COMPUTERISED NETWORK SCHEDULING AND MONITORING IN CONSTRUCTION

A DISSERTATION

Submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF ARCHITECTURE

By

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C E R T I F I C A T E

Certified that the dissertation entitled " **COMPUTERISED NETWORK SCHEDULING AND MONITORING IN CONSTRUCTION**", which is being submitted by **C. SHEELA** in partial fulfilment for the award of degree of **MASTER OF ARCHITECTURE**, in the Department of Architecture University of Roorkee, Roorkee, is a record of her own work carried out by her under our supervision and guidance. The matter embodied in this dissertation has not been submitted for award of any other degree or diploma.

This is to further certify that she has worked for a period of seven months from August 1984 to February 1985 for preparing this dissertation at this University.

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Shri K. Radhakrishnan, my beloved husband, was indeed the moving spirit behind this undertaking. My little daughter Devi, who had to forgo the tenderness of a maternal presence near her for many months now, also was a beacon of inspiration and vigour to me. Here I take the opportunity to express my gratitude towards my revered parents, who strived and strained for my well being.

Lastly, I offer my thanks to one and all who have contributed something of their own 'little bit here and there' during the progress of the work.

(C. SHEELA)

S Y N O P S I S

The relevance and importance of management techniques in construction is brought out in this report. In all projets one is concerned with developing an optimal and workable plan of the activities that make up the project including a specification of their interrelationships.

It is **inevitable** in a project that delays and changes are likely to occur due to unavoidable reasons. So updating at suitable intervals is necessary. For a small project hand computation can be adopted. But due to complexities arising in construction process the use of computer program is most suitable. A program for updating purpose has been presented followed by the scheduling and bar chart programs.

Two live projects have been taken as case studies. The importance of scheduling and monitoring of projects has been brought out by reviewing the case studies.

To illustrate the monitoring program one example has been presented with two different cases. To illustrate the program in the live project, a part of one of the case studies has been taken and revised. The results containing basic data, revised data, schedule and bar charts of all examples have been presented.

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CHAPTER-1

I N T R O D U C T I O N

1.1 IMPORTANCE OF NETWORK SCHEDULING IN BUILDING CONSTRUCTION

Construction is one of the major sectors of developmental plans. Day by day construction activity is increasing. All these projects are highly capital intensive. To achieve targets economically and as per schedule construction planning and management are highly relevant.

Construction projects undertaken in the public and private sectors have been imposing strain on the country's economy, because majority of the project could not keep up to their original schedule and cost estimate. The major reasons for over-run in time and cost may be attributed to the inadequate planning of the project.

During the past few years interest has grown in phenomenal rate in the use of 'critical path methods' in planning, scheduling and controlling of projects. Critical path methods can reduce even a complex project plan to a single graphical form which is free of ambiguity and complex mathematical analysis.

1.2 IDENTIFICATION OF THE PROBLEM

In all the projects one is concerned with developing an optimal workable plan of the activities that make up the project, including a specification of their inter-relationships. Also one is interested in scheduling these activities in an acceptable timespan and finally comes the controlling of project in hand.

The manpower and facilities required for carrying out the programme alongwith the progress in time must be considered. The programme is planned to ensure economical use of time, money and material. Field control depends upon monitoring the expenditure of time and money for carrying out the scheduled program, as well as the resulting 'product quality and performance'.

Planning and scheduling is the basis of all projects and they run almost on the similar line. They differ mainly in the way with which they are controlled. Since economy and output depends upon efficient control, control efficiency is also a major factor.

1.3 SCOPE OF THE PROBLEM

Network of a project defines the logic and sequence of operations involved in its execution. Therefore, network is an efficient technique which can fulfil the requirements for an effective management. The first essential need of a project's overall success is a good economic and financial plan. Achievement of such a plan is possible through network analysis with selection of best alternative of cost-time analysis and proper monitoring and controlling of construction project.

This method can be applied effectively for construction management in three different phases viz. planning, scheduling and controlling of construction projects, to make an economical and feasible plan of the work. The ultimate aim of the project management is to complete the construction of a project at minimum cost, within the scheduled time and with available resources.

The application of critical path methods are obvious and straightforward. If the project is to be executed the proposed network serves as a framework for developing a detailed plan and schedule to be used in carrying out the project.

A schedule for anything as complex as a construction project cannot be expected to remain constant. Changes are introduced by many variables. Complete project management revises the schedule either at specific intervals or as and when it is necessary. With the revised informations the computer will revise the schedule to reflect the current status of the project.

There are numerous ways in which updating and progress reporting may be accomplished. The most effective updating for construction progress is done by computer analysis. The updated information is usually furnished in the form of computer printouts in a variety of arrangements.

The following are the inputs and outputs of an updated schedule.

Input

A. (1) Actual starting date/time of activities already started.

(2) Actual starting date/time of activities already finished.

(3) Actual duration of activities already finished.

(4) Addition of activities.

(5) Deletion of certain activities.

(6) Modified interdependencies.

(7) Revised duration of remaining activities.

(8) Revised and modified arrow diagram.

(9) Actual reaource and cash requirements of remaining activities.

Output

B. (1) Revised arrow diagram.

(2) Time status of the project.

(3) Cost status of the project.

(4) Resource status - sufficient, insufficient or surplus.

(5) Systematic recording of datas available, for any future use.

(6) Revised starting and finishing dates for remaining activities.

(7) Revised cash requirements.

(8) Revised resource requirements.

(In the program, items A(1) to A(7) and B(2) to B(4) are covered).

Control monitor phase starts with the actual starting of the project, continues throughout the duration of the project and ends with the finishing of the project.

1.4 OBJECTIVE

(1) To study the different aspects of network planning, scheduling and monitoring, that is being used in the construction field. This is done through case studies where appropriate techniques are applied. Through case studies it may be possible

to form the different methods of network planning, scheduling and monitoring which can be used in the construction field. The procedure adopted for carrying out the different phases and their advantages and disadvantages can be listed.

(2) It is inevitable in a project that some delay and changes are likely to occur due to unavoidable reasons. So updating at suitable intervals is necessary. For a small project hand computation can be adopted. But due to the complexities arising in construction process the use of computer is most suitable. A computer program for updating purpose may be much useful in the field of construction management. A computer program has been developed by the author for this purpose and given in Chapter 5.

(3) Bar charts - Bar chart is the easiest technique by which one can see the progress of independent works. Once the schedule is made it is easy to make the bar chart. A program for bar chart is also given in Chapter 5.

1.5 CASE STUDIES

Two buildings under construction are considered for case studies. In these projects the following points are taken into consideration.

(1) The network method used and the original network plan.

(2) The division of the original plan into different subdivisions.

(3) Scheduling part.

(4) Monitoring part - The different methods adopted to know the progress of the work.

Case Study 1 - is an office complex (SCOPE) at New Delhi. It is a 7 storied building with 2 basements. Total floor area excluding basement is 7000 sq. m. CPM activity - on-arrow networking system is used in this project.

Case Study 2 - is a Zerox complex at Rampur. It has 139 activities overall including installation of equipments and machinery. The precedence network is used for this project.

CHAPTER-2

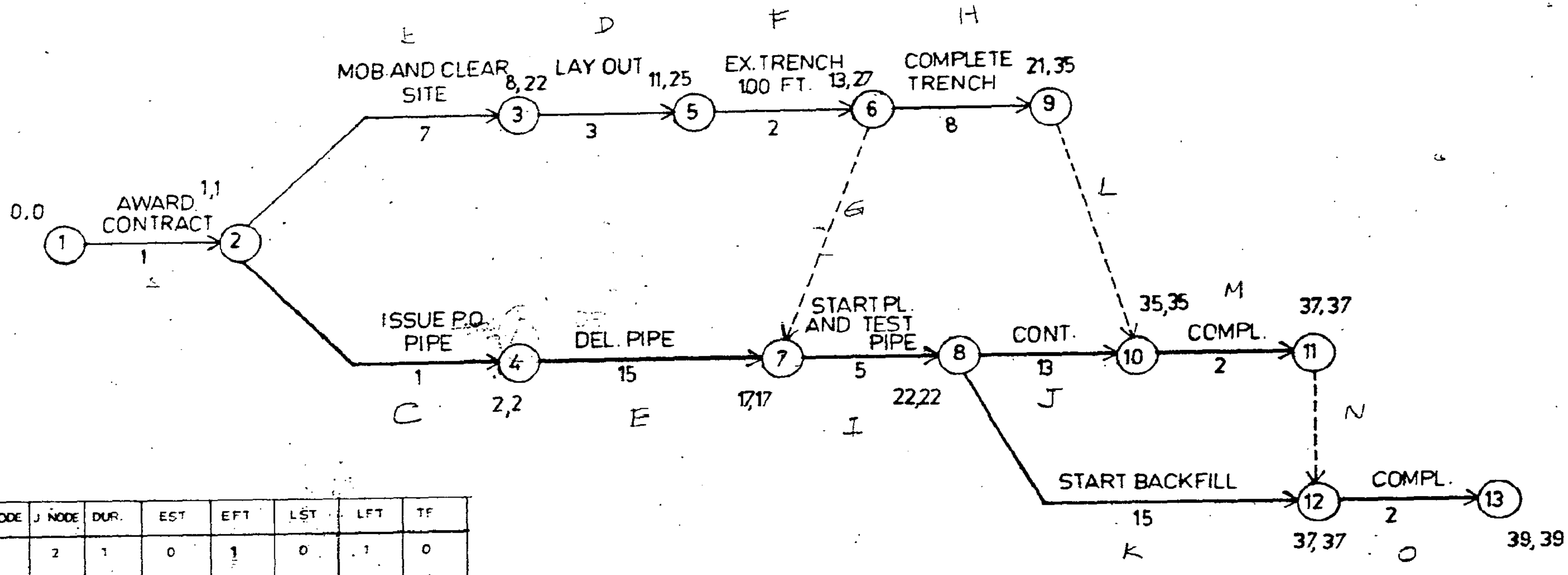
CPM AND PRECEDENCE NETWORKS

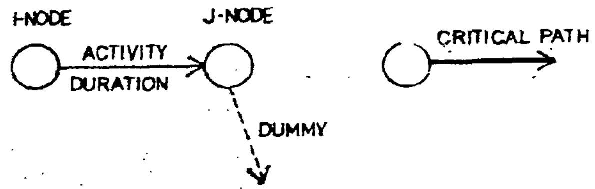
2.1 INTRODUCTION

Eventhough the ultimate aim of both CPM and Precedence networks are the same, there are some differences in the graphical representation and calculation of timings.

CPM is also known as Activity-on-Arrow (A-O-A) network and precedence is known as Activity-on-Node (A-O-N) network. In A-O-A, the activities are represented by arrows and in A-O-N , the activities are represented by nodes. One major difference between the two is that in A-O-A dummies are used, but A-O-N it is not used. In Fig. 1 and Fig.2, A-O-A and A-O-N networks for the same problem is presented. Apart from the physical variations with CPM, the A-O-N form permits three precedence relationships as against one of CPM. In A-O-A form an activity can start when the preceding activity or activities are completed and this can be termed as end to start relationships i.e., the start of an activity is linked with the finishing of another activity, whereas in A-O-N, in addition to this relationships, there are two more relations. These additional relationships are the speciality of A-O-N, and it is this flexibility that has made the technique different from A-O-A, not only in look but also in utility.

NETWORK DIAGRAM





SL. NO	I-NODE	J NODE	DUR.	EST	EFT	LST	LFT	TF
1	1	2	1	0	1	0	1	0
2	2	3	7	1	8	15	22	14
3	2	4	1	1	2	1	2	0
4	3	5	3	8	11	22	25	3
5	4	7	15	2	17	2	17	0
6	5	6	2	11	13	25	27	2
7	6	7	0	13	13	17	17	4
8	6	9	8	13	21	27	35	14
9	7	8	5	17	22	17	22	0
10	8	10	13	22	35	22	35	0
11	8	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	9	10	0	21	21	35	35	14
13	10	11	2	35	37	35	37	0
14	11	12	0	37	37	37	37	0
15	12	13	2	39	39	37	39	0

FIG.1

PRECEDENCE METHOD

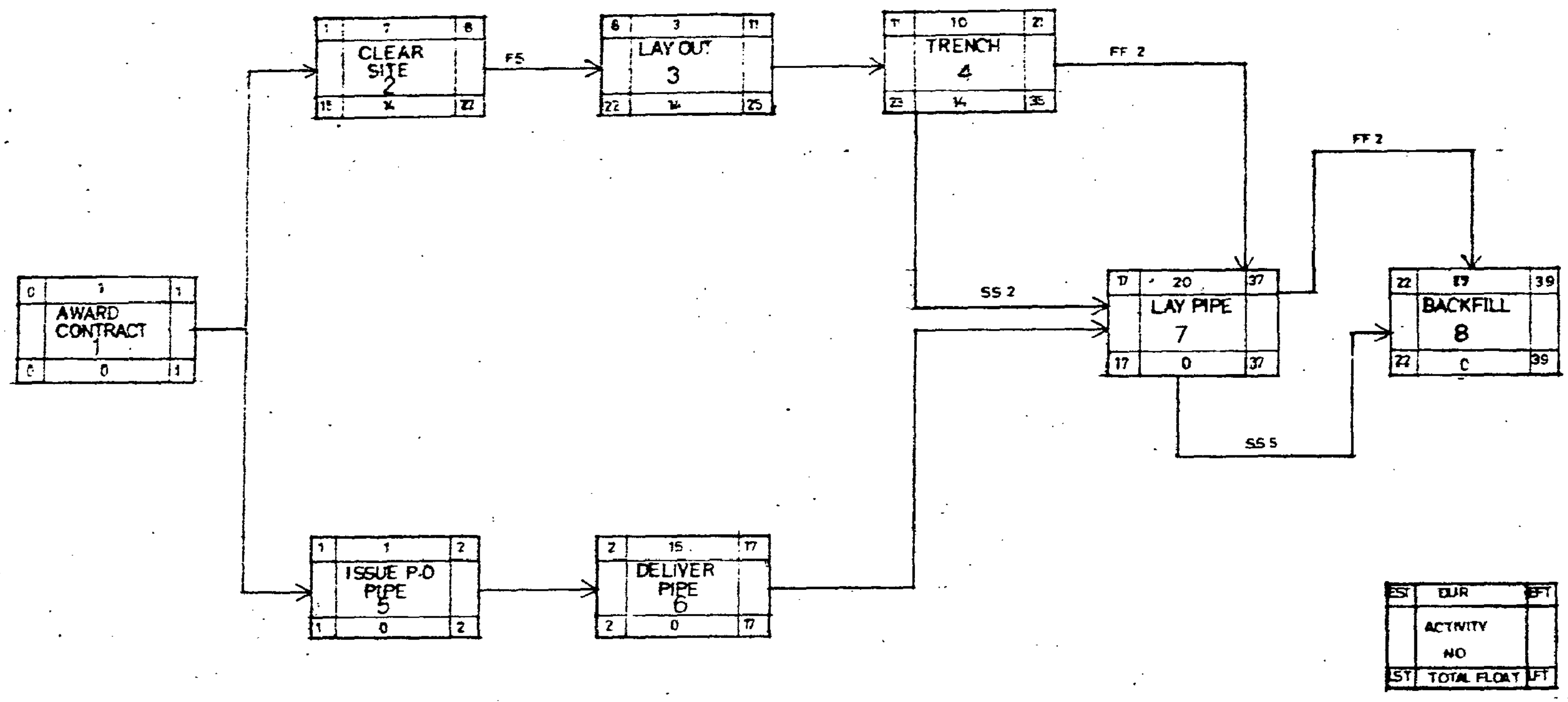


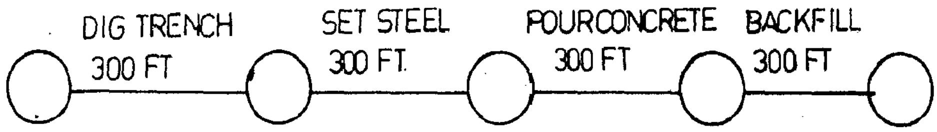
FIG 2

FS FINISH TO START RELATIONSHIP PRECEDING ACTIVITY MUST BE COMPLETE BEFORE THE FOLLOWING ACTIVITY STARTS

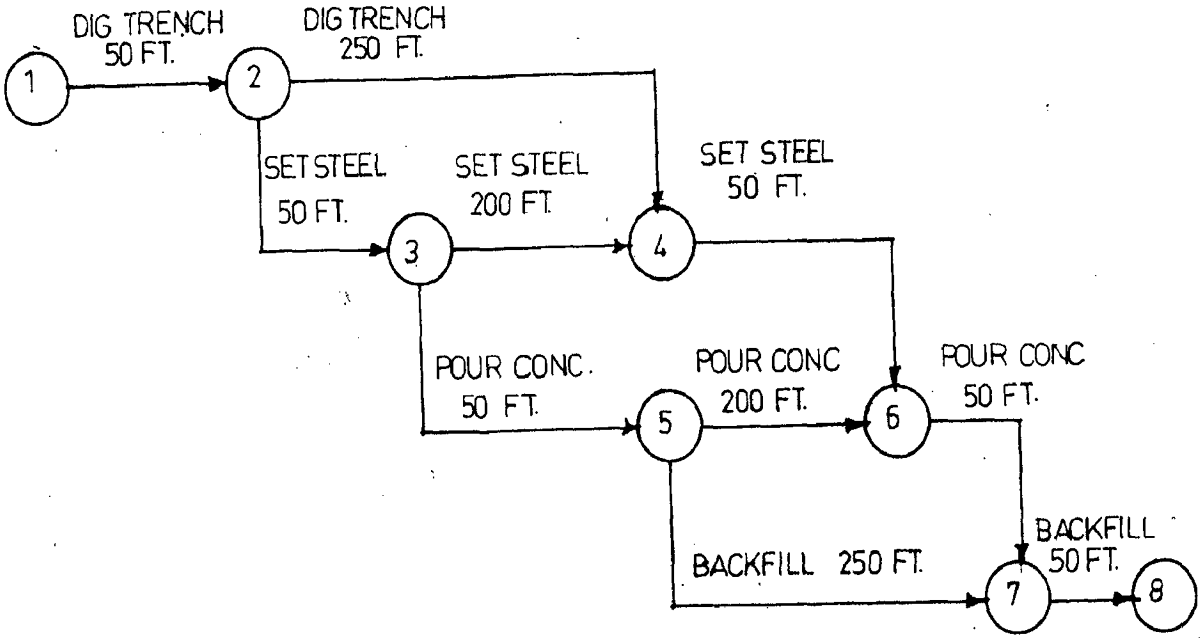
SS START TO START RELATIONSHIP FOLLOWING ACTIVITY STARTS AT A SPECIFIED TIME AFTER THE PRECEDING ACTIVITY STARTS
IN FIG. LAYING PIPE STARTS 2 DAYS AFTER TRENCH HAS BEGUN

FF FINISH TO FINISH RELATIONSHIP FOLLOWING ACTIVITY IS COMPLETED A SPECIFIED TIME AFTER THE COMPLETION OF THE PRECEDING ACTIVITY
IN FIG. TRENCHING IS COMPLETED 2 DAYS BEFORE LAYING PIPE IS COMPLETED

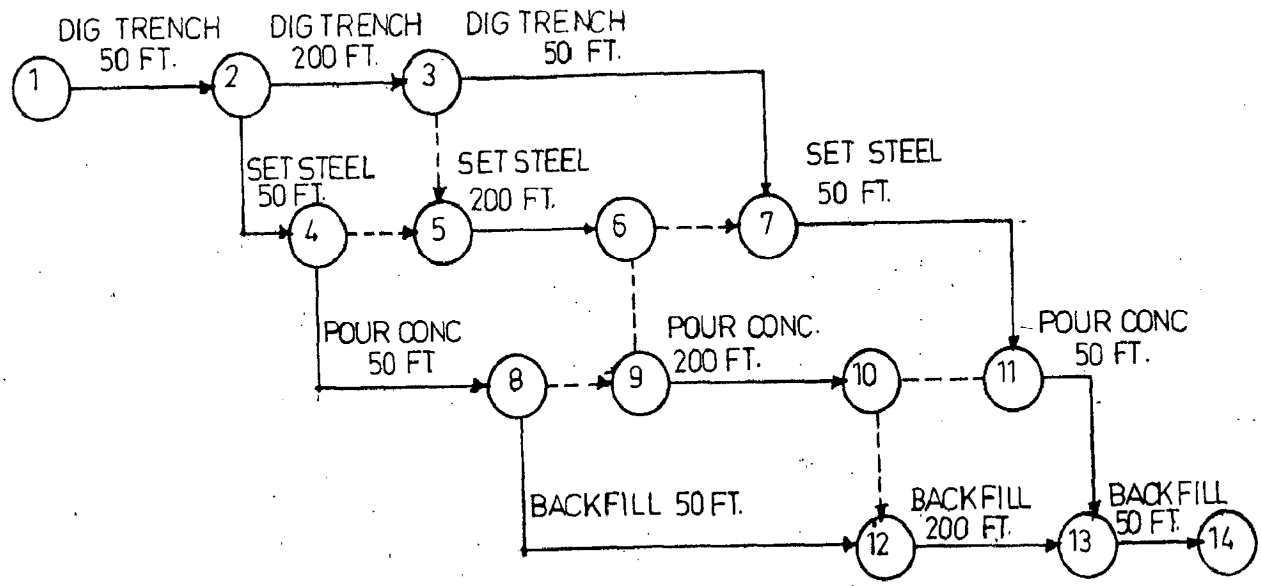
Due to the lack of lag relationships in CPM excessive dummies are to be used. This is illustrated in Fig.3 A, B and C. It is an example of casting foundations for a building. A simple diagram such as shown in 3A would not be a true representation of the situation, since it would be possible to start setting the steel before the trenching was complete, and the pouring of concreting could be started before the steel was set over the full 300 ft. A truer representation would be afforded by 3B, which showed that each job could start 50 ft. behind the previous one, and finish 50 ft. behind it. However, even the picture represented in 3B was unsatisfactory since it suggested the possibility of Backfilling 250 ft., having completed the trenching, steel setting and concrete pouring for only 50 ft. Therefore, yet more splits and dummies were required, and a final representation took the aspect of 3C. It can be seen, therefore, that although only four activities were involved, it took 19 arrows to depict fully their relationships with each other. The same network can be drawn in the precedence manner as shown in Fig.4 when compared with A-O-A network this has less number of nodes and arrows. So it is more compact. No dummies are used in this network. In A-O-A network there are 14 nodes and 19 arrows, where as in A-O-N there are 12 nodes and 14 arrows. So the same network becomes more compact in A-O-N.



(A) SIMPLE ARROW DIAGRAM FOR CASTING FOUNDATION



(B) EXTENDED ARROW DIAGRAM FOR CASTING FOUNDATION



(C) FULL ARROW DIAGRAM FOR CASTING FOUNDATION.

FIG 3 A, B, C

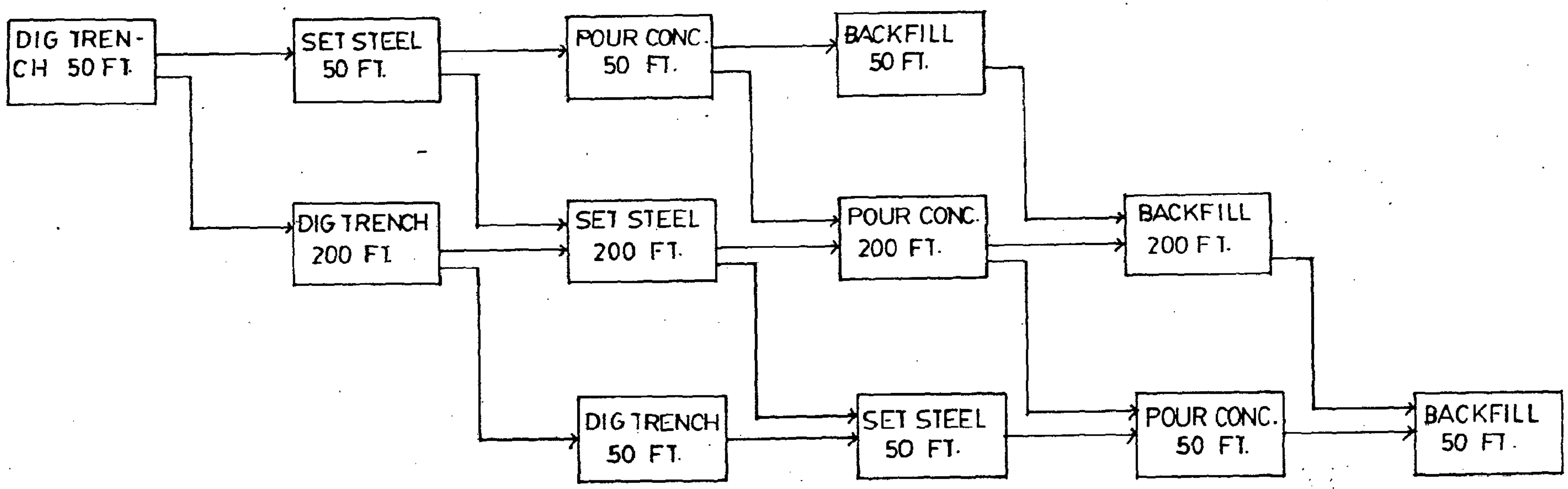


FIG. 4 PRECEDENCE NETWORK DIAGRAM FOR CASTING FOUNDATION.

2.2 CPM NETWORK PLANNING AND SCHEDULING

First step is preparing the list of activities and arranging it in a logical sequence. The next step is placing of 'duration' against each activity. It can be in any sort of units e.g. - minutes, hours, weeks, days etc., but for ease of calculations all duration should be in the same unit.

Early Occurence Time

Set the early occurence time (EOT) of the first node equal to zero. Consider each node by turn and compute the EOT of the node as follows : For each activity entering the node, add the activity duration to the EOT of the I-node of the activity. The maximum value obtained is the EOT of the node. Repeat until all the nodes are considered.

Latest Occurence Time

Set the latest occurence time (LOT) of the last node equal to its EOT. Proceeding backwards, consider each node by turn and establish its LOT as follows : For each activity leaving the node, subtract the activity duration from the LOT of the J-node of the activity. The minimum value obtained is the latest occurence time of the node. Repeat until all the nodes are considered.

Early and Latest Times

Set the Early Start Time (EST) for each activity equal to the EOT of the I-node of the activity. Compute the Early Finish Time (EFT) by adding the duration. Set the Latest finish time (LFT) of each activity as equal to the LOT of the J-node of the activity. Compute the Latest Start Time (LST) by subtracting the activities duration.

Float

The difference between early start and latest start is known as float and is the amount of time the event could be delayed without affecting the project's schedule completion date. The events of zero float will be seen to form a path through the network. This is critical path of the network and the activities along it are called critical activities. The sum of the critical activities gives the expected project completion date, and if any of these activities slip in time this completion date will slip unless time can be made up somewhere else along this path. Activities which are not critical, however can slip a certain amount without affecting the expected project completion date.

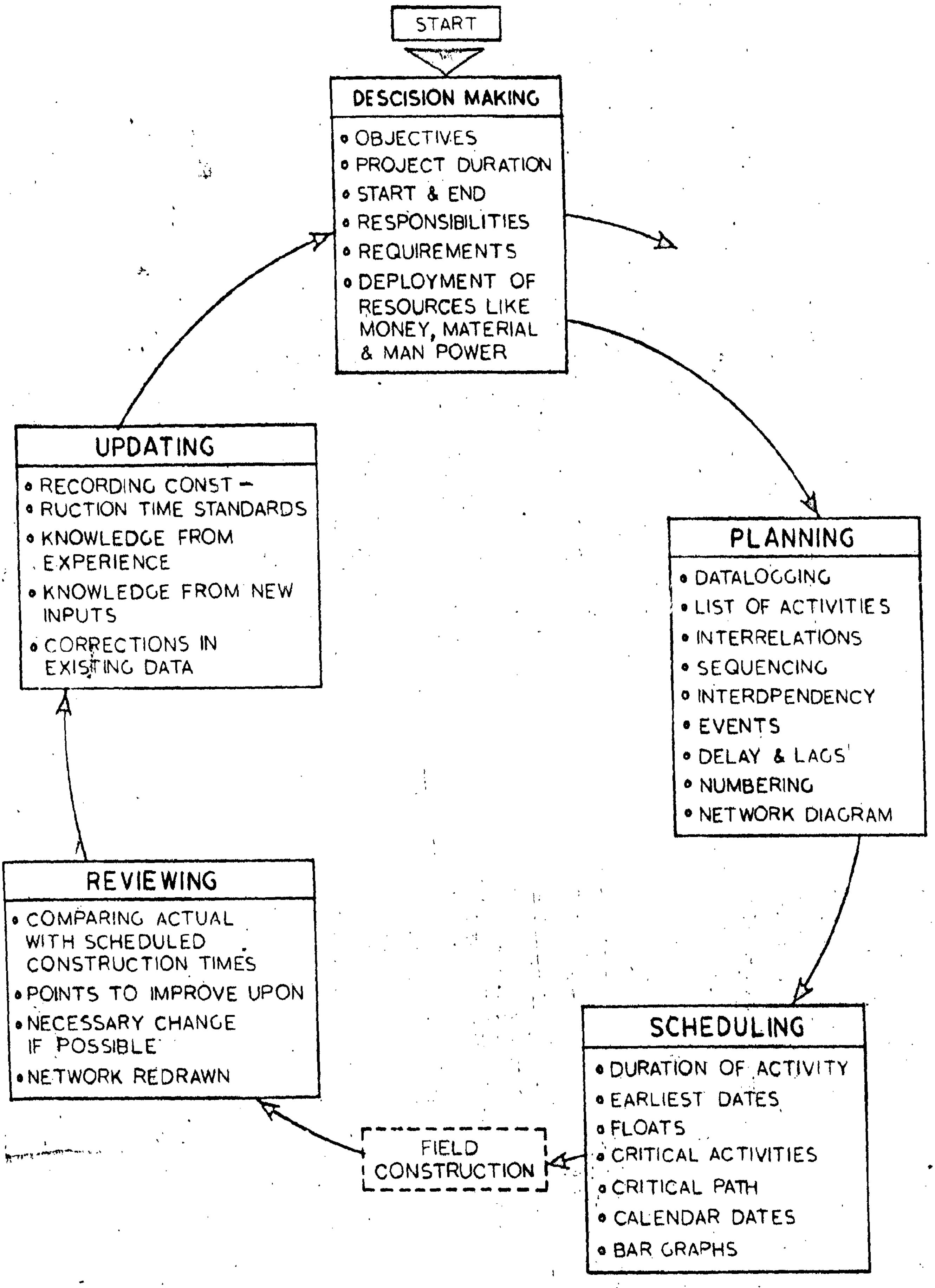
2.3 PRECEDENCE NETWORK PLANNING AND SCHEDULING

Programming of a project is a cyclic process of decision making, planning, scheduling, reviewing and updating. Fig.5 gives this diagramatic representation.

In the decision making stage, the project as such is defined and the objectives are laid down regarding the start, end, total duration requirements, responsibilities, manner of deployment of resources etc.

Next comes the planning, when the network diagram has to be drawn. To draw the network diagram is one of the important steps for programming but not an end and in itself. The network has to be drawn by previous experience of similar jobs or certain logical assumptions have to be made where we have no guiding facts. A lot of work has to be done for information collection and preparing the activity list and to fix their interrelationships and dependencies.

In the scheduling stage from the durations of activities fixed, the various starts, finished and floats are calculated. This enables very easy control of the total project.



(FIG.5.) PRECEDENCE NETWORK PROGRAMMING

The sch duled starts, finishes etc. are then tried best to adhere to during the atual construction process. Any variation of the actual time to the scheduled time is looked into and all information of the actual progress in construction are regularly maintained. The reviewing of these informations highlights the planner of the existing drawbacks in the network.

Feedback of this practical experience to the network makes the system dynamic and programming then becomes an overchanging process. Updating the network helps the future similar projects in planning their programme. No similar projects can exactly be the same. Again, with time, the nature of activities may change due to the overall technological change in available equipment and manpower.

Fig.6A and Fig.6B illustrates representation of activities in precedence network. The main advantage of this network diagram is the possibility of showing overlaps, delays etc.

Delay - is represented by the letter D (Fig. 6C).

Lead - The letter P on the link indicates a lead on the start of the preceding activity. Lead is indicated by drawing the link from midway along the preceding activity. In Fig.7A activity C may start 4 days after A is started; although activity B must wait for the final completion of activity A.

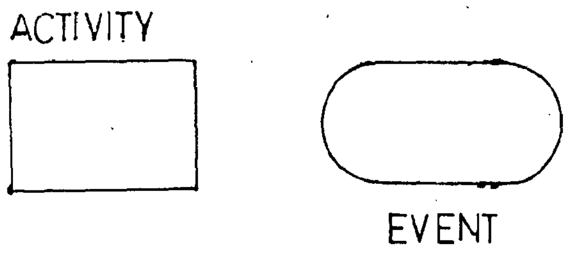


FIG-6A.PRECEDENCE METHOD - REPRESENTATION OF ACTIVITIES AND EVENTS

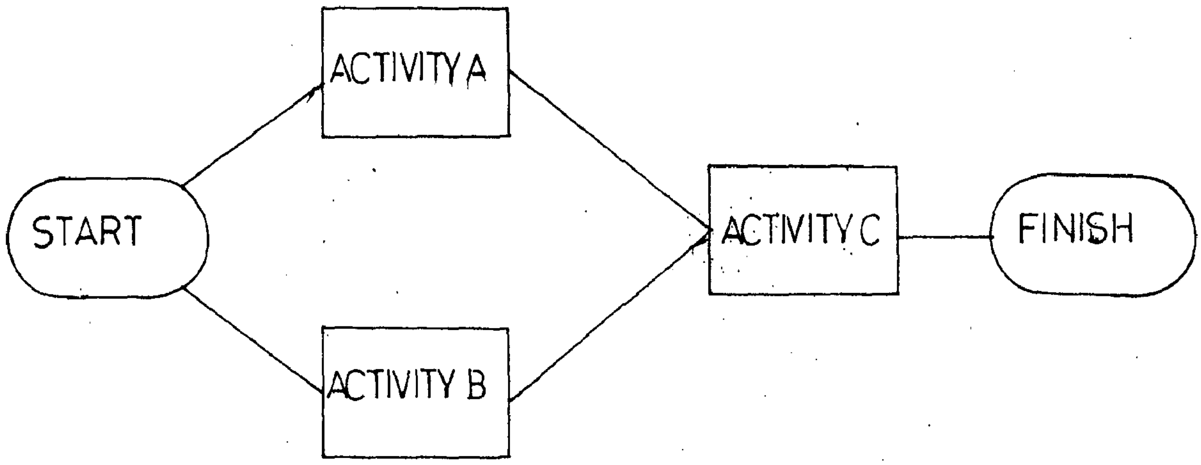


FIG.6B. SIMPLE PRECEDENCE NETWORK

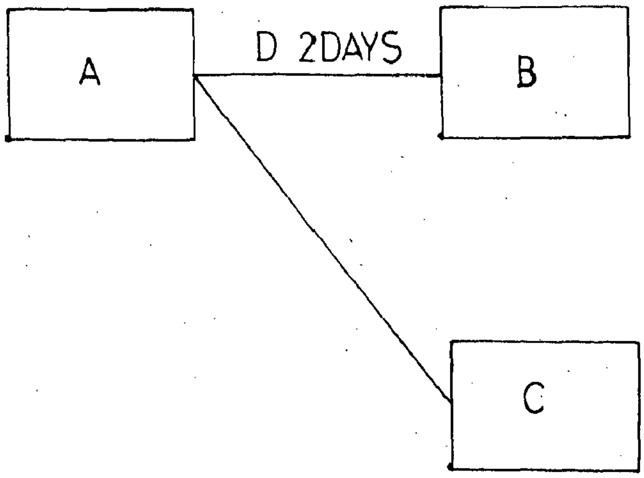


FIG.6C.REPRESENTATION OF DELAY

Lag - The letter F on the link indicates a lag on the finish of the following activity. As seen in Fig.7B a lag is indicated by drawing the link midway along the following activity. Activity D may start when activity C is complete, but will still have 4 days work left when activity A is completed.

Lead and lag on the same activities - In Fig.7C activity B may start when activity A is three days advanced, but will still have four days work left when activity A is completed.

Earliest, Latest and Scheduled Dates

There are four dates concerned with each activity i.e., earliest start, earliest finish, latest start and latest finish. The activity boxes are divided to incorporate these dates and further more to include scheduled and actual starts and finishes when the network is used for control purpose. Fig. 8 A, B.

Earliest Dates

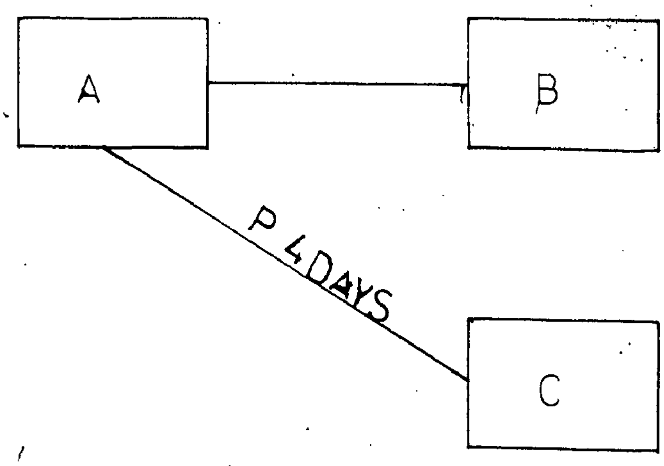
Fig. 9 A to 9J illustrates the calculation of earliest dates in different cases.

(A) Earliest start depending upon start

(B,C) Earliest start not depending on start.

(D) If there is a specified delay.

(E) When there are more than one preceding activity.



(FIG 7A) LEAD ON START OF PRECEDING ACTIVITY

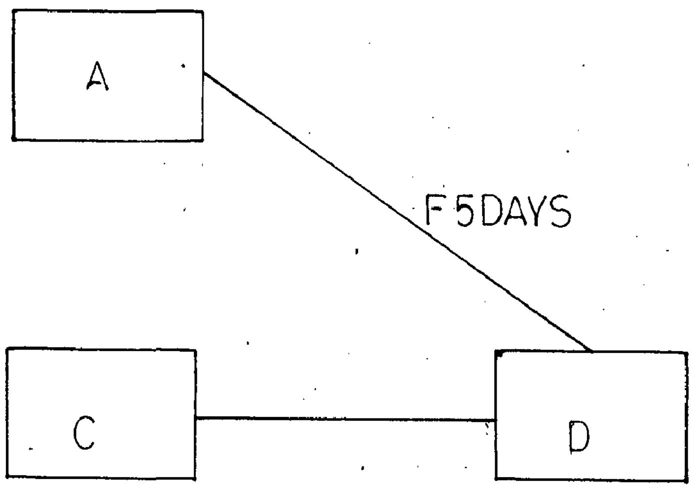


FIG 7B LAG ON FINISH OF FOLLOWING ACTIVITY

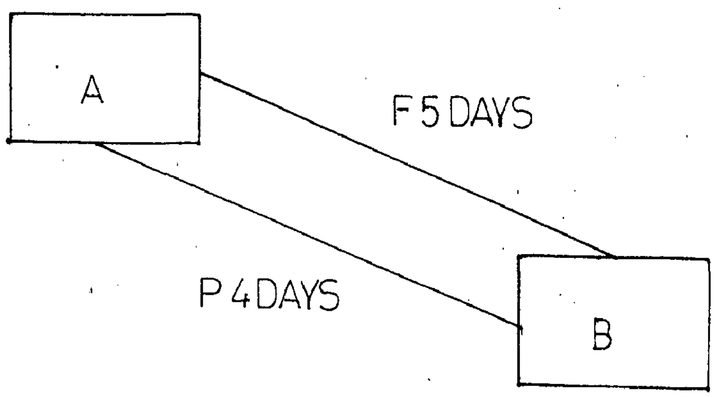
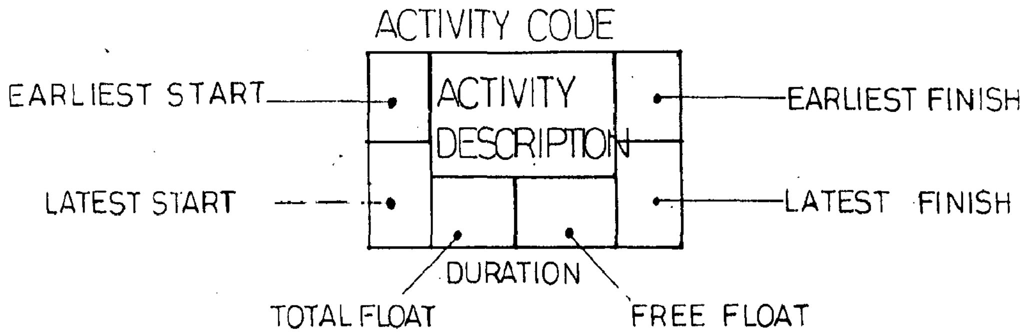
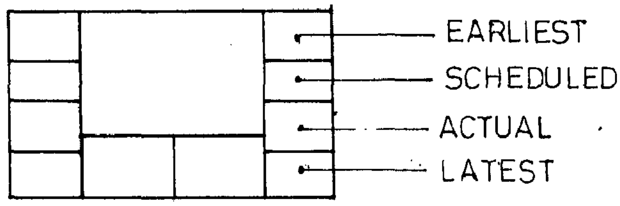


FIG 7C START AND FINISH LAG ON SAME ACTIVITIES

PRECEDENCE METHOD

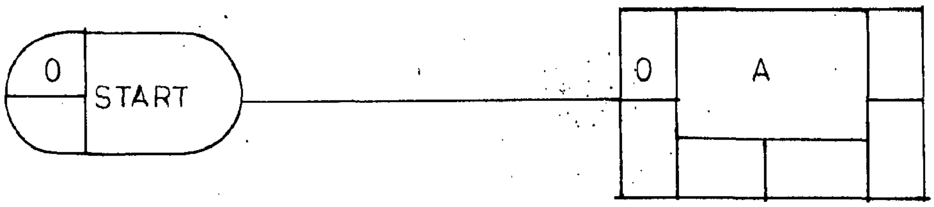


A. POSITIONS OF VARIOUS FACTORS IN ACTIVITY BOXES



B. EXTENSION OF FACTORS IN ACTIVITY BOX

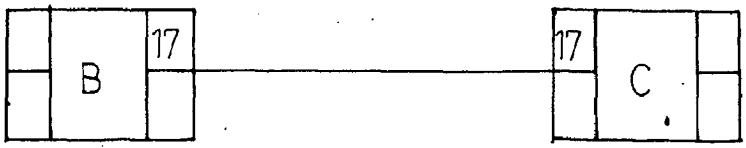
FIG. 8 PRECEDENCE METHOD SUBDIVISION OF ACT. BOXES



EARLIEST START OF A = START = 0

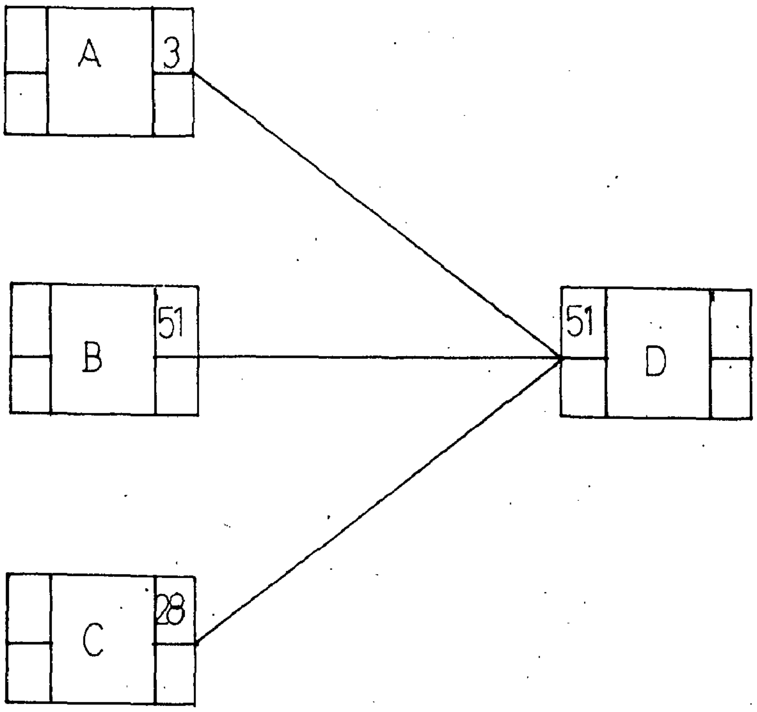
EARLIEST START DEPENDENT UPON PROJECT START

(FIG. 9 A) PRECEDENCE METHOD EARLIEST DATE SCHEDULING



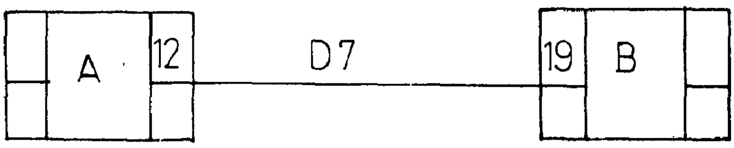
EARLIEST START OF C = EARLIEST FINISH OF B = 17

B. EARLIEST START (ONE PREDECESSOR)



EARLIEST START OF D = LATEST OF EARLIEST FINISH OF A, B OR C
= 51

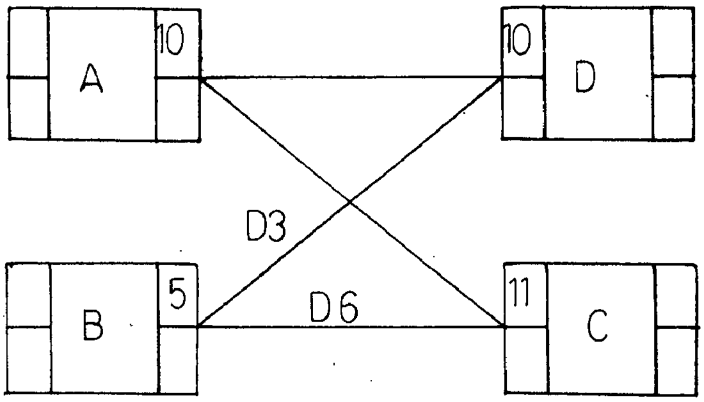
C. EARLIEST START (MULTIPLE PREDECESSORS)



EARLIEST START OF B = EARLIEST FINISH OF A + DELAY = 12+7 = 19

D. EARLIEST START INCLUDING DELAY

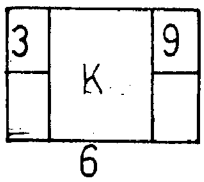
FIG. 9. PRECEDENCE METHOD – EARLIEST DATES SCHEDULING



EARLIEST START OF D = LATER OF EARLIEST FINISH OF A OR
EARLIEST FINISH OF B + DELAY = 10

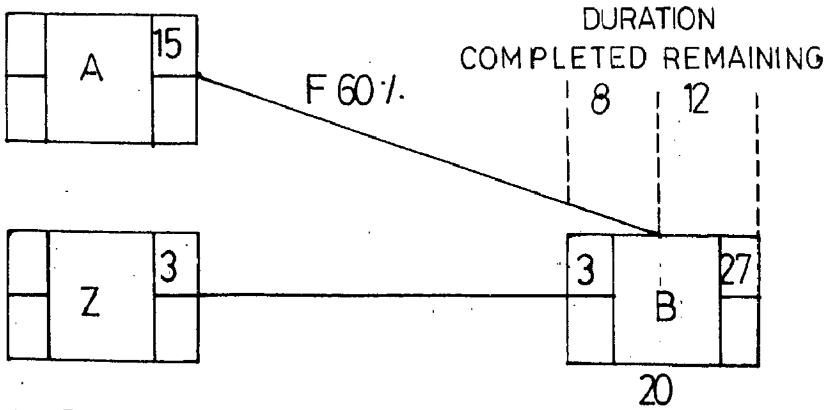
EARLIEST START OF C = LATER OF EARLIEST FINISH OF A OR
EARLIEST FINISH OF B + DELAY = 11

(E) EARLIEST START INCLUDING DELAYS



EARLIEST FINISH OF K = EARLIEST START + DURATION = 3+6 = 9

(F) EARLIEST FINISH

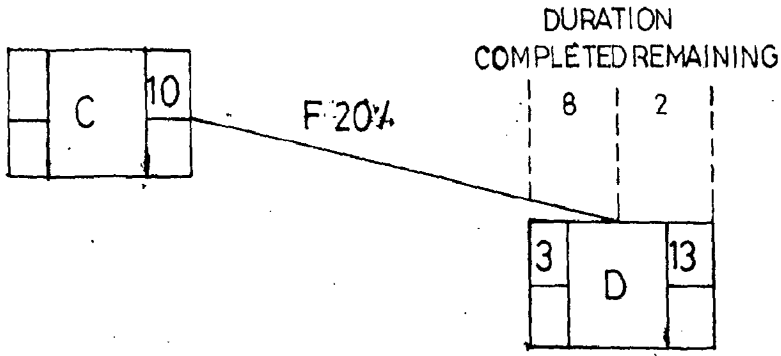


TIME AT LINKPOINT OF PARTIAL FINISH OF B = LATER OF EARLIEST START OF B + COMPLETED DURATION OR EARLIEST FINISH OF A i.e. 3+8 OR 15

EARLIEST FINISH OF B = LINK POINT + REMAINING DURATION i.e. 15+12 = 27

(G) EARLIEST FINISH AFTER F TYPE LINK

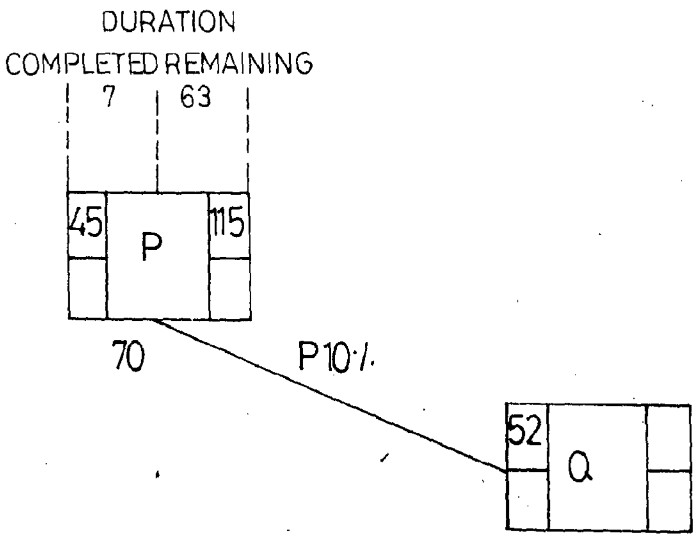
FIG. 9. PRECEDENCE METHOD EARLIEST DATES SCHEDULING



TIME AT LINKPOINT OF PARTIAL FINISH OF D = LATER OF EARLIEST START OF D + COMPLETED DURATION OR EARLIEST FINISH OF C ie, 3+8 OR 10
= 11

EARLIEST FINISH = LINKPOINT + REMAINING DURATION = 11 + 2 = 13

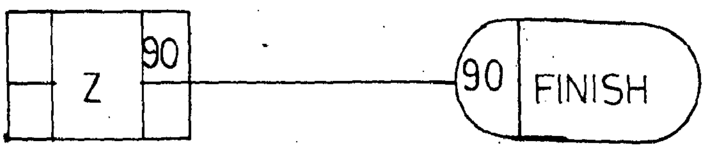
(H) EARLIEST FINISH AFTER F TYPE LINK



TIME AT LINKPOINT OF PARTIAL START OF P = EARLIEST START OF P + COMPLETED DURATION ie, 45+7 = 52

EARLIEST START OF Q = 52

(I) EARLIEST START P TYPE DEPENDENCY



(J) PROJECT FINISH DEPENDENT ON EARLIEST FINISH

FIG. 9. PRECEDENCE METHOD EARLIEST DATES SCHEDULING

(F) Earliest finish calculation.

(G,H) When there is an F type lag.

(I) When there is a P type lage.

(J) Latest finish calculation.

Latest dates

Fig.10A to 10F illustrates the calculation of latest dates in different cases.

(A) Latest finish of last node will be the finish of the project.

(B) Calculation of latest finish from the latest starts of its successors.

(C) Latest start calculation

(D) When there is a delay.

(E) When F type lag is there.

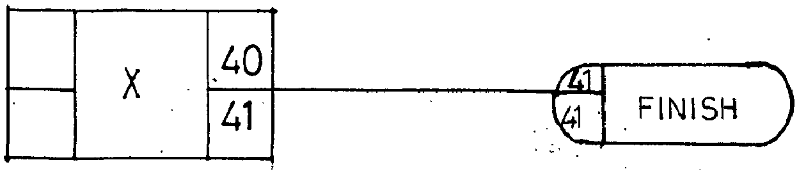
(F) When P type lag is there.

Activity Floats

This is the difference between the earliest and latest dates and is defined as the time available over and above the time, required for the performance of that activity.

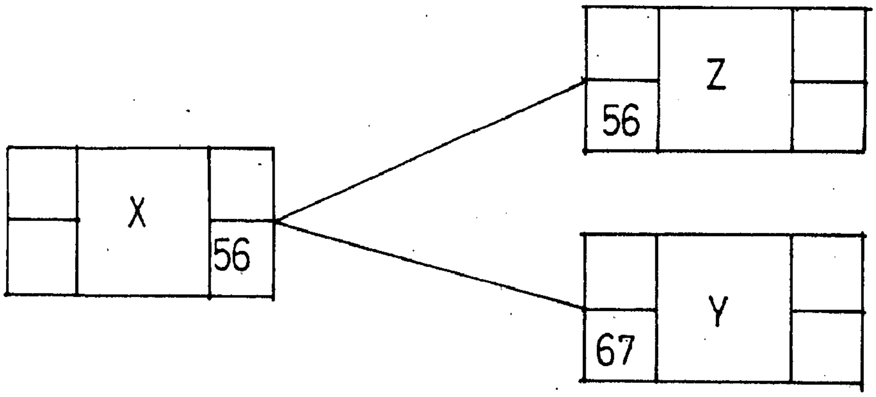
Total Float

It is the time by which an activity may be delayed without affecting the final completion date of the project. The calculation is given as follows



LATEST FINISH OF X = FINISH = 41

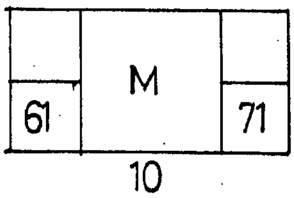
(A) LATEST FINISH DEPENDENT ON PROJECT DURATION



LATEST FINISH OF X = EARLIER OF LATEST START OF Z OR Y

i.e; 56 OR 67 = 56

(B) LATEST FINISH DEPENDENT ON SUCCEEDING ACTIVITIES

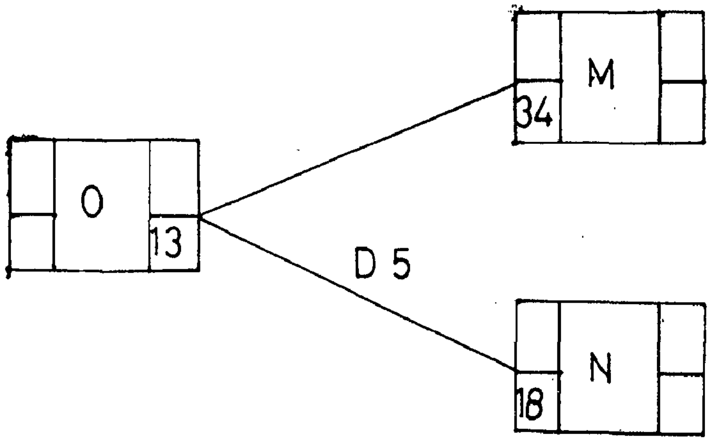


LATEST START OF M = LATEST FINISH – DURATION

= 71 – 10 = 61

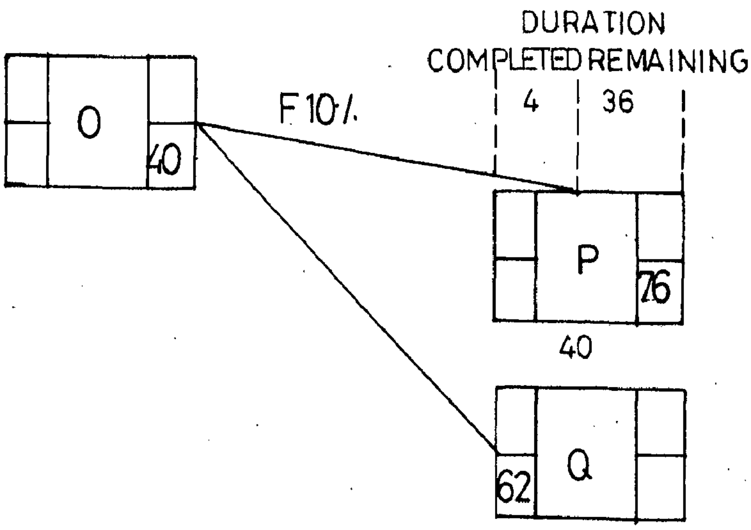
(C) LATEST START

FIG 10 PRECEDENCE METHOD LATEST DATES SCHEDULING



LATEST FINISH OF O EARLIER OF LATEST START OF M OR LATEST START OF N – DELAY = 34 OR 18 – 5 = 13

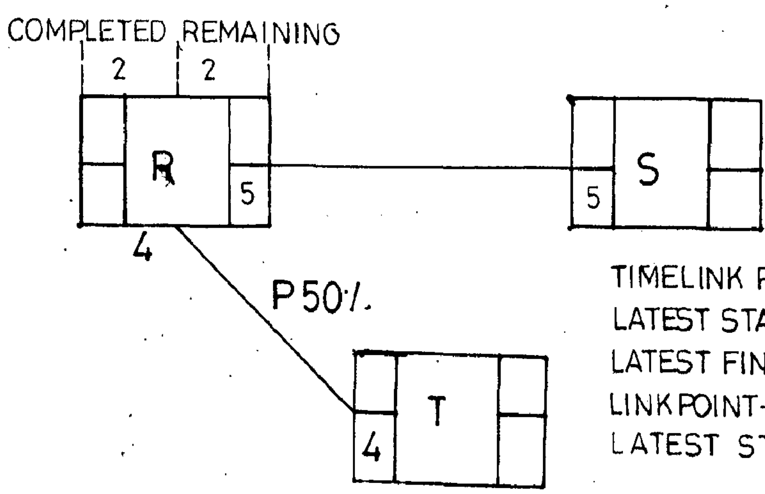
(D) LATEST FINISH (DELAYS)



TIME LINKPOINT OF PARTIAL FINISH P = LATEST FINISH OF P — REMAINING DURATION i.e; 76 – 36 = 40

LATEST FINISH OF O = EARLIER OF LINKPOINT OF P OR LATEST START OF Q = 40 OR 62 = 40

(E) LATEST FINISH F TYPE LINK



TIMELINK POINT OF PARTIAL START OF R = LATEST START OF T = 4

LATEST FINISH OF R = EARLIER OF LINKPOINT + REMAINING DURATION OR LATEST START OF S = 4 + 2 OR 5 = 5

(F) LATEST FINISH P TYPE LINK

FIG.10 PRECEDENCE METHOD LATEST DATES SCHEDULING

Total float = Latest finish time - Early finish time.
= Latest start time - Early start time.

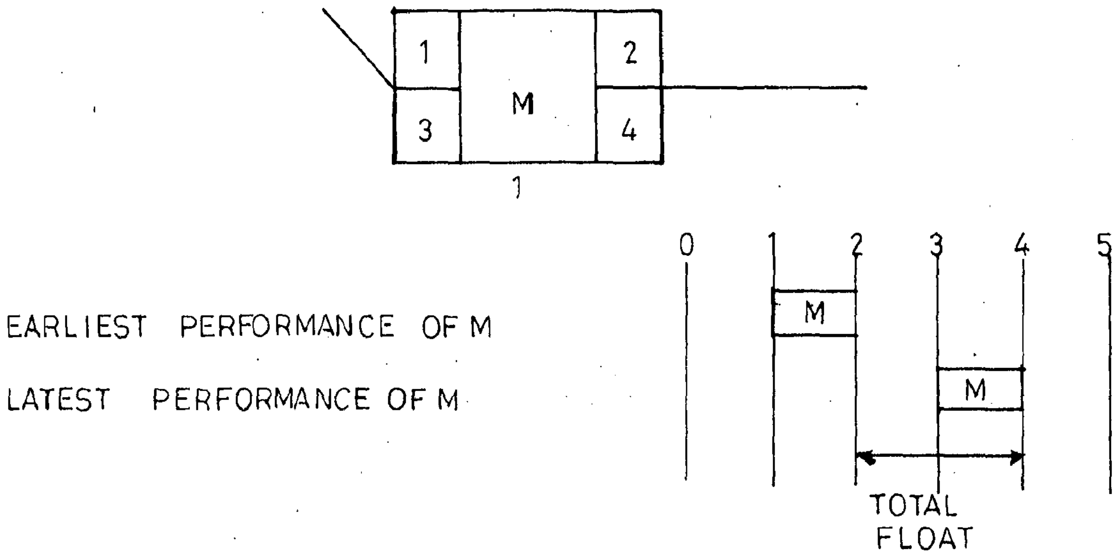
(Fig. 11A)

Free Float

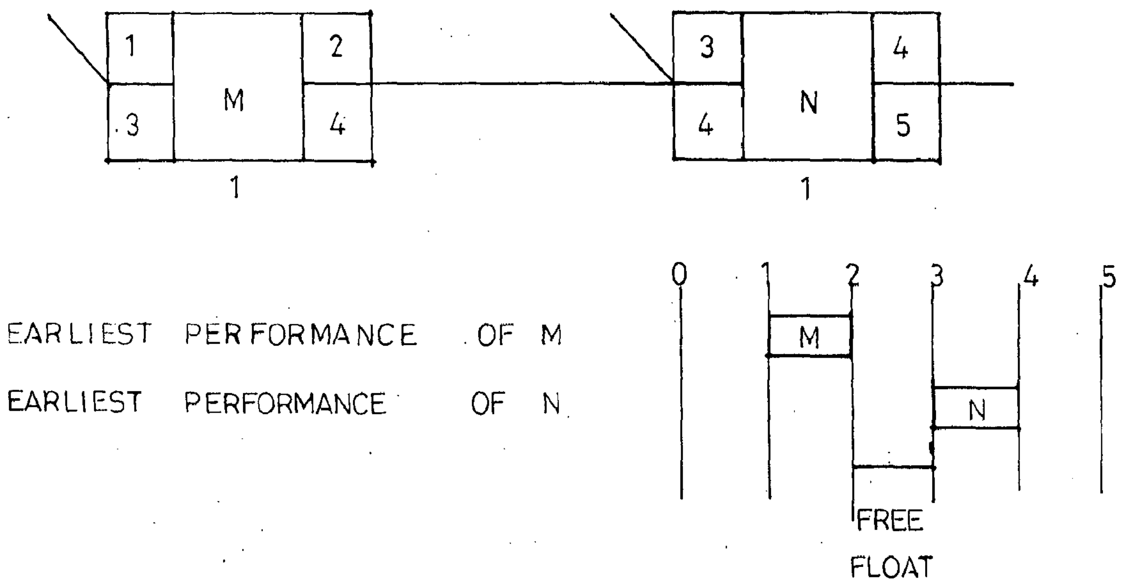
It is the time by which an activity may be delayed without affecting any other activity. The calculation is as follows.

Free Float = Early start time of the following activity - Early finish time of the activity in question.

(Fig.11B)



(A) ILLUSTRATION OF TOTAL FLOAT.



(B) ILLUSTRATION OF FREE FLOAT

FIG.11. PRECEDENCE METHOD – ACTIVITY FLOATS

CHAPTER-3

CONCEPT OF PROJECT SCHEDULING AND MONITORING

3.1 BASIC ISSUES IN SCHEDULING(9)

The process of project scheduling needs to come out with satisfactory answers on the following issues;

(1) Objective related issues

(2) Work related issues

(3) Activity and sequence related issues

(4) Time related issues

(5) Resource and constraint related issues.

3.1.1 Conceptual Model

Fig.11C presents a conceptual model interlinking the different issues. Since all the issues are arising out of the need for doing a work, the starting point for project scheduling process is WORK. The process is required to achieve certain objective. The end point of project scheduling is therefore OBJECTIVE. The project schedule model should, therefore, start with work and finally end up in objective.

Activity and sequence related issues are important only after the work is known, because each and every piece of work for its execution requires certain actions to be taken in some sequence. The linkage between WORK and

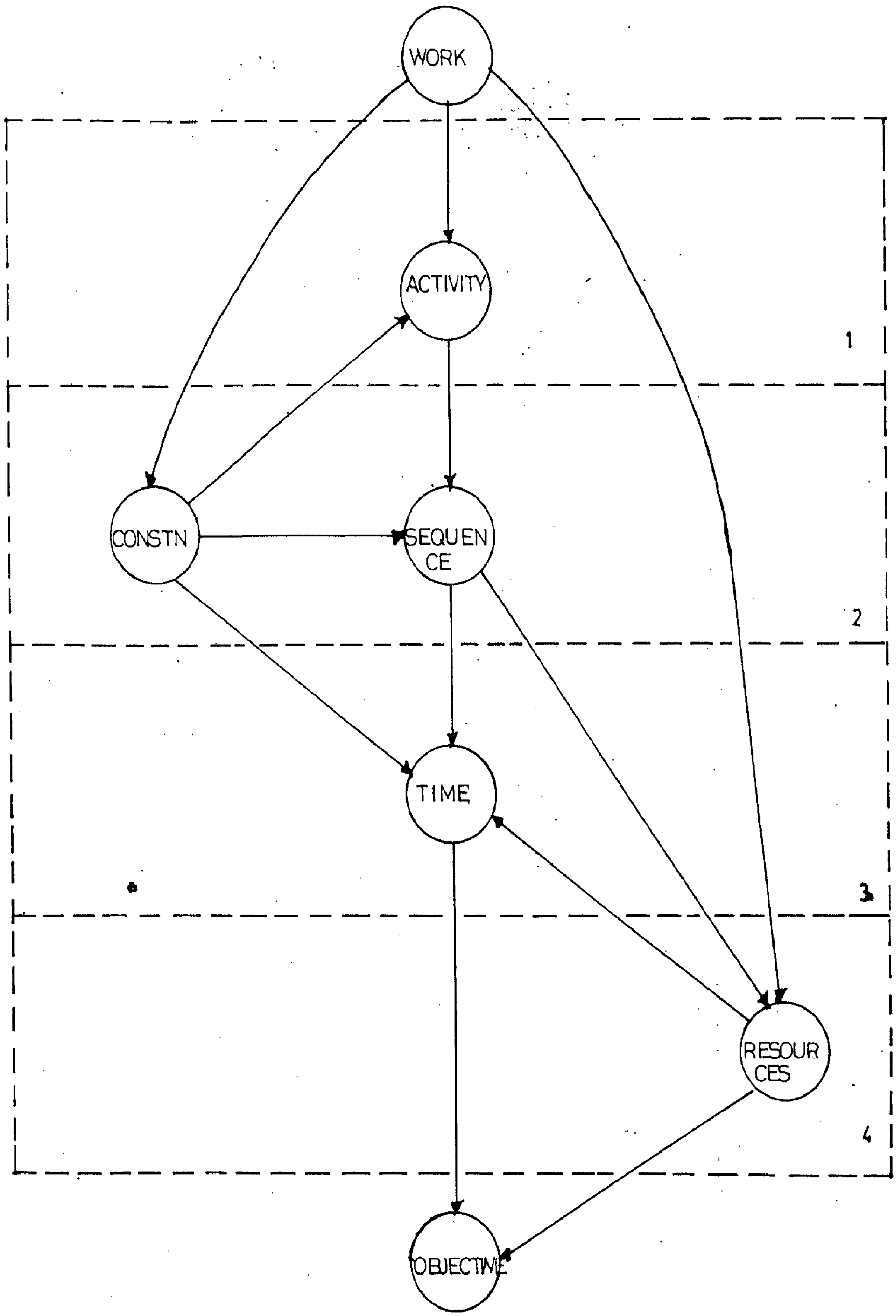


FIG.11C.PROJECT SCHEDULING CONCEPTUAL MODEL activity is therefore direct with work leading to Activity. Now we can take several actions, or we could follow different sequences for doing the same work, thus an element of choice is involved between these directly related issues.

The type of activity or the sequence chosen will again have its impact on Time and Resource required for doing the work. Better the activity or sequence, lesser may be the time and resource requirement.

Time and Resource again will depend on work, more the work, more will be the requirement of Time and Resource. But while with Resource the relationship is absolutely direct, i.e., more resource for more work. The Time required for a piece of work will depend more on Activity, Sequence, Resource and Constraints than on the quantity of work. Time, therefore, has been linked with work through Activity, Sequence, Resource and Constraints. The relationship between Time and Resource is again direct; Resource will govern the time required for completion of any work. Finally resource and time can be traded off between each other and both will govern the objective. The objective, therefore, has been jointly linked with Time and Resource.

The whole process of project scheduling, therefore, demands consideration of a number of combinations of Activity, Sequence, Resource, and Time for any piece of work in relation to defined objective and constraints.

3.2 PROJECT MONITORING (9)

The aim of monitoring is to bring about some real and positive action.

Steps in Monitoring

3.2.1 Setting the environment

This includes appointment of monitor, delegation of authority, announcing the objective of monitoring, seeking cooperation and acceptance from the participating agencies whose activities are being monitored, setting systems and procedures for monitoring and obtaining commitment of participating agencies in the same.

3.2.2 Setting Performance Standards

This is supposed to be done in the schdduling phase. However if the agencies for scheduling and monitoring are different, the schedule will require a second examination. In any case, since performance standard or target is the basis for monitoring, the monitoring process must ensure that schedule exist, and they exist in a monitorable form; i.e., performance requirement has been clearly stipulated. If performance requirement is not clear or is not in a monitorable form, the monitoring process will insist that the schedule be restructured so as to contain the targets for performance which are required to be monitored. In short, at the outset, monitor must know 'what is to be done' and so should all.

3.2.3 Measuring

This may involve collecting information regarding 'what was done', quantifying the same comparing with targets, and working out the quantum of favourable variations.

3.2.4 Reviewing

This will involve holding meetings or carrying out detailed studies with a view to work out 'what needs to be done?'. It is expected that solutions that do not involve additional expenditure or other agencies will be straightaway implemented. The review may result in a recommendation for further study involving several agencies or specialists.

3.2.5 Reporting

This will include reporting to 'what has to do' obviously unresolved issues which need to be tackled by a different responsibility centre need to be reported to the appropriate repponsibility centre. The emphasis is on exception, and only structured report, clearly specifying the involvement desired, needs to be sent to the appropriate responsibility centre.

3.2.6 Action

This involves taking decisions with regard to the steps needed to make good deviation and asking the defaulting agencies to implement the decisions.

3.2.7 Scope of Monitoring

Monitoring starts with the schedule and works for the success of schedule i.e., its implementation and effectiveness. There can neither be any monitoring without schedule, nor any schedule be even worth its paper without monitoring support. But while scheduling is basically a paper work, monitoring is not. It can be defined as the process of inducing action for adherence to schedule.

3.3 PROJECT CONTROL[9]

Project control system is a congregation of the following terms - Planning, scheduling, monitoring, resources, constraints, updating, objective, data bank, control implementation and progress report. If these terms are linked, it will represent a project control system (Fig.11D).

3.3.1 Objective

The starting and end points of the diagram should meet at the objective. Since all activities, like scheduling and monitoring are undertaken only to achieve some objective and there is no need of further activity, once the objective is achieved.

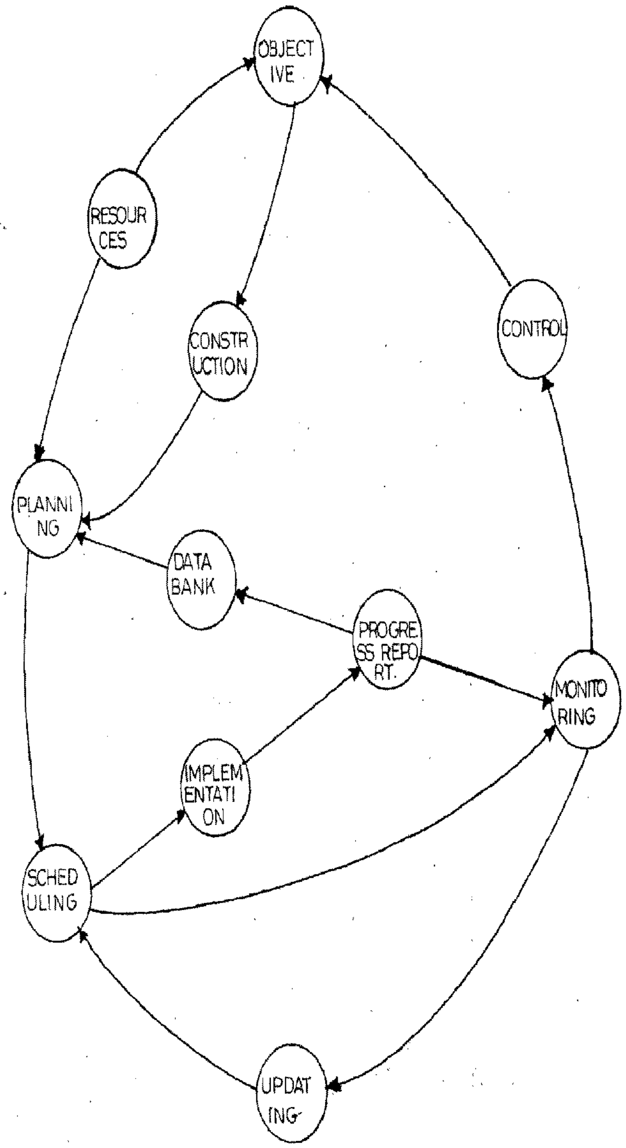


FIG. 11D PROJECT CONTROL SYSTEM

3.3.2 Planning

Once the objective is defined, the next step is to determine how the same can be achieved. It would be subject to limitations of resources and constraints. So planning can be linked to objective through resources and constraints. Objective will dictate the resources such as money, manpower, etc.that may be required, but constraints will stipulate their availability. Resources and constraints are therefore simultaneous considerations needed to arrive at a plan and are shown parallel to the diagram.

3.3.3 Scheduling

Scheduling is applied planning. There cannot be any schedule without planning, nor a plan can be made workable without a schedule. Implementation can take off once scheduling is finalised and necessary organisation for implementation of schedule is created. During the scheduling phase the different times are calculated as early start time, early finish time, latest start time, latest finish time and total float. The early start time gives the earliest time by which an activity can be started. Early finish time is that by which an activity can be finished at the earliest. Like that the latest times are that by which an activity should be started or finished at the latest. The difference between the early and latest times gives the float. The activities through zero float are called critical activities. By finding out the different timings and float, decision can be taken that which activities can be relaxed and which activities are to be done in time etc.

3.3.4 Monitoring

Monitoring depends upon scheduling. Also scheduling depends upon monitoring, for keeping it uptodate. In the monitoring stage, the actual work should be compared with the target. This can be produced by progress reports. If there are some delays and changes it should be incorporated to the basic network. Monitoring is done through updating.

3.3.5 Updating

Updating refers to incorporation of progress information/ actual occurence of events on the part of the schedule that should have been implemented uptodate. It also includes incorporation of new decisions/information on the part of the schedule yet to be started. Updating effects the schedule. It adds activities, deletes, changes duration. In short it changes schedule itself. But this can be possible only as a result of measurement and réview.

The most effective updating is done by computer analysis. The updated information is usually furnished in the form of computer printouts in a variety of arrangements. The following are the inputs and outputs of an updated schedule :-

Input

A. (1) Actual starting date/time of activities already started - Some activities may be started in the correct time and some may be delayed.

(2) Actual starting date/time of activities already finished - In the completed activities also there may be changes in the starting time.

(3) Actual duration of activities already finished - Due to the lack of materials and labourers some activities may change the duration. Also to speed up the activities the duration can be reduced by adopting more labourers.

(4) Addition of activities - After the construction starts, there may be some additions to the activities.

(5) Deletion of activities - Sometimes some activities are to be deleted due to some reasons.

(6) Modified interdependencies - The dependency between some activities may be modified due to the addition, deletion or change of duration.

(7) Revised duration of remaining acfivities - The duration of remaining activities may also be revised.

(8) Revised and modified arrow diagram - According to the changes the network diagram is to be revised.

(9) Actual resource and cash requirement of remaining activities - After the modifications the resource and cash requirements of remaining activities can be found out.

Output

B. (1) Revised arrow diagram.

(2) Time status of the project - It gives the schedule of the project. This contains the different timings, floats etc.

(3) Cost status of the project - The cost status of the project is brought out.

(4) Resource Status - This gives the resource status of the project, like whether the resources are sufficient, insufficient or surplus.

(5) Systematic recording of datas available for any future use - It stores the datas and schedules of each stage so that it will be useful in future.

(6) Revised starting and finishing dates for remaining activities - The revised schedule of the project is obtained, which contains the different timings, floats etc.

(7) Revised cash requirements - According to the revised schedule, it gives the revised cash requirements of each activities.

(8) Revised resource requirements - This gives the revised resource requirements.

3.3.6 Progress Report

Monitoring is linked with implementation through a feedback report which may be called a progress report. It is a record of the status of the activities under implementation. It originated from implementation and connects implementation and monitoring.

Since progress report provides actual performance data, it is also used for correcting various assumptions, made at the planning stage. The data provided by progress report can also be stored in the form of a data bank for planning future projects. Progress report has, therefore, on the one side been connected with the planning through data bank and on the other with monitoring.

3.3.7 Control

Monitoring must lead to action to ensure adherence to target. When as a result of monitoring an operation adjusts itself to predetermined standard, the operation is said to be under control. Control is the presence of force which ensures adherence to predetermined standards through actions. Monitoring being action oriented, it supplements and leads to control. So monitoring has been linked directly with control. Since control should lead to achievement of objective, control has been directly linked with objectives to complete the total picture.

CHAPTER-4

COMPUTERISED CONSTRUCTION MANAGEMENT

4.1 INTRODUCTION

In the construction management, because of the increased size and complexity of the projects it is beneficial to use computer. The sophisticated informations and data handling capabilities of an electronic computer offer many helpful ways, for in depth analysis of major areas of construction management. The construction manager, with the aid of computer can keep the pace with today's vastly accelerated construction technology.

4.2 COMPUTER APPLICATION IN CPM

There are three phases for any project, namely - the planning phase, the scheduling phase and the control monitor phase.

The computer is being used in all the three phases efficiently. Some of the computer programs have been developed at Civil Engineering Department, University of Roorkee. Some of the programs which are available have been briefly outlined in the following lines.

4.3 PLANNING PHASE OF CPM BY COMPUTER

Some computer programs are available for the planning. In 1964, IBM introduced their project control system (PCS) and established precedence diagramming for computerisation which was also similar to CPM and PERT. One of the most comprehensive network programs is the Mc Donnell Automatic MSCS, which has many additional capabilities such as cost control, resource control, and special output formats such as bar graphs.

But the efficiency of these programs is doubtful because of obvious reasons. Hence it is preferable to do planning manually in most of the cases.

4.4 SCHEDULING PHASE OF CPM BY COMPUTER USE

Scheduling consists of assigning an estimated start and finish time to each ativity in a project. A certain amount of flexibility or float may exist for some activities, others called critical, must be completed as per schedule, if the project as a whole is not to be delayed.

The different facets of scheduling phase are listed below :-

1. CPM time scheduling.
2. Scheduling of network with random node numbers.

3. CPM Calendar dating.
4. Resource allocation and levelling.
5. Cash requirement prediction.
6. Requirement of material and labour.

The programs have been developed for all the above facets at Civil Engineering Department, University of Roorkee, Roorkee.

4.4.1 CPM Time Scheduling :

A computer program has been developed for this job by Viswanath (1975) and presented elsewhere (Puri and Viswanath, 1984). For details of program refer Chapter 5.

4.4.2 Random Node Numbering

In general the network should have two restrictions :

(1) The I-node number of an activity should always be lesser than its J-node number,

(2) The nodes of the network should be numbered in sequential order and no node number should be missed.

With the help of this computer program, the network having random node numbers can be converted into topological order, temporarily. By doing conversion the network with random node numbers can easily be scheduled.

The program reads the number of the networks to be handled, the total number of activities, total number of nodes, and the activities data etc.

The output consists of the total random nodd numbers, the total number of activities leaving each node and their **serial numbers,** total number of activities entering in each individual node, the new topological node numbers.

The program has built in check for errors like dangling, missing nodes, incomplete list of activities, identical node numbers etc. The block diagram is shown in Fig.12A and details are available elsewhere (Mehra. S., 1975).

4.4.3 CPM Calender Dating

This program is used to convert the working days schedule into a calender dated schedule.

Input data consists of the number of activities, the date, month, year and week days, the project start date, the list of holidays, number of days in a month for each month of the year etc.

Output - The holidays are converted into corresponding calender day intervals, measured from the project start date. EST, EFT, LST, LFT are taken by turn and the computer directly assigns the date, month and year numbers. After taking into

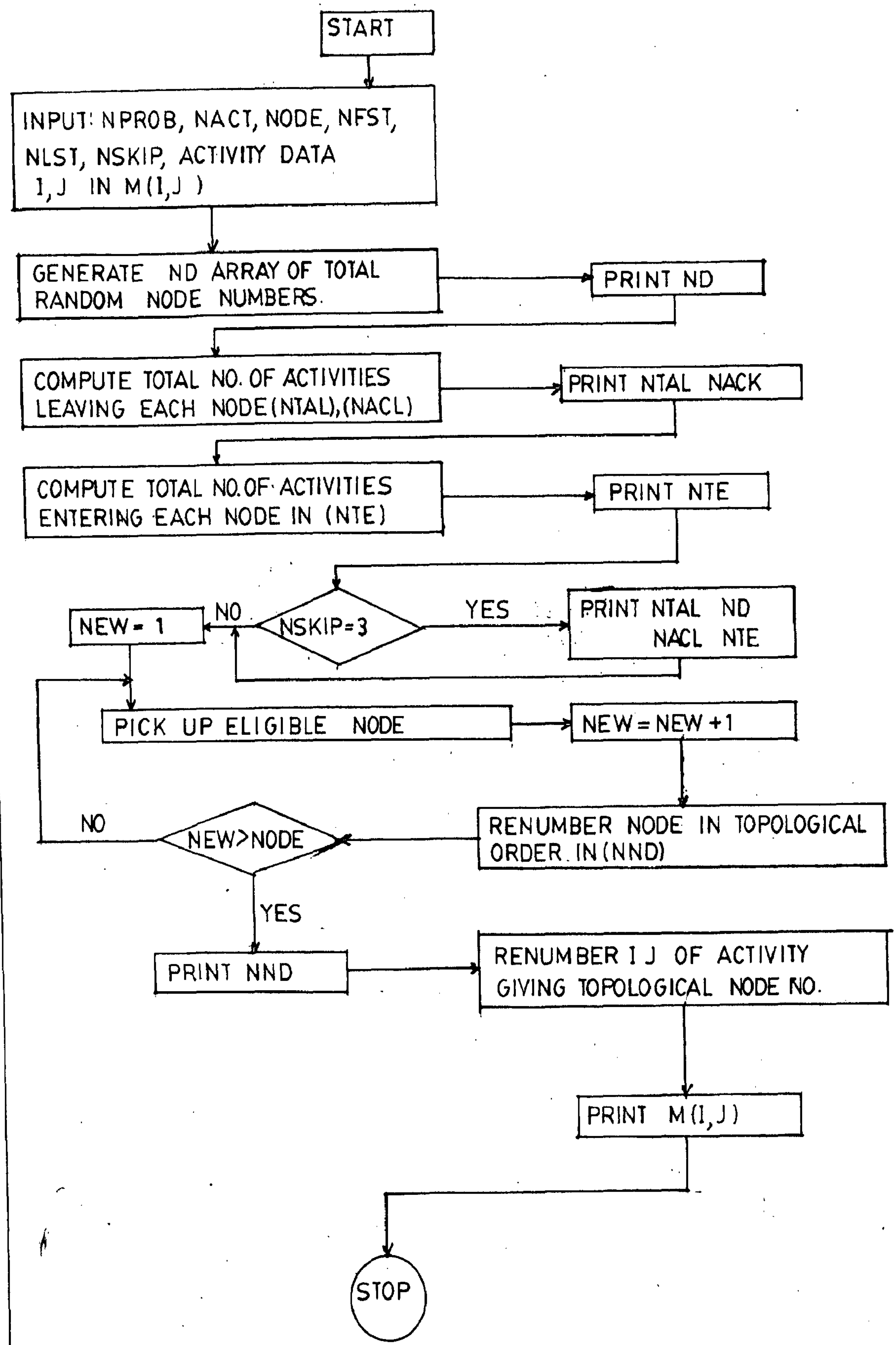


FIG. 12 A. MASTER DIAGRAM OF PROGRAM 'RANDOM'

account the holidays the program proceeds to compute the number of sundays in the interval. Once all holidays and sundays are accounted for the expanded interval is added to project start date. The final date, month and year numbers are sorted unless CPM calender dating is completed for one activity. After that they are printed in proper format. The process is repeated for every activity. The block diagram is shown in Fig.12B and details are available elsewhere Viswanath G, 1975).

4.4.4 Resource Levelling

The object is to 'level' the day to day, week to week, usage of resource, which may be the manpower or equipments within the current availability of these resources.

Input - This program reads the results of the CPM Scheduling program and the data regarding the number of resources to be considered, the availabilities of the different resources, the resource requirements of each activity and the number of resource levels to be considered.

Output - It includes the list of activities, their duration, their resource requirements and their revised start and completion dates. Also printed out are the latest start times of the CPM schedule for comparison. The output includes the total resources assigned for each day of the project, and for each resource.

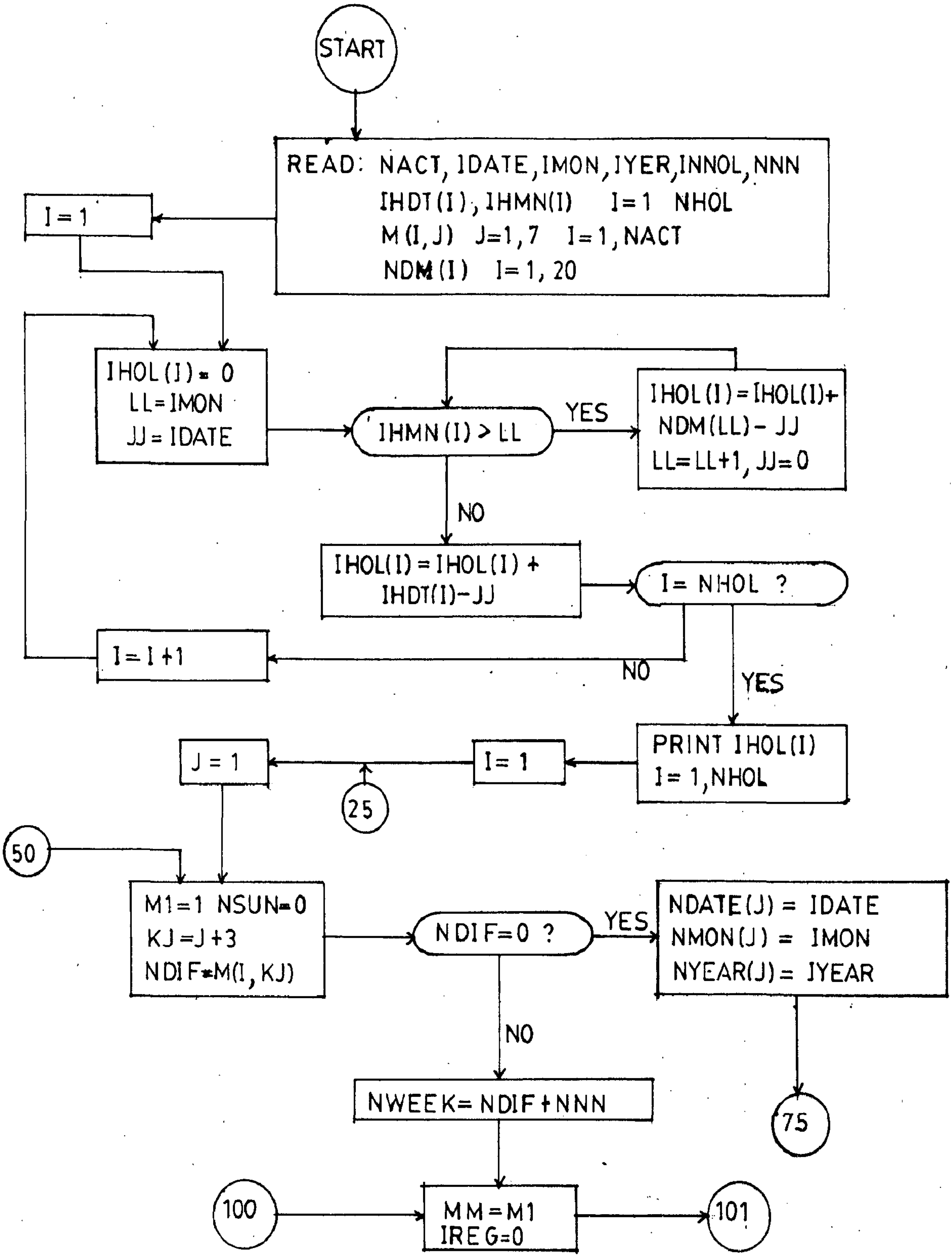


FIG.12 B. FLOW CHART FOR CALENDER DATING

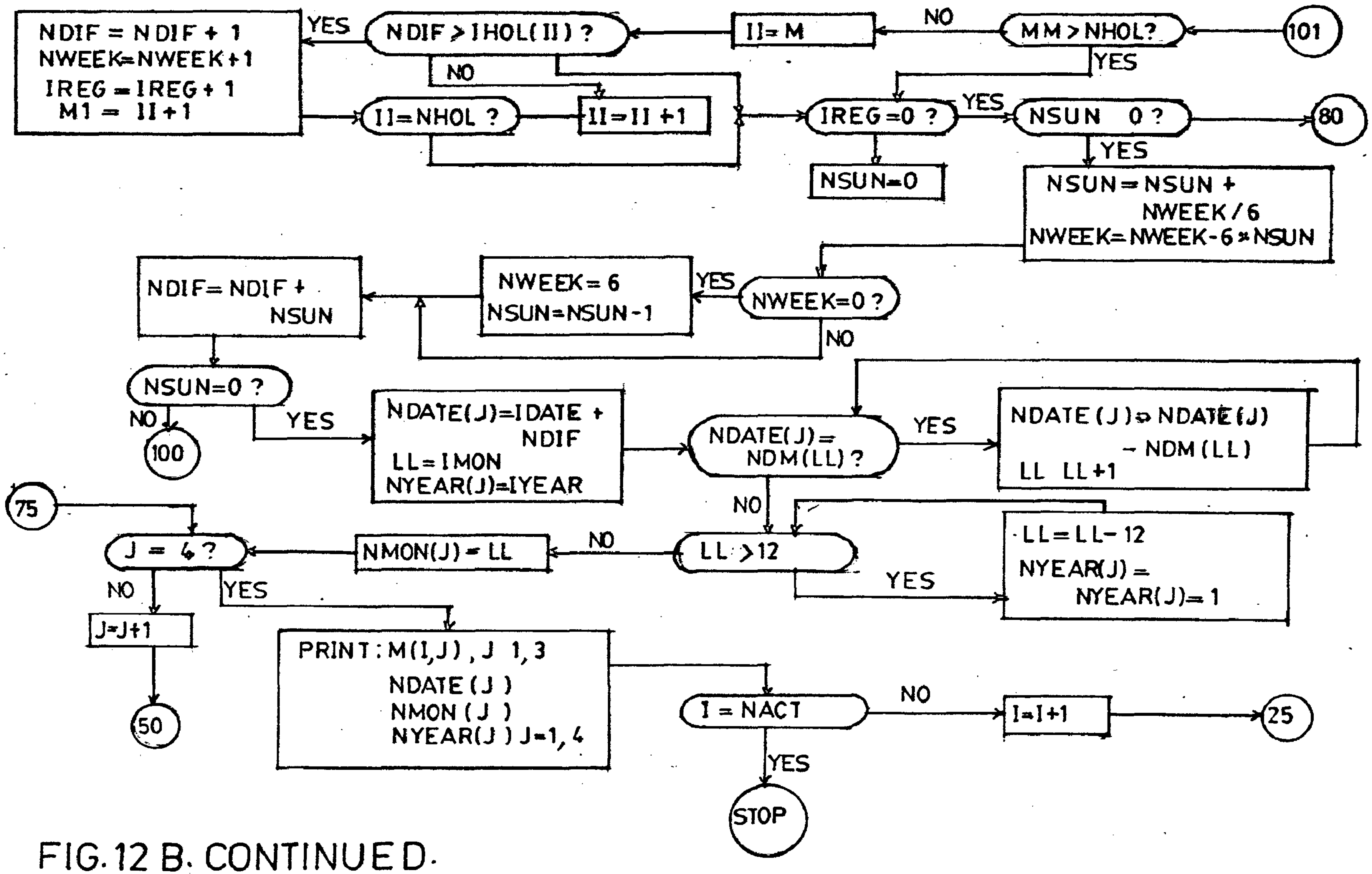


FIG. 12 B. CONTINUED.

It also checks each node and ensures that all activities entering it have been completed on the day under consideration. The activities leaving the nodes are also examined if they have not already started. The activities are re-arranged in priority order on the basis of criticality of the activity. The resources are allocated on this basis. In case some resource is not available, the resource and effected activity are reported.

The details of this program are available elsewhere (Puri and Viswanath, 1984, Viswanath, 1975).

4.4.5 Cash and Material Requirement Predictions

This program predicts how much cash and material is needed in each week of the project duration.

Input

This program take network schedule as input data. It also meads total number of nodes, total number of activities, total duration of project,total number of categories involved in different activities, their quantitites, rates of each categories, EOT etc.

Output

As output it prints out total estimated cost rate and quantity of each activity, finished activity, unfinished activity and cost of finished work in the current week category wise. It also prints out the percentage of work finished, and total upto date payments and net cost status of whole project.

The program computes the total estimated cost of each category. It also computes the weekly cost status, finds out the eligible nodes in active week, computes the quantities and respective amounts involved in activity. It also computes the total accumulated expenditure and total current week expenditure.

The details of this program are available elsewhere (Mehra S, 1975, Mujibuddin, 1976, and Puri and Jain, 1984).

4.4.6 Cost Control under Inflation :

A program has been developed by Puri N and Jain M.L. (1984) for forecasting the project cost requirements while incorporating the effect of inflation in the form of revised rate of material and labour charges. The manager is able to get the clear picture of revised estimates at a glance at any instant of time, while executing the project. The details of this program are available elsewhere (Puri and Jain, 1984).

4.4.7 Precedence Network Scheduling :

Input

The program needs total number of activities, activity numbers, preceding activity number, split/non-split character, their duration and the relationship of lag, lead or delay with preceding activities.

Output

Output consists of the complete activity schedule and prints the activity number, duration, early start time, early finish time, latest start time, latest finish time, total float at start (TFS), total float at finish (TFF), free float at start (FFS) and free float at finish (FFF).

The block diagram is given in Fig.12C and details are available elsewhere (Mrs. Das, 1976).

4.4.8 Conversion of CPM Schedule to Bar Chart :

The output of CPM scheduling program is fed as input for Bar Chart program. The first version of this program was developed by K.P. Singh, 1978. Further modifications has been made by the author and it is presented in Chapter 5.

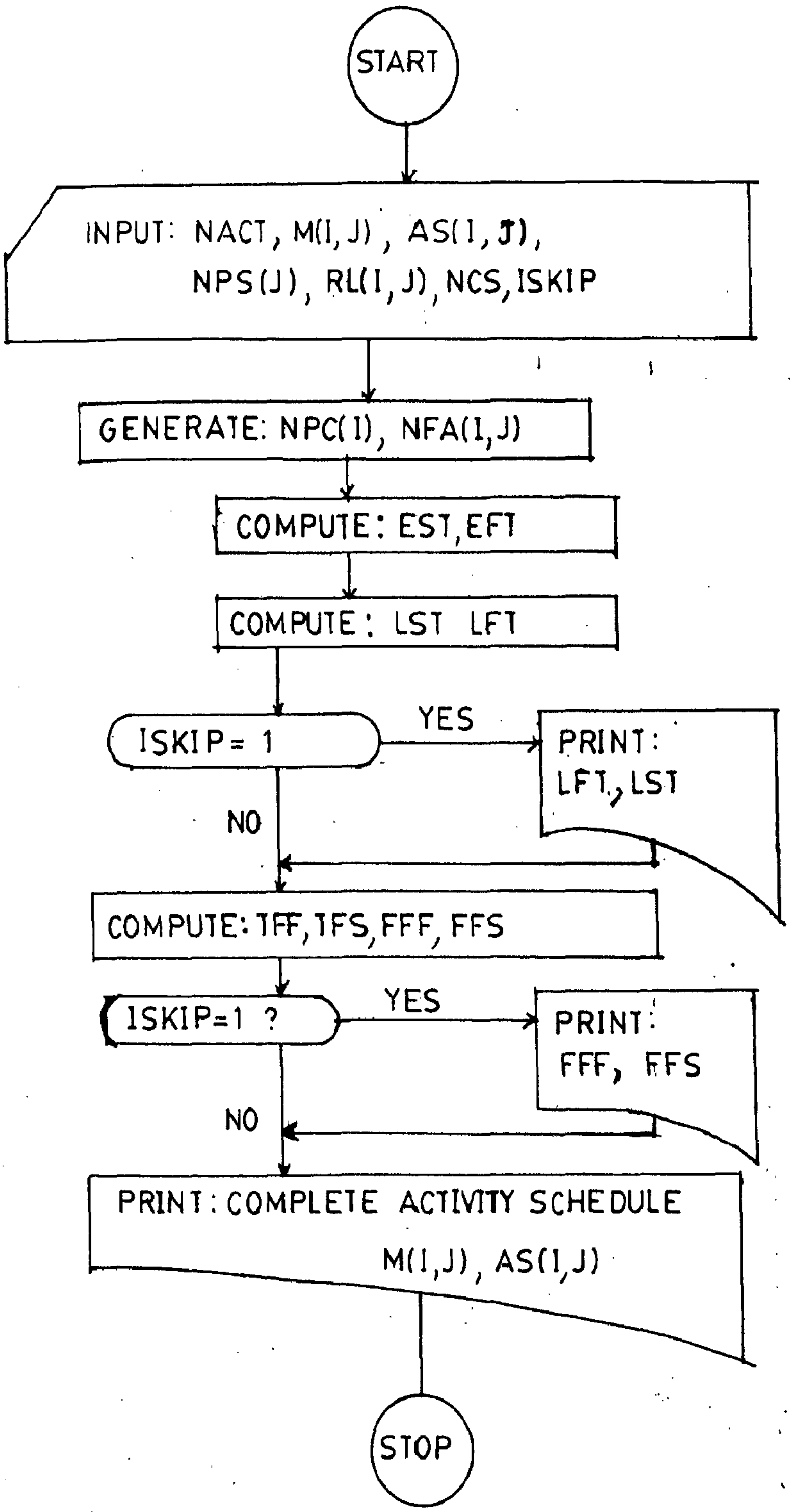


FIG.12 C MASTER DIAGRAM FOR SCHEDULING OF PRECEDENCE NETWORK

4.5 CONTROL MONITOR PHASE OF CPM BY COMPUTER USE

The autnor has developed a program for monitoring of projects.[26] It is given as an extension of scheduling program and followed by the Bar Chart program. The three programs are taken as a single unit, using sub-routines. So if revision is necessary, it goes automatically to the updating program, revises the data, reschedules it and if needed bar charts are produced.

(For the program details refer Chapter 5).

CHAPTER-5

CPM SCHEDULING AND MONITORING PROGRAM

5.1 INTRODUCTION

Control monitor phase starts with the actual starting of the project, continues throughout the duration of the project and ends with the finishing of the project. It is inevitable in a project that some delay and changes are likely to occur due to unavoidable reasons. So updating at suitable intervals is necessary. For a small project hand computation can be adopted. But due to the complexities arising in construction processes the use of computer is most suitable. A computer program for updating purpose may be much useful in the field of construction management. The developed program is presented and illustrated in this Chapter.

The monitoring program is connected to the scheduling program using subroutine. Also the Bar chart program follows both the scheduling and monitoring subroutines. Detailed description of monitoring program is given in this chapter. Also brief description of scheduling and bar chart program is given and illustrated with flow diagrams. The details of scheduling program are available elsewhere (Viswanath,1975), (Puri and Viswanath, 1984).

5.2 PROGRAM OUTLINE

The program for scheduling, monitoring and bar charting is arranged in such a way that first of all the input data is read in the main program. After that a check is introduced, to see whether the scheduling is done for the first time. It it is yes, the subroutine 'EOCCT' is called, which part deals with the scheduling. Otherwise if the scheduling is to be done for subsequent stages, the changes are to be incorporated. For that the subroutine 'CHANGE' is called. This subroutine revises the basic data. After the revision the scheduling is done by 'EOCCT'. Once the scheduling part is over, one check is introduced. If number of rearrangements is positive, the subroutine 'ARRANG' is called this part deals with the rearrangement of the activities in the ascending order of any columns. Next check is whether the counter ISKIP is one or not. If it is one, the subroutine 'ARREOT' is called, this part deals with the rearrangement in ascending order of EOT. If bar chart is needed the counter NBAR should be given as one. In that case the subroutine 'BAR' is called and the bar chart is plotted.

A block diagram for the program is given in Fig.13 and illustrates the different steps.

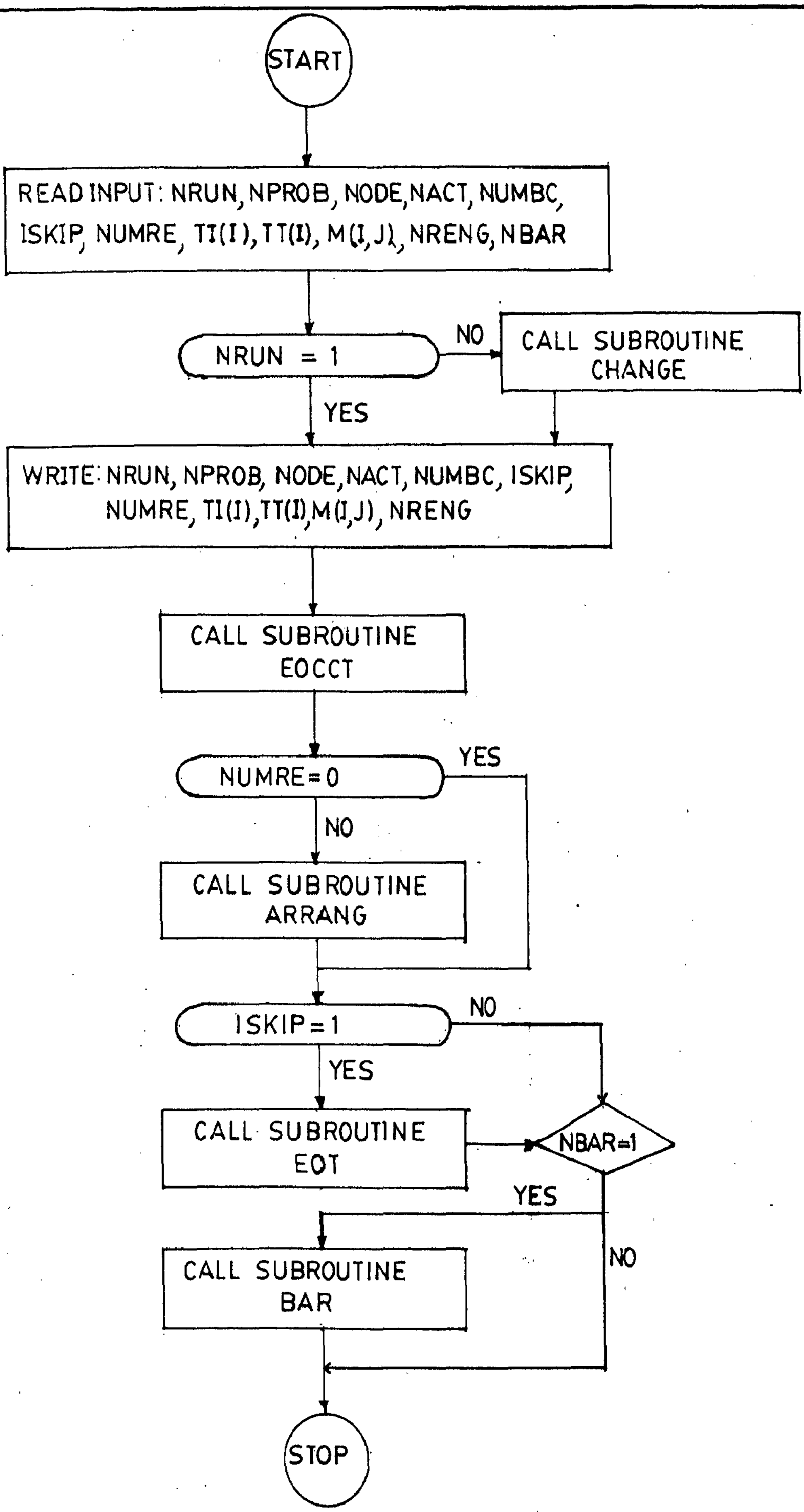


FIG.13 BLOCK DIAGRAM FOR SCHEDULING AND MONITORING PROGRAM

5.3 MAIN PROGRAM

Input

In this main program, the basic data is read first. NRUN is read. NRUN is a counter to check whether the scheduling is done for the first time or not. If it is for for the first time NRUN should be equal to 1. NPROB is read next. This gives the number of problems. Next comes NBAR. If NBAR is 1 the bar chart program is called.

Number of nodes (NODE), Number of activities(NACT), Number of columns (NUMBC), ISKIP, Number of rearrangements needed (NUMRE) are read. Read the title of the problem under the array (TI). The description of the activities is stored in the title array (TT).

The array M is the central and most important parameter and it consists of all data and results. M is a doubly subscripted array (NACT x NUMBC). The input data consisting of description of activity (TT), I-node, J-node, duration and trade indicator are read and stored in four alphanumeric fields and four columns of the array M, respectively. Each activity is assigned a row in array M and parameters describing each activity are stored in the columns from 1 to NUMBC.

The first 4 alphanumeric fields of 16 columns store the description of activity in array (TT). Then first and second columns store I-node and J-node of the activity. The third store the duration of the activity. The fourth store the trade indicator if it is read in input data, and it is immediately transferred to ninth column.

Read NRENG, which gives the column numbers in which rearrangement is needed. Lastly read E, L and a blank in 3 alphanumeric columns and it is carried over to the subroutine bar, if bar chart is needed.

All the above data are read in the main program. After that according to the values of NRUN, NPROB and NBAR the subroutines are called.

5.4 MONITORING PROGRAM (26)

5.4.1 Subroutine 'CHANGE' (Fig.14 A,B,C)

In the main program if NRUN is read as greater than 1, the subroutine 'CHANGE' is called. This means that the scheduling is done not for the first time and some revision is to be done in the basic data. This program can take care of the following points.

1) Change of duration of activities already finished or yet to finish.

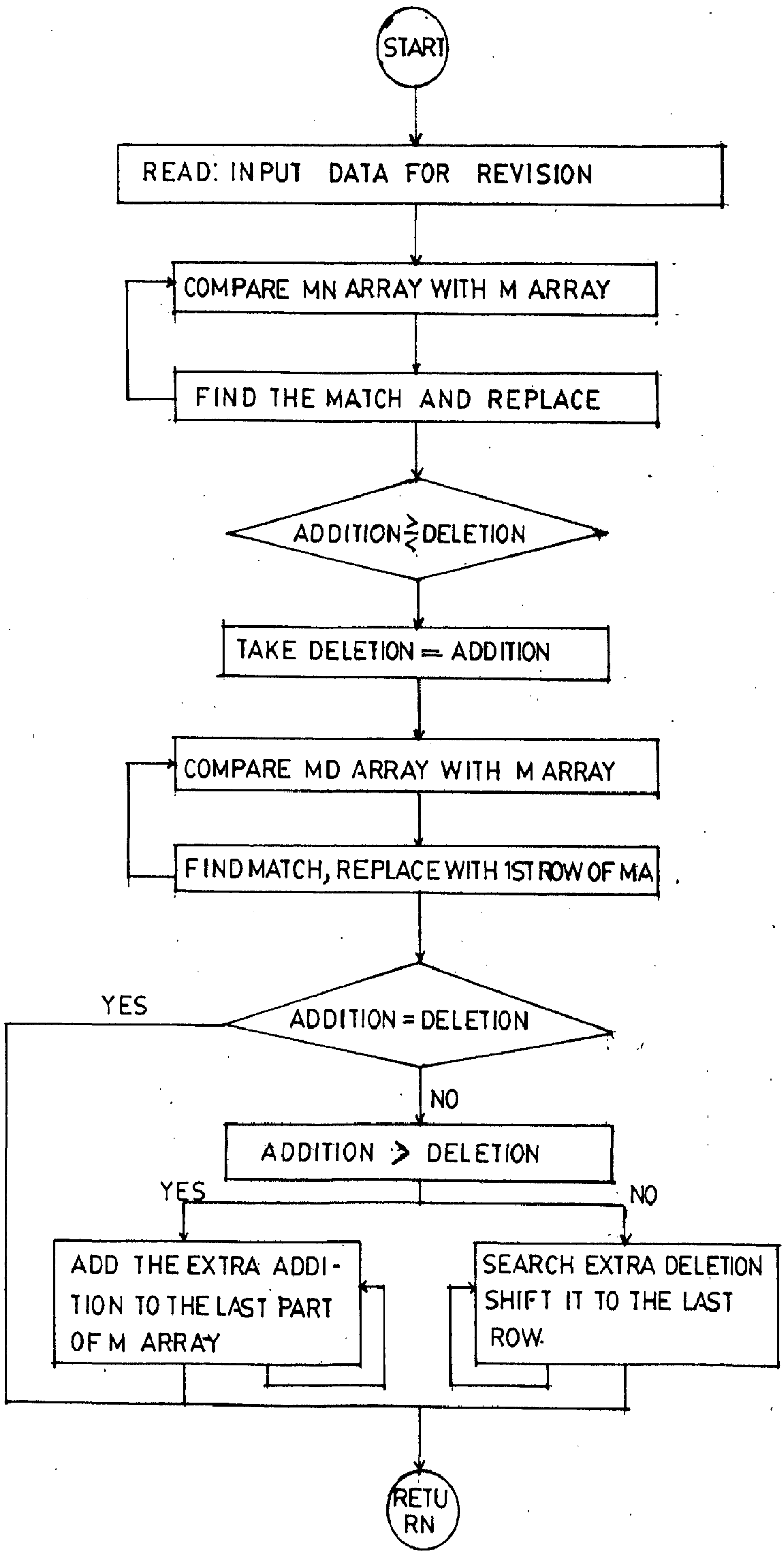


FIG.14A BLOCK DIAGRAM FOR MONITORING PROGRAM.

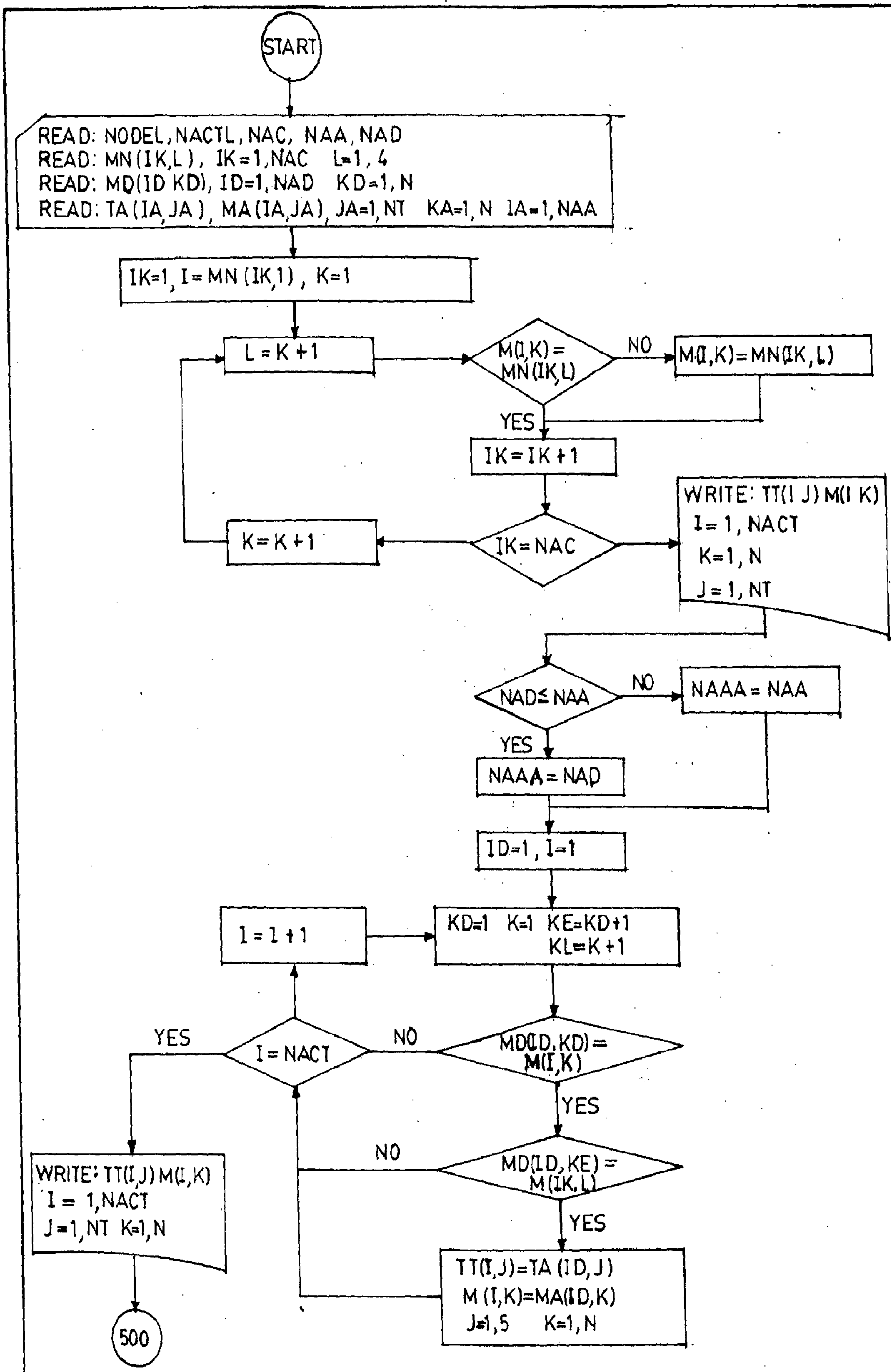


FIG.14 B SUBROUTINE 'CHANGE'

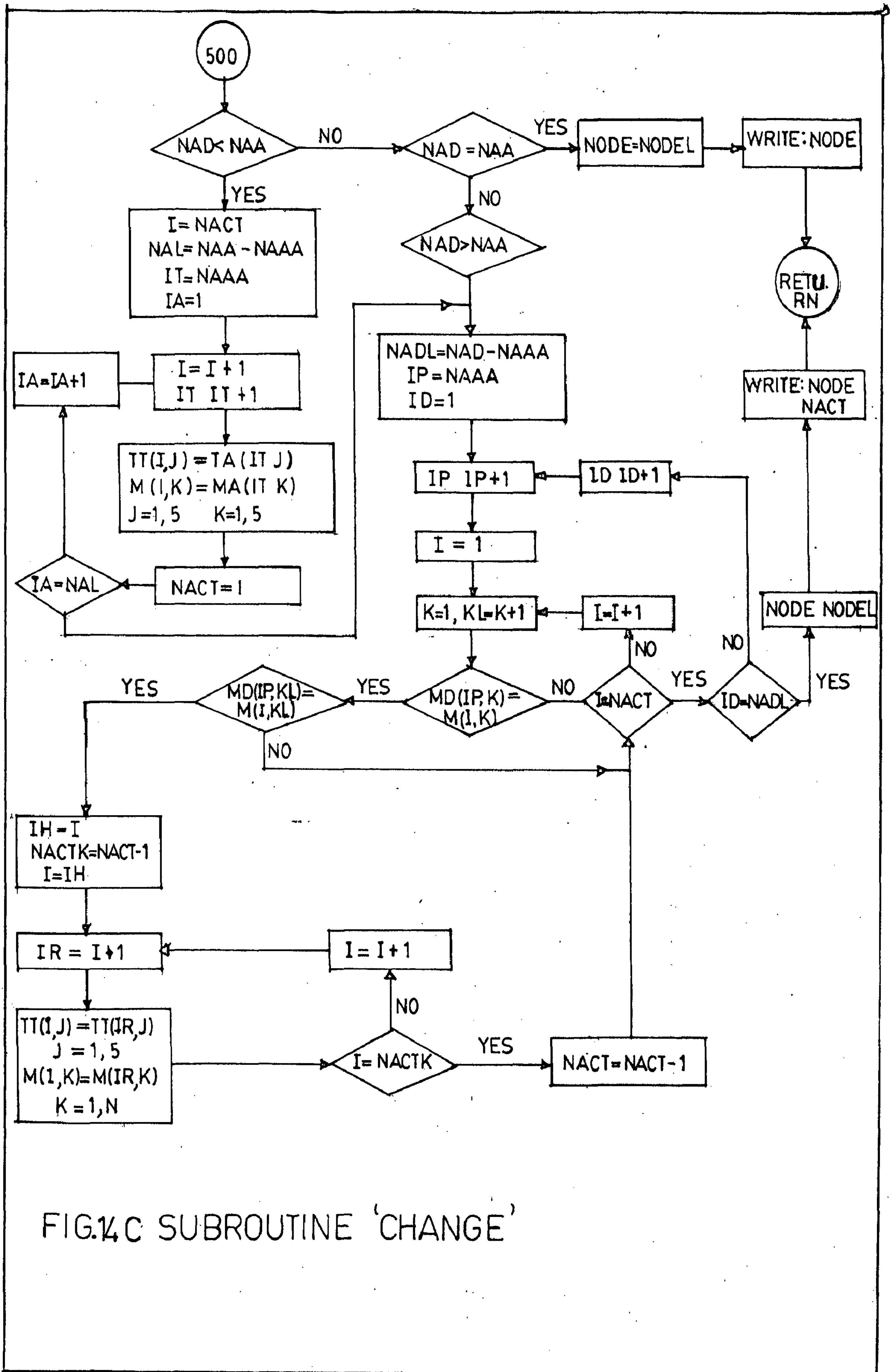


FIG.14C SUBROUTINE 'CHANGE'

2) Change of duration of activities already started/ or yet to start.

3) Modified interdependencies.

4) Addition of activities.

5) Deletion of activities.

5.4.2 Input

First input data is read. It contains the following data :-

1) The latest number of nodes (NODEL).
2) The latest number of activities (NACTL).
3) The number of changes (duration and nodes)(NAC).
4) The number of additions (NAA).
5) The number of deletions (NAD).
6) The array containing changes (MN).

The size of MN is (NACx4). The first column gives the row number of M array, second column gives the I-node, third column J-node and fourth column duration. If there are any changes from the basic data, that is read as array MN.

7) The array containing the deletions (MD). The size of this array is (NADXN). If some activities are deleted from array M, these are read as array MD, in the order of I-node, J-node and duration.

8) The array containing the additions (MA). The size of this array is (NAA X N). These activities will be added to array M, with the title TA (NAAXNT).

5.4.3 Different Stages

Ist Stage

The array containing changes (MN) is compared with the basic data array (M). The first column of MN array gives the row numbers of M array in which changes are to be incorporatec

The corresponding rows of M array are picked up and the original values are replaced by the changed values. This comparison and replacement is continued upto NAC. Thus in the basic array M if there is any change in nodes and duration, that will be taken care of by this part.

2nd Stage

The second stage deals with additions and deletions. Here three different stages arise :-

(a) If additions and deletions are equal :-

First the array MD, containing deletions is taken. Each row of MD is compared with M array. If a mathcing row is found out that row will be replaced by the first row of MA array (containing additions). This will continue till all the deleted activities are replaced by the newly added activities.

(b) If additions are more than deletions :-

First the equal number of deletions and additions will be taken and replacement is done as in (a) above. Then, the extra additions will be added to the M array, in the last part of the matrix.

(c) If deletions are more than additions :-

First the equal number of deletions and additions will be taken and replacement is done. The extra deletions will be carried out in the following manner.

The row numbers of M array, corresponding to the extra deletions is to be found out. That row will be replaced by the next row. So the row to be deleted will occupy the next row. Again it will be replaced by the row next to it and so on. This will be carried out upto one row less than the total rows.

Then the total number of activities will become one less than the basic number of activities. Again the same process is repeated until all the extra deletions are over.

After incorporating the above revisions, the scheduling program is called. So the revised schedule will be obtained as output. If a second revision is needed again give the changes as input and the same process is repeated.

Conclusion

The program gives the revised data and revised schedule. The management can use this program to get the latest time status of the project. In the control monitor phase this will be useful to have the updated schedule of all activities.

5.5 SCHEDULING PROGRAM

5.5.1 Subroutine 'EOCCT' (Fig.15A,B)

This subroutine deals with the scheduling part. The input data for this is already read in the main program. If revision is done in the basic data, the latest data is considered. The different stages of 'EOCCT' as the following.

5.5.2 Different Stages

Ist Stage

Calculation of EOT :-

The EOT of first node is set equal to zero. Starting from the second node, the program scans the list of activities for their J-nodes and picks up the activities entering the node under consideration (say node k). The duration of activity and the result is stored temporarily in IET. IET is then compared with MAX (which was intially made zero) and if IET is greater than MAX, then the value of MAX is updated to IET. The variable MAX helps in maximising the EOT. After all the activities entering the node have been considered, the values of EOT is set equal to MAX. Then the next node is considered. MAX is once again initialised as zero and the process is repeated until the EOT of all nodes are calculated.

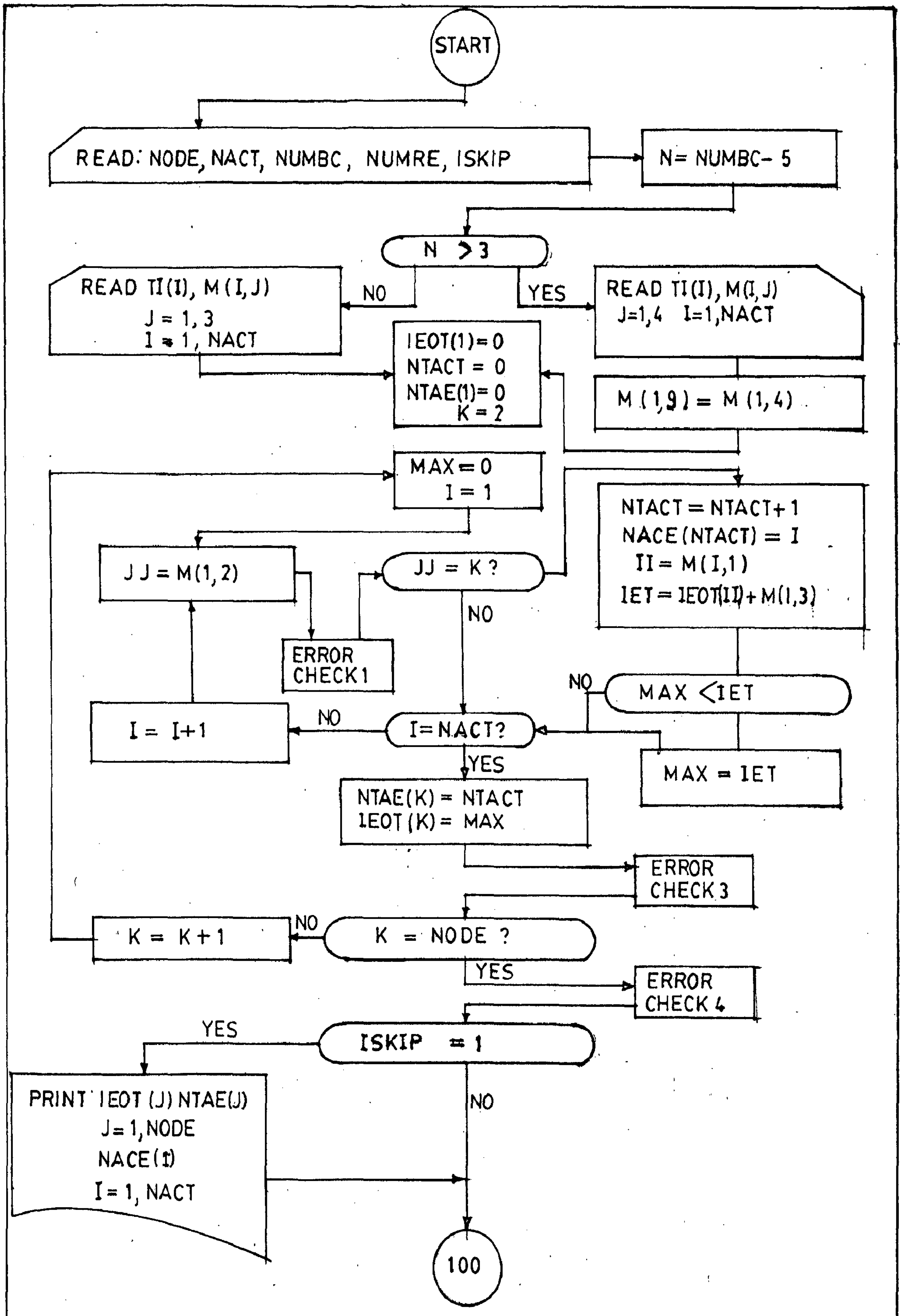


FIG.15A.FLOWCHART SUBROUTINE 'EOCCT'

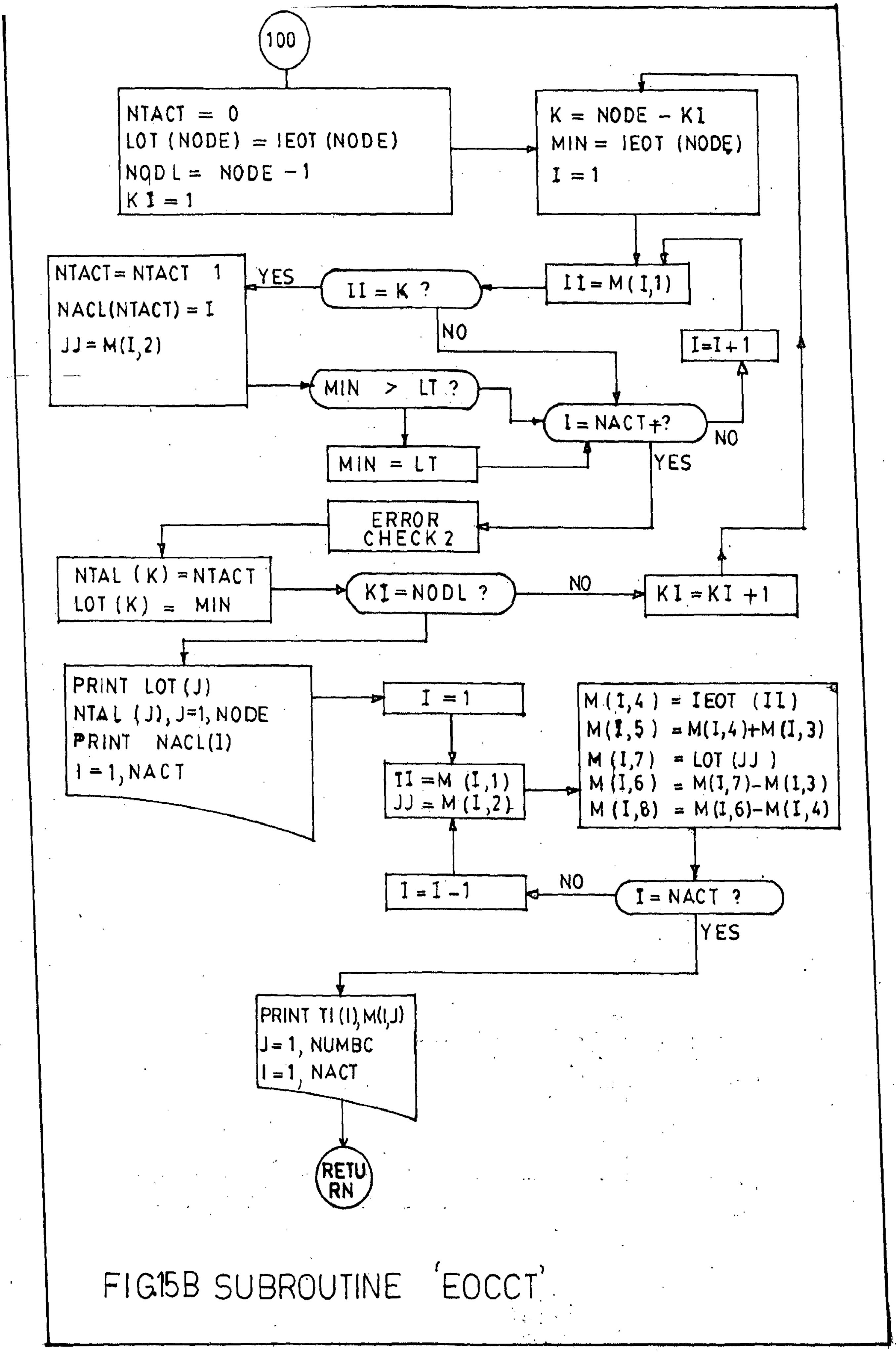


FIG.15B SUBROUTINE 'EOCCT'

During the scanning process, as soon as the activities entering a node are picked up, the cumulative total of all activities entering a node so far is stored in the array NTAE and the serial number of activities, in the array NACE See list of symbols for more details). This will be used in the resource levelling program. This stage also includes provision for checking for three types of error.

If the counter ISKIP is equal to one the arrays NTAE, NACE and IEOT are printed.

2nd Stage

Calculation of Latest Occurence time (LOT) :-

This stage is parallel to the stage 1. The operations are similar. Starting from the last node and proceeding to the first, the LOT of the nodes are calculated and the arrays NTAL and NACL are generated, as and when an activity leaving a node is encountered. This will be used in resource levelling program. As before, if ISKIP is one, results of this stage (LOT, NTAL, NACL) will be printed. This stage includes a provision for checking of one type error (Viswanath, 1975).

3rd Stage

The value of early start time (EST), early finish time (EFT), latest start time (LST) and latest finish time(LFT) are calculated. At the end of this stage, the array M will be fully populated and it contains a complete description of all the activities in the following manner - The description of the activity in the first 20 columns of TT array, I-node, J-node, duration, EST, EFT, LST, LFT, Total float and trade indicator, in the 1st column, 2nd column, and so on upto the 9th column of M array.

5.5.3 Subroutine 'ARRANG' (Fig.16)

If number of rearrangement (NUMRE) is positive, the sub-routine 'ARRANG' is called.

The array NRENG gives the type of rearrangement. The rearrangement is done according to ascending order of values in the specified columns of M array.

Each of these columns are considered one at a time, and the column number is stored in NCOL. Two temporary arrays are created ISNO and JTEM. These are single subscripted arrays of dimension NACT. ISNO stores the activity serial numbers and JTEM stores the corresponding values in the column NCOL of the array M. The values in the array JTEM are then rearranged in ascending order and as the values are

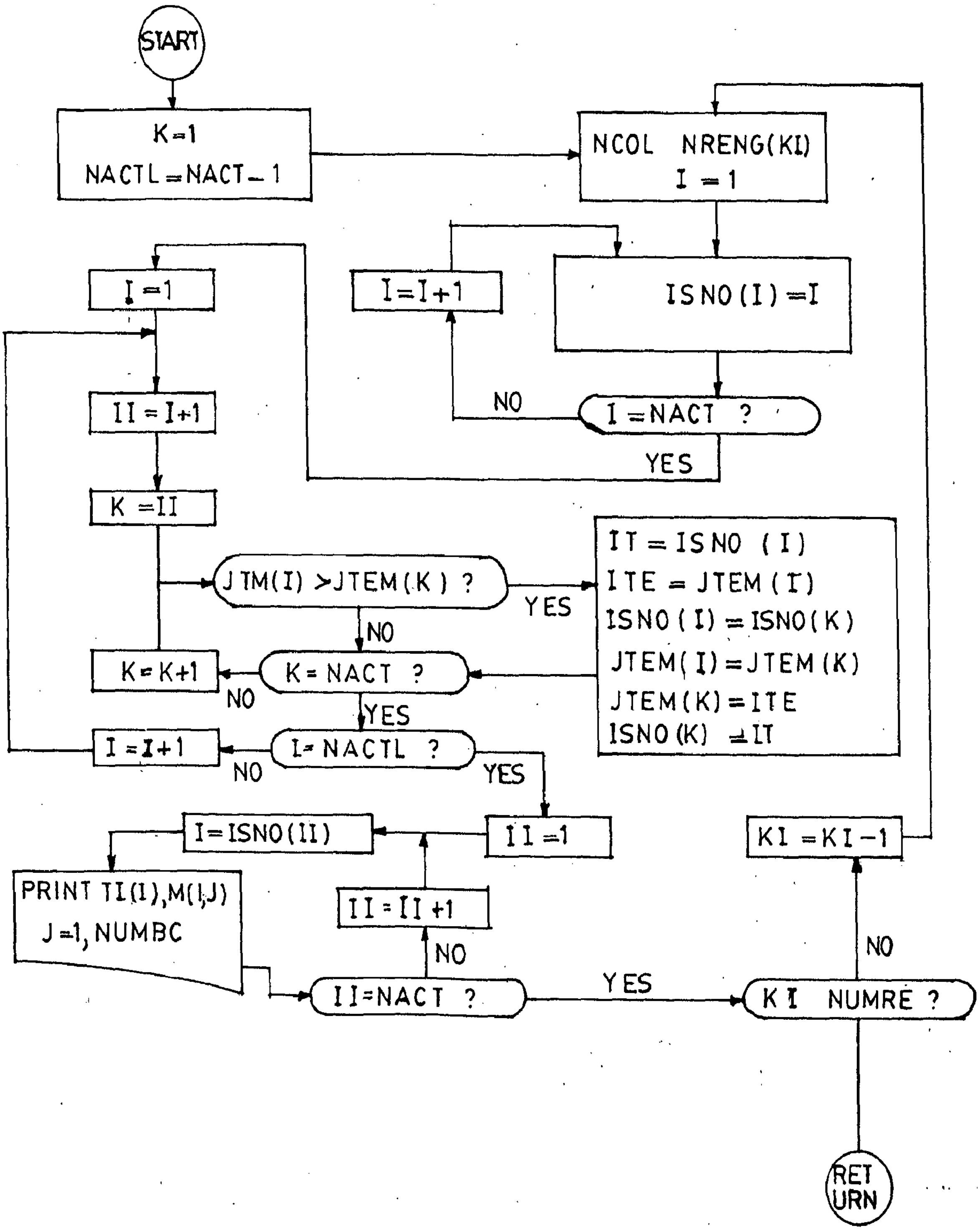


FIG. 16 FLOWCHART SUBROUTINE 'ARRANG'

rearranged in JTEM, there is a simultaneous rearrangement of the corresponding serial numbers of the activites in ISNO. The array M is printed out so that the activities are in the new order created in ISNO. The next rearrangement is considered and the operation are repeated until all the desired rearrangement have been accomplished.

5.5.4 Sub-routine 'ARREOT' (Fig.17)

If ISKIP is one, the subroutine 'ARREOT' is called. In this part nodes will be arranged in ascending order of EOT and also the total project duration iscalculated.

5.6 BAR CHART PROGRAM (FIG.18 A,B)

5.6.1 Subroutine 'BAR'

If the counter NBAR is one, the subroutine 'BAR' is called.

Input

Data needed for this program are the following :-

(1) Number of nodes (NODE)
(2) Number of activities (NACT)
(3) Number of columns (NUMBC)
(4) Duration of project (NDY)
(5) M array with description of activities and details in all the 9 columns.

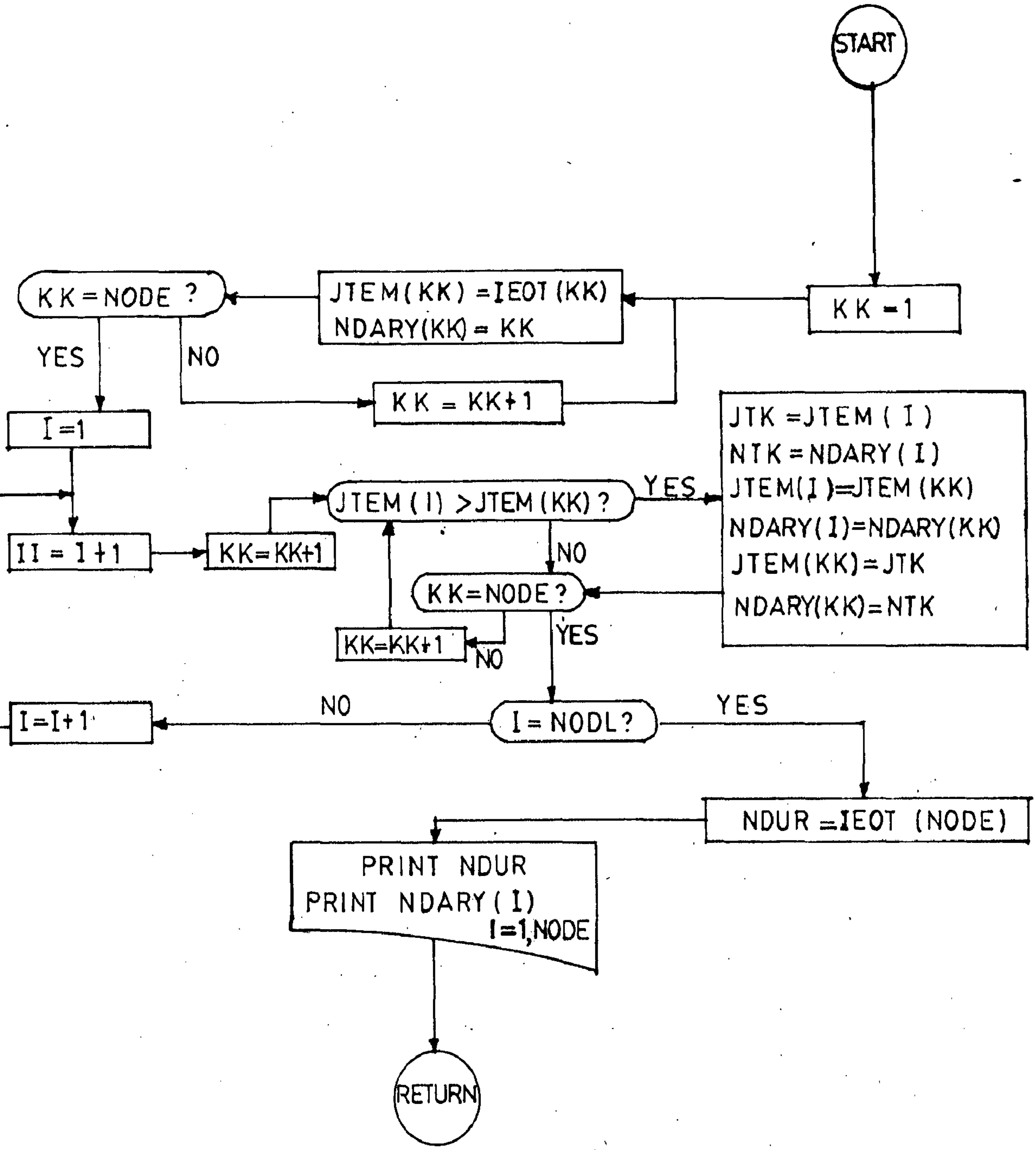


FIG. 17 SUBROUTINE 'ARREOT'

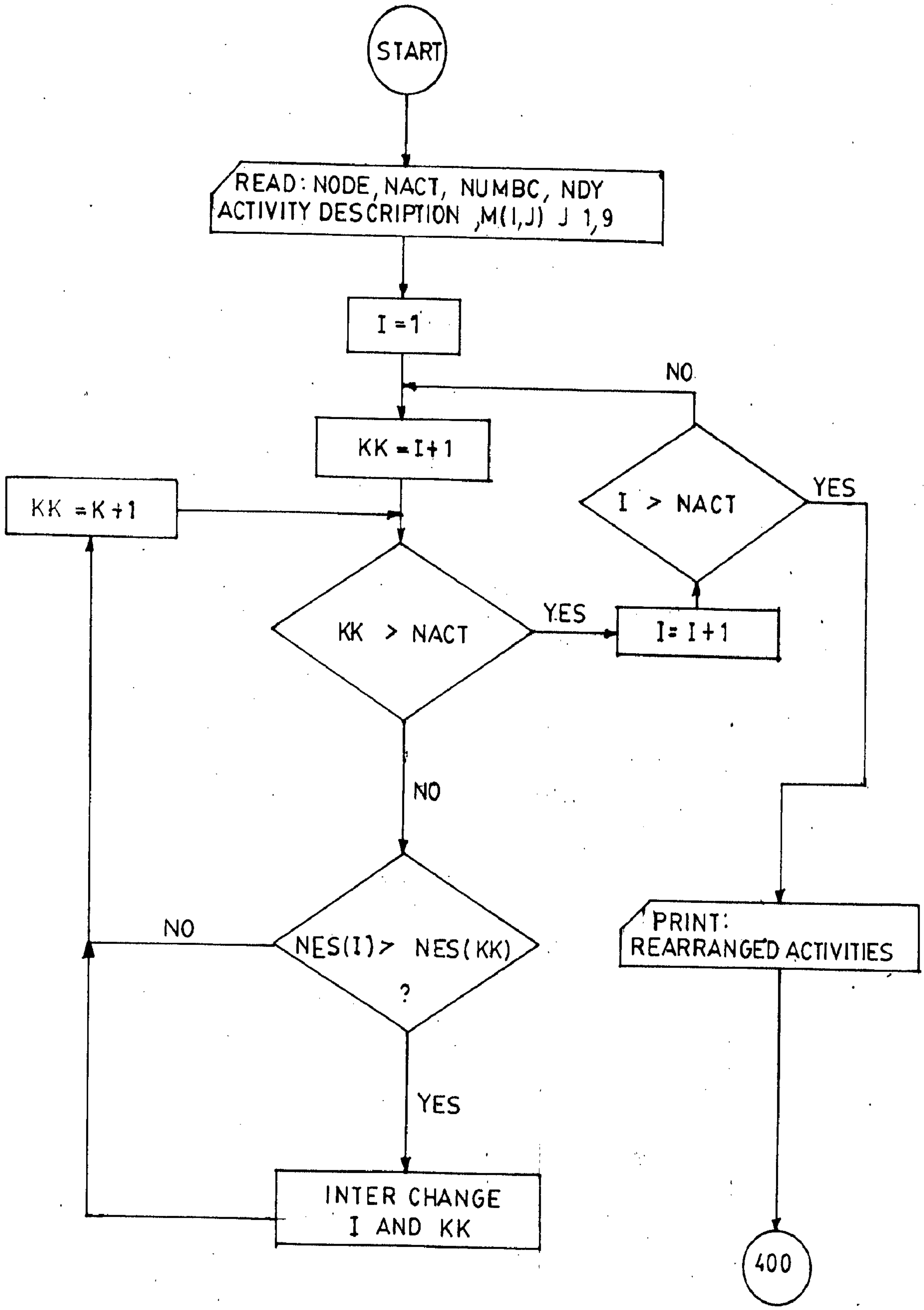


FIG.18 A SUBROUTINE 'BAR'

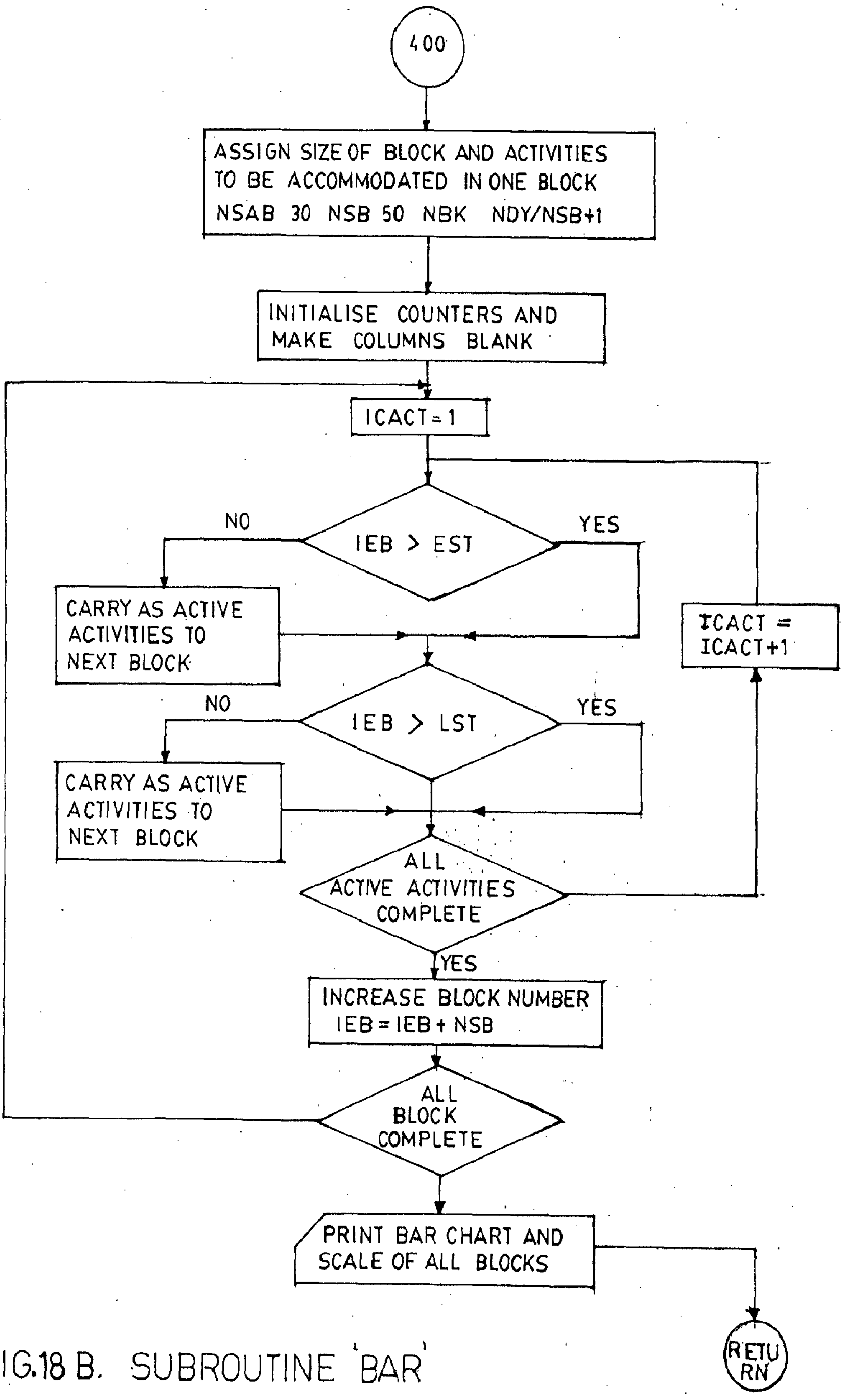


FIG.18 B. SUBROUTINE 'BAR'

(6) E,L, and a blank in 3 alphanumeric columns.

All these data will be carried over from the main program.

5.6.2 Different Stages

Ist Stage

At this stage all the activities are rearranged in the ascending order of EST, so that the picking up of activities those are eligible for a particular block is efficiently carried out.

2nd Stage

At this stage the number of blocks required for bar chart is computed. Maximum number of activities to be accommodated in the block is assigned. Size of block is fixed. NSAB, is the maximum number of activities which can be accommodated in the block and NSB is the size of the block. Hence number of blocks NBK is computed as NBK = NDY/NSB + 1 then all the columns of the two matrices XL and XE are made blank.

3rd Stage

At this stage eligibility of activities in the active block is decided. The last day of the active block is compared with EST of all the activities. The activities upto which (IEB-EST) is negative, are picked up as active activities and are eligible in active block.

4th Stage

At this stage all the activities eligible in the active block are checked for being carried over to the next block against EST, LST or both. For these activities, three different parallel single subscripted arrays NSC, NCC, and NST for storing their serial numbers against EST, LST or both are generated. ICC, IIC, ICK and ITC are the counters for activities carried over to the next block against EST, LST, or both and total carry over activities. For these activities which are being carrried over to next block, the EFT and LFT are set equal to NSB. Now the bar chart is computed against EST and LST i.e., E-bar and L-bar. The bar chart is plotted against each activities. The letter E is printed out from EST to EFT and the letter L is printed out from LST to LFT against each activity. If EFT and LFT are greater than the block number it will be carried over to the next block .

5th Stage

The duration scale in days is printed at the bottom of each block at every tenth column, a single subscripted array JT is created for this purpose. This process continues for the next block till bar chart in all the blocks are completed.

5.7 LIST OF SYMBOLS

ICACT	A counter for activities
ICC	A counter for carry over of activities to the next block against EST.
ICK	A counter for carry over of activities to next block against both EST and LST. When ICK = 5 it is to be carried over to next block.
ICSN	A counter for serial number of activities.
IEB	End block day of bar.
IEF	Earliest finish day.
IEOT	A single subscripted array that stores the early occurence times of nodes.
IES	Earliest start day.
IET	A temporary storage variable for the earliest occurence time of a node, during the process of maximising the early occurence time of a node.
IIC	A counter for carryover of activities to next block against LST,
ILF	Latest finish day.
ILS	Latest start day.
ISB	Start block day of bar.

ISKIP A counter. If ISKIP is equal to one, it means a resource levelling program will follow and the values of IEOT, LOT, NACE, NACL, NTAE and NTAL will be printed in the result.

ISN Single subscripted array, which stores those activifies active in the particular block.

ISNO Single subscripted array and is used for storing temporarily the serial numbers of the activities during the process of rearrangement.

ITC A counter for total carry over of activities.

JT Single subscripted array used for printing the scale for duration on each block of the program.

JTEM Parallel single subscripted array which stores the quantities that are to be arranged in ascending order.

LOT Single subscripted array storing the latest occurence times of the nodes.

LT Temporary storage variable for the latest occurence time of a node during the process of minimising the the latest occurence time of a node.

M The central and most important array, storing both the input and output of the scheduling program. The array M is a double subscripted variable, of dimension (NACT X NUMBC). Each row of M stores information of one activity. The first, second and third columns store the I-node, J-node and duration of the activity. The fourth column of M stores the trade indicator in the input. But in the output this is transfered to the ninth column. In the output, the fourth, fifth, sixth, seventh and eight columns store the early start, early finish, latest start, latest finish and total float respectively.

MA Double subscripted array containing the additional activities to be added to array M.

MAX A variable used for maximising the value of IEOT. Initially MAX is set equal to zero, and it is progressively increased to its maximum value which is then assigned to IEOT.

MD Double subscripted array of size (NADXN), This gives the deleted activities.

MIN This is analogous to MAX. It is used for minimising the value of LOT. Initially it is set equal to very large value and it is progressively decreased to its minimum value, which is then assigned to LOT.

MN	Double subscripted array of size (NACX4). This gives the changed data. The first column gives the row number of array M, second column I-node, third column J-node and fourth column duration.
N	A number that indicates how many values for each activity are being read. This helps to see whether trade indicator is there or not.
NAA	Number of additions.
NAC	Number of changes.
NACE	A single subscripted variable that stores the serial number of activities as and when they are picked up during the search for activities entering a node. The maximum dimension of NACE is (NACT).
NACL	A single subscripted array that stores the serial number of activities as and when they are picked up during the search for activities leaving a node. The maximum dimension of NACL is NACT.
NACT	Total number of activities.
NACTL	Latest total number of activities.
NAD	Number of deletions.
NBAR	A counter. If NBAR is one, bar chart is produced.
NBK	Number of blocks.

NCC Parallel single subscripted array, which stores the serial number of those activities, which are being carried over to the next block against latest start time.

NCOL The column in the array M whose values are to be rearranged in ascending order.

NDARY Single subscripted array of node numbers, arranged so that the corresponding early occurence times are in ascending order.

NDUR The normal duration of the project.

NDY The total duration of the project.

NES Single subscripted array which stores the quantities that are to be arranged in ascending order of EST.

NODE Number of nodes.

NODEL Latest number of nodes.

NODL Defined as NODE-1. This has no physical significance.

NPROB Total number of problems.

NRENG Array containing the column numbers of array M which are to be arranged in ascending order.

NRUN A counter. If NRUN is 1 scheduling is done directly. If it is more than 1 monitoring program is called.

NSAB Number of activities which can be accommodated in one block.

NSB Size of the block.

NSC Single subscripted array which stores the serial number of those activities which are being carried over to next block against earliest start time.

NST Single subscripted array which stores the serial number of those activities, carried over to next block against both EST and LST.

NTAE Single subscripted array that sotres the cumulative total number of activities that enter the node and all preceding nodes. The maximum dimension of this array is NODE. No two values in this array should be equal.

NTAL Single subscripted array, analogous to NTAE. This stores the cumulative total number of activities that leave the node and all suceeding nodes. The maximum dimension of NTAL is NODE. No two values in this array should be equal.

NUMBC Number of columns

NUMRE Number of rearrangements.

TA Title array which stores the description of additional activities.

TI Title array which stores the title of the problem.

TT Title array which stores the description of activities of array M.

XL Parallel double subscripted array i.e., (NACTxNUMBC) against LST, which is first made blank and letter L is punched to make bar chart against LST.

XP A double subscripted array i.e., (NACTXNUMBC) against EST which is first made blank and then letter E is punched for making bar chart against EST.

XXE The letter E is to be read as an input data.

XXL The letter L is to be read as an input data.

XBK A blank space is created. E,L and blank are given in 3 alphanumeric columns in 3A1 format.

5.8 ILLUSTRATIONS

To illustrate the working of the monitoring program, 3 different problems has been taken into consideration.

5.8.1 Problem I

This deals with 'Excavating Trench and Laying of Pipes'. There are total 15 activities and 13 nodes in the network. The total normal duration is 39 days. The following are the details of the problem.

Basic Data

Activity Description	I-node	J-node	Duration
A - Award contract	1	2	1
B - Clear site	2	3	7
C - order pipe	2	4	1
D - Lay pipe	3	5	3
E - Deliver pipe	4	7	15
F - Excavate trench 100 ft.	5	6	2
G - Dummy	6	7	0
H - Complete trench	6	9	8
I - Placing and testing pipe	7	8	5
J - Continue placing and testing pipe	8	10	13
K - Start backfill	8	12	15
L - Dummy	9	10	0
M - Complete placing and testing pipe	10	11	2
N - Dummy	11	12	0
O - Complete backfill	12	13	2

The basic network diagram is presented in Fig.19A and the basic schedule (computer output) is given in Plate 1.

Revised Schedule

Some changes are introduced in the basic network. The changes incorporated in the basic network are the following :-

1. Duration

Activity F changed the duration from 2 to 4.

2. Nodes

(a) Node 8 became node 9

(b) Node 9 became node 8

(c) Node 12 became node 13

(d) Node 13 became node 14.

3. Deletions

Activities 6-7 and 8-10 (old 9-10) are deleted

4. Additions

Activities X (4-5), Y(8-9) and P(12-13) are added.

In the revised network there are 16 activities and 14 nodes. The revised duration is 50 days. The program takes the change of node numbers and duration first. So in the basic data the changed duration and nodes are replaced by the new ones. There are 2 additions and 3 deletions in this case. So first the two deletions are replaced by the two additions. Next the third addition is adddd as the last row of the basic matrix. This the basic data is revised incorporating the changes. The critical path is also changed. In the basic network it is through 1,2,4,7,8, (8,10,11), 12, and 13. In the revised network it is through 1,2,3,5,6,8,9,10,11 (10,12), 13 and 14.

The revised data is as follows :-

Activity Description	I-node	J-node	Duration
A - Award contract	1	2	1
B - Clear site	2	3	7
C - Order pipe	2	4	1
D - Lay pipe	3	5	3
E - Deliver pipe	4	7	15
F - Excavate trench 100 ft.	5	6	4
X - Issue materials	4	5	2
H - Complete trench	6	8	8
I - Place, Test pipe	7	9	5
J - Continue place, test pipe	9	10	13
K - Start backfill	9	12	15
Y - Checking slope	8	9	5
M - Complete place, test pipe	10	11	2
N - Dummy	11	12	0
O - Complete backfill	13	14	2
P - Continue backfill	12	13	5

The revised network diagram is presented in Fig.19B and the revised schedule (computer outpout) is given in Plate 2. The bar charts for basic and revised schedule are also given in Plate 1 and Plate 2 respectively.

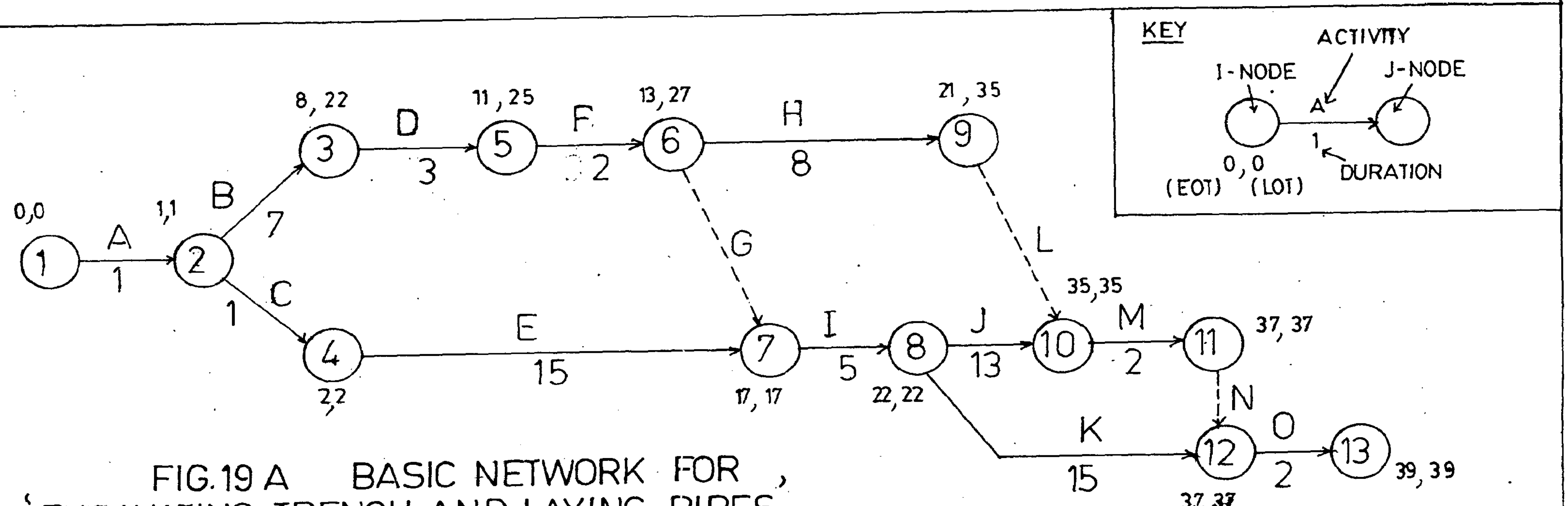


FIG. 19 A BASIC NETWORK FOR 'EXCAVATING TRENCH AND LAYING PIPES'.

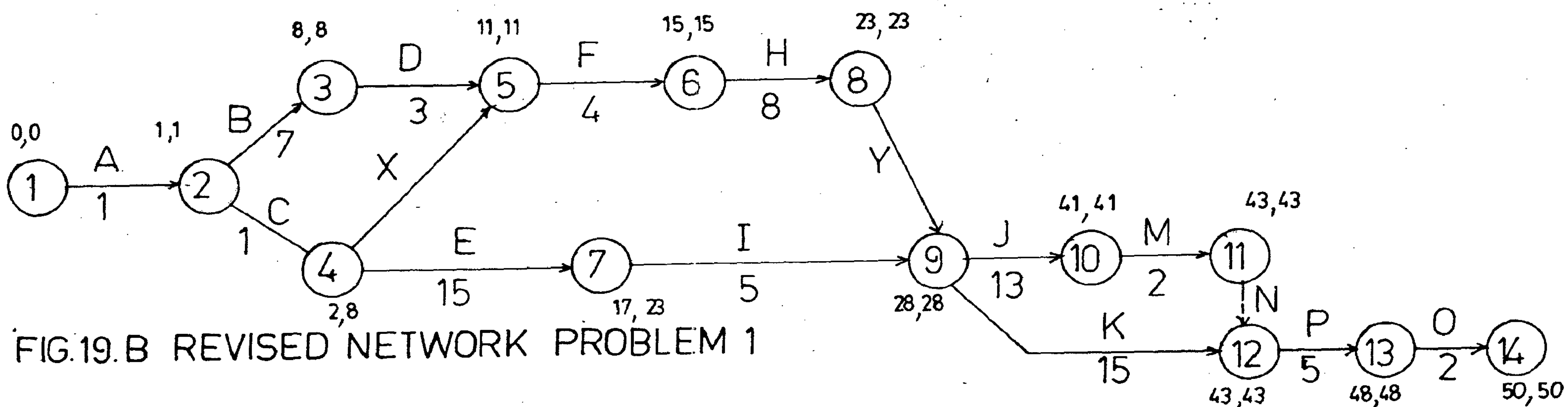


FIG. 19. B REVISED NETWORK PROBLEM 1

PLATE 1

BASIC SCHEDULE FOR

TRENCHING AND LAYING PIPES

NUMBER OF NODES = 13
NUMBER OF ACTIVITIES = 15
CPM NETWORK TEST PROBLEM BASIC DATA

	I	J	D	T
A-AWARD CONTRACT	1	2	1	1
B-CLEAR SITE	2	3	7	2
C-ORDER PIPE	2	4	1	3
D-LAY PIPE	3	5	3	4
E-DEL.PIPE	4	7	15	5
F-EX.TRENCH 100FT.	5	6	2	6
G-DUMMY	6	7	0	7
H-COMPL.TRENCH	6	9	8	8
I-PL.,TEST,PIPE	7	8	5	9
J-CONT.PL.,TEST,PIPE	8	10	13	10
K-START BACKFILL	8	12	15	11
L-DUMMY	9	10	0	12
M-COMPL.PL,TEST,PIPE	10	11	2	13
N-DUMMY	11	12	0	14
O-COMPL.BACKFILL	12	13	2	15

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
A-AWARD CONTRACT	1	2	1	0	1	0	1	0	1
B-CLEAR SITE	2	3	7	1	8	5	12	4	2
C-ORDER PIPE	2	4	1	1	2	1	2	0	3
D-LAY PIPE	3	5	3	8	11	12	15	4	4
E-DEL.PIPE	4	7	15	2	17	2	17	0	5
F-EX.TRENCH 100FT.	5	6	2	11	13	15	17	4	6
G-DUMMY	6	7	0	13	13	17	17	4	7
H-COMPL.TRENCH	6	9	8	13	21	27	35	14	8
I-PL.,TEST,PIPE	7	8	5	17	22	17	22	0	9
J-CONT.PL.,TEST,PIPE	8	10	13	22	35	22	35	0	10
K-START BACKFILL	8	12	15	22	37	22	37	0	11
L-DUMMY	9	10	0	21	21	35	35	14	12
M-COMPL.PL,TEST,PIPE	10	11	2	35	37	35	37	0	13
N-DUMMY	11	12	0	37	37	37	37	0	14
O-COMPL.BACKFILL	12	13	2	37	39	37	39	0	15

REARRANGEMENT IN ASCENDING ORDER OF EST

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
A-AWARD CONTRACT	1	2	1	0	1	0	1	0	1
B-CLEAR SITE	2	3	7	1	8	5	12	4	2
C-ORDER PIPE	2	4	1	1	2	1	2	0	3
E-DEL.PIPE	4	7	15	2	17	2	17	0	5
D-LAY PIPE	3	5	3	8	11	12	15	4	4
F-EX.TRENCH 100FT.	5	6	2	11	13	15	17	4	6
G-DUMMY	6	7	0	13	13	17	17	4	7
H-COMPL.TRENCH	6	9	8	13	21	27	35	14	8
I-PL.,TEST,PIPE	7	8	5	17	22	17	22	0	9
L-DUMMY	9	10	0	21	21	35	35	14	12
K-START BACKFILL	8	12	15	22	37	22	37	0	11
J-CONT.PL.,TEST,PIPE	8	10	13	22	35	22	35	0	10
M-COMPL.PL,TEST,PIPE	10	11	2	35	37	35	37	0	13
N-DUMMY	11	12	0	37	37	37	37	0	14
O-COMPL.BACKFILL	12	13	2	37	39	37	39	0	15

NORMAL PROJECT DURATION= 39

```
*****************************************************************************************************
  S.N. OF ACTIVE ACTIVITIES     1    2    3    5    4    6    7    8    9   12   11   10   13   14   15
*****************************************************************************************************
  BLOCK NUMBER    1
*****************************************************************************************************
  A-AWARD CONTRACT    *
                      *E
                      *L
                      *
  B-CLEAR SITE        *
                      * EEEEEEE
                      *     LLLLLLL
                      *
  C-ORDER PIPE        *
                      * E
                      * L
                      *
  E-DEL.PIPE          *
                      *  EEEEEEEEEEEEEEE
                      *  LLLLLLLLLLLLLLL
                      *
  D-LAY PIPE          *
                      *        EEE
                      *            LLL
                      *
  F-EX.TRENCH 100FT.  *
                      *           EE
                      *               LL
                      *
  G-DUMMY             *
                      *             E
                      *                 L
                      *
  H-COMPL.TRENCH      *
                      *             EEEEEEEE
                      *                           LLLLLLLL
                      *
  I-PL.,TEST,PIPE     *
                      *                 EEEEE
                      *                 LLLLL
                      *
  L-DUMMY             *
                      *                      E
                      *                                    L
                      *
  K-START BACKFILL    *
                      *                      EEEEEEEEEEEEEEE
                      *                      LLLLLLLLLLLLLLL
                      *
  J-CONT.PL.,TEST,PIPE*
                      *                      EEEEEEEEEEEEE
                      *                      LLLLLLLLLLLLL
                      *
  M-COMPL.PL,TEST,PIPE*
                      *                                    EE
                      *                                    LL
                      *
  N-DUMMY             *
                      *                                      E
                      *                                      L
                      *
  O-COMPL.BACKFILL    *
                      *                                      EE
                      *                                      LL
                      *
*****************************************************************************************************
                      0         10        20        30        40        50        60        70        80
```

PLATE 2

REVISED SCHEDULE PROBLEM 1
OF TRENCHING AND LAYING PIPES

NUMBER OF NODES =13
NUMBER OF ACTIVITIES =15
CPM NETWORK TEST PROBLEM BASIC DATA

	I	J	D	T
A-AWARD CONTRACT	1	2	1	1
B-CLEAR SITE	2	3	7	2
C-ORDER PIPE	2	4	1	3
D-LAY PIPE	3	5	3	4
E-DEL.PIPE	4	7	15	5
F-EX.TRENCH 100FT.	5	6	2	6
G-DUMMY	6	7	0	7
H-COMPL.TRENCH	6	9	8	8
I-PL.,TEST,PIPE	7	8	5	9
J-CONT.PL.,TEST,PIPE	8	10	13	10
K-START BACKFILL	8	12	15	11
L-DUMMY	9	10	0	12
M-COMPL.PL,TEST,PIPE	10	11	2	13
N-DUMMY	11	12	0	14
O-COMPL.BACKFILL	12	13	2	15

THE QUANTITIES WRITTEN BELOW ARE CHANGED DATA

14	16	7	3	2
6	5	6	4	
8	6	8	8	
9	7	9	5	
10	9	10	13	
11	9	12	15	
12	8	10	0	
15	13	14	2	
6	7	0	0	
8	10	0	0	

X-ISSUE MATERIALS	4	5	2	0
Y-CHECKING SLOPE	8	9	5	0
P-CONT.BACKFILL	12	13	5	0

CPM NETWORK TEST PROBLEM REVISED DATA

NUMBER OF NODES = 14
NUMBER OF ACTIVITIES = 16

	I	J	D	T
A-AWARD CONTRACT	1	2	1	1
B-CLEAR SITE	2	3	7	2
C-ORDER PIPE	2	4	1	3
D-LAY PIPE	3	5	3	4
E-DEL.PIPE	4	7	15	5
F-EX.TRENCH 100FT.	5	6	4	0
X-ISSUE MATERIALS	4	5	2	0
H-COMPL.TRENCH	6	8	8	0
I-PL.,TEST,PIPE	7	9	5	0
J-CONT.PL.,TEST,PIPE	9	10	13	0
K-START BACKFILL	9	12	15	0
Y-CHECKING SLOPE	8	9	5	0
M-COMPL.PL,TEST,PIPE	10	11	2	13
N-DUMMY	11	12	0	14
O-COMPL.BACKFILL	13	14	2	0
P-CONT.BACKFILL	12	13	5	0

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
A-AWARD CONTRACT	1	2	1	0	1	0	1	0	1
B-CLEAR SITE	2	3	7	1	8	1	8	0	2
C-ORDER PIPE	2	4	1	1	2	7	8	6	3
D-LAY PIPE	3	5	3	8	11	8	11	0	4
E-DEL.PIPE	4	7	15	2	17	8	23	6	5
F-EX.TRENCH 100FT.	5	6	4	11	15	11	15	0	6
X-ISSUE MATERIALS	4	5	2	2	4	9	11	7	7
H-COMPL.TRENCH	6	8	8	15	23	15	23	0	8
I-PL.,TEST,PIPE	7	9	5	17	22	23	28	6	9
J-CONT.PL.,TEST,PIPE	9	10	13	28	41	28	41	0	10
K-START BACKFILL	9	12	15	28	43	28	43	0	11
Y-CHECKING SLOPE	8	9	5	23	28	23	28	0	12
M-COMPL.PL,TEST,PIPE	10	11	2	41	43	41	43	0	13
N-DUMMY	11	12	0	43	43	43	43	0	14
O-COMPL.BACKFILL	13	14	2	48	50	48	50	0	15
P-CONT.BACKFILL	12	13	5	43	48	43	48	0	0

REARRANGEMENT IN ASCENDING ORDER OF
EST

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
A-AWARD CONTRACT	1	2	1	0	1	0	1	0	1
B-CLEAR SITE	2	3	7	1	8	1	8	0	2
C-ORDER PIPE	2	4	1	1	2	7	8	6	3
E-DEL.PIPE	4	7	15	2	17	8	23	6	5
X-ISSUE MATERIALS	4	5	2	2	4	9	11	7	7
D-LAY PIPE	3	5	3	8	11	8	11	0	4
F-EX.TRENCH 100FT.	5	6	4	11	15	11	15	0	6
H-COMPL.TRENCH	6	8	8	15	23	15	23	0	8
I-PL.,TEST,PIPE	7	9	5	17	22	23	28	6	9
Y-CHECKING SLOPE	8	9	5	23	28	23	28	0	12
K-START BACKFILL	9	12	15	28	43	28	43	0	11
J-CONT.PL.,TEST,PIPE	9	10	13	28	41	28	41	0	10
M-COMPL.PL,TEST,PIPE	10	11	2	41	43	41	43	0	13
N-DUMMY	11	12	0	43	43	43	43	0	14
P-CONT.BACKFILL	12	13	5	43	48	43	48	0	0
O-COMPL.BACKFILL	13	14	2	48	50	48	50	0	15

REVISED PROJECT DURATION= 50

```
*********************************************************************************************************
  S.N. OF ACTIVE ACTIVITIES    1    2    3    5    7    4    6    8    9   12   11   10   13   14   16
15
*********************************************************************************************************
  BLOCK NUMBER    1
*********************************************************************************************************
  A-AWARD CONTRACT    *
                      *E
                      *L
                      *
  B-CLEAR SITE        *
                      * EEEEEEE
                      * LLLLLLL
                      *
  C-ORDER PIPE        *
                      * E
                      *       L
                      *
  E-DEL.PIPE          *
                      *  EEEEEEEEEEEEEEE
                      *        LLLLLLLLLLLLLLL
                      *
  X-ISSUE MATERIALS   *
                      *  EE
                      *         LL
                      *
  D-LAY PIPE          *
                      *        EEE
                      *        LLL
                      *
  F-EX.TRENCH 100FT.  *
                      *           EEEE
                      *           LLLL
                      *
  H-COMPL.TRENCH      *
                      *               EEEEEEEE
                      *               LLLLLLLL
                      *
  I-PL.,TEST,PIPE     *
                      *                 EEEEE
                      *                       LLLLL
                      *
  Y-CHECKING SLOPE    *
                      *                       EEEEE
                      *                       LLLLL
                      *
  K-START BACKFILL    *
                      *                            EEEEEEEEEEEEEEE
                      *                            LLLLLLLLLLLLLLL
                      *
  J-CONT.PL.,TEST,PIPE*
                      *                            EEEEEEEEEEEEE
                      *                            LLLLLLLLLLLLL
                      *
  M-COMPL,PL,TEST,PIPE*
                      *                                         EE
                      *                                         LL
                      *
  N-DUMMY             *
                      *                                           E
                      *                                           L
                      *
  P-CONT.BACKFILL     *
                      *                                           EEEEE
                      *                                           LLLLL
                      *
  O-COMPL.BACKFILL    *
                      *                                                EE
                      *                                                LL
                      *
*********************************************************************************************************
                      0         10        20        30        40        50        60        70        80
```

PLATE 3

REVISED SCHEDULE PROBLEM 2

TRENCHING AND LAYING PIPES

NUMBER OF NODES =13
NUMBER OF ACTIVITIES = 15
CPM NETWORK TEST PROBLEM BASIC DATA

	I	J	D	T
A-AWARD CONTRACT	1	2	1	1
B-CLEAR SITE	2	3	7	2
C-ORDER PIPE	2	4	1	3
D-LAY PIPE	3	5	3	4
E-DEL.PIPE	4	7	15	5
F-EX.TRENCH 100FT.	5	6	2	6
G-DUMMY	6	7	0	7
H-COMPL.TRENCH	6	9	8	8
I-PL.,TEST,PIPE	7	8	5	9
J-CONT.PL.,TEST,PIPE	8	10	13	10
K-START BACKFILL	8	12	15	11
L-DUMMY	9	10	0	12
M-COMPL.PL,TEST,PIPE	10	11	2	13
N-DUMMY	11	12	0	14
O-COMPL.BACKFILL	12	13	2	15

THE QUANTITIES WRITTEN BELOW ARE CHANGED DATA

13	13	6	1	3
6	5	6	4	
8	6	8	8	
9	7	9	5	
10	9	10	13	
11	9	12	15	
12	8	10	0	
6	7	0	0	
9	12	15	0	
8	10	0	0	

X-CHECKING SLOPE 8 9 5 0

13 13 9 1 1

NUMBER OF NODES = 13
NUMBER OF ACTIVITIES = 13

CPM NETWORK TEST PROBLEM REVISED DATA

	I	J	D	T
A-AWARD CONTRACT	1	2	1	1
B-CLEAR SITE	2	3	7	2
C-ORDER PIPE	2	4	1	3
D-LAY PIPE	3	5	3	4
E-DEL.PIPE	4	7	15	5
F-EX.TRENCH 100FT.	5	6	4	0
X-CHECKING SLOPE	8	9	5	0
H-COMPL.TRENCH	6	8	8	0
I-PL.,TEST,PIPE	7	9	5	0
J-CONT.PL.,TEST,PIPE	9	10	13	0
M-COMPL.PL,TEST,PIPE	10	11	2	13
N-DUMMY	11	12	0	14
O-COMPL.BACKFILL	12	13	2	15

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
A-AWARD CONTRACT	1	2	1	0	1	0	1	0	1
B-CLEAR SITE	2	3	7	1	8	1	8	0	2
C-ORDER PIPE	2	4	1	1	2	7	8	6	3
D-LAY PIPE	3	5	3	8	11	8	11	0	4
E-DEL.PIPE	4	7	15	2	17	8	23	6	5
F-EX.TRENCH 100FT.	5	6	4	11	15	11	15	0	6
X-CHECKING SLOPE	8	9	5	23	28	23	28	0	7
H-COMPL.TRENCH	6	8	8	15	23	15	23	0	8
I-PL.,TEST,PIPE	7	9	5	17	22	23	28	6	9
J-CONT.PL.,TEST,PIPE	9	10	13	28	41	28	41	0	10
M-COMPL.PL,TEST,PIPE	10	11	2	41	43	41	43	0	11
N-DUMMY	11	12	0	43	43	43	43	0	12
O-COMPL.BACKFILL	12	13	2	43	45	43	45	0	13

REARRANGEMENT IN ASCENDING ORDER OF
EST

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
A-AWARD CONTRACT	1	2	1	0	1	0	1	0	1
B-CLEAR SITE	2	3	7	1	8	1	8	0	2
C-ORDER PIPE	2	4	1	1	2	7	8	6	3
E-DEL.PIPE	4	7	15	2	17	8	23	6	5
D-LAY PIPE	3	5	3	8	11	8	11	0	4
F-EX.TRENCH 100FT.	5	6	4	11	15	11	15	0	6
H-COMPL.TRENCH	6	8	8	15	23	15	23	0	8
I-PL.,TEST,PIPE	7	9	5	17	22	23	28	6	9
X-CHECKING SLOPE	8	9	5	23	28	23	28	0	7
J-CONT.PL.,TEST,PIPE	9	10	13	28	41	28	41	0	10
M-COMPL.PL,TEST,PIPE	10	11	2	41	43	41	43	0	11
N-DUMMY	11	12	0	43	43	43	43	0	12
O-COMPL.BACKFILL	12	13	2	43	45	43	45	0	13

REVISED PROJECT DURATION= 45

```
*********************************************************************************************************
   S.N. OF ACTIVE ACTIVITIES     1    2    3    5    4    6    8    9    7   10   11   12   13
*********************************************************************************************************
   BLOCK NUMBER    1
*********************************************************************************************************
  A-AWARD CONTRACT    *
                      *E
                      *L
                      *
  B-CLEAR SITE        *
                      * EEEEEEE
                      * LLLLLLL
                      *
  C-ORDER PIPE        *
                      * E
                      *       L
                      *
  E-DEL.PIPE          *
                      *  EEEEEEEEEEEEEEE
                      *        LLLLLLLLLLLLLLL
                      *
  D-LAY PIPE          *
                      *        EEE
                      *        LLL
                      *
  F-EX.TRENCH 100FT.  *
                      *           EEEE
                      *           LLLL
                      *
  H-COMPL.TRENCH      *
                      *               EEEEEEEE
                      *               LLLLLLLL
                      *
  I-PL.,TEST,PIPE     *
                      *                 EEEEE
                      *                       LLLLL
                      *
  X-CHECKING SLOPE    *
                      *                       EEEEE
                      *                       LLLLL
                      *
  J-CONT.PL.,TEST,PIPE*
                      *                            EEEEEEEEEEEEE
                      *                            LLLLLLLLLLLLL
                      *
  M-COMPL.PL,TEST,PIPE*
                      *                                         EE
                      *                                         LL
                      *
  N-DUMMY             *
                      *                                           E
                      *                                           L
                      *
  O-COMPL.BACKFILL    *
                      *                                           EE
                      *                                           LL
                      *
*********************************************************************************************************
                      0         10        20        30        40        50        60        70        80
```

This first problem deals with more number of additions than deletions. The second problem is same as the first when considering the basic data. But in that deletions are more than additions. The second case is explained below.

5.8.2 Problem 2

The basic data is same as that of first problem. There are total 15 activities and 13 nodes. The total normal duration is 39 days. For basic network diagram refer Fig.19A and for basic schedule (computer output) refer Plate 1.

Revised Schedule

The changes are incorporated in the basic data. The revised data is as follows :-

Activity Description	I-node	J-node	Duration
A - Award contract	1	2	1
B - Clear site	2	3	7
C - Order pipe	2	4	1
D - Lay pipe	3	5	3
E - Deliver pipe	4	7	15
F - Excavate trench 100 ft.	5	6	4
X - Checking slope	8	9	5
H - Complete trench	6	8	8
I - Place, test pipe	7	9	5
J - Continue place, test pipe	9	10	13
M - Complete place, test pipe	10	11	2
N - Dummy	11	12	0
O - Complete backfill	12	13	2

Total number of nodes after revision is 13 and number of activities is also 13. The revised duration is 45 days. The changes incorporated in this case are the following :-

1. Duration

   Activity F changed the duration from 2 to 4.

2. Nodes

   (a) Node 8 became node 9

   (b) Node 9 became node 8

3. Deletions

   Activities 6-7, 9-12 (old 8-12) and 8-10 (old 9-10) are deleted.

4. Additions

   Activity X (8-9)is added.

In this case first of all activity F which changed duration, the nodes 8 and 9 are replaced by the new ones. There are 3 deletions and 1 addition. One deletion is replaced by the addition. The extra deletions are shifted to the last part of the matrix and each time it is shifted the activities become one less, so that finally the total number of activities are (15-2) i.e., 13. Thecritical path is through 1,2,3,5,6,8, 10,11,12 (8,12) and 13.

The revised network diagram is presented in Fig.19C. The revised schedule and bar chart are given in Plate 3.

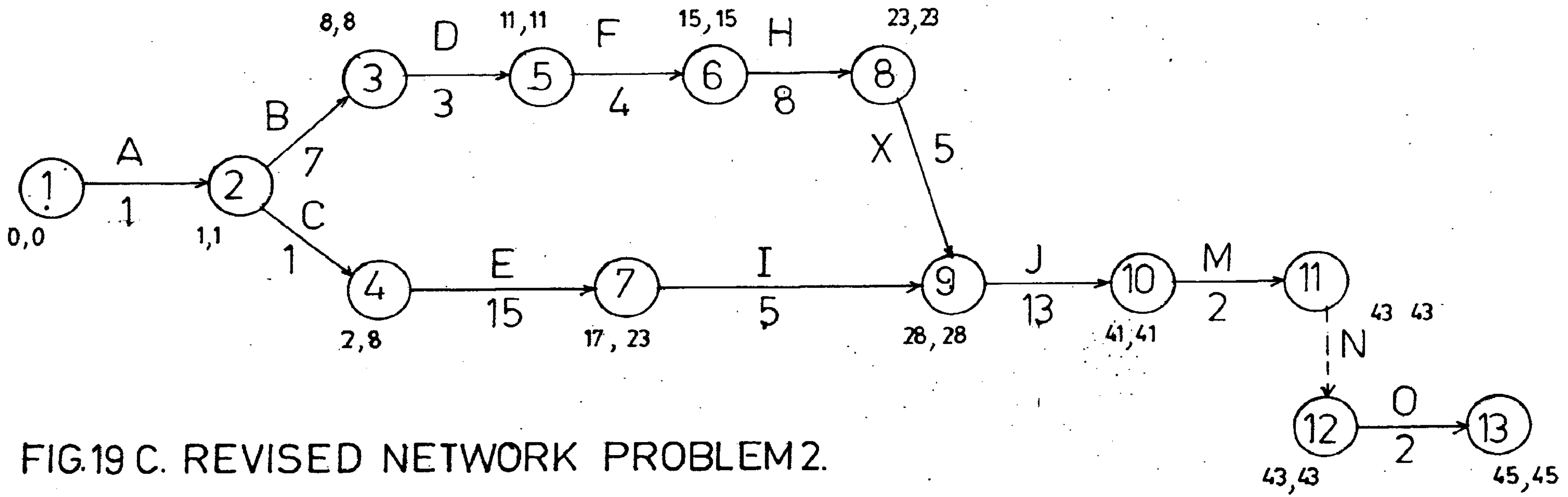


FIG.19 C. REVISED NETWORK PROBLEM 2.

5.8.3 Problem 3

From the network diagram for 'SCOPE' office complex, a small part is taken into consideration. It is fed as data to test the monitoring program. The only change in it is its duration. For the details of this part refer Chapter 6.

CHAPTER-6

REVIEW OF CASE STUDIES

6.1 INTRODUCTION

The case studies relate to the network scheduling and monitoring used in two separate buildings under construction. One is 'SCOPE' office complex, New Delhi, and second is 'Zerox complex' at Rampur. The management part of these projects are done by the management wing connected with the Architect's office. The project management wing, who has done 'SCOPE', has got more experience than those who has done Zerox complex. Zerox complex is their first project in which they used management technique. In SCOPE the computer has been used for scheduling, for daily schedules of labourers, materials etc. The type of technique used, is different. In SCOPE the CPM network is used, and in Zerox complex precedence network is used. Both these techniques have their own advantages and disadvantages. But the fact is that one will find it easier to use one technique, if he is used to it. If one person is accustomed with CPM networks, he will find it difficult to work on precedence network and vice versa.

6.2 SCOPE OFFICE COMPLEX

This is a seven storeyed building with two basements. Total floor area excluding basement is 70,000 sq.m. The total area is divided into 8 cores with independent stair-cases (Fig.20A). Estimated total cost is around 15 lakhs. Each floor is divided into 8 regions and physical division of network is done accordingly.

6.2.1 Schedule

Basic Schedule

The first step to start the project management is the discussion with the contractor. It is the contractor who decides about the duration, sequenc of works etc. It will be checked by the management team later. If there are manipulations it will be pointed out by the manager and the contractor and manager will try to come to a compromise. In any case if contractor is failing to make the basic schedule, the manager has got the right to make the drqwings himself. In that case contractor is forced to accept it. But in most cases contractor will prepare the basic network. It need not be much sophisticated or upto the standard. What the project manager needs is the approximate duration and the sequence to which the contractor can stick. He will do this according to the availability of resources like money, materials, labourers etc.

In this 'SCOPE' complex, the management section took over the work after some months. So by that time foundation

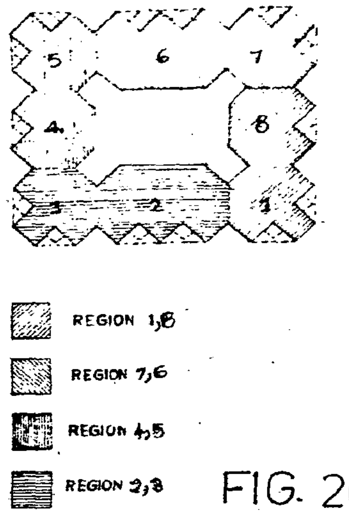


FIG. 20 -A

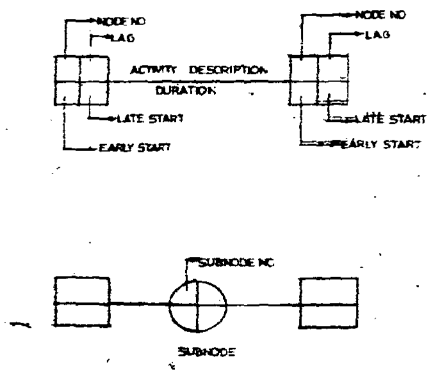
KEY

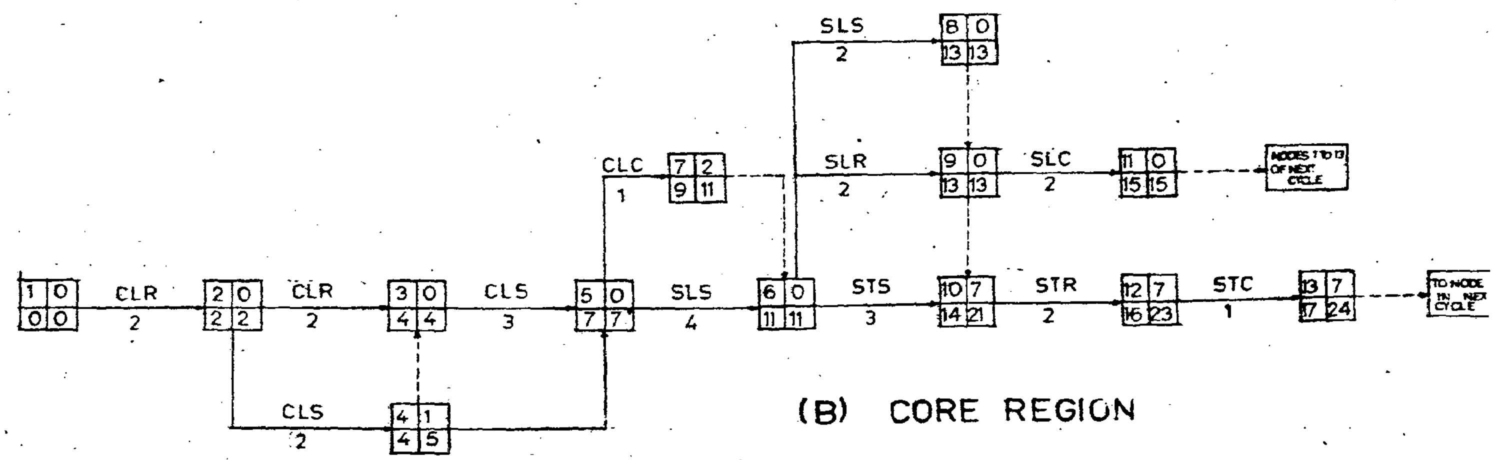
CLR COLUMN REINFORCEMENT
CLS COLUMN SHUTTERING
CLC COLUMN CONCRETING
SLR SLAB REINFORCEMENT
SLS SLAB SHUTTERING
SLC SLAB CONCRETING
STR STAIRCASE REINFORCEMENT
STS STAIRCASE SHUTTERING
STC STAIRCASE CONCRETING
LR LOUVRE REINFORCEMENT
LS LOUVRE SHUTTERING
LC LOUVRE CONCRETING

TOTAL WORKS INVOLVED IN EACH REGION ARE AS FOLLOWS

S.NO	ACTIVITY DESCRIPTION	QTY OF WORK	DURATION DAYS
1	SLAB AND BEAM SHUTTERING IN REGION 1,8; 4,5	5700 M^2	24 EACH
2	SLAB AND BEAM SHUTTERING IN REGION 7,6; 2,3	7100 M^2	24 EACH
3	REINFORCEMENT IN ABOVE MEMBERS IN REGION 1,8; 4,5	85 MT	20 EACH
4	REINFORCEMENT IN ABOVE MEMBERS IN REGION 7,6; 2,3	100 MT	20 EACH
5	CONCRETING OF ABOVE MEMBERS IN REGION 1,8; 4,5	550 M^3	16 EACH
6	CONCRETING OF ABOVE MEMBERS IN REGION 7,6; 2,3	520 M^3	16 EACH
7	REINFORCEMENT TYING IN COLUMNS, REGION 1,8; 4,5	25 M.T	8 EACH
8	REINFORCEMENT TYING IN COLUMNS REGION 7,6; 2,3	28 MT	8 EACH
9	SHUTTERING OF COLUMNS IN REGION 1,8; 4,5	80 NOS	8 EACH
10	SHUTTERING OF COLUMNS IN REGION 7,6; 2,3	96 NOS	8 EACH
11	CONCRETING OF COLUMNS IN REGION 1,8; 4,5	125 M^3	8 EACH
12	CONCRETING OF COLUMNS IN REGION 7,6; 2,3	150 M^3	8 EACH

FIG. 20 - C





(B) CORE REGION

FIG.20 -B

SCOPE

13. Internal stone cladding and Kotah stone flooring.

14. Marble cladding and flooring Lift lobby

15. Internal services water supply and sewerage.

16. External sewerage and drainage.

Brief descriptions of these items are given below.

1. R.C.C. Structure (Fig.A)

Upto 6th floor columns were over and this part of the network deals with the rest of the structure like columns above 6th floor level, roof slab, liftwell in the cores 1 and 5 etc.

2. Lower Basement (Fig.B)

The work left in this part are the following :-

Refill slab

Brickwork in different areas

P.C.C. over refill slab

Flooring hardonite

Door frame

Door shutters

Distemper, paint and polish.

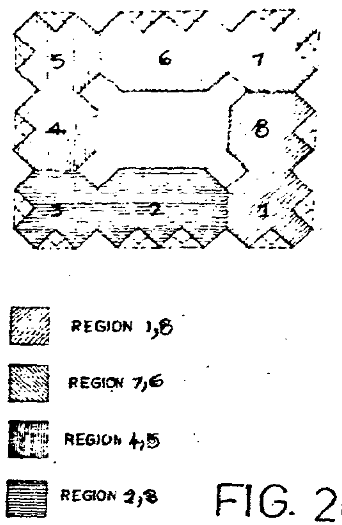


FIG. 20 -A

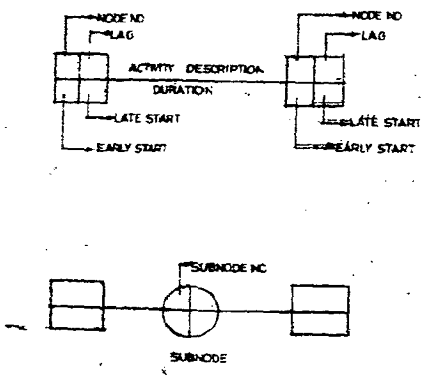
KEY

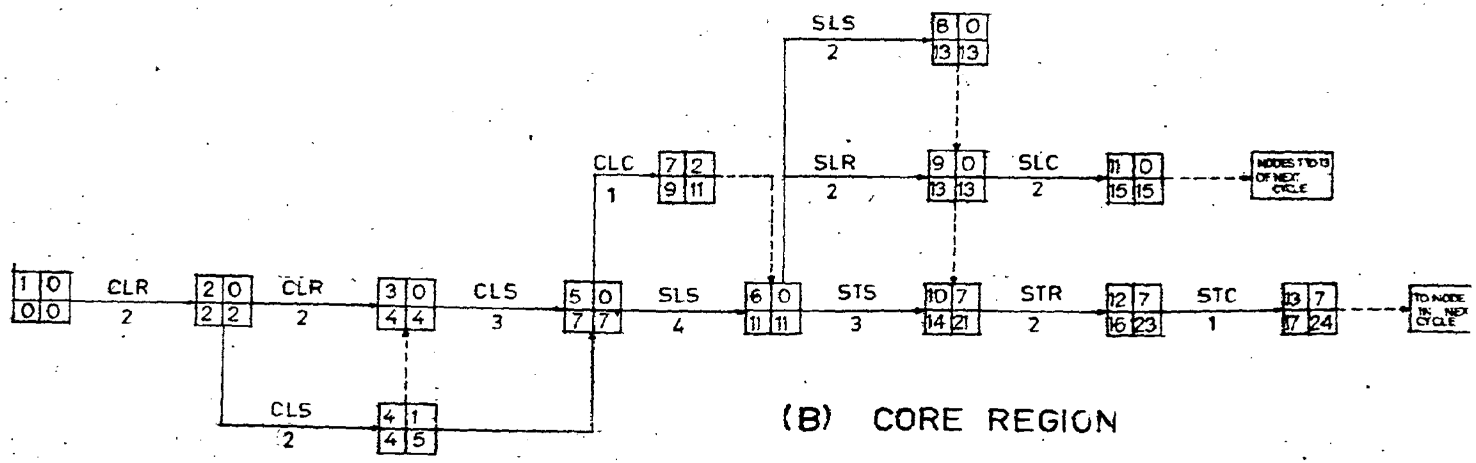
CLR COLUMN REINFORCEMENT
CLS COLUMN SHUTTERING
CLC COLUMN CONCRETING
SLR SLAB REINFORCEMENT
SLS SLAB SHUTTERING
SLC SLAB CONCRETING
STR STAIRCASE REINFORCEMENT
STS STAIRCASE SHUTTERING
STC STAIRCASE CONCRETING
LR LOUVRE REINFORCEMENT
LS LOUVRE SHUTTERING
LC LOUVRE CONCRETING

TOTAL WORKS INVOLVED IN EACH REGION ARE AS FOLLOWS

S.NO	ACTIVITY DESCRIPTION	QTY OF WORK	DURATION DAYS
1	SLAB AND BEAM SHUTTERING IN REGION 1,8; 4,5	5700 M²	24 EACH
2	SLAB AND BEAM SHUTTERING IN REGION 7,6; 2,3	7100 M²	24 EACH
3	REINFORCEMENT IN ABOVE MEMBERS IN REGION 1,8; 4,5	85 MT	20 EACH
4	REINFORCEMENT IN ABOVE MEMBERS IN REGION 7,6; 2,3	100 MT	20 EACH
5	CONCRETING OF ABOVE MEMBERS IN REGION 1,8; 4,5	550 M³	16 EACH
6	CONCRETING OF ABOVE MEMBERS IN REGION 7,6; 2,3	580 M³	16 EACH
7	REINFORCEMENT TYING IN COLUMNS, REGION 1,8; 4,5	25 MT	8 EACH
8	REINFORCEMENT TYING IN COLUMNS REGION 7,6 2,3	28 MT	8 EACH
9	SHUTTERING OF COLUMNS IN REGION 1,8; 4,5	80 NOS	8 EACH
10	SHUTTERING OF COLUMNS IN REGION 7,6; 2,3	96 NOS	8 EACH
11	CONCRETING OF COLUMNS IN REGION 1,8; 4,5	125 M³	8 EACH
12	CONCRETING OF COLUMNS IN REGION 7,6; 2,3	150 M³	8 EACH

FIG. 20 - C





(B) CORE REGION

FIG.20 -B

SCOPE

and a part of the structure was over. From that position, the contractor prepared an overall schedule for the complex. Since it is a big project and the drawings cannot be prepared in the same sheet they have split it into different parts and linked with connectors. Refer Fig. A to J for the basic network. It also gives the revised network. The project started on April 1983. First of all they wanted to finish it by January 1985. So accordingly the basic schddule is prepared.

The overall network diagram is drawn in the following order :-

1. R.C.C. structure
2. Lower basement
3. Upper basement
4. Ground floor
5. Mezzanine floor
6. First floor
7. Second Floor
8. Third floor
9. Fourth floor
10. Fifth floor
11. Sixth floor
12. Above 6th floor

13. Internal stone cladding and Kotah stone flooring.

14. Marble Cladding and flooring Lift lobby

15. Internal services water supply and sewerage.

16. External sewerage and drainage.

Brief descriptions of these items are given below.

1. R.C.C. Structure (Fig.A)

Upto 6th floor columns were over and this part of the network deals with the rest of the structure like columns above 6th floor level, roof slab, liftwell in the cores 1 and 5 etc.

2. Lower Basement (Fig.B)

The work left in this part are the following :-

Refill slab

Brickwork in different areas

P.C.C. over refill slab

Flooring hardonite

Door frame

Door shutters

Distemper, paint and polish.

3. Upper Basement (Fig.B)

In this area work to be done is shown as -

Door frame timber.

Door shutters.

Distemper, paint and polish.

4. Ground Floor (Fig.B)

Left over brick.

Kotah stone flooring.

Door frame timber.

External stone cladding.

Glazing.

Waterproofing in open area.

Marble flooring in general area.

Internal stone cladding.

Painting and polishing.

Floor polishing.

5. Mezzanine Floor (Fig.C)

Left over brickwork.

Door Frame timber.

Internal stone cladding.

Left over plaster.

Delivery door shutters.

External stone cladding.

Painting and polishing of shutters.

Glazing.

Window painting and floor polishing.

6. First Floor (Fig.C)

Left over brick work.

Door frame timber.

Steel door and window frames.

Plastering.

Terrazo flooring.

Cement flooring.

Grinding and cutting.

Glazing.

Door Shutters in general area

Painting and polishing of door shutters.

Painting walls and ceiling.

Window painting and door polishing.

7. Second Floor (Fig.D)

Left over brick work.

Door frame timber.

Steel frames for doors and windows.

Plaster.

Terrazo flooring.

Cement flooring.

External stone cladding.

Door shutters in general area.

Painting and polishing door shutters.

Glazing.

Window painting and floor polishing.

8. Third Floor (Fig.D)

Left over brick work.

Door frame timber.

Steel frame doors and windows.

Plastering.

Terrazo flooring.

Cement flooring.

Grinding and cutting.

External stone cladding.

Door shutters in general area.

Painting and polishing door shutters.

Glazing.

Painting walls and ceiling.

Window painting and floor polishing.

9. Fourth Floor (Fig.E)

Brickwork.

Door frame timber.

Steel door and window frame.

Plastering.

Terrazo flooring.

Cement flooring.

Grinding and cutting.

External stone cladding.

Door shutters in general area.

Painting and polishing door shutters.

Painting walls and ceiling.

Glazing.

Window painting and floor polishing.

10. Fifth Floor (Fig.E)

Brick work.

Additional fins.

Steel door and window frame.

External stone cladding.

Grinding and cutting.

Plastering.

Terrazo flooring.

Cement flooring.

Door shutters in general area.

Painting and polishing door shutters.

Glazing.

Window painting and floor polishing.

Painting wall and ceiling.

11. Sixth Floor (Fig.F)

Brick work.

Additional fins.

Door frame timber.

Steel door and window frame.

Plastering.

Terrazo flooring.

Cement flooring.

Door shutters in general area.

Painting and polishing door shutters.

Painting wall and ceiling.

Glazing.

Window painting and floor polishing.

12. Above 6th Floor (Fig.G)

Brick work.

Steel and timber door frame.

External stone cladding.

Plastering.

Flooring.

Roof heat insulation.

Glazing.

Window painting.

Door shutters.

Water proofing.

Terracing.

Site clear.

Hand over.

13. Internal Stone Cladding and

Kotah Stone Flooring (Fig.G)

This part deals with the Kotah stone flooring and internal s tone cladding in all floors.

14. Marble Cladding and Flooring Lift Lobby (Fig.I).

SCI fix.

Rain water pipe.

Lean Concrete filling.

Marble flooring in toilets.

Ceramic and glazed tiles in toilets.

Door shutters in toilet.

Brick work and door fi xing.

Sanitary fixing.

Testing and commissioning sanitary system.

16. External Sewerage and Drainage

Earthfill and consolidation.

Construction of mamhole covers.

Layihg and jointing sewer lines.

Construction of manhole for water drainage.

Laying water lines.

Testing and commencing waterlines.

Laying and jointing rain water.

Pipe line.

Testing and commissioning rain water pipe line.

From the above list of activities it can be seen that in all floors the work is almost same since it is single block and all the floors are similar. So work is taken floor by floor. So once the same category of work is completed in one floor, it can be started in the next floor.

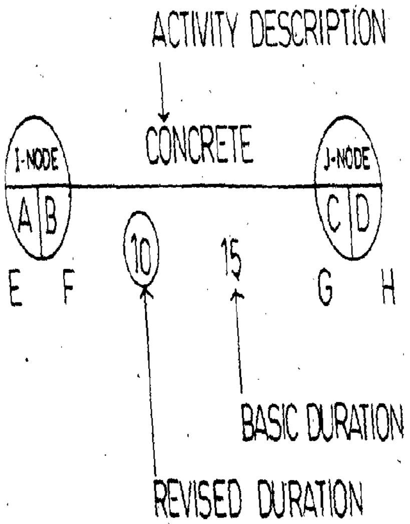
Revised Schedule (Fig. A to J)

When the construction was in progress they decided to speed it up and to complete by October '84. It was due to the fact that if it can be completed three months before the original schedule, the benefit will be more when compared with the total additional cost that to be spent. For that they reduced the duration of certain activities, without disturbing the sequence. In (Table 1) the activities, I-nodes, J-nodes, old duration revised duration and reduced duration are given. Door shutters, stone cladding, plastering, and flooring are the main items in which the time is reduced. This is done by increasing the number of labourers for these items.

FIG(A) TO (J) **SCOPE OFFICE COMPLEX**

CPM-NETWORK DIAGRAM
GIVING BASIC AND REVISED DURATION

KEY



A, C - EARLY OCCURENCE TIME
B, D - LATEST OCCURENCE TIME
→ REVISED

E, G - EARLY OCCURENCE TIME
F, H - LATEST OCCURENCE TIME
→ BASIC

RCC STRUCTURE

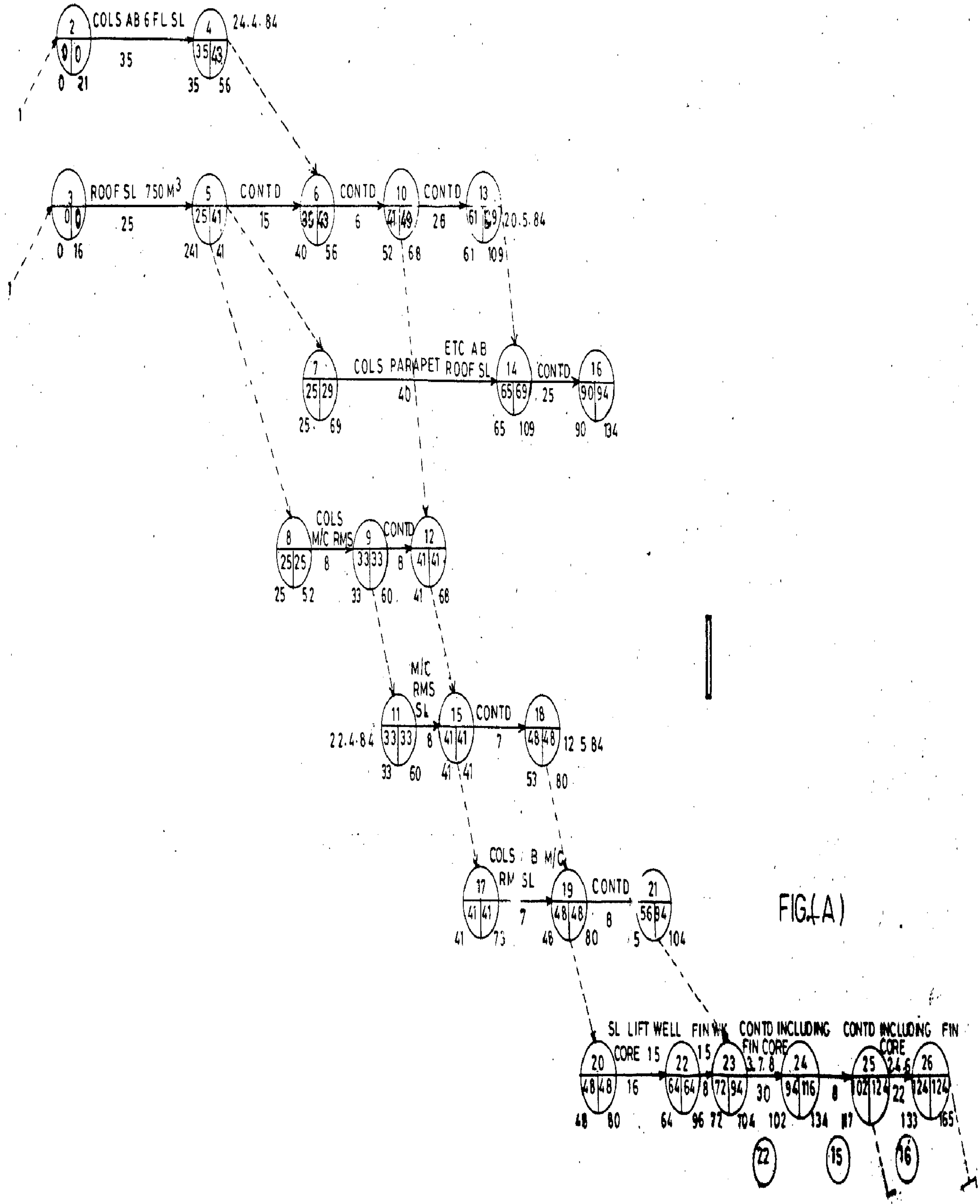
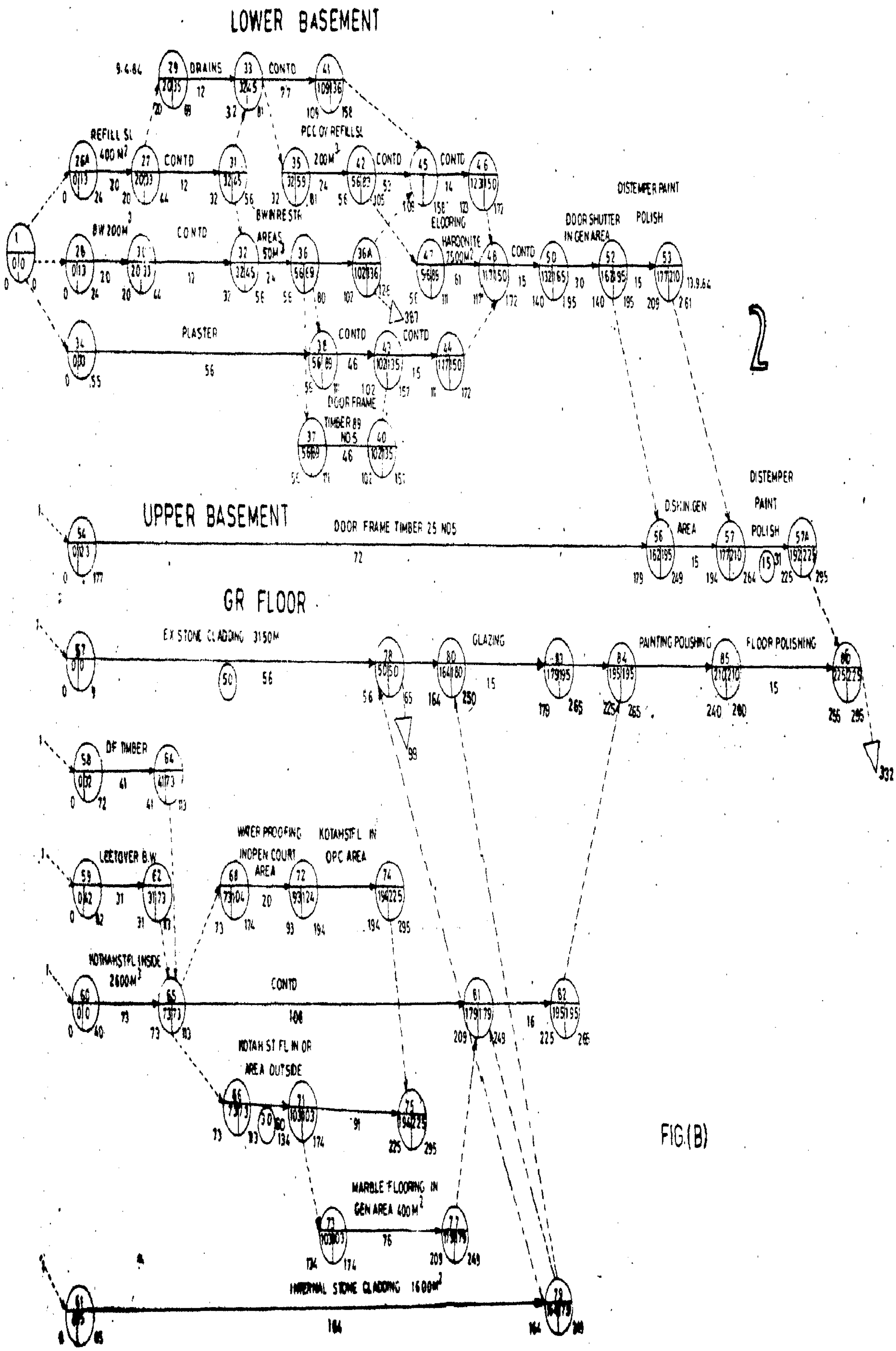


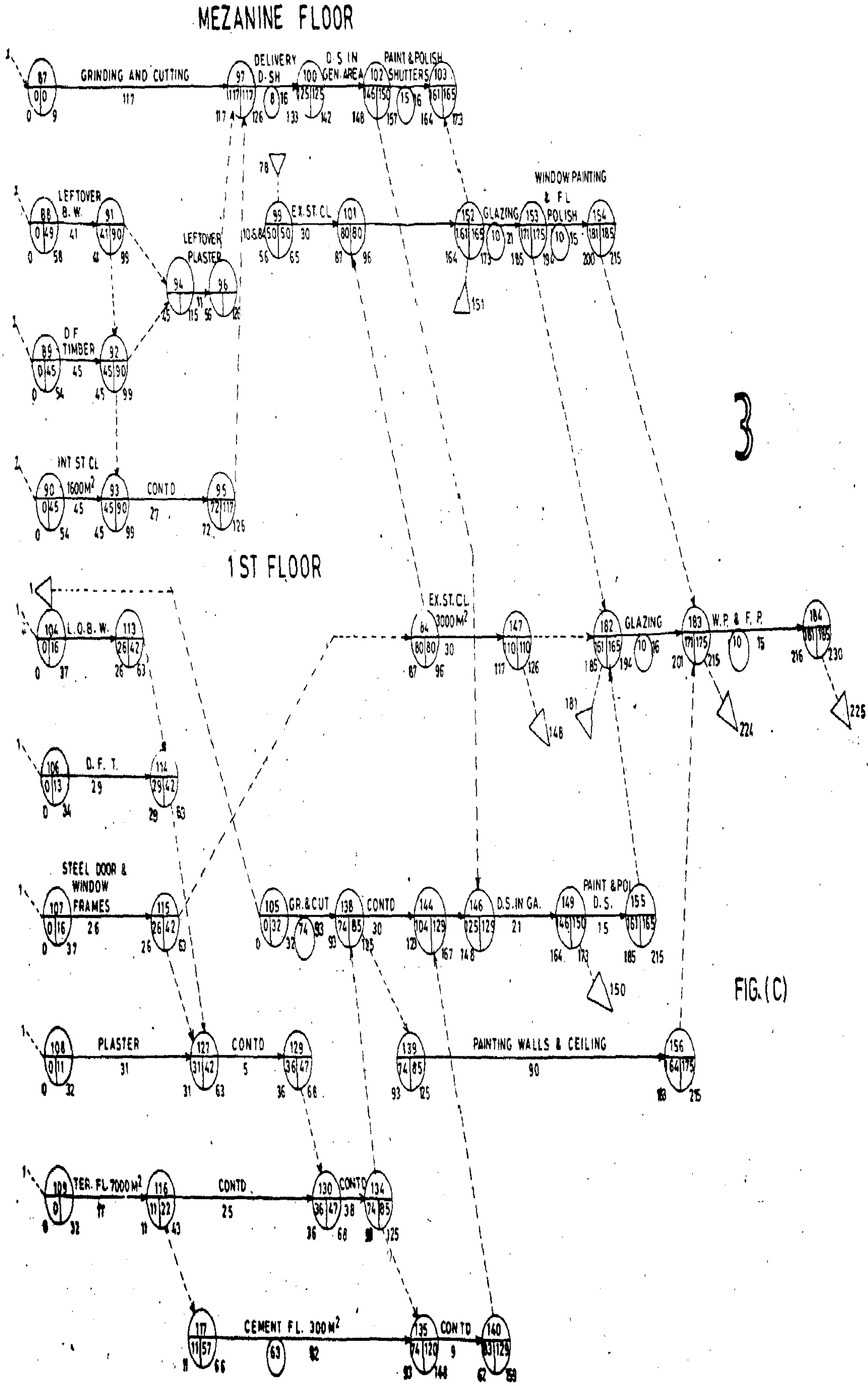
FIG.(A)

2



LOWER BASEMENT
DRAINS
CONTD
REFILL SL 400 M²
PCC OV REFILL SL 200 M³
BW 200 M³
PLASTER
BW IN REST AREAS 50 M³
DOOR FRAME TIMBER 89 NOS
FLOORING HARDONITE 2500 M²
DOOR SHUTTER IN GEN AREA
DISTEMPER PAINT POLISH
UPPER BASEMENT
DOOR FRAME TIMBER 25 NOS
DISTEMPER PAINT POLISH
GR FLOOR
EX STONE CLADDING 3150 M
GLAZING
PAINTING POLISHING
FLOOR POLISHING
DF TIMBER
LEFTOVER B.W
WATER PROOFING IN OPEN COURT AREA
KOTAH ST FL IN OPC AREA
KOTAH ST FL INSIDE 2600 M²
KOTAH ST FL IN OR AREA OUTSIDE
MARBLE FLOORING IN GEN AREA 400 M²
INTERNAL STONE CLADDING 1600 M²

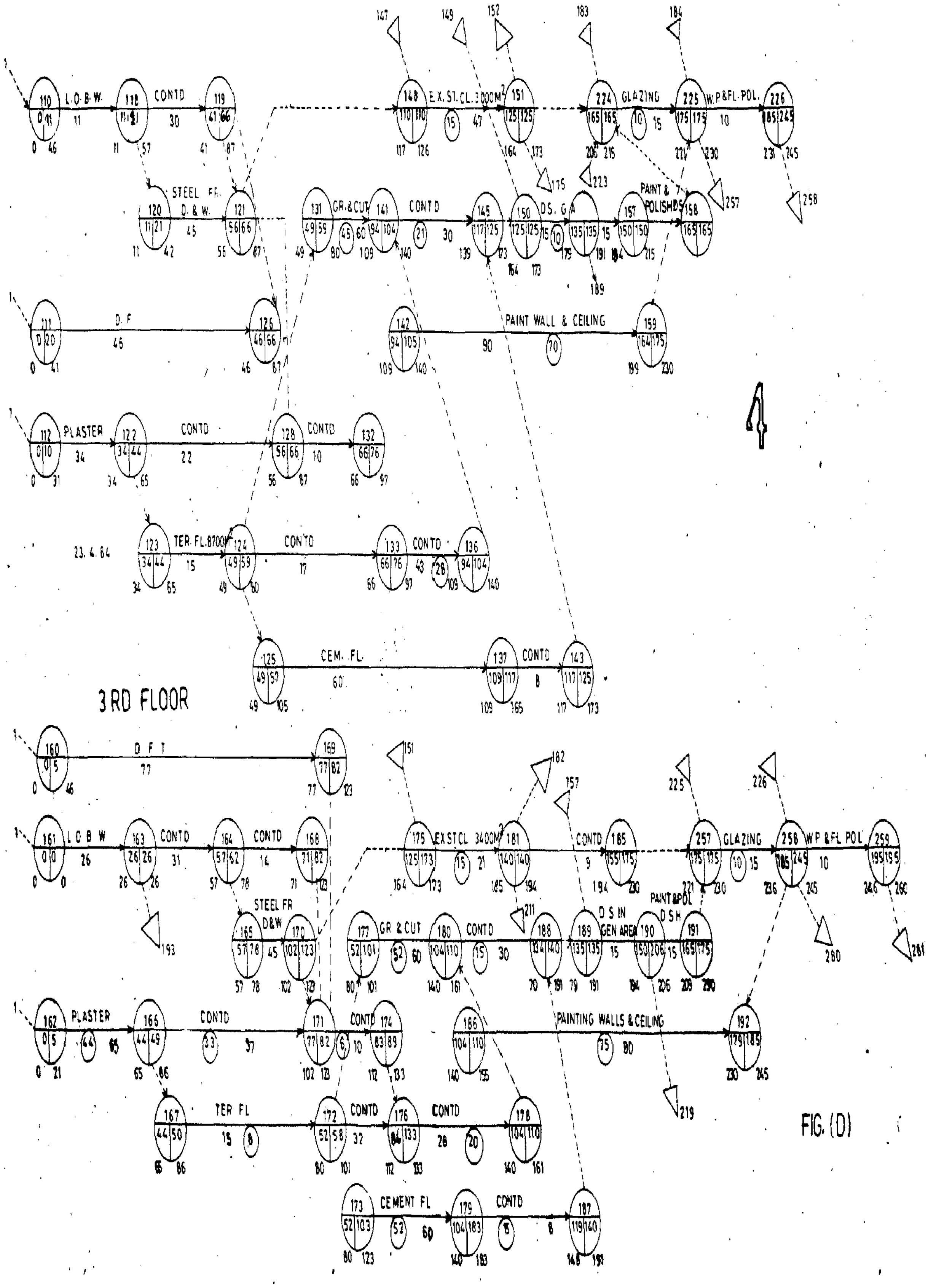
FIG.(B)


MEZANINE FLOOR
GRINDING AND CUTTING
DELIVERY D-SH
D.S IN GEN. AREA
PAINT & POLISH SHUTTERS
LEFTOVER B.W.
LEFTOVER PLASTER
EX.ST.CL.
GLAZING
WINDOW PAINTING & FL POLISH
D F TIMBER
INT ST CL 1600M²
CONTD
1 ST FLOOR
L.O.B.W.
EX.ST.CL. 3000M²
GLAZING
W.P. & F.P.
D.F.T.
STEEL DOOR & WINDOW FRAMES
GR.& CUT
CONTD
D.S.IN GA.
PAINT & POL D.S.
PLASTER
CONTD
PAINTING WALLS & CEILING
TER. FL 7000M²
CONTD.
CONTD
CEMENT F.L. 300M²
CONTD

3

FIG. (C)

2 ND FLOOR



4

FIG. (D)

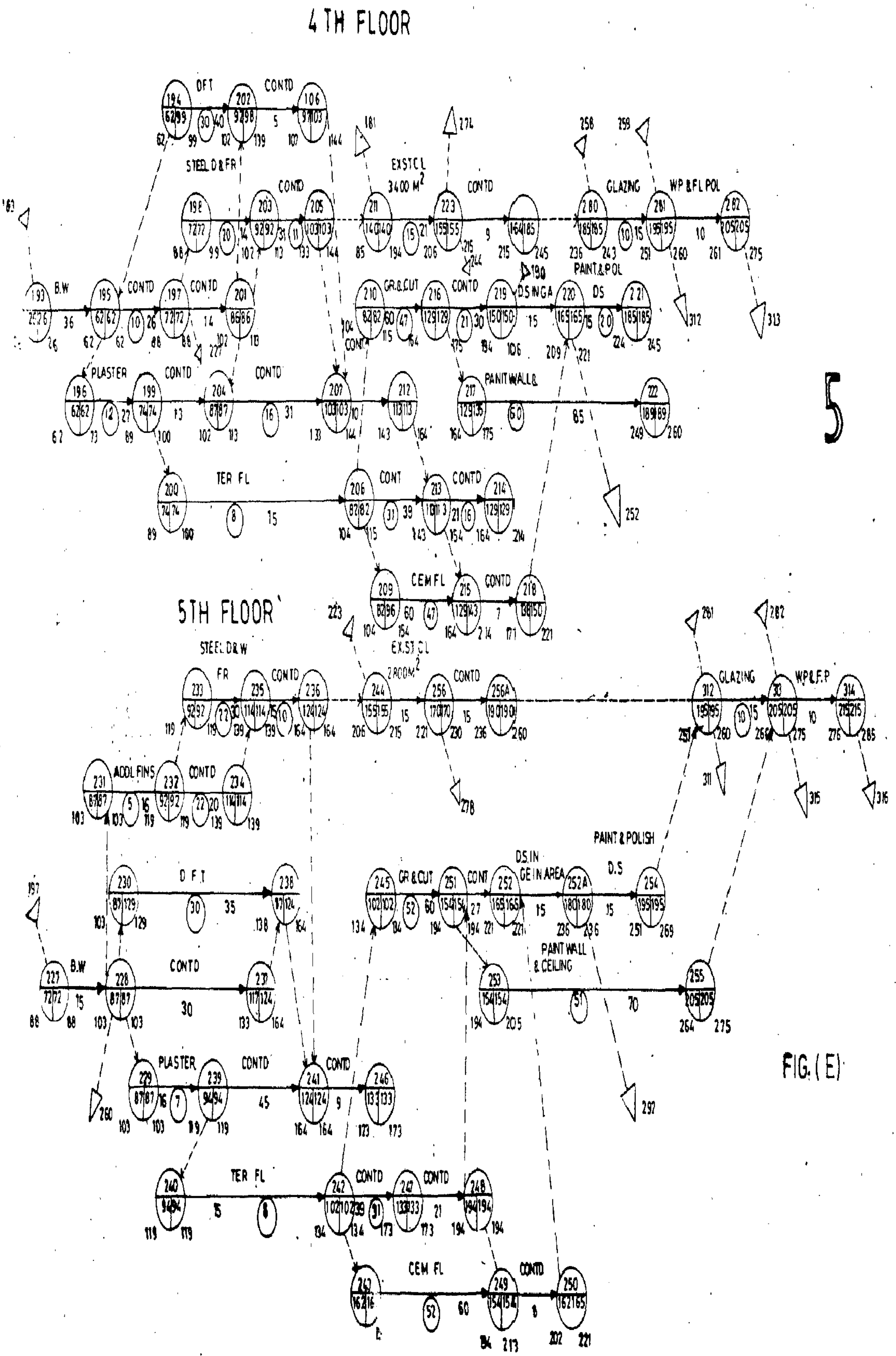

4 TH FLOOR
DFT
CONTD
STEEL D & FR
EXST CL
3400 M²
GLAZING
WP & FL POL
B.W
PAINT & POL
GR & CUT
DS IN GA
DS
PLASTER
PAINT WALL &
TER FL
CONT
CEM FL
5
5TH FLOOR
STEEL D & W
FR
EX.ST.CL
2 ROOM²
ADDL FINS
WP & F.P
PAINT & POLISH
D.S
DS IN
GE IN AREA
GR & CUT
D F T
PAINT WALL
& CEILING

FIG. (E)

6 TH FLOOR

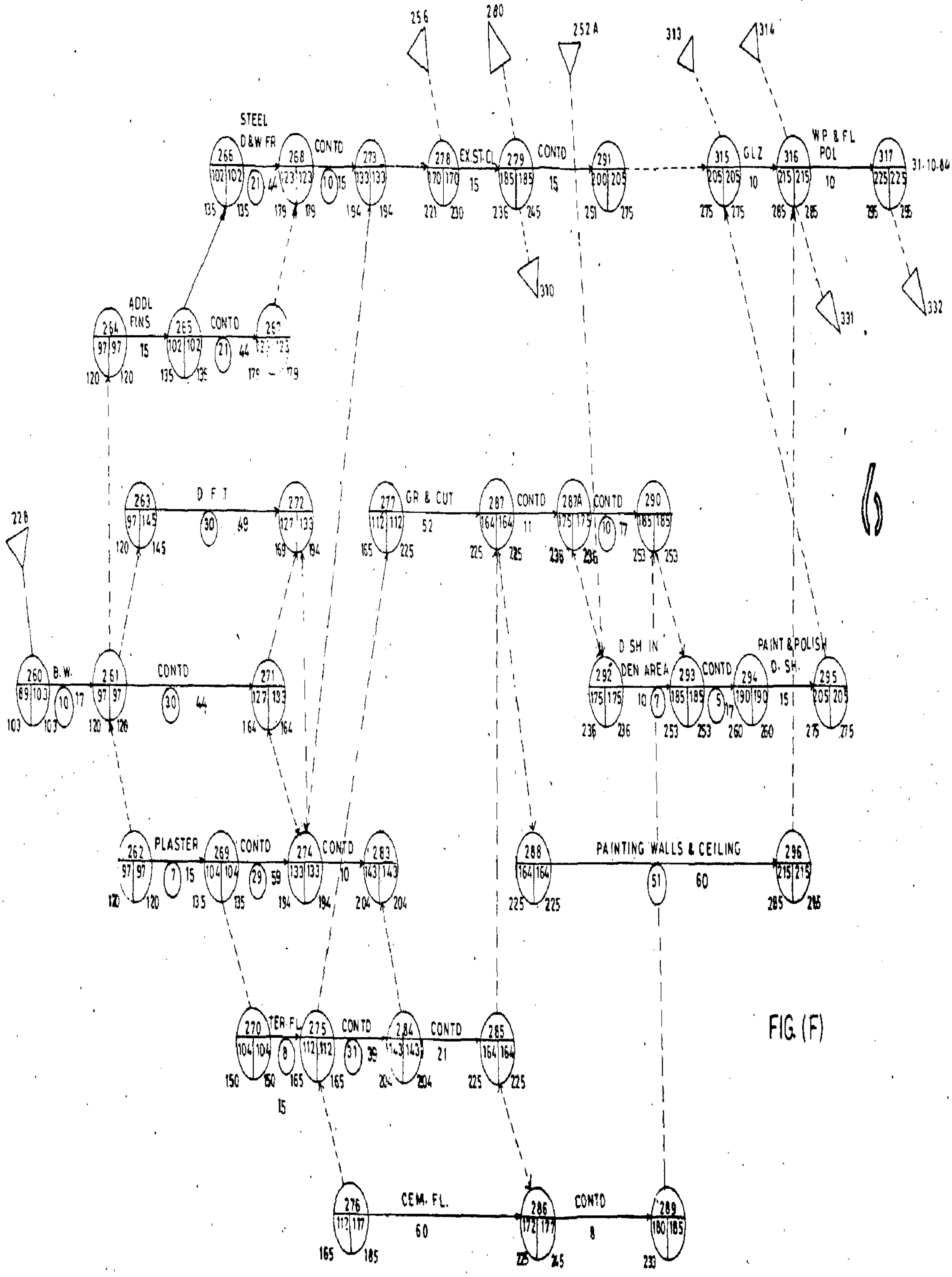
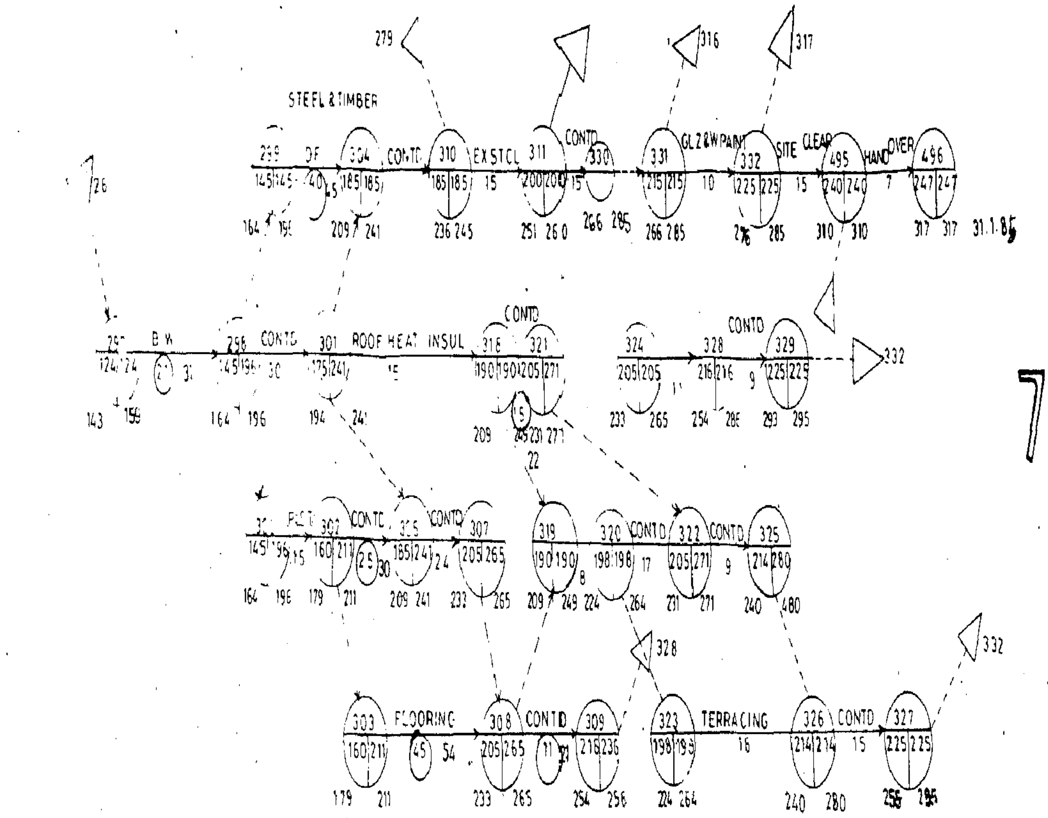


FIG. (F)

ABOVE 6TH FLOOR



7

INTERNAL STONE CLADDING
KOTAH STONE FLOORING

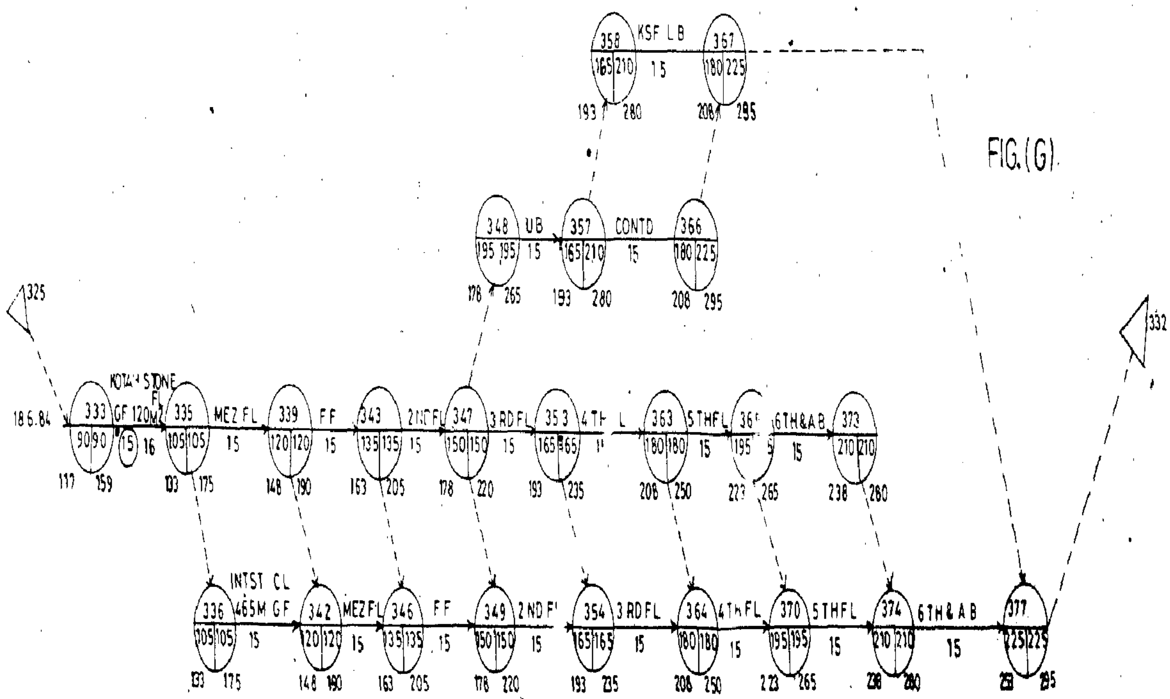
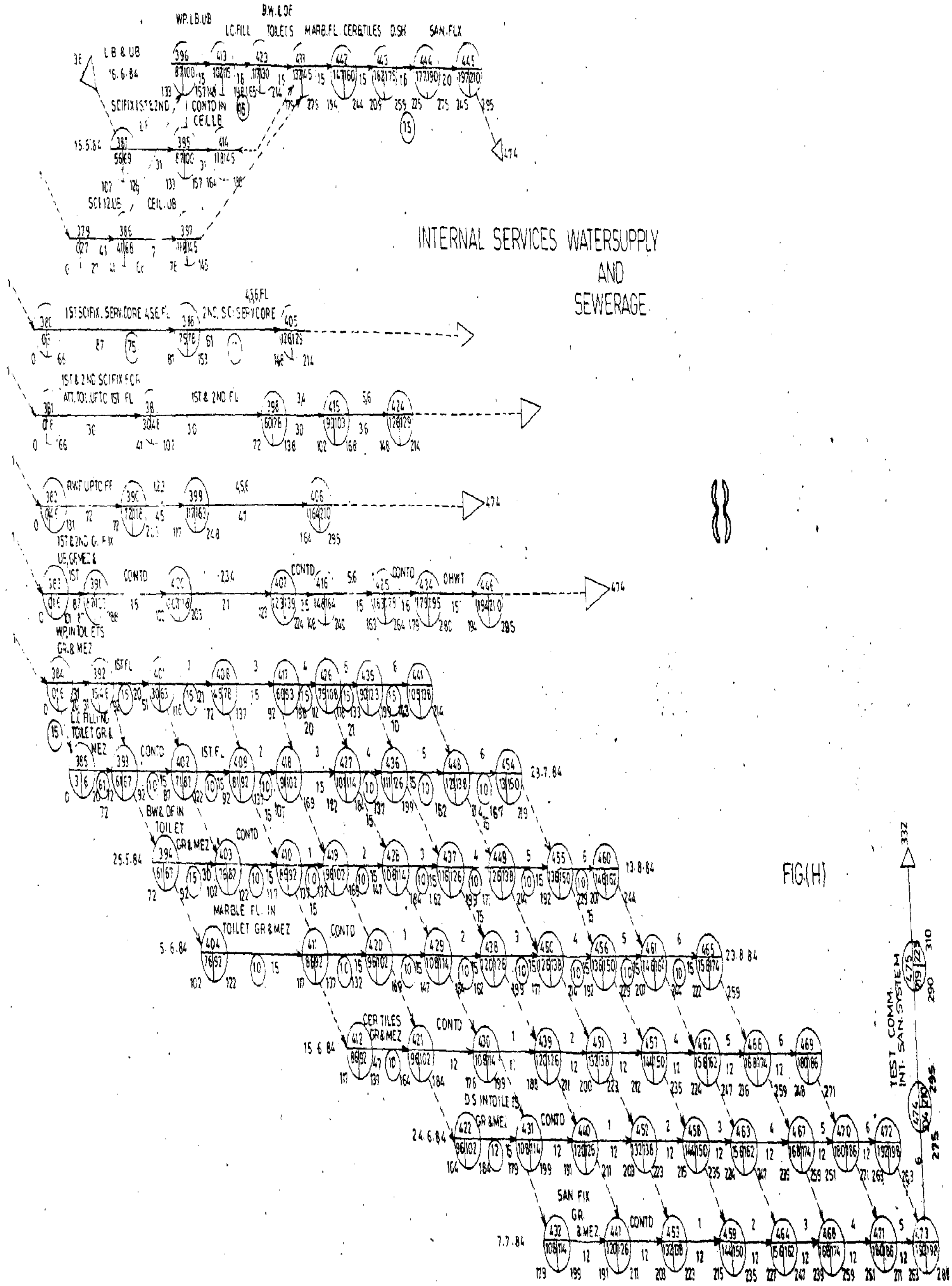


FIG.(G)

INTERNAL SERVICES WATERSUPPLY AND SEWERAGE

88



FIG(H)

MARBLE CLADDING
AND FLOORING LIFT
LOBBY

9

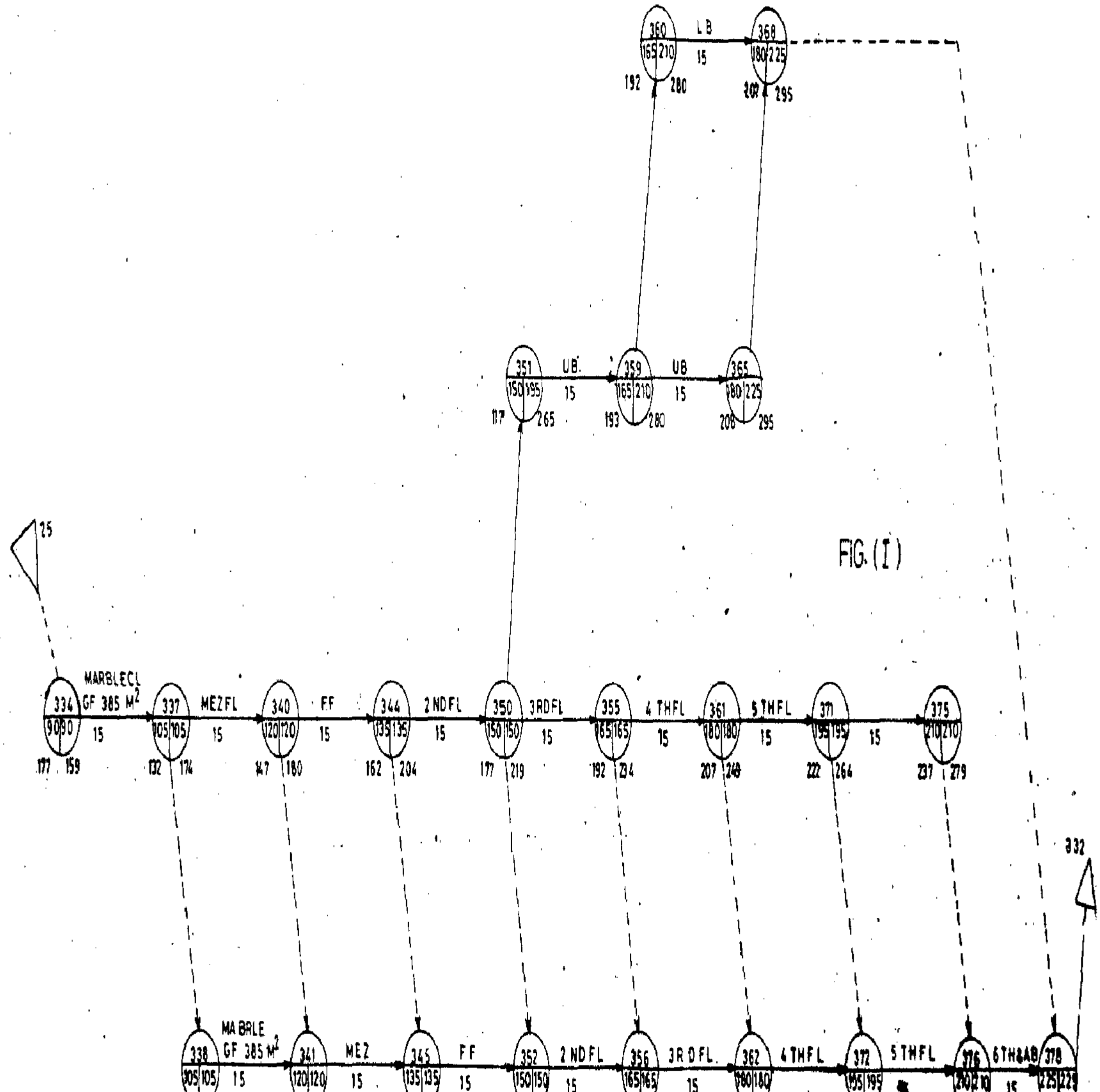
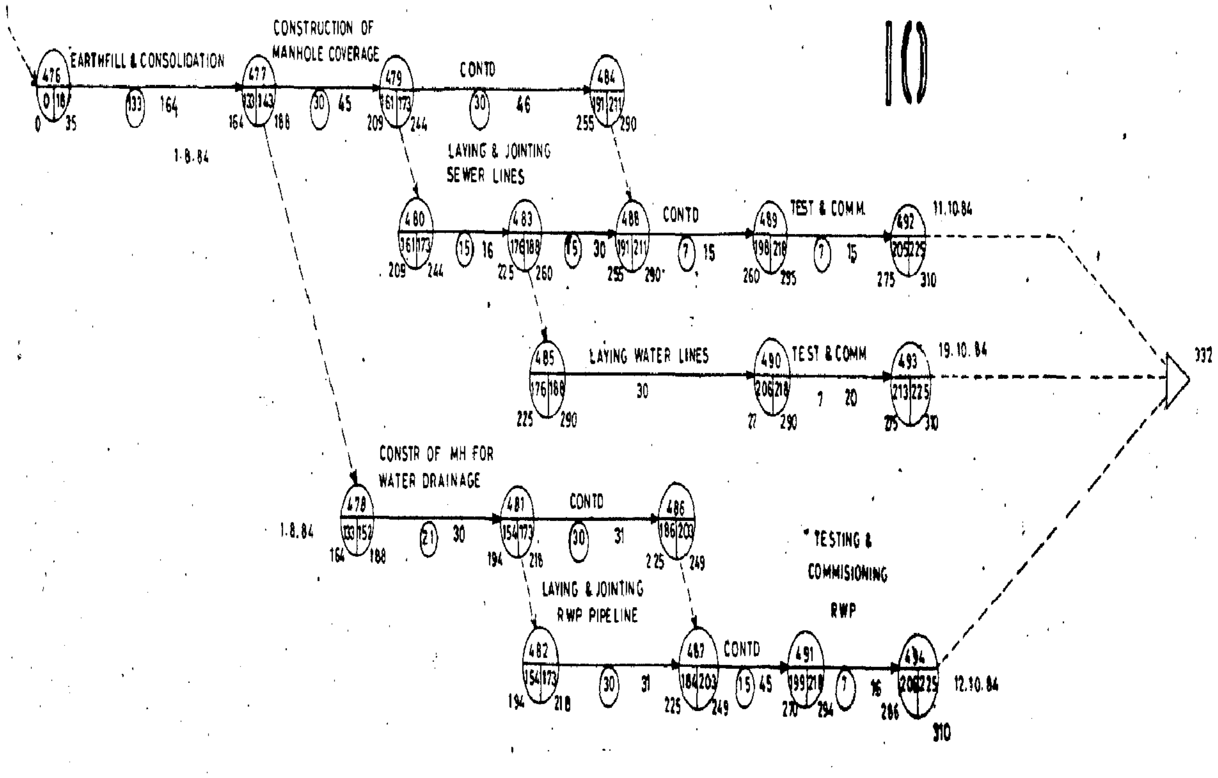


FIG. (I)

EXTERNAL SEWERAGE DRAINAGE

10



FIG(1)

DECRIPTION	I	J	OLD DUR.	REV. DUR.	RED. DUR.
1. LOWER BASEMENT					
DOOR SHUTTER IN GEN AREA	51	52	39	30	9
PAINTING & POLISHING	52	53	30	15	15
FLOORING CONTD	48	50	23	15	8
2. UPPER BASEMENT					
DISTEMPERING & PAINTING	57	57A	31	15	16
3. GROUND FLOOR					
EXTERNAL STONE CLADDING	67	78	56	50	6
KOTAH STONE FLOORING	66	71	61	30	31
MARBLE FLOOR IN GEN AREA	73	77	75	75	0
4. MEZZANINE FLOOR					
DELIVERY OF DOOR SHUTTER & D.SHUTTERS IN GEN. AREA	98 100	100 102	31	29	2
EXTERNAL STONE CLADDING	99	101	31	30	1
GLAZING	152	153	21	10	11
WINDOW PAINTING & POLISHING	153	154	15	10	5
5. FIRST FLOOR					
GRINDING & CUTTING	105	138	93	74	19
GLAZING	182	183	16	10	6
WINDOW PAINT & FLOOR POLISH	183	184	15	10	5
TER FLOORING CONTD	130	134	57	38	19
CEMENT FLOORING	117	135	82	63	19
DOOR SHUTTER IN GEN AREA PAINT & POLISH D SHUTTERS	146 149	149 155	37	36	1
6. SECOND FLOOR					
GRINDING & CUTTING	131	145	90	66	24
EXTERNAL STONE CLADDING	148	151	47	45	2
PAINTING WALL & CEILING	142	159	90	70	20
GLAZING	224	225	15	10	5
7. THIRD FLOOR					
PLASTERING	162	171	112	84	28
TER FL. CONTD	176	178	28	21	7
CEMENT FLOORING	173	187	68	67	1
PAINT WALL & CEILING	186	192	90	75	15
GLAZING	257	258	15	10	5
8. FOURTH FLOOR					
DOOR FRAME TIMBER	194	202	40	30	10
STEEL DOOR & WINDOW FRAME	198	205	45	31	14
PLASTERING	196	212	81	53	28
TER FLOORING	200	214	75	55	20
CEMENT FLOORING	209	275	60	47	13
GLAZING	280	281	15	10	5

DECRIPTION	I	J	O.D	R.D	RED. DUR.
9. FIFTH FLOOR					
STEEL DOOR & WINDOW FRAME	233	236	45	32	13
ADDITIONAL FINS	231	234	36	27	9
DOOR FRAME TIMBER	230	238	35	30	5
PLASTERING	229	241	70	61	9
CUTTING & GRINDING	245	251	60	52	8
PAINTING WALL & CEILING	253	255	85	51	34
TER. FLOORING	240	248	75	50	15
CEMENT FLOORING	243	250	68	60	8
10. SIXTH FLOOR					
DOOR & WINDOW FRAME STEEL	266	273	59	31	28
ADDITIONAL FINS	264	267	59	26	33
DOOR FRAME TIMBER	263	272	49	30	19
BRICKWORK	260	271	61	40	21
PLASTERING	262	283	84	46	38
TER. FLOORING	270	285	75	60	15
PAINTING WALL & CEILING	286	296	60	51	9
11. ABOVE SIXTH FLOOR					
STEEL & TIMBER DOOR FRAME	299	304	45	40	5
BRICKWORK	297	298	31	21	10
PLASTERING CONTD	302	305	30	25	5
FLOORING CONTD	303	309	75	56	19
12. INTERNAL SERVICE					
SCI FIX SERVICE CORE	380	388	87	75	12
SCI 2ND FIX SERVICE CORE	388	405	61	51	10
SCI ATTACHED TOILET	381	424	118	96	22
WATERPROOFING IN TOILETS MEZ FL	384	392	31	15	16
CONTD	392	401	20	15	5
CONTD	401	408	21	15	6
CONTD	417	426	20	15	5
LEAN CONCRETE FILLING TOILETS GF & MEZ	385	393	72	61	11
CONTD	393	402	15	10	5
1ST. FL	402	409	15	10	5
BRICKWORK & DOOR FIXING IN TOILETS GF & MF	394	403	30	15	15
CONTD	403	410	15	10	5
1ST FL	410	419	15	10	5
2ND FL	419	428	15	10	5
3RD FL	428	437	15	10	5
4TH FL	437	449	15	10	5
5TH FL	449	455	15	10	5
6TH FL	455	460	15	10	5
MARBLE FLOORING IN ALL FLOORS	404	465	120	80	40
CERAMIC TILE GR. & MEZ	412	421	47	10	37
DOOR SHUTTERS IN TOILETS	422	431	15	12	3

DESCRIPTION	I	J	O.D	R.D	
13. EXTERNAL SEWERAGE					
EARTHFILL & CONSOLIDATION	476	477	164	133	31
CONSTRUCTION OF MANHOLE	477	479	45	30	15
CONTD	479	484	46	30	16
LAYING & JOINTING SEWER LINE	480	483	16	15	1
CONTD	483	488	30	15	15
CONTD	488	489	15	7	8
TESTING & COMMISSIONING SEWER LINE	489	492	15	7	8
TESTING & COMM. WATERLINE	480	483	20	7	13
CONSTN OF MANHOLE FOR DRAINAGE	478	481	30	21	9
CONTD	481	486	31	30	1
LAYING & JOINTING RWP PIPELINE	482	487	31	30	1
CONTD	487	491	45	15	30
TESTING	491	494	16	7	9

REVISED DURATION OF ACTIVITIES

TABLE 1

SCOPE

6.2.2 Labour Norms and Per Day Output :

The duration for each activities depended on the materials and manpower available. Network diagram was drawn assuming that the materials were available. If some unavoidable circumstances arise like shortage of cement and steel, that should be taken into account. In this project it is assumed that materials are available at time. The next factor is manpower. It should be calculated that how much manpower is required for each job. Then it should be compared to the available number. For calculating the manpower for each work, either the contractor can findout the number from his experienc or he can adopt some standard norms derived by some other organisation. In SCOPE complex the NBO (National Building Organisation) Labour Norms are used. But since the management team was not satisfied with some of these, they made some changes. Table 2 A gives the norms for SCOPE office complex. For each item it gives the required manpower for certain quantity of work.

From these norms it can be seen that for certain amount of work certain manpower is required. The total quantity of work can be calculated. Table 2B gives per day output required for completion by January 1985. In this case it becomes easier to check the progress of the work done per day. In the monitoring stage it will be useful.

(A) LABOUR NORMS FOR SCOPE OFFICE COMPLEX

(A)

1. R.C.C. COLUMNS PER COLUMN

BAR BENDER	2.1 DAY
CARPENTER	1.964 DAY
MASON	0.116 DAY
HELPER	11.035 DAY

2. R.C.C. SLAB CASTING PER M^3

BAR BENDER	1.260 DAY
CARPENTER	2.864 DAY
MASON	0.100 DAY
HELPER	8.261 DAY

3. BRICKWORK PER M^3

MASON	0.95 DAY
HELPER	2.109 DAY

4. PLASTER PER M^2

MASON	0.863 DAY
HELPER	0.166 DAY

5. TERRAZO FLOOR PER M^2

MASON	0.300 DAY
HELPER	0.600 DAY

6. D&W FRAME FIXING (TIMB) NOS

MASON	0.300 DAY
HELPER	0.500 DAY

7. D&W FRAME FIXING (STEEL) NOS

MASON	1.000 DAY
HELPER	3.000 DAY
WELDER	0.500 DAY

8. EXTERNAL STONE CLADDING PER M^2

MASON	0.500 DAY
HELPER	0.300 DAY

9. CEMENT FLOORING PER M^2

MASON	0.180 DAY
HELPER	0.450 DAY

10. DOOR SHUTTER FIXING NOS

CARPENTER	0.500 DAY
HELPER	1.000 DAY

11. REFILL SLAB PER M^3

BAR BENDER	0.600 DAY
MASON	0.100 DAY
HELPER	3.840 DAY

12. P.C.C. OVER REFILL SLAB PER M^3

MASON	0.100 DAY
HELPER	3.000 DAY

13. HARDONITE FLOORING PER M^2

MASON	0.200 DAY
HELPER	0.450 DAY

14. INTERNAL STONE CLADDING ALL TYPE PER M^2

MASON	0.67 DAY
HELPER	0.45 DAY

15. FLOOR CUTTING & GRINDING PER M^2

HELPER	0.200 DAY

16. ADDITIONAL FINS PER NOS

MASON	0.026 DAY
BAR BENDER	0.315 DAY
CARPENTER	1.500 DAY
HELPER	3.060 DAY

17. MARBLE & KOTAH STONE FLOORING PER M^2

MASON	0.170 DAY
HELPER	0.220 DAY

18. MARBLE/KOTAH STONE FLOORING IN STAIR & LIFT LOBBY PER M^2

MASON	0.236 DAY
HELPER	0.220 DAY

TABLE 2-A

(B) PER DAY OUTPUT REQD. FOR COMPLETION BY 31ST JAN. 1985

A. STRUCTURE	
1 COLUMN ABOVE 6TH FLOOR	3 NOS
2 CASTING ROOF SLAB	40 M^3
3 M/C ROOMS COLUMNS	6 NOS
4 M/C ROOMS SLAB (INCLUDING FINISHING PARAPET WATER TANK ETC)	12 M^3
5 REFILL SLAB (L.B)	13 M^3
6 P.C.C. OVER REFILL SLAB L B	23 M^3
B. FINISHING WORKS	
1 BRICKWORK	16 M^3
2 DOOR FRAMES TIMBER	6 NOS.
3 DOOR & WINDOW FRAMES S...	6 NOS
4 PLASTERING	91 M^2
5 FLOORING	
A. KOTAH STONE (GF)	19 M^2
B. TERRAZO	180 M^2
C. CEMENT	7 M^2
D. HARDONITE (L B)	100 M^2
E. MARBLE (GF)	20 M^2
6 TERRAZO FLOOR CUTTING	170 M^2
7 STONE CLADDING	
A. INTERNAL STONE CLADDING (GF & MF)	35 M^2
B. EXTERNAL STONE CLADDING	96 M^2
8 FIXING OF DOOR SHUTTERS	10 NOS
9 STAIRCASE & SERVICE CORES	
A. SANDSTONE FLOORING	7 M^2
B. INTERNAL STONE CLADDING	24 M^2
10 LIFT LOBBY	
A. MARBLE CLADDING	20 M^2
B. MARBLE FLOORING	8 M^2

TABLE 2-B

SCOP

6.2.3 Division of Network

As stated in the introduction part of this chapter, if the Fig.20A is referred it can be seen that the total area of the building is divided into 4 regions and 8 cores. Since it is similar in all floors the network can be divided into different parts, insuch a way that it represents cycles or chains. In Fig.21 the cycles used in different part is shown. In that network nodes 1 to 18 represent work in one zone (either 1 or 8, 7 or 6, 4 or 5, 2 or 3), and nodes 19 to 35 represent work in the other zone.

Cycle time for a zone is 22 days. Node 15 is the start of the second cycle beginning with node 1 again with similar progress in other floors. From the node 1 the work for anyone region will be started. Node 1 to 18 gives the column reinforcement, column shuttering, column concreting slab shuttering, slab reinforcement and slab concreting for one region. When the work is completed it will take for another region. Simultaneously with the first cycle, nodes 19 to 35 can be used for another region. By the time this is over the cycle (1 to 18) will be already started.

Core Region

Fig. 20B shows the cycle of activities for the core region. It consists of the following activities :- column reinforcement, column shuttering, column concreting, slab

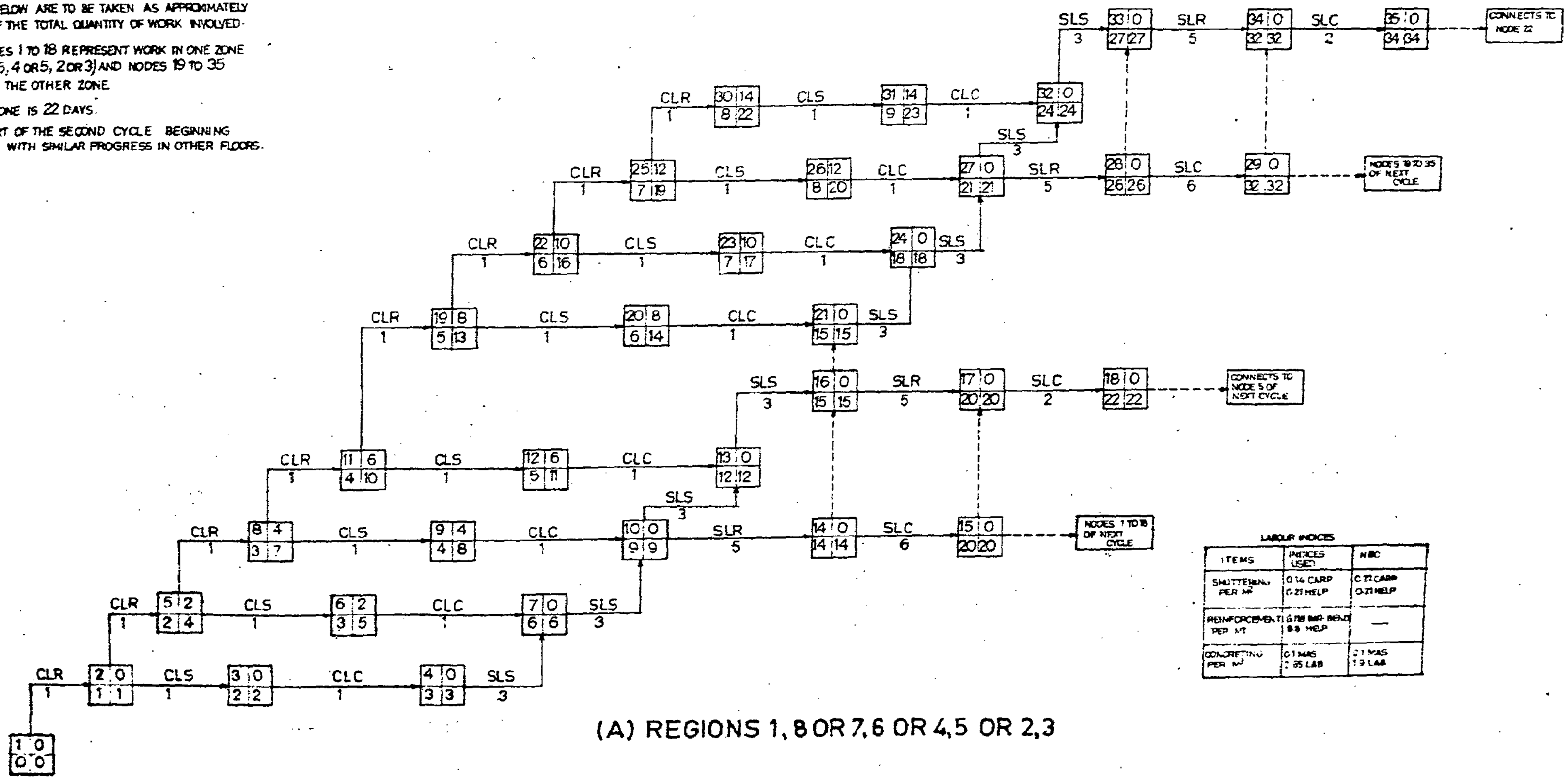
NOTES

ACTIVITY DESCRIPTORS EXPLAINED IN THE KEY AND DETAILED IN THE NETWORKS BELOW ARE TO BE TAKEN AS APPROXIMATELY EQUAL DIVISIONS OF THE TOTAL QUANTITY OF WORK INVOLVED.

IN NETWORK (A) NODES 1 TO 18 REPRESENT WORK IN ONE ZONE (EITHER 1 OR 8, 7 OR 6, 4 OR 5, 2 OR 3) AND NODES 19 TO 35 REPRESENT WORK IN THE OTHER ZONE.

CYCLE TIME FOR A ZONE IS 22 DAYS.

NODE 15 IS THE START OF THE SECOND CYCLE BEGINNING WITH NODE 1 AGAIN WITH SIMILAR PROGRESS IN OTHER FLOORS.



LABOUR INDICES

ITEMS	INDICES USED	NBC
SHUTTERING PER M^2	0.14 CARP 0.27 HELP	0.72 CARP 0.27 HELP
REINFORCEMENT PER MT	6.78 BAR BEND 8.8 HELP	—
CONCRETING PER M^3	0.1 MAS 2.85 LAB	0.1 MAS 1.9 LAB

(A) REGIONS 1, 8 OR 7, 6 OR 4, 5 OR 2, 3

FIG-21

SCOPE

shuttering, slab reinforcement, slab concreting, staircase shuttering, staircase reinforcement and staircase concreting. From Node 1 to node 11 column and slab work will be over and it comes to the node 1 for second cycle. Simultaneously the staircase work will be over and node 13 will be connected to node 5 for all the core region. Fig.20C gives the total works involved in each region.

- Structural Work

Fig. 22 is a revised form of the structural work. It consists of three cycles. Node 1 to 20 is the first cycle, node 24 to 46 is the second cycle and node 40 to 53 the third cycle. These cycles will be repeated until the particular work is over.

Finishing Work

Fig. 23A refers to the electrical work.
This includes ;

Brickwork.

Conduits/Boxes fixing.

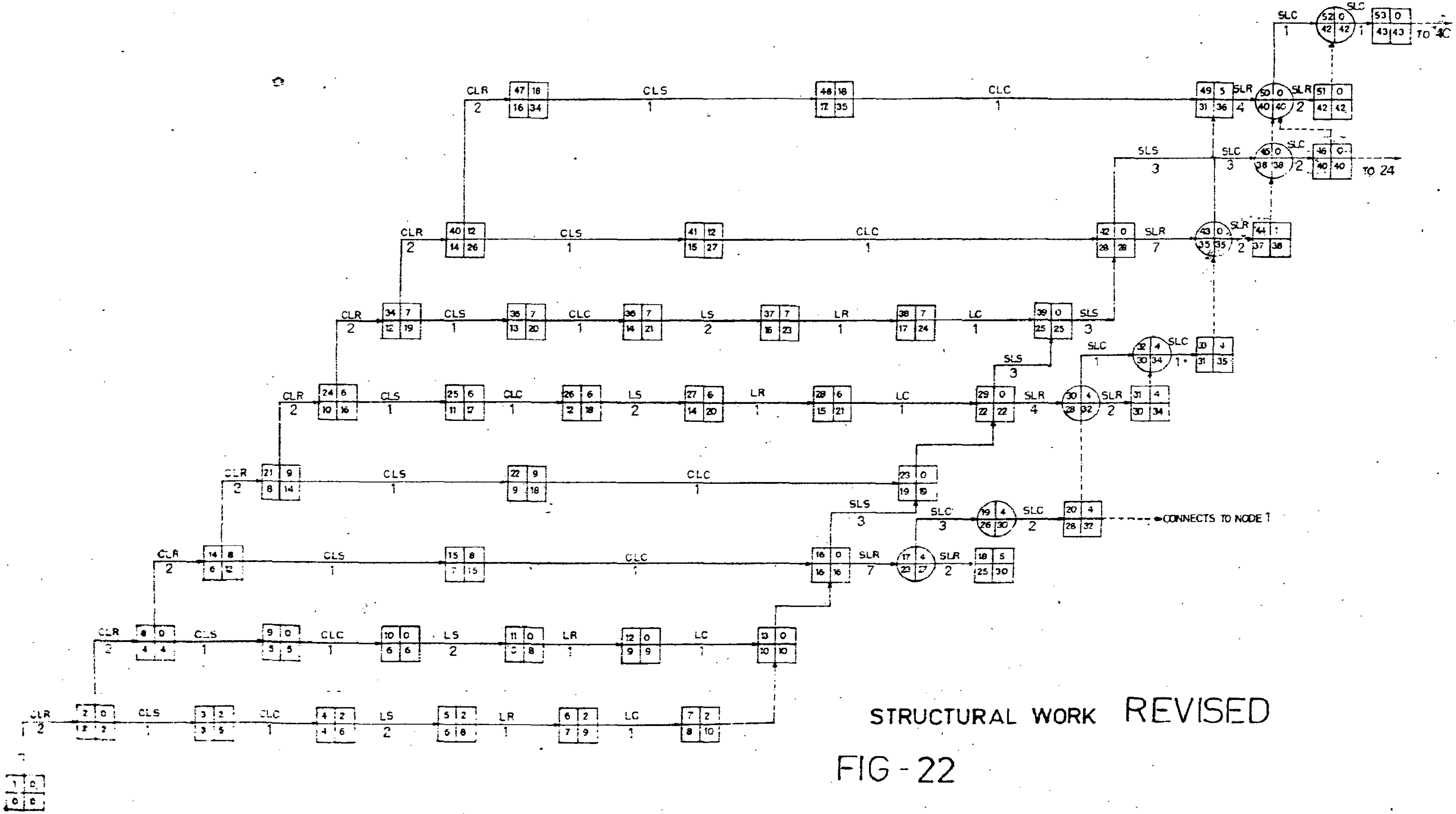
wire pulling.

Plastering.

Under cushion.

Painting.

Electrical fitting etc.



STRUCTURAL WORK REVISED

FIG - 22

SCOPE

From Node 1 to node 14 one cycle progresses in one region. Again it will be repeated in other region Fig.23B gives the work in the toilet area. This part includes :-

Brick work

Conduit boxes fixing.

Sanitary water piping.

Sanitary fixtures.

Plastering.

Stone cladding.

Under cushion.

Floor skirting.

Curing and polishing.

Fixing door, window and glazing.

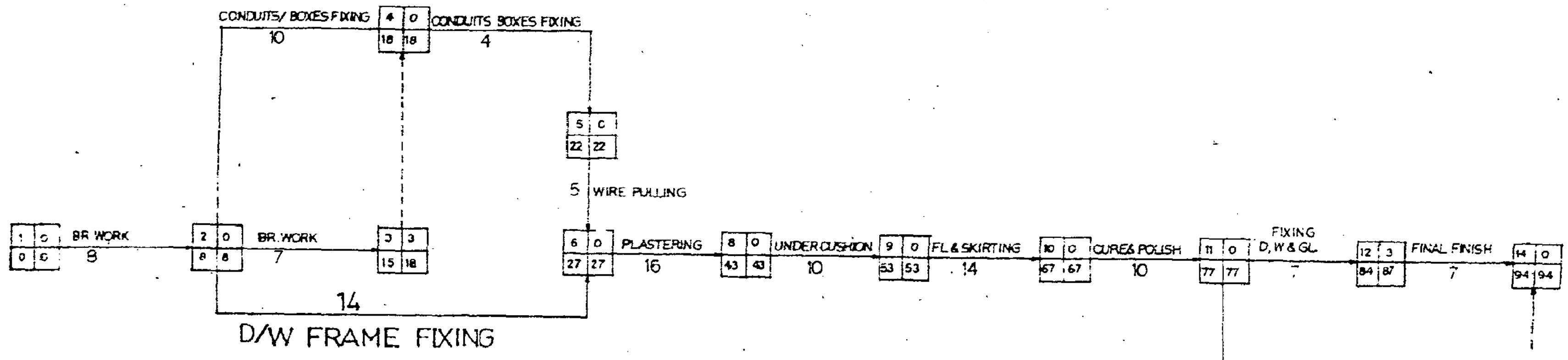
Final finish.

Electrical fittings.

From node 1 to 18 the finishing work in the toilet area in each region is progressed. After completing one region, it will be repeated in other regions also.

6.2.4 Bar Chart

Bar chart is the earliest technique by which one can see the progress of the work. From network diagram bar chart for different regions will be drawn. From a bar chart at a glance we can tell that whether one work is in time,

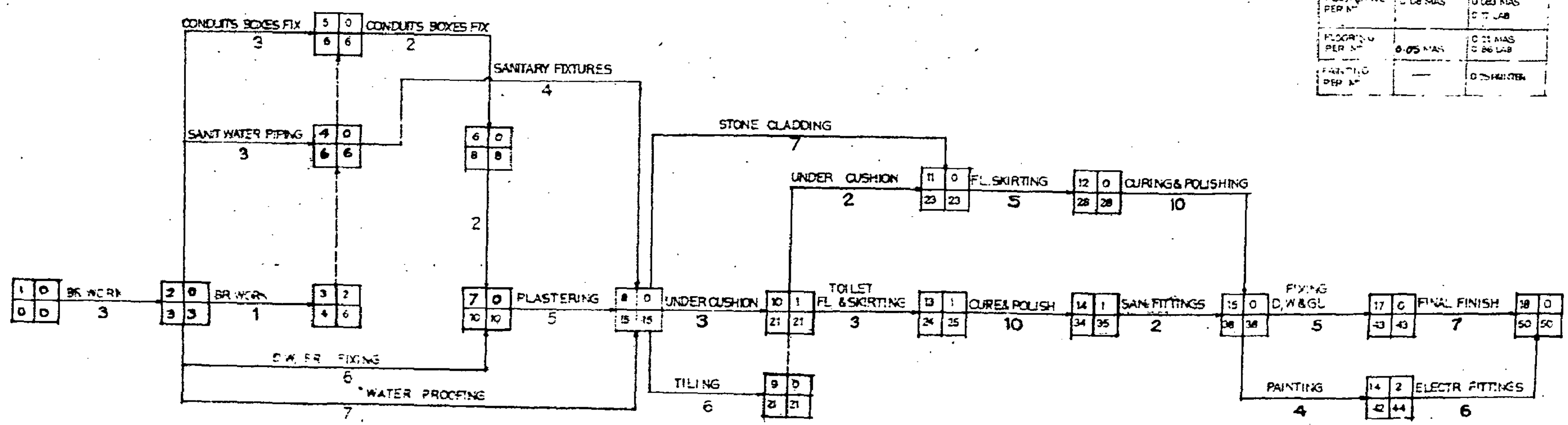


REGIONS 1,8 OR 7,6 OR 4,5 OR 2,3

FIG. 23-A

LABOUR INDICES

ITEMS	INDICES USED	NBO
BRICKWORK PER M3	0.86 MAS 1 LAB	0.82 MAS 1.6 LAB
PLASTERING PER M2	0.08 MAS	0.083 MAS 0.17 LAB
FLOORING PER M2	0.05 MAS	0.21 MAS 0.86 LAB
PAINTING PER M2	—	0.25 [illegible]



CORE REGIONS 1 OR 2 OR 3 ------ OR 8

FINISHING WORK TYPICAL CYCLE

FIG. 23 B

SCOPE

ahead of time, or behind the time. First of all the bars will be drawn for all the work in a time scale. At a point in time the bar can be shaded to show the progress of work. In Fig.24 bar chart is drawn for all the work in the work in SCOPE complex.

6.2.5 Use of Computer

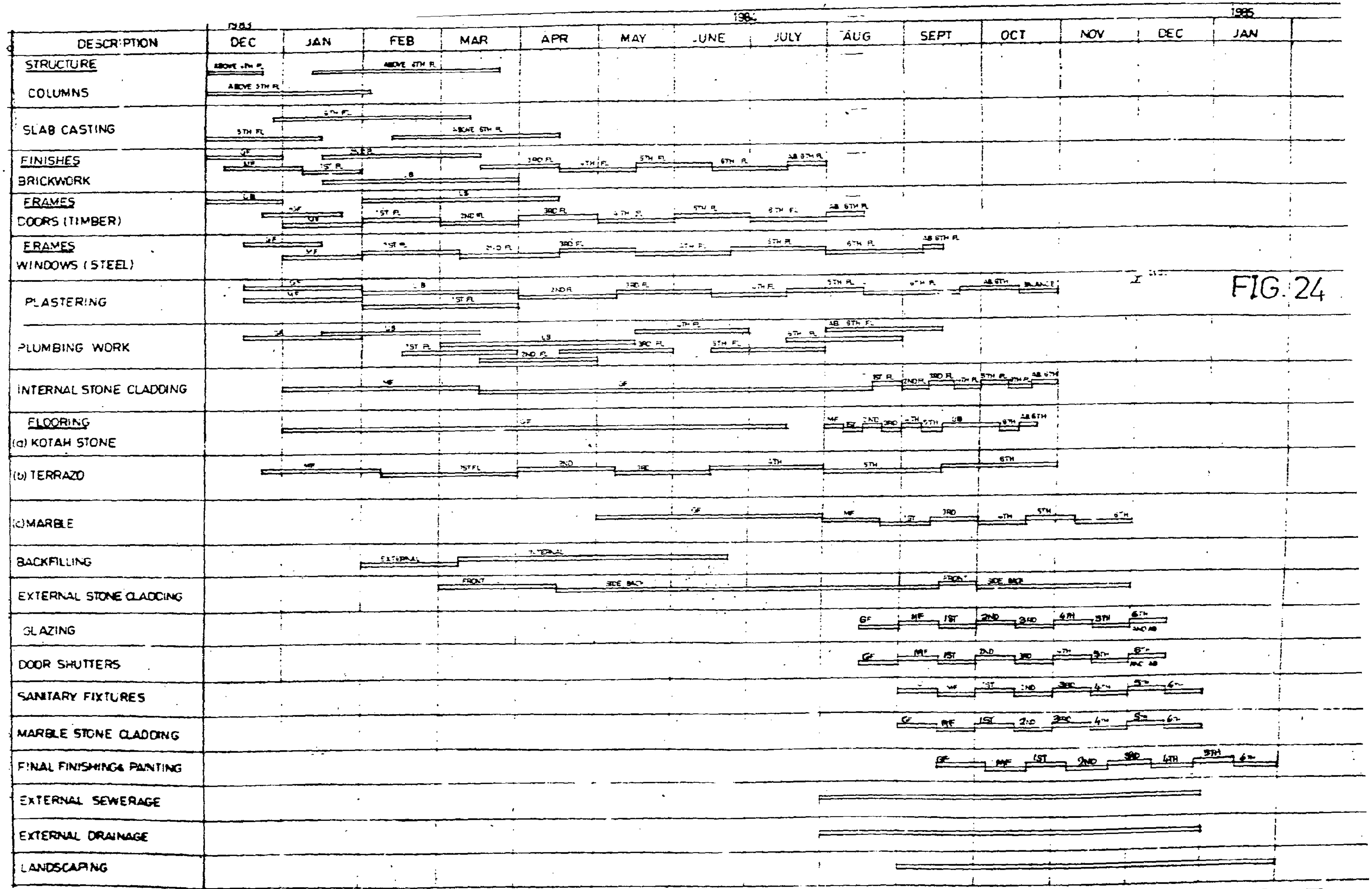
Computer had been used for scheduling purpose. A sample computer output is presented in Table 3A. The daily schedules were also produced through computer. Table 3B gives a sample computer output for daily schedules. From this day by day demand of materials for different items is got. Refer Table 3C.

6.2.6 Progress Report

In each week they prepare a progress report (Table 4A). From the progress report the week target and achievement in each week for different items is given. Also cumulative target and achievement is also given. So shortfall can be easily make out per different items of work.

6.2.7 Monitoring of Work

If the different cycles of work is concerned they are particular about the completion of each cycle. If it is a 22 day cycle they will see that the work is completed in the 22nd day itself. In between if there is any lag, it will not



BAR CHART

FIG. 24

SCOPE

T A B L E 3 A

ACTIVITY NODES		DESC	DUR	EARLY START	LATE START	EARLY FINISH	LATE FINISH	FLOATS			STATUS
								TOT	FREE	IND	
52	55	SLC 16(3)	18	01/09/83(0)	01/09/83 (0)	22/09/83(18)	22/09/83(18)	0	0	0	CRITICAL
53	124	DUM 10(3)	5	22/09/83(18)	22/09/83(18)	28/09/83(23)	28/09/83(23)	0	0	0	CRITICAL
61	62	SLR 14(3)	6	01/09/83(0)	15/09/83(12)	08/09/83(6)	22/09/83(18)	12	12	0	CRITICAL
62	63	SLC 16(3)	6	22/09/83(18)	22/09/83(18)	29/09/83(24)	29/09/83(24)	0	0	0	CRITICAL
63	34	DUM 10(3)	5	29/09/83(24)	29/09/83(24)	05/09/83(29)	05/09/83(29)	0	0	0	CRITICAL
70	71	SLS 15(3)	3	01/09/83(0)	19/09/83(15)	05/09/83(3)	22/09/83(18)	15	15	0	CRITICAL

SLC = SLAB CONCRETING;
SLR = SLAB REINFORCEMENT;
SLS = SLAB SHUTTERING.

TABLE 3B

ACTIVITIES		DESCRIPTION	DURATION	CONCRETE	SHUTTERING	STEEL	CEMENT	QTY.OVER	REMAINING	TOF
DAY= 06/09/83(TUE)										
52	53	SLC 16(3)	18(13)	39.58	0.00	0.00	15.83	391.32(20)	1469.10(77)	
61	62	SLR 14(3)	6(1)	0.00	0.00	8.54	0.00	336.16(57)	165. 30(40)	12
86	87	CLC 13(3)	2(0)	15.00	0.00	0.00	6.00	467.00(17)	0.00(0)	16
95	96	CLS 12(2)	4(2)	1.00	12.00	0.00	0.00	22.00(4)	446.00(93)	7
104	105	CLR 11(4)	4(2)	0.00	0.00	15.00	0.00	80.00(16)	385.00(80)	8
		TOTAL DEMAND =		55.58	12.00	23.54	21.83			
DAY= C7/09/83(WEN)										
52	53	SLC 16(3)	18(12)	39.58	0.00	0.00	15.83	430.90(22)	1429.52(75)	
61	62	SLR 14(3)	6(0)	0.00	0.00	8.54	0.00	244.70(59)	156.76(38)	12
87	88	LUS 18(3)	2(1)	0.00	21.56	0.00	0.00	302.12(87)	21.32(28)	16
95	96	CLS 12(4)	4(1)	0.00	12.00	0.00	0.00	34.00(7)	434.50(90)	7
1C4	105	CLR 11(4)	4(1)	0.00	0.00	15.00	0.00	95.00(19)	370.00(77)	8
		TOTAL DEMAND =		39.58	33.56	23.54	15.83			

SLC = SLAB CONCRETING; SLR = SLAB REINFORCEMENT; CLC = COLUMN CONCRETING;

CLS = COLUMN SHUTTERING; LUS= **LOUVER SHUTTERING.**

T A B L E 3 C

DAY	CARPENTER	BARBENDER	MASON	LABOUR	TOTAL
1	2	3	4	5	6
1.	144.0	231.2	9.9	588.8	974.0
2.	147.5	141.2	9.9	472.6	771.2
3.	141.2	144.0	9.9	468.5	763.6
4.	3.5	141.2	14.6	339.4	498.7
5.	3.5	141.2	13.6	330.1	488.4
6.	9.7	141.2	9.9	300.4	461.2
7.	9.7	90.0	9.9	231.7	341.3
8.	3.5	92.8	13.6	265.1	375.0
9.	3.5	90.0	14.6	270.8	378.8
10.	3.5	90.0	13.6	261.4	368.5
11.	3.5	90.0	13.6	261.4	368.5
12.	9.7	0.0	9.9	111.1	130.7
13.	9.7	0.0	13.6	148.6	172.0
14.	3.5	2.8	13.6	144.5	164.4
15.	3.5	0.0	14.6	150.2	168.2
16.	141.2	0.0	13.6	313.0	467.9
17.	147.5	0.0	9.9	283.3	440.7
18.	144.0	0.0	13.6	316.5	474.1
19.	275.5	54	13.6	553.2	896.4
20.	275.5	51.2	14.6	558.9	900.2
21.	275.5	102.5	13.6	618.1	1009.8
22.	281.8	102.5	9.9	588.5	982.6
23.	281.8	102.5	9.9	588.5	982.6
24.	137.8	195.3	9.9	532.8	875.7
25.	275.5	192.5	10.8	710.6	1189.4
AVERAGE DEMAND	109.4	87.8	12.2	376.3	585.8

TABLE 4A

Item of work	Unit M^3	Qty. Balance as on 1.8.84	Date of completion	Qty. achieved up to 21.8.84	During the week ending on 28.8.84		Cummulative up to 28.8.84		Short fall	Remarks
					Target	Achieved	Target	Achieved		
Structural										
Finishing										
Flooring etc.										
Steel window frame fixing	Nos.	914	30.11.84	10	53	–	168	10	158	
Brick work	M^3	1910/390	30.11.84	183	140/150	25	200	208	+8	

be considered. But it makes the speeding up of that work. Even if one cycle is not finished by time, the next cycle will be started by time. Otherwise every work will have lagging. Simultaneously they try to complete the previous cycle. In a large project like this it is not easy to see the small details. So they try to complete the cycles in time and try to start the cycle eventhough the previous one is not finished. If there is major change they will change the network and duration. Like, when the date is shifted from January '85 to October '84 there was a major change. So they had to schedule again. Since they use computer they could get the schedule easily. Monitoring depends upon the progress reports and computer outputs. From these two things they will get the idea about the progress of the work. Also from bar charts the progress of work is obtained.

In most of the weeks, they conduct meetings of contractors, engineers and project manager. Most of the decisions will be taken by discussions. The different agencies doing the work is also called on for discussions. So their opinions and problems can also be taken into account. It is difficult to decide these things by the project manager alone. So the meetings and discussions are a must in the monitoring phase.

6.3 ZEROX COMPLEX

It has 139 activities overall including installation of equipments and machinery. The precedence network method is used. Total duration of the project is 83 weeks. The different areas in the project are:-

1. Main plant area, divided into four sections.
2. Utility building.
3. Toner and developer building.
4. Overhead water tank.
5. Fire protection system.
6. Effluent treatment system.
7. Uninterrupted power supply system.
8. Installation of equipments and machinery.

In Fig.25 overall network diagram is presented and in Table 4B the details of activities are given. The work started on August 1983.

The first step they have done is making the overall network diagram. For convenience they have divided it into different parts according to the different areas. So it will be easier to handle each area. The duration and labour norms were taken from the contractor. This will be checked by the engineer who is responsible for it.

TABLE 4 B

No.	ACTIVITY DESCRIPTION	DURA-TION (WEEK)	EST	EFT	LST	LFT	TOTAL FLOAT
1	2	3	4	5	6	7	8
1.	Approval of preliminary design report	0	0	0	0	0	0
2.	Design tender and award of contract	2	0	2	5	7	5
3.	Site Mobilization	2	2	4	7	9	5
4.	Earth filling-Main plant	4	4	8	9	13	5
5.	Design and issue of tender documents	5	0	5	0	5	0
6.	Evaluation of tender and award of contract	5	5	10	5	10	0
7.	Site Mobilization	2	10	12	10	12	0
8.	Preparation and Approval of construction drawings.	2	10	12	13	15	3
9.	Stone columns, Assembly/ Store	3	12	15	12	15	0
10.	Stone colums,Ectrical, Mechanical paint shop.	2	15	17	15	17	0
11.	Stone columns photo-receptor and lab.	1	17	18	17	18	0
12.	Stone columns Admin, Canteen,Workers entry	3	18	21	18	21	0
13.	Earth fill, Water tower	2	4	6	21	23	17
14.	Stone column,water tower	1	23	24	23	24	0
15.	Footing and plinth beam	5	13	18	13	18	0
16.	Footing and plinth beam	5	16	21	16	21	0
17.	Footing and plinth beam	4	18	22	18	22	0
18.	Footing and plinth beam	6	21	27	21	27	0
19.	Raft construction	2	24	26	24	26	0
20.	Tender Prep. and issue	6	0	6	0	6	0

1	2	3	4	5	6	7	8
21.	Finalisation of design requirements drawings	36	0	36	0	36	0
22.	Evaluation of Tender, Award of contract	7	8	15	8	15	0
23.	Site Mobilisation	2	15	17	15	17	0
24.	Earthfill etc.Tower Developer Building	2	4	6	31	33	27
25.	Stone column & Footings	3	24	27	33	36	9
26.	Construction of columns	6	17	23	17	23	0
27.	Filling hard care pest control	4	21	25	21	25	0
28.	Construction of folded plate roof	22	23	45	23	45	0
29.	Brick work and partition wall	8	39	47	39	47	0
30.	Plastering of walls	7	42	49	42	49	0
31.	Fixing doors, windows and glazing	8	43	51	43	51	0
32.	Floor slab, floor finish	7	44	51	47	54	3
33.	Construction of columns	6	17	23	17	23	0
34.	Filling hardcore pest-control	9	25	28	25	28	0
35.	Construction of beams and roof slab	16	27	43	27	43	0
36.	Brickwork and partition wall	6	39	45	39	45	0
37.	Plastering of walls	7	40	47	40	47	0
38.	Fixing doors,windows and glazing	5	42	47	42	47	0
39.	Floor slab, Floor finish	6	42	48	50	54	6
40.	Construction of columns	6	21	27	21	27	0

1.	2	3	4	5	6	7	8
41.	Filling hardcore pest control	2	27	29	27	29	0
42.	Construction of beams and slab.	15	29	44	29	44	0
43.	Brickwork and partition wall	8	38	46	38	46	0
44.	Plastering of walls	7	41	48	41	48	0
45.	Fixing doors, windows of glazing	5	43	48	43	48	0
46.	Floor slab floor finish	6	43	49	56	62	13
47.	Construction of columns	7	25	32	25	32	0
48.	Filling hardcore pestcontrol	4	30	34	30	34	0
49.	Construction of beams and roof slab	18	32	50	32	50	0
50.	Brickwork and partition wall	7	45	52	45	52	0
51.	Plastering of walls	7	41	48	41	48	0
52.	Fixing doors, windows and Glazing	6	48	54	48	54	0
53.	Floor slab and floor finish	7	49	56	63	70	14
54.	Construction of R.C.wall at +17M	10	26	36	26	36	0
55.	Slab at +17M levelevel and columns upto bottom of tank	2	36	38	36	38	0
56,	Bottom slab of tank and tank walls	5	38	43	38	43	0
57.	Top slab of Tank & parapet	2	43	45	43	45	0
58.	R.C.C.stair, Railing, ladder and piping	8	40	48	40	48	0
59.	Fixing doors & windows	2	46	48	46	48	0
60.	Painting	4	48	52	48	52	0

1.	2.	3	4	5	6	7	8
61.	Completion and handing over	4	49	53	49	53	0
62.	Construction of columns	8	36	44	36	44	0
63.	Filling hardcore pest control	3	42	45	42	45	0
64.	Beams and Roof slab	18	44	62	44	62	0
65.	Brickwalls, R.C.and partition walls	16	48	64	48	64	0
66.	Plastering of walls	7	59	66	59	66	0
67.	FIXING doors, Windos	6	60	66	60	66	0
68.	Floor slab, floor finish	9	61	70	62	71	1
69.	White wash, painting	9	62	71	62	71	0
70.	Layout, excavation, foundation, footings-utility building.	6	20	26	23	29	3
71.	Backfilling and hardcore	4	23	27	26	30	3
72.	Preparation, Approval of shop drawings	6	19	25	19	25	0
73.	Fabrication of steel structure	10	25	35	25	35	0
74.	Erection of portals	9	27	36	27	36	0
~~75.~~	~~Roofing and side sheeting~~	~~5~~	~~35~~	~~40~~	~~39~~	~~44~~	~~4~~
76.	Construction of Mezzanine Brickwork.	7	34	41	34	41	0
77.	Fixing door, shutters, windows plastering, white wash	7	37	44	47	54	10
78.	Machine foundations, Handling equipments.	6	38	44	38	44	0
79.	Flooring and floor finish	3	43	46	53	56	10
80.	Finishing and handing over	2	45	47	55	57	10

1.	2	3	4	5	6	7	8
81.	Tender preparation and issue tender	4	[illegible]	4	[illegible]	10	6
82.	Submission Evaluation of Tender Award of contract HT,LT,Panel Transformer Sub-Stn.and Related works.	2	4	6	10	12	6
83.	Construction of outdoor switch board	4	6	1[illegible]	46	50	40
84.	Installation upset metering for 33 KV supply	1	10	11	50	51	40
85.	Manufacture of HT,LT panels	32	6	38	12	44	6
86.	Delivery of HT,LT panels to site.	5	38	43	44	49	6
87.	Installation of HT panels	2	43	45	52	54	9
88.	Installation of HT par[illegible]s in utility building.	2	43	45	49	51	6
89.	Manufacture of transformer	32	6	38	16	48	10
90.	Delivery of transformer to site	1	38	39	48	49	10
91.	Installation of transformer	2	39	41	49	51	10
92.	Layout of HT cables, coupling HT panels,transformer and upset supply.	3	45	48	51	54	6
93.	Couple LT panel and transformer by Bus Duct	2	48	50	54	56	6
94.	Submission, Eval.of Tender Award of Contract	12	8	2[illegible]	15	27	7
95.	Manufacture of DGSET	16	20	36	27	43	7
96.	Delivery of DG SET to site	1	36	37	43	44	7
97.	Installation of Equipment in utility building.	13	44	57	44	57	0
98.	Installation of essential panel	3	54	57	54	57	[illegible]
99.	Layout,installation cables, wiring,fittings, DB,SDB	12	45	57	45	57	0

1.	2	3	4	5	6	7	8
100.	Layout,installation,cables wiring,fittings, DB,SDB in Main plant Area C&D	12	49	612	50	62	1
101	Layout,installation,cables wiring,fittings,DB,SDB, in Toner and Developer Building.	10	61	71	61	71	0
102	Design Tender preparation short list contractors	6	0	6	0	6	0
103.	issue,submission Evaluation of Tender HVAC	13	10	23	10	23	0
104.	Award of contract HVAC	1	33	34	33	34	0
105.	Ducting,piping in and up to areas A & B Main plant	10	45	55	45	55	0
106.	Supply,Delivery of HVAC Equipment.	7	46	53	46	53	0
107.	Installation of equipment	6	49	55	49	55	0
108.	Coupling and Testing	2	55	57	55	57	0
109.	Ducting,piping in and upto Areas C&D Main plant	10	50	60	53	63	3
110.	Coupling and Testing.	2	60	62	63	65	3
111.	Issue,submission evaluation deionised Water supply tender	13	10	23	20	33	10
112.	Award of contract Deionised W/Supply.	1	33	34	43	44	10.
113.	Supply Delivery of Equipment to site	8	34	42	44	52	10
114.	Installation of Equipment	3	42	45	52	55	10
115.	Ducting,piping in and upto toner and developer building.	8	34	42	73	81	39

1.	2	3	4	5	6	7	8
116.	Coupling and testing	2	55	57	81	83	26
117.	Piping in paint shop	4	34	38	51	55	17
118.	Coupling and testing.	2	45	47	55	57	10
119.	Issue,submission compressor tender toner and Developer building.	15	6	21	45	60	39
120	Award of contract compressor toner & Dev.	1	21	22	60	61	39
121.	Delivery of compressor to site	16	22	38	61	77	39
122.	Installation of compressor in utility building.	4	44	48	77	81	33
123.	Issue, submission compressor tender assembly, paint.	1	6	7	38	39	32
124.	Award of contract compressor,Assembly, paint.	1	7	8	39	40	32
125.	Delivery of compressor to site.	12	8	20	40	52	32
126.	Installation of compressor	3	44	47	52	55	8
127.	Piping for compressed air in Ton & Dev.and upto utility bldg.	4	22	26	77	81	55
128.	Coupling and testing.	2	48	50	81	83	33
129.	Piping for compressed air in Main plant Bldg. and upto utility bldg.	6	45	51	49	55	4
130.	Coupling and testing	7	51	5	55	57	4
131.	White wash,painting	5	47	52	49	54	2

1.	2	3	4	5	6	7	8
132.	Whitewash, painting	7	43	50	47	54	4
133.	Whitewash, painting	6	55	61	56	62	1
134.	Whitewash, painting	8	53	61	62	70	9
135.	Completion, cleaning and handing over	3	54	57	54	57	0
136.	Completion, cleaning and handing over.	3	54	57	54	57	0
137.	Completion, cleaning and handing over.	3	61	64	62	65	1
138.	Completion, cleaning and handing over	4	61	65	70	74	9
139.	Completion installation of fire fighting equp. and handing over.	12	71	83	71	83	0

6.3.1 Monthly Progress Reports

6.3.1.1 Progress Report for May 1984

Construction proceeded apace during May 1984. The minor structures (security block, driver's toilet, underground water reservoir, pump house) etc. were either completed or neared completion. By the end of the month 2100 m^2 of folded plate roof was completed in the main plant building. In area B 1900 m^2 of roof slabs were concreted. Brick walls had been constructed in photoreceptor and most of the above mentioned areas. Fabrication and erection of steel skeleton and roof sheeting for the utility building were completed.

- Main Plant Building - Assembly Area

Six sets of folded plates covering an area of 10 m x 30 m have been completed. However, against a target of 900 m^3 concreting only 100 m^3 could be achieved. M/s UNITECH were instructed to mobilise an additional set of shuttering and other necessary resources. M/s Unitech however felt that, with the available 5 sets of shuttering, they would be able to maintain a 35 day cycle for casting of folded plates. They will ensure that no further slippage occur and will endeavour to make up for the earlier shortfalls. Brickwork and fixing of windows have also been taken up.

- Main Plant Building - Other Areas

Roof slab in area 'B' are to be completed by June 20,'84. The quantity of concreting fell behind target by about 60 m^3 because of delay in finalising roof cut out locations. This short fall will be made good by providing additional shuttering and manpower. A panel wise programme for casting of slabs in this area has already been issued at site. Equipment details for electrical and mechanical workshop are still awaited for finalising the foundation details. Substantial progress has been made in construction of brick walls in photoreceptor area. CES have however cautioned that additional masons should be deployed to maintain the pace and meet the targets for the following weeks.

- Toner and Developer Building

Details of footing have already been issued by CES (Consulting Engineering Services). The process consultants KTI, wanted the height of the building to be 8 m + 3 m instea of 5 m + 3 m as decided earlier. After discussion with Mx, the increase in height was restricted to 0.5 m. This would entail an additional expense of approximately Rs.100,000 on construction.

- Utility Building

Erection of all portals was completed by May 12. Roof sheeting commenced on May 20, and was over by the end of the month. Work began on the construction of machine foundations and cable trenches. Generator foundations is scheduled to be cast by 4th June 1984. Trenches and flooring in this area would be completed by June 15. It was also decided to expedite flooring and trenches of HT and LT rooms. Details of the air conditioning plant, after cooler and main ccompressor are yet to be finalised. The foundation for these areas would be finalised as soon as these details are available.

- Culvert at Main Entrance

An 8 meters wide nullah runs between the front boundary wall and the national highway. A slab culvert is being constructed at the main entrance to span across this channel.

Access Roads

Subgrade for roads has been completed. Water bound macadam topping has been laid over a length of 925 m. All essential roads are expected to be completed with in June before the oneet of the monsoon.

- Overhead Water Tank

The viewing gallery at a height of 17 meters has been completed. Construction of the reservoir shall commence at the end of May.

- Listing for next month

After completing the progress report of one month, the listing of works for the next month is done. Listing of June 1984 is given in Table 4C.

6.3.1.2 Progress Report for July 1984

- Main Plant Building - Assembly Area

Fifteen sets of folded plate have been cast. These cover an area of 5250 m^2 out of 7700 m^2. Brick work between assembly and store area is in progress and expected to be completed by the second week of August. 1400 m^2 of flooring is complete and progress is on schedule. G.I. strips upto 200 metres for lighting protection have been laid. The airconditioning duct fabrication is in progress. Erection of same is expected to start from the first week of August. Plastering is in progress and 50% of the windows have been fixed in this area.

- Paintshop/Electrical, Mechanical

The brick work is under completion.

- Toner and Developer Building

The hold on the foundation's has been released and drawings for the same for the steel structures have been issued. Fabrication of work for columns has commenced. No progress, however, is reported in civil works, except for the foundation, for which work was completed earlier.

- Utility Building

Most of the building work have been completed. Finishing work and machine foundation for the air-conditioning plant room are in progress. The details of the Toner Compressor foundations have been finalised.

- 33 KV Station

Foundation in substation have been completed. The erection of steel structures and the installations of transformers are expected to commence by the 7th August 1984.

- Access roads and parking area

200 mm thick water bound macadam in parking area is 50% complete and paving works in portion between security block and site offices is in progress. The remaining roads and

pavements are under hold, pending decisions regarding the deletion of the administrative block.

- Boundary Lighting Poles

17 Nos. poles along front boundary wall including cabling, have been fixed. Junction box fittings are in progress.

- Overhead Water Tank

The construction of tower has been completed. The piping work will be taken up thereafter.

- Listing for August 1984

Table 4D gives the listing for August '84.

6.3.2 Progress Monitoring Chart

Progress Monitoring chart is prepared for each month. Fig.26 gives the progress monitoring chart for the month of July 1984. From that the target and actual can be found out. So in the reviewing date we can see that whether the work is in time, ahead of time or behind time.

6.3.3 Estimated Manpower Requirement

Manpower requirement for each work/week will be calculated. In Table 5 estimated manpower requirement for HVAC works for main plant and utility building is given.

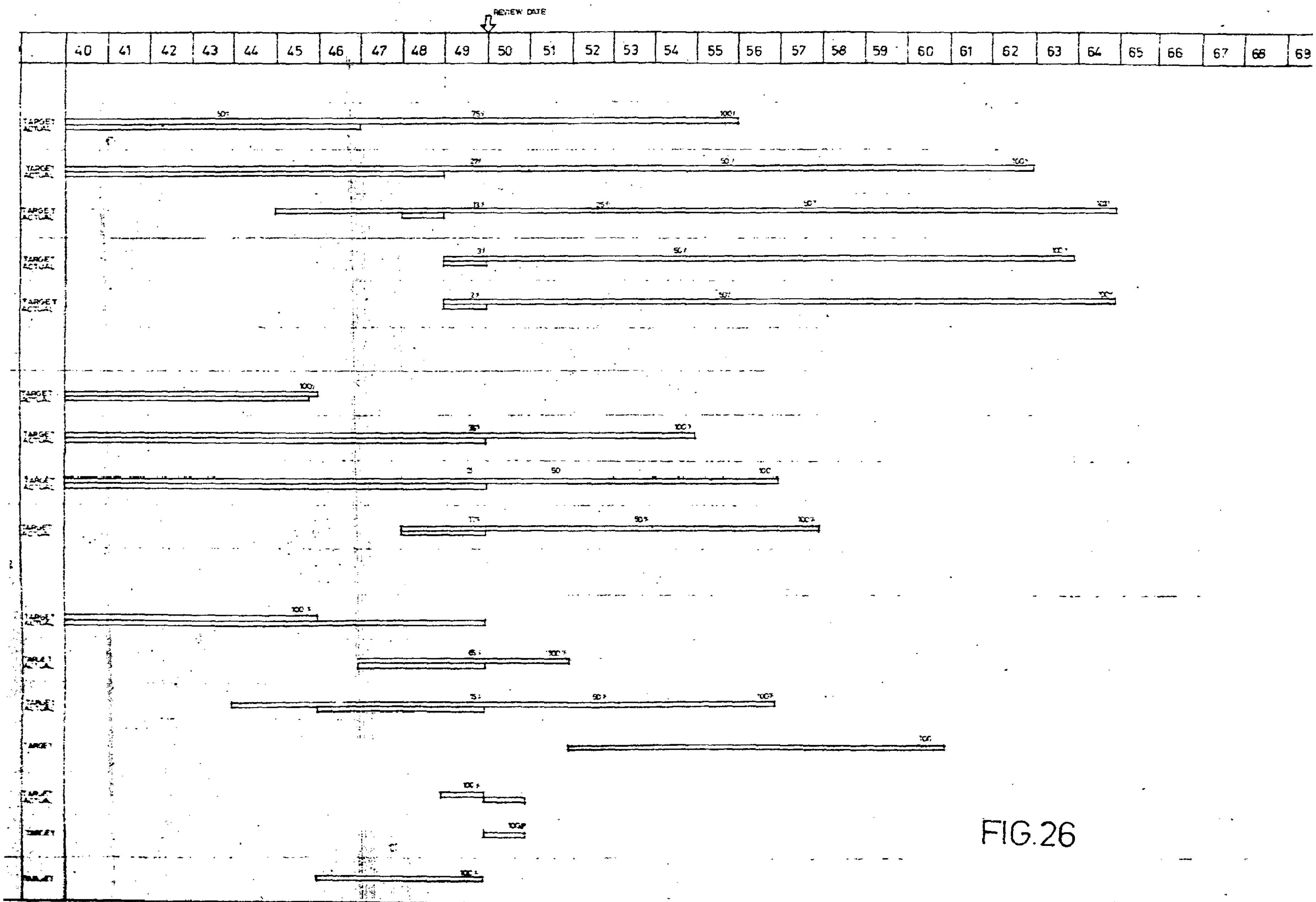


FIG.26

MONITORING CHART (ONGOING ACTIVITIES ONLY)
JULY 1984

ZEROX COMPLEX

DO LIST FOR JUNE 1984

ACTIVITY	ACTION
• CONCRETING OF FOLDED PLATE	7TH TO 9TH SET OF FOLDED PLATE TO BE CAST CYCLE OF 35 DAYS TO BE STRICTLY ADHERED TO
• EQUIPMENT LAYOUT IN ASSEMBLY AREA TO BE MADE AVAILABLE TO CES	MX
• REVISED LAYOUT OF LOADING/UNLOADING BAY HAS BEEN APPROVED DETAILED ENGINEERING DRAWING FOR THE SAME TO BE SUBMITTED TO MP	CES
• BATTERY CHARGING ROOM DETAILS TO BE FORWARDED TO CES	MX
• AIRCONDITIONING DRAWINGS TO BE MADE AVAILABLE TO CES	VOLTAS
APPROVAL TO BE GIVEN ON COMPRESSED AIR PIPELINE DETAILS	MP
• ORDER FOR BUSBAR SYSTEM TO BE PLACED	MX
• TARGETS FOR JUNE: FOLDED PLATE CONCRETING – 400 M^3 BRICKWORK – 500 M^2	UNITECH
• SLIPPAGE IN CONCRETING OF 60 M^3 TO BE MADE UP	UNITECH TO MOBILISE ADDITIONAL RESOURCES
• ROOF EXTRACTOR CUTOUT SIZES AND LOCATION TO BE CONFIRMED	MX
• HEATLOAD IN PAINT SHOP: DATA APPROVED BY THERMAX TO BE RECONCILED	MP/CES
• TARGETS FOR JUNE: ROOF SLABS TO BE COMPLETED BRICKWORK – 370 M^2 PLASTERING – 800 M^2	UNITECH
• LAYOUT OF EQUIPMENT TO BE FINALISED AND FORWARDED TO CES.	FTI
TARGETS FOR JUNE: SLAB CONCRETING TO COMMENCE, 110 M^2 BRICKWORK	UNITECH
• LAYOUT OF OFFICES TO BE FINALISED	MX

AREA	ACTIVITY	ACTION
UTILITY BUILDING	• BALANCE FABRICATION DRAWINGS TO BE SUBMITTED TO CES	UNITECH
	• CONSTRUCTION OF CABLE TRENCHES DG SET AND COMPRESSOR FOUNDATIONS TO BE COMPLETED, DEIONISED WATER PLANT FOUNDATION TO COMMENCE	
	• SUPPLY OF DOORS WINDOWS TO COMMENCE, SUPPLIER FOR ROLLING SHUTTERS TO BE SELECTED AND APPROVAL OBTAINED	UNITECH
TONER AND DEVELOPER BUILDING	• CONSTRUCTION DRAWINGS TO BE ISSUED AT SITE	CES
	• ADDITIONAL REQUIREMENT OF STRUCTURAL STEEL TO BE WORKED OUT AND SUBMITTED TO MX	CES
ROADS AND CULVERTS.	• REMAINING WORK TO BE COMPLETED ON PRIORITY BASIS	UNITECH
OVERHEAD TANK	• WATER RETAINING PORTION TO BE CONSTRUCTED AND PIPING WORK TO BE TAKEN UP.	UNITECH
FIREPROTECTION SYSTEM	• DETAILED ENGINEERING DRAWING TO BE PREPARED.	MATHER AND PLATT
	• CONSTRUCTION DRAWING FOR SUCTION TANK AND NEW PUMPHOUSE CONNECTION TO BE ISSUED AT SITE	CES
EFFLUENT TREATMENT SYSTEM.	• ON RECEIPT OF TENDER (DUE TO JUNE) - TENDER ASSESSMENT REPORT TO PREPARED	CES
UNINTERRUPTED POWER SUPPLY SYSTEM	• TENDER ASSESSMENT REPORT TO BE SUBMITTED	CES

TABLE 4C

DO LIST FOR AUGUST 1984

AREA	ACTIVITY	ACTION
MAIN PLANT BUILDING AREA A	• CONCRETING OF FOLDED PLATE	15TH TO 18TH SETS OF FOLDED PLATE TO BE CAST
	• REVISED OFFICE AREA IN RECEIVING D.C. TO BE APPROVED.	MP
	• ERECTION OF DUCTING FOR AIRCONDITIONING TO BE COMPLETED IN ASSEMBLY AREA	VOLTAS
	• TARGETS FOR AUGUST: FOLDED PLATE CONCRETING – 400 M^3 BRICKWORK – 450 M^2 PLASTERING – 950 M^2 FLOORING – 1400 M^2 NORTHLIGHT GLAZING – 500 M^2	UNITECH
AREA B (PAINT SHOP)	• PLASTERING AROUND Y – GRID TO BE RECTIFIED	UNITECH
	• REVISED DUCTING DRAWINGS TO BE SENT TO THERMAX FOR APPROVAL AND FINALISED	CES/THERMAX
	• DUCT FABRICATION FOR ELECTRICAL MECHANICAL SHOP TO BE STARTED	VOLTAS
	• TARGETS FOR AUGUST BRICKWORK TO BE COMPLETED PLASTERING – 875 M^2 FLOORING – 1480 M^2	UNITECH
AREA C (PHOTORECEPTOR AREA)	• DROP CEILING DRAWINGS FOR LABORATORY AREAS TO BE APPROVED	MP
	• PUMPROOM AND ALL REMAINING DETAILS TO BE FINALISED	CES
	• ELECTRIC LIGHTING DETAILS TO BE APPROVED AND FINALISED	CES/MP
	• TARGETS FOR AUGUST: ROOF SLAB CONCRETE – TO BE COMPLETED BRICKWORK – 775 M^2 PLASTERING – 600 M^2	UNITECH
AREA D (ADMINISTRATIVE AREA)	• DECISION TO BE TAKEN ABOUT DELETION OF THIS AREA	MP
UTILITY BUILDING	• RECTIFICATION WORKS TO BE CHECKED AND COMPLETED	CES/UNITECH
	• REMAINING FOUNDATIONS TO BE COMPLETED	UNITECH
	• ELECTRICAL FITTINGS AND FIXTURES TO BE COMPLETED	SIEMENS
33 KV STATION	• ERECTION WORK FOR TRANSFORMERS TO BE TAKEN UP	SIEMENS/UNITECH
OVERHEAD WATERTANK	• FINISHING DETAILS TO BE FINALISED AND ISSUED FOR CONSTRUCTION	CES MX
TONER AND DEVELOPER BUILDING	• ALL STRUCTURAL DRAWINGS EXCLUDING MEZZANINE TO BE FINALISED AND ISSUED FOR CONSTRUCTION	MX CES KTI
	• FABRICATION AND FOUNDATION WORKS TO BE COMPLETED	UNITECH

ZEROX COMPLEX

TABLE 4D

TABLE - 5

HVAC. WORKS FOR MAIN PLANT & UTILITY BLDG
ESTIMATED MANPOWER REQUIREMENT

ACTIVITY	1984																							
	AUG								SEP								OCT							
	51		52		53		54		55		56		57		58		59		60		61		62	
	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK
DUCTING	6	4	6	4	6	4	6	4	4	2	4	2	6	4	6	4	6	4	6	4	6	4	6	4
DUCT INSULATION							2	6	2	8	2	8	2	8	2	8			2	6	2	6	2	6
PIPING							4	2	5	3	5	3	5	3	5	3	4	2	4	2	4	2	4	2
COOLING TOWER													1	2	1	2	1	2						
PIPING NSULATION															2	6	2	8	2	8	2	8	2	3
ELECTRICAL WORKS											3	4	4	6	4	6	4	6	3	4	2	1	2	1

ACTIVITY	1984																1985							
	NOV								DEC								JAN							
	63		64		65		66		67		68		69		70		71		72		73		74	
	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK	SK	SSK
DUCTING	6	4	6	4	1	1	1	1	1	1														
DUCT INSULATION	2	6	2	6																				
PIPING	4	2	4	2	4	2	4	2	2	2	2	2	2	2										
COOLING TOWER																								
PIPING NSULATION	4	3	2	3	2	3	2	3	2	3	1	1	1	1	1	1								
ELECTRICAL WORKS	2	1	2	1	2	1	2	1	1	1	1	1	1	1	1	1								

SK — SKILLED
SSK — SEMI SKILLED

6.3.4 Construction Programme

Tables 6.1 to 6.5 give construction programme for different areas. In that the target i.e,, the quantity of work to be completed, actual i.e., actual quantity of work achieved, target cumulative i.e,, the total quantity of work to be completed and actual cumulative i.e,, the total quantity of the work achieved is given.

6.3.5 Bar Charts

From the original schedule and progress schedules bar charts for different areas are drawn. Fig.27 gives the bar chart for assembly area. Two bars are drawn for each work. One is for schedule and the other is for actual. In the date of revision the actual will be shaded to show the progress of work. Fig.28 gives the bar chart for fire protection system and Fig.29 gives bar chart for supply erection and commissioning of busbar trunking.

6.3.6 Project Cost Report

Project cost report for land site, development and building is prepared for every month. The report contains the following points.

1. Description.
2. Contractor.

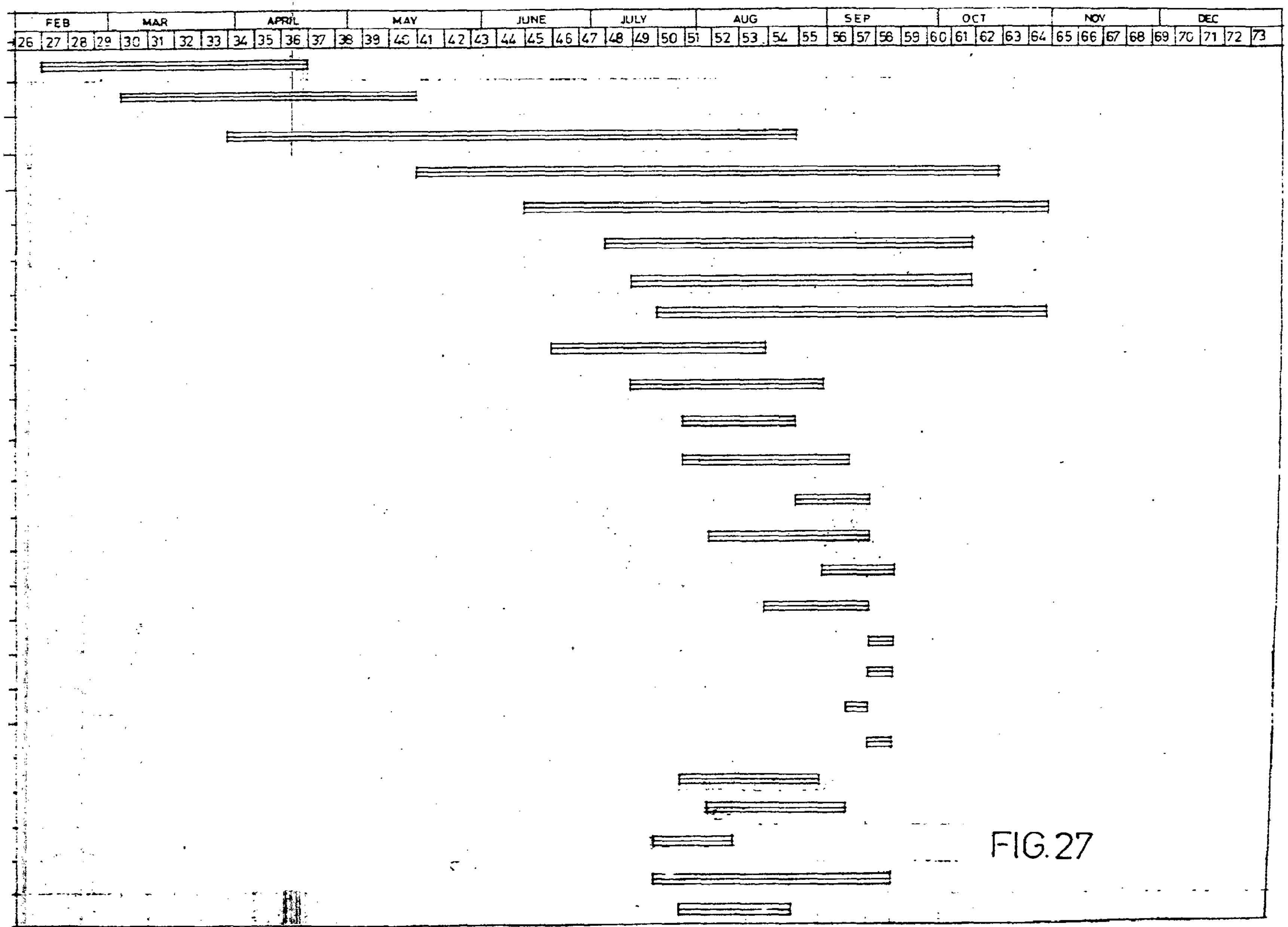


FIG. 27

BAR CHART ASSEMBLY AREA

ZEROX COMPLEX

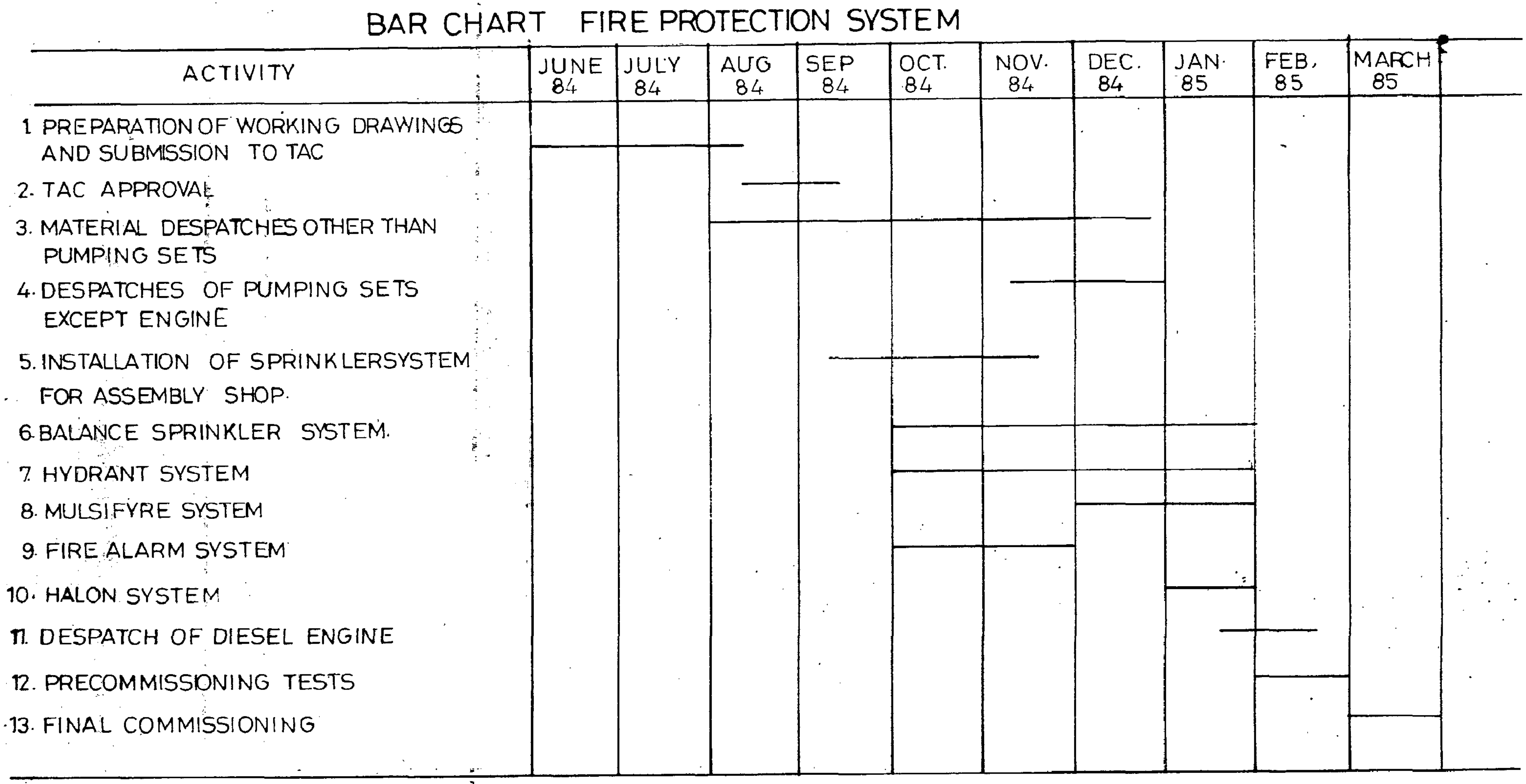

BAR CHART FIRE PROTECTION SYSTEM
ACTIVITY
JUNE 84
JULY 84
AUG 84
SEP 84
OCT. 84
NOV. 84
DEC. 84
JAN. 85
FEB. 85
MARCH 85
1. PREPARATION OF WORKING DRAWINGS AND SUBMISSION TO TAC
2. TAC APPROVAL
3. MATERIAL DESPATCHES OTHER THAN PUMPING SETS
4. DESPATCHES OF PUMPING SETS EXCEPT ENGINE
5. INSTALLATION OF SPRINKLERSYSTEM FOR ASSEMBLY SHOP.
6. BALANCE SPRINKLER SYSTEM.
7. HYDRANT SYSTEM
8. MULSIFYRE SYSTEM
9. FIRE ALARM SYSTEM
10. HALON SYSTEM
11. DESPATCH OF DIESEL ENGINE
12. PRECOMMISSIONING TESTS
13. FINAL COMMISSIONING

FIG. 28

BAR CHART FOR SUPPLY ERECTION AND COMMISSIONING OF BUSBAR TRUNKING

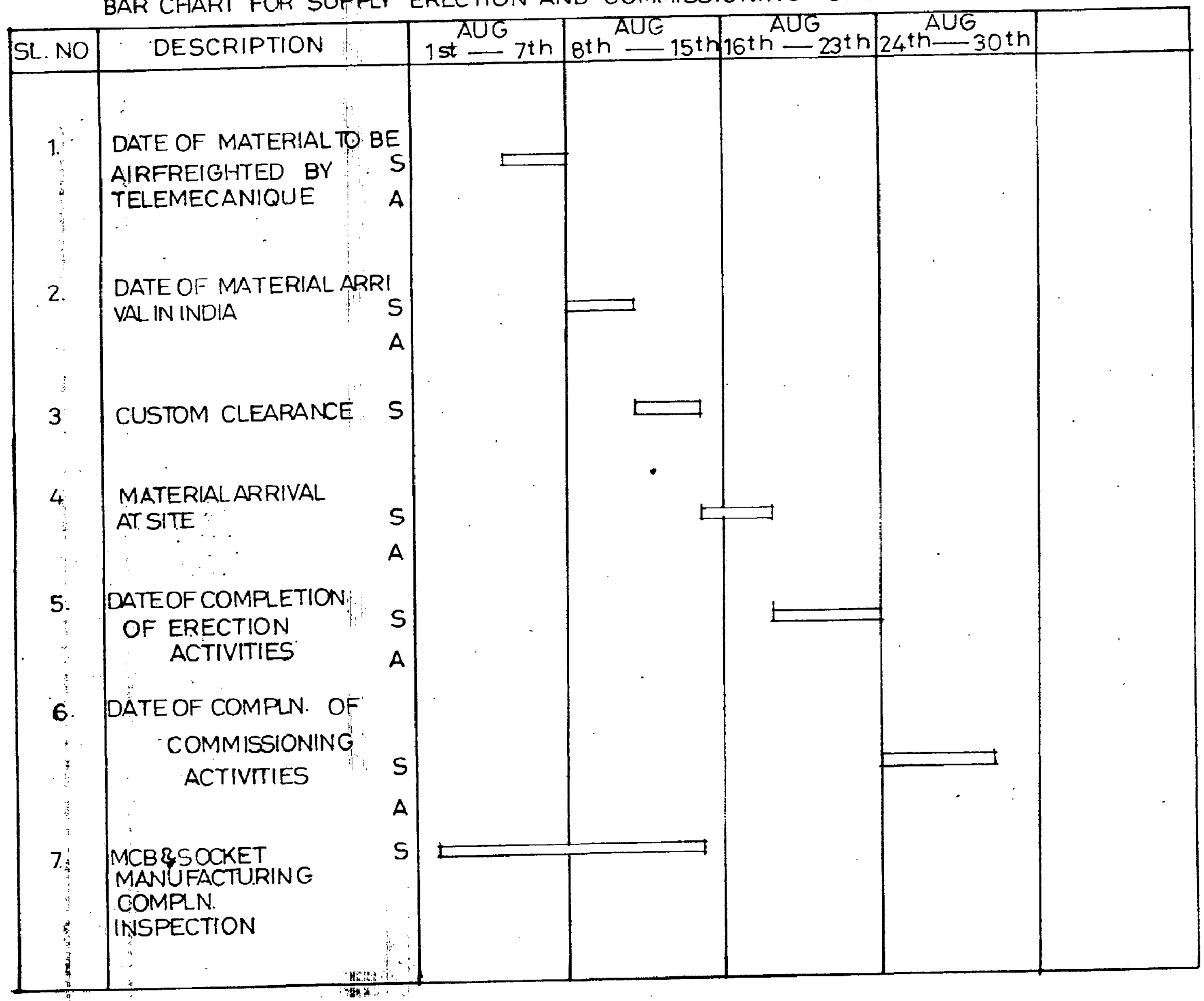


FIG. 29

S-SCHEDULE
A-ACTUAL

CONSTRUCTION PROGRAM

TABLE 6.1

ASSEMBLY AREA (A)

ACTIVITY	UNIT	PERIODS / WEEKS / PROGRESS	PROGRESS UPTO 53 WKS	AUG		SEP					OCT				NOV		
			53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
CONCRETING OF COLUMNS UPTO ROOF LEVEL	M^3	T															
		A															
		TC															
		AC	97.5	JOBS COMPLETED													
FILLING HARDCORE PESTCONTROL	M^2	T															
		A															
		TC															
		AC	7700														
CONCRETING OF FOLDED PLATE	M^3	T		110	110												
		A															
		TC	2200	2310	2420												
		AC	1870														
BRICKWORK	M^2	T		150	150	100	150	200	200	300	360	320					
		A															
		TC	1070	1220	1370	1470	1620	1820	2020	2320	2680	3000					
		AC	2000														
PLASTERING	M^2	T		325	325	325	325	375	375	375	325	325	325	400			
		A															
		TC	1100	1425	1750	2075	2400	2775	3150	3525	3850	4175	4500	4900			
		AC	1225														

T-TARGET TC-TARGET CUMULATIVE
A-ACTUAL AC-ACTUAL CUMULATIVE

CONSTRUCTION PROGRAM

TABLE 6.2

ASSEMBLY AREA (A)

ACTIVITY	UNIT	PERIODS WEEKS / PROGRESS	PROGRESS UPTO 53WKS	AUG		SEP					OCT				NOV		
			53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
DOORS, WINDOWS FIXING	NOS	T		8	8	8	8	4	6	5	4	4	4				
		A															
		TC	28	36	44	52	60	64	70	75	79	83	87				
		AC	22														
FLOOR SLAB	M^2	T		350	350	700	700	700	350	350	350	350	352				
		A															
		TC	2800	3150	3500	4200	4900	5600	5950	6300	6650	7000	7352				
		AC	2600														
PAINTING POLISHING	M^2	T		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000			
		A															
		TC	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000			
		AC															
NORTHLIGHT GLAZING	M^2	T		70	180	180	180	180	180	180	225	225	225	225	225	265	
		A															
		TC		70	250	430	610	790	970	1150	1375	1600	1825	2050	2275	2540	
		AC															
WATERPROOFING	M^2	T		675	675	675	675	675	675	675	675	950	950	950	950	950	950
		A															
		TC	500	1175	1850	2525	3200	3875	4550	5225	5900	6850	7800	8750	9700	10650	11600
		AC	500														

CONSTRUTION PROGRAMME TABLE 6.3

PAINTSHOP AREA (B)

ACTIVITY	UNIT	PERIOD WEEKS / PROGRESS	PROGRESS UPTO 53WKS	AUG		SEP				
			53	54	55	56	57	58	59	60
CONCRETING OF COLUMNS	M^3	T								
		A								
		TC								
		AC								
HARDCORE PEST CONTROL	M^2	T								
		A								
		TC								
		AC								
CONCRETING OF SLAB	M^3	T		30	30					
		A								
		TC	960	990	1020					
		AC	960							
BRICKWORK	M^2	T		100	100	100	100	90		
		A								
		TC	1260	1360	1460	1560	1660	1750		
		AC	1518							
PLASTERING	M^2	T		100	100	100	100	150		
		A								
		TC	2250	2350	2450	2550	2650	2800		
		AC	1600							
FLOOR SLAB FLOOR FINISH	M^2	T		370	370	370	385			
		A								
		TC	1530	1900	2270	2640	3025			
		AC	1350							
DOORS, WINDOWS	NOS	T		4	5	4	8	8	3	3
		A								
		TC		4	9	13	21	29	32	35
		AC								
PAINTING POLISHING	M^2	T		1000	1000	2000	2000			
		A								
		TC	4000	5000	6000	8000	10000			
		AC								

TABLE 6.4

CONSTRUCTION PROGRAM PHOTORECEPTOR/ELECTRONICS LAB AREA (C)

ACTIVITY	UNIT	WEEK PROGR	UP TO WK. 53	AUG 54	55	SEP 56	57	58	59	60	OCT 61	62	63	64	65	66	67	68	69	70
CONCRETING OF COLUMNS	M^3	T																		
		A																		
		TC																		
		AC		JOBS COMPLTD.																
FOOTING HARDCORE	M^2	T																		
		A																		
		TC																		
		AC																		
CONCRETING OF SLAB	M^3	T		60	100	135														
		A																		
		TC	375	435	535	670														
		AC	375																	
BRICKWORK	M^2	T		100	100	100	200	100	100	260										
		A																		
		TC	440	540	640	740	940	1040	1140	1400										
		AC	440																	
PLASTER	M^3	T		200	200	200	300	300	200	200	200	200	200							
		A																		
		TC		200		400	900	1200	1400	1600	1800	2000	2200							
		AC																		
FLOOR SLAB FL. FINISH	M^2	T						300	300	300	300	300	225							
		A																		
		TC						300	600	900	1200	1500	1725							
		AC																		
DOOR WINDOW	NOS	T						3	8	8	8	8	8	8	8					
		A																		
		TC						3	11	19	27	35	43	51	59					
		AC																		
PAINTING POLISHING	M^2	T									500	500	500	500	500	500	500	500	500	500
		A																		
		TC									500	1000	1500	2000	2500	3000	3500	4000	4500	5000
		AC																		

TABLE 6.5

CONSTRUCTION PROGRAM

AREA A, B, C

ACTIVITY	UT	WEEKS PROGRES	UP TO WK. 53			SEP				OCT					NOV
				54	55	56	57	58	59	60	61	62	63	64	65
CONCRETE COLUMNS	M^3	T													
		A													
		TC													
		AC			JOBS COMPLTD										
HARDCORE	M^2	T													
		A													
		TC													
		AC													
CONCRETE SLAB		T		200	240	135									
		A													
		TC	3535	3735	3975	4110									
		AC	3205												
BRICKWORK		T		350	350	300	450	390	300	560	360	320			
		A													
		TC	2770	3120	3470	770	4220	4510	4910	5470	5830	6150			
		AC	3958												
PLASTER		T		625	625	625	725	825	575	575	525	525	525	400	
		A													
		TC	3350	3975	4600	5225	5950	6775	7350	7925	8450	8975	9500	9900	
		AC	2825												
FL. SLAB FL. FINISH		T		720	720	1070	1085	1000	650	650	650	650	577		
		A													
		TC	4330	5050	5770	8040	7925	6925	9573	10225	10875	11525	12102		
		AC	3950												
DOORS WINDOWS		T		15	21	20	24	20	17	16	12	4	4		
		A													
		TC	28	43	64	84	108	128	145	161	173	177	181		
		AC	22												
PAINTING POLISHING		T		2000	2000	3000	3000	1000	1000	1000	1500	1500	1500	1500	500
		A													
		TC	8000	10000	12000	15000	18000	19000	20000	21000	22500	24000	25500	27000	27500
		AC													

ACTIVITY	WEEKS PROGRES	NOV				DEC				JAN			
		66	67	68	69	70	71	72	73	74	75	76	77
CONCRETE COLUMNS	T												
	A												
	TC												
	AC												
HARDCORE	T												
	A												
	TC												
	AC												
CONCRETE SLAB	T												
	A												
	TC												
	AC												
BRICKWORK	T												
	A												
	TC												
	AC												
PLASTER	T												
	A												
	TC												
	AC												
FL. SLAB FL. FINISH	T												
	A												
	TC												
	AC												
DOORS WINDOWS	T												
	A												
	TC												
	AC												
PAINTING POLISHING	T	500	500	500	500	500							
	A												
	TC	28000	28500	29000	29500	30000							
	AC												

3. Budgeted sum.
4. Contract value.
5. Revised sum.
6. Over run/under run and remarks.

The summary of a project cost report is as follows :-

Item	Budgeted Sum	Revised Sum	Over run/ under run
1. Land and site development	40,50,000	50,74,000	(+) 10,24,000
2. Civil works	3,12,10,000	3,44,81,257	(+) 32,71,257
3. Utilities	4,46,72,000	4,42,76,200	(-) 3,95,800
Over sum			(+) 38,99,457

6.3.7 Monitoring

From the progress reports we will understand that they are taking corrective measures in every month. If there is any shortage of materials or labourers they arrange it in time. As far as this project is concerned the slippage of time was very less. There was no need of changing the original schedule so far. The main part of monitoring is keeping check on the progress of the activities and take corrective measures.

6.4 ILLUSTRATION

To illustrate the monitoring program, a part of the network of SCOPE complex is taken. The data is fed to the computer and the result is obtained. The following are the data :-

Basic Data

Activity Description	I-node	J-node	duration
1	2	3	4
1. Dummy	1	2	0
2. Earthfill, consolidation	2	3	164
3. Dummy	3	4	0
4. Constn. MH cover	3	5	45
5. MH for water drainage	4	7	30
6. Dummy	5	6	0
7. Continue constn. MH cover	5	10	46
8. Lay, join sewer line	6	9	16
9. Dummy	7	8	0
10. Continue MH for water drainage	7	12	31
11. Lay, join, RWP	8	13	31
12. Dummy	9	11	0
13. Continue lay, join sewer line	9	14	30
14. Dummy	10	14	0
15. Lay water lines	11	16	30
16. Dummy	12	13	0
17. Continue lay,join RWP	13	17	45
18. Continue lay,join sewer line	14	15	15
19. Test,commission sewer line	15	18	15

1	2	3	4
20. Test, commission water line	16	19	20
21. Test, commission RWP	17	20	16
22. Dummy	18	21	0
23. Dummy	19	21	.0
24. Dummy	20	21	0
25. Dummy	21	22	0
26. Site clear	21	23	15
27. Clear site	22	23	34
28. Hand over	23	24	7

Total there are 34 nodes and 28 activities. The total duration is 327 days.

Revised Data

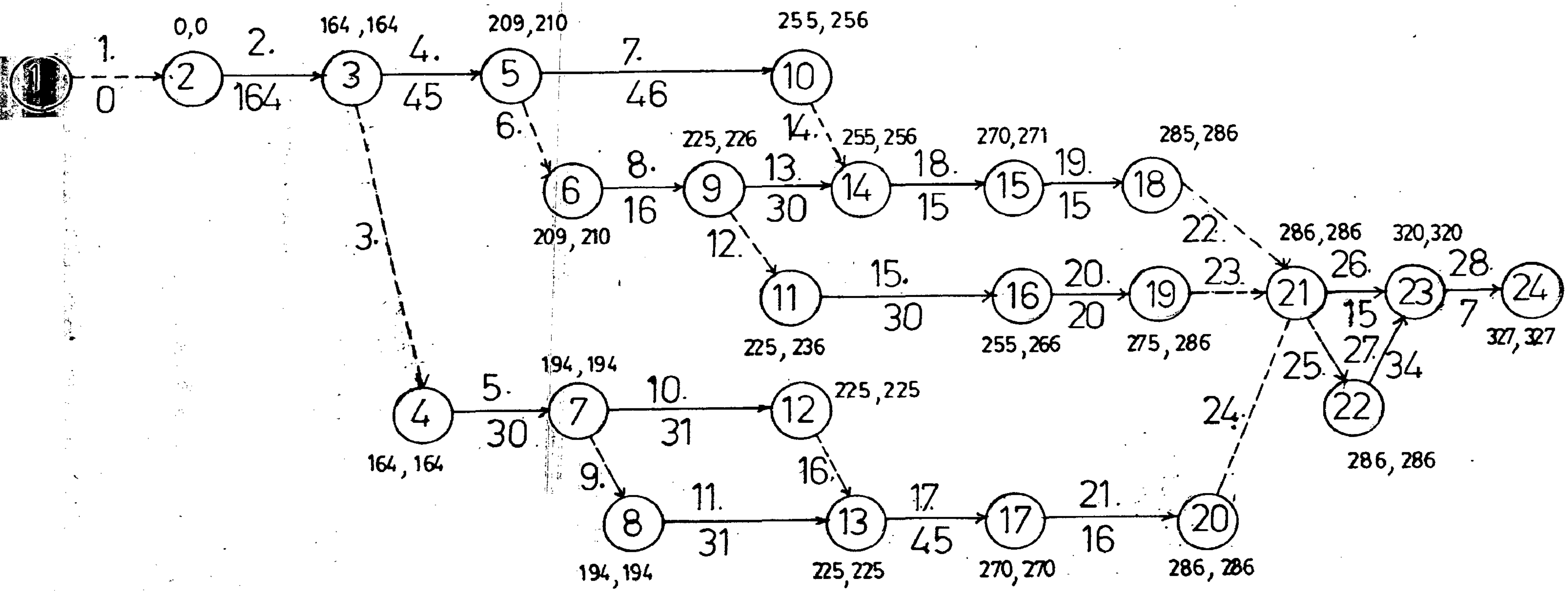
The changes incorporated in the basic data are only change of duration for certain activities. The changes are the following

Activity Description	I-node	J-node	Revised Duration
2. Earthfill, consolidation	2	3	133
4. Construction MH cover	3	5	30
5. MH cover for water drainage	4	7	21
7. Continue constn. MH cover	5	10	30
8. Lay, join sewer line	6	9	15
10. Continue MH for water drainage	7	12	30
11. Lay, join RWP	8	13	30
13. Continue lay, join sewer line	9	14	15
17. Continue lay, join RWP	13	17	15

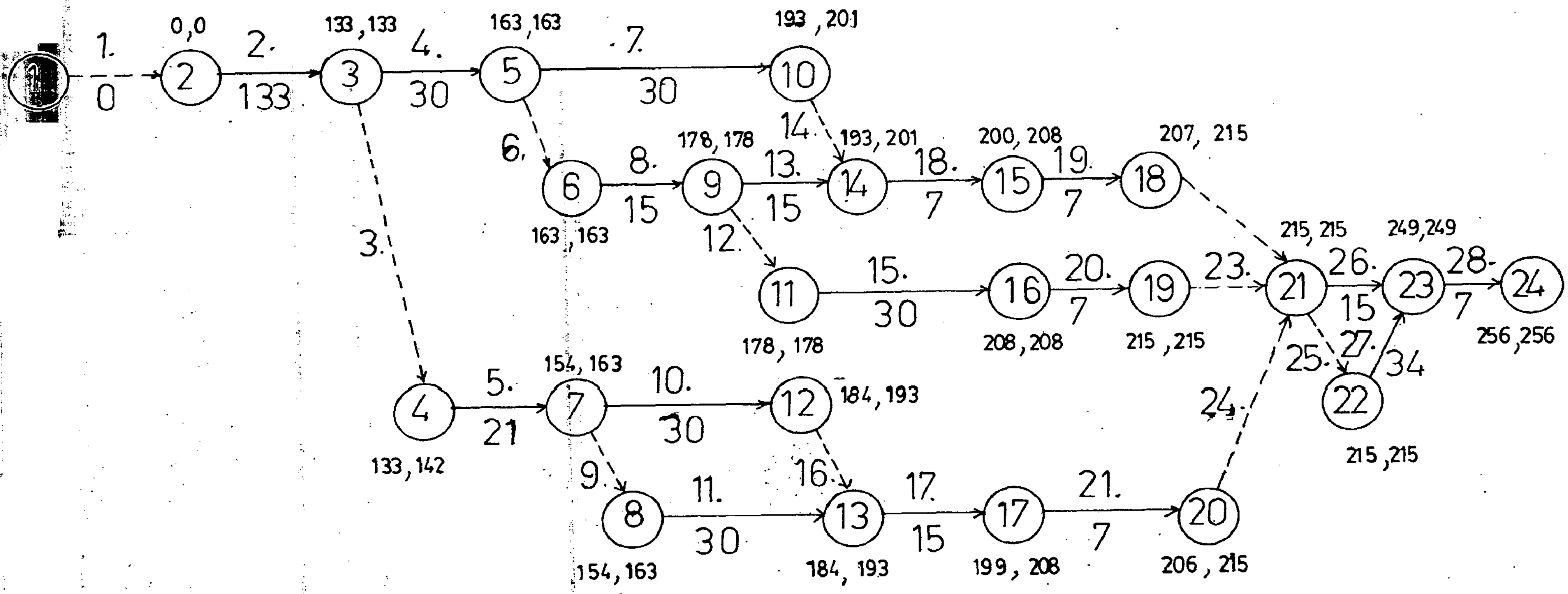
Activity Description	I-node	J-node	Revised Duration
18. Continue lay, join sewer line	14	15	7
19. Testing, commissioning sewer line.	15	18	7
20. Test, commission water line	16	19	7
21. Test, commission RWP	17	20	7

The network diagram is presented in Fig.30 A,B. The basic schedule and bar chart is given in Plate 4 and the revised schedule and bar chart is given in Plate 5. The number of nodes and activities are same. But the duration is changed to 256 days. It can be seen from the drawing that by changing the duration, the critical path is also changed. In the basic network diagram the critical path passes through 1,2,3,4,7,8, 13, (also 7,12,13) 17,20,21,22,23 (also 21,23) and 24. In the revised network the critical path passes through 1,2,3,5,6,9, 11,16,19,21,22 (21,23) and 24. When the duration is reduced. Critical activities reduced to 13 from 15.

By using this monitoring program it becomes easy to revise the schedule without much effort.



=IG. 30 A. BASIC NETWORK 'SCOPE COMPLEX'



30 B NETWORK WITH REVISED DURATION 'SCOPE COMPLEX'

PLATE 4

BASIC SCHEDULE 'SCOPE COMPLEX'

NUMBER OF NODES = 24
NUMBER OF ACTIVITIES = 28
BASIC DATA FROM SCOPE COMPLEX

	I	J	D
1.DUMMY	1	2	0
2.EARTHFILL,CONSOL.	2	3	164
3.DUMMY	3	4	0
4.CONSTN.MH.COVER	3	5	45
5.MH.FOR WATER DR.	4	7	30
6.DUMMY	5	6	0
7.CONT.CONST.MH CR	5	10	46
8.LAY,JOIN SEW.LINE	6	9	16
9.DUMMY	7	8	0
10.CONT.MH WATER DN.	7	12	31
11.LAY,JOIN RWP	8	13	31
12.DUMMY	9	11	0
13.CONT.LAY,JN,SW	9	14	30
14.DUMMY	10	14	0
15.LAY WATER LINES	11	16	30
16.DUMMY	12	13	0
17.CONT.LAY,JN,RWP	13	17	45
18.CONT.LAY,JN,SW.	14	15	15
19.TEST COMM.SEW.L	15	18	15
20.TEST.COMM.WATER L	16	19	20
21.TEST.COMM.RWP	17	20	16
22.DUMMY	18	21	0
23.DUMMY	19	21	0
24.DUMMY	20	21	0
25.DUMMY	21	22	0
26.SITE CLEAR	21	23	15
27.CLEAR SITE	22	23	34
28.HAND OVER	23	24	7

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
1.DUMMY	1	2	0	0	0	0	0	0	
2.EARTHFILL,CONSOL.	2	3	164	0	164	0	164	0	
3.DUMMY	3	4	0	164	164	164	164	0	
4.CONSTN.MH.COVER	3	5	45	164	209	165	210	1	
5.MH.FOR WATER DR.	4	7	30	164	194	164	194	0	
6.DUMMY	5	6	0	209	209	210	210	1	
7.CONT.CONST.MH CR	5	10	46	209	255	210	256	1	
8.LAY,JOIN SEW.LINE	6	9	16	209	225	210	226	1	
9.DUMMY	7	8	0	194	194	194	194	0	
10.CONT.MH WATER DN.	7	12	31	194	225	194	225	0	
11.LAY,JOIN RWP	8	13	31	194	225	194	225	0	
12.DUMMY	9	11	0	225	225	236	236	11	
13.CONT.LAY,JN,SW	9	14	30	225	255	226	256	1	
14.DUMMY	10	14	0	255	255	256	256	1	
15.LAY WATER LINES	11	16	30	225	255	236	266	11	
16.DUMMY	12	13	0	225	225	225	225	0	
17.CONT.LAY,JN,RWP	13	17	45	225	270	225	270	0	
18.CONT.LAY,JN,SW.	14	15	15	255	270	256	271	1	
19.TEST COMM.SEW.L	15	18	15	270	285	271	286	1	
20.TEST.COMM.WATER L	16	19	20	255	275	266	286	11	
21.TEST.COMM.RWP	17	20	16	270	286	270	286	0	
22.DUMMY	18	21	0	285	285	286	286	1	
23.DUMMY	19	21	0	275	275	286	286	11	
24.DUMMY	20	21	0	286	286	286	286	0	
25.DUMMY	21	22	0	286	286	286	286	0	
26.SITE CLEAR	21	23	15	286	301	305	320	19	
27.CLEAR SITE	22	23	34	286	320	286	320	0	
28.HAND OVER	23	24	7	320	327	320	327	0	

REARRANGEMENT IN ASCENDING ORDER OF
EST

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
1.DUMMY	1	2	0	0	0	0	0	0	
2.EARTHFILL,CONSOL.	2	3	164	0	164	0	164	0	
3.DUMMY	3	4	0	164	164	164	164	0	
4.CONSTN.MH.COVER	3	5	45	164	209	165	210	1	
5.MH.FOR WATER DR.	4	7	30	164	194	164	194	0	
9.DUMMY	7	8	0	194	194	194	194	0	
10.CONT.MH WATER DN.	7	12	31	194	225	194	225	0	
11.LAY,JOIN RWP	8	13	31	194	225	194	225	0	
6.DUMMY	5	6	0	209	209	210	210	1	
7.CONT.CONST.MH CR	5	10	46	209	255	210	256	1	
8.LAY,JOIN SEW.LINE	6	9	16	209	225	210	226	1	
12.DUMMY	9	11	0	225	225	236	236	11	
13.CONT.LAY,JN,SW	9	14	30	225	255	226	256	1	
15.LAY WATER LINES	11	16	30	225	255	236	266	11	
16.DUMMY	12	13	0	225	225	225	225	0	
17.CONT.LAY,JN,RwP	13	17	45	225	270	225	270	0	
14.DUMMY	10	14	0	255	255	256	256	1	
18.CONT.LAY,JN,SW.	14	15	15	255	270	256	271	1	
20.TEST,COMM.WATER L	16	19	20	255	275	266	286	11	
19.TEST COMM.SEW.L	15	18	15	270	285	271	286	1	
21.TEST.COMM.RWP	17	20	16	270	286	270	286	0	
23.DUMMY.	19	21	0	275	275	286	286	11	
22.DUMMY	18	21	0	285	285	286	286	1	
24.DUMMY	20	21	0	286	286	286	286	0	
25.DUMMY	21	22	0	286	286	286	286	0	
26.SITE CLEAR	21	23	15	286	301	305	320	19	
27.CLEAR SITE	22	23	34	286	320	286	320	0	
28.HAND OVER	23	24	7	320	327	320	327	0	

REVISED PROJECT DURATION= 327

```
********************************************************************************************************
   S.N. OF ACTIVE ACTIVITIES    1    2
********************************************************************************************************
   BLOCK NUMBER    1
********************************************************************************************************
  1.DUMMY                *
                         *
                         *L
                         *
  2.EARTHFILL,CONSOL.    *
                         *EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                         *LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                         *
********************************************************************************************************
                         0         10        20        30        40        50        60        70        80
1
********************************************************************************************************
   S.N. OF ACTIVE ACTIVITIES    2
********************************************************************************************************
   BLOCK NUMBER    2
********************************************************************************************************
  2.EARTHFILL,CONSOL.    *
                         *EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                         *LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                         *
********************************************************************************************************
                         80        90        100       110       120       130       140       150       160
1
```

```
**************************************************************************************************************
  S.N. OF ACTIVE ACTIVITIES    2    3    4    5    9   10   11    6    7    8   12   13   15   16   17
**************************************************************************************************************
  BLOCK NUMBER     3
**************************************************************************************************************
 2.EARTHFILL,CONSOL. *
                     *EEEE
                     *LLLL
                     *
 3.DUMMY             *
                     *    E
                     *    L
                     *
 4.CONSTN.MH.COVER   *
                     *    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                     *     LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                     *
 5.MH.FOR WATER DR.  *
                     *    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                     *    LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                     *
 9.DUMMY             *
                     *                                    E
                     *                                    L
                     *
 10.CONT,MH WATER DN.*
                     *                                    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                     *                                    LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                     *
 11.LAY,JOIN RWP     *
                     *                                    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                     *                                    LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                     *
 6.DUMMY             *
                     *                                                    E
                     *                                                     L
                     *
 7.CONT,CONST.MH CR  *
                     *                                                    EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                     *                                                     LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                     *
 8.LAY,JOIN SEW.LINE *
                     *                                                    EEEEEEEEEEEEEEEEE
                     *                                                     LLLLLLLLLLLLLLLLL
                     *
 12.DUMMY            *
                     *                                                                     E
                     *                                                                                L
                     *
 13.CONT.LAY,JN,SW   *
                     *                                                                     EEEEEEEEEEEEEEEE
                     *                                                                      LLLLLLLLLLLLLL
                     *
 15.LAY WATER LINES  *
                     *                                                                     EEEEEEEEEEEEEEEE
                     *                                                                                 LLLL
 16.DUMMY            *
                     *                                                                     E
                     *                                                                     L
                     *
 17.CONT.LAY,JN,RWP  *
                     *                                                                     EEEEEEEEEEEEEEEE
                     *                                                                     LLLLLLLLLLLLLLLL
                     *
**************************************************************************************************************
                  160        170        180        190        200        210        220        230        240
1
**************************************************************************************************************
```

```
  S.N. OF ACTIVE ACTIVITIES     7    13   15   17   14   18   20   19   21   23   22   24   25   26   27
********************************************************************************************************
   BLOCK NUMBER    4
********************************************************************************************************
  7.CONT.CONST.MH CR   *
                       *EEEEEEEEEEEEEEE
                       *LLLLLLLLLLLLLLL
                       *
  13.CONT.LAY,JN,SW    *
                       *EEEEEEEEEEEEEEE
                       *LLLLLLLLLLLLLLL
                       *
  15.LAY WATER LINES   *
                       *EEEEEEEEEEEEEEE
                       *LLLLLLLLLLLLLLLLLLLLLLLLL
                       *
  17.CONT.LAY,JN,RWP   *
                       *EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                       *LLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                       *
  14.DUMMY             *
                       *               E
                       *                L
                       *
  18.CONT.LAY,JN,SW.   *
                       *               EEEEEEEEEEEEEEE
                       *                LLLLLLLLLLLLLL
                       *
  20.TEST.COMM.WATER L *
                       *               EEEEEEEEEEEEEEEEEEEE
                       *                          LLLLLLLLLLLLLLLLLLLL
                       *
  19.TEST COMM.SEW.L   *
                       *                              EEEEEEEEEEEEEEE
                       *                               LLLLLLLLLLLLLL
                       *
  21.TEST.COMM.RWP     *
                       *                              EEEEEEEEEEEEEEEE
                       *                              LLLLLLLLLLLLLLLL
                       *
  23.DUMMY             *
                       *                                   E
                       *                                              L
                       *
  22.DUMMY             *
                       *                                             E
                       *                                              L
                       *
  24.DUMMY             *
                       *                                              E
                       *                                              L
                       *
  25.DUMMY             *
                       *                                              E
                       *                                              L
                       *
  26.SITE CLEAR        *
                       *                                              EEEEEEEEEEEEEEE
                       *                                                                  LLLLLLLLLLLLLLL
                       *
  27.CLEAR SITE        *
                       *                                              EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                       *                                              LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                       *
********************************************************************************************************
                     240       250       260       270       280       290       300       310       320
```

PLATE 5

REVISED SCHEDULE 'SCOPE COMPLEX'

NUMBER OF NODES =24
NUMBER OF ACTIVITIES =28
BASIC DATA FROM SCOPE COMPLEX

	I	J	D
1.DUMMY	1	2	0
2.EARTHFILL,CONSOL.	2	3	164
3.DUMMY	3	4	0
4.CONSTN.MH.COVER	3	5	45
5.MH.FOR WATER DR.	4	7	30
6.DUMMY	5	6	0
7.CONT.CONST.MH CR	5	10	46
8.LAY,JOIN SEW.LINE	6	9	16
9.DUMMY	7	8	0
10.CONT.MH WATER DN.	7	12	31
11.LAY,JOIN RWP	8	13	31
12.DUMMY	9	11	0
13.CONT.LAY,JN,SW	9	14	30
14.DUMMY	10	14	0
15.LAY WATER LINES	11	16	30
16.DUMMY	12	13	0
17.CONT.LAY,JN,RWP	13	17	45
18.CONT.LAY,JN,SW.	14	15	15
19.TEST COMM.SEW.L	15	18	15
20.TEST.COMM.WATER L	16	19	20
21.TEST.COMM.RWP	17	20	16
22.DUMMY	18	21	0
23.DUMMY	19	21	0
24.DUMMY	20	21	0
25.DUMMY	21	22	0
26.SITE CLEAR	21	23	15
27.CLEAR SITE	22	23	34
28.HAND OVER	23	24	7

THE QUANTITIES WRITTEN BELOW ARE CHANGED DATA

24	28	13	0	0
2	2	3	133	
4	3	5	30	
5	4	7	21	
7	5	10	30	
8	6	9	15	
10	7	12	30	
11	8	13	30	
13	9	14	15	
17	13	17	15	
18	14	15	7	
19	15	18	7	
20	16	19	7	
21	17	20	7	

NUMBER OF NODES = 24
NUMBER OF ACTIVITIES = 28
REVISED DATA FROM SCOPE COMPLEX

	I	J	D
1.DUMMY	1	2	0
2.EARTHFILL,CONSOL.	2	3	133
3.DUMMY	3	4	0
4.CONSTN.MH.COVER	3	5	30
5.MH.FOR WATER DR.	4	7	21
6.DUMMY	5	6	0
7.CONT.CONST.MH CR	5	10	30
8.LAY,JOIN SEW.LINE	6	9	15
9.DUMMY	7	8	0
10.CONT.MH WATER DN.	7	12	30
11.LAY,JOIN RWP	8	13	30
12.DUMMY	9	11	0
13.CONT.LAY,JN,SW	9	14	15
14.DUMMY	10	14	0
15.LAY WATER LINES	11	16	30
16.DUMMY	12	13	0
17.CONT.LAY,JN,RWP	13	17	15
18.CONT.LAY,JN,SW.	14	15	7
19.TEST COMM.SEW.L	15	18	7
20.TEST.COMM.WATER L	16	19	7
21.TEST.COMM.RWP	17	20	7
22.DUMMY	18	21	0
23.DUMMY	19	21	0
24.DUMMY	20	21	0
25.DUMMY	21	22	0
26.SITE CLEAR	21	23	15
27.CLEAR SITE	22	23	34
28.HAND OVER	23	24	7

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
1.DUMMY	1	2	0	0	0	0	0	0	
2.EARTHFILL,CONSOL.	2	3	133	0	133	0	133	0	
3.DUMMY	3	4	0	133	133	142	142	9	
4.CONSTN.MH.COVER	3	5	30	133	163	133	163	0	
5.MH.FOR WATER DR.	4	7	21	133	154	142	163	9	
6.DUMMY	5	6	0	163	163	163	163	0	
7.CONT.CONST.MH CR	5	10	30	163	193	171	201	8	
8.LAY,JOIN SEW,LINE	6	9	15	163	178	163	178	0	
9.DUMMY	7	8	0	154	154	163	163	9	
10.CONT.MH WATER DN.	7	12	30	154	184	163	193	9	
11.LAY,JOIN RWP	8	13	30	154	184	163	193	9	
12.DUMMY	9	11	0	178	178	178	178	0	
13.CONT.LAY,JN,SW	9	14	15	178	193	186	201	8	
14.DUMMY	10	14	0	193	193	201	201	8	
15.LAY WATER LINES	11	16	30	178	208	178	208	0	
16.DUMMY	12	13	0	184	184	193	193	9	
17.CONT.LAY,JN,RWP	13	17	15	184	199	193	208	9	
18.CONT.LAY,JN,SW.	14	15	7	193	200	201	208	8	
19.TEST COMM.SEW.L	15	18	7	200	207	208	215	8	
20.TEST.COMM.WATER L	16	19	7	208	215	208	215	0	
21.TEST.COMM.RWP	17	20	7	199	206	208	215	9	
22.DUMMY	18	21	0	207	207	215	215	8	
23.DUMMY	19	21	0	215	215	215	215	0	
24.DUMMY	20	21	0	206	206	215	215	9	
25.DUMMY	21	22	0	215	215	215	215	0	
26.SITE CLEAR	21	23	15	215	230	234	249	19	
27.CLEAR SITE	22	23	34	215	249	215	249	0	
28.HAND OVER	23	24	7	249	256	249	256	0	

REARRANGEMENT IN ASCENDING ORDER OF EST

ACTIVITY DESCRIPTION	I-NODE	J-NODE	DURAT	EST	EFT	LST	LFT	T.FLOAT	TRADE
1.DUMMY	1	2	0	0	0	0	0	0	
2.EARTHFILL,CONSOL.	2	3	133	0	133	0	133	0	
3.DUMMY	3	4	0	133	133	142	142	9	
4.CONSTN.MH.COVER	3	5	30	133	163	133	163	0	
5.MH.FOR WATER DR.	4	7	21	133	154	142	163	9	
9.DUMMY	7	8	0	154	154	163	163	9	
10.CONT.MH WATER DN.	7	12	30	154	184	163	193	9	
11.LAY,JOIN RWP	8	13	30	154	184	163	193	9	
6.DUMMY	5	6	0	163	163	163	163	0	
7.CONT.CONST.MH CR	5	10	30	163	193	171	201	8	
8.LAY,JOIN SEW.LINE	6	9	15	163	178	163	178	0	
12.DUMMY	9	11	0	178	178	178	178	0	
13.CONT.LAY,JN,SW	9	14	15	178	193	186	201	8	
15.LAY WATER LINES	11	16	30	178	208	178	208	0	
16.DUMMY	12	13	0	184	184	193	193	9	
17.CONT.LAY,JN,RWP	13	17	15	184	199	193	208	9	
14.DUMMY	10	14	0	193	193	201	201	8	
18.CONT.LAY,JN,SW.	14	15	7	193	200	201	208	8	
21.TEST.COMM.RWP	17	20	7	199	206	208	215	9	
19.TEST COMM.SEW.L	15	18	7	200	207	208	215	8	
24.DUMMY	20	21	0	206	206	215	215	9	
22.DUMMY	18	21	0	207	207	215	215	8	
20.TEST.COMM.WATER L	16	19	7	208	215	208	215	0	
23.DUMMY	19	21	0	215	215	215	215	0	
25.DUMMY	21	22	0	215	215	215	215	0	
26.SITE CLEAR	21	23	15	215	230	234	249	19	
27.CLEAR SITE	22	23	34	215	249	215	249	0	
28.HAND OVER	23	24	7	249	256	249	256	0	

REVISED PROJECT DURATION= 256

```
*********************************************************************************************************
   S.N. OF ACTIVE ACTIVITIES     1    2
*********************************************************************************************************
   BLOCK NUMBER     1
*********************************************************************************************************
  1.DUMMY             *
                      *
                      *L
                      *
  2.EARTHFILL,CONSOL. *
                      *EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                      *LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
*********************************************************************************************************
                      0         10        20        30        40        50        60        70        80
1
*********************************************************************************************************
   S.N. OF ACTIVE ACTIVITIES     2    3    4    5    9   10   11
*********************************************************************************************************
   BLOCK NUMBER     2
*********************************************************************************************************
  2.EARTHFILL,CONSOL. *
                      *EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
                      *LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
  3.DUMMY             *
                      *                                                      E
                      *                                                               L
                      *
  4.CONSTN.MH.COVER   *
                      *                                                      EEEEEEEEEEEEEEEEEEEEEEEEEEE
                      *                                                      LLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
  5.MH.FOR WATER DR.  *
                      *                                                      EEEEEEEEEEEEEEEEEEEEE
                      *                                                               LLLLLLLLLLLLLLLLLL
                      *
  9.DUMMY             *
                      *                                                                           E
                      *
                      *
  10.CONT.MH WATER DN.*
                      *                                                                           EEEEEE
                      *
                      *
  11.LAY,JOIN RWP     *
                      *                                                                           EEEEEE
                      *
                      *
*********************************************************************************************************
                      80        90        100       110       120       130       140       150       160
```

```
1
************************************************************************************************
   S.N. OF ACTIVE ACTIVITIES    4    5    9   10   11    6    7    8   12   13   15   16   17   14   18
21   19   24   22   20
   S.N. OF ACTIVE ACTIVITIES   23   25   26   27
************************************************************************************************
   BLOCK NUMBER    3
************************************************************************************************
  4.CONSTN.MH.COVER   *
                      *EEE
                      *LLL
                      *
  5.MH.FOR WATER DR.  *
                      *
                      *LLL
                      *
  9.DUMMY             *
                      *
                      *   L
                      *
 10.CONT.MH WATER DN.*
                      *EEEEEEEEEEEEEEEEEEEEEE
                      *   LLLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
 11.LAY,JOIN RWP      *
                      *EEEEEEEEEEEEEEEEEEEEEE
                      *   LLLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
  6.DUMMY             *
                      *   E
                      *   L
                      *
  7.CONT.CONST.MH CR  *
                      *   EEEEEEEEEEEEEEEEEEEEEEEEEEE
                      *          LLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
  8.LAY,JOIN SEW.LINE *
                      *   EEEEEEEEEEEEEE
                      *   LLLLLLLLLLLLLL
                      *
 12.DUMMY             *
                      *                 E
                      *                 L
                      *
 13.CONT.LAY,JN,SW    *
                      *                 EEEEEEEEEEEEEE
                      *                        LLLLLLLLLLLLLL
                      *
 15.LAY WATER LINES   *
                      *                 EEEEEEEEEEEEEEEEEEEEEEEEEEEE
                      *                 LLLLLLLLLLLLLLLLLLLLLLLLLLLL
                      *
 16.DUMMY             *
                      *                       E
                      *                               L
                      *
```

```
17.CONT.LAY,JN,RWP  *                 EEEEEEEEEEEEEEE
                    *                          LLLLLLLLLLLLLLL
                    *
                    *
14.DUMMY            *
                    *                          E
                    *                                  L
                    *
18.CONT.LAY,JN,SW.  *
                    *                          EEEEEEE
                    *                                  LLLLLLL
                    *
21.TEST.COMM.RWP    *
                    *                                EEEEEEE
                    *                                        LLLLLL
                    *
19.TEST COMM.SEW.L  *
                    *                                 EEEEEEE
                    *                                        LLLLLL
                    *
24.DUMMY            *
                    *                                        E
                    *                                                L
                    *
22.DUMMY            *
                    *                                         E
                    *                                                L
                    *
20.TEST.COMM.WATER L*
                    *                                          EEEEEEE
                    *                                          LLLLLL
                    *
23.DUMMY            *
                    *                                                E
                    *                                                L
                    *
25.DUMMY            *
                    *                                                E
                    *                                                L
                    *
26.SITE CLEAR       *
                    *                                                EEEEEEEEEEEEEEE
                    *                                                                  LLLLLL
                    *
27.CLEAR SITE       *
                    *                                                EEEEEEEEEEEEEEEEEEEEEEEEE
                    *                                                LLLLLLLLLLLLLLLLLLLLLLLLL
                    *
*********************************************************************************************
                   160       170       180       190       200       210       220       230       240
1
*********************************************************************************************
  S.N. OF ACTIVE ACTIVITIES   26   27   28
*********************************************************************************************
  BLOCK NUMBER    4
*********************************************************************************************
26.SITE CLEAR       *
                    *
                    *LLLLLLLLL
                    *
27.CLEAR SITE       *
                    *EEEEEEEEE
                    *LLLLLLLLL
                    *
28.HAND OVER        *
                    *         EEEEEEE
                    *         LLLLLLL
                    *
*********************************************************************************************
                   240       250       260       270       280       290       300       310       320
```

6.5 CONCLUSION

By using the management techniques both the projects had benefits. Zerox complex was successfully completed in time. It was through frequent monitoring and taking corrective measures at the correct time. In scope complex eventhough there was some lagging it is also about to complete. By using these techniques the critical path was found out and more importance was given on that activities which were lying in critical path. Since requirement of men, materials, money and machinery were calculated before hand delays were minimised. The use of computer in the Scope complex reduced the manual labour in preparing the schedule. The progress reports and bar charts were found very useful in deciding the status of the project.

From this it can be concluded that in any project, the management techniques can be used beneficially. It will become economical and work can be carried out as per schedule with optimum resources and within required time.

CHAPTER-7

CONCLUSION AND DISCUSSIONS

In the previous chapters the author has tried to explain the different aspects of network scheduling and monitoring. Two different types of network techniques i.e., CPM and precedence have been taken into account.

Each of the techniques has got its own significance. If the network is examined, we can see that when compared with precedence network CPM network is very simple in logic and also in drawing. One thing is that if CPM network is to be drawn for a project we have to prepare more drawings for that when compared with precedence. In precedence network different lag times are shown in the drawing itself. If one work can be started as soon as the precedent work is started or it can be finished before the precedent work is finished, these type of relationships are clearly shown in precedence network using lag factors. In CPM network if this type of relationship is to be shown, the activity should be split into different sections and dummies are to be introduced properly. If one is accustomed to CPM he will find it easier to use CPM and vice-versa.

If we take the case studies, Zerox complex was completed in time and scope complex is about to be completed. This gives us the information that in a developing country like India also we can use these type of techniques beneficially.

Some time back people were doubtful about the use of management techniques in India. They thought that these modern techniques have nothing to do with Indian conditions. But now it is realised that it will be more useful in developing countries like India. In those two case study projects, they had benefits, when compared with the little amount of effort that they spent for management.

In both the projects they have found it useful in the following ways :-

- For completing the project in time.
- Progress of work was watched consiously, so that any slippage was found out and corrective measures were taken. This helped in reducing extra cost, time, labour etc.

- Financial benefit.
- Since requirement of men, materials, money, machinery etc. can be calculated beforehand, delays were minimised.

- Since strict control is applied, any deviation from the schedule can be noticed quickly.

- Since the activities are divided into different sections according to physical segregation, work can be done easily. The cycles or chains used for repeated activities are very useful.

- The preparation of bar charts from the progress of work enables in the better control of project.

- Progress reports and charts are made at frequent intervals, so that the progress of work is readily seen.

- From the progress, financial status of the project is also found out at frequent intervals, so that cost status of the project is also readily available.

If we take SCOPE complex we can see that they have even introduced computer in this field. The schedules, the per day output and labour requirement which are done through computer is found useful. This saved time also. In each monitoring stage these schedules and outputs were revised. Since it is the work of computer it needs only a little time when compared with manual work.

In the Zerox complex, if we go through the reports we can see that in May '84 the concreting was lagging behind by 200 m^3. So the construction company made arrangements to accelerate this facet of work. They instructed the responsible agency to mobilise an additional set of shuttering and other necessary resources. So at last with the 5 sets of shutterings, M/s Unitech could maintain a 85 day cycle for casting of folded plates. Like this, corrective measures can be taken if there is a plan and constant watch is there on the work.

Eventhough substantial progress had been made in construction of brickwalls consulting Engineers had cautioned that additional masons should be deployed to maintain pace and meet the targets for the following weeks.

Since there are preplans at each stage, there is clear idea of what is to be done and when. If some of the details of a particular item of work are not yet finalised, it can be done when preceding work is in progress.

The progress reports are found to be very useful in the monitoring stage. Any slippage in the work, any shortage of materials and resources are clearly indicated in the progress report. Therefore corrective measures can be taken at appropriate time

From the above study it can be concluded that the use of management techniques in construction project is unavoidable for efficient and timely completion of the project. In terms of money and time it helps the user in different ways. So if we have to finish the work in time and economically, the answer is to adopt any of the management techniques, which is convenient to the user. If computer is accessible it will further improve the efficiency and save time, because big projects contain the hundreds of activities and large amount of calculations.

CHAPTER-8

SCOPE FOR FUTURE WORK

In the monitoring part of the program the changes of durations, nodes, additions, and deletions are considered. These are concerned with the time monitoring of the project. Cost monitoring and resource monitoring can be followed this part. When there is revision in the cost of materials and availability of resources how the basic network can be changed and how the new schedule can be obtained, is one of the problems which can be taken up as a scope for future work. Resource levelling and crashing of network are other facets where emphasis can be given. By crashing the activities, the optimum cost can be found out. At one point the total cost becomes minimum. After that point again the total cost increases. So the point at which the total cost is minimum is the optimum duration of the project. In the monitoring program if the random node numbering is used, it will be useful to change the node numbers. If some node numbers are changed in between, any number can be given to those nodes, if random node numbering program is used. Otherwise all the node numbers should be changed.

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