IEE ELECTRICITY AUTHORITY
RESEARCH CORPORATION OF THAILAND

MISCELLANEOUS INVESTIGATION NO. 22

MISCELLANEOUS DIGITAL COMPUTER PROGRAMMES

REPORT NO. 1

CRITICAL PATH SCHEDULING PROGRAMME FOR IBM 360 SYTEM

BY

JOHN W. MAYNE JR.

PHYSICS AND ENGINEERING GROUP

TECHNOLOGICAL RESEARCH INSTITUTE

ASRCT, BANGKOK 1969

not for publication

YANHEE ELECTRICITY AUTHORITY

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

MISCELLANEOUS INVESTIGATION NO. 22

MISCELLANEOUS DIGITAL COMPUTER PROGRAMMES

REPORT NO. 1

CRITICAL PATH SCHEDULING PROGRAMME FOR IBM 360 SYTEM

BY

JOHN W. MAYNE JR.

PHYSICS AND ENGINEERING GROUP

TECHNOLOGICAL RESEARCH INSTITUTE

ASRCT, BANGKOK 1969

not for publication

F O R E W O R D

In conjunction with Cooperative Research Programme No. 28, Power system analysis, it was found that from time to time programmes were desired which would be of great assistance to the System Planning Division at YEA but which were not directly related to power system analysis work. They either covered other phases of work at the System Planning Division or were general programmes which were applicable with all the work and not only that of power system analysis. As a result, this Miscellaneous Investigation was initiated with the idea that it would contain these various computer programmes.

Report No. 1 deals with a programme which assists in construction scheduling in the System Planning Division.

Earlier work on construction scheduling at YEA was carried out by hand calculations, and because of the length of time and accuracy involved in these calculations the finding of the critical path had limited use. However, when the IBM 360/40 computer system became available to YEA it was readily realized that, with a CPM/PERT computer programme the scheduling of various jobs in the construction of sub-stations, power lines, etc. could be easily accomplished, and the schedule kept up-to-date.

A CPM/PERT programme for use with the IBM 1130 system was obtained from IBM (IBM 1966). Through cooperative work between YEA and ASRCT this programme has been converted for use on the IBM 360/40 system. A preliminary report on this programme was made at YEA in January 1968. Work has been going on since then and the present programme YEA501 has a great many options and output reports not available with the earlier programmes. This report discusses the theory and application of the programme.

The author of this report is a voluntary member of the Canadian Universities Service Overseas. He has been assigned by that organisation to work with ASRCT for a two year period. He has been attached to the Physics and Engineering Group of TRI where he has worked on the Yanhee Power Authority sponsored programme on power system analysis

and on other programmes involving computer programming. Grateful acknowledgement is made of this valuable contribution to ASRCT's research effort.

CRITICAL PATH SCHEDULING PROGRAMME FOR IBM 360 SYSTEM

By John W. Mayne Jr.*

SUMMARY

The programme described in this report is used to process network scheduling problems. It provides both critical path scheduling (CPM) and probability scheduling analysis. The programme is in FORTRAN IV language for a IBM 360/40 or IBM 360/30 Disk system with card reader and printer, and is designed for use with an accurate arrow diagram of the scheduling process. The programme has a capacity of 3000 jobs and 1500 nodes, and provides a series of output reports giving the scheduling of the jobs both in bar chart and calendar form. In addition, arranging the jobs under different groups and/or subgroups is permitted. It is designed with the idea of providing the field construction engineer with an easily readable and useful report on the current situation of the project.

INTRODUCTION

The project for which the scheduling analysis is to be done will have a number of jobs to be carried out in a certain order. The first work toward the solution involves drawing a logical arrow diagram of the complete project such as shown in Appendix V, with the jobs represented by arrows showing the sequences and interrelations of the individual jobs in the project. In this job network diagram if the head and tail of each arrow, i.e. each node, is given a number, then the logic of the sequence is maintained if each job is given a two number label consisting of its tail and head node. This information, along with the estimated time of the job, is the basic information required before the computer analysis can begin.

---

* Physics and Engineering Group, Technological Research Institute, ASRCT.

The programme for this work incorporates both CPM (Critical Path Method) and PERT (Project Evaluation and Review Technique) analysis. CPM is designed to plan, schedule, and control projects in which the activities, duration, and interdependence are relatively easy to define and hence is a deterministic model. PERT, on the other hand, deals with activities that are ill defined and is a probablistic model. Whether PERT or CPM is used is determined by how the estimated time (ET) of a job is arrived at. For PERT, three times may be given for the ET of each job, viz.,

A an optimistic time, the best or shortest time. There is little chance of completing the activity in less than the optimistic time,

M a most likely time, the time which most probably will be required,

B a pessimistic time, the worst or longest time. There is little chance the activity would require longer time than the pessimistic estimate, and ET is calculated. In CPM, only one time is inputted for ET.

The main purpose of the programme is to find the critical path of the scheduling network. The critical path (CP) through the network is the longest path time and there will be at least one critical path. All the activities or jobs comprising the critical path are critical in themselves, and delay of one of these will proportionately delay the project completion, or conversely any speed-up will decrease the total project time.

The calculation of the required critical path data is accomplished by first making a forward pass through the network cards to determine the early start times (ES) and early finish times (EF). The ES for an activity is the first day the activity can begin. EF of the activity is the day the activity will be completed, provided it begins at its ES. Late start times (LS) and late finish times (LF) for an activity are computed by making a backward pass through the network from the final activity to the initial activity. The LS for an activity is the last day an activity can begin without delaying project completion. LF cor-

responds to EF for the late times.

The difference between the early and late start time, or early and late finish times for one activity, is leeway time for accomplishing that activity and is called "total float" (TF). TF is the amount of time an activity may be delayed without delaying the project completion date.

Float has to be watched very carefully. In a chain of activities total float is identical for each of the activities in the chain. It cannot be assumed that each activity in fact has the stated leeway time, because the leeway is only available for the first activity in that chain. If any or all of the float is used up for the first activity (or any other activity in the chain), the total float for all following activities is reduced by the same amount of time until the chain becomes critical (see the sample problem at the end of this report). In addition, other chains starting from the chain in question will be affected. Therefore, in any diagram, the degree of criticality of chains, not of the critical path, should be examined carefully. If some or all of the total float of an activity is used, the expected time of the activity should be changed and the programme rerun to see if a new critical path emerges.

The amount of time by which an activity may be delayed without delaying any following activities is called "free float" (FF). If some of the time of the total float of an activity which has zero FF is used, then the programme should be rerun to check for changes in the critical path.

For further details and discussion about constructing arrow diagrams and basic CPM/PERT ideas the reader is referred to the references at the end of the report.

A simplified flow chart of the actions taken by the computer is shown in Appendix I.

USES OF THE PROGRAMME

The programme may be used to find the critical path of a network process and the associated CPM variables.

In addition, one of the main features of the programme is that it can be used as an up-to-date check on the actual construction. It is readily revisable and hence can be used to establish the effects of increasing or decreasing job times i.e. what effects delays or speed-ups have on the criticality of all jobs. It should be able to be used on the construction site to enable an easy check of what jobs should be going on at present, and when new jobs should be started in order to keep the completion date unchanged.

This revised programme is able to save computer time by providing reports on any number of projects with only one EXEC statement.

METHODS

The computer programme for this CPM/PERT analysis consists of five separate programmes, YEA501A to YEA501E, which are self-linked together using an overlay technique to reduce the amount of core storage required. Only YEA501A needs be executed and each successive part calls the next.

YEA501A is the section which reads and stores all the input data information (the titles for the various groupings being stored on a disk or Direct Access Storage Device (DASD), and calculates all the basic CPM information. As already mentioned, the required input data for the programme consists of the node numbers I and I for each job and either the estimated time ET, or the probable times A, M, and B.

If the three times are given, i.e. PERT is wanted, the estimated time must be calculated. Consider Figure 1 where these three times estimates are shown. The probability that the actual time will be A or B is very small while M may be anywhere in between, depending on the estimators judgement.

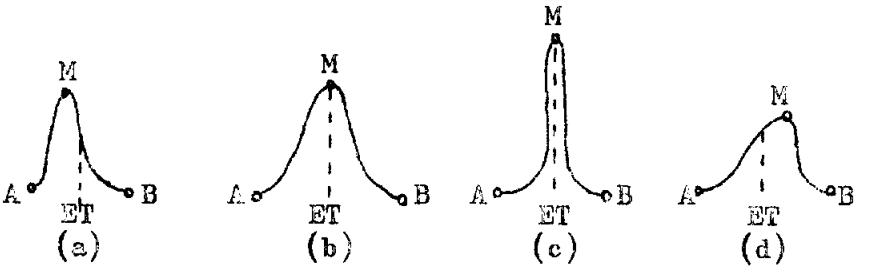


Figure 1. Activity time estimates and mean activity time.

Curve (a) shows a distribution skewed toward the most optimistic time while curve (d) shows a distribution skewed toward the most pessimistic time. Curves (b) and (c) show a normal distribution of job time, with curve (c) showing less "spread" than curve (b).

The formula for ET, the estimated time, has been arrived at after extensive experience with PERT on the U.S. Navy Polaris Programme. It was found (Machol 1965) that valid expressions are:

$$ET = \frac{A + 4M + B}{6}$$

$$VAR = \left\{\frac{B - A}{6}\right\}^2$$

where VAR gives the variance of ET and hence is a measure of confidence in the calculated expected time.

The required CPM data is calculated by making network "passes" through the input data. This technique is adapted from the original IBM 1130 programme and consists of setting up a vector MTI(I) of all ES times listed by node number. Initially all MTI(I) = 0, then as each card of I, J, ET values is read, the MTI(I) value is added to the ET value and compared to the MTI(J) value of the next sequential job. If the ES value of any job is greater than that of the job which follows it, this following job takes the new ES value of the preceding job. This process is repeated until no MTI(I) value changes upon comparing with MTI(J) values. In this way all the ES values are found with the MTI(I) value of the last sequential node having the largest numerical value and being equal to the total project duration, LMBD.

By initiallizing a vector MTJ(I) equal to LMBD and this time subtracting ET an analogous "backward pass" through the network is made to determine the LF values. Obviously

$$EF = ES + ET$$
$$LS = LF - ET$$
$$TF = LS - ES$$
$$FF = MTI(J) - EF$$

All this information as well as all that was on the input network cards is stored on the disk for later use.

Also calculated is BMA = B - A to see if PERT analysis is required. YEA501A calls YEA501B if PERT is required and calls YEA501C if PERT is not required.

If PERT is required, YEA501B first writes an output report consisting of all the calculated CPM data as well as the inputted data for each job, i.e. there is a listing of I, J, A, M, B, ET, VAR, COST, TS, D, ES, LS, EF, LF, TF, FF

where COST is an optional input cost of the job,

D is the description of the job,

VAR is the variance of the A, M, B times, previously mentioned,

TS is an optional scheduled completion date which may be assigned to any job in order to find out the probability of finishing the job on that date.

An additional inputted option is to specify the project completion date (PDUR). Then in this PERT report the times LS, LF, TF are adjusted by (PDUR - LAMBD) when printed out.

YEA501B then provides two probability reports which give the probability of finishing a job on a given day. This probability is calculated by assuming a normal distribution for the times about the expected finish time as in Figure 2 where the shaded region under the curve gives the probability of finishing by a given scheduled time, TS.

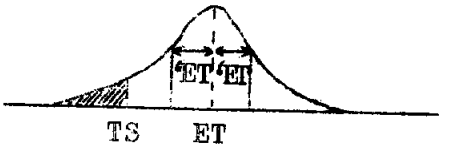


Figure 2. Estimate of probability of meeting scheduled date TS.

This probability is calculated for a five day spread about the assigned TS time.

The next two parts YEA501C and YEA501D consist of the days of the year written as double precision constants. These are used, in alpha-numeric form, in the calendar reports of YEA501E.

YEA501E, then, writes the main output reports. These reports are described in detail later in this report. The titles stored on the desk in YEA501A are read one by one, and the appropriate jobs for each title are found and sorted in early starting time order. Using the CPM data already calculated, both bar chart and calendar reports are made.

At the end YEA501E checks to see if another project follows. If there is another project YEA501A is called again, otherwise the programme exists.

FEATURES OF THE PROGRAMME

The complete programme YEA501 consists of five separate programmes YEA501A-E. These programmes are coupled using an overlay technique which allows for a greater capacity of jobs than the system used for the January 1968 programme.

Other features include:

(1) Node numbering may be entirely random.

(2) Multiple starting and/or multiple ending nodes are allowed.

(3) A project pre-set completion date option is provided.

(4) Independent networks belonging to the same project may be processed together.

(5) Network data processed is left on disk ready for further processing by user-writer programmes.

(6) If CPM is desired, only a single duration for each job needs to be specified on input.

(7) Each job may be assigned a scheduled completion time (TS).

(8) PERT reporting is automatic if the data includes a range of job times for any job. If no TS values are inputted, the PERT report will be for the project conclusion.

(9) For up-to-date operational use the current date is printed on each output report.

(10) An option is provided to indicate if a job is finished or not by assigning 0 or 1 to the variable FN.

(11) Different reader and writer unit numbers may be assigned by changing the values of IN and IP respectively.

(12) An option is provided for arranging the jobs in groups and/or subgroups by, for example, type of work or location of work.

(13) On a given run the user can specify which type of output it wanted, i.e. either or both of the group arrangements. The grouping of all jobs together and then a listing of all critical jobs always conclude a run.

(14) In the revised programme a description title of up to 36 character may be used.

(15) This programme allows any number of projects to be run under the one execution statement.

(16) The execution time of this revised programme is faster. For a project consisting of 27 jobs, the running time was 3 minutes. For a project of 200 jobs, the running time was 10 minutes 17 seconds.

DATA FOR THE PROGRAMME

The first cards contains the current run date, and is punched as

	22	JUL	1967
Columns	1	4	9

The second card, the date header card, is a completely free form project description card. Any valid punching in column 1 through 80 is acceptable. This description is printed on each page of the output as

the project title.

There follows a group of data cards, punched with the network data detail as follows:

Variable	Column	Format
I	1-5	I5
J	6-10	I5
A	11-14	I4
M	15-18	I4
B	19-22	I4
COST	23-32	I10
FN	33	I1
TS	34-38	I4
GP	39-40	I2
SG1	41-42	I2
SG2	43-44	I2
D	45-80	9A4

Description of variables

I - node number at the beginning of each job.

J - node number at the end of each job.

A - the best or shortest duration time of a job.

M - the most likely duration time of a job.

B - the worst or longest duration time of a job.

COST - the cost of the job.

FN - a control variable which is 1 if the job has been finished and blank if the job has not been finished.

TS - a job completion date. This may be assigned to any job in order to calculate the probability of completing the job by the desired date. This 'date' is counted in days, starting at day zero.

GP - the group number for the job. Jobs with the same GP will be in the same group. The group number is any two digit number.

SG1, SG2 - each of the main groups can be further divided into subgroups by assigning integer values to SG1 and/or SG2 i.e. each job can be placed into two different subgroup types. The group option can be omitted by leaving GP blank, and then only SG1 and SG2 are used.

D - the job description and can have any valid punching.

Normally the programme computes the project duration time. An option is provided for this time to be pre-set; an asterisk (*) in column 45 identifies a project completion date assignment card, and the TS field is picked up for this purpose. (This pre-set date is used only in PERT REPORT NO. 1.) Columns 1-33 of the project completion date assignment card must be left blank. This card may be placed anywhere among the CPM data cards after the header card. (See the sample problem in Appendices.)

The end of the network data cards is indicated by a blank card.

The next data card gives the project starting date and must be punched as follows:

Variable	Column
YEAR	1-6
BEGIN	7-12
IMONTH	15-16
IYEAR	19-20

YEAR is the project starting year.

BEGIN is the project starting day given on a 366 day year basis. The 29th of February is day 366.

IMONTH is the number of the starting date month, i.e. May is 5.

IYEAR are the last two digits of YEAR.

The following data card indicates the type of output report desired:

Variable	Column
IOUT	5
IGROUP	10

IOUT can have the following values:

Blank for an output consisting only of a report of all jobs grouped together and a listing of the critical jobs.

1 for output reports with SG1 grouping only,

2 for output reports with SG2 grouping only,

3 for output reports with both SG1 and SG2 grouping.

If IGROUP is blank, the GP values are ignored. If IGROUP is equal to some positive integer, the GP grouping is used.

The present programme, as already mentioned, allows for the jobs to be grouped together in two different arrangements. The last group of data cards consists of the titles which the user wishes to be placed as a heading for these groups. The general format for these cards is as follows:

Variable	Column
MAST	2
NAST	3-4
TITLE	5-80

MAST can have the values:

1 for the title of a group, i.e. using GP,

2 for the title of a subgroup, i.e. using SG1 or SG2,

3 for the title of the type of group arrangement used. (This title should be positioned in the center of the data card for symmetric output. It is printed as a title for the output report.)

-1 with the rest of the card blank. This card indicates the separation between SG1 titles and SG2 title.

Blank to indicate the end of a project data deck, (see below).

NAST is equal to either SG1 or SG2, i.e. NAST correlates the SG1, SG2 numbers for each job with the appropriate subgroup title.

TITLE is the heading desired and can have any format.

The next card is a blank card when it is the last card in the data deck. If, however, another project follows, this card has NAST equal to any two digit positive integer with MAST equal to zero. In this case all of the above mentioned data cards except the 'Current Date' card, are expected to follow for this new project.

A summary of the data cards can be found in Appendix II. The data cards for a sample problem are listed in Appendix III.

RESULTS OF THE PROGRAMME

Output descriptions

There are maximum of eleven possible output reports available to the user, three of which are only given if PERT reporting is required.

The reports can be divided into three sections.

(i) The first output report, entitled: JOB LISTING WITH ESTIMATED TIME (ET). This report is always given. It is a listing of the data given to the programme. In addition, the ET variable has been calculated and printed, and inconsistances in the A, M, B data resolved. The number of jobs, total project cost, the total project duration, and all beginning and ending nodes are also recorded here.

(ii) The PERT output reports. These are only given if PERT is required, and consist of

(1) JOB LISTING WITH CALCULATED CPM DATA. This report is the schedule for the jobs within the project. The input data is repeated, the individual job variances, the scheduled times, and the floats are recorded. Critical jobs are indicated by the letters "CP".

(2) PERT REPORT NO. 1. SIMPLE JOB PROBABILITIES. This report is the job-oriented (activity-oriented) PERT analysis. Each job for which a TS time was given, and each job ending on the last node, is reported upon for a five day spread, i.e. by assigning a schedule completion time to a job the probability of finishing the job around the assigned date is given.

(3) PERT REPORT NO. 2 EVENT PROBABILITIES. This report is the job-oriented (node oriented) counterpart of the above report. The expected completion time (TE) of a node is given. This is the largest early finish time of all the jobs ending at it; more simple, it is the earliest start time of all the jobs beginning at it. Again a five day spread is given for each TS number inputted.

(iii) The following reports, some of which are optional, consist of bar chart and calendar reports with the jobs organized in different ways. A maximum of three bar charts and four calendar reports may be given. These reports can be discussed under the two headings: for bar chart and calendar reports.

(1) BAR CHART OF THIS PROJECT-JOBS LISTED IN EARLY STARTING TIME ORDER. The jobs have been arranged in early starting time order and a simple bar chart, excluding dummy jobs, given. The entire project is scaled to fit a range of 9.8 inches. For each job a series of asterisks and minus signs, F's or X's is given. A series of asterisks indicates the duration of the job (ET) while the minus signs indicate the total float time available. A series of F's means the job is finished and a series of X's is given for jobs on the critical path. The bar chart reports, as they must fit the scale, are not an exact picture of the schedule, and the actual dates should be looked for on the calendar reports. A rough idea of the month and year is given above the scale range. The first month letter corresponds to the project start date immediately above.

If the jobs are arranged in groups and/or subgroups, the jobs within each group are listed in early starting time order.

(2) CALENDAR SCHEDULE OF THE PROJECT IN EARLY STARTING TIME ORDER. On each of the various calendar reports the jobs, listed again in ES order even if in groups, are given with their expected time, total float and free float time and early start, late start, early finish, late finish dates. If the job is finished or on the critical path, this is so indicated under the late start, early finish headings. At the end of the report the starting and finishing dates for the project are given.

The last report given is a calendar listing, in ES order, of

all the jobs which are on the critical path.

Appendix IV shows the results of the CPM study of the example data mentioned previously.

PROGRAMME OPERATION AND CAPACITY

The programme YEA501 is catalogued on a YEA disk pack at the National Statistical Office in Bangkok. In order to use it the control cards found in Appendix VI are required. If it should happen that it is required to analyze a project which has more than 3000 jobs and/or 1500 nodes, there is also on the YEA disk pack a set of programme YEA501 G-K which may be used. These programmes operate in the same manner as YEA501 A-E and accept the same data. For these programmes the capacity is 2500 nodes and at present 4000 jobs. This maximum number of jobs can be easily greatly increased. The control cards are different and the executing time is over twice as long as with the YEA501 A-E system.

DISCUSSION

Every effort was made to try to make the programme easy to use, and yet provide a wide range of useful results.

The sample data listed in Appendix III was run, and the results were given in Appendix IV. Two of the reports are omitted here for brevity: the calendar schedule of the first subgroup arrangement and the bar chart of the second subgroup arrangement. All the information omitted appears elsewhere and the other reports shown are very similar to those omitted. The various output reports are discussed earlier in this report. The following points, peculiar to the particular project, can be noted:

(1) For some jobs A, M, and B are different and hence there are PERT reports.

(2) There is an inputted project completion time of 40 days. (See the data list, Appendix II, and the card with the asterisk.) However, the calculated completion time is 44 days and hence the project

slack is -4 days, i.e. 4 days will have to be eliminated in order to finish by day 40.

(3) IOUT is set equal to 3 indicating that both SG1 and SG2 groupings are to be used.

(4) GP is left blank and there is no title card with MAST = 1. Thus only subgrouping results. The second, third, fourth, and fifth output reports in Appendix II show how this subgrouping was arranged.

(5) Some of the jobs have FN = 1, indicating they have been finished. They have FF...F on the bar charts and JOB FINISHED on the calendar reports.

(6) As an example of how the programme can be used as an up-to-date check on the project, the job 1-20 (WAITING FOR ERECTOR) was introduced. (It is not found on the arrow diagram in Appendix V. Job 1-4 was labelled 20-4.) The old job 1-4 had a total float of 8 days. It was supposed, however, that all this time was used waiting for an erector which was needed in order to begin the job. This change of plans is noted by the insertion of the job 1-20. Previously there was only one critical path, 1-16-17-18. However, when the updating of the project is done, another critical path emerges namely, 1-20-4-10-14-15-17-18 (which was expected since all the TF for that brance was used up). If, in addition to changes of this type, it is noted (putting FN = 1) when jobs are finished, and if some of the estimated job times need revising, then an accurate picture of the current construction situation will be obtained.

The programme has proved quite successful and is presently used at YEA to schedule the construction of many projects including transmission lines, substations, and steam generating plants.

REFERENCES

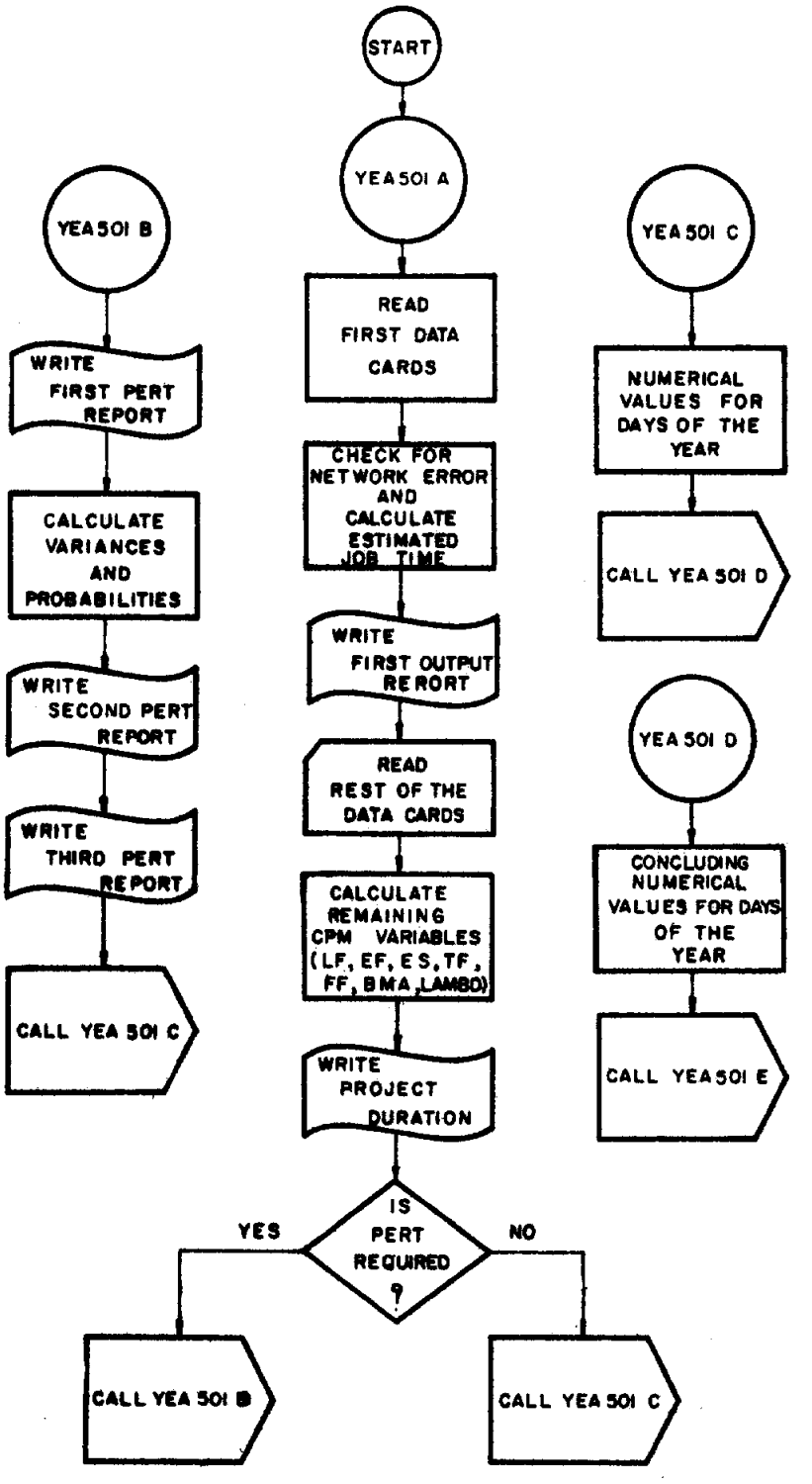
IBM, (1966).—CPM/PERT for the IBM 1130 FORTRAN. IBM 1130 General Programme Library.

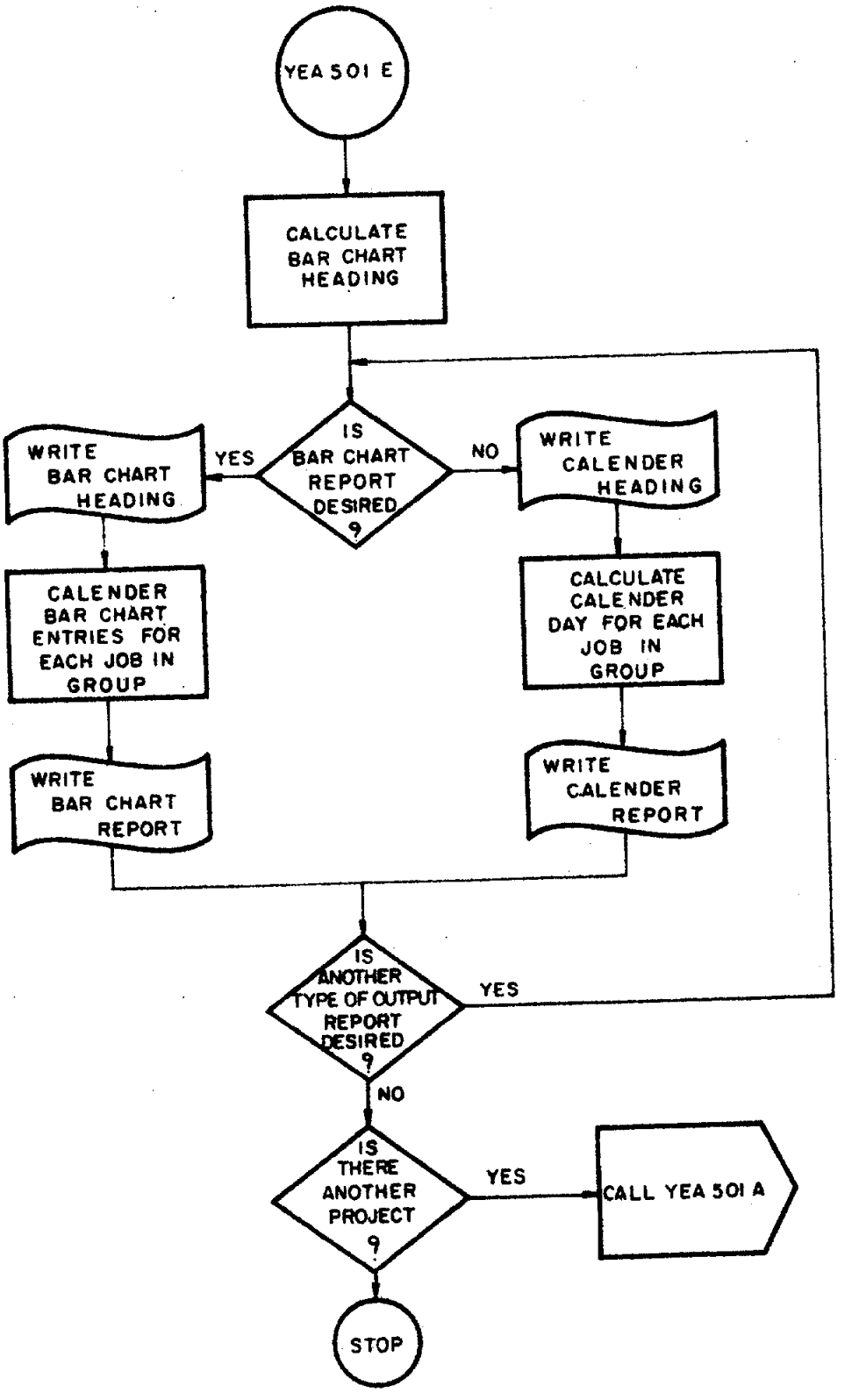
MACHOL, R.E., ed. (1965).—"Systems Engineering Handbook." pp. 36-40. (McGraw-Hill Book Co.: New York.)

RIGGS, J.L., and HEATH, C.O. (1963).—"Guide to Cost Reduction Through Critical Path Scheduling." (Prentice-Hall Inc.: New Jersey.)

APPENDIX I

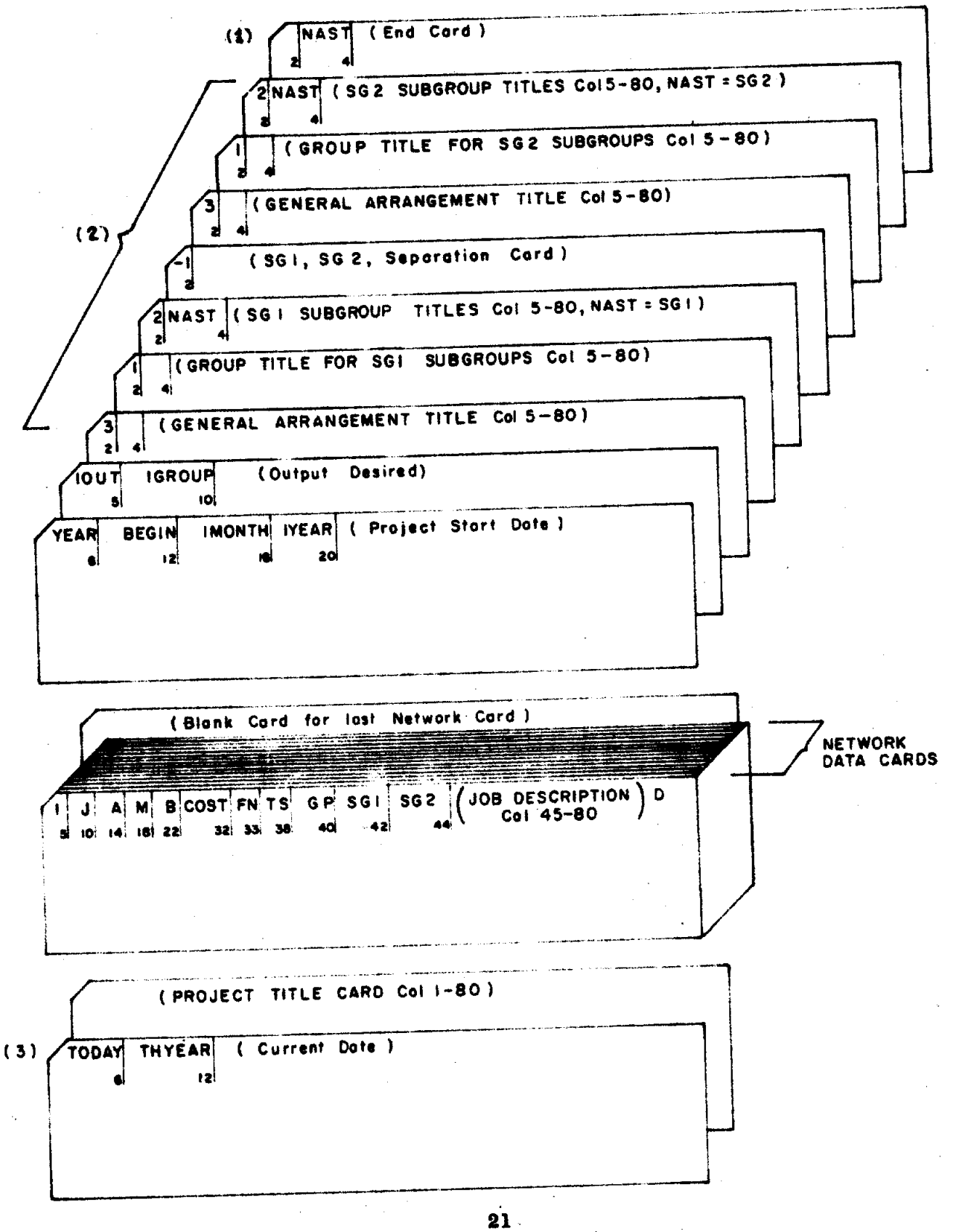
SIMPLIFIED FLOW CHART




YEA 501 E
CALCULATE BAR CHART HEADING
IS BAR CHART REPORT DESIRED ?
YES
NO
WRITE BAR CHART HEADING
WRITE CALENDER HEADING
CALENDER BAR CHART ENTRIES FOR EACH JOB IN GROUP
CALCULATE CALENDER DAY FOR EACH JOB IN GROUP
WRITE BAR CHART REPORT
WRITE CALENDER REPORT
IS ANOTHER TYPE OF OUTPUT REPORT DESIRED ?
YES
NO
IS THERE ANOTHER PROJECT ?
YES
CALL YEA 501 A
STOP

APPENDIX II

SUMMARY OF DATA CARDS



Comments

(1) MAST = 0 if this is the last card in the data deck

= 1 if there is another project to follow, in which case all of the cards shown on the previous page are repeated, except for the current date card.

(2) The arrangement of title cards shown is the most general one possible. If not all the options are used, then the appropriated cards are left out. The numbers on the extreme left are the various values of MAST. For example, if SG1 grouping is not used, then the three cards immediately preceding the "-1" SG1, SG2 separation card may be dropped. The "-1" card is, however, always required. On the sample data list found in Appendix III, the GP grouping option is not used hence there are no "Group title" cards (MAST = 1).

(3) The 'Current date' card is the first card of the data deck. It is not repeated if another project follows.

APPENDIX III

SAMPLE DATA LIST

```
17 SEP  1968
YEA*MAF-2-1          SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION
    7   16    7    8   10                  15    4 1EXCITER POWER+CONTROL CABLE INSTALL
    1    3    5                         1        6 1COOLING TOWER INSTALLATION
    1    7    8                         1        4 1EXCITER BOARD+EQUIPMENT INSTALLATION
    1    5   10                         1        3 113.8KV INDOOR BUS SUPPORT STR ERECT
   20    4    7                                  1 1TRANSFORMER ACCESSORIES INSTALLATION
    1   20    8                         1        1 1WAITING FOR ERECTOR
    4   10   10   12   15                       1 3OIL FILING PURIFICATION + TEST
    4   14    2                                  1 2CONNECT TRANSF TO 69KV LINE+13.KVBUS
   10   14    2                                  1 2TRANSFORMER CONTROL WIRING
   14   15    2                                  1 3TRANSFORMER TEST
    1    6   15                                  2 169KV BREAKER + CONYROL BOARD INDTALL
    6   15    1                                  2 369KV BREAKER TEST
   15   17    1                                  1 3TRANSFORMER ENERGIZING TEST
    5    8    5    7    8                  17    3 1COPPER BUS BAR+INSULATOR INSTALL
    8   11    3                                  3 1BREAKER INSTALLATION
    8   12    3                                  3 1CT + PT INSTALLATION
                                           40      *
   11   16    3    5    6                       3 1BREAKER POWER+CONTROL CABLE INSTALL
   12   16    3                                  3 2CT + PT CONTROL WIRING
    1   16   25                                  4 1EXCITER SET INSTALLATION
    1    2    2                                  5 1416VOLTS DISTRIBUTION BOARD INSTALL
    2   16    2                                  5 1416VOLTS CABLE INSTALLATION
   13   17    3    5    8                  22    6 3COOLING SYSTEM TEST
    9   13    2                                  6 2COOLING WATER MOTER PUMP WIRING
    1    9    2                                  6 1COOLING WATER MOTER PUMP BRD INSTALL
    3    9   10                                  6 1PIPES INSTALLATION
   16   17    5                                  4 3EXCITER TEST
    1   17   20                                  7 1SYNC CON ACCESSORIES INSTALLATION
   17   18   10   12   16                  45    7 3SYNCHRONOUS CONDENSER COMMISSIONING

 1968      2   1  68
    3
3                ARRANGED IN GROUPS ACCORDING TO EQUIPMENTS + MATERIALS
2 1      TRANSFORMER ACCESSORIES
2 2      69KV BREAKER + CONTROL BOARD
2 3      13.8KV INDOOR BUS SUPPORT STRUCTURE
2 4      EXICITER SET,EXCITER BOARD + EQUIPMENT
2 5      416VOLTS DISTRIBUTION BOARD + CABLE
2 6      COOLING SYSTEM
2 7      SYNCHRONOUS CONDENSER
-1
3                ARRANGED IN GROUPS ACCORDING TO TYPE OF WORK
2 1      INSTALLATION + ERECTION
2 2      WIRING
2 3      TESTING + COMMISSIONING
```

APPENDIX IV

OUTPUT REPORTS FROM DATA IN APPENDIX III

YEA501 CPM/PERT ANALYSIS PROGRAM * MAYAE * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT 8K SUBS SYSTEM PLANNING DIVISION

JOB LISTING WITH ESTIMATED TIME %ET¤ PAGE 1

I	J	A	M	B	CCST	FR	TS	GR	SG1	SG2	JOB DESCRIPTION	ET
7	16	7	8	10	0	0	15	0	4	1	EXCITER POWER&CONTROL CABLE INSTALL	8
1	3	5	5	5	0	1	0	0	6	1	COOLING TOWER INSTALLATION	5
1	7	8	8	8	0	1	0	0	4	1	EXCITER BOARD&EQUIPMENT INSTALLATION	8
1	5	10	10	10	0	1	0	0	3	1	13.8KV INDOOR BUS SUPPORT STR ERECT	10
20	4	7	7	7	0	0	0	0	1	1	TRANSFORMER ACCESSORIES INSTALLATION	7
1	20	8	8	8	0	1	0	0	1	1	WAITING FOR ERECTOR	8
4	10	10	12	15	0	0	0	0	1	3	OIL FILING PURIFICATION & TEST	12
4	14	2	2	2	0	0	0	0	1	2	CONNECT TRANSF TO 69KV LINE&13.8KVBUS	2
10	14	2	2	2	0	0	0	0	1	2	TRANSFORMER CONTROL WIRING	2
14	15	2	2	2	0	0	0	0	1	3	TRANSFORMER TEST	2
1	6	15	15	15	0	0	0	0	2	1	69KV BREAKER & CONTROL BOARD INSTALL	15
6	15	1	1	1	0	0	0	0	2	3	69KV BREAKER TEST	1
15	17	1	1	1	0	0	0	0	1	3	TRANSFORMER ENERGIZING TEST	1
5	8	5	7	8	0	0	17	0	3	1	COPPER BUS BAR&INSULATOR INSTALL	6
8	11	3	3	3	0	0	0	0	3	1	BREAKER INSTALLATION	3
8	12	3	3	3	0	0	0	0	3	1	CT & PT INSTALLATION	3
						0	40	0	0	0	*	ASSIGND PROJ FINISH DATE
11	16	3	5	6	0	0	0	0	3	1	BREAKER POWER&CONTROL CABLE INSTALL	4
12	16	3	3	3	0	0	0	0	3	2	CT & PT CONTROL WIRING	3
1	16	25	25	25	0	0	0	0	4	1	EXCITER SET INSTALLATION	25
1	2	2	2	2	0	0	0	0	5	1	416VOLTS DISTRIBUTION BOARD INSTALL	2
2	16	2	2	2	0	0	0	0	5	1	416VOLTS CABLE INSTALLATION	2
13	17	3	5	5	0	0	22	0	6	3	COOLING SYSTEM TEST	5
9	13	2	2	2	0	0	0	0	6	2	COOLING WATER MOTER PUMP WIRING	2
1	9	2	2	2	0	0	0	0	6	1	COOLING WATER MOTER PUMP PRC INSTALL	2
3	9	10	10	10	0	0	0	0	6	1	PIPES INSTALLATION	10
16	17	5	5	5	0	0	0	0	4	3	EXCITER TEST	5
1	17	20	20	20	0	0	0	0	7	1	SYNC CON ACCESSORIES INSTALLATION	20
17	18	10	12	14	0	0	45	0	7	3	SYNCHRONOUS CONDENSER COMMISSIONING	12

28 JOBS IN THIS PROJECT. TOTAL ET # 185.

THE FOLLOWING ARE - FIRST NODES - 1

LAST NODES - 18

TOTAL PROJECT COST # 0

DURATION CALCULATED # 44

Y6A501 CPM/PERT ANALYSIS PROGRAM * MAYAG * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT 8K SUBS SYSTEM PLANNING DIVISION

JOB LISTING WITH CALCULATED CPM DATA PAGE 4

START NODE	END NODE	CRT TIME	MED TIME	PESS TIME	EXP TIME	EXP TIME VARIANCE	JOB COST	SCHED TIME	JOB DESCRIPTION	EARLY START	LATE START	EARLY FINSH	LATE FINSH	TOTAL FLOAT	FREE FLOAT	
7	16	7	8	10	8	0.25	0	15	EXCITER POWER&CONTROL CABLE INSTALL	8	15	16	23	7	9	
1	3	5	5	5	5	0.0	0		CCOLING TOWER INSTALLATION	0	6	5	11	6	0	
1	7	8	8	8	8	0.0	0		EXCITER BOARD&EQUIPMENT INSTALLATION	0	7	8	15	7	0	
1	5	10	10	10	10	0.0	0		13.8KV INDOOR BUS SUPPORT STR ERECT	0		10				CP
20	4	7	7	7	7	0.0	0		TRANSFORMER ACCESSORIES INSTALLATION	8	4	15	11	-4	0	
1	20	8	8	8	8	0.0	0		WAITING FOR ERECTOR	0	-4	8	4	-4	0	
4	10	10	12	15	12	0.69	0		OIL FILING PURIFICATION & TEST	15	11	27	23	-4	0	
4	14	2	2	2	2	0.0	0		CONNECT TRANSF TO 69KV LINE&13.8KVBUS	15	23	17	25	8	14	
10	14	2	2	2	2	0.0	0		TRANSFORMER CONTROL WIRING	27	23	29	25	-4	0	
14	15	2	2	2	2	0.0	0		TRANSFORMER TEST	29	25	31	27	-4	0	
1	6	15	15	15	15	0.0	0		69KV BREAKER & CONTROL BOARD INDTALL	0	11	15	26	11	0	
6	15	1	1	1	1	0.0	0		69KV BREAKER TEST	15	26	16	27	11	11	
15	17	1	1	1	1	0.0	0		TRANSFORMER ENERGIZING TEST	31	27	32	28	-4	0	
5	8	5	7	8	6	0.25	0	17	COPPER BUS BAR&INSULATOR INSTALL	10		16				CP
8	11	3	3	3	3	0.0	0		BREAKER INSTALLATION	16		19				CP
8	12	3	3	3	3	0.0	0		CT & PT INSTALLATION	16	17	19	20	1	0	
11	16	3	5	6	4	0.25	0		BREAKER POWER&CONTROL CABLE INSTALL	19		23				CP
12	16	3	3	3	3	0.0	0		CT & PT CONTROL WIRING	19	20	22	23	1	3	
1	16	25	25	25	25	0.0	0		EXCITER SET INSTALLATION	0	-2	25	23	-2	0	
1	2	2	2	2	2	0.0	0		416VOLTS DISTRIBUTION BOARD INSTALL	0	19	2	21	19	0	
2	16	2	2	2	2	0.0	0		416VOLTS CABLE INSTALLATION	2	21	4	23	19	21	
13	17	3	5	8	5	0.69	0	22	COOLING SYSTEM TEST	17	23	22	28	6	10	
9	13	2	2	2	2	0.0	0		CCOLING WATER MOTER PUMP WIRING	15	21	17	23	6	0	
1	9	2	2	2	2	0.0	0		CCOLING WATER MOTER PUMP BRD INSTALL	0	19	2	21	19	19	
3	9	10	10	10	10	0.0	0		PIPES INSTALLATION	5	11	15	21	6	0	
16	17	5	5	5	5	0.0	0		EXCITER TEST	25	23	30	28	-2	2	
1	17	20	20	20	20	0.0	0		SYNC CON ACCESSORIES INSTALLATION	0	8	20	28	8	12	
17	18	10	12	16	12	1.00	0	45	SYNCHRONOUS CONDENSER COMMISSIONING	32	28	44	40	-4	0	

TOTAL PROJECT COST # 0 DURATION CALCULATED # 44

PROJECT DURATION DESIRED # 40 PROJECT SLACK # -4

```
YEA501 CPM/PERT ANALYSIS PROGRAM * MAYNE * SYSTEM PLANNING DIVISION * 17 SEP 1968

             YEA*MAF-2-1       SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

                        PERT REPCRT NO. 1  SIMFLE JCB PROBABILITIES

JCB   7   16 %EXCITER POWER&CONTROL CABLE INSTALL ¤ HAS AN EF DATE OF   16.ITS PROBABILITY OF COMPLETION BY DAY  13 IS    0.0 PCT.
                                                                                                     BY DAY  14 IS    0.3 PCT.
                                                                                                     BY DAY  15 IS    7.9 PCT.
                                                                                                     BY DAY  16 IS   50.0 PCT.
                                                                                                     BY DAY  17 IS   92.1 PCT.

JCB   5    8 %CCPPER BUS BAR&INSULATOR INSTALL    ¤ HAS AN EF DATE CF   16.ITS FRCBABILITY OF CCMPLETICN BY DAY  15 IS    2.3 PCT.
                                                                                                     BY DAY  16 IS   50.0 PCT.
                                                                                                     BY DAY  17 IS   97.7 PCT.
                                                                                                     BY DAY  18 IS  100.0 PCT.
                                                                                                     BY DAY  19 IS  100.0 PCT.

JCB  13   17 %COOLING SYSTEM TEST                 ¤ HAS AN EF DATE CF   22.ITS FRCBABILITY OF CCMPLETION BY DAY  20 IS    0.8 PCT.
                                                                                                     BY DAY  21 IS   11.5 PCT.
                                                                                                     BY DAY  22 IS   50.0 PCT.
                                                                                                     BY DAY  23 IS   88.5 PCT.
                                                                                                     BY DAY  24 IS   99.2 PCT.

JCB  17   18 %SYNCHRONOUS CONDENSER CCMMISSICNING ¤ HAS AN EF DATE CF   44.ITS FRCBABILITY OF CCMPLETION BY DAY  43 IS   22.2 PCT.
                                                                                                     BY DAY  44 IS   50.0 PCT.
                                                                                                     BY DAY  45 IS   77.8 PCT.
                                                                                                     BY DAY  46 IS   93.7 PCT.
                                                                                                     BY DAY  47 IS   98.9 PCT.
```

YEA501 CPM/PERT ANALYSIS PROGRAM * MAYNE * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

PERT REPORT NO. 2 EVENT PROBABILITIES

EVENT	16 HAS AN EXPECTED COMPLETION TIME (TE) OF	25.	THE PROBABILITY OF COMPLETION	BY DAY	13 IS 0.0 PERCENT.
				BY DAY	14 IS 0.0 PERCENT.
				BY DAY	15 IS 0.0 PERCENT.
				BY DAY	16 IS 0.0 PERCENT.
				BY DAY	17 IS 0.0 PERCENT.
EVENT	8 HAS AN EXPECTED COMPLETION TIME (TE) OF	16.	THE PROBABILITY OF COMPLETION	BY DAY	15 IS 2.3 PERCENT.
				BY DAY	16 IS 50.0 PERCENT.
				BY DAY	17 IS 97.7 PERCENT.
				BY DAY	18 IS 100.0 PERCENT.
				BY DAY	19 IS 100.0 PERCENT.
EVENT	17 HAS AN EXPECTED COMPLETION TIME (TE) OF	32.	THE PROBABILITY OF COMPLETION	BY DAY	20 IS 0.0 PERCENT.
				BY DAY	21 IS 0.0 PERCENT.
				BY DAY	22 IS 0.0 PERCENT.
				BY DAY	23 IS 0.0 PERCENT.
				BY DAY	24 IS 0.0 PERCENT.
EVENT	18 HAS AN EXPECTED COMPLETION TIME (TE) OF	44.	THE PROBABILITY OF COMPLETION	BY DAY	43 IS 22.2 PERCENT.
				BY DAY	44 IS 50.0 PERCENT.
				BY DAY	45 IS 77.8 PERCENT.
				BY DAY	46 IS 93.7 PERCENT.
				BY DAY	47 IS 98.9 PERCENT.

YE/SCI CPM/PERT ANALYSIS PROGRAM * MAYAE * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

BAR CHART OF THIS PROJECT - JOBS LISTED IN EARLY STARTING TIME ORDER PAGE 1

ARRANGED IN GROUPS ACCORDING TO EQUIPMENTS & MATERIALS

PROJECT STARTING DATE 2 JAN 1968 SCALE FACTOR - 1 INCH = 10 POINTS = 10 DAYS

LEGEND FFF-JOB FINISHED , XXX-CRITICAL JOB , ***-JOB DURATION , ----TOTAL FLOAT

START NODE	FAC NODE	JOB DESCRIPTION	J 02 15	01 30	15 14	02 28	F 14 14	03 28	14 14	04 25	M 04 11	05 09	05 23	06 06	06 20	07 04	07 18	08 01	08 15
	1	TRANSFORMER ACCESSORIES																	
1	20	WAITING FOR ERECTOR	FFFFFFF																
20	4	TRANSFORMER ACCESSORIES INSTALLATION	XXXXXXX																
4	14	CONNECT TRANSF TO 69KV LINE&13.8KVBUS	**----------																
4	10	OIL FILING PURIFICATION & TEST	XXXXXXXXXXX																
10	14	TRANSFORMER CONTROL WIRING	XX																
14	15	TRANSFORMER TEST	XX																
15	17	TRANSFORMER ENERGIZING TEST	X																
	2	69KV BREAKER & CONTROL BOARD																	
1	6	69KV BREAKER & CONTROL BOARD INSTALL	**********----------																
6	15	69KV BREAKER TEST	*----------																
	3	13.8KV INDOOR BUS SUPPORT STRUCTURE																	
1	5	13.8KV INDOOR BUS SUPPORT STR ERECT	FFFFFFFFF																
5	8	COPPER BUS BAR&INSULATOR INSTALL	*******---																
8	12	CT & PT INSTALLATION	***------																
8	11	BREAKER INSTALLATION	***----																
12	16	CT & PT CONTROL WIRING	***------																
11	16	BREAKER POWER&CONTROL CABLE INSTALL	******---																
	4	EXICITER SET,EXCITER BOARD & EQUIPMENT																	
1	16	EXCITER SET INSTALLATION	**********--																
1	7	EXCITER BOARD&EQUIPMENT INSTALLATION	FFFFFFF																
7	16	EXCITER POWER&CONTROL CABLE INSTALL	********----------																
16	17	EXCITER TEST	*****--																

START ACTE	END ACTE	JOB DESCRIPTION	J 01 05	11 10	11 15	12 20	12 25	F 13 01	13 05	14 10	14 15	15 20	15 25	M 16 01	16 05	17 10	17 15	18 20	18 25
	5	416VOLTS DISTRIBUTION BOARD & CABLE																	
1	2	416VOLTS DISTRIBUTION BOARD INSTALL	**	----------	----------														
2	16	416VOLTS CABLE INSTALLATION		**	----------	----------	----------												
	6	COOLING SYSTEM																	
1	9	COOLING WATER MOTER PUMP BRD INSTALL	**	----------	----------														
1	3	COOLING TOWER INSTALLATION	FFFFF																
3	9	PIPES INSTALLATION			**********	----------													
9	13	COOLING WATER MOTER PUMP WIRING				**	----------												
13	17	COOLING SYSTEM TEST					*****	----------											
	7	SYNCHRONOUS CONCENSER																	
1	17	SYNC CON ACCESSORIES INSTALLATION	**********	----------															
17	18	SYNCHRONOUS CONCENSER COMMISSIONING																XXXXXXXXXXX	

YEAR01 CPM/PERT ANALYSIS PROGRAM * MAYNE * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAE-S-1 SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

CALENDAR SCHEDULE OF THE PROJECT IN EARLY STARTING TIME ORDER PAGE 1

START NODE	END NODE	JOB	DESCRIPTION	EXP TIME	TOTAL FLOAT	FREE FLOAT	EARLY START	EARLY FINISH	LATE START	LATE FINISH
1	17		SYNC CON ACCESSORIES INSTALLATION	20	12	12	2 JAN 1968	25 JAN 1968	16 JAN 1968	9 FEB 1968
1	3		COOLING TOWER INSTALLATION	5			2 JAN 1968	6 JAN 1968	JOB FINISHED	
1	9		COOLING WATER MOTOR PUMP BRG INSTALL	2	23	23	2 JAN 1968	3 JAN 1968	25 JAN 1968	26 JAN 1968
1	7		EXCITER BOARD&EQUIPMENT INSTALLATION	9			2 JAN 1968	9 JAN 1968	JOB FINISHED	
1	2		416VOLTS DISTRIBUTION BOARD INSTALL	2	23	0	2 JAN 1968	3 JAN 1968	25 JAN 1968	26 JAN 1968
1	5		13.8KV INDOOR BUS SUPPORT STR ERECT	20			2 JAN 1968	31 JAN 1968	JOB FINISHED	
1	16		EXCITER SET INSTALLATION	25	2	0	2 JAN 1968	26 JAN 1968	4 JAN 1968	28 JAN 1968
1	20		WAITING FOR ERECTOR	8			2 JAN 1968	9 JAN 1968	JOB FINISHED	
1	6		69KV BREAKER & CONTROL BOARD INSTALL	15	15	0	2 JAN 1968	16 JAN 1968	17 JAN 1968	30 JAN 1968
2	16		416VOLTS CABLE INSTALLATION	2	23	23	4 JAN 1968	5 JAN 1968	27 JAN 1968	28 JAN 1968
2	5		PIPES INSTALLATION	10	10	0	7 JAN 1968	16 JAN 1968	17 JAN 1968	28 JAN 1968
20	4		TRANSFORMER ACCESSORIES INSTALLATION	7	0	0	10 JAN 1968	16 JAN 1968	******ON CRITICAL PATH******	
7	16		EXCITER POWER&CONTROL CABLE INSTALL	8	9	9	10 JAN 1968	17 JAN 1968	21 JAN 1968	28 JAN 1968
5	8		COPPER BUS BAR&INSULATOR INSTALL	6	4	0	12 JAN 1968	17 JAN 1968	16 JAN 1968	21 JAN 1968
5	12		COOLING WATER MOTOR PUMP WIRING	2	10	0	17 JAN 1968	18 JAN 1968	27 JAN 1968	28 JAN 1968
6	15		69KV BREAKER TEST	1	15	15	17 JAN 1968	17 JAN 1968	1 FEB 1968	1 FEB 1968
4	10		OIL FILING PURIFICATION & TEST	12	0	0	17 JAN 1968	26 JAN 1968	******ON CRITICAL PATH******	
4	14		CONNECT TRANSF TO 69KV LINE&13.8KVBUS	2	12	12	17 JAN 1968	18 JAN 1968	29 JAN 1968	30 JAN 1968
8	12		CT & PT INSTALLATION	3	5	0	18 JAN 1968	20 JAN 1968	23 JAN 1968	25 JAN 1968
8	11		BREAKER INSTALLATION	3	4	0	18 JAN 1968	20 JAN 1968	22 JAN 1968	24 JAN 1968
13	17		COOLING SYSTEM TEST	5	10	10	19 JAN 1968	23 JAN 1968	26 JAN 1968	2 FEB 1968
11	16		BREAKER POWER&CONTROL CABLE INSTALL	4	4	2	21 JAN 1968	24 JAN 1968	25 JAN 1968	28 JAN 1968
12	16		CT & PT CONTROL WIRING	2	5	3	21 JAN 1968	23 JAN 1968	26 JAN 1968	28 JAN 1968
16	17		EXCITER TEST	5	2	2	27 JAN 1968	31 JAN 1968	29 JAN 1968	2 FEB 1968
10	14		TRANSFORMER CONTROL WIRING	2	0	0	29 JAN 1968	30 JAN 1968	******ON CRITICAL PATH******	
14	15		TRANSFORMER TEST	1	0	0	31 JAN 1968	1 FEB 1968	******ON CRITICAL PATH******	
15	17		TRANSFORMER ENERGIZING TEST	2	0	0	2 FEB 1968	2 FEB 1968	******ON CRITICAL PATH******	
17	18		SYNCHRONOUS CONDENSER COMMISSIONING	12	0	0	3 FEB 1968	14 FEB 1968	******ON CRITICAL PATH******	

PROJECT STARTING DATE 2 JAN 1968 PROJECT COMPLETION DATE 14 FEB 1968

YEASCI CPM/PERT ANALYSIS PROGRAM * WAYNE * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

BAR CHART OF THIS PROJECT - JOBS LISTED IN EARLY STARTING TIME ORDER PAGE 1

PROJECT STARTING DATE 2 JAN 1968 SCALE FACTOR - 1 INCH # 10 POINTS # 10 DAYS

LEGEND FFF-JOB FINISHED , XXX-CRITICAL JOB , ***-JOB DURATION , ----TOTAL FLOAT

START NODE	END NODE	JOB DESCRIPTION	J 02 05	F 09 12 16 19 23 26	M 02 05 09 12 16 19 23 26 30
1	17	SYNC CON ACCESSORIES INSTALLATION	**********	**********	----------
1	3	COOLING TOWER INSTALLATION	FFFFF		
1	5	COOLING WATER MOTOR PUMP PKG INSTALL	**	----------	----------
1	7	EXCITER EQUIPMENT INSTALLATION	FFFFFFF		
1	2	416VOLTS DISTRIBUTION BOARD INSTALL	**	----------	----------
1	5	13.8KV INDOOR BUS SUPPORT STR ERECT	FFFFFFFFF		
1	16	EXCITER SET INSTALLATION	**********	**********	---
1	20	WAITING FOR ERECTOR	FFFFFFF		
1	6	69KV BREAKER & CONTROL BOARD INSTALL	**********	**********	----------
2	16	416VOLTS CABLE INSTALLATION	**	----------	----------
2	9	PIPES INSTALLATION	**********	----------	----------
20	4	TRANSFORMER ACCESSORIES INSTALLATION	XXXXXXX		
7	16	EXCITER POWER&CONTROL CABLE INSTALL	********	----------	----------
5	8	COPPER BUS BAR&INSULATOR INSTALL	******	----	----------
9	13	COOLING WATER MOTOR PUMP WIRING	*	----------	----------
6	15	69KV BREAKER TEST	XXXXXXXXXXX		
4	10	OIL FILING PURIFICATION & TEST	**	----------	----------
4	14	CONNECT TRANSF TO 69KV LINE&13.8KVBUS	***	-----	----------
8	12	CT & PT INSTALLATION	***	----	----------
8	11	BREAKER INSTALLATION	*****	----------	----------
13	17	COOLING SYSTEM TEST	****	----	----------
11	16	BREAKER POWER&CONTROL CABLE INSTALL	***	-----	----------
12	16	CT & PT CONTROL WIRING	*****	--	----------
16	17	EXCITER TEST	XX		
16	14	TRANSFORMER CONTROL WIRING	XX		
14	15	TRANSFORMER TEST	X		
15	17	TRANSFORMER ENERGIZING TEST	XXXXXXXXXXX		
17	18	SYNCHRONOUS CONDENSER COMMISSIONING			

VS/SQ1 CPM/PERT ANALYSIS PROGRAM * MAYAE * SYSTEM PLANNING DIVISION* 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

CALENDAR SCHEDULE OF THE PROJECT IN EARLY STARTING TIME ORDER PAGE 1

ARRANGED IN GROUPS ACCORDING TO TYPE OF WORK

START NODE	END NODE	JOB DESCRIPTION	EXP TIME	TOTAL FLOAT	FREE FLOAT	EARLY START	EARLY FINISH	LATE START	LATE FINISH
	1	INSTALLATION & ERECTION							
1	17	SYNC CON ACCESSORIES INSTALLATION	20	12	12	2 JAN 1968	21 JAN 1968	14 JAN 1968	2 FEB 1968
1	3	COOLING TOWER INSTALLATION	5			2 JAN 1968	6 JAN 1968	JOB FINISHED	
1	9	COOLING WATER MOTER PUMP BRD INSTALL	2	23	13	2 JAN 1968	3 JAN 1968	25 JAN 1968	26 JAN 1968
1	7	EXCITER BOARD&EQUIPMENT INSTALLATION	8			2 JAN 1968	9 JAN 1968	JOB FINISHED	
1	2	416VOLTS DISTRIBUTION BOARD INSTALL	2	23	0	2 JAN 1968	3 JAN 1968	25 JAN 1968	26 JAN 1968
1	5	13.8KV INDOOR BUS SUPPORT STR ERECT	10			2 JAN 1968	11 JAN 1968	JOB FINISHED	
1	16	EXCITER SET INSTALLATION	25	2	0	2 JAN 1968	26 JAN 1968	4 JAN 1968	28 JAN 1968
1	20	WAITING FOR ERECTOR	8			2 JAN 1968	9 JAN 1968	JOB FINISHED	
1	6	69KV BREAKER & CONTROL BOARD INSTALL	15	15	0	2 JAN 1968	16 JAN 1968	17 JAN 1968	31 JAN 1968
2	16	416VOLTS CABLE INSTALLATION	2	23	21	4 JAN 1968	5 JAN 1968	27 JAN 1968	28 JAN 1968
2	9	PIPES INSTALLATION	10	10	0	7 JAN 1968	16 JAN 1968	17 JAN 1968	26 JAN 1968
20	4	TRANSFORMER ACCESSORIES INSTALLATION	7	0	0	10 JAN 1968	16 JAN 1968	******CN CRITICAL PATH******	
7	16	EXCITER POWER&CONTROL CABLE INSTALL	8	11	9	10 JAN 1968	17 JAN 1968	21 JAN 1968	28 JAN 1968
5	8	COPPER BUS BAR&INSULATOR INSTALL	6	4	0	12 JAN 1968	17 JAN 1968	16 JAN 1968	21 JAN 1968
8	12	CT & PT INSTALLATION	3	5	0	18 JAN 1968	20 JAN 1968	23 JAN 1968	25 JAN 1968
8	11	BREAKER INSTALLATION	3	4	0	18 JAN 1968	20 JAN 1968	22 JAN 1968	24 JAN 1968
11	16	BREAKER POWER&CONTROL CABLE INSTALL	4	4	2	21 JAN 1968	24 JAN 1968	25 JAN 1968	28 JAN 1968
	12	WIRING							
9	13	COOLING WATER MOTER PUMP WIRING	2	10	0	17 JAN 1968	18 JAN 1968	27 JAN 1968	28 JAN 1968
4	14	CONNECT TRANSF TO 69KV LINE&13.KVBUS	2	12	12	17 JAN 1968	18 JAN 1968	29 JAN 1968	30 JAN 1968
12	16	CT & PT CONTROL WIRING	3	5	3	21 JAN 1968	23 JAN 1968	26 JAN 1968	28 JAN 1968
10	14	TRANSFORMER CONTROL WIRING	2	0	0	29 JAN 1968	30 JAN 1968	******CN CRITICAL PATH******	
	3	TESTING & COMMISSIONING							
6	15	69KV BREAKER TEST	1	15	15	17 JAN 1968	17 JAN 1968	1 FEB 1968	1 FEB 1968
4	10	OIL FILING PURIFICATION & TEST	12	0	0	17 JAN 1968	28 JAN 1968	******CN CRITICAL PATH******	
13	17	COOLING SYSTEM TEST	5	10	10	19 JAN 1968	23 JAN 1968	25 JAN 1968	2 FEB 1968
16	17	EXCITER TEST	5	2	2	27 JAN 1968	31 JAN 1968	29 JAN 1968	2 FEB 1968
14	15	TRANSFORMER TEST	2	0	0	31 JAN 1968	1 FEB 1968	******CN CRITICAL PATH******	
15	17	TRANSFORMER ENERGIZING TEST	1	0	0	2 FEB 1968	2 FEB 1968	******CN CRITICAL PATH******	
17	18	SYNCHRONOUS CONDENSER COMMISSIONING	12	0	0	3 FEB 1968	14 FEB 1968	******CN CRITICAL PATH******	

PROJECT STARTING DATE 2 JAN 1968 PROJECT COMPLETION DATE 14 FEB 1968

YEA5C1 CPM/PERT ANALYSIS PROGRAM * MAYNE * SYSTEM PLANNING DIVISION * 17 SEP 1968

YEA*MAF-2-1 SYNCHRONOUS CONDENSER AT BK SUBS SYSTEM PLANNING DIVISION

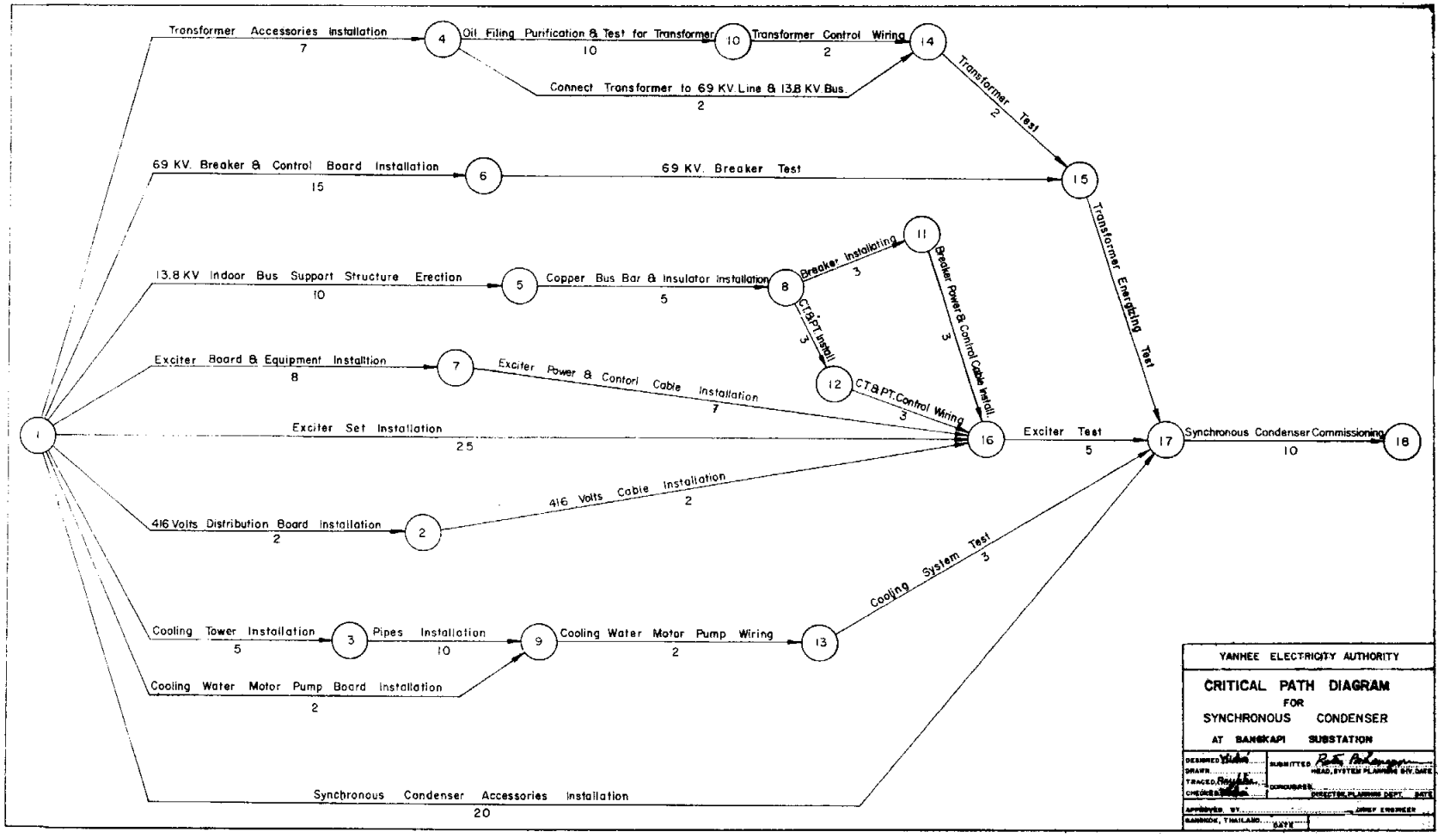
CALENDAR SCHEDULE OF CRITICAL JOBS IN EARLY STARTING TIME ORDER PAGE 1

START NODE	END NODE	JOB DESCRIPTION	EXP TIME	CRITICAL START	CRITICAL FINISH	REMARKS
1	20	WAITING FOR ERECTOR	8	2 JAN 1968	9 JAN 1968	JOB FINISHED
20	4	TRANSFORMER ACCESSORIES INSTALLATION	7	10 JAN 1968	16 JAN 1968	
4	10	OIL FILING PURIFICATION & TEST	12	17 JAN 1968	29 JAN 1968	
10	14	TRANSFORMER CONTROL WIRING	2	29 JAN 1968	30 JAN 1968	
14	15	TRANSFORMER TEST	2	31 JAN 1968	1 FEB 1968	
15	17	TRANSFORMER ENERGIZING TEST	1	2 FEB 1968	2 FEB 1968	
17	18	SYNCHRONOUS CONDENSER COMMISSIONING	12	3 FEB 1968	14 FEB 1968	

PROJECT STARTING DATE 2 JAN 1968 PROJECT COMPLETION DATE 14 FEB 1968

APPENDIX V

ARROW DIAGRAM OF SAMPLE PROBLEM



APPENDIX VI

CONTROL CARDS FOR YEA501