# PROBLEMS OF WATER PROTECTION TECHNOLOGIES IN THE PRACTICS OF MINE CONSTRUCTION

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**SUMMARY**

The water protection system used in the practice of mine construction is described by the author.

When constructing mine endangered by water, in addition to the protection of human life and assets the conditions of applying shaft sinking technologies mechanizable have to be created. In terms of technique and economy the practical efficiency of preventive protection has to be considered. There has to be designed the margin where from the shaft deepening can be continued under the protection of safety measures. The problems related to determining the site of safety and prospecting borings, their evoluation and the injection are described by the author on the example of a tank solved.

# THE PROBLEMS OF MINE WATER PROTECTION TECHNOLOGIES

It is know that the correct selection of the effective method and technology for protection against mine water basicelly depends upon the reliability of hydrogeological knowledges.

It is know by the miner practising that also during the development well prepared by expert hydrogeological prospecting there can arise water protcction and control problems whose quick and succesful solving proves to be very important in the term of mine construction too.

From the point of view of mine economics an important object of the investor is to reduce the time for development causing the mine constructors to use advanced technology well adaptable to the mine geological conditions, being possibly completely mechanized. In selecting practical technologies there have to be frequently made compromisses when the condition of applying equipments control too. The welcome mine construction programs in the recent years often require the sinking of 500 - 1200 m deep shafts 9 m in diameter with monolithic concrete support /in the area of the Eocene/ or even with traversing the carotic basement rocks /deep level prospecting at the cooper ore deposit Recsk, Hungary/.

In examining the water protection and control requirements from the point of view of mine construction it can be stated that principially it is the same as those necessary for extracting the mineral reserves. However, up to implementing the final /operating/ water control system of the mine designed the mine constructors are in a peculiar situation. Their technologies are to an extent increased sensitive to mine water. They experience as the first ones the extent of danger as a result of which they have to perform the prospecting within the mine with precising the hydrogeological knowledges.

When performing mechanized sinking of vertical or inclined shafts the problems caused by water are of different character. One extreme case occurs in the sand bearing strata containing water under pressure. Partly the simple traversing of the layer /drainage in the open/ can lead to hydraulic rock fracture when there is no sufficient floor strength for the cutter-loader in addition of the impossibility to provide the condition of concreting and partly difficulty is caused by the pump wearing effect of the water containing sand. Thus in the case above the face output is reduced not by the water volume but its indirect effect. The other extreme case occurs when sinking the shaft /driving the road/ in the karstic basement rocks when under the karstic water level the lower rate inflow /100 l/min/ makes difficult the concreting and the higher rate water inflow causes difficulty in water lifting or the danger of mine flooding. The mine constructors are aimed at applying mine water control methods and technologies provoding the conditions of normal shaft sinking. The methods /technologies/ used in the practice of the Mining Shaft Sinking Company are shown in Table 1 giving a scheme for review.

It can be seen from the review scheme that in the practice of the Hungarian mine constructing there are used nearly all of the water protection methods. As one of the traditional technologies for rock cementing there has been considered also the application of clay-cement suspension and organic resins. It is possible to select the most practical and economical method.

When using water control technologies in the practice of mine construction the following questions arise:

1./ When using preventive water protection method what is the optimum of efficiency and how high can be the water inflow remaining. This question is important when performing the prevention during sinking the shaft with stopping productive work.

It is practical to justify the decision making performed in this case always with individual investigation. The principle of our method is shown by Fig.1. It can be seen on the basis of this Figure that when planning the water control depending upon the efficiency two kinds of cost factors exercise influence. The cost of handling and lifting the water inflowing into the working space $K_e$ /Ft/$\ell$/min/ and the specific cost of water sealing. $K_k$ /Ft/$\ell$/min/ are changing partly exponentially. By summarizing the two cost functions a cost minimum is obtained pointing out simultaneously the optimum degree of water sealing /$K_o$/ in term of economy. In term of technique -- depending upon tne "sensibility" of the shaft sinking technology -- there can be dermined a marginal value /$\tau_h$/. Finally the decision can be made by comparing $K_o$ with $\tau_h$.

2./ Which fore-boring has to be performed in driving development excavations. In addition to the legal obligations towards the authorities this problem arises in marginal cases e.g. when the investigation results obtained in boring the shaft axis have to be determined more precisely in order to make decision about the water control to be used.

Such type of fore-boring is used e.g. when it is aimed to relax or drain the layer containing the water under pessure from the bottom of the pit /roadhead/. A special task is the fore-boring when the filter tube has to be installed in loose sandy layer under overpressure. In this case a filter with drilling head has to be installed from the stable strata.

As far as it is planned to perform primary rock cementing from the bottom of the shaft being sunk in order to provide water sealing or rock strengthening, the fore-boring is carried out to prepare the technological plan. The water permeability of the rock massive is analyzed by the specific water absorption of the bore-hole /q/ on the basis of which the rock injectability can be considered with selecting the practical cementing material. Under specific water absorption we understand the water absorption achieved in unit of time at 1 m water head overpressure per 1 m of the bore-hole section without casing according to the formula as follows:

$$q = \frac{Q}{H \cdot h}$$

where

q = the specific absorbability /$\ell$/min . m, m/

Q = water absorption /$\ell$/min/

H = injection overpressure in water head /m/

h = borehole length without casing /m/

3./ How much can the layer /strata series/ dangerous because of water inrush be approached by pit bottom during shaft sinking without causing danger. Where is the margin where from the protection against water becomes necessary. This question arises in determining the water protection margin.

After the strata series above the water bearing rock layer can be assumed to be load bearing on the basis of its rock physical /compressive and shearing strength, porosity, etc./ and geological characteristics /cleavage, tectonic conditions, homogeneity/ there has to be determined the thickness resisting to the loading occurring on the pit bottom.

I.e. the role of the safety rock layer is the same as that of the safety pillar whose dimensions can be calculated by using the following equation:

$$b = \frac{P_o \cdot D_o}{4 \cdot \sigma}$$

where

- b = length of the safety rock layer /m/
- $P_o$ = the hydraulic pressure acting on the bottom of the pit /$P_o = P + P_i$/
- $P_i$ = injection overpressure /$kp/cm^2$/
- P = hydrostatic pressure /$kp/cm^2$/
- $D_o$ = internal diameter of the shaft /road/ /m/
- = allowed shearing stress of rock /$kp/cm^2$/

Within this safety pillar calculated the shaft deepening is continued under the protection of safety measures taken.

4./ Setting on the liner of boreholes drilled from the bottom of pit or roadhead. This problem is important when the draining injecting hole is accomodated deeply under the water level of rest with loading it by an overpressure of 150 - 200 bar.

In our practice accomodating and fixing the liner is effected when:

- the for-boring is expected to traverse water or gas bearing layer with overpressure when starting from draining the bearing layer an activity regulated begins,
- the fore-boring serves for rock cementing or back-filling.

The liners to be considered as traditional are considered as suitable when

- the site, direction and collar of the borehole is fixed,
- the pressure res stance /loadability/ of the borehole is provided,
- when it serves as an adequate holder for the tube head.

In our company the technological order of the liner accomodation is as follows:

a./ The function and expectable loading of the liner to be accomodated is determined.

b./ The rock mechanical characteristics of the liner nestle are examined.

c./ The diameter of the liner to be accomodated has to be determined.

d./ The length and material characteristics of the liner have to be calculated with considering the diameter and loading of liner.

5./ Operative control of water protection activity. It is know that also implementing a technology well prepared requires the active cooperation of the designing engineer. Dewatering the sand bearing measures containing ground water involves always the danger of excavation formation. Injecting a karstic strata series can be expertly performed in the practice on the basis of drilling injecting holes and observing the absorption tests. As example there are shown the characteristic phases of injecting with cement mortar performed from 963 m depth of the shaft No. II, Recsk, Hungary.

Our tank was to create the water protection system necessary for deeping the shaft. In first step we have performed the hydrogeological prospecting of the section up to the following level division /70 m/ on the basis of which it could be seen that water sealing preceding shaft sinking is necessary. In the second step we have performed the water sealing in such a way that a water sealing mantle around the shaft section to be sunk was formed by injecting cement mortar. The maximum of water inflow remaining after sealing as marginal condition was equal to 100 l/min.

The main characteristics of rock cementing:

Depth of pit bottom: 963 m; internal diameter of shaft: 8 m; support monolithic concrete.

Ground traversed: Triassic, tectonically disturbed, fissured limestone.

Character of the water: karstic water with a pressure at the end of the section to be cemented: 89 bar. Its temperature: 41 °C, sulphate content: 1000 mg/l, gas content solved: 8 --10 Nm3/m3 water.

Cementing material: S-54 slurry /sulphate resistant/ made of cement. Planned final pressure of injecting 200 bar.

Loadability of the liner in the cementing hole: 250 bar. Liner length: 9 m.

Diameter of the prospecting and cementing holes: 64 mm, their length 70 m.

Type of the boring machine used: BVB-25 /ATLAS COPCO/.

Type of the inrush inhibitor used: RPR-3.

The accomodation plan of the prospecting and cementing holes is shown by Fig.2. The boreholes designated with 1, 2 and 3 in the Fig. were drilled in the first step. It has been indicated by the hydrodynamic investigation carried out in the prospecting boreholes that a water inflow of 1100 /min related to the excavated cross-sectional area of the shaft has to be taken into account. From technological and water lifting points of view the maximum water inflow allowable was equal to 100 /min, as a result of which the planned efficiency of rock cementing: $\eta_t = 90.9$ %.

The prospecting borings are completed by further 13 cementing boreholes being drilled outwards along the circumference of a circle 6,5 m in diameter with an angle of inclination of 80°. Within the shaft four vertical completing boreholes /18, 19, 20, 21/ and 1 checking borehole along the axis were drilled /No. 7/.

The rock cementing was implemented in four cycles. Prior to injecting each hole water absorption test was made on the basis of which the specific absorbability and the starting specific weigth of cement mortar could be calculated.

The different phases of rock cementing can be followed in the Fig. 3, 4, 5 and 6.

In the Figures there are shown the relations beween the cementing bore-holes with illustrating the volume of the water flowing out from the bore-holes drilled after cementing according to scale. On the basis of the Figures there can be followed the process of sealing controlled according to the goal during injecting. However, prior to starting the sealing, following the drilling of the cementing bore-holes, and the absorption test the main direction and rate of water inflow can be perceived. Forming of the zone cemented can be followed and evaluated by each cycle. On the basis of the absorption test the closing of the flow paths can be perceived.

According to Fig. 6 the rock sealing with cement mortar has finished at a pressure level of 200 bar still at the end of cycle III. The water inflow calculated for the excavational cross section of the shaft reduced to a value of 150 ℓ/ min/ $\eta$ = 86,4 per cent/. The demensions of the water conducting fissure system reduced and at a pressure level of 200 bar the cement particles could not be transported further. Prior to implementing the final cycle two variants could be considered:

a./ secondary injection using low viscosity chemicals,

b./ secondary injection with cement mortar at pressure level raised /220 bar/ using plasticicator and agent slowing binding.

In considering technical and economical aspects the decision was made for variant "b" whose result is indicated by the data of cycle IV. It was obtained to continue the injection with finishing the cementing by an efficiency of 93 per cent.

Finally it can be concluded by summarizing that in addition to the protection of human life and assets the water protection and control technologies of mine construction create the preconditions for using shaft sinking technologies advanced. Solving the taskes requires not only circumspect panning but also a continuous in situ analysis and operative control.

Appendix 1.

/Az eredeti magyar alapján készitendő el/

1- Reviewing scheme of the water control methods /technologies/ used in the working places of the Mining Shaft Sinking Company
2- Preventive
3- Secondary
4- Back-filling of brick lining /by injecting/
5- Sealing the protected side of brick lining /by internal lining/
6- Sealing the rock mantle /by injecting/
7- In loose sediments with ground water
8- In consistent rocks with water in the fissures
9- Hydrogeological prospecting /with fore-boring/
11- Rock strengthening
12- /by cementing/ injecting
13- And water sealing
14- /by freezing/
15- Cement
16- Clay
17- Reagent based material
18- Relaxation /by draining boring/
19- Dewatering /by draining boring/
20- Water sealing /by rock cementing/
21- Hydraulic pack
22- Cement mortar injection
23- Mud slurry injection
24- Reagent injection
25- Drop filter
26- Deep well
27- Vacuum well

FIG. 1.

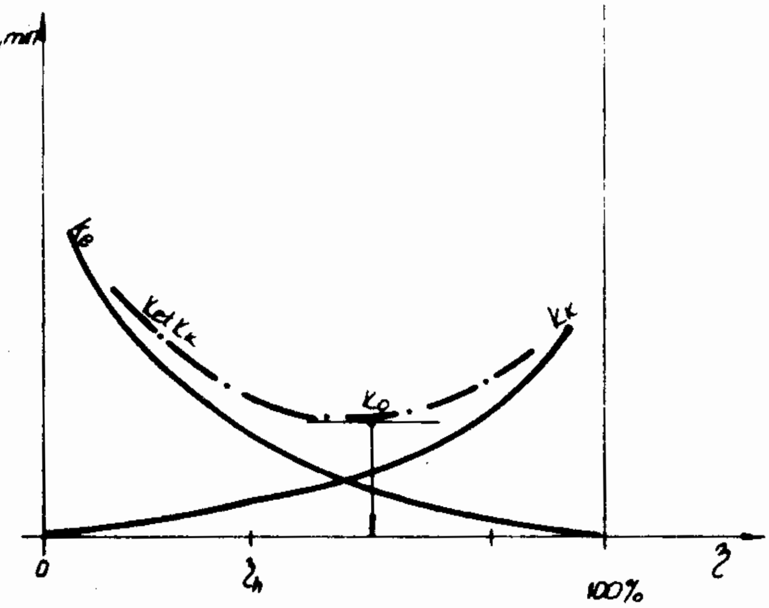


FIG. 2.

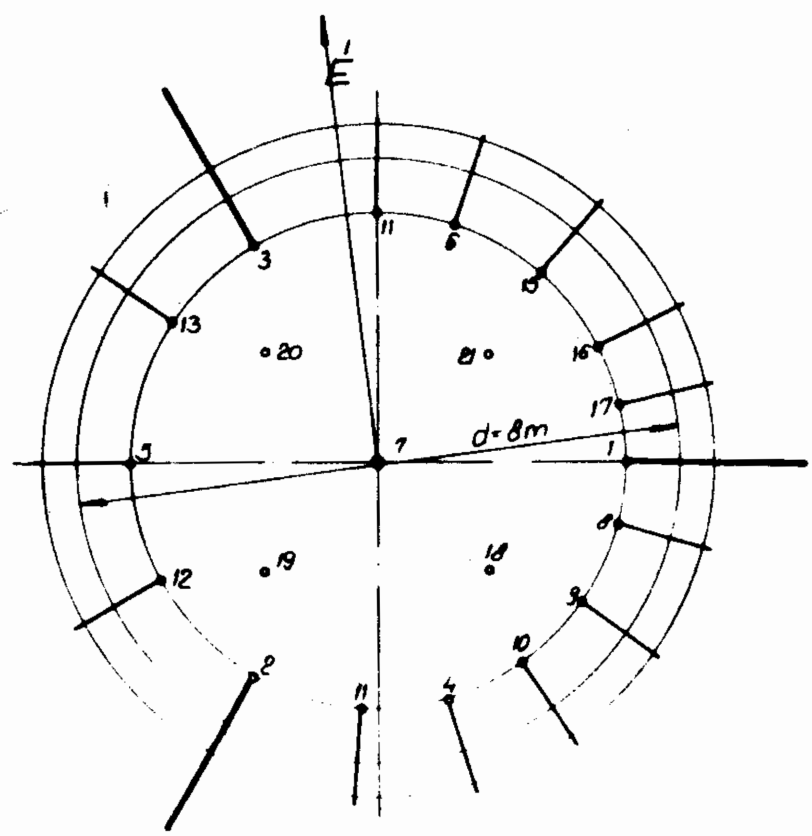

FIG. 3.

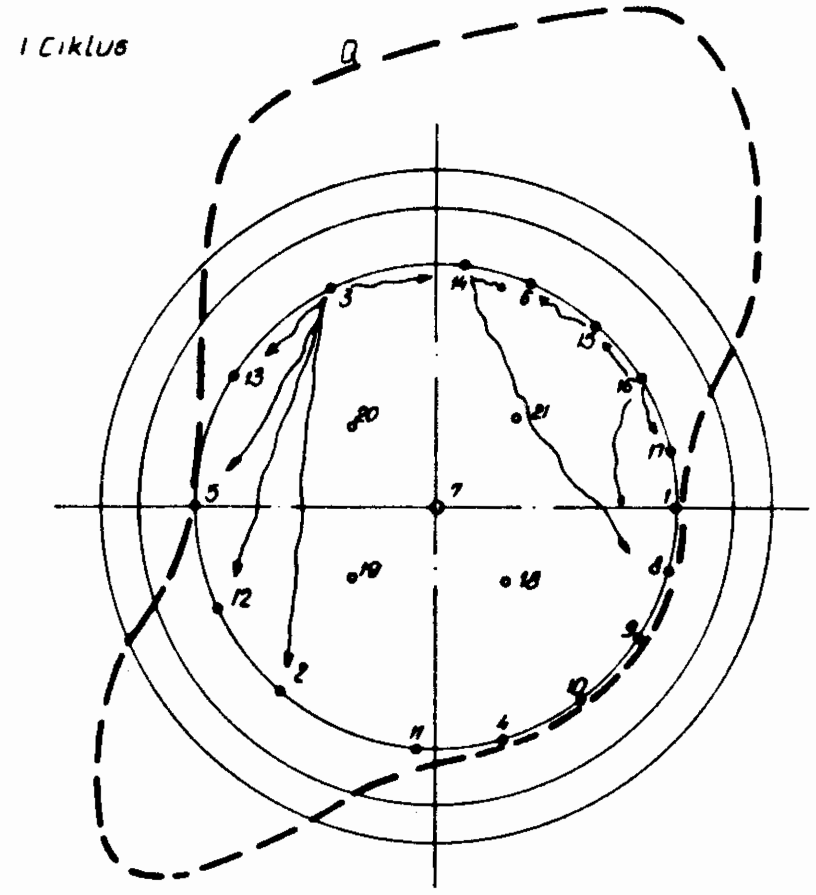
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FIG. 4.

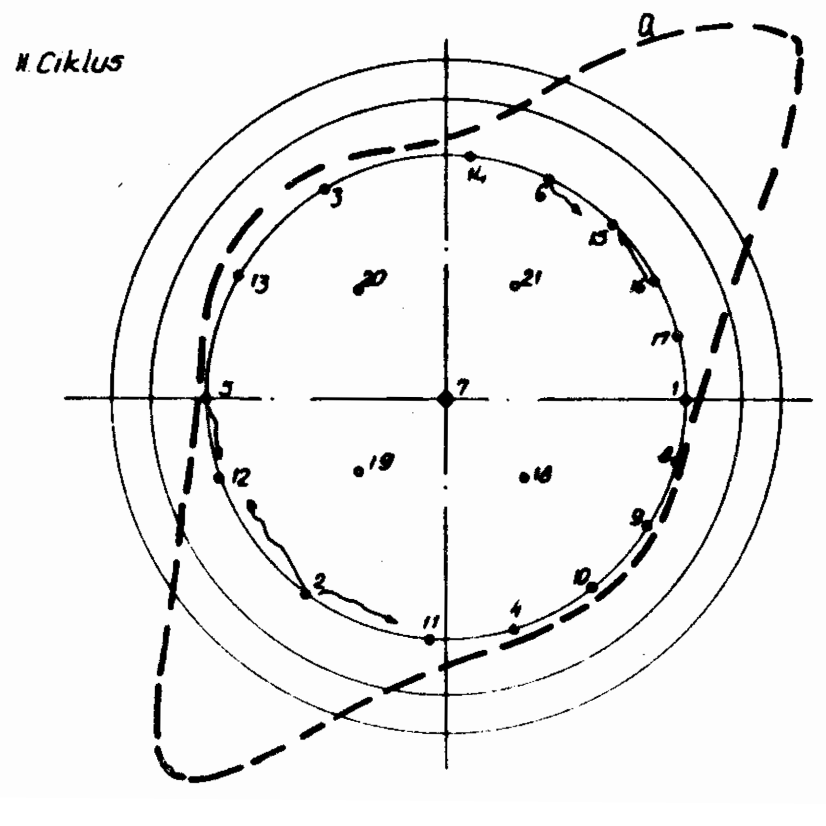
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FIG. 5.

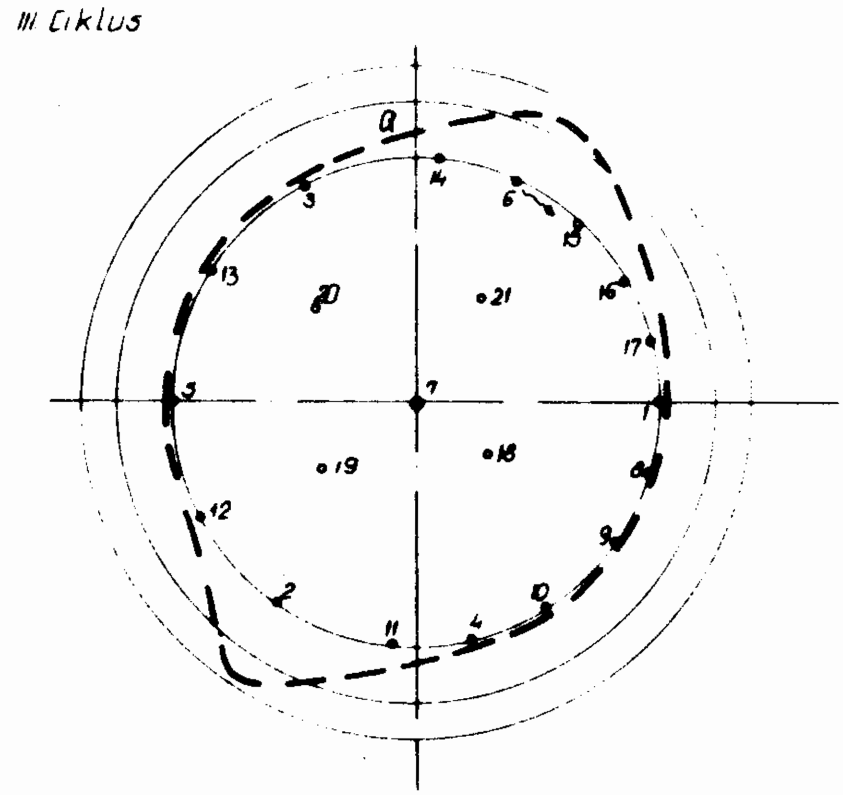
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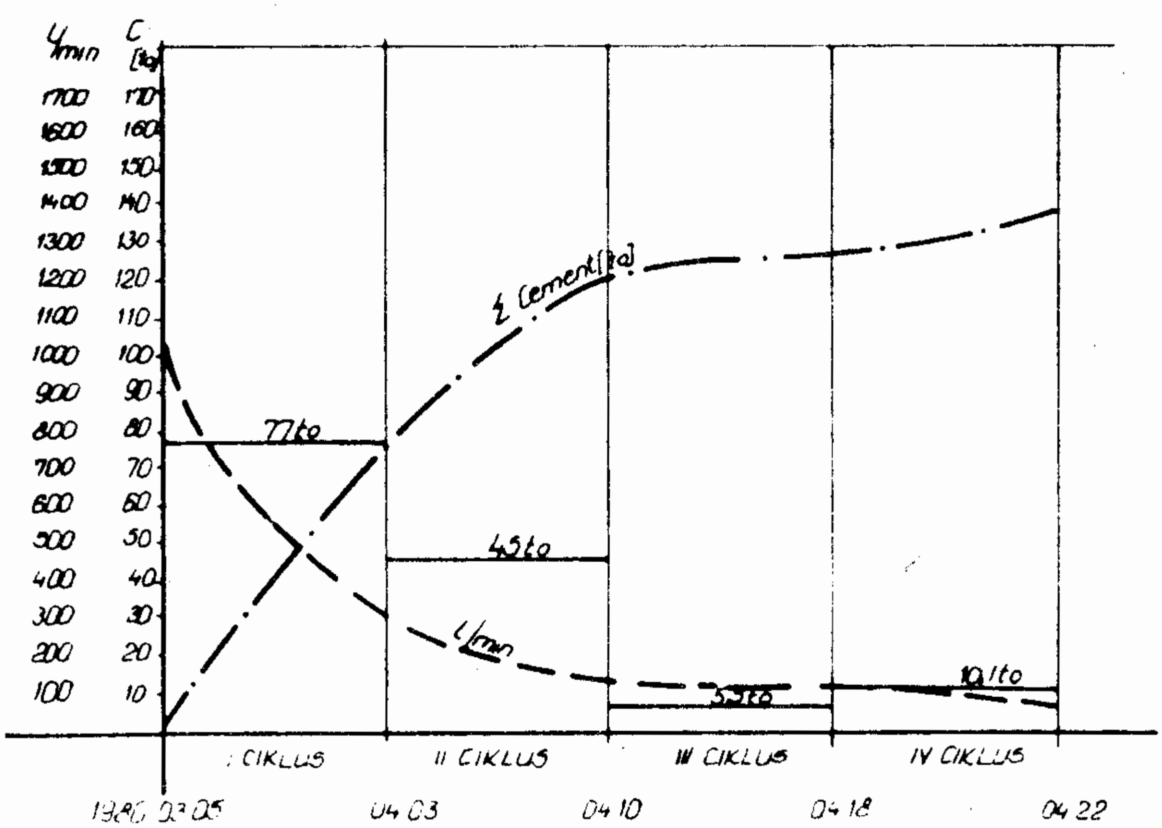
FIG. 6.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