HONEYWELL EDP

SERIES 200

CRITICAL PATH METHOD A

GENERAL SYSTEM: SERIES 200/BASIC PROGRAMMING SYSTEM

SUBJECT: Programming and Operating procedures for CPM A, A Computer Implementation of the Critical Path Method for Project Scheduling

SPECIAL INSTRUCTIONS: This publication supersedes the publication of the same title having file number 122.8105.000A.00.00, dated September 8, 1965.

PREFACE

This publication describes the capabilities of Honeywell's CPM A (Critical Path Method A) program and is intended to serve three types of readers:

1. The managers, contractors, and technical consultants who jointly prepare data for input to the CPM A program. Sections I, II, and IV apply.

2. The operator who runs the program on the Series 200 computer. Section V applies.

3. The managers at all levels who evaluate the output reports resulting from computer analysis. Sections I through III apply.

The following are related Honeywell publications:

1. Floating Tape Loader-Monitor C and Interrupt Control D, File No. 122.5005.001C.00.00.

2. Easycoder 4K Operating Procedures, DSI-243.

3. Honeywell 200 Equipment Operators' Manual (Model 200), DSI-294.

For some additional information regarding critical path techniques, see Finding the Critical Path, by R. L. Martino, published by the American Management Association, 135 West Street, New York, N. Y. 10020. About $15 (or about $10 for AMA members), this 144 page book is volume one of a projected series entitled Project Management and Control.

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SECTION I

INTRODUCTION

CPM A (Critical Path Method A) is a set of planning and control techniques designed to assist the project manager in estimating and controlling the elapsed time, cost, and technical performance required to attain the project objectives. The CPM A program reduces the work involved in using network modeling techniques. It does this by performing the voluminous computations automatically and by providing managers with brief, timely reports on which to base operational decisions. It can be used on all projects, large or small.

The program requires the user to identify the necessary tasks (activities) within the project and to record the sequence in which they must be performed. Using this information, the planning group constructs a graphic representation known as an arrow diagram or network diagram (see Figure 1-1). Time estimates (and, optionally, cost estimates) for each of the network activities are prepared. The time estimates may be entered in the arrow diagram for display. In any case, they are submitted to the CPM A program together with data describing the structure of the network. The program calculates the expected duration of the project, the critical path, and other time tolerances described below.

DEVELOPING THE NETWORK

Usually, network development is simplified by first establishing the major milestone events or check points that must be reached. Each supporting activity is then added to the network, and its interaction with other activities is indicated in terms of the activities that must precede it, the activities that must succeed it, and the activities that can be performed concurrently with it. Significantly, the set of activities that must be finished (and events that must have occurred) before any given activity can begin is exhibited by the network diagram. Thus, the network defines the relationship of any given activity to the needs of the total project, insuring that, if there are no breaks in the network and no loops, the project is probably fully planned and all derivative plans and activities contribute directly to the desired objectives. Construction of a network diagram requires the planning group to identify and record the project's internal time dependencies — dependencies that might otherwise go unnoticed until a deadline slips and the project manager has to "put out the fire" using frantic across-the-board expediting. Using CPM A, the project manager puts out his fires on paper and avoids costly emergencies.

If the arrow diagram is to be an effective planning tool and not merely a display of work that is already in progress, the network must be developed in as much detail as possible before

actual work on the project begins.   Then discrepancies, omissions, and work coordination problems can be resolved inexpensively, at least to the extent that they can be foreseen.

In a relatively deterministic project in which the sequence and interdependence of activities is well known (e. g. , building a house), planning can be carried out in detail before work begins. A detailed network can be constructed even if, say, architectural details are not yet available. As detailed information becomes available, the network can be revised and control of the project tightened.

On the other hand, in one-of-a-kind projects (e. g., research and development of a new product), a detailed network usually cannot be made far in advance of the actual work. Situations of this kind do not invalidate network modeling as a project control technique, however. If the network is established in detail only one step ahead of present accomplishments and/or only a general network is available, network modeling can be used to attain immediate and/ or general project objectives in minimal time and at minimal cost.   There are, of course, tradeoffs between minimal time and minimal cost.   Network modeling techniques enable the project manager systematically to investigate and control these tradeoffs, as described below.

PROCESSING THE NETWORK

Each time an arrow diagram is revised, a single elapsed-time re-estimate, expressed in some standard user-specified time unit, is reassigned to each activity by the persons qualified to judge the activities concerned.   When these re-estimates have been submitted to the CPM A program, the program sums them over every forward path through the network from the beginning event toward the end event.   A network path is a forward path if, and only if, each activity arrow in the path is traversed from its tail to its head.   To traverse an activity arrow backward would imply (incorrectly) that the activity can be performed in reverse to complete the project.

The longest time path from the network starting event to the end event, where length is measured in time units, is the critical path for the network.   The critical path is important because any increase in the expected duration of an activity on the critical path necessarily causes an increase in the expected duration of the project and will probably delay the occurrence of the network end event.   Any increase in the expected duration of an activity not on the critical path will not necessarily cause an increase in the expected duration of the project.   Resources can often be withdrawn from such activities to expedite activities on the critical path.

EVALUATING PROJECT STATUS

The CPM A output reports contain the data needed for evaluation of the project's status.

They repeatedly focus management's attention on resources that can be reallocated and on potential problems. The reports may become the basis for recommending changes in the project plan or in the team's performance. CPM A reports identify the critical activities so that the project manager can decide whether further shortening of the critical time path is economically feasible.

A. DEVELOPMENT OF THE ARROW DIAGRAM

B. ASSIGNMENT OF DURATION ESTIMATES TO ACTIVITY ARROWS

LEGEND

An activity arrow, connecting the preceding and succeeding event nodes. The number (n) is the user's estimate of the expected duration of the activity.

An event node. The number (n) is the user's unique identification of the corresponding event.
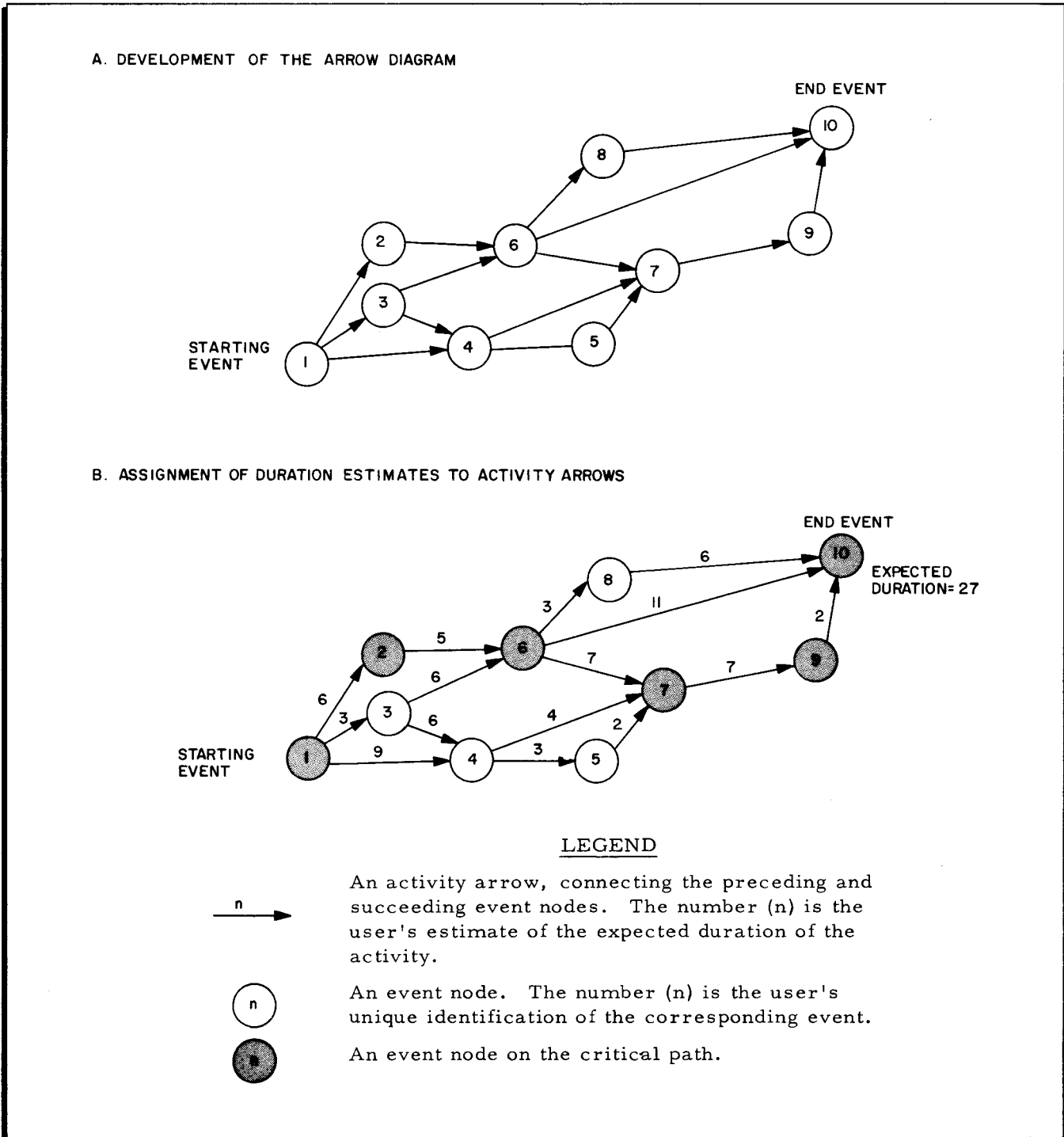
An event node on the critical path.

Figure 1-1. The Arrow Diagram

In the CPM Bar Chart report, the network activities are listed so that the project manager can tell which activities are critical and which are not. He can identify those non-critical activities from which he can divert resources without delaying the project.

UPDATING THE PROJECT PLAN

Control of both the planning and the operating phase of a project is usually iterative. That is, output from the planning phase is reviewed by management, and modifications to the network are submitted to the CPM A program until acceptable critical paths and time schedules are attained.

Both the time estimates and the structure of the network are generally altered during the planning phase. Ideally, this is not the case during project execution: if the network (i. e., project) is well planned, time estimates may be changed during execution of the project, but the topological structure of the network will not be changed.

If CPM A calculations indicate that the network end event or a given milestone event is expected to occur after the requested (or scheduled) completion date for that event, the project manager can expedite the activities on the critical path, resubmitting time and cost estimates until the event is expected to occur on or before the requested date; else a time schedule for each activity and for the whole project is followed, based on the time estimates submitted for each activity. To replan the network is to reallocate resources: time estimates for the affected activities change, and the critical path must be recomputed by the CPM A program, usually giving a new critical path which the manager can expedite. Armed with CPM A reports, the manager directs his attention selectively, never expediting any but the critical activities and avoiding unnecessary across-the-board overtime costs and premium payments. CPM A permits management by exception.

As the project progresses toward completion, work is completed behind or ahead of schedule and over or under budget, and time and cost estimates for unfinished work are revised. CPM A methodology provides for systematic file maintenance and plan revision by:

1. Requiring the establishment of reporting dates and the assignment of responsibility for estimate preparation and revision.

2. Supplying the current schedule and cost status to the project manager and/or to the persons responsible for preparing the estimates.

3. Requiring re-estimates for activities not yet completed.

Of course, time and cost estimates rendered for activities that are to be performed in the distant future are likely to be less reliable than estimates for activities that are to be performed in the near future or that are in progress. Standard CPM A practice requires the reporting

organization for each activity to periodically submit a re-estimate for the expected total duration of the activity and, optionally, for the expected total cost of the activity. This requirement remains in force until the activity is complete, at which time actual time and cost are known. In this way, the risks inherent in following tentative estimates are steadily reduced.

Simulation of Alternative Solutions

Creation or redefinition of network activities may require changes in the time estimates and structure of the network. If the analyst or project manager wants to determine the effects of proposed resource trade-offs, he can do so by testing the sensitivity of the network to changes in the estimated duration of one or more activities. He may ask a question such as "If n men were withdrawn from your activity and no overtime were available, what would be your new estimate of the most likely duration of your activity?" or "If n additional dollars are supplied to your activity will your time estimate change?" Accordingly, the analyst submits a smaller (optimistic) or larger (pessimistic) time estimate in place of the current estimate. The CPM A program treats the submitted estimate as the most likely estimate (i.e., a current estimate) and re-computes the critical path and other network data. Of course, the "real" (i.e., current) network must not be destroyed: it is saved in a separate file.

Optimizing the Network

In Figure 1-1, if additional resources are supplied to activity 1, 2 in an amount sufficient to cause the estimated duration of that activity to change from 6 units to 4, the critical path is no longer unique: there are two forward paths that are critical, viz., 1, 2, 6, 7, 9, 10 and 1, 3, 6, 7, 9, 10. The paths 1, 2, 6 and 1, 3, 6 are each expected to have a duration of 9 units. The important change is not that the number of critical paths increases but rather that the number of critical activities increases. In this case, two non-critical activities become critical, viz., activity 1, 3 and activity 3, 6. Reiteration of this optimization procedure causes more and more activities and events to become critical.

In the preceding paragraph, the assumption is made that the additional resources are supplied to activity 1, 2 from outside the system. The same optimization principles apply if the additional resources are diverted from activities in the network, except that time estimates are likely to increase for the activities from which the resources are diverted.

If the CPM A program is used regularly during the course of the project, the times and costs of network activities should be re-estimated and resources should be reapportioned until the new estimates cause the network to become "tight," i.e., until every activity is critical. In practice, this goal can be approached, but there are usually a few events that do not respond significantly to any reasonable amount of increased input.

A practical impediment to the attainment of perfect optimization is the administrative cost of reapportionment. In one-of-a-kind projects, resources should be reapportioned in units large enough so that the reapportionment yields a net improvement, i.e., more than offsets the cost of reapportionment. In a continuous (e.g., manufacturing) process being controlled by CPM A techniques, the reapportionment should offset the cost of reapportionment within a reasonable period of time.

SUMMARY

By applying CPM A, the project manager provides himself with a detailed, systemetized plan and time schedule before the project begins. As work on the project progresses, the time and cost estimates can be refined to provide tighter control over cost, profits, and time schedules. The arrow diagram and the output reports provide the manager with the means to:

1. Define the project tasks and establish their cost and time relationship to the project end event.

2. Insure that the total project is fully planned and that all derivative plans contribute directly to the desired objectives.

3. Ascertain the interdependence of project activities and the effect of these on project duration.

4. Evaluate progress.

5. Manage the reallocation of resources on an exception basis.

6. Summarize the cost and time status of the project for progressively higher levels of management.

SECTION II
ELEMENTS OF NETWORK MODELING

A project can be analyzed into a set of constituent <u>activities</u>, each of which may consume time and resources. An activity may be a process, procurement cycle, task, waiting period, etc. An activity may consume any amount of time or zero time. An activity may consume any amount of money (or resources measured in any other convenient unit), or, as may be the case in a waiting activity, no money at all. An activity is represented on the network diagram by an arrow, as in Figure 2-1. Because any activity is assumed to be bounded in time by its beginning event and its end event, each activity arrow is bounded in space (on the network) by a node which represents an instantaneous event. Whereas an activity can consume time, an event cannot. The node can be drawn as a circle or else as a rectangle or other convenient symbol. The event node from which a given activity arrow emanates (i. e. , to which the tail of the arrow is connected) represents the <u>preceding event</u> (also known as the <u>tail event</u>) for the activity. The node upon which a given activity arrow impinges (i. e. , to which the head of the arrow is connected) represents the <u>succeeding event</u> (also known as the <u>head event</u>) for the activity. The network starting event usually represents work authorization (e. g. , acceptance of a prototype for field testing, award of a contract, receipt of funds, purchase of a building plot, etc.).

The arrow diagram must be constructed in such a way that it correctly represents the project as follows:

1. Each activity is represented on the arrow diagram by only one arrow that is bounded at each end by a node. The node at the tail of the arrow represents the beginning of the activity; the node at the head of the arrow represents the successful completion of the activity. See Figure 2-1.

2. Event nodes are uniquely identified by numbers assigned to them by the user. Random numbering is permissable. Processing efficiency is enhanced by submitting the activity cards to the program in proper (i. e. , roughly start-to-finish) sequence. In the following network, the recommended sequence of activity cards in the data deck is A, B or B, A; then C; then D, E or E, D.
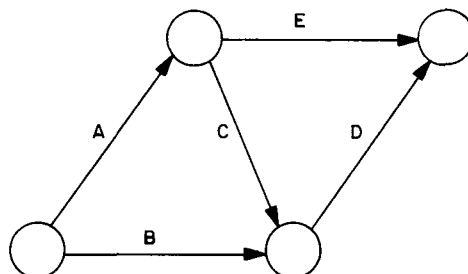
3. Each activity can be identified uniquely by citing the number of the preceding event node (i) and the number of succeeding event node (j). We speak of an activity i, j where i and j are node identifications. See Figure 2-1. Given that an activity arrow is identifiable uniquely by reference to its two event numbers, an activity arrow can also be identified by a descriptive title appended to the arrow. In Figure 2-2, the activity PREPARE SITE can be represented as the arrow so labeled, or it can be represented as the number pair (20, 21).

4. Arrows indicate precedence relationships between activities. The length, curvature, and bearing of each arrow are all matters of topological convenience and convey no information concerning the project.

5. Where one or more activity arrows impinge on or emanate from an event node, the information conveyed is that no activity starting from that event can start until all activities terminating at the event have been completed. Thus, if not all the arrows (activities) impinging on a given node (event) have been completed, the given event is said to have not occurred; else the given event is said to have occurred. And if a given event has not occurred, the arrows (activities) that emanate from the node (event) cannot begin; else they can begin. Whether they do in fact begin depends on scheduling considerations. An event node, then, resembles a logical-AND operator or multi-legged AND gate which fires if, and only if, it is driven by all the allowable inputs. For example, in Figure 2-2 the activity BUY COMPUTER and the activity PREPARE SITE end at event 21, indicating that the activity INSTALL COMPUTER cannot begin until both (20, 21) and (19, 21) have been successfully completed.

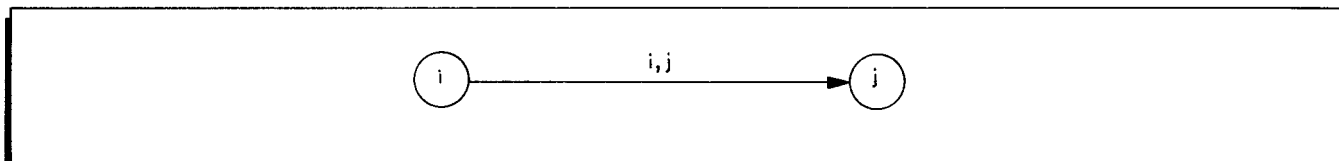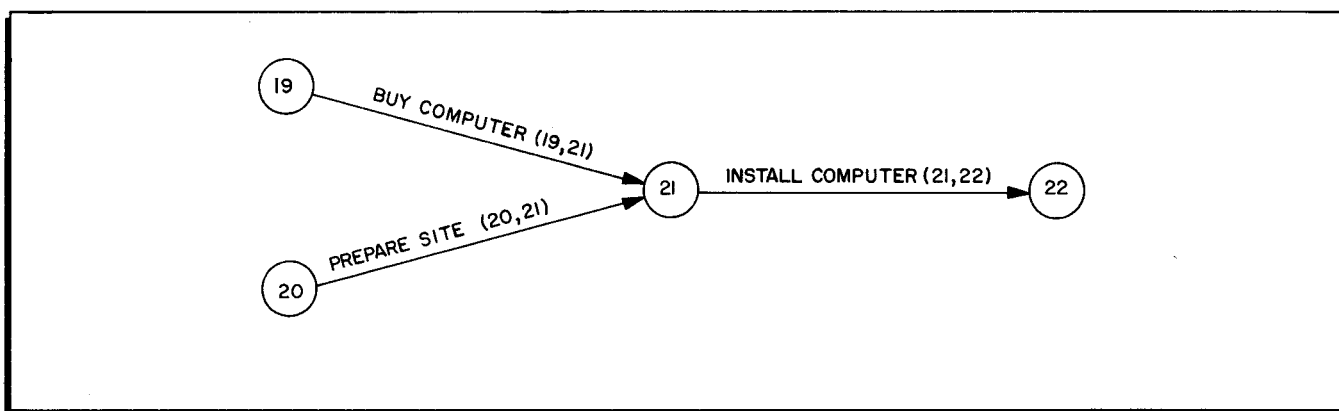
Figure 2-1. The Activity Arrow

Figure 2-2. Network Dependency

An activity or activity arrow can be thought of as a network, i.e., as a set of several interdependent activities having the same preceding event and succeeding event. Therefore, activities diagrammed during the planning phase can be elaborated into subactivities as the

planning or the work progresses.   These subactivities are known as operating-level networks or as fragnets.   Networks can be elaborated to whatever degrees of detail is desired.

Some implications and uses of the networking rules stated above are suggested by a few examples which follow.

THE DUMMY ACTIVITY

The dummy activity, as distinguished from the time-consuming and resource-consuming activity sometimes called the "structural" activity, consumes no resources and no time.   It merely indicates a precedence or dependency relationship between events.   It is usually drawn on the arrow diagram as a dashed line having the usual arrowhead.   Several conditions can be distinguished in which the dummy activity is needed.   They are as follows.

Concurrent Activities

A project is likely to have many concurrent activities in it.   A superficially logical (but incorrect) way to indicate concurrence of activities is to join two events together by more than one activity arrow, as in Figure 2-3A.   Because each activity must be uniquely identifiable by means of its preceding and succeeding event numbers, a dummy activity must be introduced to prevent ambiguity, as in Figure 2-3B.

Pacing Activities

Suppose that, as the master network is elaborated, two activities that were thought to be independent (e. g., BUY COMPUTER and PREPARE SITE in Figure 2-3) are discovered to have interdependencies between some of their constituent activities.   Such interdependence can be indicated by dummy activity arrows as in Figure 2-4.   The figure indicates that the equipment complement must be known before the customer can approve the installation layout and that the contract must be signed before the appropriate air conditioning and electrical power is ordered or installed.   Thus, the activity DETERMINE EQUIPMENT COMPLEMENT paces the activity CUSTOMER APPROVES LAYOUT, and the activity DETERMINE EQUIPMENT COMPLEMENT is a pacing activity.   Expressed another way, event 19a paces event 20, and event 19a is a pacing event.

If this network is deemed too time consuming, it can be further elaborated to show that the computer can be connected (but not operated) as soon as power distribution outlets are installed and before air conditioning is installed.   Thus, the critical path can be shortened by replanning the network to include more concurrance (parallel processing) of activities.

Terminal Activities

A project that has multiple starting events (e. g. , Figure 2-2) can be converted to a project having a single starting event by connecting the multiple start events to a preceding (dummy) event using dummy activity arrows.   A project having multiple end events can be treated similarly.

BUY COMPUTER (18,21)

18

21

INSTALL COMPUTER (21,22)

22

PREPARE SITE (18,21)

A. AMBIGUOUS CONCURRANCE OF ACTIVITIES

BUY COMPUTER (18,19)

19

DUMMY (19, 21)

18

21

INSTALL COMPUTER (21,22)

22

PREPARE SITE (18,21)

B. CONCURRANCE OF UNIQUELY IDENTIFIED ACTIVITIES
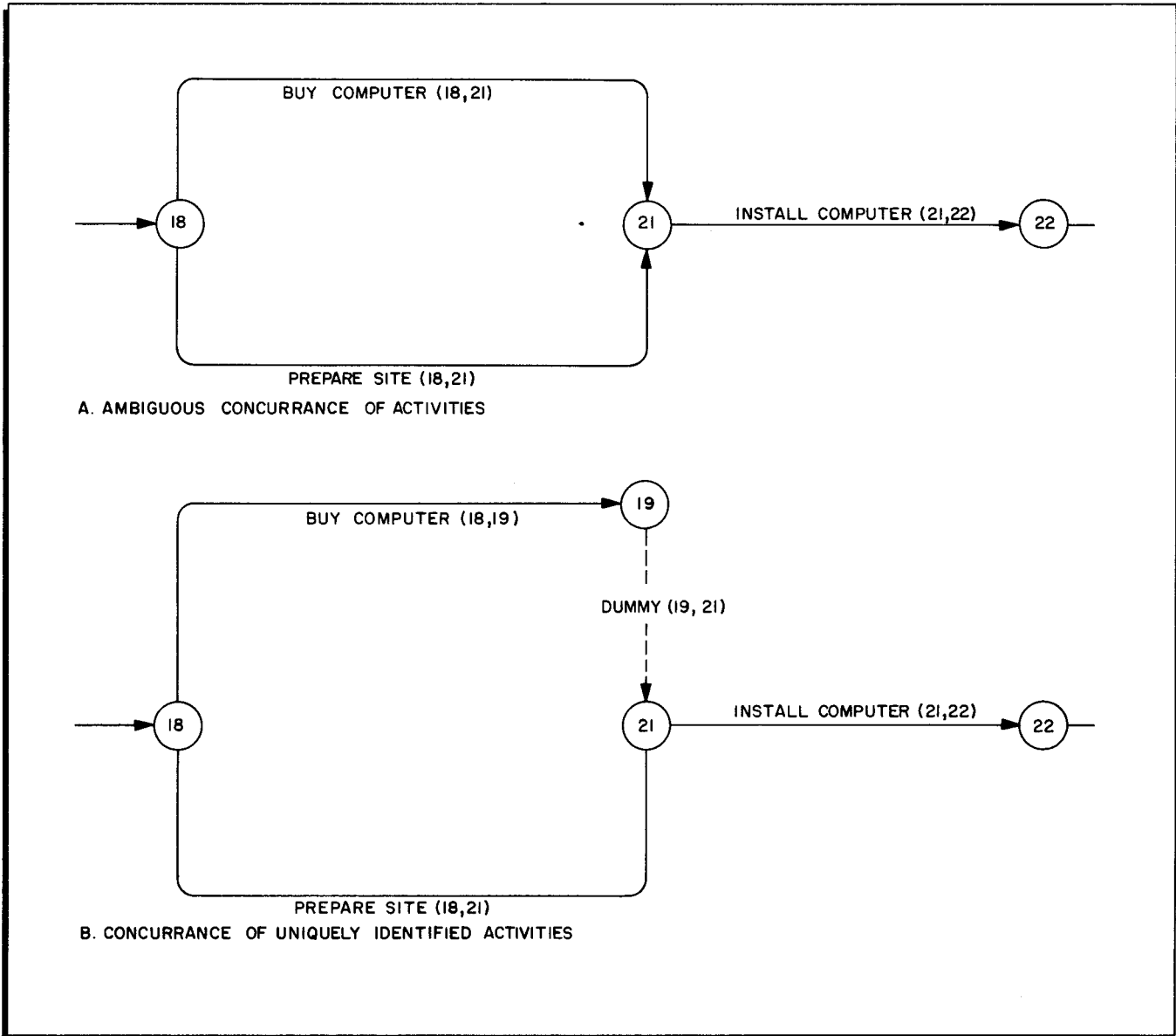
Figure 2-3.   Concurrance of Activities

RESTRICTIONS IMPOSED ON ARROW DIAGRAMS

1.   Looping, as in Figure 2-5, is not permitted.   A network contains a loop if any forward path therein can be traversed more than once.

2.   Conditional branching, as in Figure 2-6, must be avoided if the corresponding network is to be processed by CPM A.
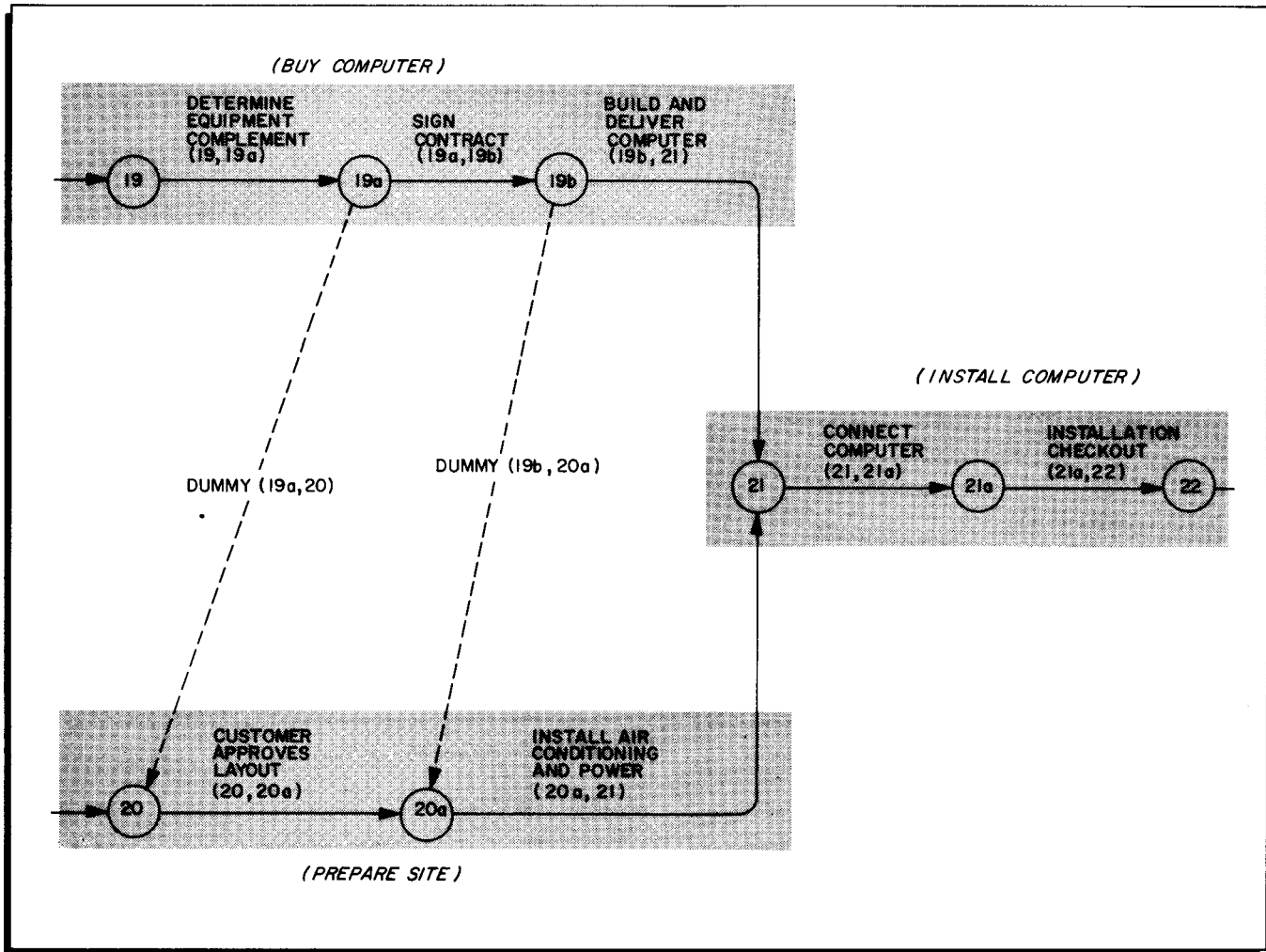
Figure 2-4. Pacing of Activities

3. Terminal events must be unique if the corresponding network is to be processed by CPM A: there must be a single network starting event and a single network end event. See "Terminal Activities" above.

4. The maximum number of events in a network is limited by the computer's main-memory size as specified in Table 2-1. The number of activities has no practical limit.
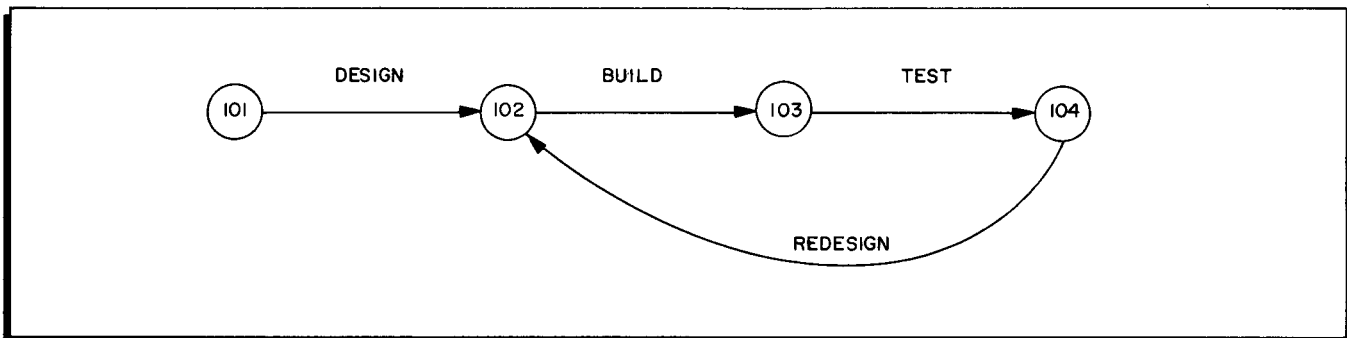
Figure 2-5. An Illegal Loop
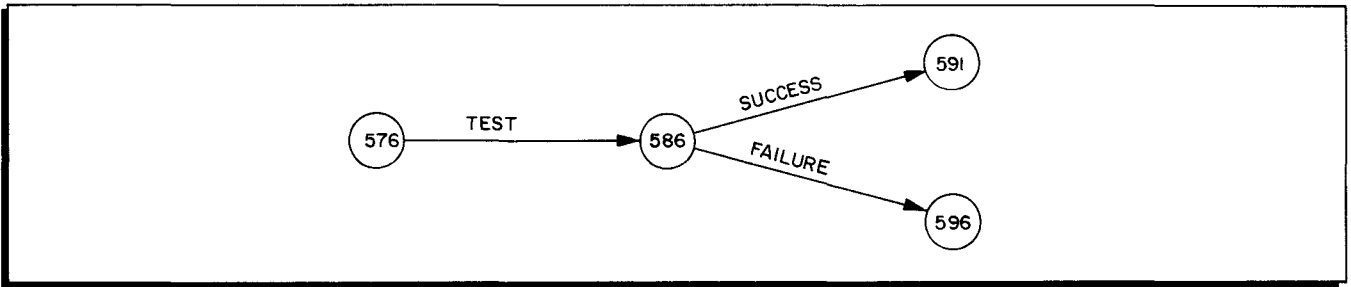
Figure 2-6. An Illegal Branch

Table 2-1. Maximum Number of Events Permitted in Network

Memory Used	Basic Programming System	Operating System - Mod 1
4K	200	n/ap
8K	710	n/ap
12K	1220	1030
16K	1730	1540
20K	2240	2050
24K	2750	2560
28K	3260	3070
32K	3770	3580

SECTION III

CPM A FUNCTIONS AND OUTPUT

This section demonstrates how CPM A can be used to plan, schedule, and monitor a small project — the building of a house. Sample CPM A output reports are included, the fields in the reports are defined, the calculations are described, and formulas are given.

PLANNING

Before constructing the network, make a list of the activities considered necessary in building the house. For each listed activity, indicate the immediately preceding activity or activities, as in Table 3-1.

Use this list to construct an arrow diagram. As the diagram is being constructed, the initial activity list may be refined, additional dependencies may be discovered, etc. The arrow diagram for the house building project is in Figure 3-1.

Table 3-1. List of Required Activities

| Activity Number	Activity Description	Number of Preceding Activity
1	Excavate	none
2	Lay Foundation	1
3	Rough Plumbing	2
4	Basement Flooring	3
5	Frame	4
6	Sewers and Drains	5
7	Heating	4, 5
8	Basic Wiring	5
9	Brickwork	5
10	Roofing	5, 9
11	Gutters	10
12	Plastering	3, 7, 8
13	Flooring	12
14	Finish Plumbing	13
15	Carpentry	13
16	Painting	14
17	Varnish Floors	15, 16
18	Finish Electrical Work	16
19	Grading	6
20	Landscaping	19

Figure 3-1. Arrow Diagram for the House Building Project

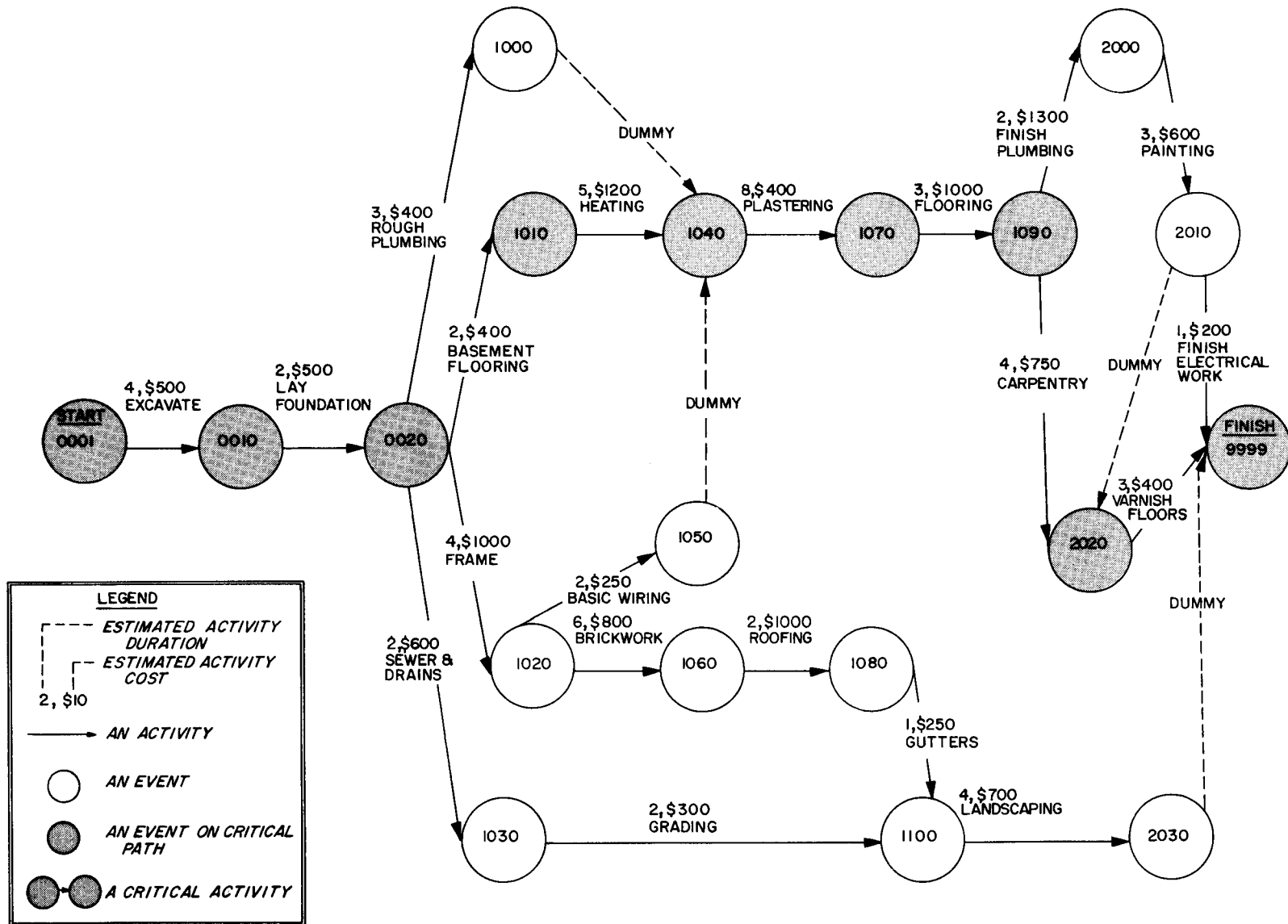## TIME AND COST ESTIMATES

When the arrow diagram has been constructed, obtain time and cost estimates for each activity.   Cost estimates are optional, but time estimates are required.

The user determines the length of the standard time period in which the estimates are expressed.   The chosen period can be a day, week, month, or any convenient unit.   Fractions of the chosen unit are not allowed.   Therefore, the chosen unit should be small enough to give a resolution comparable to the smallest of the estimates.   The size of the unit chosen affects the resolution and probable number of reporting periods in the Bar Chart output report.

A cost estimate for each activity can also be prepared.   Cost, estimated in a standard unit determined by the user, is usually expressed in monetary units but can be expressed as the consumption of other resources such as man-hours, machine-hours, labor-hours, tons of raw material, etc.

When time and/or cost estimates have been prepared, reduce the data to the corresponding CPM A input format as specified in Section IV.   Submit this data to the CPM A program together with data specifying the structure of the network, as described in Section V.   The completed arrow diagram can be used as an information source when the input data are being prepared.

CPM A PROGRAMS

CPM A contains two major programs: the CPM Main program and the CPM Bar Chart program.   The main program produces the Activity List output report and calculates network tolerances which are summarized in the Bar Chart report.   The Bar Chart program produces the Bar Chart output report.   Output from these programs can be controlled by several options which are discussed in the operating procedures.

CALCULATION FORMULAS

The methods used to calculate the values appearing in the Activity List and in the Bar Chart report depend on the type of float requested by the programmer: total float, free float, or independent float.   CPM A uses the following formulas:

Earliest start time $= EST (i, j)$

Latest start time $= EST (i, j) + (Total,\ Free,\ or\ Independent)\ Float$

Latest finish time $= EST (i, j) + DUR (i, j) + (Total,\ Free,\ or\ Independent)\ Float$

Earliest finish time $= EST (i, j) + DUR (i, j)$

The above timings are computed as follows:

$$EST (i, j) = \max_{h=1,\ N} (EST(h, i) + DUR (h, i))$$

$$EFT\ (i,\ j) = EST\ (i,\ j) + DUR\ (i,\ j)$$

$$LFT\ (i,\ j) = \min_{k=1,\ M}\ (LFT(j,\ k) - DUR\ (j,\ k))$$

$$LST\ (i,\ j) = LFT\ (i,\ j) = DUR\ (i,\ j)$$

$$TF\ \ \ (i,\ j) = LFT\ (i,\ j) - EFT\ (i,\ j)$$

$$FF\ \ \ (i,\ j) = EST\ (j,\ k) - EFT\ (i,\ j)$$

$$IF\ \ \ (i,\ j) = \max\ \begin{cases} EST\ (j,\ k) - LFT\ (h,\ i) - DUR\ (i,\ j) \\ \emptyset \end{cases}$$

where: DUR $(m,\ n)$ = estimated duration for activity $(m,\ n)$

EST $(m,\ n)$ = earliest start time for activity $(m,\ n)$

EFT $(m,\ n)$ = earliest finish time for activity $(m,\ n)$

LFT $(m,\ n)$ = latest finish time for activity $(m,\ n)$

LST $(m,\ n)$ = latest start time for activity $(m,\ n)$

TF $(m,\ n)$ = total float for activity $(m,\ n)$

FF $(m,\ n)$ = free float for activity $(m,\ n)$

IF $(m,\ n)$ = independent float for activity $(m,\ n)$

N = number of activities ending at event i

M = number of activities beginning at event j

OUTPUT FROM THE CPM MAIN PROGRAM

The Activity List

The CPM main program generates an Activity List output report such as the one in Figure 3-2. This figure corresponds to the arrow diagram in Figure 3-1. The Activity List displays the following information:

1. Problem title.

2. Total number of network activities.

3. Number of activities on the critical path.

4. Total calculated duration of the project (i.e., length of the critical path).

5. Total cost of the project (i.e., the sum of the costs of all the network activities).

6. For each activity, its tail-event identification, its head-event identification, its description, its estimated duration in standard time units, its estimated cost if any (in standard cost units), various time tolerances described below, and whether or not the activity is on the critical path.

The time tolerances appearing in the Activity List are these:

1. EARLIEST START TIME (EARLY START). The earliest start time of an activity is the shortest period of time required to complete all activities ending at the beginning event for that activity.

2. LATEST START TIME (LATE START). The latest start time of an activity is the latest time at which the activity can begin without lengthening the time required to complete the entire network.

3.   EARLIEST FINISH TIME (EARLY FINISH).   The earliest finish time of an activity is the earliest time required to complete the activity.

4.   LATEST FINISH TIME (LATE FINISH).   The latest finish time of an activity is the latest time at which the activity can be completed without lengthening the time required to complete the entire network.

5.   TOTAL FLOAT.   The total float of an activity is the difference between the maximum time available to complete the activity (i.e., the latest finish time) and the earliest time required to complete the activity (i.e., earliest finish time).

6.   FREE FLOAT.   The free float of an activity is the amount of time the activity can be delayed assuming that all activities ending at the beginning event of the activity start as early as possible and allowing all activities beginning at the end event of the activity to start as early as possible.

7.   INDEPENDENT FLOAT.   The independent float of an activity is the amount of time the activity can be delayed assuming all activities ending at the beginning event of the activity are completed as late as possible and allowing all activities beginning at the end event of the activity to start as early as possible.

The CPM main program regards any activity as critical if the activity has a total float equal to zero. In such cases, the total time expected to be available to complete the activity equals the time expected to be required to complete it. If more than one network path is critical, all of the critical activities are so identified in the Activity List. By definition, all such paths are of the same expected duration, and only one such path is used to compute the expected duration of the project.

CRITICAL PATH METHOD   BUILDING A HOUSE

TOTAL NUMBER OF ACTIVITIES   24
NUMBER OF ACTIVITIES ON CRITICAL PATH   10
TOTAL DURATION OF PROJECT   32
TOTAL COST OF PROJECT   12550

TAIL	HEAD	DESCRIPTION	TIME	COST	EARLY START	LATE START	EARLY FINSH	LATE FINISH	TOTAL FLOAT	FREE FLOAT	INDEPENDENT FLOAT	
0001	0010	EXCAVATE	4	500			4	4				CRITICAL PATH
0010	0020	LAY FOUNDATION	2	500	4	4	6	6				CRITICAL PATH
0020	1000	ROUGH PLUMBING	3	400	6	10	9	13	4			
0020	1010	BASEMENT FLOORING	2	400	6	6	8	8				CRITICAL PATH
0020	1020	FRAME	4	1000	6	7	10	11	1			
0020	1030	SEWER AND DRAINS	2	600	6	24	8	26	18			
1000	1040	DUMMY			9	13	9	13	4	4		
1010	1040	HEATING	5	1200	8	8	13	13				CRITICAL PATH
1020	1050	BASIC WIRING	2	250	10	11	12	13	1			
1020	1060	BRICKWORK	6	600	10	19	16	25	9			
1030	1100	GRADING	2	300	8	26	10	28	18	9		
1040	1070	PLASTERING	8	400	13	13	21	21				CRITICAL PATH
1050	1040	DUMMY			12	13	12	13	1	1		
1060	1080	ROOFING	2	1000	16	25	18	27	9			
1070	1090	FLOORING	3	1000	21	21	24	24				CRITICAL PATH
1080	1100	GUTTERS	1	250	18	27	19	28	9			
1090	2000	FINISH PLUMBING	2	1300	24	24	26	26				CRITICAL PATH
1090	2020	CARPENTRY	4	750	24	25	28	29	1	1	1	
1100	2030	LANDSCAPING	4	700	19	28	23	32	9			
2000	2010	PAINT	3	600	26	26	29	29				CRITICAL PATH
2010	2020	DUMMY			29	29	29	29				CRITICAL PATH
2010	9999	FINISH ELECTRICAL WORK	1	200	29	31	30	32	2	2	2	
2020	9999	VARNISH FLOORS	3	400	29	29	32	32				CRITICAL PATH
2030	9999	DUMMY			23	32	23	32	9	9		

Figure 3-2.   Activity List for the House Building Project.

Bar Chart Data Cards

If the CPM main program is run alone, i.e., is not followed sequentially by the Bar Chart program, optional output from the CPM main program is a deck of cards for input to the Bar Chart program. This deck contains the timings calculated by the CPM main program. The format of these cards is specified in Section IV.

If the main program and the Bar Chart program are processed sequentially, the data that are input to the Bar Chart program are written on magnetic tape by the CPM main program, and a Bar Chart deck is not produced.

OUTPUT FROM THE BAR CHART PROGRAM

The Bar Chart Report

The CPM Bar Chart program generates a Bar Chart output report such as the one in Figure 3-4. This figure corresponds to the arrow diagram in Figure 3-1, as do Figure 3-5 and 3-6. The Bar Chart provides the following information:

1. Problem title.

2. Specification as to the type of float requested for use in the calculations (total float, free float, or independent float).

3. For each activity, its tail-event identification, its head-event identification, its description, its estimated duration in standard time units, and its float (of the type requested).

4. Bar-graph entries X, C, *, and -, as described below.

Definitions of Bar Chart Entries

In the portion of the Bar Chart report containing the bar chart entries themselves, each entry (X, C, *, or -) lies in a specific column. Each column corresponds to a calendar time period as specified by the programmer. Thus, an entry appearing in one or more time-period columns indicates that, for the activity reported in the current line, certain conditions are true for the time-period column in which the entry appears, as follows.

EARLY RANGE

Entries X lie in the early range, i.e., in the period of time during which the activity can begin. This range is the time period that lies between the earliest start time and either the latest start time or the earliest finish time. The activity can begin at any time during the early range without increasing the total duration of the project. An example is opposite the activities A and C in Figure 3-3.

CRITICAL RANGE

Entries C lie in the critical range, i.e., in the time period during which the activity must be in progress to avoid extending the total duration of the project (i.e., to avoid causing slippage of the network end event). If the float used in the calculations equals zero, the whole range of the activity is critical, there is no early range or late range, and the time periods within the activity range are all represented as C's. Examples are opposite the activity B in Figure 3-3.

LATE RANGE

Entries * lie in the late range, i.e., in the time period during which the activity must reach completion to avoid scheduling failures (slippage of succeeding activities). The time period lies either (1) between the earliest finish time and the latest finish time or (2) between the latest start time and latest finish time. It indicates the time period during which the activity can end without increasing the total duration of the project. Examples are opposite activities A and C in Figure 3-3.

DASH BEFORE EST AND AFTER LFT

If a dash lies in time periods before the earliest start time or after the latest finish time, the dash indicates that the activity cannot be in progress during this period without violating the relationships indicates in the arrow diagram or increasing the expected duration of the project.

DASH BETWEEN EST AND LFT

If a dash lies in time periods between the earliest start time and the latest finish time, the dash indicates that the activities need not necessarily be in progress during this period.

Activity	EST	LFT	Float	DUR	Period							
					1	2	3	4	5	6	7	8
A	0	7	2	5	X	X	C	C	C	*	*	-
B	2	5	0	3	-	-	C	C	C	-	-	-
C	1	8	5	2	-	X	X	-	-	-	*	*

Figure 3-3. Examples of Ranges

```
                    CRITICAL PATH METHOD - BAR CHART

                      [BUILDING A HOUSE]◄── from title card

                    USING TOTAL FLOAT                              or  [M
                                                                       A ] , etc
                                                                       Y]

                                                             ┌ TIME PERIODS        ┐◄── from one set of
                                                             │            1        2        3  │     3 header cards
    TAIL   HEAD          DESCRIPTION          TIME  FLOAT    │ 1234567890123456789012345678901 2│
    0001   0010   EXCAVATE                      4            │ CCCC--------------------------- │
    0010   0020   LAY FOUNDATION                2              ----CC-------------------------
    0020   1000   ROUGH PLUMBING                3     4        ------XXX-*##-------------------
    0020   1010   BASEMENT FLOORING             2              ------CC------------------------
    0020   1020   FRAME                         4     1        ------XCCC#---------------------
    0020   1030   SEWER AND DRAINS              2     18       ------XX-----------------##------
    1010   1040   HEATING                       5              --------CCCCC-------------------
    1020   1050   BASIC WIRING                  2     1        ---------XC#--------------------
    1020   1060   BRICKWORK                     6     9        ---------XXXXXX---*#####--------
    1030   1100   GRADING                       2     18       ------.--XX----------------##----
    1040   1070   PLASTERING                    8              ------------CCCCCCCC------------
    1060   1080   ROOFING                       2     9        ---------------XX---------##----
    1070   1090   FLOORING                      3              ----------------------CCC-------
    1080   1100   GUTTERS                       1     9        ----------------X---------#-----
    1090   2000   FINISH PLUMBING               2              -----------------------CC------
    1090   2020   CARPENTRY                     4     1        ----------------------XCCC#----
    1100   2030   LANDSCAPING                   4     9        ------------------XXXX-----####
    2000   2010   PAINT                         3              -------------------------CCC---
    2010   9999   FINISH ELECTRICAL WORK        1     2        --------------------------X-#
    2020   9999   VARNISH FLOORS                3              --------------------------CCC

                                             KEY - X EARLY RANGE
                                                   C CRITICAL RANGE
                                                   # LATE RANGE
```

Figure 3-4.   Bar Chart Using Total Float

```
                       CRITICAL PATH METHOD - BAR CHART

                           BUILDING A HOUSE

                         USING FREE FLOAT

                                                    TIME PERIODS
                                                            1        2        3
    TAIL   HEAD          DESCRIPTION          TIME  FLOAT   1234567890123456789012345678901 2
    0001   0010   EXCAVATE                      4           CCCC---------------------------
    0010   0020   LAY FOUNDATION                2           ----CC-------------------------
    0020   1000   ROUGH PLUMBING                3           ------CCC----------------------
    0020   1010   BASEMENT FLOORING             2           ------CC-----------------------
    0020   1020   FRAME                         4           ------CCCC---------------------
    0020   1030   SEWER AND DRAINS              2           ------CC-----------------------
    1010   1040   HEATING                       5           --------CCCCC------------------
    1020   1050   BASIC WIRING                  2           ---------CC--------------------
    1020   1060   BRICKWORK                     6           ------.----CCCCCC--------------
    1030   1100   GRADING                       2     9     -------.--XX----------------##--
    1040   1070   PLASTERING                    8           ------------CCCCCCCC-----------
    1060   1080   ROOFING                       2           ---------------CC--------------
    1070   1090   FLOORING                      3           ----------------------CCC------
    1080   1100   GUTTERS                       1           ----------------C--------------
    1090   2000   FINISH PLUMBING               2           -----------------------CC------
    1090   2020   CARPENTRY                     4     1     ----------------------XCCC#----
    1100   2030   LANDSCAPING                   4           ------------------CCCC---------
    2000   2010   PAINT                         3           -------------------------CCC---
    2010   9999   FINISH ELECTRICAL WORK        1     2     --------------------------X-#
    2020   9999   VARNISH FLOORS                3           --------------------------CCC

                                             KEY - X EARLY RANGE
                                                   C CRITICAL RANGE
                                                   # LATE RANGE
```

Figure 3-5.   Bar Chart Using Free Float

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```
                CRITICAL PATH METHOD - BAR CHART

                        [BUILDING A HOUSE]←—on the title card
                USING INDEPENDENT FLOAT
                                                                        ┌─or ┌─┐,etc.
                                                                            │M│
                                                                            │A│
                                                                            │Y│
                                                                            └─┘
                                                         ┌TIME PERIODS                        ┐
                                                         │              2         3           │←—on the set of
TAIL   HEAD            DESCRIPTION         TIME FLOAT    │1234567890123456789012345678901 2   │  3 header cards
0001   0010  EXCAVATE                        4           CCCC-------------------------------
0010   0020  LAY FOUNDATION                  2           ----CC-----------------------------
0020   1000  ROUGH PLUMBING                  3           ------CCC--------------------------
0020   1010  BASEMENT FLOORING               2           ------CC---------------------------
0020   1020  FRAME                           4           -----CCCC--------------------------
0020   1030  SEWER AND DRAINS                2           ------CC---------------------------
1010   1040  HEATING                         5           --------CCCCC----------------------
1020   1050  BASIC WIRING                    2           ----------CC-----------------------
1020   1060  BRICKWORK                       6           ----------CCCCCC-------------------
1030   1100  GRADING                         2           --------CC-------------------------
1040   1070  PLASTERING                      8           -------------CCCCCCCC--------------
1060   1080  ROOFING                         2           --------------CC-------------------
1070   1090  FLOORING                        3           --------------------CCC------------
1080   1100  GUTTERS                         1           ------------------C----------------
1090   2000  FINISH PLUMBING                 2           -------------------------CC--------
1090   2020  CARPENTRY                       4      1    -------------------XCCC*---
1100   2030  LANDSCAPING                     4           ----------------CCCC-----------
2000   2010  PAINT                           3           ----------------------------CCC---
2010   9999  FINISH ELECTRICAL WORK          1      2    -----------------------------X-*
2020   9999  VARNISH FLOORS                  3           ----------------------------CCC

                                         KEY - X EARLY RANGE
                                               C CRITICAL RANGE
                                               * LATE RANGE
```

Figure 3-6.   Bar Chart Using Independent Float

SUMMARY

The Activity List and the Bar Chart keep the project manager informed of developments that affect the duration and cost of the project.   Early successes, failures, delays, etc., are reportable using CPM A.   Using the time tolerances displayed in CPM A reports, the manager can shift job start times around peak work load times, rescheduling activities that conflict with activities on the critical path.   By diverting resources from activities having a large float, he may succeed in reducing overtime costs and premium payments without lengthening the duration of the project.   CPM methodology has proved itself a powerful profit-maximizing technique.

MAIN PROGRAM INPUT FORMATS

The makeup of the deck submitted to the CPM A main program is specified in the operating procedures. Specifications for individual cards in the deck follow.

Main Program Control Card Formats

Control cards for the CPM main program are required whether or not the program is run independently of the Bar Chart program.

CALL CARD (FOR OPERATING SYSTEM — MOD 1 ONLY)

COLUMN(S)	CONTENTS	INTERPRETATION
1-6	AFACPM	The name of the program.
7-8	$\emptyset$1	Punched as shown.
9	n	DRIVE TO CONTAIN THE BRT. This octal digit cannot be 1 or 2.
10-17		Not used.
18	*	Punched as shown.
19-80		Not used.

TITLE CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-50	x...x	TITLE OF PROJECT. Alphanumeric.
51-80		Not used.

PARAMETER CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-2	MEMORY SIZE OF MACHINE IN 4K MODULES. Punch one of the two-digit numbers listed below. Memory size restricts the total number of events as specified in Table 2-1. NOTE: The Floating Tape Loader-Monitor C used in the Operating System — Mod 1 occupies the top end of memory. It stores in its communication region a parameter specifying the lower limit of the memory it occupies, so that every location after that address through the end of memory is used by the loader-monitor. The CPM A program considers this parameter as an effective stopper address and computes from it the number of 4K memory modules	

PARAMETER CARD (cont)

COLUMN(S)	CONTENTS	INTERPRETATION
1-2 (cont)	available for use. If the computed value does not equal the value punched in columns 1-2 of this card, the smaller value is assumed.	
	01	4K
	02	8K
	03	12K
	04	16K
	05	20K
	06	24K
	07	28K
	08	32K
3-4	FORMAT OF NETWORK ACTIVITY CARDS. Specify the mode in which the cards are to be interpreted:	
	ΔΔ	Honeywell input format. This is standard.
	SP	Special input format.
5	PUNCH BAR CHART INPUT CARDS?	
	∅	Do not punch cards for input to the Bar Chart program. This option must be used if the CPM main program and the Bar Chart program are to be processed sequentially in the same run.
	P	Punch cards for input to the Bar Chart program. If this option is used, the CPM main program must be processed alone (cannot be followed sequentially by the Bar Chart program in the same run), and column 11 of this card must contain zero.
6-10		Not used.
11	PROCESSING OPTION. This column is used to specify which programs are to be run and which type of float is to be calculated. Types of float are discussed in Section II; sequencing and output options offered here are discussed in Section V.	
	∅	Run the CPM main program alone giving an Activity List. The Bar Chart program is not to be processed sequentially in the same run.
	T	Run the CPM main program followed sequentially by the Bar Chart program. Use total float for the bar chart.
	F	Run the CPM main program followed sequentially by the Bar Chart program. Use free float for the bar chart.
	I	Run the CPM main program followed sequentially by the Bar Chart program. Use independent float for the bar chart.
12-13	nn	NUMBER OF TIME PERIODS TO BE PRINTED (HORIZONTALLY) PER PAGE OF BAR CHART OUTPUT. A two-digit decimal number equal to or less than 55. For the use of this parameter, see "Number of Bar Chart Reporting Periods" below.

PARAMETER CARD (cont)

COLUMN(S)	CONTENTS	INTERPRETATION
14-17	nnnn	FIRST TIME PERIOD TO BE REPORTED. A four-digit decimal number identifying the first time period to be included in the Bar Chart report. The programmer can print all of the project time periods or a range of periods within the project, using the two parameters in columns 14-21. The duration of the reporting time period is the duration of the time unit used in preparing elapsed-time estimates for network activities. To include the first time period in the Bar Chart report is to include the first unit of expected elapsed time which is in the network.
18-21	nnnn	LAST TIME PERIOD TO BE REPORTED. A four-digit decimal number identifying the last time period to be included in the Bar Chart report. For example, in the house building project, the total duration of the project is expected to be 32 units (see TOTAL DURATION OF PROJECT in the Activity List in Figure 3-2). To report the whole project as in Figure 3-6, code this parameter 0032 into these columns (18-21), and code 0001 into columns 14-17.
22-80		Not used.

END OF NETWORK CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-11	ENDΔ NETWORK	Punched as shown. Announces the end of the current data deck.
12-80		Not used.

Main Program Activity Card Format

The activity cards specify the structure (i. e. , topology) of the network. CPM A can process any number of activities in a given run, but the number of events that a given network can contain is limited by memory as specified in Table 2-1 which appears under "Restrictions Imposed on Arrow Diagrams" in Section II.

In the set of activity cards, activity cards can appear in random sequence. However, activity cards are not sorted automatically; the activities appear in the output reports in the sequence in which they appear in the input deck. A recommended procedure is to presort the cards on a major key of beginning-event number and a minor key of end-event number.

Activity cards are usually punched in standard Honeywell format, which is compatible with IBM 1401 format. The special format described below is also available. The type of

4-3

format used must be specified in columns 3-4 of the parameter card. Regardless of the format used, one activity card must be prepared for each network activity, as specified below.

HONEYWELL (IBM 1401 COMPATIBLE)

COLUMN(S)	CONTENTS	INTERPRETATION
1-4	xxxx	BEGINNING (TAIL) EVENT. Identifies the beginning event of the activity. Alphanumeric.
5-8	xxxx	END (HEAD) EVENT. Identifies the end event of the activity. Alphanumeric.
9-12	nnnn	TIME ESTIMATE. The (usually current) estimate of expected total duration of the activity, expressed in standard units. Four decimal digits.
13-17	nnnn	COST ESTIMATE. Optional. The (usually current) estimate of expected total cost of the activity, expressed in standard cost units. Four decimal digits.
18-49	x...x	DESCRIPTION OF ACTIVITY. Alphanumeric.
50-80		Not used.

SPECIAL FORMAT

COLUMN(S)	CONTENTS	INTERPRETATION
1-2		Not used.
3-7	xxxxx	BEGINNING (TAIL) EVENT. Identifies the beginning event of the activity. Alphanumeric.
8-12	xxxxx	END (HEAD) EVENT. Identifies the end event of the activity. Alphanumeric.
13-49	x...x	DESCRIPTION OF ACTIVITY. Alphanumeric.
50-52	nnn	TIME ESTIMATE. The (usually current) estimate of expected total duration of the activity, expressed in standard units. Three decimal digits.
53-58	nnnnnn	COST ESTIMATE. Optional. The (usually current) estimate of expected total cost of the activity, expressed in standard cost units. Six decimal digits.
59-80		Not used.

BAR CHART PROGRAM INPUT FORMATS

If the Bar Chart program is run independently of the main program, all of the control cards described below must be prepared. If it is run sequentially after the main program, only the heading cards need be submitted. If it is not run at all, no Bar Chart input cards need be submitted.

Bar Chart Heading Cards

For each network that is reported via the Bar Chart program, the correct number of sets of heading cards must be submitted.   A set of heading cards contains exactly three cards.   The literal contents of columns 1-55 of these cards are printed as the column headings of the bar chart.   Column 1 of each of the three cards is aligned above the first time-period column in the bar chart report, and so on for the remaining card columns that are printed.   The first-processed heading card generates the first heading line of the bar chart proper, the second card generates the second line, etc.   For example, in Figure 3-6 the three heading lines in square brackets at the right-hand side of the printout were generated by the three heading cards shown in Figure 4-1.

The number of heading sets required must be determined by the programmer.   The parameters in columns 12-21 of the Bar Chart parameter card provide the needed information. The required number of sets of heading cards is the smallest integer that is equal to or greater than this:

$$\frac{(LAST\ PERIOD) - (FIRST\ PERIOD)}{(NUMBER\ OF\ PERIODS\ PER\ PAGE)}$$

Readers desiring an explanation of the logic behind this formula may read "Number of Bar Chart Reporting Periods" below.
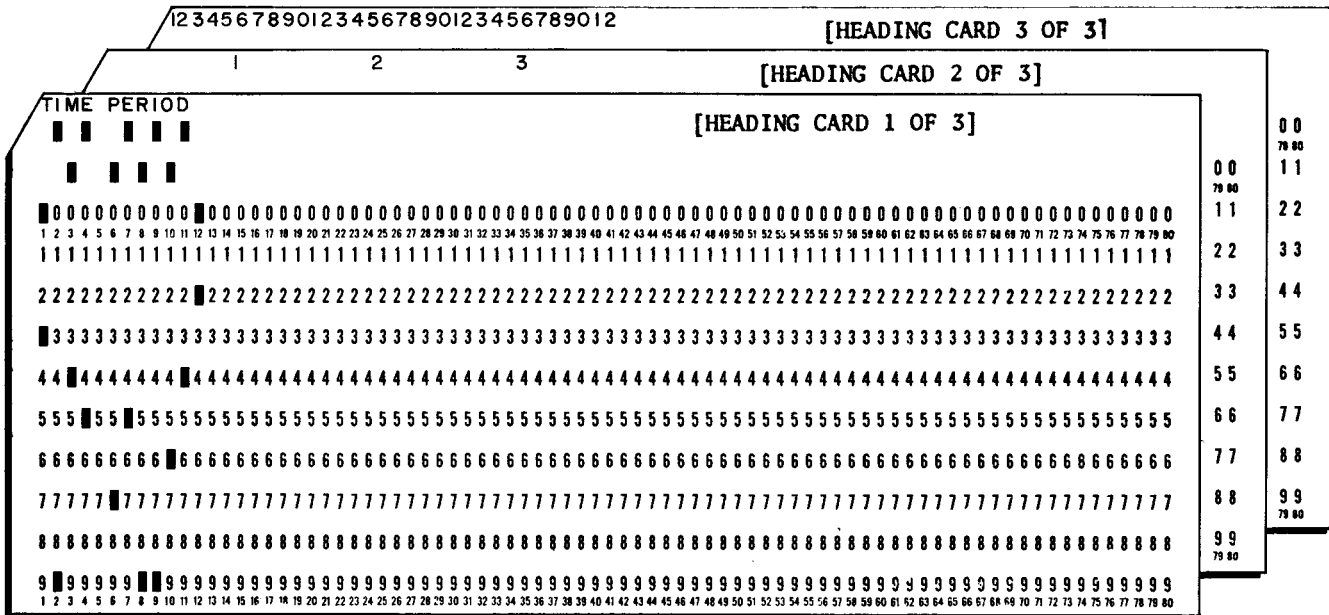
Figure 4-1.   One Set of Bar Chart Heading Cards

Number of Bar Chart Reporting Periods

On any page of the Bar Chart output report, up to 55 horizontal print positions can be

occupied by bar chart entries (i. e., by X, C, *, and -). Because each print position corresponds to one standard time period in the project, up to 55 time periods can be recorded horizontally per page, or fewer than 55 periods can be recorded, the exact number being specified in columns 12-13 of the Bar Chart program parameter card. In Figure 3-6, 32 time periods are recorded; columns 12-13 of the corresponding parameter card contained the number 32.

The number of time periods that can be reported for a given activity is not limited to 55. Any number of time periods can be reported, but more than one set of header cards must be submitted, as follows.

For any activity reported in the Bar Chart report, if more than 55 time periods are to be reported, the number of sets of header cards required is determined as follows. The parameter card for the Bar Chart report contains a parameter in columns 12-13 specifying how many time periods are reportable on each page of output, i. e., how many horizontal print positions can be used for the actual bar chart entries. Let this parameter be called p. To determine how many sets of header cards are needed, divide p into the number of reporting periods to be spanned in the Bar Chart output report. The quotient of this division is the number of required header sets if the division has no remainder; else the quotient plus one is the number of required header sets.

Some examples may clarify the above remarks. Suppose that 150 activities are to be reported in a Bar Chart report. A standard size printer form holds about 60 lines of print: more than one page of output is generated. Suppose that, including heading lines on each page, exactly N pages will be required to list the 150 activities, where N is any (real) number.

If the reported activities, considered together as a project, span no more than 55 time periods, only the standard number of header sets need be submitted to the Bar Chart program, viz., one set. In this case, parameter p on the parameter card must be punched 55. N pages of Bar Chart output are generated, each page containing the heading defined in the header set.

If some of the project's activities lie in the 56^{th} time period and following, more than one set of header cards must be submitted, the precise number being as described above. In this case, parameter p on the parameter card must be punched as a parameter equal to or less than 55. N pages of output are generated, each page containing the heading defined in the first header set. For all 150 activities, these pages report for time periods 1 through p (usually 1 through 55).

Then, because there are more time periods to be reported for at least one of the 150 activities, the Bar Chart program looks for a second header set in the input deck. If the set is

found, a second set of up to N output pages is printed. For each activity reported in these pages, the time periods p + 1 through 2p (i. e., the second p time periods) are spanned. These time periods are labelled as specified in the second header set.

And so on, until there are no more time periods to be reported.

Bar Chart Program Control Card Formats

CALL CARD (FOR OPERATING SYSTEM — MOD 1 ONLY)

COLUMN(S)	CONTENTS	INTERPRETATION
1-6	AFACPB	The name of the program.
7-8	Ø1	Punched as shown.
9	n	DRIVE TO CONTAIN THE BRT. This octal digit cannot be 1 or 2.
10-17		Not used.
18	*	Punched as shown.
19-80		Not used.

TITLE CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-50	x...x	TITLE OF PROJECT. Alphanumeric.
51-80		Not used.

PARAMETER CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-10		Not used.
11		TYPE OF FLOAT TO BE USED IN CALCULATIONS. Specify one of the following:
	T	Use total float.
	F	Use free float.
	I	Use independent float.
12-13	nn	NUMBER OF TIME PERIODS TO BE PRINTED (HORIZONTALLY) PER PAGE OF BAR CHART OUTPUT. A two-digit decimal number equal to or less than 55. For the use of this parameter, see "Number of Bar Chart Reporting Periods."
14-17	nnnn	FIRST TIME PERIOD TO BE REPORTED. A four-digit decimal number identifying the first time period to be included in the Bar Chart report. The programmer can print

PARAMETER CARD (cont)

COLUMN(S)	CONTENTS	INTERPRETATION
14-17 (cont)		all of the project time periods or a range of periods within the project, using the two parameters in columns 14-21. The duration of the reporting time period is the duration of the time unit used in preparing elapsed-time estimates for network activities. To include the first time period in the Bar Chart report is to include the first unit of expected elapsed time which is in the network.
18-21	nnnn	LAST TIME PERIOD TO BE REPORTED. A four-digit decimal number identifying the last time period to be included in the Bar Chart report. For example, in the house building project, the total duration of the project is expected to be 32 units (see TOTAL DURATION OF PROJECT in the Activity List in Figure 3-2). To report the whole project as in Figure 3-6, code this parameter 0032 into these columns (18-21), and code 0001 into columns 14-17.
22-80		Not used.

END OF NETWORK CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-11	END△ NETWORK	Punched as shown. Announces the end of the current data deck.
12-80		Not used.

END OF FILE CARD

COLUMN(S)	CONTENTS	INTERPRETATION
1-8	END△ FILE	Punched as shown. Announces the end of the current file.
9-80		Not used.

Bar Chart Program Data Card Format

    If the CPM main program is processed separately, a deck of cards for input to the Bar Chart program is punched out. A card is punched for each network activity. Each card is punched in this format:

Column(s)	Contents
1-5	Tail event number.
6-10	Head event number.
11-47	Description of the activity.
48-51	Time estimate for the activity.
52-55	Earliest start time.
56-59	Total float.
60-63	Free float.
64-67	Independent float.
68-73	Cost estimate for the activity.
74-80	Not used.

SECTION V
COMPUTER OPERATING PROCEDURES

This section describes operating procedures for the Series 200 Basic Programming System and for the Series 200 Operating System — Mod 1.

PROCESSING OPTIONS

The following processing options are available in both the Basic Programming System and the Mod 1 Operating System.

Option 1

In this option, the CPM Main program is followed sequentially and automatically by the CPM Bar Chart program.

PARAMETER CARD FORMAT

The main-program parameter card must be punched as follows:

1. Column 5 must contain a zero.
2. Column 11 must contain T, F, or I.

OUTPUT

1. A single copy of the Activity List report is produced. Multiple copies are not available in this option.

2. A single copy of the Bar Chart report is produced. Multiple copies can be obtained by successively depressing the RUN button, beginning after the final halt.

Option 2

In this option, the CPM main program is run alone, i.e., it is not followed automatically by the CPM Bar Chart program.

PARAMETER CARD FORMAT

The main-program parameter card must be punched as follows:

1. Column 5 must contain a zero.
2. Column 11 must contain a zero.

OUTPUT

1. A single copy of the Activity List report is produced. Multiple copies can be obtained by successively depressing the RUN button, beginning after the final halt.

Option 3

In this option, the CPM Main program is run alone. The Bar Chart data cards (i.e., the activity cards from the corresponding network) are punched out to be used as input to subsequent running of the CPM Bar Chart program as in Option 4. This processing option is recommended for all initial runs and for all subsequent runs containing updated activity data cards. This option provides the programmer with parameters for the CPM Bar Chart run.

PARAMETER CARD FORMAT

The main-program parameter card must be punched as follows:

1. Column 5 must contain P.

2. Column 11 must contain a zero.

OUTPUT

1. A single copy of the Activity List report is produced. Multiple copies can be obtained by successively depressing the RUN button, beginning after the final halt.

2. A deck of Bar Chart data cards is produced, one card per network activity. These cards can be used as input to a subsequent CPM Bar Chart program run.

Option 4

In this option, the CPM Bar Chart program is run alone. The CPM main program must have been run previously.

PARAMETER CARD FORMAT

The parameter card for the Bar Chart program is punched in the format specified for the CPM Bar Chart program in Section IV.

OUTPUT

A single copy of the Bar Chart report is produced. Multiple copies can be obtained by successively depressing the RUN button beginning after the final halt.

OPERATING PROCEDURES FOR THE BASIC PROGRAMMING SYSTEM

Equipment Requirement

The basic programming system requires the following minimum equipment configuration:

1. A Series 200 processor with 4K characters of main memory.

2. One card reader.

3. One printer.

4.   Two 1/2-inch tape drives.

5.   The Advanced Programming Option.

6.   Editing instructions.

Additional usable equipment is as follows:

1.   One tape drive if programs are loaded from an SLT.

2.   Additional memory to a maximum of 32K total. Memory size limits network size as specified in Table 2-1.

3.   One card punch.

Makeup of the Input Files

CPM MAIN PROGRAM

When the CPM Main Program is used alone (indicated by a $\emptyset$ punch in column 11 of its parameter card), the input deck is composed of (1) the AFACPM program, title, parameter, network data and end network cards, and (2) the AFACP2 program (see Figure 5-1). Only one network can be processed in a given run.
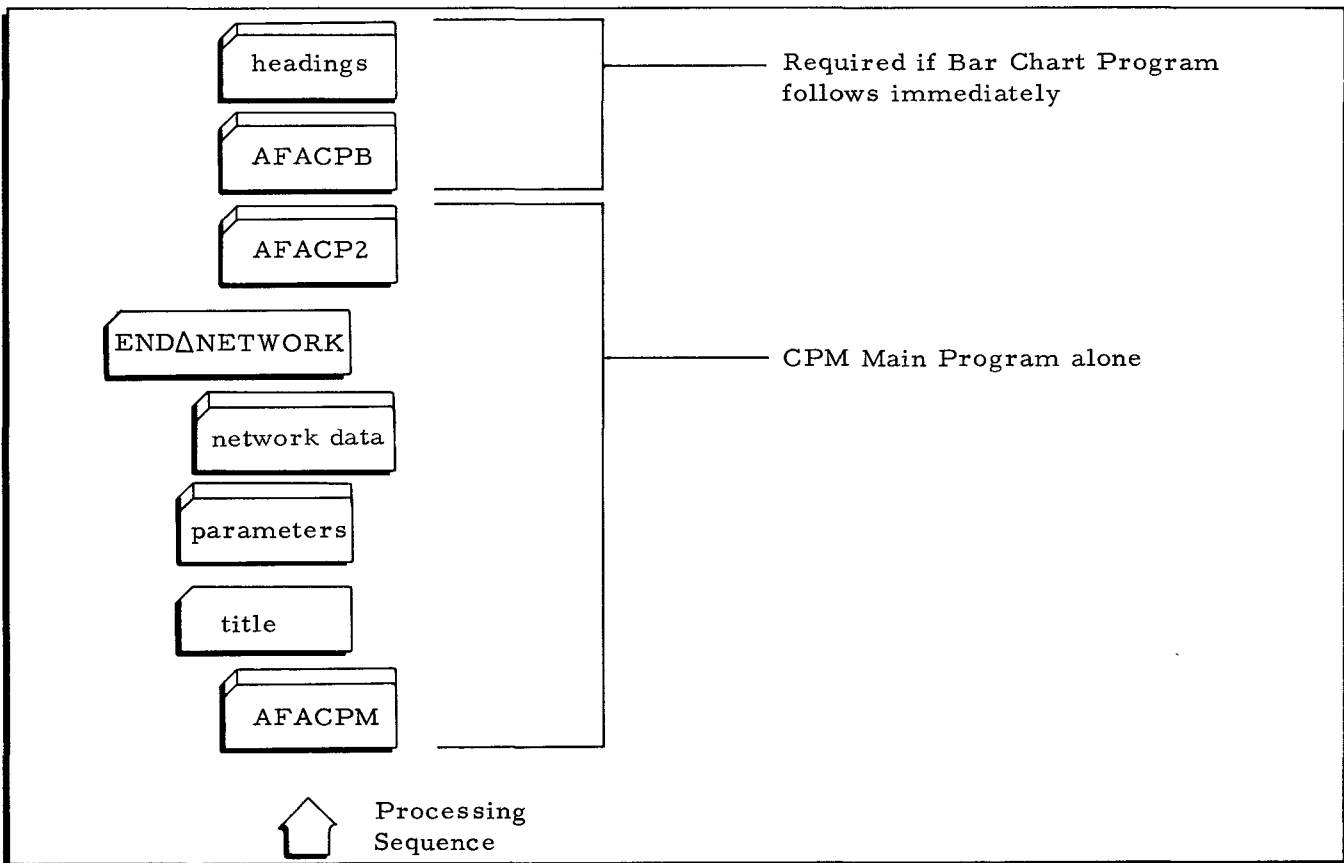
Figure 5-1. Input Deck for CPM Main Program Using Basic Programming System

If the Bar Chart Program follows immediately, then in addition to the above there must be the AFACPB program and the appropriate number of heading cards (see Figure 5-1).

BAR CHART PROGRAM

If the Bar Chart Program is used independently, the input deck consists of (1) the AFACPB program, title, parameter, bar chart data, end network and heading cards for each network, and (2) an end file card (see Figure 5-2). In this case, more than one network (i.e., multiple CPM Bar Chart data decks) can be run together.

ENDΔFILE

headings

ENDΔNETWORK

bar chart data

parameters

title

— Second Network, etc.

headers

ENDΔNETWORK

bar chart data

parameters

title

— First Network

AFACPB

Processing Sequence
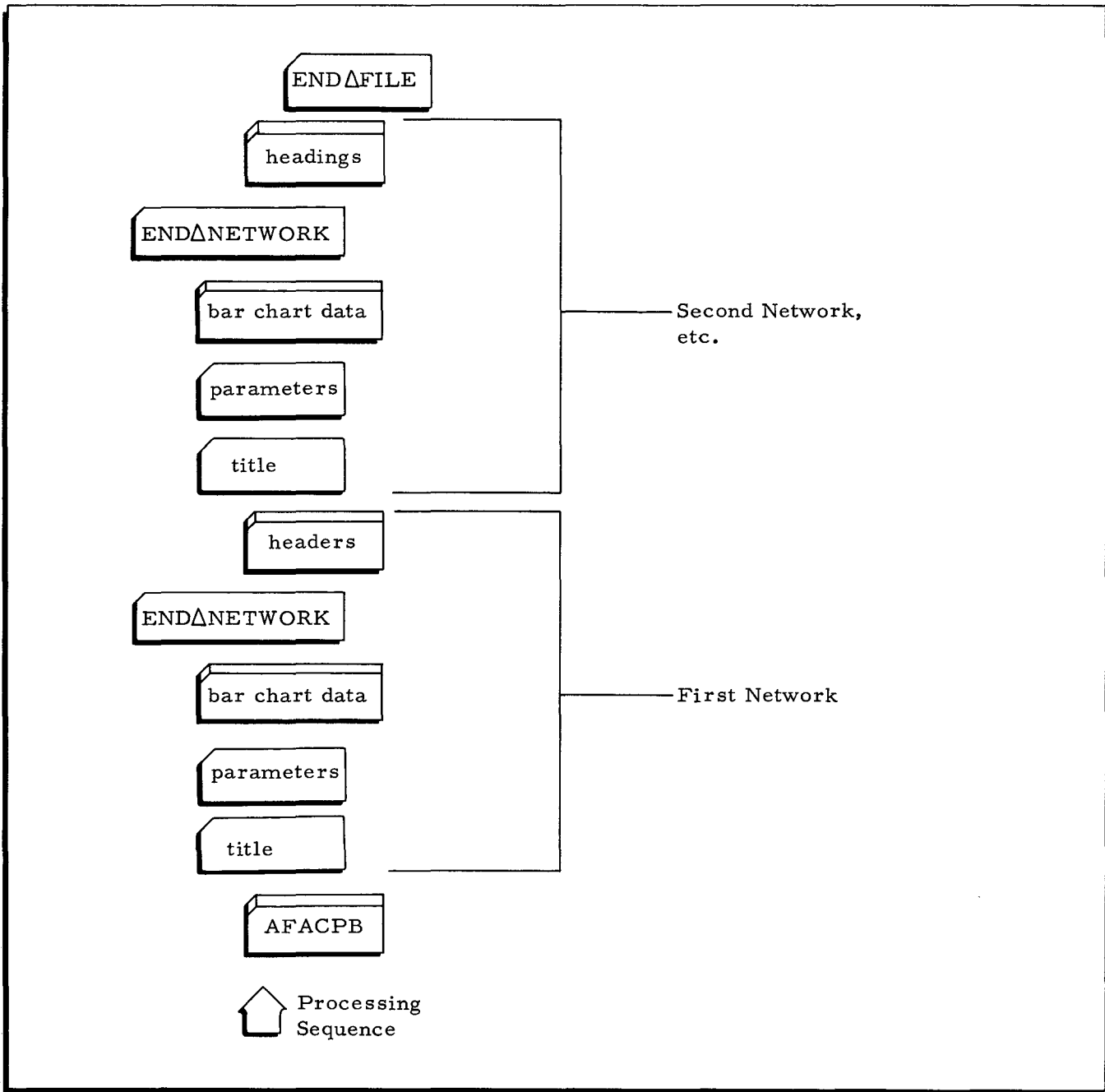
Figure 5-2. Input Deck for Bar Chart Program Using Basic Programming System

Starting Procedures

CPM MAIN PROGRAM

This procedure applies to the Basic Programming System whether or not the Bar Chart program is to follow immediately.

1. Mount work tapes on drives 1 and 2.

2. Load the card reader with the deck shown in Figure 5-1.

3. Load the card punch if cards are to be punched, i.e., if column 5 of the parameter card contains P.

4. Set up the printer.

5. Bootstrap program into octal location 32. Press the RUN button.

Program AFACP2 is part of the CPM main program; it is loaded automatically and cannot be used independently.

If the Bar Chart program is to follow immediately, it will be loaded automatically.

If the CPM main program is used alone and more than one copy of the Activity List printout is desired, an additional copy will be printed each time the RUN button is pressed, beginning after the final halt.

BAR CHART PROGRAM

Use this procedure in the Basic Programming System if the Bar Chart program is to run separately.

1. Mount a work tape on drive 2.

2. Load the card reader with the deck shown in Figure 5-2.

3. Set up the printer.

4. Set sense switch 2 ON.

5. Bootstrap the card program into octal location 32 and press the RUN button.

If more than one copy of the Bar Chart printout is desired, an additional copy will be printed if sense switch 2 is turned OFF, the heading cards are reloaded into the reader, and the RUN button is pressed. If more than one network has been processed, the additional copies obtained are for the last network.

OPERATING PROCEDURES FOR OPERATING SYSTEM — MOD 1

Equipment Requirement

The Mod 1 Operating System requires the following minimum equipment configuration:

1.   A Series 200 processor with 12K characters of main memory (for assembly).

2.   One card reader.

3.   One printer.

4.   Three 1/2-inch tape drives.

5.   The Advanced Programming Option.

6.   Editing Instructions.

Additional usable equipment is as follows:

1.   Additional memory to a maximum of 32K total. Memory size limits network size as specified in Table 2-1.

2.   One card punch.

Makeup of the Input Files

CPM MAIN PROGRAM

When the CPM Main Program is used alone (indicated by a 0 punch in column 11 of its parameter card), the input deck is composed of the call card, title, parameter, network data, and end network cards (see Figure 5-3).
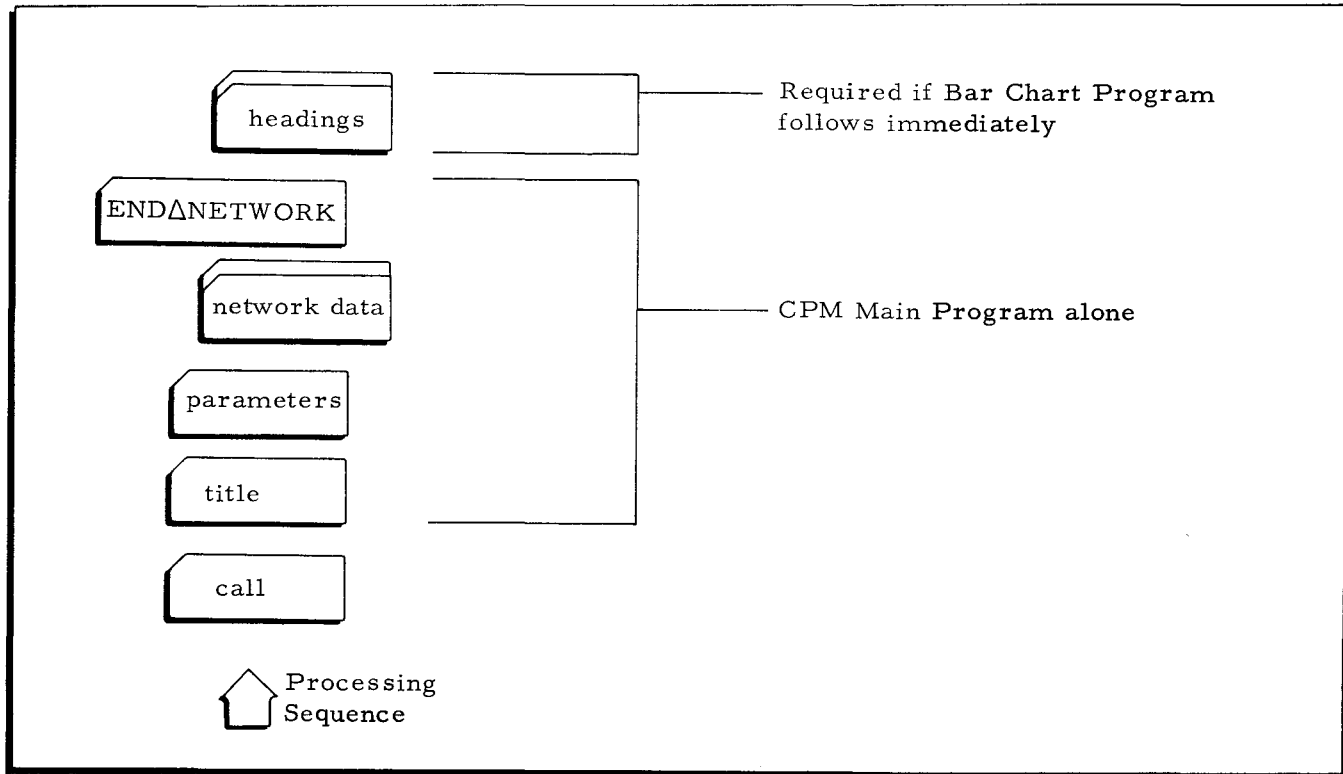
Figure 5-3. Input Deck for CPM Main Program Using Operating System-Mod 1

If the Bar Chart Program follows immediately, then in addition to the above, there must be the appropriate number of heading cards and column 11 of the main-program parameter card must contain non-zero. See Figure 5-4.

BAR CHART PROGRAM

If the Bar Chart Program is used independently, the input deck consists of (1) the call card, title, parameter, bar chart data, end network, and heading cards for each network, and (2) an end file card. See Figure 5-4. In this case, more than one network (i.e., multiple CPM Bar Chart data decks) can be run together.
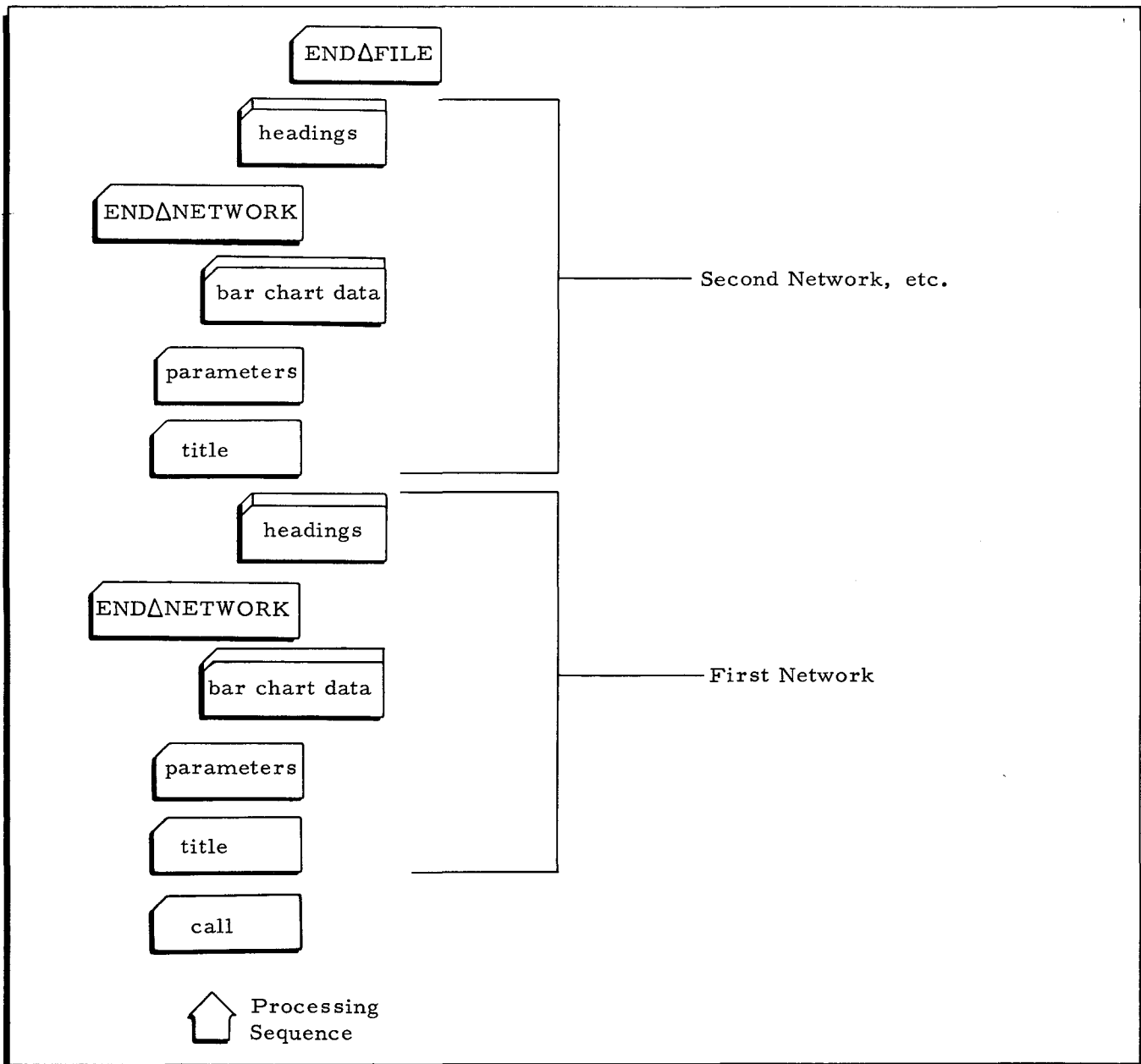
Figure 5-4. Input Deck for Bar Chart Program Using Operating System-Mod 1

Starting Procedures

CPM MAIN PROGRAM

This procedure applies to the Operating System-Mod 1 whether or not the Bar Chart program is to follow immediately.

1. Mount work tapes on drives 1 and 2.

2. Mount the BRT on any other drive.

3. Load the card reader with the deck shown in Figure 5-3.

4. Load the card punch if cards are to be punched, i.e., if column 5 of the main-program parameter card contains P.

5. Set up the printer.

6. Load the program from the BRT by bootstrapping into octal location zero (see the Floating Tape Loader-Monitor manual). Press the RUN button.

If the Bar Chart program is to follow immediately, it will be loaded automatically.

If the CPM main program is used alone and more than one copy of the printout is desired, an additional copy will be printed each time the RUN button is pressed, beginning after the final halt.

BAR CHART PROGRAM

Use this procedure in the Operating System-Mod 1 to run the Bar Chart program separately.

1. Mount work tapes on drives 1 and 2.

2. Mount the BRT on any other drive.

3. Load the card reader with the deck shown in Figure 5-4.

4. Set up the printer.

5. Set sense switch 2 ON.

6. Load the program from the BRT by bootstrapping into octal location zero (see the Floating Tape Loader-Monitor C manual). Press the RUN button.

If more than one copy of the last Bar Chart printout is desired, do this:

1. Set sense switch 2 OFF.

2. Reload the header cards into the card reader.

3. Press the RUN button, beginning after the final halt.

RUNNING PROCEDURES

In the Basic Programming System and in the Operating System — Mod 1, if an error halt occurs, the operator should consult the halt codes at the back of the manual.

Whether the CPM main program and CPM Bar Chart programs are run together or in separate runs, the final halt is indicated by the display of octal address 04777 in the A and B registers. This EOJ (end of job) halt is an indication that the run is complete and has terminated normally.

Error Conditions

TAPE READ/WRITE ERRORS

If a tape read or write error occurs, the program makes an additional 63 attempts to read or write before halting. At the halt, the operator can reread an additional 64 times by depressing the RUN button or he can rerun the program. He can also use the THRESHOLD ADJUST control on the tape control logic drawer to correct read errors. Briefly, the procedure is to turn the potentiometer control progressively to the left (or, if this doesn't clear the error, to the right), holding down the spring-loaded push button while the tape is being reread. Detailed instructions concerning the use of the THRESHOLD ADJUST control are contained in the Hardware Bulletin entitled Adjusting Thresholds on Tape Controls, File Number 112.0005.0200.00.07.

BAR-CHART HEADING CARD ERRORS

If there are too few heading cards submitted, the Bar Chart program attempts to read the correct number of header cards. If this attempt exhausts the supply of cards in the reader, the program stalls trying to read additional cards. If any cards remain in the reader, they are read in sets of three and are printed as headings on the Bar Chart report.

If there are too many heading cards submitted, and the CPM main program and Bar Chart program are processed sequentially, the excess heading cards are not read, and the program reaches a normal halt.

If there are too many heading cards submitted, and the CPM Bar Chart is running alone, the results are unspecified.
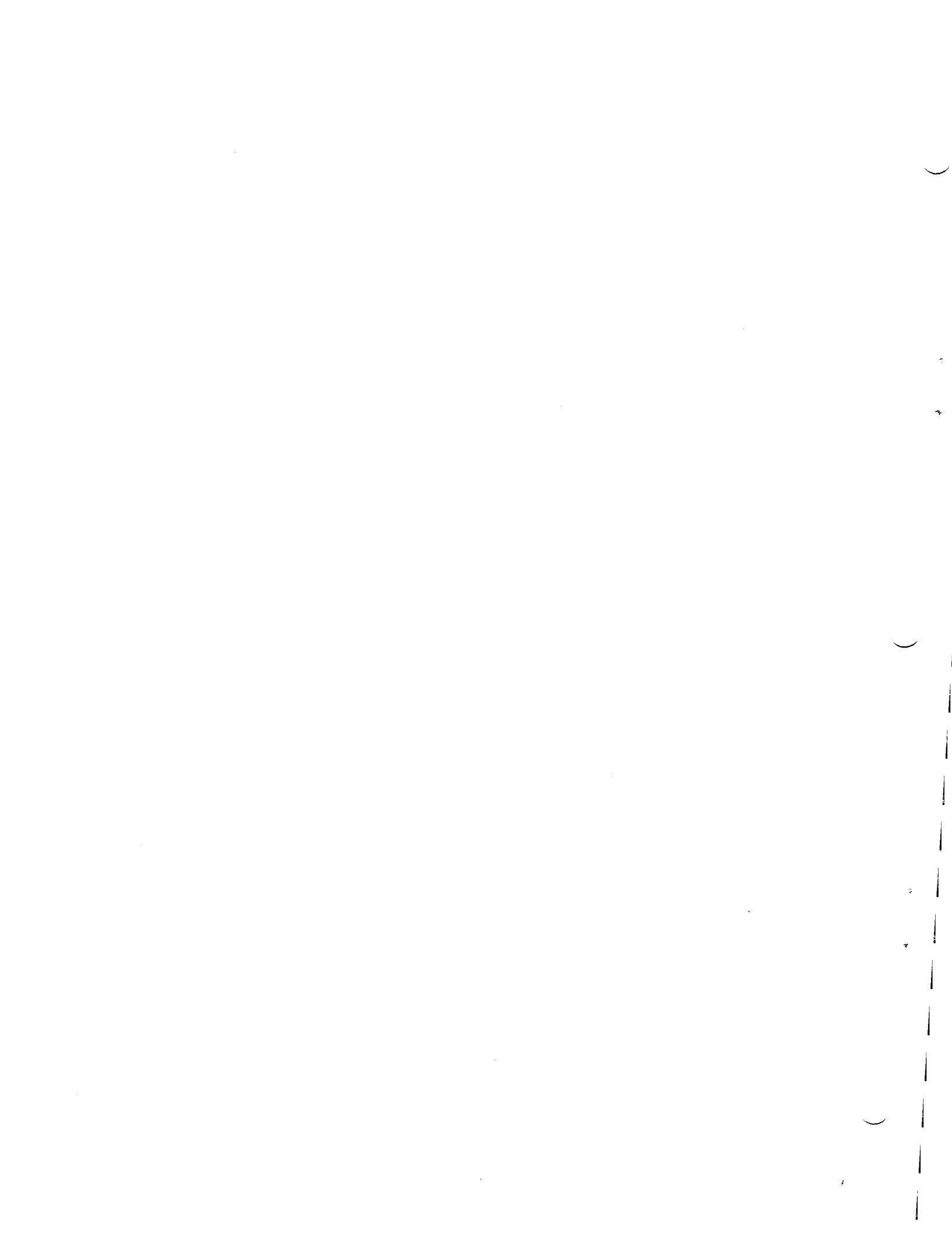
APPENDIX A

HALT CODES

B Register	Printer Message	Explanation	Corrective Action
0xxcd	(None)	Peripheral error condition	Card reader: correct error, reload input deck, press RUN.
		xx = 0pp ppp where pp ppp are the rightmost bits of the PCU address	Card punch: correct error, press RUN.
		c = 0 for device inoperable	Tape: press RUN to re-enter error routine. Or use THRESHOLD AD-JUST to correct read error. Or rerun.
		= 1 for uncorrectable read error	
		= 2 for uncorrectable write error	
		= 3 for end of tape	
		d = device number (if any)	
04111	EVENTS EXCEED MAX ALLOWED	The number of events in the network is greater than the maximum permitted for the memory size and loading process.	Use larger memory if possible or change network to reduce number of events. Rerun.
04222	NETWORK BREAK AT EVENTS .... AND......	A break in network flow has been detected; event numbers of the two events which are only beginning or end ones are printed (one should be a correct beginning or end event for the network).	Change network so that there are no breaks and there is one beginning event and one end event for the networks. Re-run.
04333	LOOP DISCOVERED AT TAIL.......... HEAD............	Loop in network has been detected at the activity indicated. The activity it-self is not necessarily in the loop.	Change network to elim-inate loop. Rerun.

HONEYWELL EDP TECHNICAL PUBLICATIONS
USERS' REMARKS FORM

TITLE: SERIES 200 CRITICAL PATH METHOD A
SOFTWARE MANUAL

DATED: December, 1965

FILE NO: 123.8105.000A.0-084

ERRORS NOTED:

Fold

SUGGESTIONS FOR IMPROVEMENT:

Fold

FROM: NAME _____   DATE _____

COMPANY _____

TITLE _____

ADDRESS _____

_____

Cut Along Line

Cut Along Line

Honeywell
ELECTRONIC DATA PROCESSING