In summary, the next version of the program is visualised as providing a tool for the planning as well as the control of mining enterprises.

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Pert, and how Pert techniques can be used in modern mine management

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SYNOPSIS

This paper covers the stages of planning required to be performed and the implementation of the plan from grass roots to the partial completion of the sinking of a mine shaft system. The various steps involved in the planning are also examined in some detail. The experience gained in this project and the conclusions reached convince the authors that Pert Planning is a valuable aid to top management.

SINOPSIS

Hierdie verhandeling dek die stadiums van beplanning wat noodsaaklik is vir die uitvoering en aanwending vanaf die begin-stadium tot gedeeltelike voltooiing, van die sinking van 'n mynskag sisteem. Die verskillende stappe wat betrokke is by die beplanning word ook noukeuriger ondersoek. Die ondervinding wat in hierdie projek opgedoen is en die gevolgtrekkinge bereik, het die skrywers oortuig dat ,Vrypostige Beplanning' waardevolle hulp aan die hoogste bestuur verleen.

INTRODUCTION

PERT, as is well known, is a planning technique which originated in America and was commissioned by the American Navy for the purpose of controlling and coordinating the POLARIS MISSILE PROJECT. PERT, which stands for "Program Evaluation and Review Technique", is a computerised system of planning, initially used only for project time analysis, which makes use of three time estimates for each task. These time estimates are *optimistic*, *pessimistic* and *realistic*. The reason for the use of three time estimates is to establish a weighted average time for each activity during processing on the computer. The computer program allows for the geometric mean of the three time estimates to be established by adding the *optimistic* and *pessimistic* time estimates to four times the *realistic* time estimate, then dividing the result by six.

One difficulty with the system has been to get three time estimates for a given task. For example, tenderers generally quote two time estimates for a job, basing these time estimates on their capacity for doing the job, and their own experience of the probability of obtaining materials, raw or manufactured, and their current work load. Thus the delivery time for a specific piece of equipment could appear on their quotation in the form "Delivery can be effected from 18 to 24 weeks from the receipt of firm instructions to proceed". These estimates can reasonably be assumed to be *optimistic* and *pessimistic*. In other instances, based on their best knowledge of capacity and their known workload, they are far more explicit, and the delivery time appearing on their quotation could read: "Delivery can be made within 8 weeks of receipt of order". Again, this type of estimate can be assumed to be either *realistic* or a misleading *optimistic*.

An instance of misleading time estimates can be gained from the analysis of a supplier's past delivery promises and their actual delivery times, because some estimates tend to be over optimistic. A useful feature to be considered is the inclusion of a period over and above that quoted by the supplier, referred to in the various planning departments as "liar's time".

Arising from the inability, or reluctance, of contractors to provide three time estimates for a task, other techniques such as "Critical Path Scheduling", "Critical Path Method", etc. were evolved for use with single task durations. These latter techniques were designed initially for project time analysis, although in recent years the techniques have been sophisticated to include, in addition to project time analysis, such features as

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cost analysis, resource analysis and assignment, and other features which can be used as aids to management.

PLANNING TECHNIQUES

The first prerequisite in the use of PERT or any of the other techniques is that the planning department have the backing of top management. As one writer so aptly describes the use of planning techniques, "All roads lead to the top of the mountain, but the best way to the top is via the royal road of top management backing. Lesser departments may try to introduce the system, but unless it has the backing of top management, it is doomed to failure".

The use of PERT or any other of the techniques depends on the ability of the user to interpret the results from the computerised versions of the output, and in this respect education in the use of planning techniques is essential, although in practice it is usually the task of the planner to interpret the output, evaluate the changes and advise management of the implications of the changes.

It is also to be borne in mind that there is a "break even" point in a project where the use of manual planning becomes an economic proposition. One must remember that it is not necessary to use computerised planning just for the sake of using it, because certain tasks, such as the sinking of a shaft, lend themselves readily to the use of a manually prepared bar chart, by reason of the fact that each activity naturally follows its predecessor. Tasks which lend themselves to computer application are those where a large number of independent and unrelated activities have to be moulded into a whole job. This involves the sequencing of such activities into the most likely order in which they are to take place, and it is usually the task of the planner to prepare a network diagram showing the relationships of these activities.

There are two basic types of network diagrams. The first and earliest type being the arrow diagram, where the arrow itself identifies the activity description, and the second and more popular the precedence diagram, where the activity is identified by a numbered block. Both types of diagram achieve the same end, although it is generally felt that the precedence diagram is more widely used. Again, it is not necessary to make a network diagram when the requirement of the job in hand is only to prepare a bar chart.

At this stage it is necessary to realise one essential feature of the computerised version of project time analysis, and that is that some thought has to be given to the availability of resources. These may be summarised as machines, materials manpower, money. The logical reason for this thinking is that one resource might conceivably be required for many tasks at the same time on the same day. The most critical of the resources is usually manpower. Since the computer schedules all activities to start at their earliest times, and calculates the float available for such activities, within the areas of criticality too much of one resource may be required at any one time. This feature, if not carefully considered, can cause delays in the project.

It can to some extent be overcome by the re-deployment of resources, e.g., if the resource is manpower, it could be necessary to take personnel from non essential work on to critical tasks, to call in outside contractors etc., whereas if the resource is material, there may be a grave necessity to obtain the materials elsewhere. In the latter case, and in the not too distant past, South African concerns were in great difficulty with steel and cement supplies, and within the mining industry there was some re-deployment of both these resources. Where machinery is employed, be it earth moving equipment or cranes, consideration must be given not only to the availability of the machines themselves, but also the scheduling of the work to keep these machines used to their maximum availability.

Thus, wherever possible, the "planning" thinking should be to maintain as clear cut a continuity of work as possible.

Where money is concerned, cost is a decisive factor in the procurement of equipment. Thus, if essential equipment which is required urgently is weighted costwise with time, and several suppliers have submitted tenders, it is not always wise to accept the cheapest tender. One excellent example could be the use of a civil engineering contractor. A small concern with limited manpower might well be the preferable concern on a cost basis, whereas a large concern in the position to supply a greater manpower resource could complete the work in a far shorter period.

Penultimately, there is the unknown and unexpected time factor, inclement weather in the field of both civil and mechanical construction on surface, and underground the greatest enemy of all — water. It is not usual to take into account the possibility of inclement weather, although where a country has a specific rainy period, analysis of the program would indicate whether a task which is critical and which could be delayed by rainy weather does fall within the rainy season. Underground, as in the case of shaft sinking, it is possible to program for optimistic and realistic conditions. The pessimistic condition is completely unknown.

Finally, and a fact which is often neglected, is that it is not always necessary to have completed a project before it is commissioned. A classification may be made of plant and ancillaries, buildings etc., in the order essential, desirable, desirable but not essential and definitely not essential. In this way, the control of work in hand can be so much easier. Resources can be deployed on the essential items, even if this is to the detriment of non essential work.

THE PLANNING OPERATION

The process of planning may be described so as to include the activities enumerated hereunder, whilst bearing in mind their elaborated descriptions.

1. *Policy*

This defines the purpose to be achieved and the principles or constraints which have to be obeyed.

2. *Forecast*

This is the definition of the events and the circumstances to be expected now and in the future.

3. *Planning and executing*

This is the act of deciding what, where, when, who

TABLE I

PRE-PLANNING ——>	1. POLICY/PROBLEM OBJECTIVES & CONSTRAINTS	}——> SELECT
↓		
PLANNING ——>	2. CONSTRUCT MODELS & INSERT ESTIMATES	}——> RECORD
	3. CALCULATE CRITICAL PATH & EVALUATE FOR VULNERABILITY 4. SIMULATE ALTERNATIVES & EVALUATE	}——> EXAMINE
	5. SELECT BEST PLAN	}——> DEVELOP
↓		
EXECUTION ——>	6. EXECUTE & CO-ORDINATE WORK	}——> INSTALL
↓		
CONTROL ——>	7. COMPARE PROGRESS WITH PLAN 8. TAKE APPROPRIATE ACTION	}——> MAINTAIN
↓ OR		
CONTROL ——>	9. RE-PLANNING	}——> RE-SELECT

how, etc., including the marshalling of resources, the communication of plans and the motivation of action.

4. *Co-ordinating and controlling*

This describes the guiding of action or activity towards the achievement of purposes and the concerted use of means or resources. It includes the measurement of results achieved and the means used, the comparison with the plan and the taking of the appropriate preventive, corrective, re-planning or no action.

5. *Conditions*

This depicts the events and circumstances now prevailing, as expected or otherwise.

6. *Results*

This defines the achievement of purposes, the means employed and the resources used.

The planning operation may be broken down into a number of phases. These phases are:

Pre-planning.
Planning.
Execution.
Control.
Re-planning.

which are further broken down into their respective phases of:

Select.
Record.
Examine.
Develop.
Install.
Maintain.
Re-select.

At the pre-planning stage, many and varied difficulties may be experienced. Under the headings mentioned previously, they can be enumerated thus:

1. *Policy*

The undertaking may be multiple purpose, so initially the purpose must be determined.

2. *Constraints*

There may be many varied but limited resources.

3. *Forecast*

This is usually of long term duration and there may be many additional factors to forecast or to estimate in the immediate future.

4. *Planning*

The basic difficulty is to determine the size of the Project and also to get the whole picture or overview.

Controlling

The greatest difficulty experienced is the lack of planning. The dynamic difficulties in planning and controlling are:

5. *Conditions*

Their relevance to the plan and the lack of good forecasting.

6. *Results*

The lack of control criteria built into the plan. By this is meant that there may be an end result but a lack of control over the means used, e.g.:

End result → Foundations dug.
Means etc. → Method.
Men.
Materials.
Machines.
Information.
Money.
Time.

PRE-PLANNING OR SELECT

Assuming that the backing of top management and the approval of the various departmental heads has been obtained, the first step is to *define the policy/problem.*

Usually, by the time that the planner is called in to assist, some, if not most, of the policy/problem is known. Since our subject is mining, let us assume that a market has become available for a certain mineral, and that the price that that mineral fetches makes the opening of a new mine a proposition worth considering and that the concerned Company has the knowledge that there are deposits of this mineral within an area for which they have the mineral rights.

Within the bounds of a feasibility study, ownership of the land within the expected area that the mine will accommodate has been established, tentative discussions have been held with the Electricity Supply Commission to establish when supplies of electricity can be reasonably expected to become available, talks with the Water Affairs Department have been held to establish the procedure to be followed with the use and return of underground water, cost estimates have been made, availability of equipment has been determined, and myriads of other tasks have been performed and analysed to determine whether the project is likely to be a profitable one.

The results of the feasibility study are channelled to top management and the decision as to whether or not they go ahead with the project is then made. Assuming that the decision they have made is to go ahead with the project, action is called for and top management require to know when they can reasonably expect to get a return on the capital that they anticipate spending.

RECORD

It is usually at this stage that the planner is called in to assist by preparing some documentation of the project on a time basis. The task of the planner is arduous in respect of the fact that at this stage the actual definition of what is required may be somewhat nebulous, and he must try to establish what tasks must be performed to achieve results up to the start of production.

As an individual, he must be able to talk to people at all levels and in all departments, requiring their cooperation to ensure that the information that they provide is correct.

His first task will be to prepare a network or networks of the project showing in broad detail the activities which have to be performed up to the start of production.

Now a "network" may be aptly described as a graphical and numerical model representing time, activity and/or cost factors and their inter-dependence. It may also include the additional "resource" factor.

Whilst he is engaged in this mountainous task, others will be engaged on such tasks as the designing of the mine layout, the selection of equipment, the preparation of tender documents, civil and mechanical enquiries, shaft sinking documentation like the preparation of a schedule of responsibilities, the design of the shaft configuration, the availability of new or secondhand hoists, the provision of portable generators and compressors etc. Firm electricity and water requirements must be established and the appropriate action taken to advise the suppliers. All this information should be channelled to the planner as early as possible to facilitate his task.

Having prepared the network/s, he must now check these for the correct logic with the project manager or his delegate, thereafter obtaining durations for the various tasks. It may not be possible due to various factors at that stage of the planning to insert realistic time estimates for every activity on the network/s and he may be obliged to use "thumbsuck" durations which he must base on previous and similar tasks. It is, however, a well known fact that the design stage of the project can become very protracted due to such problems as lack of design staff, change of design due to the revision of the layout, staff leave and sickness, and other factors.

EXAMINE

Having completed the "model", the planner now evaluates the *critical path*. When the computer is used, as no doubt it will be in this and similar cases at this stage of the project, he will now establish one or more *critical paths*. Now the *critical path* through the project is defined as the shortest time that it will take to complete the project with no free time, or float, on any of the activities which make up the *critical path*.

The *critical path/s* must now be examined and evaluated. It must be determined whether the completion date is acceptable, and, if it is required to try to reduce the project duration, how the re-planning or the simulation of an alternative can be determined. With the cooperation of the departmental heads, or their delegates, revision of the plan may be the decisive factor if an attempt must be made to reduce the overall project duration. This can be attempted by assessing the amount of time by which it is desired to reduce the project and by examination of the *critical* and near *critical paths* having float slightly greater than the amount of time by which the overall project duration is to be reduced. Further, as has been previously mentioned, at this stage the work can be separated into that which is essential, that which is desirable, and that which is not essential. For example, a workshop and a store may be desirable, but at the same time they may not be essential if in the meantime temporary facilities are available, or can be made available.

DEVELOP

If the latest plan is approved, further examination will have established already which path or paths are critical. At this point, a list of the tasks in broad outline should give the reader an insight into the magnitude of the problem. It is not possible to go into each and every detail of the work which goes into the make-up of the mine, but at the same time it is necessary to give the reader some idea of the work content involved.

Assuming that the various permissions required to go ahead are to hand, then the following steps, (in broad outline) can be followed.

1. Boring and cementation around the shaft area, and also possibly within a much larger area to determine the possible whereabouts of sinkholes and also to establish if possible the levels at which the mineral deposits lie so as to get the best

possible surface layout of the mine.
2. Pre-sink and headgear foundation construction.
3. Construction of all winder buildings and ancillary buildings such as offices, stores, workshops, substations etc.
4. Main sinking, after essential work has been completed.
5. Development.
6. Changeover from sinking to permanent conditions.
7. Construction of a metallurgical works, or the modification to an existing plant.
8. Provision of transport for conveying ore and personnel.
9. Storage facilities etc.

1. It is usual to commence the boring and cementation quite soon after the decision to go ahead has been made. In the area of the shaft or shafts, the cementation can go to the full depth of the shaft or shafts.

While this work is being carried out, certain other decisive investigations and preparatory work must be carried out. The investigation covers such items as the availability of plant, buildings, hoist etc., and whether they must be new or can be secondhand. The preparatory work consists of the preparation and return of tender documents for mechanical dismantling (if this is involved), and erection and/or re-erection, and the design and tender documentation for headgear and winders (if new ones are envisaged).

2. When the boring and cementation is under way and the pre-sinking contract has been awarded, the next step is for the shaft-sinking team, or the civil engineering contractor (where the pre-sink is a shallow one), to establish facilities on site for the purpose of carrying out the pre-sink.

For this purpose no doubt the Company will be responsible for the supply of electricity and compressed air, possibly from portable generators and compressors, potable and service water (which might conceivably be supplied from an adjacent borehole), and sanitary facilities which are essential, to the civil engineering contractor or shaft sinker. It may well be that for a shallow pre-sink the civil engineering contractor will install the foundations for the permanent headgear right away, but, where the pre-sink is deep, the shaft sinker will install foundations for his temporary headgear, carry out the pre-sink to the desired depth, whereafter either he or the civil engineering contractor may remove these foundations in order to cast the foundations for the permanent headgear.

3. Once the civil engineering contractor is on site, he must cast winder house and winder foundations, building and other foundations, and also possibly erect a substation building and a permanent magazine. To do this, the bank layout and level must have been established.

For the sub-station, switchgear and transformers, cabling etc., must be ordered or requisitioned, and a contractor organised for the purpose of equipping it. A source of supply for the winder or winders must be determined, and if this or these are not ordered new they will have to be dismantled and overhauled. Buildings, if not new, will have to be dismantled and re-erected. Their foundations will no doubt have had to be redesigned to suit the new ground conditions.

One important factor which must be considered by the planner at this stage is the amount of "downtime" between the completion of the pre-sink and the start of the permanent sink. There must be a fairly liberal amount of time available to the shaft sinker after he has been awarded the sinking contract to enable him to carry out his designs, to prepare his equipment and if it has to be made, to have it manufactured and also to deliver it to site and install it. He may well be the responsible party when it comes to the supply and erection of the stage winder or winders and the sinking stage or stages, and inevitably this will involve his staff in considerable design work. Recapitulating, he must have sufficient time to muster his resources, repair or overhaul his equipment, install foundations for his stage winder/s, batching plant/s and any other fixed equipment he must have. He must also have sufficient design time where required, and he must also be able to organise the supply of explosives, sand, stone and cement, so that everything is to hand when the permanent sink starts.

4. For the shaft sinker to have submitted a tender for the shaft sinking, he must have prepared a detailed estimate, which would have included an estimate of his proposed sinking rates, station cutting and development etc. This would no doubt have been prepared on an optimistic basis, in other words, the various adverse ground conditions which might be encountered during sinking would not have been considered. His estimate would have been based on straightforward sinking.

However, during sinking he would have to perform cover drilling and cementation, during which process he would also measure the amount of water he was making from his cover drill holes. Since it is unlikely he would know the amount of sealing which would in fact, be required, the cementation of the holes for which he has made the optimistic estimate may conceivably be a much more protracted process. Therefore when the planning is done, to be realistic, the activity of cementation could take three times as long, and being pessimistic, could even take years.

It is an easy task, therefore, to provide a bar chart for the sinking based on optimistic and reasonably realistic times. The shaft sinker may well find this bar chart extremely useful for recording his sinking progress.

5. If the shaft system has two shafts, it is likely that, at a particular level, development could proceed from one of the shafts, while sinking continued in the other shaft. Therefore, a program covering the development subsequent to the sinking of the shaft is also helpful. This program would cover the requisition or supply of equipment necessary for the work of development to proceed underground.

Again, the attempt has been made only to give the reader a general rather than a detailed overview of the requirements.

6. When the sinking of the second shaft is completed, this shaft can be returned from the sinking to the permanent condition. Again, a program for this "changeover"

is required. It is possible for this program and that of development to be combined.

7, 8 and 9. The metallurgical works may be the last step in the planning. The planner must be acquainted with the delivery times for the large items of equipment, such as ball, rod and pebble mills which inevitably, if new, are long delivery items which also take some considerable time to install and commission. Depending on the type of mineral being processed, flotation equipment, and crushers may also be required, together with instrumentation, which together may all be classed as fairly long delivery items. If the plant is a new one, the problem of staffing it must also be considered. Once again, design of the plant, with probable provisions for extensions must be considered fully, and bearing in mind, that the design stage (which has been previously referred to), can be a very protracted task, thought should be given to this very early on.

With an existing plant, thought must be given to its suitability and where changes are involved, the availability of suitable equipment.

An early evaluation of transport requirements must also be made. This evaluation involves the transport of personnel to and from the mine, the removal of the rock from the mine to the metallurgical works etc. Irrespective of the type of transport envisaged, its provision takes time, and the evaluation of the different types should be made early on in the project.

Last, but not least, and in parallel with the transport of personnel must also be considered the housing of the mine staff; the ramifications of this are obvious.

We have now covered, even if only in very broad detail, the bulk of the work required to be done to bring a mine to the stage of "start of production". To complete the picture let us now study a Case History.

CASE HISTORY

Within the J.C.I. Group, the conditions outlined earlier occurred. A new mine was required to be opened on the Witwatersrand, as early as possible. Initially, a plan was prepared covering the work which had to be performed to the start of permanent sinking. A two shaft system was envisaged, being a ventilation and a main shaft. Second-hand equipment generally was available, but some new equipment was also called for.

At the outset of the job, bi-monthly meetings were held at the Head Office to discuss problems encountered by the various involved parties, at which computerised versions of the PERT plan were discussed. One point which was made earlier was that of the computer creating all activities to start at their earliest date, which in the case in question involved the start of the project at the then current date. However, with the many varied factors and problems which had to be considered, in almost every case involving design, delays were the order of the day. A nationwide shortage of steel and cement were vital factors, and designs for both concrete and steel headgear were made. Management was faced with the task of deciding which type of construction to use, and tenders were called for and evaluated timewise and costwise for both types. Tenders were called for the dismantling and re-erection of buildings and winders on prepared foundations. Civil tenders based on schedules of rates were called for and evaluated. Promises of supply date for electricity, temporary and permanent, were obtained. Design was continued during this period of uncertainty, and slowly the overall picture became clearer.

At this stage it is pointed out that two separate shaft systems were envisaged, and although the sinking at one of these was deferred, it was decided to site the compressor station at this shaft site which was some two miles or so from the site of the other shaft system. The pipeline between the shaft systems had been designed fairly early in the project and a start had been made on its installation and also the cables between the temporary and site sub-station some two months before the final decisions were made.

Also, at about this time, a temporary magazine had been installed and licenced at the first shaft, and tenders for the pre-sink had been called for. The dolomites in the shaft area were at about 200 feet below ground level, and the pre-sink was envisaged to go to 250 feet in both the main and the vent shafts.

The Pert program, meanwhile, was continually updated, presented and discussed at bi-monthly site meetings, and the completion of the first shaft system up to the start of permanent sink in both shafts continued to go further into the future with each up-dating due to the fact that no pre-sink, civil, headgear or mechanical dismantling and re-erection contracts had been awarded.

In the meantime, boring at the proposed shafts and its associated cementation was continuing, and eight months after the start of meetings final decisions were made and the implementation of these decisions had begun.

The contract for the pre-sink was awarded, and after a short period the sinking contractor was established on site and the pre-sink of both shafts commenced.

A few weeks later the civil contract was awarded, and the civil contractor established at both shaft systems. His first tasks at the site where the pre-sink was taking place were to construct foundations for the vent shaft winder and winder building, to construct the permanent magazines and also the site sub-station building. Laying out of these buildings and foundations was started, along with the appropriate excavation work, some three weeks after the award of the contract.

When the planner had evaluated the latest computer printout, it was realised that between the completion of the pre-sink and the start of the permanent sink there would be a considerable amount of "downtime", and it was then decided to evaluate ways of reducing this "downtime" if the tender for the permanent sink from the particular shaft sinker was accepted. Three programs were prepared, in the following order. The first was for the sinking at both shafts to continue until their respective pre-sinks were completed. The second was for the main shaft pre-sink to continue until the civil contractor required the collar to be cast, and for the ventilation shaft pre-sink to continue until the main shaft was ready for the permanent sink. The third was for the ventilation shaft pre-sink to continue until the civil contractor required the collar to be cast, and the main shaft pre-sink to continue until the vent shaft was ready for the permanent sink.

Since the sinking rates at that time had not been regular, three rates were assumed for the pre-sink for each of the main and ventilation shafts. These were, for the ventilation shaft 10, 12 and 14 feet per day and, for the larger main shaft 7, 9 and 11 feet per day. Tabulating the results showed that, in the first case the maximum and minimum "off-site" duration would be 11 weeks each, in the second case the maximum "off-site" durations would be maximum $13\frac{1}{2}$ weeks, minimum 11 weeks, and in the third case the maximum "off-site" time would be 3 weeks and the minimum "off-site" time nil.

However, none of the three alternatives evaluated seemed to cover the requirement of minimum downtime without one or the other of the shafts being delayed. An acceptable compromise, which, to all intents and purposes, was a combination of the second and third, was agreed upon. This compromise was to continue the pre-sink below the depth of 250 feet, at which the shafts were "toed-in", until the last possible moment before it was necessary to stop so as to cast the foundations for the headgear, which would be followed by the erection thereof, followed by sinking alterations and con-current with the installation of stage winders and permanent winder. It was planned for all of these items to be completed, together with the equipping of the sub-station, at such a time that power should be available for the commissioning of the main and stage winders.

This plan was agreed upon, although the additional depth of pre-sink would be unknown, and therefore a completion date could not be established. Moreover, at that stage, the tender for the erection of the winders and buildings, which had hitherto been submitted piecemeal by a number of erection concerns, was again called for to be submitted in its entirety.

These contracts were awarded, and discussions ensued with contractors to establish a *modus operandi*, delivery and erection times in the case of the headgear contractor and dismantling and re-erection times in the case of the contractor doing the dismantling and re-erecting. One thing also not known at this stage was the extent of any repair work required to be done to the winders.

At the second site, the construction of the temporary sub-station (which was due to be the second source of supply when the permanent sub-station was commissioned) the main site sub-station and the compressor station was proceeding. The compressor station was initially to be equipped with three second hand compressors, and all required to be overhauled to a greater or lesser extent. A further compressor had been ordered very early in the project to cater for the total supply of compressed air from the start of development. The civil contractor was also required to construct a large spray cooling pond, which had, as yet, not been started, but was desired to be completed in time for the start of the permanent sink of the ventilation shaft, envisaged to be the first to start.

All this while, the program was continually updated, mainly by establishing from the contractors on site, their progress to date, and with the other contractors by a visit to establish their progress. The program was eventually finalised some 12 months after the start of the meetings, leaving a very clear picture of the state of events completed, in progress and pending. It can be mentioned here that, subsequent to the time when the overall picture was clear and firm activity durations obtained from the various contractors, and a computer printout including all the most up to date information had been obtained and evaluated, the continuation of the Project was controlled only by the provision of manually prepared and updated bar charts to the concerned parties.

At this time the first serious problem reared its ugly head. The sheaves required for the ventilation shaft headgear were going to be the subject of a considerable delay due to the suppliers of bearings, (in the U.S.A.) having promised a certain delivery period and not adhered to it. With this knowledge available some three months before the expected start date for the permanent sink, time was available for the making of alternative plans. One plan was for the supplier of the sheaves to obtain the bearings from another source. Another was to establish whether, within the group, there was a set of similar sheaves available. The third was to establish whether the shaft sinking concern could supply a suitable set of sheaves. In actual fact, the shaft sinker was able to provide suitable sheaves, and there was therefore no necessity to take any action regarding the supply of the bearings.

Meanwhile, other work was progressing, and the contract for the sinking of the shaft had been awarded. When the contractor supplying the headgear was able to give a definite start date for the erection of the headgear at the ventilation shaft, the program was again evaluated to assess the best time at which to stop the pre-sink, and further discussions held with the civil contractors to establish how much time would be required to cast the foundations for the headgear. A target date was established, and at this particular time the pre-sink was stopped.

At the main shaft meanwhile, the pre-sink was continuing, foundations for the winder building and for one of the two winders being installed were in hand, and pipe and cable trenches were started. The building for the sub-station was almost completed, the ventilation shaft winder building had been dismantled and re-erection had been completed, and the ventilation shaft winder had been dismantled and transported to site.

At the second shaft system, the temporary sub-station had been constructed and fenced, the compressor station was partially erected, and the foundations of the three initial sinking compressors were complete.

However, at this stage of the project, no news as to when a start was to be made on the installation of the landline to the temporary sub-station was available, and it was decided to prepare a PERT program to cover the contingency of "no power available" if the permanent ventilation shaft sinking target date was otherwise met. At this stage, crash programming had to be resorted to by the civil contractor to complete the permanent magazine.

The shaft sinker had decided where to site the stage winder for the ventilation shaft, and the progress of the installation of the equipment proceeded according to plan.

At the main shaft, installation of the main shaft winder building was started. The pre-sink was continuing, and a stage had been reached where the limit of the pre-sink equipment had been reached. The installation of the main winder was started, and the headgear foundations started.

At the second shaft it became apparent that, by the target date for the start of the permanent ventilation shaft sink the spray cooling pond required for the compressors would not be ready, and estimates were obtained for a temporary "farm type" tank to be used until the spray cooling pond was able to be commissioned. This tank was then purchased and installed. The installation of the compressors meanwhile, was proceeding.

It soon became apparent that the temporary power supply would not be available when the target date for the start of the permanent ventilation shaft sink was reached, and it was decided to install a 150 HP hoist for the kibble at the shaft.

All of the equipment had been installed and was ready for use before the target date, but, as anticipated, no power was available, except for that supplied by the portable generators.

The permanent ventilation shaft sink in fact started at 3 p.m. on the day previous to the target date, but using the temporary 150 HP winch. The target date had been finally established, however, some 6 months earlier. Power from the temporary supply became available some 3 weeks after this, and the shaft winder was commissioned.

At the same time that the ventilation shaft winder was being commissioned, the compressors at the second shaft system were also commissioned, together with the pipeline between the two shafts, and also the power lines and both site sub-stations.

At the main shaft progress was continuing to be made according to the plan. The installation of the main winder continued, and the installation of the stage winder had started, and all indications were that the target date for the permanent main shaft sink would be met. However, it transpired that a number of small but essential parts of some items of equipment had been lost during an overhaul, and these had to be re-made. This delayed the start of the permanent main shaft sink for a period of 8 days beyond the target date which had been established some 8 months or so previously.

On the civil side, some of the foundations for buildings had had to be stopped very early in the project, due both to the fact that the site layout had been changed and also that, had they been continued, other essential equipment foundations would have inevitably been delayed and this delay would have influenced the target dates for permanent ventilation and main shaft sink.

Prior to the start of the permanent ventilation shaft sink, bar charts had been prepared covering the sinking period of each of the shafts, these showing the optimistic and the realistic activity times. They were passed to the shaft sinker.

Currently the shaft sinking is continuing, and, despite the dealy of 8 days at the main shaft, progress continues to be plotted and shows the sinking to be between the optimistic and the realistic times which had been established, and this despite a delay due to the incursion of some underground water during the sink at both shafts.

CONCLUSIONS

When due consideration has been given to the various causes and effects related to the problems that were encountered, the indications are that planning is essential to achieve a smooth flow of work throughout the project and that when problems do occur, as inevitably they will, those in control must be in a position to be able to analyse the problem, and more important, to be in a position to do something about it. Further it can be of considerable help if alternative plans can be evolved to cover possible delays before these delays arise. Proof of this has already been shown to have been achieved.

From a planning viewpoint, the programs prepared were followed closely. Certain facets can, however, be highlighted. These are that:

1. There is an essential need for the people in charge of the project to think objectively about it early in its inception.
2. Had it not been established that the sheaves for the ventilation shaft were the subject of a possibly considerable delay, the start of the permanent shaft sink target date would probably not have been met.
3. The decision to continue with the pre-sink was the right one, in that at least one month of additional sinking at the permanent sinking rates was achieved at the ventilation shaft and about two months at the main shaft.
4. The downtime of the shaft sinker was reduced to a minimum which turned out to be approximately 8 weeks of no sinking, but at the same time he was still on site carrying out erection of stage winders, batching plants and other essential work.
5. The delay in the supply of power was circumvented by installing the 150 HP hoist, and a further delay due to loose laminations on the ventilation shaft motor was obviated for the same reason.
6. The decision to install the temporary farm tank for the compressor cooling water was the correct one.
7. That the provision of realistic but not impossible target dates based on the estimates of the people and/or contractors responsible for doing the work gave these people a series of tangible dates to work towards. It is clear that if every contractor knows by what date his work is required to be completed, he can deploy his resources so as to meet those dates and this cannot be done effectively unless the overall picture is first obtained through the use of planning.

There is found to be a trend of thought towards the uselessness of planning and also the probability that it is ineffectual. However, when the people responsible for the management of the project, from the Consulting Engineer downwards, are aware of the problem, the progress, and the likelihood of delays in the implementation of the plan, they are in a position to say "what can be done to overcome the problem", and this can, in fact, often be done before the problem arises rather than after it has arisen.

Another and very vital feature is the necessity for the planning to be started as early as possible, as well as the necessity for the people concerned with the provision of planning information to be motivated to action, preferably by the senior management, and also at the earliest possible time.

It is rarely realised that a feature of planning which is, in fact, an aid to the people responsible for carrying out the work is that when they are asked what they have to do to achieve a certain end result, they are forced to think of what is the nature of the project, how they are going to do the job, what materials or other resources are required to do it, what is the best way of doing it, and how long they can reasonably take to do it with the resources that are available to them.

If, as would be the case with a Civil Contractor, there are a number of different areas to be worked on, it is best to tackle the most critical rather than the easiest tasks first. Therefore, for a Civil Contractor, target dates are a "must".

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