS',20X,6F10.2)
      WRITE(L,17)
   17 FORMAT(////)
      CALL DATSW(0,LM)
      IF(LM-1)90,90,300
   90 PAUSE 1111
      GO TO 300
      END
```