BELTCON 1

BELT CONVEYORS - DESIGN, OPERATION AND OPTIMIZATION

PAPER B4

UNDERGROUND CONVEYOR NETWORK DESIGN

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SYNOPSIS.

From recent feasibility studies conducted on underground conveyor networks in large collieries, it was found that the fully established conveyor network constituted between 15 and 30 percent of the total capital cost when considered in present day money terms.

This sizeable proportion of the total cost of establishing a colliery gives definite food for thought, it is certainly worthwhile giving some consideration to the optimising of conveyor networks.

This paper will deal with a design method which can be applied to any proposed network layout, but the method will be discussed with particular reference to the designing of conventional underground coal mine conveyor networks.

TERMINOLOGY USED.
(CONVENTIONAL SECTION)

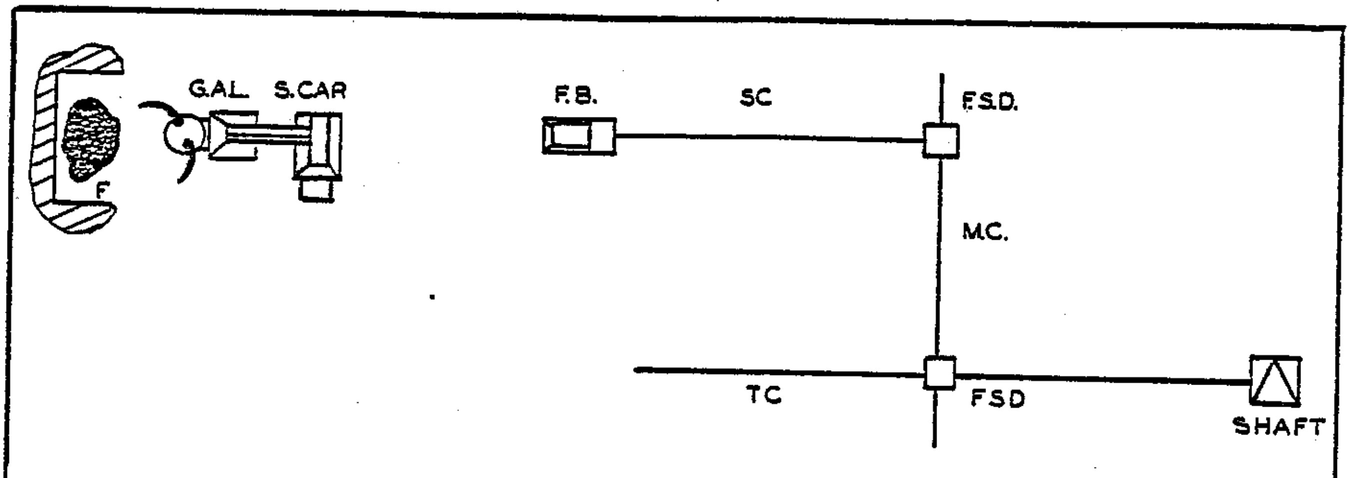


FIG. 1.

i) Gathering Arm Loader:- Device for gathering coal broken from the mining face.

ii) Shuttle Car :- A transport vehicle for displacing broken coal from the loader to a conveyor feeder point.

iii) Feeder Breaker :- Primary purpose is to smooth loading effects of shuttle car onto section conveyors, has a secondary facility of reducing coal size for better conveyor transport application.

iv) Section Conveyors:- Conveyors leading out of any mined section. These advance with the advance of the face.

v) Secondary Flow Smoothing Device:- "Ratio Feeder" positioned between main and section conveyors, reduces the step loading effect carried over from the feeder breaker.

vi) Main Conveyor:- Conveyor gathering the output from a number of section conveyors common to one particular area of the mine.

vii) Tertiary Flow Smoothing Device:- Device applied between main and trunk conveyors, to smooth any step loading effect still present in the system.

viii) Trunk Conveyor:- Conveyor gathering output from all the main conveyors, and which feed the shaft bottom bins.

1. PROBLEM STATEMENT

The initial or broad statement of the problem is best layed out as follows :-

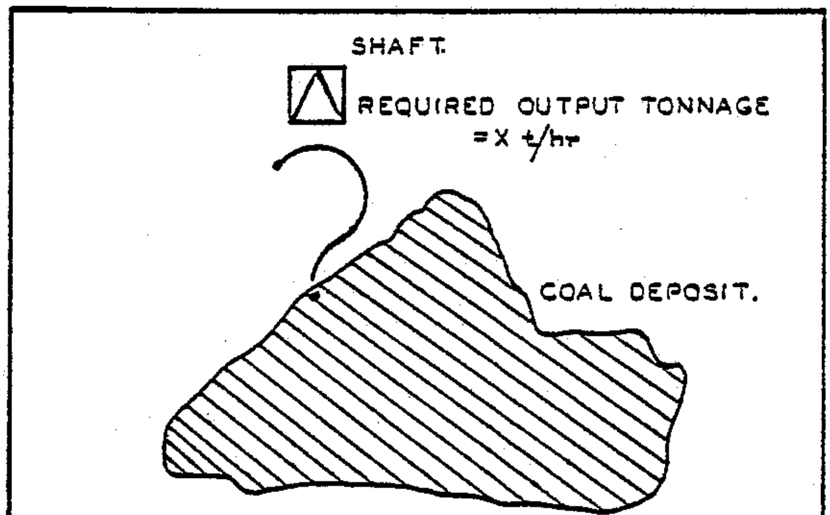


FIG 2

Given an ore deposit and the position of a shaft through which a set tonnage is to be taken out per unit time, (i.e one day, month or year), what is the best system or network of conveyors which can be used in displacing this required tonnage from the proposed working faces to the shaft bottom bins ?

In order to completely define a solution to this problem, initial considerations will have to include:- i) Mining and geological survey results which usually consist of the results of a number of borehole samples taken from the proposed area to be mined. Information obtained from boreholes include :- (a) Coal or Ore properties such as calorific values, ash contents and grindability.

(b) Seam properties such as seam thickness, seam seperation in multiseam reef compositions, and the effective mining accessibility.

From the above information, the base data for the location of the shafts and geometric layout of the proposed mining sites can be determined.

ii) Mining method to be used:- which will determine the required formats of mining faces, as well as the expected loading format of coal onto the conveyor system.

Two basic types of mining method exist, namely that of (1) <u>Conventional Mining</u> which basically consists of a sequencial operation of mining face preparation, blasting, broken coal removal or face cleaning, and hanging wall support.

This type of mining operation usually results in the following loading format onto the conveyor network :-

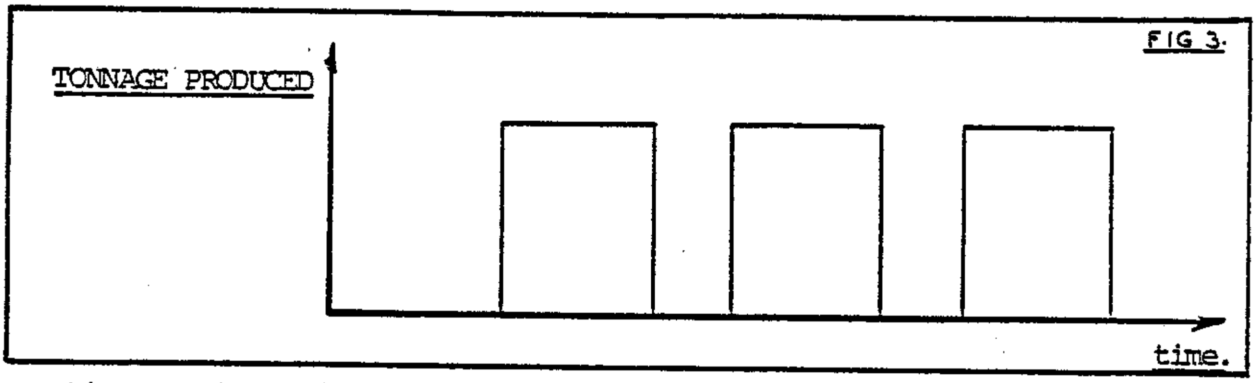


FIG 3.

Operation consists of transport vechiles discharging load onto conveyor feeder. A number of faces are worked simultaneously. Situations can arise where either the loading operation catches up with the face mining operation, or vice-versa. This obviously affects the section conveyor loading.

(2) Continuous mining methods ; which can consist of either a longwall section, (essentially a shearer operating along a coal face), or a mechanical continuous mining machine feeding directly onto a section conveyor.

Effective loading format onto the conveyor network is as follows :-

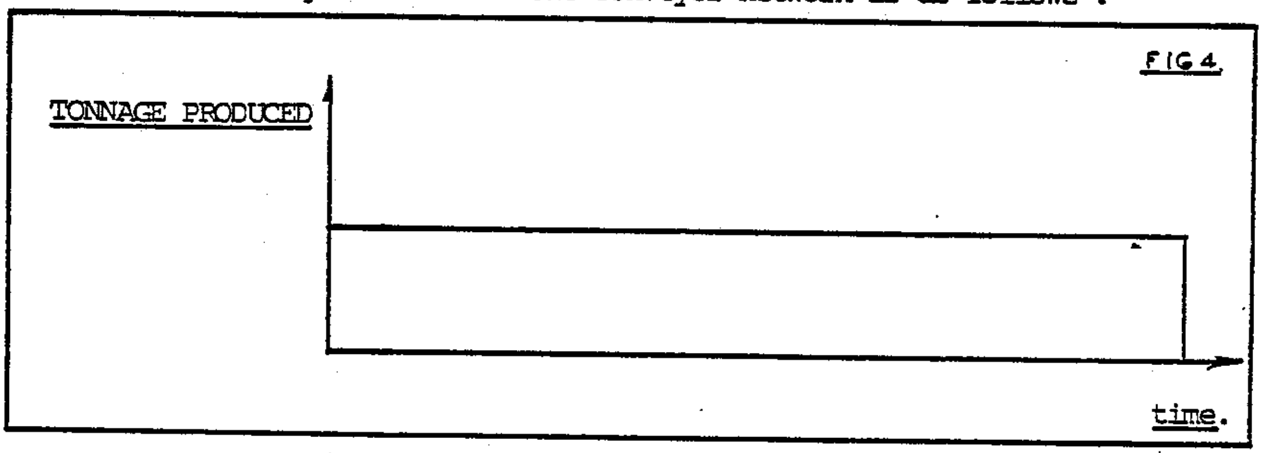


FIG 4.

System operates continuously, supplying a constant output tonnage onto the section conveyor.

2. <u>NETWORK LAYOUT AND OPTIMISATION</u>

When designing a conveyor network, some of the problems facing the designer with respect to conveyor and equipment selection are :-

i) Conveyor and face equipment requires a certain amount of "Down Time" per period of operating time to allow for scheduled maintenance

ii) Equipment break - downs require "On Site" repairs, and cause unscheduled stoppages.

iii) Production output tends to vary over the work shift

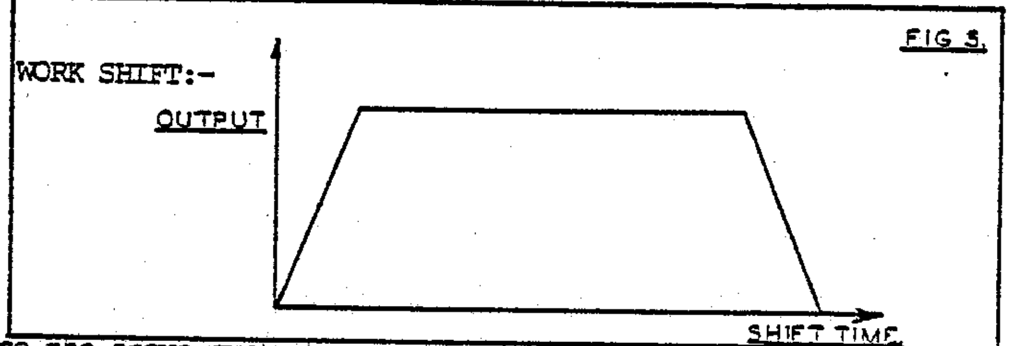


FIG 5.

Since the above system properties are usually evident in any production network, it is necessary to base a system design on some working period less than the total shift time available. In view of this, the design approach adopted in the following algorithm is as follows :-

- Since the required system output is known, and the amount of "Down Time" per period of time for any selected network format can be determined, the instantaneous capacity of the face mining equipment can be predicted.

- Optimisation of the system will be conducted by virtue of a cost comparison between the various possible network layouts.

In order to implement the above design approach, an applied statistical analysis using simple probability theory will be used. This theory will be used to determine the total time available in which the required tonnage is to be mined, and hence the instantaneous mining capacity.

2.1 ELEMENTARY "AVAILABILITY" THEORY

When examining any conveyor network system, it can be seen that two basic component formats exist in the system, namely "series components", and "parallel components".

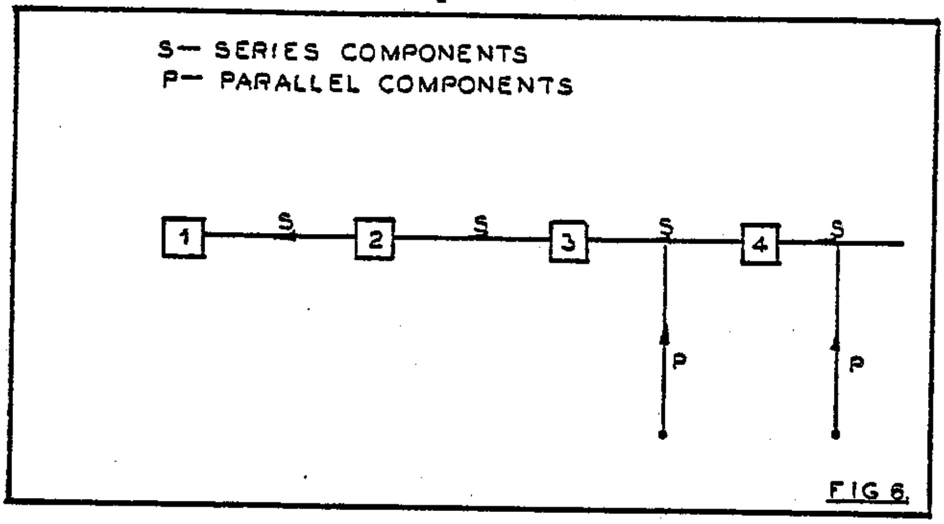


FIG 6.

Theory governing the behaviour of these component formats is as follows:-

(i) AVAILABILITY OF "SERIES"COMPONENTS:-

Consider two components in series with each other, where both must operate in order to allow a system output. (Independent Events).

Let A(1) = Availability of component 1.
A(2) = Availability of component 2.

Total system availability A(T) is given by :-

$$A(T) = A(1) \times A(2)$$

For "N" seriesed components,

$$A(T) = A(1) \times A(2) \times \ldots\ldots \times A N$$

(ii) <u>AVAILABILITY OF "PARALLEL" COMPONENTS:-</u>

Consider a system in which two components are in parallel which implies that both components must fail simultaneously in order to stop system output. (Mutually non exclusive events).

Using the above nomenclature, total system availability is given by :-

$$\boxed{A(T) = A(1)+A(2)-A(1)XA(2)}$$

For "N" parallel components.

$$\boxed{A(T) = A(1)+A(2)++A(N)-A(1)XA(2)X...XA(N)}$$

The resultant availability is the effective percentage of the operational time that the components will be operable.

The above equations can now be applied in context to any conveyor network system, to find the effective available time per operational shift during which the required tonnage is to be displaced.

2.2 <u>DETERMINATION OF EFFECTIVE SYSTEM AVAILABILITIES</u>

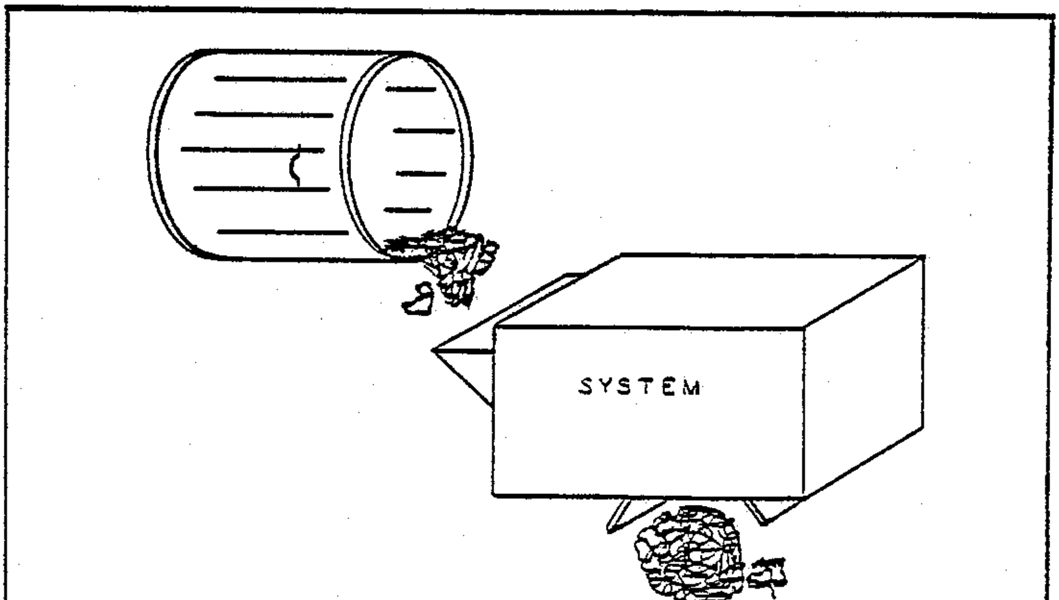


FIG 7

Since the approach used is effectively statistical, the effective results obtained will only be meaningful provided the input data into the design system is accurate.

Various theoretical data correlated in the U.K. and United States from which component, (i.e. conveyors, shuttle cars, gathering arm loaders etc), availabilities can be determined is available, but the applicability of these to the South African coal mining conditions is dubious for the following reasons:-

- i) Higher hardness factors South African coals have as opposed to American or United Kingdom coals.
- ii) Lower degree of sophistication of South African coal mining equipment.
- iii) Power job education levels of equipment operators in South African collieries.

The data required to implement the proposed design scheme is best gathered and correlated from 'time and motion studies' on collieries. The primary data required is the effective time per unit time period that each machine or system partaking in the mining operation is non operational owing to maintenance or breakdown stoppages.

The "in system order availability", (ISOA), is defined as :-

$$ISOA = \frac{\text{REMAINING OPERATING TIME AVAILABLE-COMPONENT DOWN TIME}}{\text{REMAINING OPERATING TIME AVAILABLE}}$$

or ISOA = (RTA - CDT) /RTA

This implies that the order of series component operation now becomes important, as will be shown in the following examples.

Example 1:- Consider the system of "seriesed" components as is shown below.

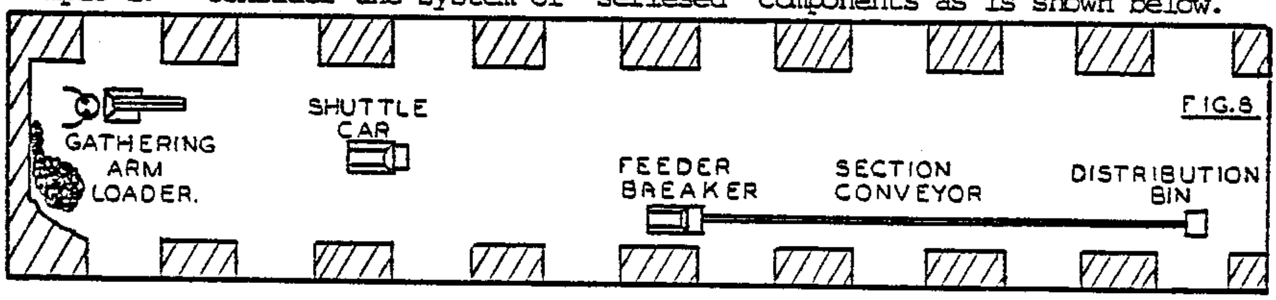


FIG.8

Assume that time and motion studies yield the following component down time results over 250 hours of operating:-

Component	Order of Operation	Down time due to Break Down and Maintenance
		Hours
Gathering Arm Loader	1	10
Shuttle Car	2	17
Feeder Breaker	3	17
Section Conveyor	4	9
Distribution Bin	5	1

The "in system order availability" for each of the above components is as follows :-

i) Gathering Arm Loader:- $ISOA = \frac{RTA-CDT}{RTA} = \frac{250-10}{250} = 0{,}9600$

Time remaining during which the shuttle car can break down = 250-10=240 hrs.

ii) Shuttle Car:- $ISOA = \frac{RTA-CDT}{RTA} = \frac{240-17}{240} = 0{,}9292$

Time remaining during which the feeder breaker can break down = 240-17=223 hrs.

iii) Feeder Breaker:- $ISOA = \frac{RTA-CDT}{RTA} = \frac{223-17}{223} = 0{,}9238$

Time remaining during which the section conveyor can break down = 223-17=206 hrs.

iv) Section Conveyor:- $ISOA = \frac{RTA-CDT}{RTA} = \frac{206-9}{206} = 0{,}9563$

Time remaining during which the distribution bin can break down = 206-9=197 hrs.

v) Distribution bin:- $ISOA = \frac{RTA-CDT}{RTA} = \frac{197-1}{197} = 0{,}9949$

Example 2:- Consider a two seriesed component system as shown :-

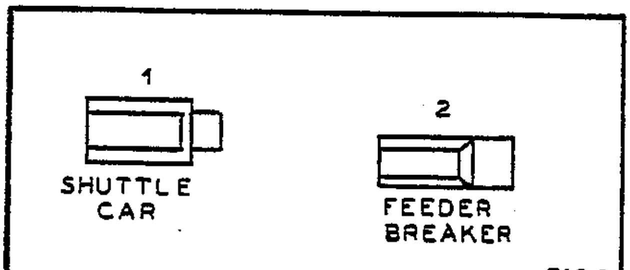


FIG 9.

Assume time and motion studies were conducted over an eight hour shift, and it was found that of the eight operating hours, the shuttle car was out of order for 4 hours, and the feeder breaker was out of order for 4 hours.

In system order avalibility for the two components are as follows:-

i) Shuttle car :- $ISOA = \frac{8-4}{8} = 0{,}5000$

Time remaining during which feeder breaker can break down = 4 hours.

ii) Feeder breaker :- $ISOA = \frac{4-4}{4} = 0{,}000$

NOTE:- i) Component availibility should be considered over period of contract. (i.e by month average for export coal, by week average for power station supply etc).

ii) The longer and more wide spread the time and motion study undertaken the more accurate will be the obtained results.

iii) For the design approach suggested, the availability of each component which will be used in the system should be obtained.

2.3 APPLICATION OF AVAILABILITY THEORY

In order to demonstrate the use of simple availibility theory, the following systems will be considered:- i) Face Equipment and section Belt Conveyor.

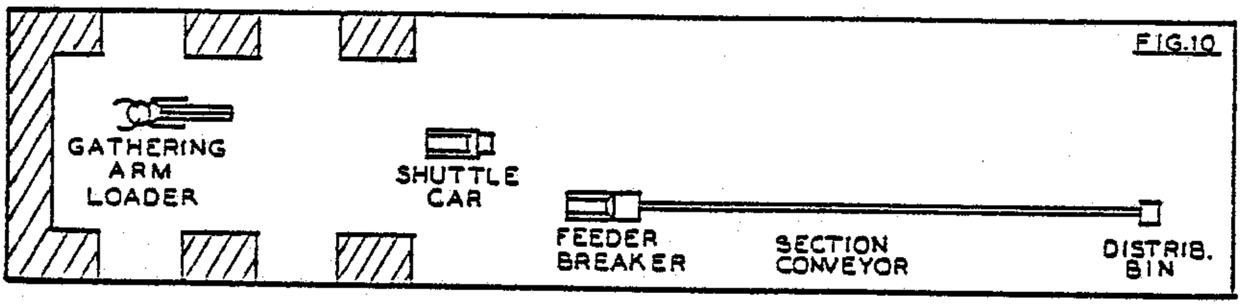


FIG.10

Assume that time and motion studies yield the following component availabilities :-

Gathering Arm Loader	=	0,95
Shuttle Car	=	0,95
Feeder Breaker	=	0,90
Section Conveyor	=	0,90
Distribution Bin	=	0,95

∴ Total section availability = 0,95x0,95x0,90x0,90x0,95=0,69 or 69%
i.e For 69% of unit time, section will be productive.

Since there is usually more than 1 section in the mining area, it is quite possible that two sections can fail at the same time. The duration of this happening is 1-A(T) for two sections in parallel.

∴ Period per unit time two sections are non productive = N(T)
Where N(T) = 1- 0,69+0,69-(0,69)² = 0,096 or 9,6% of unit time.

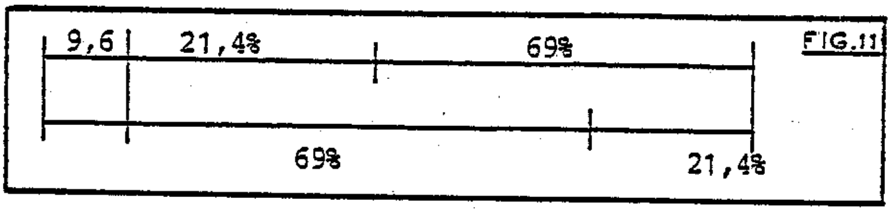
i.e


FIG.11

∴ Both sections will operate for 47,6% of unit time, and either 1 or 2 for 42,8% of unit time.

The duration per unit time three sections are out of order = N(T)

Where $N(T) = 1 - (3 \times 0{,}69 - (0{,}69)^3)$

< 0 which implies that statistically, three sections cannot fail simultaneously.

ii) Main Conveyor Consideration :-

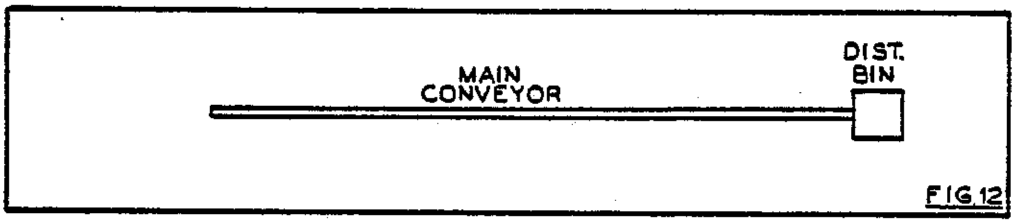


FIG 12

Assume that time and motion studies fix system availabilities as follows :-

Main Belt = 0,95

Distribution Bin = 0,95

∴ Total system availability = 0,95x0,95=0,903, or 90,3%

If two main belts are set up in parallel, duration during which both belts will be non operational = N(t), where

$N(t) = 1 - (0{,}903 \times 2) - (0{,}903)^2)$

$= 0{,}01$ or 1% of unit time

i.e.

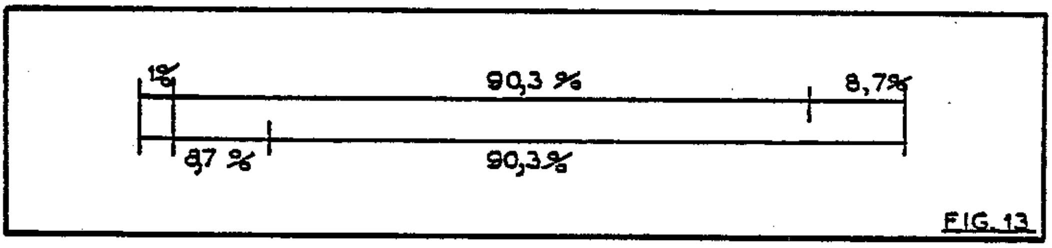


FIG. 13

∴ For 1% of unit time, both conveyors non operational, for 81,6% of unit time both conveyors operate, and for 17,4% either 1 or 2 will operate.

iii) Trunk Conveyor Consideration :-

For purpose of following example, availability will be taken as 0,95 or 95%.

2.4 NETWORK OPTIMISATION

Assume that the results of the mining and geological survey are such that the mining area and shaft location are as shown :-

Required output per unit time from shaft bottom bin=$\dot{M}B$

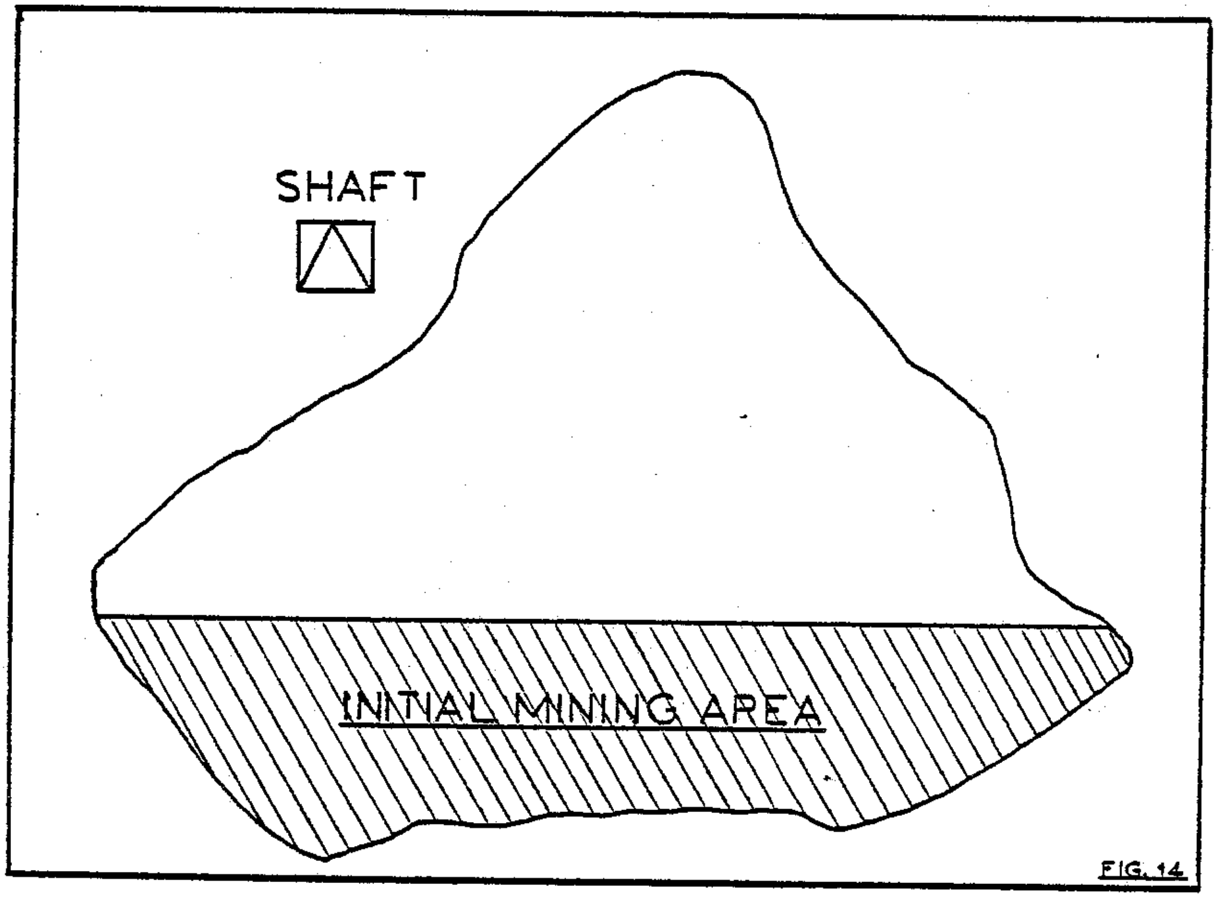


FIG. 14

Possible solutions to the above requirement are as shown in the two conveyor networks overleaf.

2.4.1 POSSIBLE NETWORK NO. 1

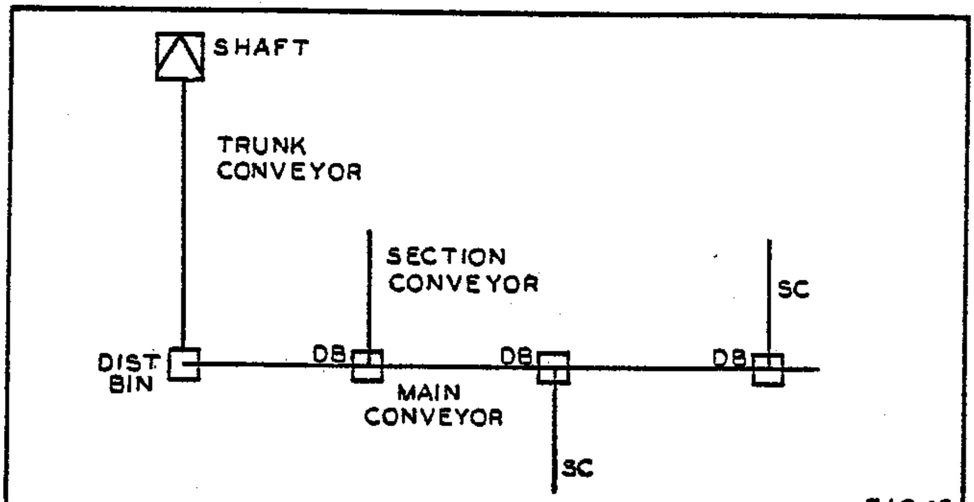


FIG.15

i) Section Mass Input Consideration :-

Let :- Number of sections = N

Mass produced per section = MS, per unit time

Applying availability results as calculation for components of section equipment :-

For 47,6% of unit time, total mass produced by sections = NxMS

For 42,8% of unit time, total mass produced by sections = (N-1)xMS

For 9,6% of unit time, total mass produced by sections = (N-2)xMS

∴ Total input to main conveyor per unit time = MM=(0,476(N)+0,428(N-1)
+ 0,096(N-2) xMS
= (N-0,62)xMS

ii) Main Conveyor Mass Consideration:-

Mass input to main conveyor = MM from above (per unit time).

Availability of conveyor = 90,3%

∴ Total input to trunk conveyor = 0,903 x MM per unit time
= MT

iii) Trunk Conveyor Mass Consideration :-

Mass input to trunk conveyor per unit time = MT from above.
Availability of conveyor system = 0,95.

∴ Mass input to shaft bottom bin = 0,95 MT per unit time

= 0,95 (0,903 MM)

= 0,95 (0,903 (N-0,62)MS)

= 0,8579 (N-0,62)MS

iv) Total Mass Flowrate Consideration

Required mass output from bin per unit time = MB

∴ Taking the total system availability into account, the instantaneous section capacity required is MS, where :-

$$MS = \frac{MB}{0,8579(N-0,62)}$$

2.4.2 POSSIBLE NETWORK NO. 2

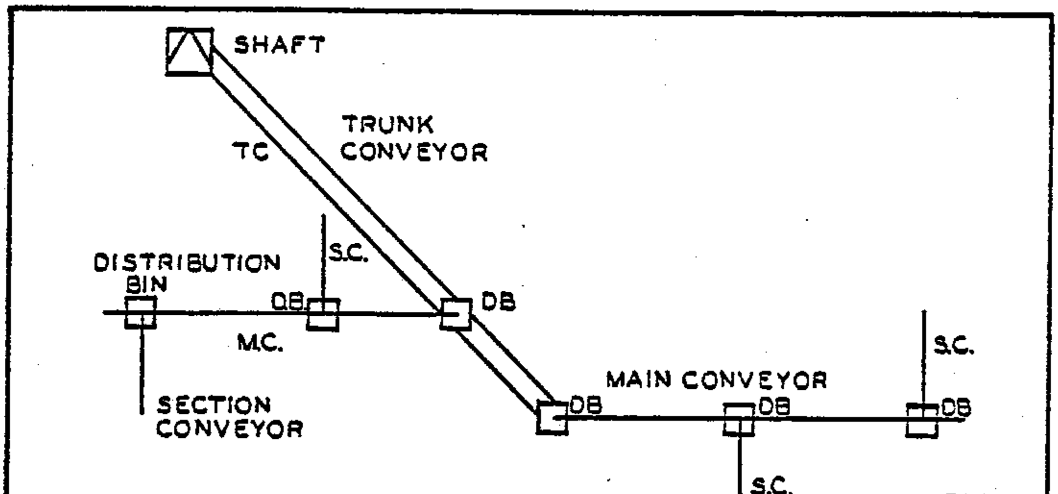


FIG.16

i) Section Mass Input Consideration

This will be identical to the consideration conducted on Network No. 1.

∴ Total input to main conveyor per unit time = (N−0,62)xMS=MM

ii) Main Conveyor Mass Consideration

Assume that the system layout is such that 50% of the total number of sections feed each main belt.

∴ Applying availability results as obtained in section on Availability application :-

For 81,6% of unit time, total mass transported = MM
For 17,4% of unit time, total mass transported = 0,5 MM

∴ Total input to trunk conveyor per unit time =(0,816+0,174x0,5)xMM

=0,903xMM=MT

iii) Trunk Conveyor Mass Consideration

As opposed to possible network No. 1, this format uses two trunk conveyors, either of which are capable of displacing the full tonnage.

Total Trunk Conveyor Capacity Now Becomes :-

$$A(T) = 0{,}95x2 = (0{,}95)^2$$
$$= 0{,}997 \quad \text{or} \quad 99{,}7\%$$

∴ Mass input to shaft bottom bin per unit time = $0{,}997xMT$

$= 0{,}997(0{,}903MM)$

$= 0{,}997(0{,}903(N-0{,}62)MS)$

$= 0{,}9003(N-0{,}062)MS$

iv) Total Mass Flowrate Consideration

Required mass output from bin per unit time = MB

∴ Taking the total system availability into account, the instantaneous section capacity required is MS, where :-

$$MS = \frac{MB}{0{,}9003(N-0{,}62)}$$

2.4.3 SYSTEM SELECTION

The required number of sections can be selected by comparing the effective cost for various numbers of sections of required capacity.

Once the number of sections and hence section capacities have been determined, the following parameters can be calculated:-

i) Section mining equipment requirements

ii) Smoothing bin sizes

iii) Conveyor capacities

Final network selection can be obtained by comparing the total system cost :- i.e

Capital Costs
Replacement Costs
Installation Costs
Maintenance Costs
Operating Costs
Power Costs

For each of the proposed networks.

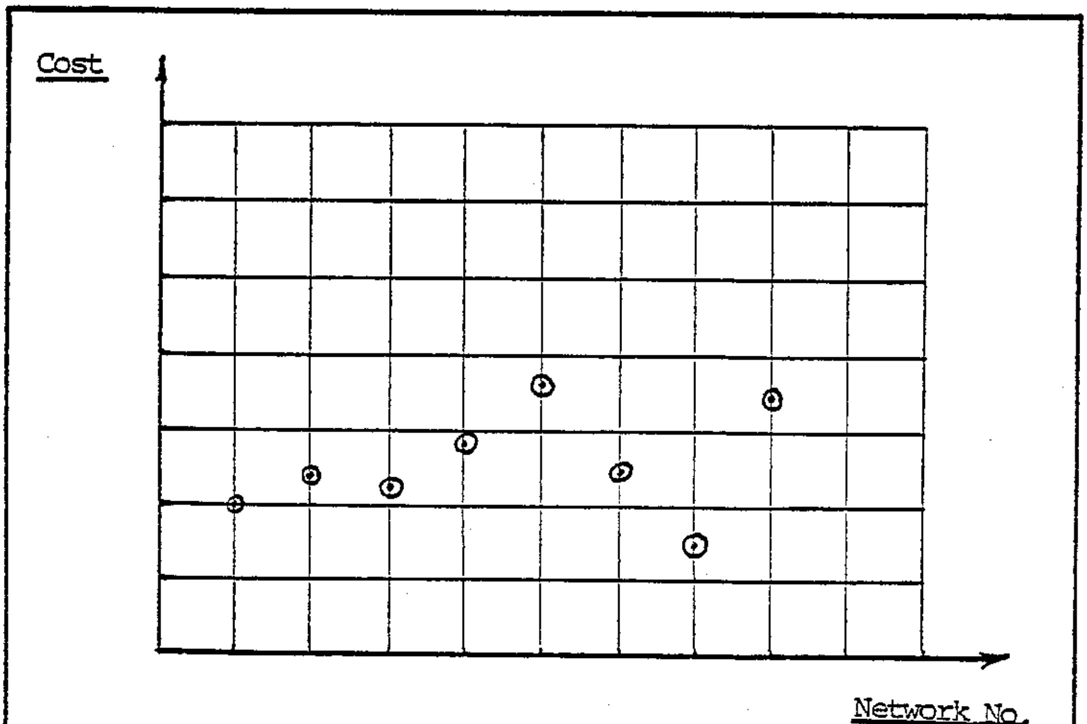


FIG. 17

3. <u>CONCLUSIONS AND RECOMMENDATIONS</u>

3.1 Conclusions:- (i) The above method of network layout does give the designer a basic tool which he can apply in deciding on a possible conveyor network.

(ii) The system is highly dependent on input data, and unless the correctness of this is guaranteed, the validity of the obtained results will be suspect.

(iii) The required "instantaneous" mined tonnage will be determined by the overall network availability.

(iv) In view of the final product of any mining operation being the nett profit made; the use of cost as an optimisation method is sound.
(The aquisition of cost data is easily executed, as well as the update thereof.

3.2 Recommendations:-

(i) The above approach should be compared with an existing colliery with respect to the effective output tonnages obtained.

(ii) The above method can succesfully be computerised and can include methods of optimising ratios of shuttle cars and gathering arm loaders.

(iii) Even although the Chamber of Mines does have computer packages such as face-sim and belt-sim, these packages can only check a design once it has been completed. It is therefore recommended that some research be conducted into setting up an interactive computer package which can assist in the formatting of underground conveyor networks.