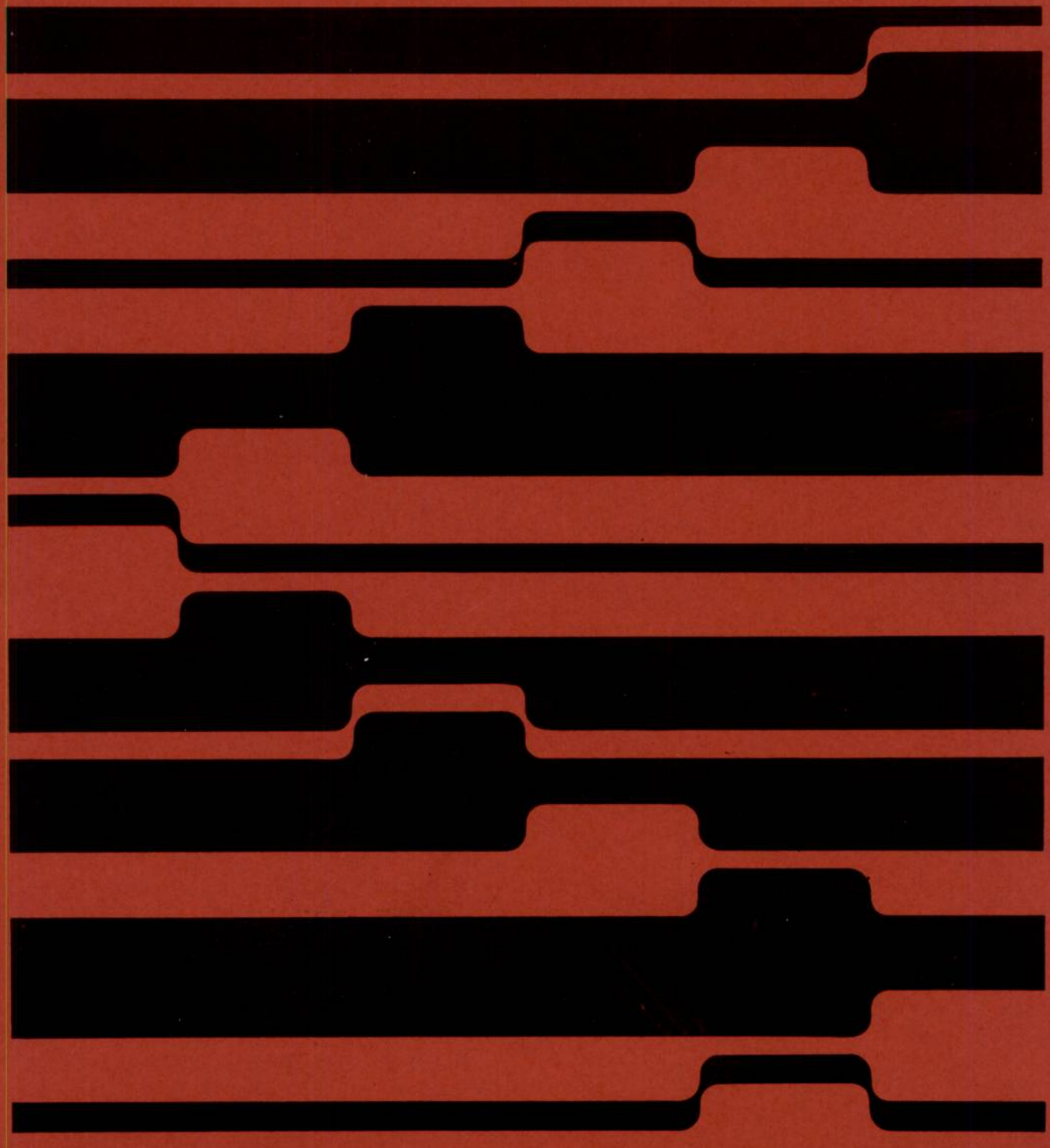
ICL

Line of balance user's guide

1900 Series



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1900 Series

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Contents

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User notice

MANUAL (NOTICE NO.) 8/10/69

3387 LINE OF BALANCE USER'S GUIDE (1)

File one copy of this notice with each of the manuals indicated.

CORRECTION OF ERRORS IN LINE OF BALANCE #X5LB

The following two errors have been corrected in Issue 3 of the above program.

1 An error in paper tape input which caused the Title Block to be rejected.

2 An error in the Progress Report Print routine which resulted in the halt: 'HALTED ??' if an attempt was made to follow a Progress Report Print by any print other than a Progress Chart sorted on the same key.

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Introduction

Line of Balance is used to control batch production with progressive feed. It gives control over small numbers of similar articles whose completion is required over a period of time. The production of an article is split into intermediate stages. The time and quantity relationship between stages forms input data to the system, together with the schedule of dates and quantities that the production programme must meet. The computer program calculates targets for the intermediate stages, compares these targets with any available progress data and produces printed reports highlighting over- and under -production.

The program is designed to use three magnetic tape decks in order to minimize card handling. However, it can be operated with only two decks.

The minimum machine configuration is:

4K	1901 Processor
2 (3)	20 kch/s Magnetic tape decks.
1	Card or paper tape reader.
1	Line printer (120 print positions)

The program is compatible with larger machine configurations.

The I.C.T. Line of Balance Package consists of:

1 The computer program X5LB, available on magnetic tape.

2 This user's guide.

1 The Application of Line of Balance

In any type of medium to large manufacturing organization the problem of keeping management accurately informed of the progress of production programmes in a timely manner is a real challenge, particularly as manufacturing programmes become more complex and as more programmes are involved simultaneously.

Line of Balance can supply the answers; it is a management oriented charting technique designed to broaden managements' view of programme progress so that it may implement corrective action whenever necessary.

To consider Line of Balance in relation to batch production work: in a batch with one completion date, work usually proceeds in a series of discrete steps, the work on the batch normally being completed on one stage before the batch is passed on to the next. Thus, if a batch of 100 units is to be produced, passing through a number of manufacturing stages, 100 units are completed in stage one, and then passed on to stage two, where again they are completed and passed on to the next stage. For long cycle jobs, this type of production results in long through-put times with its attendant high investment in Work-in-Progress.

Work-in-Progress levels can be reduced by progressive feeding, or splitting the batch, with the result that instead of one completion date we may have several covering a given period of time. In such instances, it is often not known whether the work being carried out in each stage is in balance with the work in other stages, and in order to monitor this type of work flow, Line of Balance requires two pieces of information: firstly, knowledge of delivery dates and quantities; and secondly, a statement of the sequence of operations or stages and their individual manufacturing times. The need to isolate and define the stages and agree their time relationships is an essential requirement of the Line of Balance system.

Once delivery schedules and stage/time relationship have been established the I.C.T. 1900 series Line of Balance program will calculate the volume of work that should have passed through each stage of manufacture at any particular point in time if the production programme is to be maintained. The performance and achievements are quoted in the form of charts which have as their horizontal axes the stage number, and as their vertical axes the volume of work which should have been completed in order to achieve the delivery schedule.

3387 (10.66)

2 The Line of Balance Technique

The I.C.T. Line of Balance program is a simple mathematical manipulation of sets of data which are input on cards, paper tape or magnetic tape. The value of a computer in this type of application lies in its ability to handle large volumes of such data with great speed and accuracy, selecting for output only those results meeting certain criteria. In Line of Balance there are three distinct kinds of input data. In the formats described in section 4, 3000 separate numbers might be input on a first run and a thousand or more on subsequent runs. Line of Balance reduces these to a readily comprehended picture. It was designed for use in production control and has been described here in those terms. The program, however, treats its data purely as numbers and this manual by no means exhausts all the possible applications.

Line of Balance can control the production of a small number of like articles. 'Small' means of the order of a thousand or less; 'like' refers to the main features, not necessarily every detail. For a typical article, a production plan can be drawn in the form of a 'family tree', illustrated below and in Appendix 1. The 'patriarch' is the finished article, an office desk; younger generations represent various intermediate stages. Each member of the family represents a definite step towards the finished product. Such a member is called a milestone.

In this family, the youngest member appears first. There is a certain minimum time, dictated by the amount of work involved, required to 'progress' from son to father. The minimum time between any one member and the patriarch, which is the sum of such times for the line of descent joining them, is called the lead time of that member or milestone.

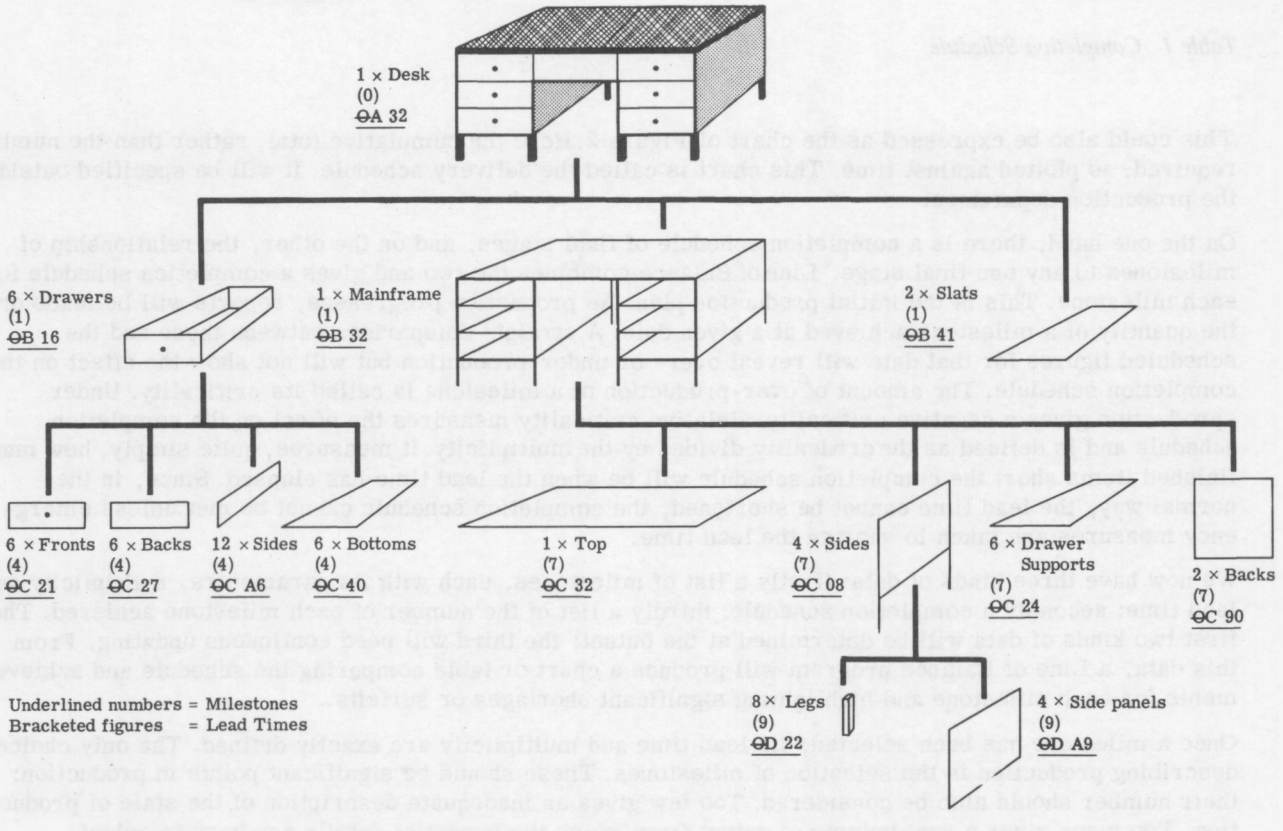


Figure 1 Production Family Tree

There is one departure from this analogy: Several identical sons may be required to produce one father. These are not shown separately on the tree. The number of a milestone required to produce one final stage is called the multiplicity of that milestone. The words 'final stage' cover completion of the product, delivery or any other point at which the responsibility of the department using Line of Balance ends.

Obviously, the time elapsing between a milestone and the final stage could be greater than the lead time. When this happens, it may be that the work is progressing more slowly. More often the work will be finished and a part-completed product will remain static, occupying space and tying up capital.

All members of a batch must be the same as far as they are defined by milestones, lead times and multiplicities. Each milestone will have a lead time and multiplicity.

The lead time of one milestone could be zero: this is the most convenient way of referencing the final stage. The multiplicity of a milestone can be anything from one upwards. It must be stressed that multiplicity and lead time define the relationship of a milestone to the final stage, *not to the next stage in production*. Any logical or sequential relationship of the milestones is ignored.

Were there to be a unique delivery date for the batch, it would be easy to control the intermediate steps from a knowledge of the lead time of suitable milestones. More often, the batch will be required over a period of time as in Table 1.

Week No.	No. Required
7	1
10	3
14	4
15	6
20	3

Table 1 Completion Schedule

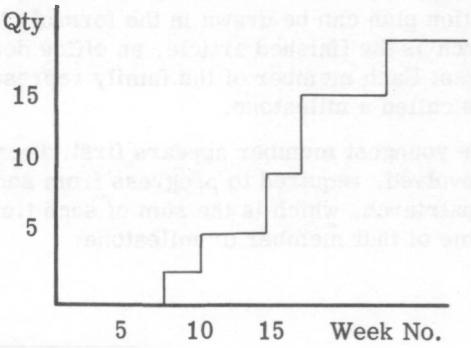


Figure 2

This could also be expressed as the chart of Figure 2. Here the cumulative total, rather than the number required, is plotted against time. This chart is called the delivery schedule. It will be specified outside the production department.

On the one hand, there is a completion schedule of final stages, and on the other, the relationship of milestones to any one final stage. Line of Balance combines the two and gives a completion schedule for each milestone. This is the initial production plan. As production progresses, reports will be made on the quantity of a milestone achieved at a given date. A straight comparison between these and the scheduled figures for that date will reveal over- or under-production but will not show the effect on the completion schedule. The amount of over-production of a milestone is called its criticality. Under-production gives a negative criticality. Relative criticality measures the effect on the completion schedule and is defined as the criticality divided by the multiplicity. It measures, quite simply, how many finished items short the completion schedule will be when the lead time has elapsed. Since, in the normal way, the lead time cannot be shortened, the completion schedule cannot be met unless emergency measures are taken to shorten the lead time.

We now have three kinds of data: firstly a list of milestones, each with its parameters, multiplicity and lead time: secondly a completion schedule: thirdly a list of the number of each milestone achieved. The first two kinds of data will be determined at the outset: the third will need continuous updating. From this data, a Line of Balance program will produce a chart or table comparing the schedule and achievements for each milestone and highlighting significant shortages or surfeits.

Once a milestone has been selected, its lead time and multiplicity are exactly defined. The only choice in describing production is the selection of milestones. These should be significant points in production: their number should also be considered. Too few gives an inadequate description of the state of production. Too many gives a vast volume of output from which the essential details are hard to select.

Line of Balance bears a superficial resemblance to PERT. In PERT there is usually one target event to be achieved, whereas L.o.B. has a list of dates on each of which a target must be achieved one or more times, i.e.

PERT is one-off but L.o.B. is associated with batches. Further, the basic data for PERT is a network in which the exact relationship of one event to another is given (Figure 3). In L.o.B., the basic data is a list of events each related to a target event but not, as far as the data is concerned, to each other (Figure 4).

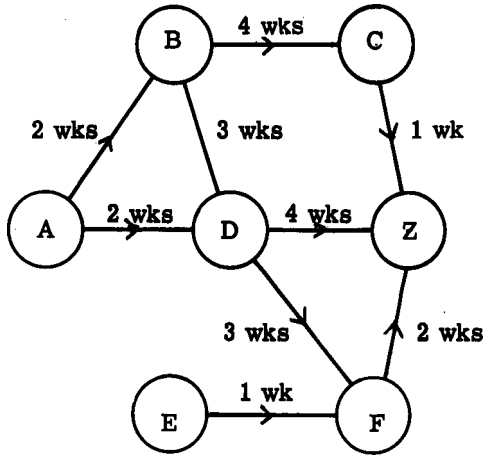


Figure 3 Event Relationship in a PERT Network

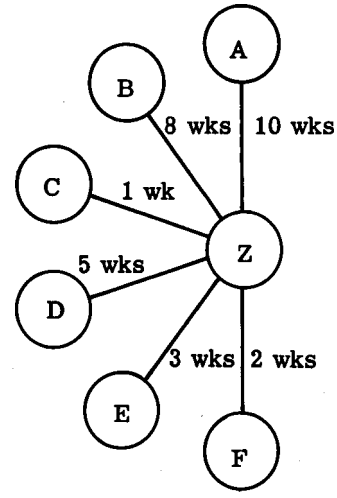


Figure 4 Event Relationship in a Line of Balance Network

In Figure 4, the time of 10 weeks for AZ is derived from AB + BD + DF + FZ = 2 + 3 + 3 + 2 = 10.

PERT handles a more detailed network but only considers one network at a time. L.o.B. handles a much simplified network but can duplicate it many times.

3 The Computer Program

The I.C.T. Line of Balance program is in eight sections. The first data input determines which sections are to be used and in what order. Once activated, the program runs to completion without any further operator action.

There are three types of run available: original, update and report. When a project is first analysed, information will be collected on the milestones. If the project is already in progress, there may also be information on the quantity of milestones achieved. The initial information is likely to remain constant throughout the project although facilities must be available to alter it. In order that this information does not have to be input on each run, it is held, together with quantities achieved, if any, on a master file on magnetic tape. The first run creates this file; subsequent runs update it.

This first run is called the original run; the subsequent runs are called update runs. An original run can contain progress information; likewise an update run can amend 'constant' information. More often it will be the other way round. On each of these runs, details of progress can be printed out on the line printer. The formats are given in Section 5.

The third type of run is for output alone and is called a report run. The master file remains unaltered but calculations are performed on its data, as in an original or update run, to give the required outputs.

On each run, the first card (data block) input is a parameter card (block). This determines the course of the run. On a report run, no further data are read in. The medium of input (card or paper tape) is determined by a switch which can be set before the program is activated,

In order to handle this multi-section type of program efficiently, it is held on a magnetic tape of its own which must be on-line to the computer all the time. For an update run, two further magnetic tape decks are required, one for the old master file, one for the new. An original or report run requires only one deck, for the master file. If two decks are available, it is possible to run the program as a succession of original or report runs.

Any one run will involve a considerable number of sorting operations. Sorts are performed internally to reduce the number of decks used and the time taken. This imposes a limitation on the volume of data that can be handled. Each milestone requires six computer words and the permanent part of the program requires 2600 words. The number of milestones that can be handled (N) is thus related to core store available (C) by

$$N = \frac{C-2600}{6}$$

Allowance must be made in calculating C for the I.C.T. Executive program. Thus, on an 8192 word machine, C is approximately 5800. Therefore

$$N = \frac{5800-2600}{6} = \frac{3200}{6} = 530$$

The maximum number of points acceptable on the completion schedule is 200 and the maximum number of report dates that may be input at any one time is 18. The report dates are used by the output program.

All dates and times are input and stored as numbers less than 10000. The units are undefined as is the zero 'date'. All calculations are performed on differences. Therefore the 'dates' of a completion schedule will be numbers in the same units as lead times, report dates and time now. Lead time will be unaffected by the choice of a zero date since it is a difference between two dates. Report dates, 'time now' and completion schedules will depend on the choice of a base date. Thus, if the minimum time interval is a week, some lead times might be 3 weeks, 5 weeks and 8 weeks. These would be input as 3, 5 and 8. If the report dates are 14th February 1966, 28th February 1966, 9th May 1966, 20th June 1966 and the 'zero date' is 3rd January 1966, these dates would be input as 6, 8, 18, 24; there being 6 weeks between 3rd January and 14th February, 24 weeks between 3rd January and 20th June. If the 'zero date' were a year earlier, 4th January 1965, the lead times would still be 3, 5 and 8. The report dates would

now be 58 (52+6), 60 (52+8), 70 (52+18) and 76 (52+24). A 'time now' of 11th April 1966 would be 10 in the first case, 62 in the second. There are no facilities for handling more than one level of time nor for handling interruptions in the time scale, such as holidays. All dates must be non-zero.

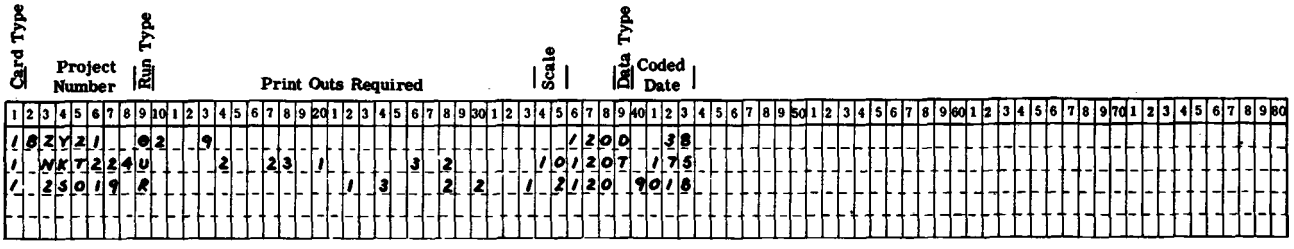
All I.C.T. programs are designated by a four character name: in the case of Line of Balance it is X5LB.

4 Input Formats

CARD INPUT 4.1

Parameter Card

One must be present on every run and must be the first card input. It determines the path of the run.



COLUMN 1 - CARD TYPE Used by the program to identify the card type. For this card, it is the number 1.

COLUMNS 2 TO 8 - PROJECT NUMBER A maximum of seven alphanumeric characters: this appears on every card and is checked against the Project Number given in the Parameter Card. The number appears on the printed outputs. The choice of number is up to the user.

COLUMN 9 - RUN TYPE

Θ for Original run.

U for Update run.

R for Report run.

COLUMNS 10 to 33 - PRINT REQUIREMENTS A maximum of nine copies of each of the 24 types of print-out is available. The three basic types are:

Project Report, Columns 10 to 17

Progress Report, Columns 18 to 25

Progress Chart, Columns 26 to 33.

Each basic type has eight variants and the quantity of each print-out required appears in one of the eight columns allotted to each type. The variants differ in the order in which the milestones appear. Sequence can be by

Milestone Numbers	Ascending Order	Columns 10, 18, 26.
Milestone Numbers	Descending Order	Columns 11, 19, 27.
Lead Time	Ascending Order	Columns 12, 20, 28.
Lead Time	Descending Order	Columns 13, 21, 29.
Absolute Criticality	Ascending Order	Columns 14, 22, 30.
Absolute Criticality	Descending Order	Columns 15, 23, 31.
Relative Criticality	Ascending Order	Columns 16, 24, 32.
Relative Criticality	Descending Order	Columns 17, 25, 33.

COLUMNS 34 and 35 - SCALE This determines the scale used in the progress chart prints. It can be 1, 2, 5 or 10 units per line printer column. If no charts are required, the field is left blank.

COLUMNS 36 to 38 - THE NUMBER 120

COLUMN 39 - PROGRESS INFORMATION TYPE This specifies the type of data on a milestone updating card.

T - all quantities are input as totals and therefore replace any numbers already on record.

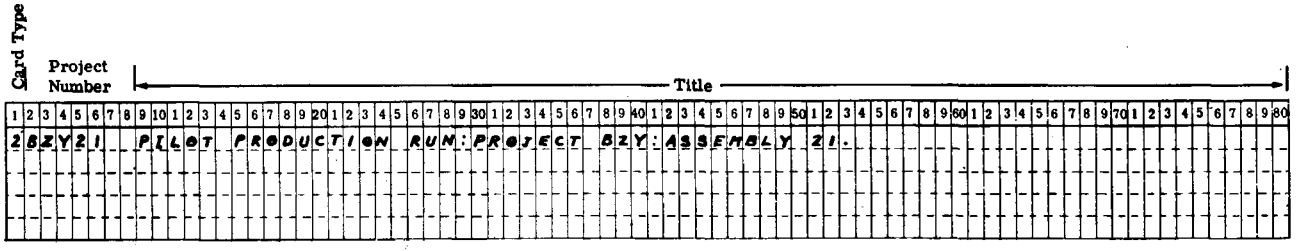
D - all quantities are input as differentials and are therefore added to existing numbers.

COLUMNS 40 to 43 - DATE The date is in the same format as all project dates; namely, an integer less than 9999, the time scale or units being undefined.

COLUMNS 44 to 80 Ignored.

Title Card

One must be present on an original run. The title is printed on all outputs.



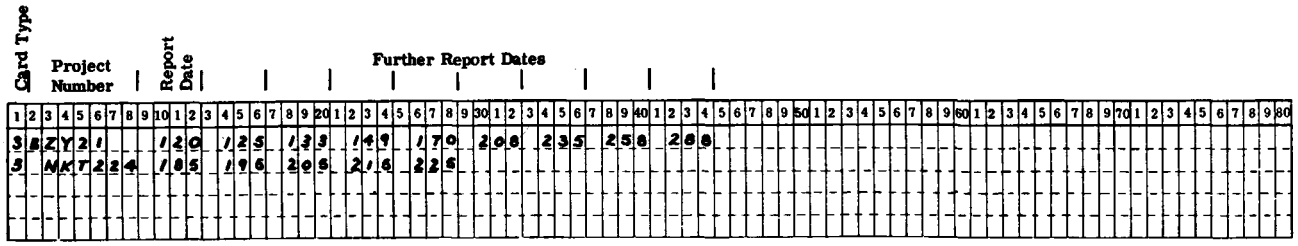
COLUMN 1 - CARD TYPE 2

COLUMNS 2 to 8 - PROJECT NUMBER As on parameter card.

COLUMNS 9 to 80 - TITLE A maximum of 72 characters

Report Dates Card

This card gives the dates for which targets are required in the Project Report Print. It is also used to give the next report date in the Progress Chart Print.



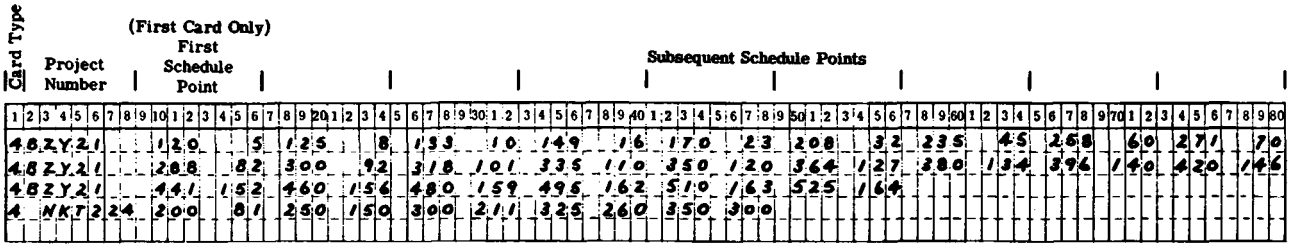
COLUMN 1 - CARD TYPE 3

COLUMNS 2 to 8 - PROJECT NUMBER As on parameter card.

COLUMNS 9 to 80 A maximum of 18 dates input, four columns per date, in ascending order.

Completion Schedule Card

This gives data on the completion schedule. A maximum of 200 points are allowed. For each, a date, in the usual four digit format, and a quantity are input. The quantities are cumulative. The dates must be in ascending order: hence so must the quantities. Up to 23 cards may be used to input up to 200 points. Columns 1 to 8 are the same for all type 4 cards.



COLUMN 1 - CARD TYPE 4

COLUMNS 2 to 8 - PROJECT NUMBER As on parameter card.

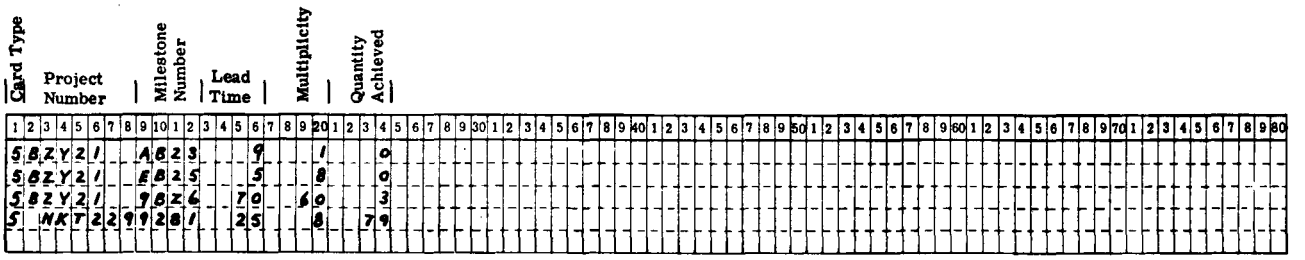
COLUMNS 9 to 16 - FIRST SCHEDULE POINT Columns 9 to 12 contain the date and 13 to 16 the corresponding quantities required.

COLUMNS 17 to 24, 25 to 32 etc. - SUBSEQUENT SCHEDULE POINTS

NOTE Since there are no sequence numbers on the type 4 cards, they must be in the correct order.

Milestone Data Card

This is the card giving the basic information about a milestone and such cards will constitute the bulk of the original run.



COLUMN 1 - CARD TYPE 5

COLUMNS 2 to 8 - PROJECT NUMBER As on Parameter card.

COLUMNS 9 to 12 - MILESTONE NUMBER Up to four alphanumeric characters.

COLUMNS 13 to 16 - LEAD TIME Number of time units between the completion of this particular part and the final stage.

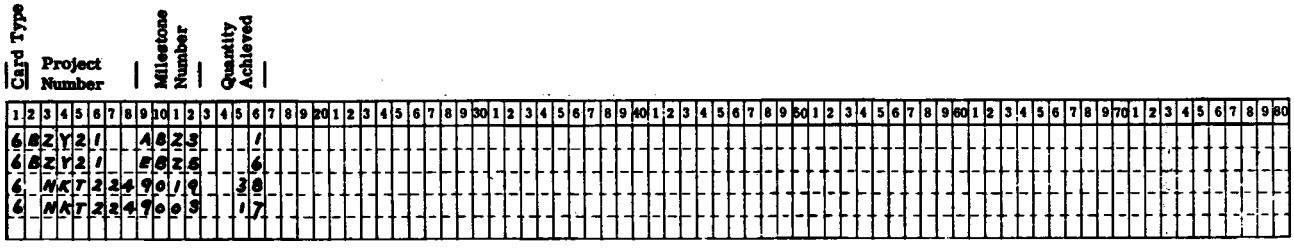
COLUMNS 17 to 20 - MULTIPLICITY Quantity of this particular milestone which is required to complete one of the final article.

COLUMNS 21 to 24 - QUANTITY ACHIEVED Quantity of this particular milestone completed to date. This will frequently be zero.

COLUMNS 25 to 80 Ignored.

Milestone Updating Card

Amends data already held on a master file. It can be accepted only on an updating run.



COLUMN 1 - CARD TYPE 6

COLUMNS 2 to 8 - PROJECT NUMBER As on Parameter Card.

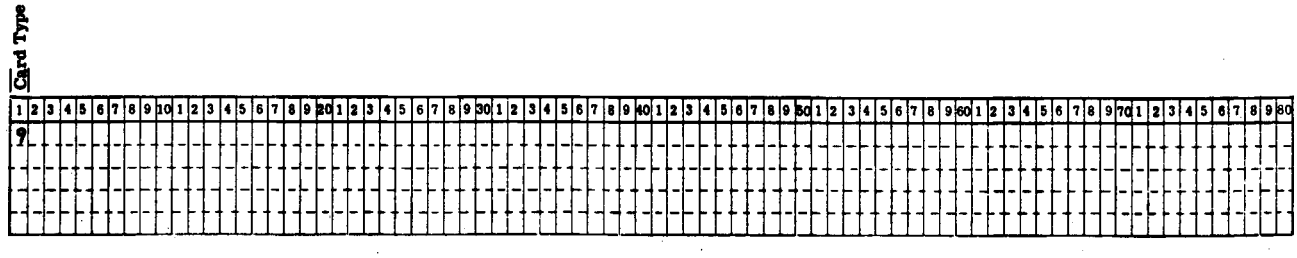
COLUMNS 9 to 12 - MILESTONE NUMBER Identifies the Milestone to be updated.

COLUMNS 13 to 16 - QUANTITY ACHIEVED Either the quantity achieved to date or the quantity achieved since the last report on the milestone (see Parameter Card Column 39). The quantity must be a positive integer.

COLUMNS 17 - 80 Ignored.

Last Card

This must be present to terminate the pack for an original or updating run. For a report run, only the Parameter Card will be read.



COLUMN 1 - CARD TYPE 9

COLUMNS 2 to 80 Ignored.

Each field must be followed by ↑, and the end of a block by a new-line character. Fields are variable unless otherwise stated. For a report run, only the Parameter Block is required. The blocks follow the same pattern as the cards.

Parameter Block

BLOCK TYPE - 1

Project Number a maximum of seven alphanumeric characters used for distinguishing one project's data from another. The project number in the Parameter Block is used for comparison with the Project Number in all subsequent blocks.

Type of Run Θ for original run.

U for update run.

R for report run.

Print Requirements the number of print-outs required is punched in a position dependent on the type required. There are eight character positions for each of the three basic types of print-out. This is one character position for each of the eight variants. In order, the three basic types are

Project Reports

Progress Reports

Progress Charts.

The eight variants, again in order, are given by the sequence in which the milestone numbers appear in the output. They are

Milestone Numbers	Ascending Order
Milestone Numbers	Descending Order
Lead time	Ascending Order
Lead time	Descending Order
Absolute Criticality	Ascending Order
Absolute Criticality	Descending Order
Relative Criticality	Ascending Order
Relative Criticality	Descending Order

This field is fixed length. All 24 character positions must be filled, either by a space or by a digit in the range 0 to 9.

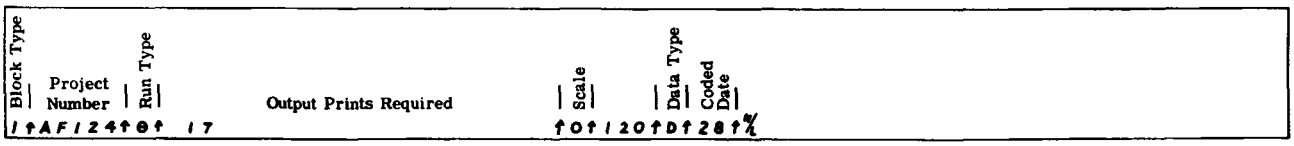
Scale the scale required in the Progress Charts. It is the quantity per Line Printer print position. It must be 0, 1, 2, 5 or 10. Zero covers the case when no such prints are required.

The Number 120

Progress Information Type when updating information is input it may be either the total new value or the difference between the last value and the present value. These are indicated by T or D respectively.

Date given in the standard four digit format.

A typical type 1 block for an original run is:



and for an updating run, on the same project:

```
Block Type | Project Number | Run Type | Output Prints Required | Scale | Data Type | Coded Date |
1↑AF124↑U↑ 37 672 1↑10↑20↑T↑35↑%
```

Note that all fields are terminated by ↑ .

Title Block

BLOCK TYPE - 2

Project Number as in parameter block

Title a maximum of 72 characters. It is output on all documentation produced. A typical type 2 block is:

```
Block Type | Project Number | Title |
2↑↑AB7↑AUTOMATION X ↑%
```

Report Date Block

BLOCK TYPE - 3

Report Date a maximum of 18 fields, each containing one date in the usual format. These dates are used by the output program in producing Project Reports and Progress Charts. A typical type 3 block is:

```
Block Type | Report Date | Further Report Dates |
3↑17↑18↑23↑30↑40↑60↑85↑100↑110↑%
```

Completion Schedule Block

BLOCK TYPE - 4

First Schedule Point a date in the usual format of up to four digits, separated by a comma from the quantity to be completed at that date. The quantity has a maximum value of 9999.

Subsequent Schedule Points set out as above. Each schedule point constitutes a field. A maximum of 12 dates can be input per block and a maximum of 16 blocks of type 4. The dates must be in ascending order and the quantities must be cumulative. Hence, the quantities must also be in ascending order. A typical type 4 block is:

```
Block Type | First Schedule Point | Subsequent Schedule Points |
4↑18,↑↑21,3↑26,6↑30,7↑33,9↑38,12↑45,15↑50,19↑55,23↑60,28↑65,31↑70,33↑%
4↑75,40↑%
```

Milestone Data Block

Data on a milestone constitute a field: the quantities are separated by commas.

BLOCK TYPE - 5
Milestone Data

Milestone Number up to four alphanumeric characters.

Lead Time the number of time units between the completion of this particular part and the final stage.

Multiplicity the quantity of this milestone required to achieve one final stage: a maximum of four characters.

Quantity Achieved the number achieved of this milestone at the date given in the parameter block. Up to six milestones may appear in one block. A typical type 5 block is:

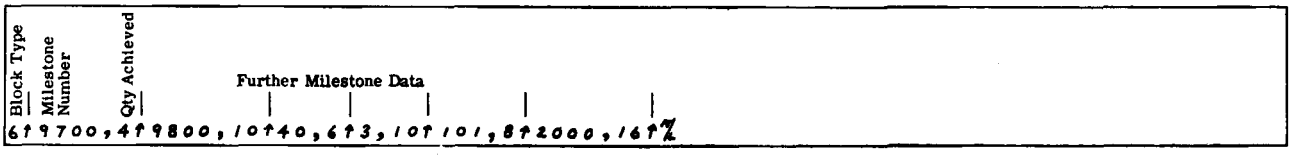
Updating Master Block

Date on a milestone constitutes a field: the quantities are separated by commas.

BLOCK TYPE - 6
Milestone Data

Milestone Number maximum of four alphanumeric characters.

Quantity Achieved either the total achieved or the quantity achieved since the last report was made on this milestone. The third field of the Parameter Block determines which is to be used. Up to twelve milestones may be updated in one block. A typical type 6 block is:



Last Block

*** four asterisks.

5 Output Formats

There are three basic types of output available.

Project Reports

Progress Reports

Progress Charts.

Each of these outputs gives data corresponding to milestones. It is possible to arrange the output data into eight different sequences. This is performed by a sort routine which is entered before a print is performed. All prints in one sequence are produced consecutively to minimise sorting. The sort key is taken from the milestone record so that the sequences that can be obtained are:

Milestone Number

Lead Time

Absolute Criticality

Relative Criticality

Each can be given in either ascending or descending order. There are therefore 24 types of print-out available and the number of each required, up to a maximum of nine, is specified in the Parameter Card (or Block).

PROJECT REPORT **(see Figure 7, page 22)**

In this report, the project name and number are printed on the top line, together with the report title. On the next line are printed the system title, (Line of Balance), and the date of the computer run. Below the run date is the coded date; in this example it is 43. This coded date represents the run date. The user must have some numerical calendar whereby he can express points in time on his schedule. These may be weeks, months, days, shifts etc. The coded date shown here represents the run date in terms of the user's calendar.

In the main body of the print-out, project targets for the future are listed. The quantities of milestones that will have to be produced by given coded dates are listed vertically against their appropriate milestone numbers. The coded dates at the heads of the project target columns are the report dates. These are points on the production schedule chosen by the user.

In the column to the right of the milestone numbers, the number achieved, at the date of this computer run, is listed. In this case, all the values for 'numbers achieved' are zero since the run date is 43 and none of the milestones listed are required until coded date 46.

At the bottom of the print-out, the sequence in which it has been printed is stated. Here it is 'ascending milestone number'. In the bottom right-hand corner, the page number is printed.

Since the data can overflow a page both horizontally and vertically, a two-digit number is given in the bottom right hand corner of each page. The first digit gives the order of pages vertically and the second digit, the horizontal order. If six pages are produced, they will be printed in the order

1/1, 2/1, 3/1, 1/2, 2/2, 3/2.

To assemble these into a single chart, they are arranged:

1/1	1/2
2/1	2/2
3/1	3/2

The headings are repeated on each page, as are the quantities achieved. The latter are in a single column on the left hand side. Since only 18 report dates are permitted, overflow horizontally will only cover two sheets.

PROGRESS REPORT (see Figure 12, page 25)

The main headings for the Progress Report print-out are the same as those described for the project report, with the exception of the report title.

Basically, this print-out shows the progress of a given milestone by allowing comparison of the number achieved with the current target - the number that should have been achieved. This comparison is heightened by figures for absolute and relative criticality. The former is purely a measure of over-production of a milestone, while the latter is a measure of the over-production of that milestone in terms of the final stage. It should be noted here that under-production is highlighted in the print-out by means of the minus signs; under-production being shown as negative over-production.

Again, in the left hand column, there is a list of milestone numbers for the project. Against these are shown the quantity of each milestone required for each final stage and the lead time of that milestone.

In the next two columns, the quantities achieved at the date of the computer run and the target quantities at that date are printed; providing a report on the progress of each milestone listed. This, as explained above, is converted to direct reading of under- or over-production in the next two columns headed: 'Absolute and Relative Criticality'.. The former from the point of view of milestones, the latter from the point of view of the final stage.

The sequence in which the milestones are printed is again shown in the bottom left hand corner, and the page number on the right. The sequence, in this example, is ascending relative criticality.

PROGRESS CHART (see Figure 17, page 27)

This print-out provides progress information in an easily assimilable bar-chart form. With the exception of the report title, the main headings for this print-out are the same as for the other two. An additional date is included under the coded date. This, also in coded form, shows the next date for which targets have been calculated. That is, the next report date.

Milestone numbers are listed in the left hand column and target quantities provide the horizontal scale (in this example 0 to 200). Targets and achievements are represented by the horizontal bars; targets are represented by the Is, and achievements by the Xs. These symbols form bars showing the respective quantities at the date of the computer run. Target quantities for the next report date are shown by extensions of the Is bars with 'equals' signs, terminating in a single I.

Under-production is highlighted by rows of 'minus' signs that extend the achievements bars to the run date target quantities.

Since the scale may be 1, 2, 5 or 10, each 'X' 'I' '-' or '=' may take the 'value' 1, 2, 5 or 10. These are quantities of the milestone and take no account of the multiplicity. If the bar exceeds 100 positions, it is terminated by a '+' to indicate overflow. Overflow onto another sheet is not printed, only indicated as above. Reference must be made to a progress report to obtain the values for the milestone that has overflowed.

This output, with a suitable sequence, can give the true 'Line of Balance'. This is in fact two histograms superimposed: one gives quantities achieved and the other, target quantities. The correct sequence is one in which the order is increasing lead time and increasing multiplicity. In this case, the histograms will approximate to a line with negative gradient. In subsequent runs the line will rise vertically. This is a special case and is not always the most easy to interpret. With other sequences or with a different selection of milestones, the line will not be achieved. Then, the horizontal lines of the histogram will hinder, not help. For this reason, they are omitted, and the type of print-out described above is used.

6 Operating Instructions: Error Conditions

For an original run, the data will be, in order,

Parameter Card (Block)
Title Card (Block)
(Optional) Report Dates
Completion Schedule
Milestone Records
Last Card (Block)

All other types of data will be rejected.

For an update run, the data will be, in order,

Parameter Card (Block)
(Optional) Title Card (Block)
(Optional) Report Dates
(Optional) Completion Schedules
(Optional) New Milestone Records
(Optional) Updating Milestone Record
Last Card (Block)

For a report run, the data will consist of one card or block, the parameter data.

OPERATOR INSTRUCTIONS

1 Load Program Tape without write permit ring.
2 Load Master File without write permit ring (Update and Report)
3 Load Scratch tape for new Master File with write permit ring (Update and Original)
4 Load data pack or tape.
5 FI #X5LB HALTED: LD
6 ~~O~~N #X5LB0 (Card input only)
7 G~~O~~ #X5LB HALTED: END~~O~~F X5LB

ERROR MESSAGES

Message	*Meaning*	*Action*
HALTED:LP	Needs Line Printer	Allocate one as 0 and GO#X5LB
HALTED:CR	Needs Card Reader	Allocate one as 0 and GO#X5LB
HALTED:TR	Needs Tape Reader	Allocate one as 0 and GO#X5LB
HALTED:EA	Columns 36 to 38 on Parameter Card or 6th Field on Tape not 120	Abandon run
HALTED:EB	Column 9 on Parameter Card or 3rd field on Tape not O, U or R	Abandon run
HALTED:EC	7th field on Tape not T or D	Abandon run
HALTED:ED	Non-numeric punching in numeric field in Parameter data	Abandon run
HALTED:PC	No title card or completion schedules on original run	Abandon run
HALTED:NN	Non-numeric punching in numeric field	See Special instructions
HALTED:OB	Paper tape block size exceeded	See Special instructions
HALTED:OE	No completion schedules on original run	Abandon run
HALTED:SA	No milestone records	Abandon run
HALTED:INSUFFICIENT STORE	Too many milestones	Abandon run
HALTED:CB	No scale given; hence no Progress Charts	GO#X5LB
HALTED:UA	Master file format is wrong	Abandon run
HALTED:UB	Completion schedules are not in ascending order	Abandon run
DISPLAY:ODD TYPE	Card type not acceptable for this run-type	Ignore
DISPLAY:NO REPORT DATES	Unable to give Project Reports or Progress Charts	Ignore

The action to be taken after HALTED:NN and HALTED:OB will depend on the circumstances. If the run is continued, some data will be lost. The only indication of which block or card is in error is how much data has been read. It is essential to mark the last data input in some way. Since double buffering is being used, it will be the previous card or block which is in error.

HALTED UA and HALTED UB imply system failure of some sort on the previous or present run since the master file, as read, is incorrect in layout.

Appendix

The project chosen as an example is the production of desks. Only fourteen milestones have been selected in order to keep the outputs small. Figure 5 is the family tree of production. At the top is the finished article. Each level down the page represents a stage in its breakdown. In this plan, a milestone represents the completion of the part it references. Thus ⊖B32 is the completion of the main frame. Ten desks at point ⊖B32 implies at least ten at ⊖C32, at least forty at ⊖C08, at least eighty at ⊖D22 and so on. The bracketed figure beside each milestone is its lead time. The data is set out in Table 2.

The first computer run created the master file. Figure 6 is a list of cards. Sample outputs are given in Figures 7 and 8. The only difference between the last two is in sequence. Certain features are common to all outputs. The project number, taken from columns 2 to 8 on the cards, appears in the top left hand corner. The title, from card type 2, appears across the top. The actual date of the run and the coded date appear in the top right hand corner. The last line of each page contains the sequence and the page number. The first digit of the number is its vertical position; the second, its horizontal. Figure 9 gives the paper tape layout for the same input data.

The second computer run updated the master file with progress information. The list of cards is given in Figure 10. Figure 11 is in the same format and sequence as Figure 7. The only differences are in the column *Number Achieved* and in the coded date. Figure 12 is a progress report from the same run. The *Number per Item* is another term for the multiplicity. The sequence of milestones which have a criticality of zero is indeterminate.

The third computer run was a report run. The purpose of this was to show a two-time-period pause in operations. Figure 13 is a progress report in the same sequence as Figure 12. It shows how rapidly the situation can change. Figure 14 shows the sole input card in this run.

The fourth run was a further updating run. Figure 15 is a list of the input cards. Note that the report dates have been changed: also the quantities were input as Totals. Were there to be no increment in the quantity achieved for a milestone, there would still be no need to input a type 6 card for that milestone. Figure 16 gives the targets for the revised report dates. Figure 17 introduces a new type of output, the progress chart. Each milestone has two horizontal lines. In the upper one, the quantity achieved is shown by a row of 'X's The target is shown in the lower line by 'I's. The '='s represent the difference between the target now (date 59) and at the next report date (date 65). The latter is printed in the top right hand corner. The '-'s represent under-production; '+' denotes overflow. The progress report, Figure 18 can supply the details for milestones which have 'overflowed'.

The final computer run was another updating run. Figure 19 gives the cards. The report dates have again been changed. The quantities are input as differentials. Table 2 gives the cumulative quantities. Figure 20 gives the targets. Notice how the quantities level off when end date minus lead time 91 for ODA9 for example, is achieved. Figure 21 gives the Progress Chart. The scale is now ten units per print position. Only two milestones have overflowed. In the horizontal scale, the 'V's point to the exact columns to which the numbers above them refer. Figure 22 is the corresponding Progress Report.

Table 3 lists the prints given with their Figure numbers.

Mile-stone	Lead Time	Multi-plicity	Qty Run 1	Qty Run 2	Qty Run 3	Qty Run 4	Qty Run 5	Description
⊖A32	0	1	0	0	0	10	93	Completed Table
⊖B16	1	6	0	0	0	400	700	Drawer
⊖B32	1	1	0	0	0	13	95	Mainframe
⊖B41	1	2	0	0	0	33	243	Slat
⊖C08	7	4	0	30	0	99	629	Side
⊖C21	4	6	0	0	0	451	763	Front (of Drawer)
⊖C24	7	6	0	50	0	168	655	Drawer Support
⊖C27	4	6	0	0	0	490	701	Back (of Drawer)
⊖C32	7	1	0	0	0	40	100	Top (of Desk)
⊖C40	4	6	0	0	0	601	1001	Bottom (of Drawer)
⊖C90	7	2	0	3	0	45	226	Back (of Desk)
⊖CA6	4	12	0	0	0	800	1700	Side (of Drawer)
⊖D22	9	8	0	80	0	250	1352	Leg
⊖DA9	9	4	0	31	0	100	651	Side Panel
Date			43	48	50	59	88	

Table 2 Data List

Output Type →	Progress Chart				Progress Report				Project Report				Coded Date	Run Type	
Run 1									6				43	⊖	Ascending
										7					Descending
Run 2								11	10				48	U	Ascending
															Descending
Run 3								12					50	R	Ascending
															Descending
Run 4									15				59	U	Ascending
			16				17								Descending
Run 5									19				88	U	Ascending
		20				21									Descending
	Milestone	Lead Time	Absolute Criticality	Relative Criticality	Milestone	Lead Time	Absolute Criticality	Relative Criticality	Milestone	Lead Time	Absolute Criticality	Relative Criticality			↑ Sequence

Table 3 Figure Numbers of Specimen Outputs in Appendix

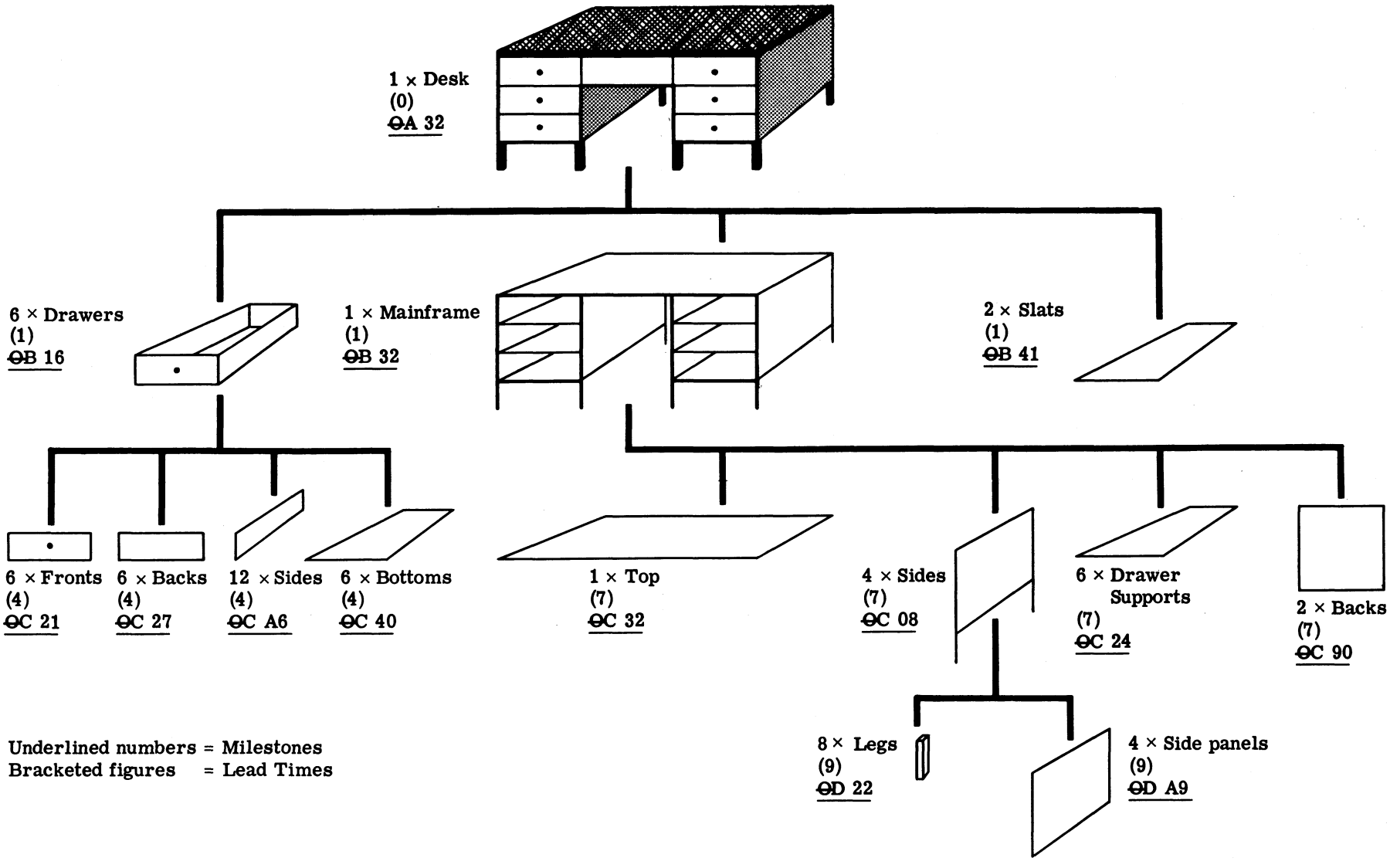


Figure 5 Production Family Tree

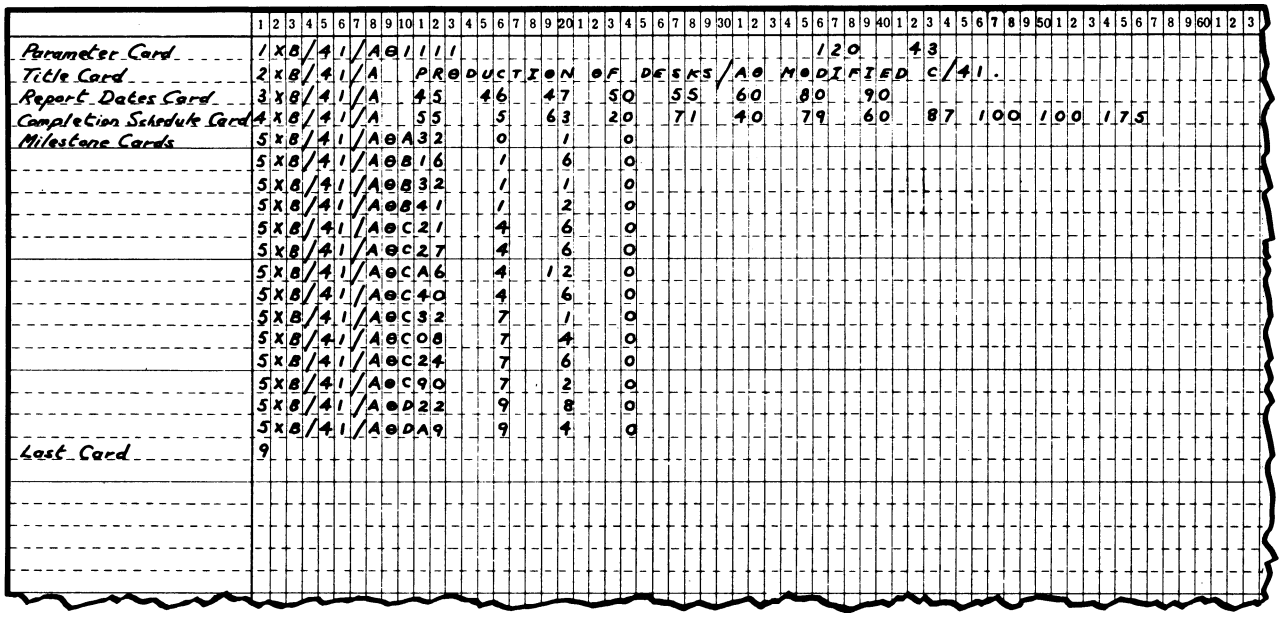


Figure 6 Cards for Original Run

PROJECT NO. XB/41/A

PRODUCTION OF DESKS/AO MODIFIED C/41.

PROJECT REPORT

DATE 07/07/56

CODED DATE 43

LINE OF BALANCE

PROJECT TARGETS

MILESTONE NUMBER	NUMBER ACHIEVED	45	46	47	50	55	60	80	90
0A32	0	0	0	0	0	5	14	65	117
0B16	0	0	0	0	0	42	96	420	738
0B32	0	0	0	0	0	7	16	70	123
0B41	0	0	0	0	0	14	32	140	246
0C08	0	0	0	0	36	72	120	400	632
0C21	0	0	0	0	0	72	132	510	840
0C24	0	0	0	0	54	108	180	600	948
0C27	0	0	0	0	0	72	132	510	840
0C32	0	0	0	0	9	18	30	100	158
0C40	0	0	0	0	0	72	132	510	840
0C90	0	0	0	0	18	36	60	200	316
0CA6	0	0	0	0	0	144	264	1020	1680
0D22	0	0	40	56	96	176	280	896	1352
0DA9	0	0	20	28	48	88	140	448	676

SEQUENCED BY ASC. MILESTONE NUMBER

PAGE 1/1

Figure 7 Project Report (Run 1) sequenced by ascending milestone number

PROJECT NO. XB/41/A PRODUCTION OF DESKS/AO MODIFIED C/41. PROJECT REPORT

LINE OF BALANCE DATE 07/07/66

CODED DATE 43

PROJECT TARGETS

MILESTONE NUMBER	NUMBER ACHIEVED	45	46	47	50	55	60	80	90
0D22	0	0	40	56	96	176	280	896	1352
0DA9	0	0	20	28	48	88	140	448	676
0C08	0	0	0	0	36	72	120	400	632
0C24	0	0	0	0	54	108	180	600	948
0C90	0	0	0	0	18	36	60	200	316
0C32	0	0	0	0	9	18	30	100	158
0C27	0	0	0	0	0	72	132	510	840
0C21	0	0	0	0	0	72	132	510	840
0C40	0	0	0	0	0	72	132	510	840
0CA6	0	0	0	0	0	144	264	1020	1680
0B16	0	0	0	0	0	42	96	420	738
0B32	0	0	0	0	0	7	16	70	123
0B41	0	0	0	0	0	14	32	140	246
0A32	0	0	0	0	0	5	14	65	117

SEQUENCED BY DSC. LEAD TIME PAGE 1/1

Figure 8 Project Report (Run 1) sequenced by descending lead time

```
1↑XB/41/A↑0↑1111                    ↑0↑120↑T↑43↑
2↑XB/41/A↑PRODUCTION OF DESKS /AO MODIFIED C/41.↑
3↑45↑46↑47↑50↑55↑60↑80↑90↑
4↑55,5↑63,20↑71,40↑79,60↑87,100↑100,175↑
5↑0B32,1,1,0↑0B41,1,2,0↑0C21,4,6,0↑0C27,4,6,0↑0CA6,4,12,0↑
5↑0C40,4,6,0↑0C32,7,1,0↑0C08,7,4,0↑0C24,7,6,0↑0C90,7,2,0↑
5↑0D22,9,8,0↑0DA9,9,4,0↑
5↑0A32,0,1,0↑0B16,1,6,0↑
****
```

Figure 9 Paper Tape Input for Original Run

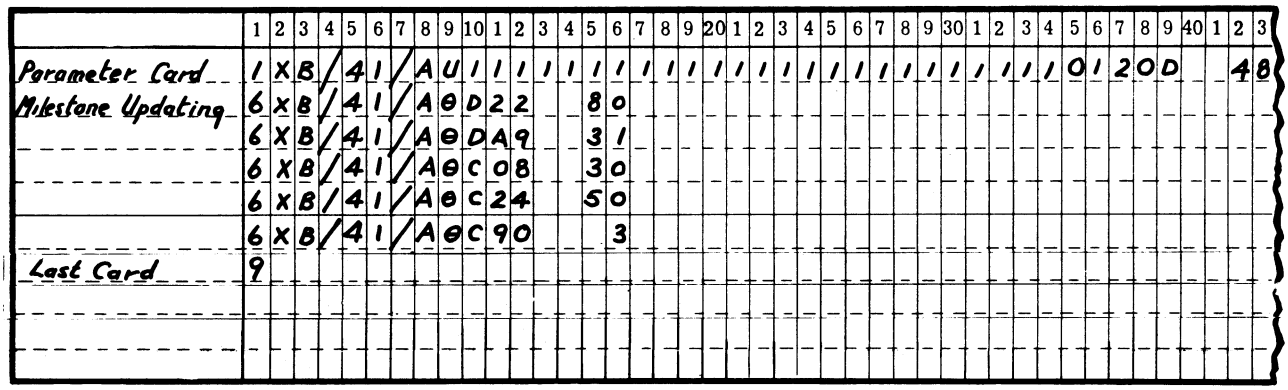


Figure 10 Cards for First Update

PROJECT NO. XB/41/A — PRODUCTION OF DESKS/AO MODIFIED C/41. — PROJECT REPORT

LINE OF BALANCE — DATE 21/07/66

CODED DATE 48

PROJECT TARGETS

MILESTONE NUMBER	NUMBER ACHIEVED	45	46	47	50	55	60	80	90
0A32	0	0	0	0	0	5	14	65	117
0B16	0	0	0	0	0	42	96	420	738
0B32	0	0	0	0	0	7	16	70	123
0B41	0	0	0	0	0	14	32	140	246
0C08	30	0	0	0	36	72	120	400	632
0C21	0	0	0	0	0	72	132	510	840
0C24	50	0	0	0	54	108	180	600	948
0C27	0	0	0	0	0	72	132	510	840
0C32	0	0	0	0	9	18	30	100	158
0C40	0	0	0	0	0	72	132	510	840
0C90	3	0	0	0	18	36	60	200	316
0CA6	0	0	0	0	0	144	264	1020	1680
0D22	80	0	40	56	96	176	280	896	1352
0DA9	31	0	20	28	48	88	140	448	676

SEQUENCED BY ASC. MILESTONE NUMBER — PAGE 1/1

Figure 11 Project Report (Run 2) sequenced by ascending milestone number

PROJECT NO. XB/41/A

PRODUCTION OF DESKS/AO MODIFIED C/41.

LINE OF BALANCE

PROGRESS REPORT

DATE 26/07/66

CODED DATE 48

MILESTONE NUMBER	NUMBER PER ITEM	LEAD TIME	NUMBER ACHIEVED	TARGET	CRITICALITY ABSOLUTE	CRITICALITY RELATIVE
0C32	1	7	0	5	-5	-5
0C90	2	7	3	10	-7	-4
0DA9	4	9	31	36	-5	-1
0B16	6	1	0	0	0	0
0C40	6	4	0	0	0	0
0B41	2	1	0	0	0	0
0C21	6	4	0	0	0	0
0CA6	12	4	0	0	0	0
0A32	1	0	0	0	0	0
0C27	6	4	0	0	0	0
0B32	1	1	0	0	0	0
0D22	8	9	80	72	8	1
0C24	6	7	50	30	20	3
0C08	4	7	30	20	10	3

SEQUENCED BY ASC.REL. CRITICALITY

PAGE:

Figure 12 Progress Report (Run 2) sequenced by ascending relative criticality

PROJECT NO. XB/41/A

PRODUCTION OF DESKS/AO MODIFIED C/41.

LINE OF BALANCE

PROGRESS REPORT

DATE 26/07/66

CODED DATE 50

MILESTONE NUMBER	NUMBER PER ITEM	LEAD TIME	NUMBER ACHIEVED	TARGET	CRITICALITY ABSOLUTE	CRITICALITY RELATIVE
0C32	1	7	0	9	-9	-9
0C90	2	7	3	18	-15	-8
0DA9	4	9	31	52	-21	-5
0D22	8	9	80	104	-24	-3
0C08	4	7	30	36	-6	-2
0C24	6	7	50	54	-4	-1
0C27	6	4	0	0	0	0
0C40	6	4	0	0	0	0
0B41	2	1	0	0	0	0
0B32	1	1	0	0	0	0
0B16	6	1	0	0	0	0
0CA6	12	4	0	0	0	0
0A32	1	0	0	0	0	0
0C21	6	4	0	0	0	0

SEQUENCED BY ASC.REL. CRITICALITY

PAGE:

Figure 13 Progress Report (Run 3) sequenced by ascending relative criticality

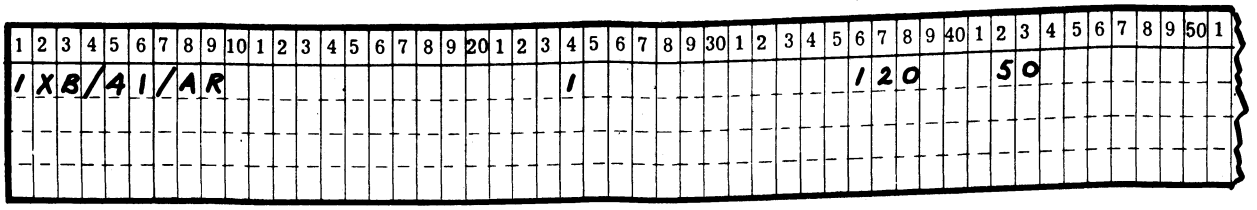


Figure 14 Input Card for Report Run

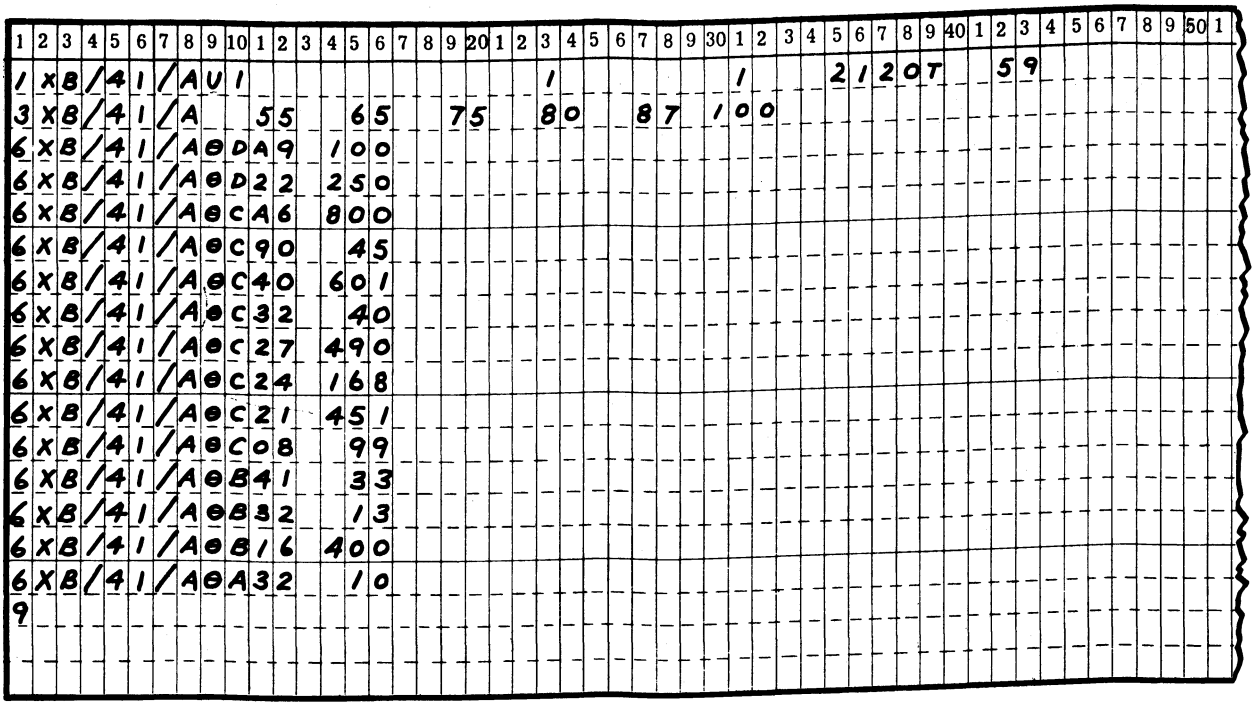


Figure 15 Input Card for Second Update

PROJECT NO. XB/41/A PRODUCTION OF DESKS/AO MODIFIED C/41. PROJECT REPORT

LINE OF BALANCE DATE 26/07/66

PROJECT TARGETS CODED DATE 59

MILESTONE NUMBER	NUMBER ACHIEVED	55	65	75	80	87	100
0A32	10	5	25	50	65	100	175
0B16	400	42	162	312	420	636	1050
0B32	13	7	27	52	70	106	175
0B41	33	14	54	104	140	212	350
0C08	99	72	168	300	400	560	700
0C21	451	72	210	360	510	738	1050
0C24	168	108	252	450	600	840	1050
0C27	490	72	210	360	510	738	1050
0C32	40	18	42	75	100	140	175
0C40	601	72	210	360	510	738	1050
0C90	45	36	84	150	200	280	350
0CA6	800	144	420	720	1020	1476	2100
0D22	250	176	376	680	896	1216	1400
0DA9	100	88	188	340	448	608	700

SEQUENCED BY ASC. MILESTONE NUMBER

PAGE 1/1

Figure 16 Project Report (Run 4) sequenced by ascending milestone number

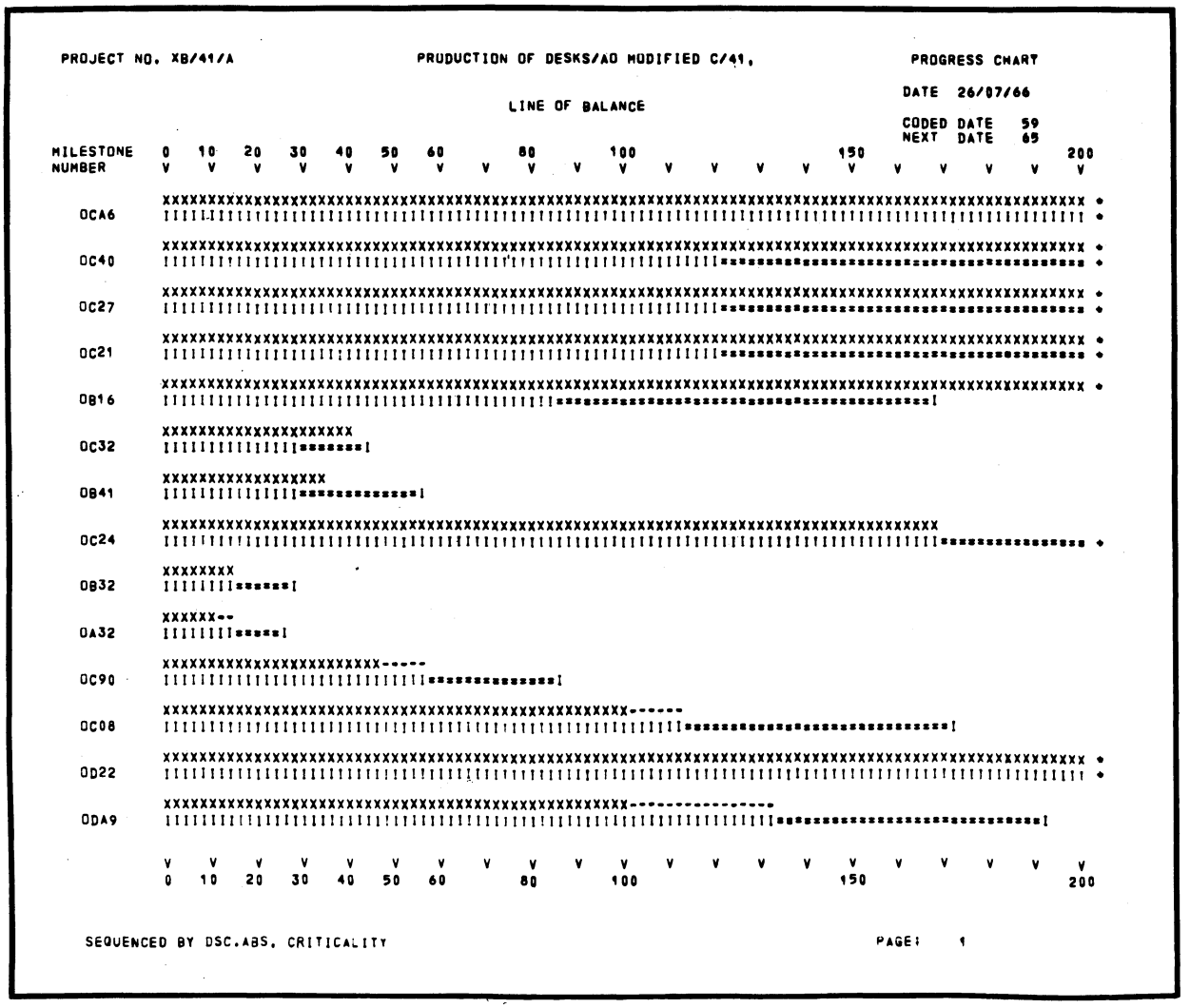


Figure 17 Progress Chart (Run 4) sequenced by descending absolute criticality

PROJECT NO. XB/41/A — PRODUCTION OF DESKS/AD MODIFIED C/41. — PROGRESS REPORT

LINE OF BALANCE — DATE 26/07/66 — CODED DATE 59

MILESTONE NUMBER	NUMBER PER ITEM	LEAD TIME	NUMBER ACHIEVED	TARGET	CRITICALITY ABSOLUTE	CRITICALITY RELATIVE
0CA6	12	4	800	240	560	47
0C40	6	4	601	120	481	80
0C27	6	4	490	120	370	62
0C21	6	4	451	120	331	55
0B16	6	1	400	84	316	53
0C32	1	7	40	28	12	12
0B41	2	1	33	28	5	3
0C24	6	7	168	168	0	0
0B32	1	1	13	14	-1	-1
0A32	1	0	10	13	-3	-3
0C90	2	7	45	56	-11	-6
0C08	4	7	99	112	-13	-3
0D22	8	9	250	264	-14	-2
0DA9	4	9	100	132	-32	-8

SEQUENCED BY DSC.ABS. CRITICALITY — PAGE: 1

Figure 18 Progress Report (Run 4) sequenced by descending absolute criticality

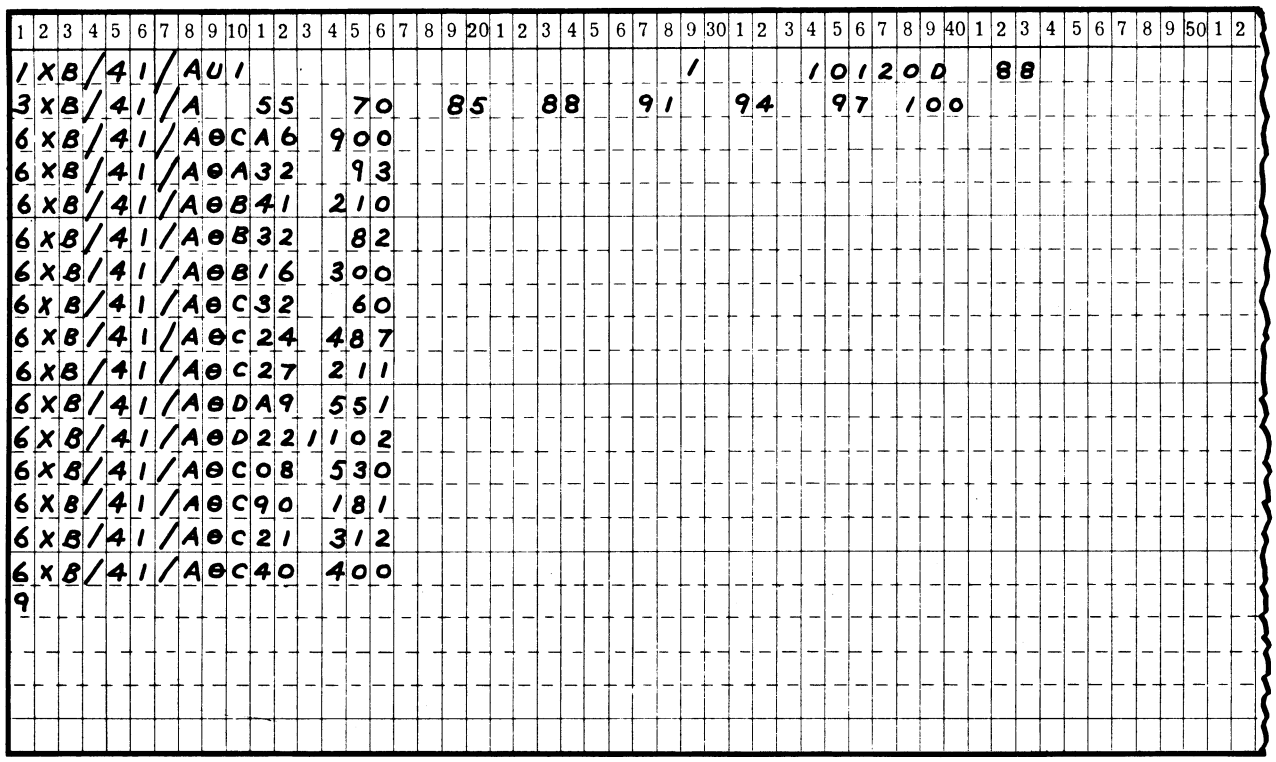


Figure 19 Input Cards for Third Update

PROJECT NO. XB/41/A PRODUCTION OF DESKS/AD MODIFIED C/41. PROJECT REPORT

LINE OF BALANCE DATE 26/07/66

CODED DATE 88.

PROJECT TARGETS

MILESTONE NUMBER	NUMBER ACHIEVED	55	70	85	88	91	94	97	100
0A32	103	5	37	90	106	123	140	158	175
0B16	700	42	240	570	672	774	876	978	1050
0B32	95	7	40	95	112	129	146	163	175
0B41	243	14	80	190	224	258	292	326	350
0C08	629	72	220	516	584	652	700	700	700
0C21	763	72	282	672	774	876	978	1050	1050
0C24	655	108	330	774	876	978	1050	1050	1050
0C27	701	72	282	672	774	876	978	1050	1050
0C32	100	18	55	129	146	163	175	175	175
0C40	1001	72	282	672	774	876	978	1050	1050
0C90	226	36	110	258	292	326	350	350	350
0CA6	1700	144	564	1344	1548	1752	1956	2100	2100
0D22	1352	176	480	1120	1264	1400	1400	1400	1400
0DA9	651	88	240	560	632	700	700	700	700

SEQUENCED BY ASC. MILESTONE NUMBER PAGE 1/1

Figure 20 Project Report (Run 5) sequenced by ascending milestone number

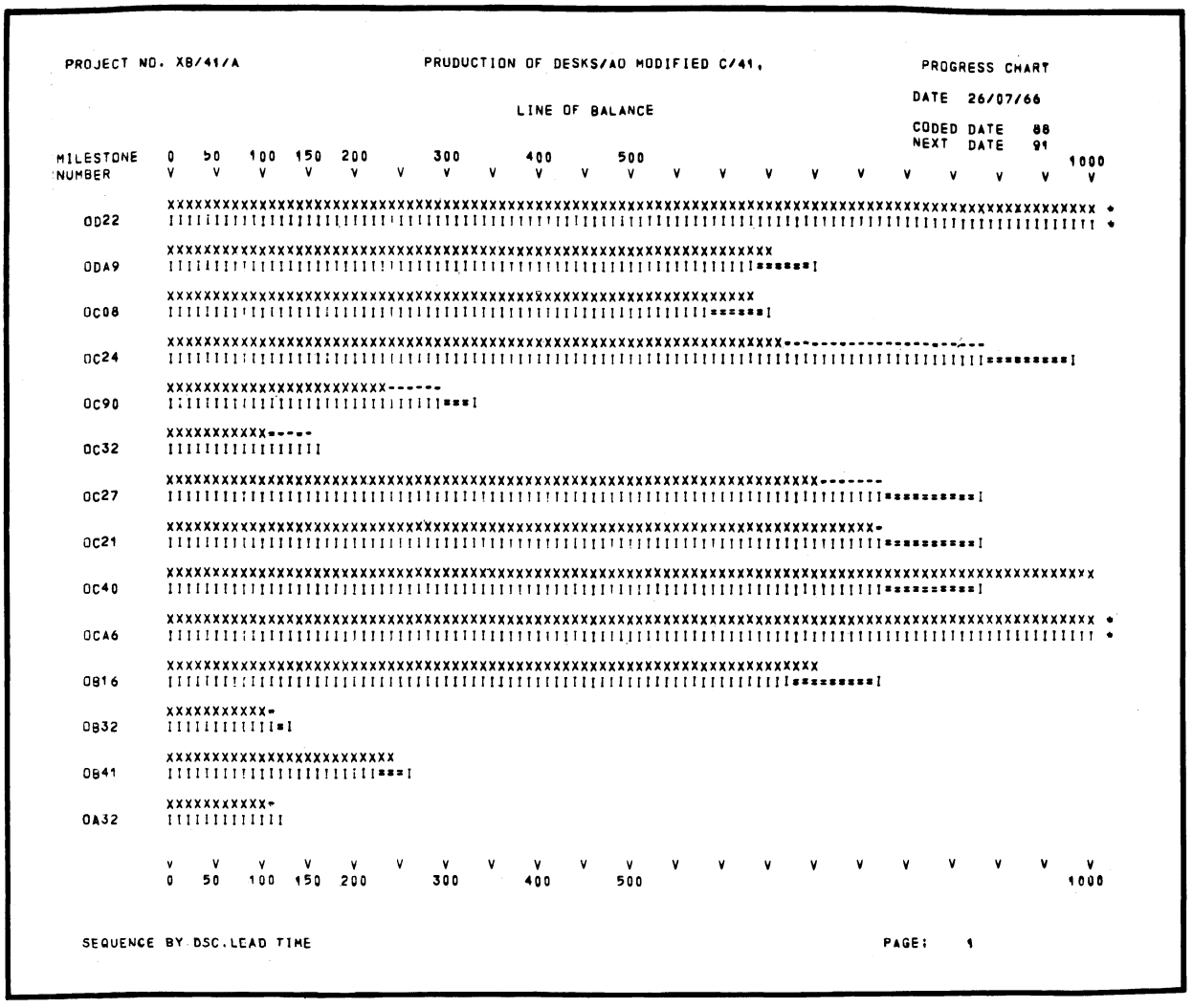


Figure 21 Progress Chart (Run 5) sequenced by descending lead time

PROJECT NO. XB/41/A

PRODUCTION OF DESKS/AO MODIFIED C/41.

PROGRESS REPORT

LINE OF BALANCE

DATE 27/07/66

CODED DATE 88

MILESTONE NUMBER	NUMBER PER ITEM	LEAD TIME	NUMBER ACHIEVED	TARGET	CRITICALITY ABSOLUTE	CRITICALITY RELATIVE
0D22	8	9	1352	1264	88	11
0DA9	4	9	651	632	19	5
0C08	4	7	629	584	45	11
0C24	6	7	655	876	-221	-37
0C90	2	7	226	292	-66	-33
0C32	1	7	100	146	-46	-46
0C27	6	4	701	774	-73	-12
0C21	6	4	763	774	-11	-2
0C40	6	4	1001	774	227	38
0CA6	12	4	1700	1548	152	13
0B16	6	1	700	672	28	5
0B32	1	1	95	112	-17	-17
0B41	2	1	243	224	19	10
0A32	1	0	93	106	-13	-13

SEQUENCED BY DSC.LEAD TIME

PAGE: 1

Figure 22 Progress Report (Run 5) sequenced by descending lead time

Glossary

ABSOLUTE CRITICALITY:
the quantity of any part produced minus the quantity required to meet delivery requirements. It is a measure of over-production.

BLOCK:
one or more fields on paper tape, terminated by an end of block marker such as a new-line symbol. Usually there is some logical connection between the fields: usually each field is terminated by a 'field terminator', such as ↑.

COMPLETION SCHEDULE:
the targets that the production department is trying to achieve.

CRITICALITY:
see Absolute Criticality.

FIELD:
one or more items of information which are closely related. When information is input on paper tape, the paper tape reader usually reads a block at a time. For ease of internal processing, it is usually subdivided into fields. Each field is usually terminated by a 'field terminator', such as ↑.. When milestone data is input, there are four items in a field and possibly nine fields in a block. When the title is input, there are only three fields, each of which has but one item of information.

FILE:
see Magnetic Tape File.

FINAL STAGE:
The point at which the responsibility of the department using Line of Balance ends.

LEAD TIME:
the minimum time required to progress from the point in question to the Final Stage.

MAGNETIC TAPE FILE:
a number of records recorded on magnetic tape. There are conventions governing the exact layout.

MASTER FILE:
the magnetic tape file in which all the permanent information relating to a Line of Balance project is held.

MILESTONE:
a definite point of part-completion in the production plan.

MULTIPLICITY
the number of a milestone required to achieve one Final Stage.

ORIGINAL RUN:
the computer run which creates the first master file.

PERT:
Programme Evaluation and Review Technique (Critical Path Method). A control technique suitable for complicated one-off jobs.

PROGRAM TAPE:
a magnetic tape on which the actual computer program is recorded. It is read into core storage by the I.C.T. Executive routine.

PROGRESS CHART:
a Line of Balance output which shows the state of production relative to the initial plan in a graphical form.

PROGRESS REPORT:
a Line of Balance output which shows the state of production relative to the initial plan in a tabular form.

PROJECT NUMBER:
a group of up to seven characters used by the program to check that all its data refers to the same project. It is printed on all outputs.

PROJECT REPORT:
a Line of Balance output which shows the target quantities for each milestone. These are calculated from the completion schedule.

RECORD:
one or more items of information which are handled as one unit when data is being read from, or written to, magnetic tape.

RELATIVE CRITICALITY:
The absolute criticality divided by the multiplicity. It is a measure of over-production in terms of final stages, as opposed to components.

REPORT DATES:
a list of dates, up to 18 in number, used by the output sections of the program.

REPORT RUN:
a computer run on which no data is input but from which outputs can be obtained.

SCHEDULE POINT:
a point on the completion schedule. It comprises a date and the number of final stages required on that date.

UPDATE RUN:
a computer run which reads in a master file, updates the information on it with data read in on punched cards or paper tape and creates a new master file. The old master file will now be out of date. For safety reasons, the old master file is usually preserved for a period of time. Should the new master file be destroyed accidentally, it will then be possible to recreate it.

Originated by
Management Systems Department
Applications Development Division

3387 (10.66)

AMENDMENT RECORD

List Number *Item Numbers*

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Should any additions or amendments to this Manual be necessary, they will be issued in the form of Amendment Lists.
When such changes have been incorporated, an appropriate entry should be made in the table on the left and the pink instruction sheet(s) should be filed behind this page.