An approach to range order analysis

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AN APPROACH TO RANGE ORDER ANALYSIS.

Dissertation submitted to the Loughborough University of Technology in part fulfilment of the requirements for the degree of Master of Science in the Department of Industrial Engineering and Management.

By;

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(Manchester).

Loughborough,
August, 1966.

CONTENTS.

1. SUMMARY.

This treatise gives an account of some of the problems involved in the management of a large and well-known clothing manufacturing firm.

It looks basically at the decisions involved in offering their product range to their clients and suggests a mathematical approach for use with a computer to facilitate some of these decisions. This approach will be useful in dealing with the range order problem in isolation and yet helpful in the extention of theories to cover the true basic problem involving the interactions involved throughout the firm.

2. THE PROBLEM.

2.1.

Background of the firm.

The firm was founded in Leeds in 1851 as a family business, evolving through public company until 1959 when the fourth generation of the founder's family were in the management roles. Throughout this stage the atmosphere appears to have been strongly paternalistic.

In 1959 the firm was taken over by a Midlands clothing firm during which time the manufacture of garments was organised on a strictly line basis, with each line manager responsible for his own decisions, statistics, etc, from raw material ordering through to marketing. Some lines were carried through in Leeds, others in the Midlands. This period therefore appears to have been rather like the amalgamation of several 'one-man' firms. This period too, appears to have been one of steady expansion.

In 1964 the amalgamated firm was subjected in turn to a further take-over by a holding company which provided its own management and which measures the success of managemenent by the attainment of the specific financial objectives which it sets.

The management of the firm has thus in five years changed from the 'old-family', easy-going type to a high-pressure, very professional system.

The firm's good record of employee treatment has nevertheless been preserved, which is perhaps essential in that, as yet, mechanisation of processes is still financially unfeasible and heavy reliance is placed on skilled labour who can get well paid, easier jobs in other industries.

Top management has recently been studying the American tailoring industry's methods and has come to the conclusion that the British industry is a long way behind the Americans in both technology and management. The technological problem presents little difficulty, but the management side will be extremely troublesome for some time insofar as suitable men are unavailable at the technical management level with business degree or engineering degree background. The trade does not foresee the payment of comparable salaries to the Americans, therefore any bright young men sent over for training will undoubtedly be poached. (The American starting salary at this stage would be an equivalent £3,000 p.a.).

The holding company which provided the existing management are also in control of a computer service bureau which is at present doing some work for the clothing company. No statistical or scientific management work is done at present, service being limited to the data processing of customer's invoices via tapes. The tapes are prepared using an N.C.R. punch-verifier unit and despatched to the computer service bureau in London.

The new management at their inception conducted a vigorous campaign reflecting their intention to modernise management technology in the industry. This is beginning to have some effect, but there is still much to be done.

2.2.

Production organisation.

One of the first jobs to be undertaken was a rough product profitability evaluation which resulted in the dropping of certain uneconomic lines.

The company then planned production around three categories;

i) Large customer accounts and special orders.

ii) Brochure goods (Stock service).

iii) Range goods (Orders taken from the representatives' catalogues).

It is this third category which is the primary concern of this report.

The product profitability evaluation, whilst showing the definitely uneconomic lines, was not considered sufficiently accurate by management to draw a Pareto curve or rank the products. There is some feeling that Brochure goods service appeared more profitable, but this is considered unsubstantiated by management.

At present, production is planned on the basis of allocation of Large Customer accounts and Specials, followed by Range, with Brochure to fill in the gaps within the constraints of production capacity, cloth availability and orders available. It is not clear what is attempted to be optimised, whether this is profit, market share or customer satisfaction. It appears to be an intuitive mixture.

The market situation at present is one of a seller's market which for some time past has been undersold. The management have been expanding production capacity rapidly and expect this market situation to change within the next year or two. This will mean a change in marketing policies.

2.3.

Forecasting.

In view of the previous structures of the company to date, detailed consistent records have not been kept and the unavailability of past data makes proper statistical evaluation impossible.

The new management after 1964 initiated several changes, noticeably more scientific control mechanisms but even so, the two years worth of data, even if it were in a convenient and complete form, would be insufficient to allow a time-series analysis system to be installed as would be usual in such forecasting problems.

2.4.

The range order analysis problem.

The range order analysis problem is in two parts as stated in the memorandum Figure (18). (Appendix 3., Page 74), which is;

i) To determine how incoming range orders may be analysed so that comparisons can be made with the cloth availability and production capacity forecasts.

ii) How this order analysis can be used for forecasting the total season's sales.

3. PROPOSED METHODS OF SOLUTION TO THE PROBLEM.

3.1.

The overall problem.

The fact that the firm has kept no statistics does not indicate that there is no information contained in the firm. The apparently desperate position is somewhat alleviated by the fact the firm is continuing in business on an accumulated experience from its founding in 1851.

Any system proposed therefore must take into account the whole of this intelligence stored within the firm in a manner which may be quantified. This is essential for any system of mathematical or logical decision rules, whether intended for clerical or computer implementation.

This approach is necessary in order to keep the limited amount of management and technical brainpower available to the firm optimally employed in the more sophisticated problems to be tackled.

3.2.

Order analysis.

The information required here is, or should be, stored within the market sales estimates for the particular period (ie, estimated rate of order receipt). However, it is also obvious that this will be a wrong model of what will actually happen. If it were correct there would be no problem to analyse.

If we therefore propose a model of the actual sales as being a direct linear function of several functions eg;

i) A Management effect $= f_1$

ii) A Salesman effect $= f_2$

iii) A Market condition effect $= f_3$

iv) A Seasonal variation effect $= f_4$

v) A Random noise effect $= f_5$

By each effect we mean;

i) The effect which a particular policy adopted by management has on sales.

ii) The effect which a particular salesman has on the sales which are made by him. (ie, his competence).

iii) The effect on the company's sales due to the condition of the market. (ie, competitors' sales policies).

iv) Seasonal variation, due to the particular time period under consideration. (eg, selling fur coats in summer or winter).

v) Purely random variations which can not be attributed to any action of the company, or its competitors.

It can be intuitively stated that;

a) Function f_4 should be fairly easy to isolate and define statistically: unless there are good reasons to believe that the market is altering its 'habits' under the influence of, say, advertising: which is really an interaction from Function f_3. (See footnote, page 13).

b) Function f_1 may be impossible to isolate and quantify. It may at best be regarded as a 'residual' variance- with some suspicion that it is a useful explanation for the inexplicable.

c) Function f_2 may be possible to isolate and quantify at the extremes of brilliant and appalling salesmanship. In between the ranges, managerial subjective opinion may well be the only possible quantifying agent.

Thus this particular model is;

$$\text{Sales}_{(\text{actual})} = \sum_{i=1}^{5} f_i$$

In order to separate these functions from the sales figures statistically we would require past data. This would take the form of many sales figures, stretching back in time, over several adopted policies, in different areas, by different salesmen etc., then performing a statistical operation known as 'Analysis of variance' to determine any significant differences between the effects.

We now propose that, in the absence of the statistics required to sort out the effects contained in the functions f_1 to f_4, we shall say that our best estimate of these effects available to us in this particular case of lack of data is the company sales (orders received) forecast. As this sales forecast is wrong however, we shall introduce an error term composed of the total differences between the actual and the estimated functions f_1 to f_4. We may therefore re-write our model as;

$$\text{Sales}_{(\text{actual})} = \text{Sales}_{(\text{forecast})} + \text{Error term} + \text{Random noise.}$$

$$= \text{Sales}_{(\text{forecast})} + \sum_{i=1}^{4} \delta f_i + f_5$$

Therefore, by this analysis, if we examine the differences between the sales forecast and the actual sales, we have then two effects to sort out, namely that of a trend from the expected value, buried in random noise.

ie;

$$\text{Sales}_{(\text{actual})} - \text{Sales}_{(\text{forecast})} = \sum_{i=1}^{4} \delta f_i + f_5$$

In order to effect this detection we shall define random noise to be Gaussian* distributed, whilst the trend, or error term, follows any other distribution.

Thus, on accounting for the Gaussian distributed component of the differences, we are then left with an estimate of trend.

---

*Gaussian;

The definition of a function which behaves randomly, it is equivalent to a statistically normal distribution

(Continued overleaf,)

NOTE.

It is not necessary for the argument that the model must be linear functional. This has been used merely for illustration. This analysis will hold equally well for any interactions between the functions f_1 to f_4, and other functions may be added. The only limitation is that no interrelationships are allowed with function f_5 (random noise). This is equivalent to saying that no action will be taken by the company on purely random variations, which is a sensible limitation.

(*Gaussian, cont.)

Written mathematically, a purely random variation may be expressed by the curve;

$$Y = \frac{1}{\sigma\sqrt{2\pi}} e^{-1/2 \, (x - s)^2/\sigma^2}$$

where;

σ = standard deviation.

s = forecast sales.

x = actual sales.

The area bounded by this curve and the x axis is unity and the area under the curve between x_β and x_α represents the probability of an event happening between these two limits due to a purely random variation.

3.3.

Estimation of trend.

As stated in the previous section, the trend is estimated by estimating the random noise in the system. Also, since we have no previous statistics to use, any proposed system must build up this estimate as it progresses in time.

Thus, considering the sales of a particular garment in a particular cloth, we may draw a cumulative sales forecast graph as shown in Figure (1). Then, if we superimpose the actual sales progressively, we can calculate the differences between the actual and forecast figures, at each stage computing the standard deviation of the error. This will then allow us to draw in 'dynamic' control limits at various confidence levels to compare with our actual error. As the standard deviation is a measure of the spread of the random component of the observed error, we can draw in limits which are a function of the standard deviation (See Figures (1) and (2).) at a certain level of confidence. This means that at a confidence level of (say) 95%, a purely randomly distributed function will have 95% of the points describing that function lying within these limits (See footnote, previous page).

We may therefore say that we are, say, 95% certain that larger deviations than the computed control limit are not due to random noise, but are due to some positive trend, as a result of which we may, if we wish, update our sales forecast on that particular item.

We can however improve the estimate by saying that the random noise accrues equally on each line throughout the total sales (by definition of random noise), and we may therefore include all other garment sales in our estimate of the random noise in the system.

Thus, as Figure (2) shows, the control limits may be brought in. By virtue of having more points (ie information) to work with, we can then improve our estimate of the random noise and thus put tighter limits on the differences from forecast. It will therefore be seen that trends will become apparent much earlier than they would in the system depicted in Figure (1).

NOTE.

This confidence level is not strictly true in that the trend effect is included in the estimate of random noise. This would cause the computed control limits to be rather wider than they should be at the stated confidence level. This is improved by re-computing without the items thrown up, but the statistical nicety of being able to establish the confidence level exactly is not worth bothering about. In this case since we can definitely say that the true (say) 95% confidence limit lies within our estimated 95% confidence limit and therefore we can say with better than 95% confidence that any trends shown up in the system are not due to random noise.

The control limits shown in Figure (2) will approach assimptotically the control limits at the same confidence level as the Kurt Salmon Forescor and other steady state control systems, because as more trends are detected and excluded, the more accurately can the random noise be estimated thus causing the control limits to narrow.

It will be noted that the proposed system is based on cumulative statistics and the system is rapidly convergent in the initial stages, which should enable early forecasts of discrepancies to be made.

The method pre-supposes of course that the sales forecasts are on the whole correct and the few faster (or slower) moving lines may be picked out. If the whole market has been badly estimated throughout the range, the system will see this as noise and fail to differentiate it. This is perhaps obvious since this is the mainstay of the argument in the absence of proper statistical evaluation.

In the case where there is reason to believe that one set of forecasts is not as good as the rest, these may be dealt with separately (See appendix 1, case 1, page 34). but it will be better from the computational point of view just to exclude using them in the estimation of the control limits and just to apply the control limits estimated from the rest to them.

It may also transpire that external influences, such as cutting constraints, put more weight on small numbers; ie, Deviations from forecast of some small quantities of some garments which are only allocated small capacities, are more important relatively than the same deviations from forecast of some other garments which have a much larger allocation; Therefore, weighted systems, such as percentages may prove more desirable.

3.4.

Tying in an order analysis system with the Firm's constraints.

The problem desired to be solved by the firm is one of analysing the incoming orders and then checking against the constraints to see if the order can be met.

Obviously if the orders follow the sales forecasts, then the production and raw material scheduling will have catered for this and the whole system will run smoothly with no trouble. (This pre-supposes material control systems beyond the frame of reference of this report.). However, the difficulty arises when the orders do not follow the forecasts and some re-scheduling must be carried out. This then becomes an optimisation problem, which may be formulated as the general programming problem (See appendix 1, case 2.)

THERE IS NO GENERAL ALGORITHM FOR ITS SOLUTION.

A solution may be effected in special cases where the functions involved are adequately defined and a possible method of solution is outlined in appendix 1, case 2, section 3. (Page 37).

It is therefore necessary for a rigorous treatment that the functions involved, ie constraints and optimisation functions, be mathematically described within the area of interest, so that a solution method may be chosen and implemented.

A rigorous treatment here is essential as these functions embody the firm's policy. Obviously, if the mathematical formulation of the functions do not exactly depict the policy, then implementation of the recommendations given by the function will cause the wrong policy to be followed with unforseen results to the firm.

Similarly, even if the functions are formulated exactly and a policy of sub-optimisation is followed (ie only part of these functions are optimised) we may have exactly the same risk of optimising the wrong thing as we did previously.

In the absence of these functions, a workable system must nevertheless be chosen which does mot make the mistakes of sub-Optimisation or optimising the wrong thimg.

To this end, we look at the present system, whereby production planning is centred on the allocation of X number of suits of a certain difficulty, or Y number of jackets plus Z pairs of trousers, all of varying but specified grades of difficulty. This broad allocation is then broken down further to particular Range Orders taking into account the required delivery dates and cloth availability.

If we take the view that the market has in general been corectly estimated, then on receipt of statistically significant information from the order analysis section, we can re-schedule the faster moving lines onto the slower moving allocations, subject to cloth constraints. The trend will have become apparent much earlier than it does at present and will allow cloth to be ordered for the quicker moving lines than it would otherwise have been, and also allows for the cancellation of cloth for the slower moving lines which has not yet been received.

Any variations not highlighted can be statistically expected to be random and variations therefore expected to even themselves out. Thus no management action is needed on these cases.

Should the market be under or over estimated, then the problem moves into the broader set of allocation between Range, Brochure and Specials, and the wider theory should be applied. By this we mean that the theory expressed in appendix 1, case 2 should be applied to the total products

4. IMPLEMENTATION OF SOLUTION.

4.1.

Personnel and equipment available.

As stated in section 2.1, there is little hope of recruiting a staff of required management calibre and so the suggested system must be capable of being implemented in the company by girls or clerks under management supervision. This means that use must be made of the services of the computer service bureau.

The system must be designed so that the onus is on the company management to take action on trend deviations and thereby provide information to the system on the products shown up. ie, management by exceptions., the rest of the system being reduced to routine. This management action required will be exactly similar to what is done at present, although the number of decisions will be reduced in dimension and carried out earlier than previously. There is no change in basic concept.

The sales (order receipt) forecasts will have to be prepared on a weekly basis, not monthly as at present, in order to provide sufficient information over a typical 12 week-sales period. Management responsible see no problem in this and agree that the time scheduled for their preparation is ample. (See Figure (4)).

The equipment necessary for the preparation of input in paper tape form for the computer service bureau is already installed in the company for use with their sales invoices. This is an;

N.C.R. class 32 W.A. 03. P13(29s)26''
A.E.C.

Linked to N.C.R. class 461-2-H.8
and N.C.R. class 411.6

A further machine to the same specification is due for delivery to the company at the commencement of December 1966. The utilisation of these machines is such that at peak periods of order invoicing, space is required for only one and a third machines. In view of the fact that daily punching of tapes for the proposed system should not take more than two hours a day, there is sufficient capacity available on this machinary.

Consultations with N.C.R. as to the computer input requirements showed that N.C.R. would be able to put both the sales forecast(orders received) and the daily order receipt punch programmes on to the same pair of programming bars for their machine. Thus the company would have to purchase a pair of programming bars at £29 each, ie, £58. It would take N.C.R. an estimated two weeks to collect the components, and one week to assemble them. The schedule shown in Figure (4) allows two months, with which N.C.R. are in complete agreement.

The codes used by the N.C.R. machine will be accepted by the computer bureau. The bureau has a standard coding system, but this is not followed by the company in the invoicing system. The bureau is quite happy to accept a non-standard code which is adequately defined.

4.2.

Organisation required within the company.

4.2.1.

Incoming order receipt proceedure.

The management structure of the company is as shown in Figure (17). At present all incoming orders arrive in the post room, and are sent to Mr. Caunt who processes them in order to take out certain statistics such as sales per particular salesman etc., The range orders are then passed to Mr. Appleyard who takes decisions as to acceptability, and then withdraws certain lines from the Range. The orders are then put out into the office and then processed through the system.

As Mr. Caunt says that he keeps the orders only twenty mins. it is suggested that this system be kept as it is, with ALL orders going to him, and thence the range orders to Mr. Appleyard as at present. It is essential that no orders go astray in this link. After being sifted by Mr. Appleyard, the orders should go for punching and then returned to Mr. Applyard for checking, and thence to the office and processed through the system as at present. In order that there is only one punch run per day it is suggested that orders arriving at any other time than first post should be held by Mr. Appleyard for the next day's run. It is unlikely that any delays will occur with this procedure, since observation suggests that orders arriving during the day are held by the clerks for inclusion in the next days batch.

It is therefore suggested that responsibility for Range orders being punched should rest with Mr. Appleyard.

The process flow chart is as shown in Figure (14).

The responsibility for the safe keeping of the tapes produced should rest with the person directly responsible for the N.C.R. machine. ie Mr. Mills. who is also the cashier.

At the end of each week the order tapes should be dispatched to Mr. Bendon at the computer service bureau. This will be Mr. Mills responsibility. (Friday afternoon provisionally).

4.2.2.

Proposed procedure for receipt of information from the computer centre.

The output will be delivered to Mr. A.J. Sumner

(Say Tuesday morning). The process flow chart is as shown in Figure (15).

This flow chart allows a figure of two and a half days to finalise the position on highlighted items. Items which fail to be finalised within this period will have to wait until the next weeks updating run normally, but in exceptional cases a special run is feasible.

After the updating tapes have been prepared these should be put in the post by Thursday 5.00p.m. in order to reach the computer service bureau first thing on Monday morning, so that they can do an updating run prior to processing the next weeks tapes.

This system assumes no weekend working by the bureau. Should this be started, the tapes should be received by the bureau by the first post on Saturday. This will enable Figure (15) to be updated to start on Monday morning and give three and a half days for management thinking.

Since by the theory all types not highlighted by the computer can be statistically accounted for as being subject to only random variations. These can be expected to even themselves out with time and therefore no management action is necessary until they are highlighted.

4.3.

Computer service bureau organisation.

4.3.1.

Procedure on receipt of tapes.

The procedures followed will be within the timescale as shown in Figure (16). (Page 71).

4.3.2.

Systems analysis of computer programmes.

The basic steps to be followed by the computer are as shown in Figure(3). The detailed breakdown of how this may be achieved in the commercial installation is shown in appendix 1, case 3.

4.4.

Data fed to computer.

It is proposed that the N.C.R. machine be programmed so as to produce a tape of the form shown in Figure (5), together with a punch document of the format shown in Figure (7). This document will assist in the manual processing of the orders, whilst the information placed on the tape which is not used in this analysis will be stored there conveniently for the future use in statistical surveys which th firm may wish to make in the future. The tapes for this exercise therefore double up as convienient backing stores, which do not clog the data processing system stores.

If a less sophisticated machine th-n the N.C.R. is used, an example of the basic tape produced is as shown in Figure (6), and a basic logic flow chart for sorting this information is shown in Figure (8).

4.5.

Cost of system.

4.5.1.

Cost at company end.

i) Punching costs,

Time. say 15 hrs. at 10/- per hour ....

.... £ 7/10/- per week.

Stationay,

i) Paper ....) say £10. per week.

ii) Tape ....) (A very generous estimate, (bureau rate; 25/- per (1,000 lines.

ii) Management time,

Approx. 10 man-hours at average £2 per hour.

.... £20. per week.

which gives us an approximate cost of £40 per week.
ie £480 per season.

plus fixed cost of £58. for programming bar.

4.5.2.

Cost at service bureau end.

i) Computer running time .... £20 to £30 per week.

ii) Programming costs............. Less than £1000.

4.5.3.

Total cost of system.

Assuming a 5 year amortisation of fixed costs, this will give us a rough approximation of £100 per season for programming costs, and £6 per season for the N.C.R. programme bars, total £106 per season. Thus, total cost per season;

	£
From 4.5.1.	480
Computer running time at £30 per week for a 12 week season	360
Fixed cost amortisation	106
TOTAL COST	946

Therefore we expect a cost per season of approximately £950 on these figures supplied by the bureau.

4.5.4.

Cost of a manual system.

A manual system, operated on an intuitive basis would probably cost;

i) Full time clerk at £800 pa ..... £15 per week.

ii) Management time

5 hrs. top management time at £5 per hour...

.... £25 per week.

10 hrs. middle management time at £2 per hour.

.... £20 per week.

iii) Stationary,

say equal to other system....... £10 per week.

ie;

£70 per week, or £840 per season.

Great difficulties would be involved in operating such a system successfully.

NOTES ON COSTS.

The largest item, and most important item in the costs of such systems is the cost of management time. The amount of time spent by management, and the benefit to the firm derived from its expediture vary greatly. One should therefore by very wary of simple monetary evaluations which take into account only explicit costs. The implicit - eg. management - costs may, realistically be much more important.

I personally feel that in view of the shortage of suitable men, the implicit opportunity cost of giving management a job that can be done by some other means can safely be given an extremely high value.

I therefore feel that section 4.5 should very much be interpreted with this consideration in mind. The calculations in this section are themselves of a highly tentative nature, and, in view of the shortage of management skill, probably represent the less important half of the true total comparative cost.

4.6.

Time schedule for implementation.

This is as shown in Figure (4) which is fairly self explanatory, one of the first things to be considered being the data fields required for the computer input.
ie. what accuracy and in what manner should the information be organised for input in the most convenient manner, taking into account the requirements of the company, the organisation mechanics of the computer bureau and the contruction of the punch machine.

Figure (4) shows the actions required by certain individuals within the allocated time periods. The programme is based on the decision made on September 2nd. to implement the system for the range selling season commencing February - March, 1967.

All those concerned have agreed as to its feasability

5.0. FUTURE EXTENTIONS AND CONCLUSIONS.

The approach outlined in this report is essentially that of a stop-gap theory designed to be of some use under the conditions of severe lack of data, and extreme flexibility.

The real solution lies in the sucessful implementation of a solution the problem put forward in appendix 1, case 2. ie, the general programming problem. To this end it is suggested that a survey be initiated to discover the true functions and constraints holding in the firm, and, once the firm has successfully been described, to discover the form of the optimising functions. It would appear that this is a useful problem for Prof. Forresters Industrial Dynamics approach.

On a less ambitious scale, the document format proposed, giving extra information stored on the tapes, will allow this information to be sifted at leisure, with regard to customer, size of orders, type and composition etc. in order to search for economies at the order acceptance level.

This concept of tape storage of information would be invaluable to the formulation of forecasts and data for model building in the company's future. Without information, no system of any sophistication can be envisaged.

Further recomendations, not directly relevent to the report's frame of referance are;

i) A clear profitability survey be undertaken throughout the whole product range.

ii) A study in design standardisation be undertaken.

iii) Investigate cloth buying procedure.

iv) A programme of recruitment of young men with analytical ability be undertaken. Such men should have some training in logic (eg. ex-computer programmers) to assist management in view of the shortage of suitable managers trained in the newer scientific methodologies of management.

It is essential however that these men have a psychological outlook which allows them to look for a 'good enough' solution which can be initiated quickly, rather than the perfectionist. The latter type would be worse than useless in this environment.

APPENDIX 1.

Mathematical treatment of concepts.

APPENDIX 1. Case 1.

A1.1.1.

Estimation of σ.

In the case where there is reason to believe that another type of error is involved in a particular set of estimates which is not contained in the rest (eg. one or more groups of order forecasts are not as good as the others), then a better estimate of the random noise in the system may be obtained by separating these from the remainder.

If we suppose that there are K groups, with the number of deviations in each group being $N_1, N_2, N_3, \ldots\ldots\ldots\ldots, N_k$.

Then, since;

$$\sigma^2_{total} = \sum_{i=1}^{k} \sigma^2_i$$

$$= \sigma^2_{main\ body} + \sum_{i=1}^{k-1} \sigma^2_{suspect\ groups}$$

ie;

$$\sum_{i=1}^{N} \frac{(x_i - x)^2}{N} = \sum_{n=1}^{n_k} \frac{(x_i - x)^2}{n} + \sum_{i=1}^{k-1} \sum_{m=1}^{m_k} \frac{(x_i - x)^2}{m}$$

Thus our estimate of σ^2 for the main body will be;

$$= \sum_{i=1}^{N} \frac{(x_i - x)^2}{N} - \sum_{i=1}^{k-1} \sum_{m=1}^{m_k} \frac{(x_i - x)^2}{m}$$

APPENDIX 1. Case 2.

A1.2.1.

Definition of the Scheduling problem.

The production system may be defined by a set of inequalities such as;

i) Production capacity constraint;

$$\sum_{i=1}^{n} A_{ijk} \leqslant C_k$$

ii) Cloth capacity constraint;

$$\sum_{j=1}^{n} A_{ijk} \leqslant D_{ik}$$

iii) Cloth feasability constraint;

$$\sum_{j=1}^{m} A_{ijk} \leqslant \sum_{i=1}^{n} A_{ijk}$$

with a cloth stock link equation between time periods;

$$D_{i,k+1} = E_{ik} + D_{ik} - \sum_{j=1}^{m} A_{ijk} \quad (k=k_1)$$

where;

k = Time period referred to.

i = Garment type.

j = Cloth type.

A_{ijk} = Number of garment types/cloth/period produced.

C_k = Production capacity available at period k.

D_{ik} =Cloth available, type i, at period k.

E_{ik} = Cloth delivered, type i, at period k.

A1.2.2.

Optimisation.

The object of the scheduling problem is to optimise (maximise or minimise) a function over the space bounded by the set of constraints defined.

Let us take for this example, the function which we wish to optimise is that which minimises the total number of orders delayed. (It would clearly be a foolish ploy to apply this sole criterion in practice.)

ie;

$$\sum_{i,j=0}^{\infty} \left(\sum_{k=k_1}^{\infty} A_{ijk} - F_{ijl} \right)$$

where F_{ijl} is the total quantity of A_{ij} ordered for delivery at period l.

It will thus be observed that the solution is fully interrelated with the production of Range, Brochure and Specials. Also, there is no policy of sub-optimisation which will yield a solution.

This problem, as set out here is the general programming problem; ie, Find the extremum values of the function $f(x_1,\ldots\ldots\ldots,x_n)$ subject to the constraints $x_i \geqslant 0$, $(i=1,\ldots\ldots n)$ and $g_i(x_1,\ldots\ldots\ldots\ldots,x_n) \leqslant A_j$, $(j=1,\ldots\ldots m)$.

There is no general algorithm in existance for its solution.

A1.2.3.

A possible approach to a solution of the scheduling problem. (Dynamic programming).

This scheduling problem is a deterministic process in that we have a system whose k^{th} state is defined by a vector, say A_k $(a_{k,1},\ldots\ldots\ldots,a_{k,n})$. Let us say for example that this corresponds to either completed or outstanding orders.

Now take T_j, a transformation arising from a decision j (ie, how much of, or how many particular garments to make), which when applied to the state A_k, ie $T_j(A_k)$, gives a new state, say A_j, representing the effect of the decision j on the system initially at state A_k.

Then, in an N stage process, we have a series of N decisions such that if A_0 is the initial state, we get;

$$A_1 = T_1(A_0)$$
$$A_2 = T_2(A_1)$$
$$\downarrow$$
$$A_N = T_N(A_{N-1})$$

Furthermore, we wish to chose our transformations $T_1,\ldots\ldots\ldots,T_N$. so as to optimise some function of the final state vector $F(A_N)$. (Let us say again for example that the number of overdue orders should be minimised).

If we now define $f_N(A_0)$ as the optimum obtained from an N state process from an initial condition A_0, we can then say that $f_N(A_0) = \text{Min. } F(A_0)$, this minimum being taken over all states resulting from all possible transformations $T_1, \ldots\ldots\ldots\ldots, T_N$.

Thus, by Bellman's principle of optimality;

$$f_N(A) = \text{Min. } F_{N-1}(T(A)) \quad \text{for } N \geqslant 2 \qquad \text{over all } T.$$

and $$f_1(A) = \text{Min. } F(T(A))$$

Now in our case, the system is unbounded in that N is infinite, we may therefore re-write this as the functional equation;

$$f(A) = \text{Min. } f(T(A)).$$

This has thus reduced the problem dimensionally to the recurrence relationship whereby the first state must be chosen to give a new state, which, when optimised over the remaining states results in an optimal final state.

It is therefore theoretically possible, with an adequate knowledge of the functions involved, to proceed step by step calculating each stage, numerically if necessary, until a solution is reached.

APPENDIX 1. Case 3.

A1.3.1.

Computer centre general system.

The standard system in the computer centre follows the schematic diagram shown in figure (9).

However, in view of the size of the proposed matrices, it would be uneconomic to attempt to follow this system, and also impossible to get the matrices into core store. ie;

Autumn 1966	Styles	42	
	patterns	504	
	Resulting combinations		831
Spring 1967	Styles	28	
	Patterns	304	
	Resulting combinations		1002

We would therefore have to provision for a 1500 x 12 sales forecast matrix, a deviations matrix of similar size, a 1500 x 1 cumulative actual sales matrix and a withdrawn sales type matrix together with working space and programme.

The machime available is a GE-415, with 16k core store of which approximately 10 to 12k would be available. This clearly rules out doing the operation entirely in core store.

It is therefore proposed that the basic logic flow chart shown in Figure (8) should be adopted as a primary sort and the matrices be read into backing store sequentially and interleaved with each other so that blocks of information can be brought down into core store, and all relevant information will be contained within that block. The withdrawn sales matrix could be tagged on to the end of the sequential interleaving separately.

Both the Systems Manager and the Production Manager of the Bureau feel that this system is feasable and the time period allowed in Figure (4) for its implementation to be adequate.

The fact that the machine employs basically fixed point arithmetic will make the computation of the standard deviation rather more complicated than it would have been on a more scientific machine with floating point arithmetic, but software floating point is available to ease the problem.

A1.3.2.

Organization of the programme.

The cumulative sales forecast should be held in a two-dimensional matrix of size 1500 x 12 on backing tape.

This will be brought down by column in the form of a one dimensional matrix of size 1500 x 1 for the particular week under consideration.

Thus for any particular run we should bring down six one-dimensional matrices of this size. ie;

i)	Actual sales this period	.... A
ii)	Cumulative sales to date (beginning of period)	.... B
iii)	Cumulative sales forecast (end of period)	 C
iv)	Number of weeks since updated	.... D
v)	Cumulative deviations squared	.... E
vi)	This week's deviations	.... F

These are depicted in Figure (13), only three columns need to be brought down at any one time. Using single word length, this will take up 3 x $1^1/2$k ie, $4^1/2$ k locations. Should single word length prove inadequate for accuracy, double or treble word lengths may be used. This will require that the above arrangement be held in backing store and brought down by pieces. (See Figure (11)). This will require a further single matrix to hold the information contained in the previous sections after processing. (See Figure (12)).

The facility to withdraw one or more types from the standard deviation computation will be required by the company, whilst keeping the check of their difference from forecast against the confidence limits computed from the rest. This may be effected by using a variation on the updating proceedure, but this would cause the original information stored in the cumulative difference file to be destroyed. The effect of this being that all tapes would have to be re-input in the effect of a mistake by the company.

It may also transpire that with experience the company may wish to operate the system on weighted differences such as percentages. Therefore, to cover these points it will probably be more advantageous to double up on the difference and cumulative difference files, using the basic files previously outlined alongside the weighted ones. This will take no more core store, in that when one set is being used, the other is not, and during the updating proceedure between these files the rest of the system is not needed in core.

A1.3.3.

Punch Code.

The code used by the company at present with the N.C.R. machine on invoices does not comply with the bureau standard code headers. It will therefore be necessary to fix this at the time of fixing the data fields.

APPENDIX 2

Figures.

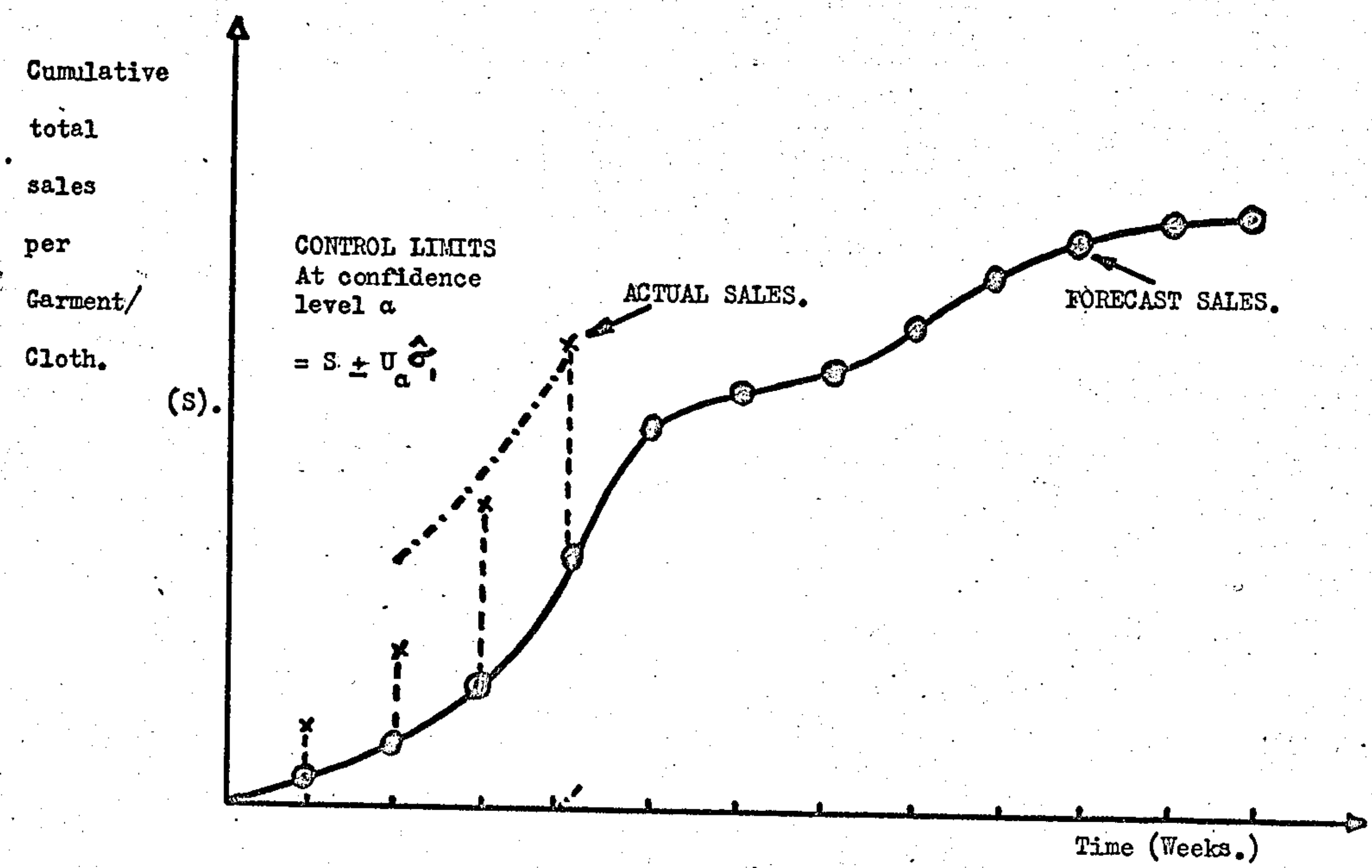

Cumulative
total
sales
per
Garment/
Cloth.
(S).
CONTROL LIMITS
At confidence
level α
= S ± U_α σ̂
ACTUAL SALES.
FORECAST SALES.
Time (Weeks.)

FIGURE (1).

44.

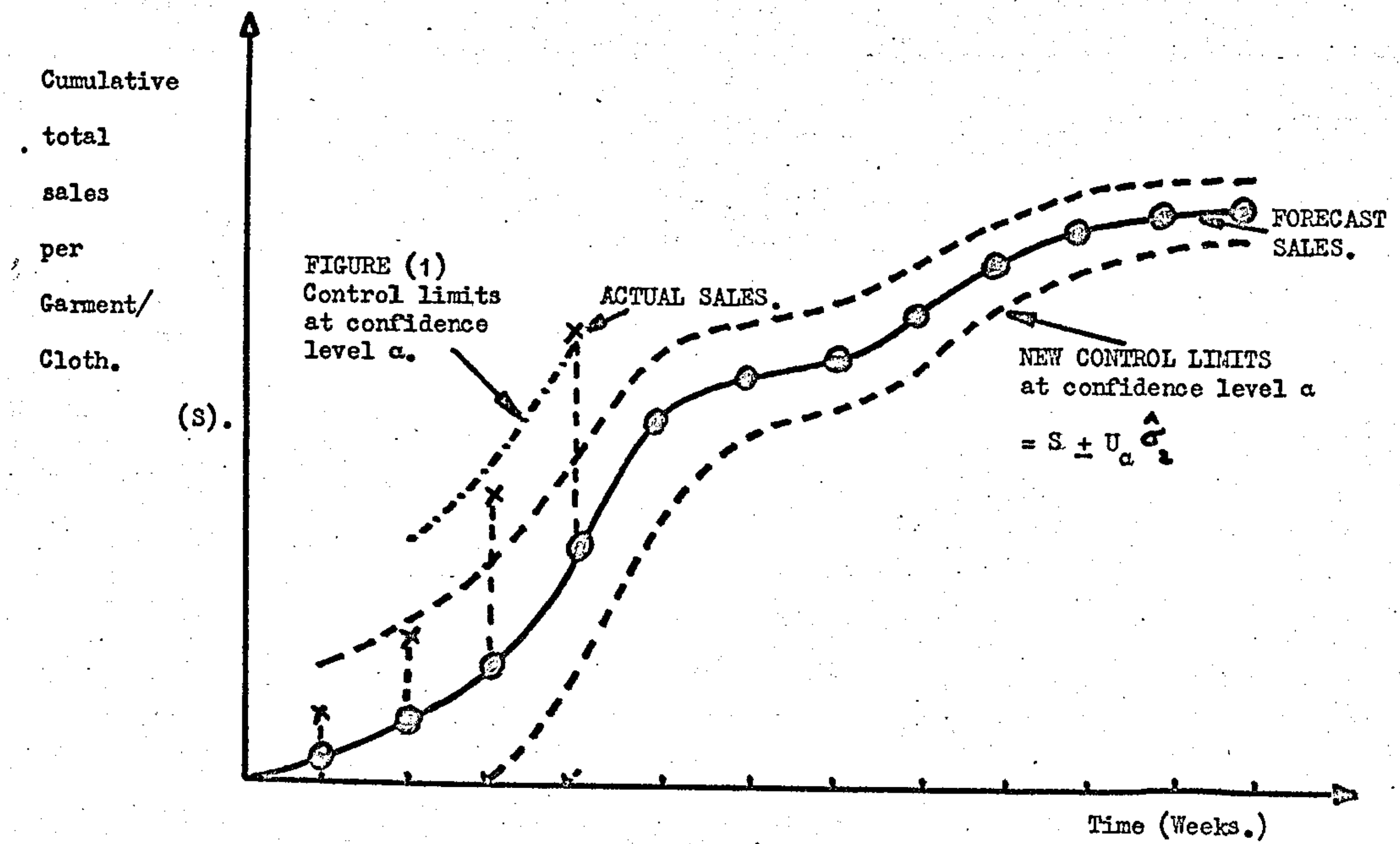

Cumulative total sales per Garment/ Cloth.
(S).
FIGURE (1) Control limits at confidence level α.
ACTUAL SALES.
FORECAST SALES.
NEW CONTROL LIMITS at confidence level α
$= S \pm U_{\alpha} \hat{\sigma}_{2}$
Time (Weeks.)

FIGURE (2).

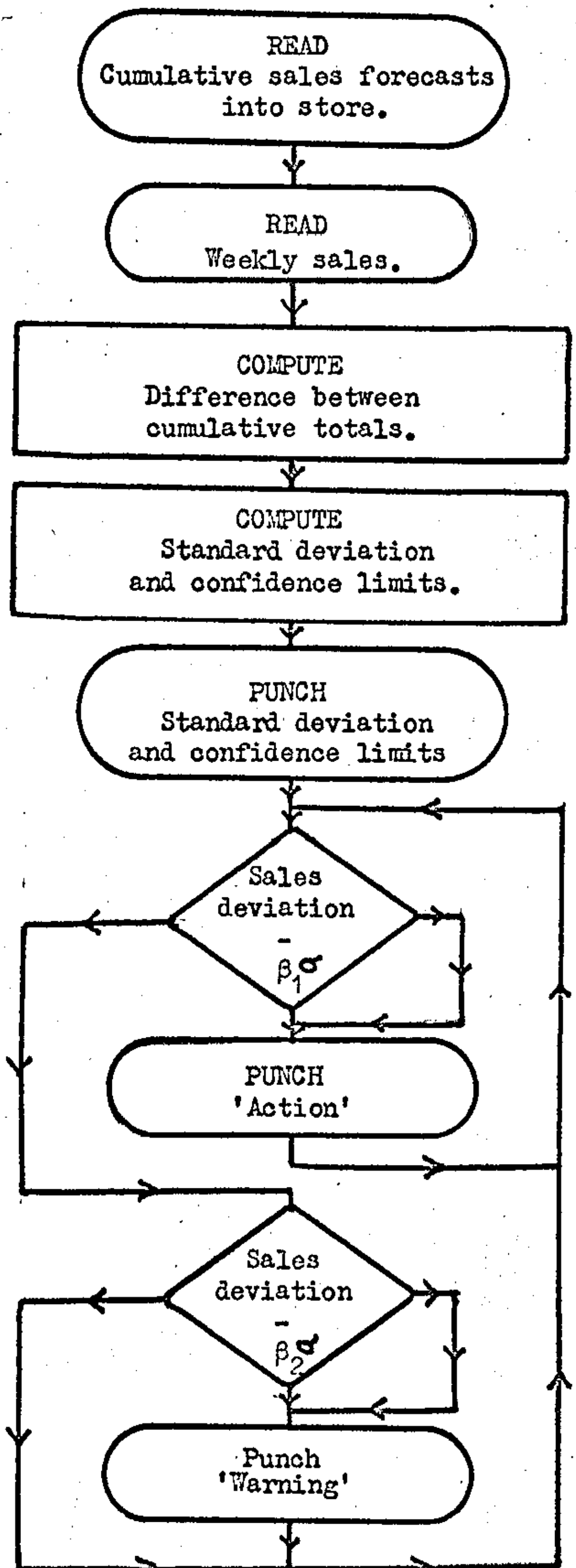

READ
Cumulative sales forecasts into store.
READ
Weekly sales.
COMPUTE
Difference between cumulative totals.
COMPUTE
Standard deviation and confidence limits.
PUNCH
Standard deviation and confidence limits
Sales deviation - $\beta_1\sigma$
PUNCH
'Action'
Sales deviation - $\beta_2\sigma$
Punch
'Warning'

FIGURE (3).

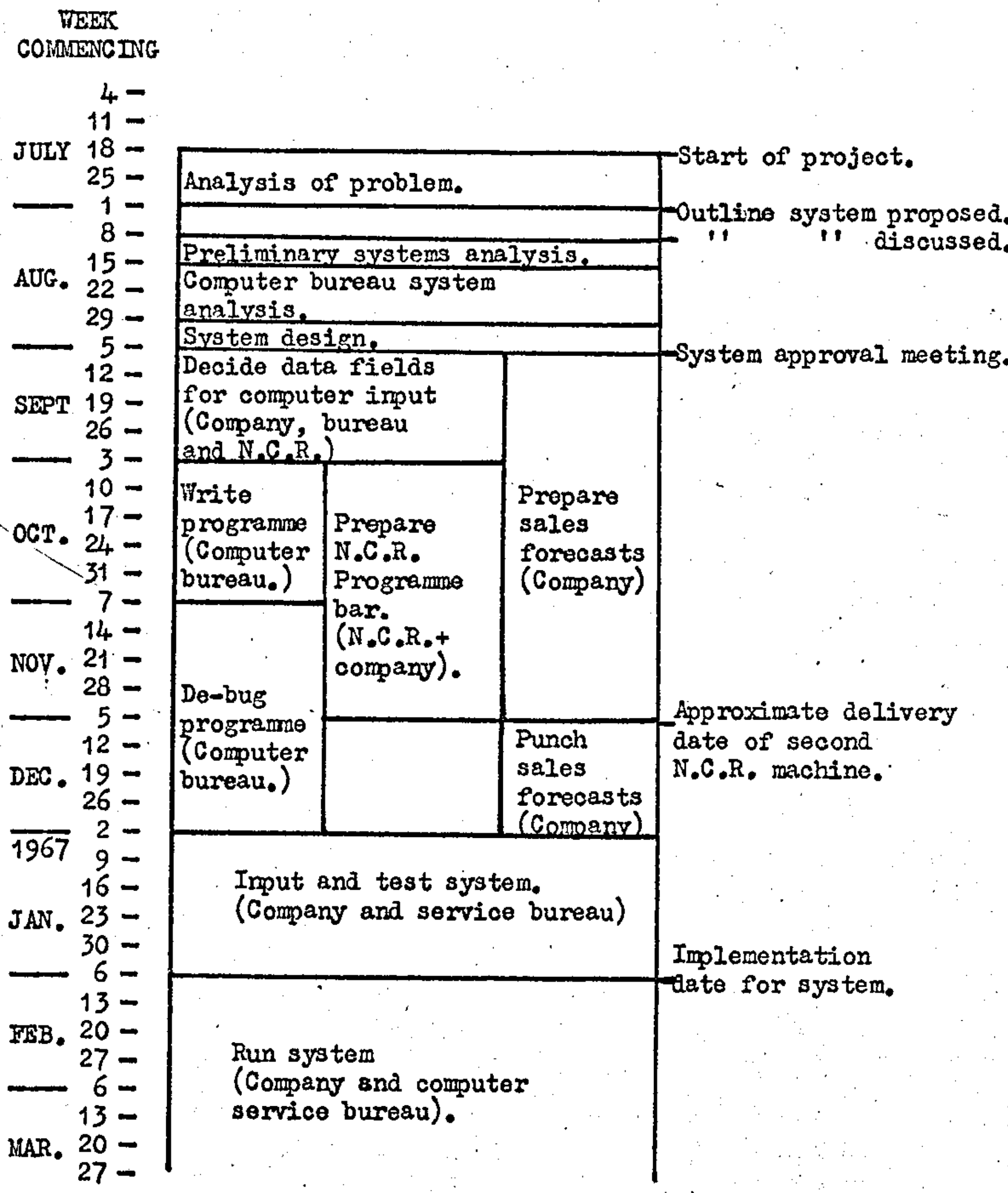

WEEK COMMENCING
4
11
JULY 18
25
1
8
AUG. 15
22
29
5
12
SEPT 19
26
3
10
OCT. 17
24
31
7
14
NOV. 21
28
5
12
DEC. 19
26
2
1967 9
16
JAN. 23
30
6
13
FEB. 20
27
6
13
MAR. 20
27
Analysis of problem.
Preliminary systems analysis.
Computer bureau system analysis.
System design.
Decide data fields for computer input (Company, bureau and N.C.R.)
Write programme (Computer bureau.)
Prepare N.C.R. Programme bar. (N.C.R.+ company).
Prepare sales forecasts (Company)
De-bug programme (Computer bureau.)
Punch sales forecasts (Company)
Input and test system. (Company and service bureau)
Run system (Company and computer service bureau).
Start of project.
Outline system proposed.
" " discussed.
System approval meeting.
Approximate delivery date of second N.C.R. machine.
Implementation date for system.

FIGURE (4).

N.C.R. OUTPUT TAPE.

Header information	xxx	To be specified by bureau.
Week number	xxx	Field to be decided.
Day number	xxx	
Tape number	xxx	
Emitted symbol	56	
Customer order number	xxx	9 decimal digits.
Type	xxx	6 decimal digits.
Control number	xxx	2 binary digits.
Emitted symbol	56	
Number off	xxx	Field to be decided.
Delivery date	xxx	
Control number	xxx	
Emitted symbol	56	
↓	↓	
Close tape symbol	76	

If the control number is;	Next field is;
Blank -	Number off + Delivery date + Control number.
α -	Sub-Total + Control number.
β -	Customer order number + Type number + Control number. (If the customer order number is not specified in this field, then the last specified customer order number is carried foward.)

NOTE. The field separation symbols and header information are in 6 digit octal format.

FIGURE (5).

BASIC PUNCH OUTPUT TAPE.

Week number	xxx
Day number	x
Tape number	xxxx
Customer order number	xxxxxxxxx
Type	xxxxxx
Number off	xxxx
Delivery date	xxx
Number off	xxxx
Delivery date	xxx
↓	↓
Number off	xxxx
Delivery date	xxx
Control number	-1
Sub-Total	xxxxx
Type	xxxxxx
Number off	xxxx
Delivery date	xxx
↓	↓
Number off	xxxx
Delivery date	xxx
Control number	-55
Customer order number	xxxxxxxxx
Type	xxxxxx
↓	↓
Control number	-1
Sub-Total	xxxxx
Control number	-99999

NOTE:

FIGURE (6) is an alternative to FIGURE (5) assuming a less sophisticated machine than the N.C.R. machine.

FIGURE (6).

WEEK NUMBER	xxxx
DAY NUMBER	xxxx
TAPE NUMBER	xxxx

CUSTOMER ORDER NUMBER	TYPE	NUMBER OFF	DELIVERY DATE	SUB TOTAL	CONTROL DIGIT
xxxxxxxxxx	xxxxxx	xxxx	xxx		
		xxxx	xxx		-1
				xxxxx	
	xxxxxx	xxxx	xxx		-1
				xxxxx	-55
xxxxxxxxxx	xxxxxx	xxxx	xxx		
		xxxx	xxx		-1
				xxxxx	
	xxxxxx	xxxx	xxx		
		xxxx	xxx		-1
				xxxxx	-9999

FIGURE (7).

CONTROL PROGRAMME

Initial settings input;

Week number	= K (Initial setting=1)
Maximum type number	= M
Tape number	= L (Initial setting=1)
Total number of discontinued types	= Imax.
Discontinued type numbers stored in	N(I), I=1......Imax.
Keyboard control number equal to 'yes'	= IR
Keyboard control number equal to 'no'	= IS

FIGURE (8.1).

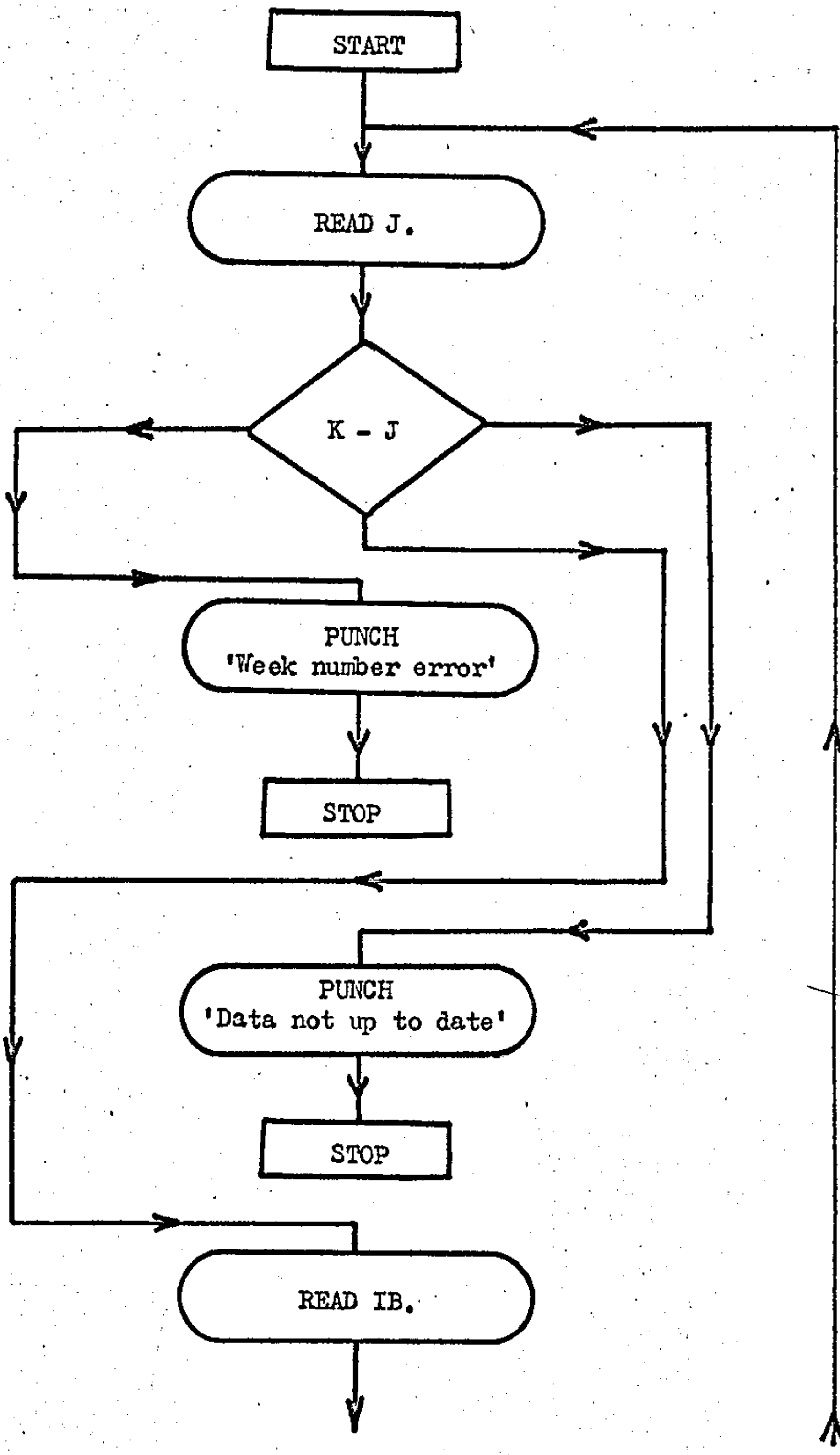

START
READ J.
K - J
PUNCH
'Week number error'
STOP
PUNCH
'Data not up to date'
STOP
READ IB.

FIGURE (8.2).

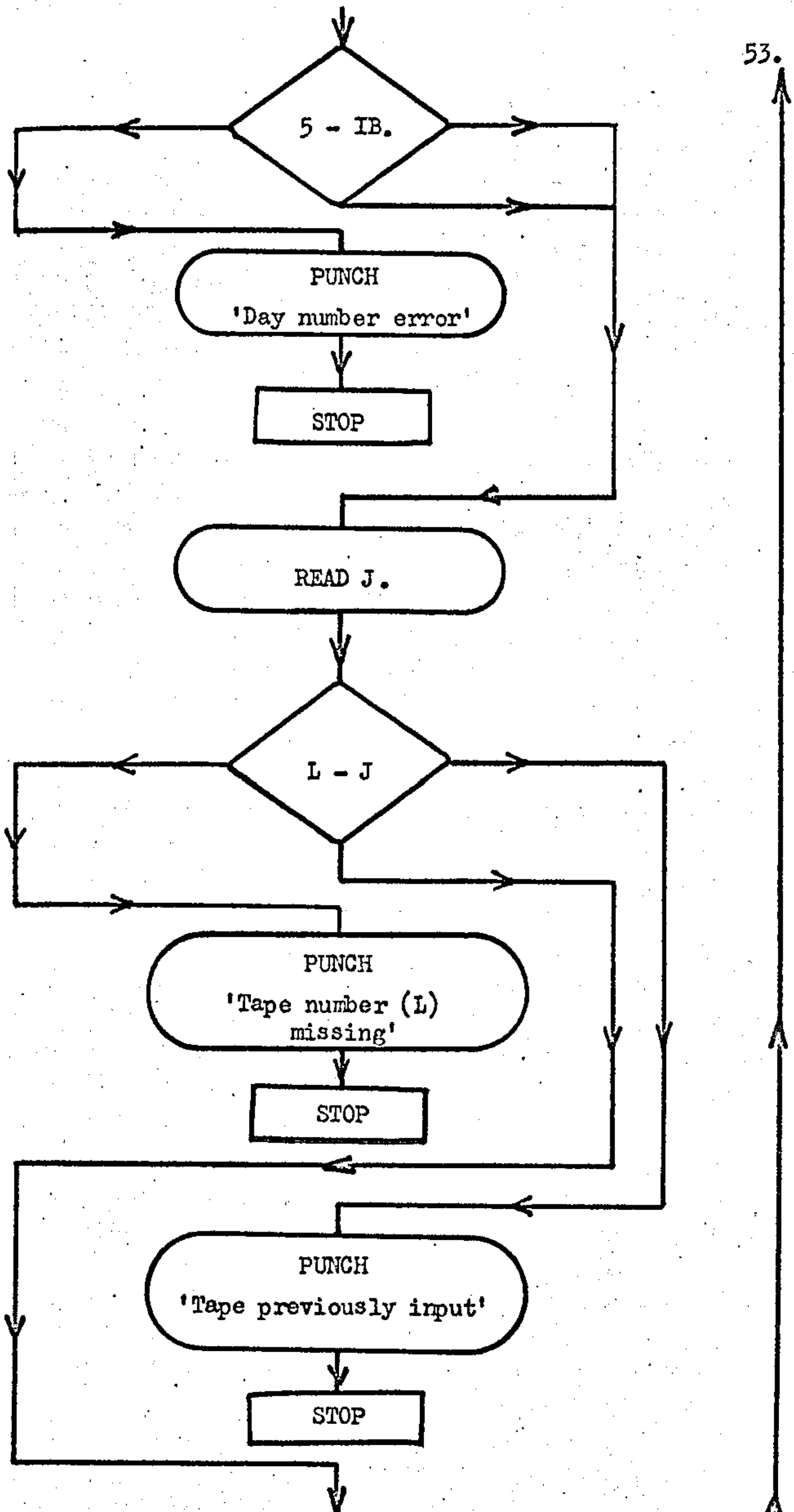

5 - IB.
PUNCH
'Day number error'
STOP
READ J.
L - J
PUNCH
'Tape number (L) missing'
STOP
PUNCH
'Tape previously input'
STOP

FIGURE (8.3).

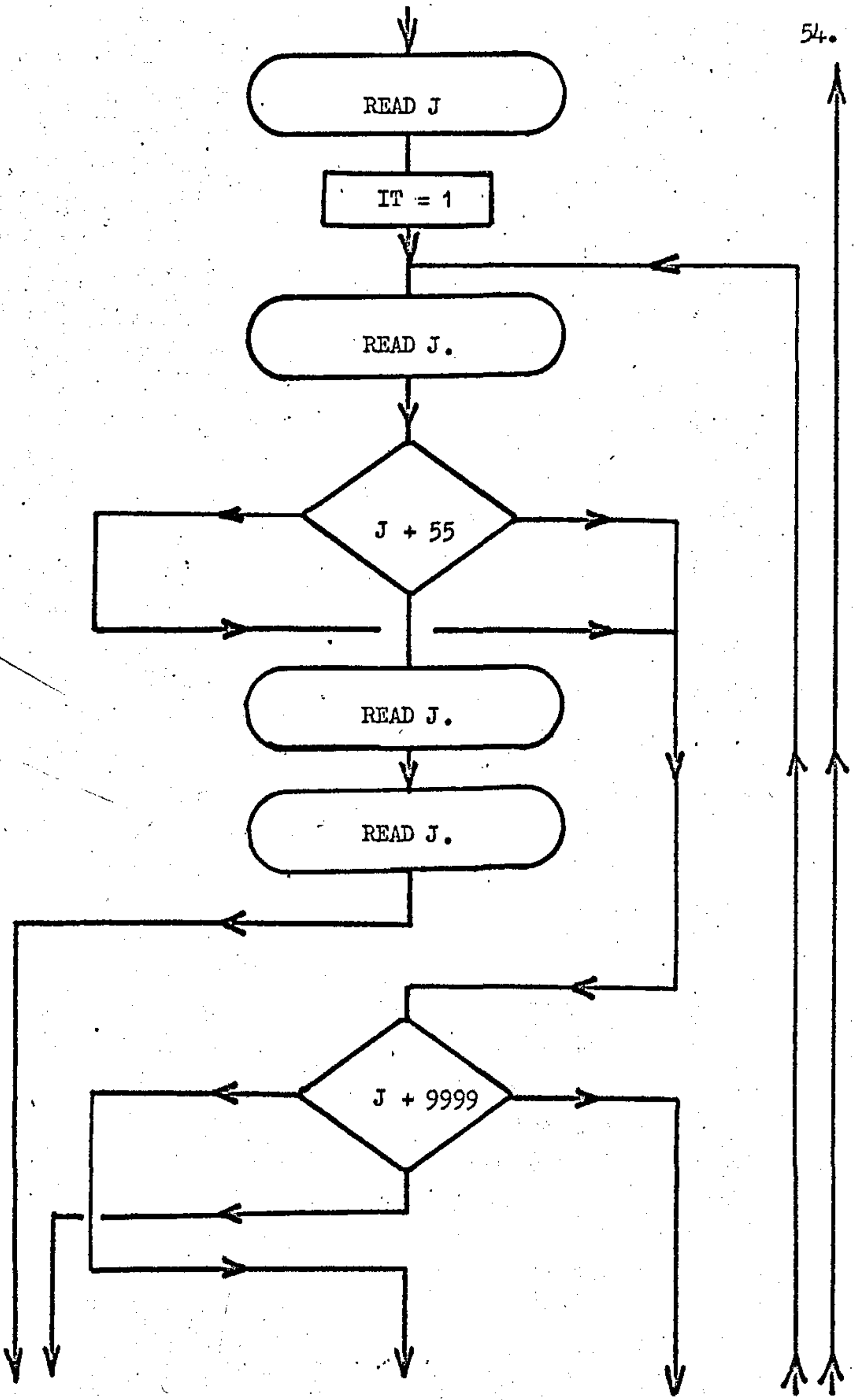


FIGURE (8.4).

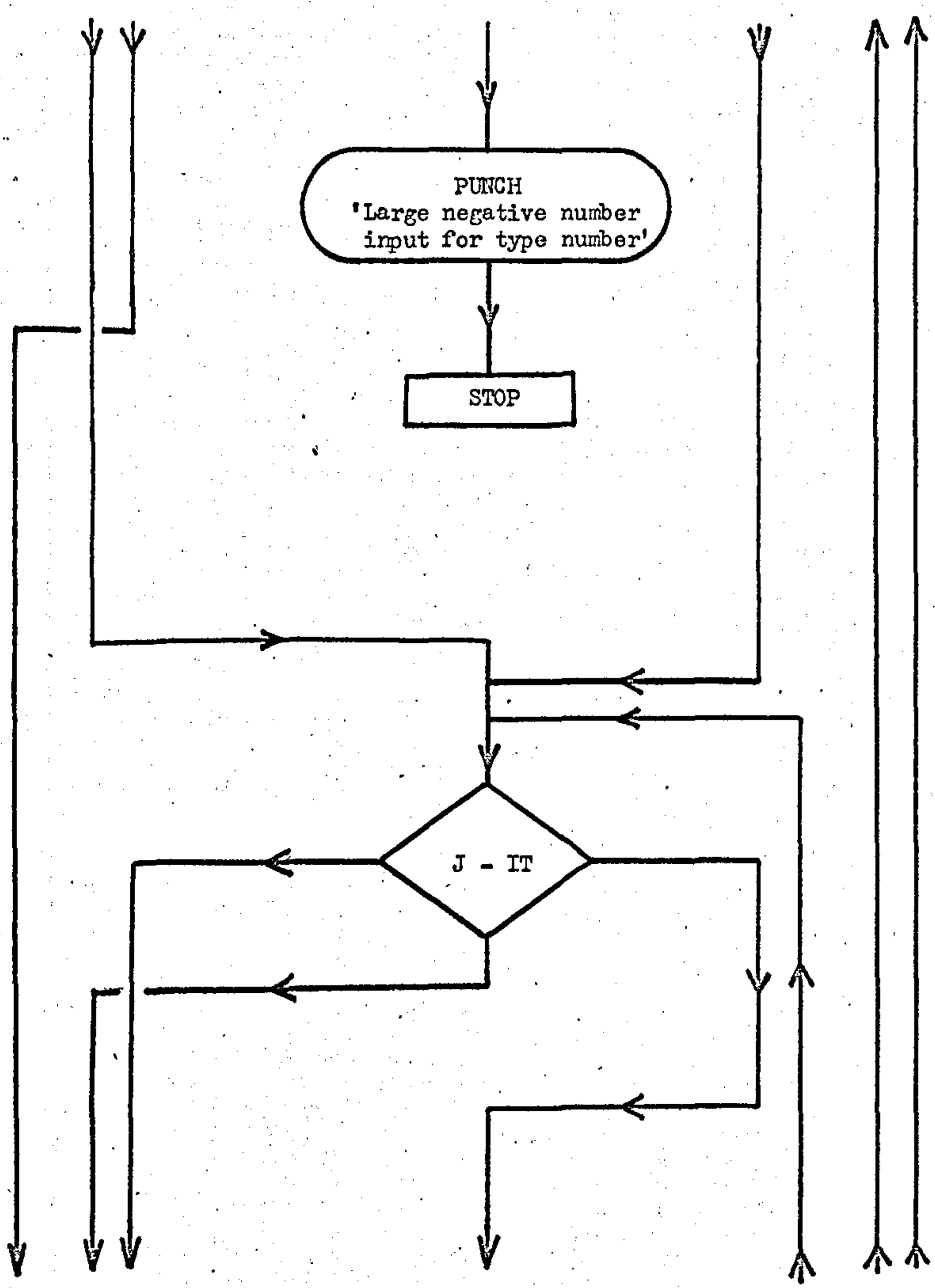


FIGURE (8.5).

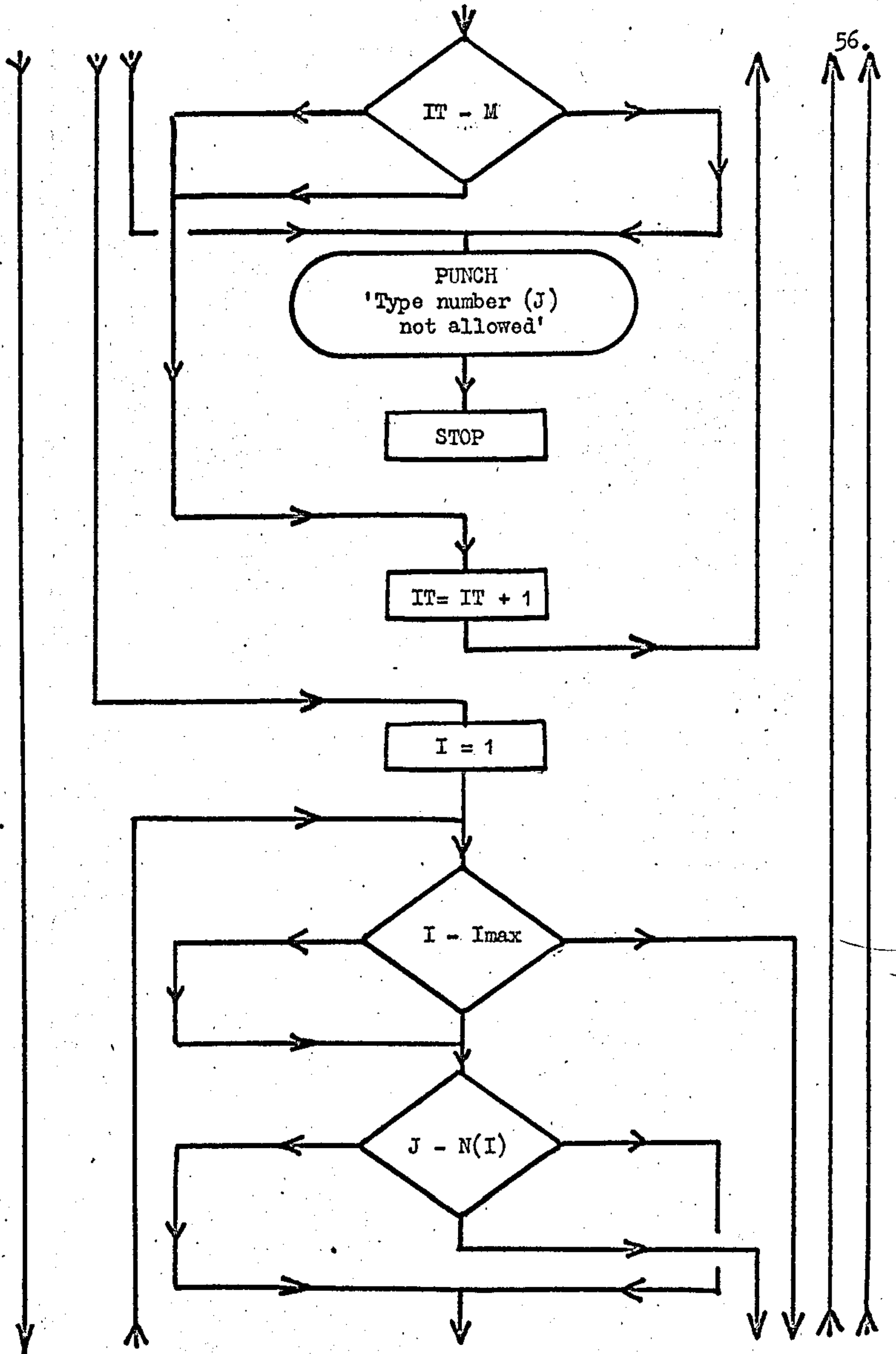


FIGURE (8.6)

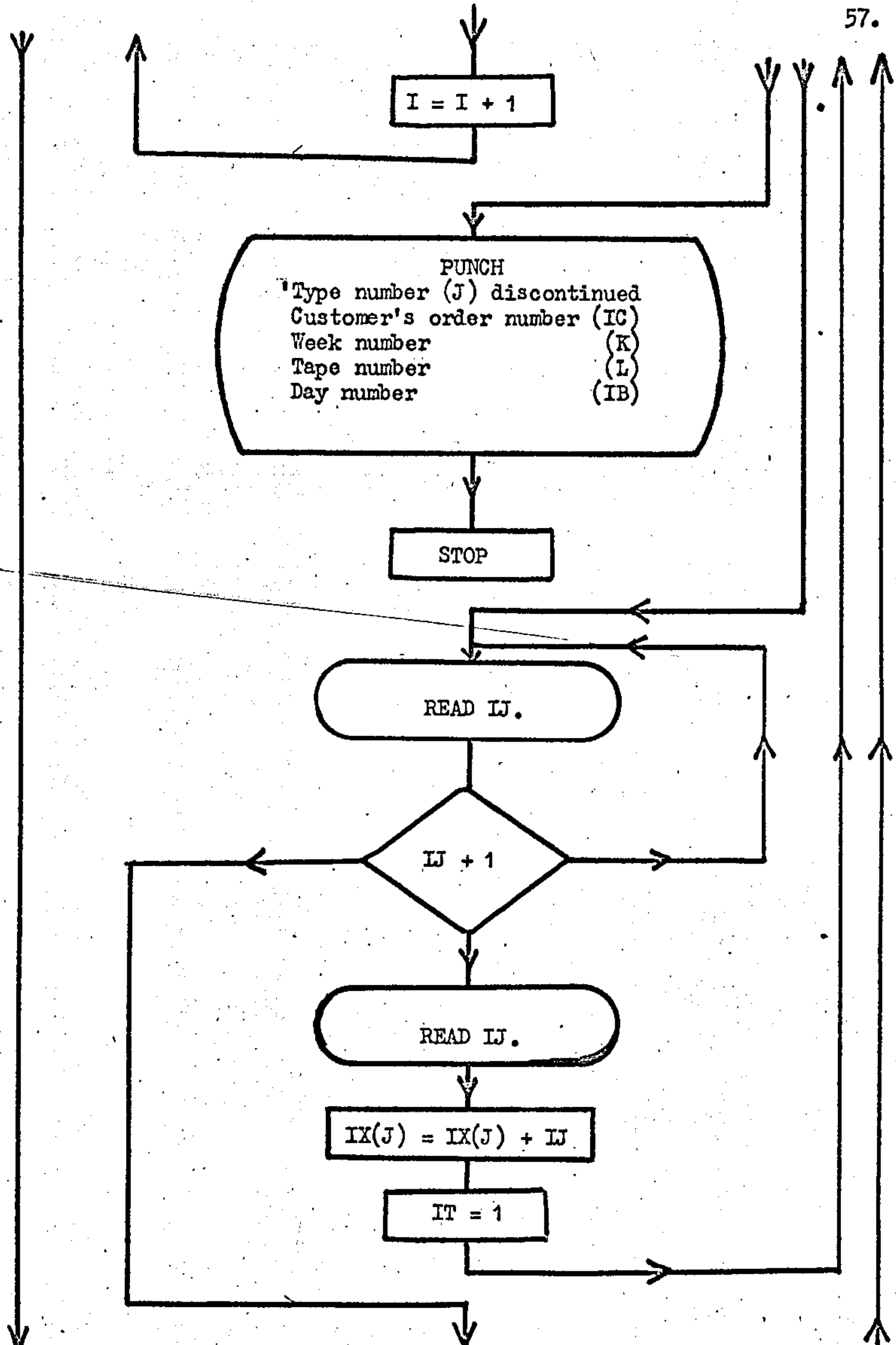

I = I + 1
PUNCH
Type number (J) discontinued
Customer's order number (IC)
Week number (K)
Tape number (L)
Day number (IB)
STOP
READ IJ.
IJ + 1
READ IJ.
IX(J) = IX(J) + IJ
IT = 1

FIGURE (8.7).

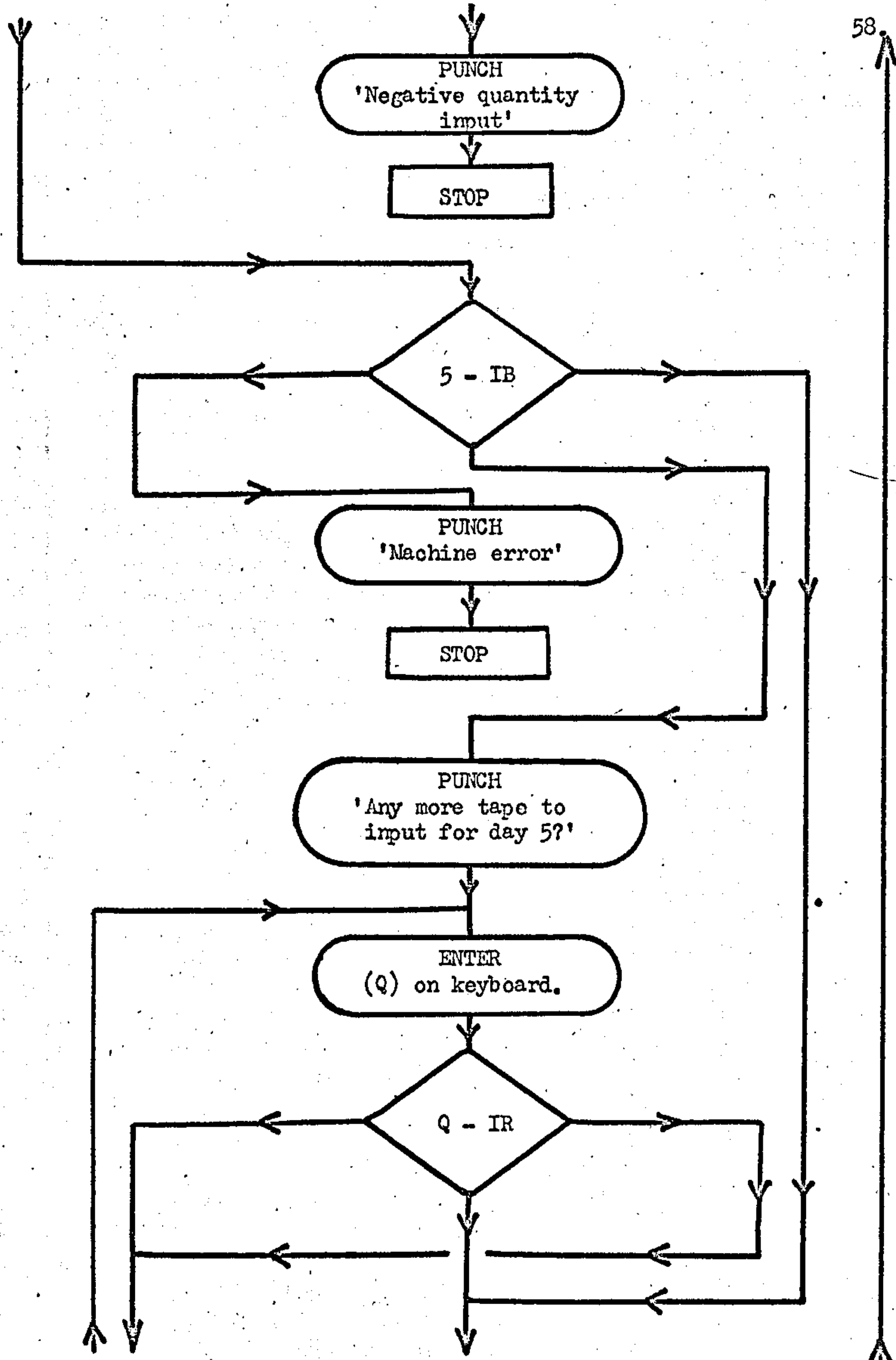

PUNCH
'Negative quantity input'
STOP
5 - IB
PUNCH
'Machine error'
STOP
PUNCH
'Any more tape to input for day 5?'
ENTER
(Q) on keyboard.
Q - IR

FIGURE (8.8).

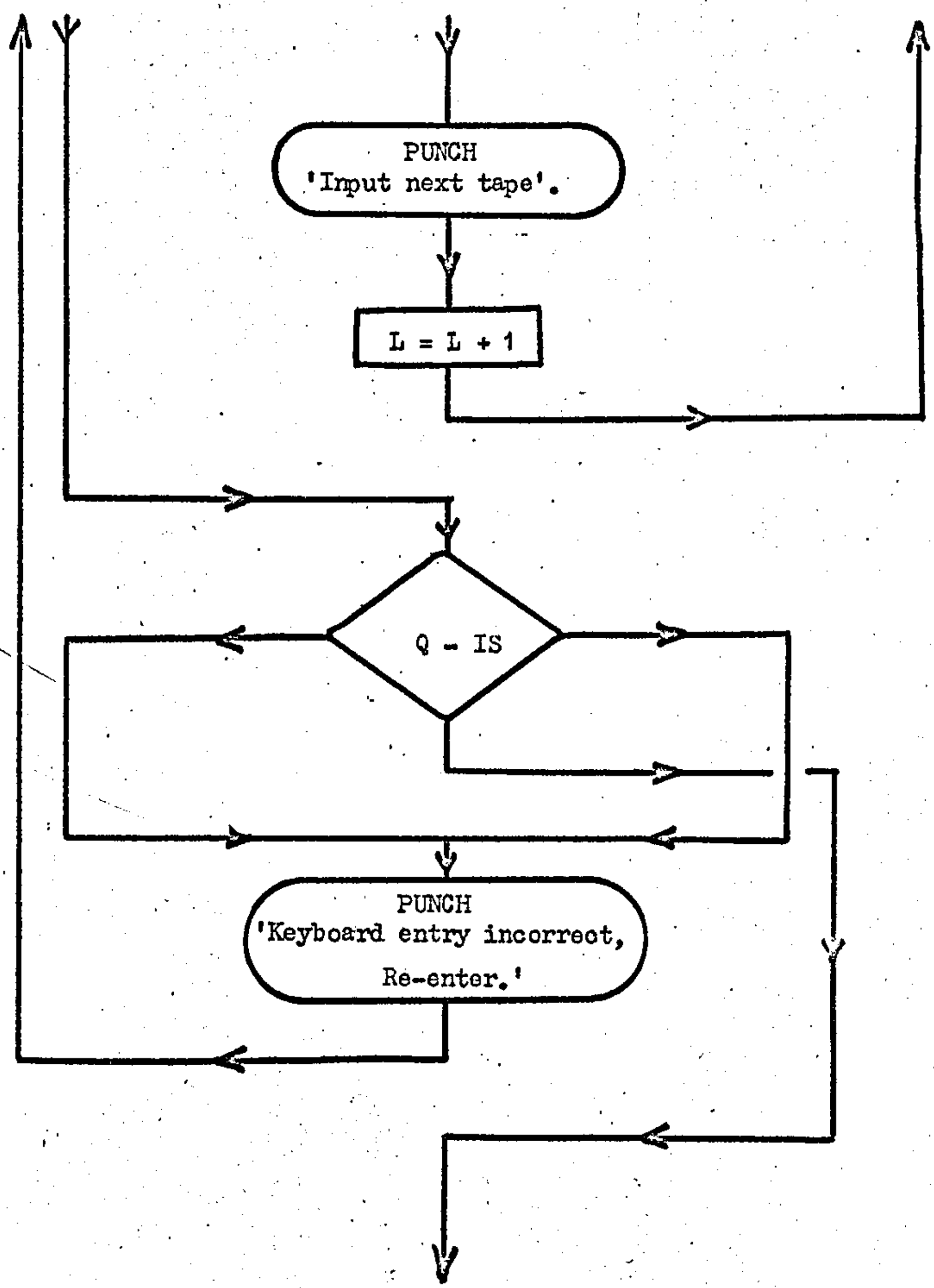

PUNCH
'Input next tape'.
L = L + 1
Q - IS
PUNCH
'Keyboard entry incorrect,
Re-enter.'

FIGURE (8.9).

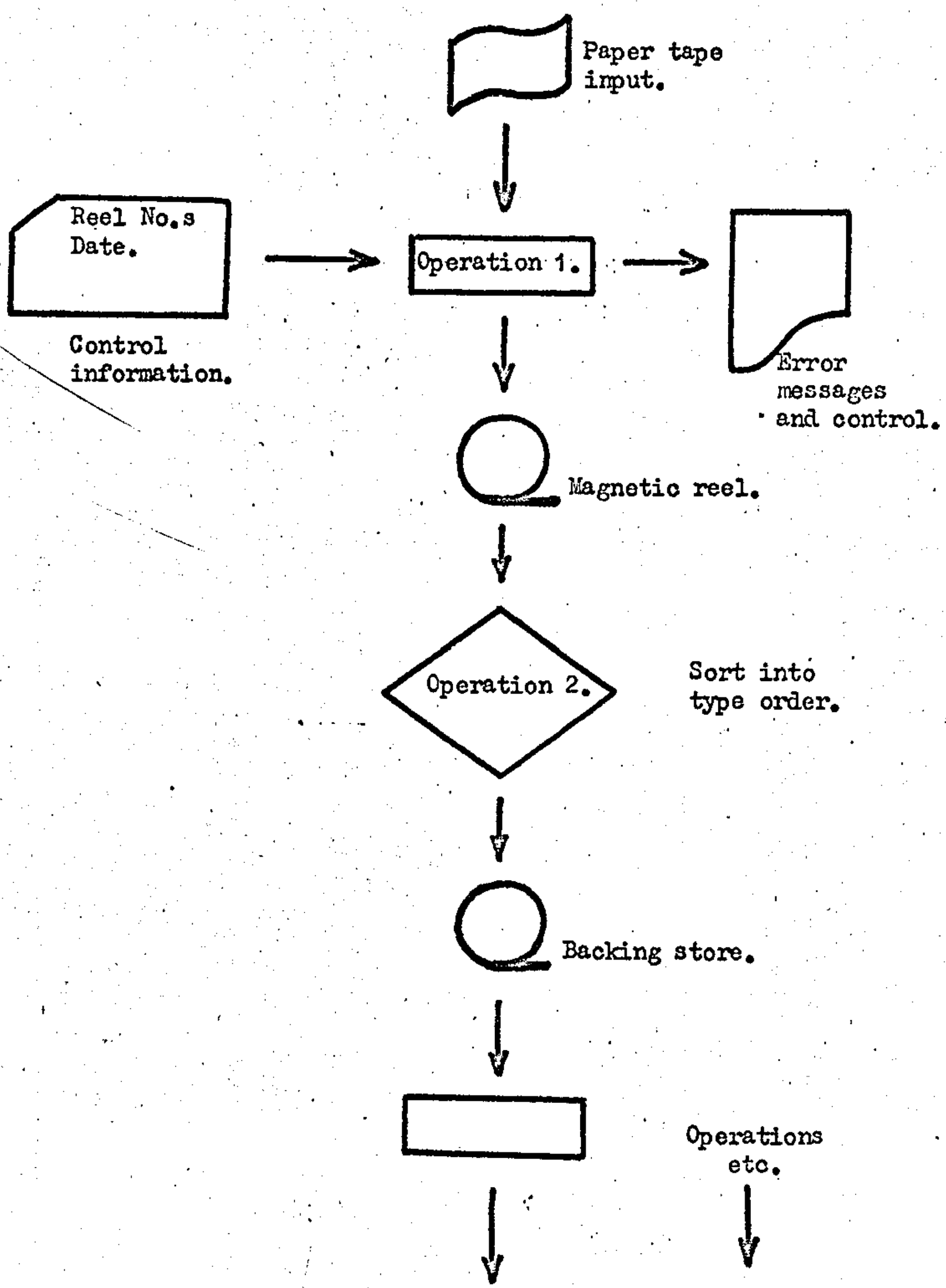

Paper tape input.
Reel No.s Date.
Control information.
Operation 1.
Error messages and control.
Magnetic reel.
Operation 2.
Sort into type order.
Backing store.
Operations etc.

FIGURE (9).

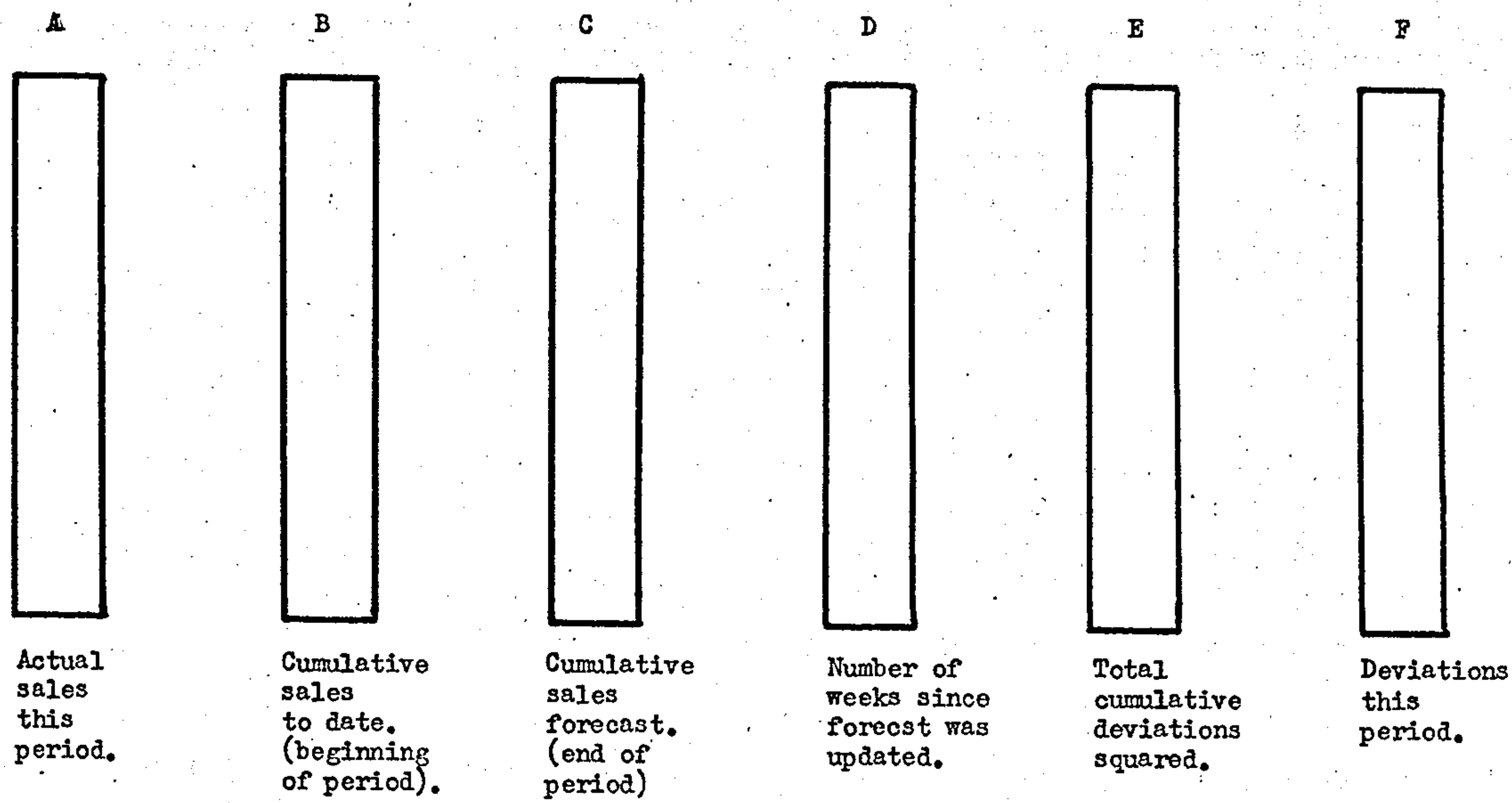
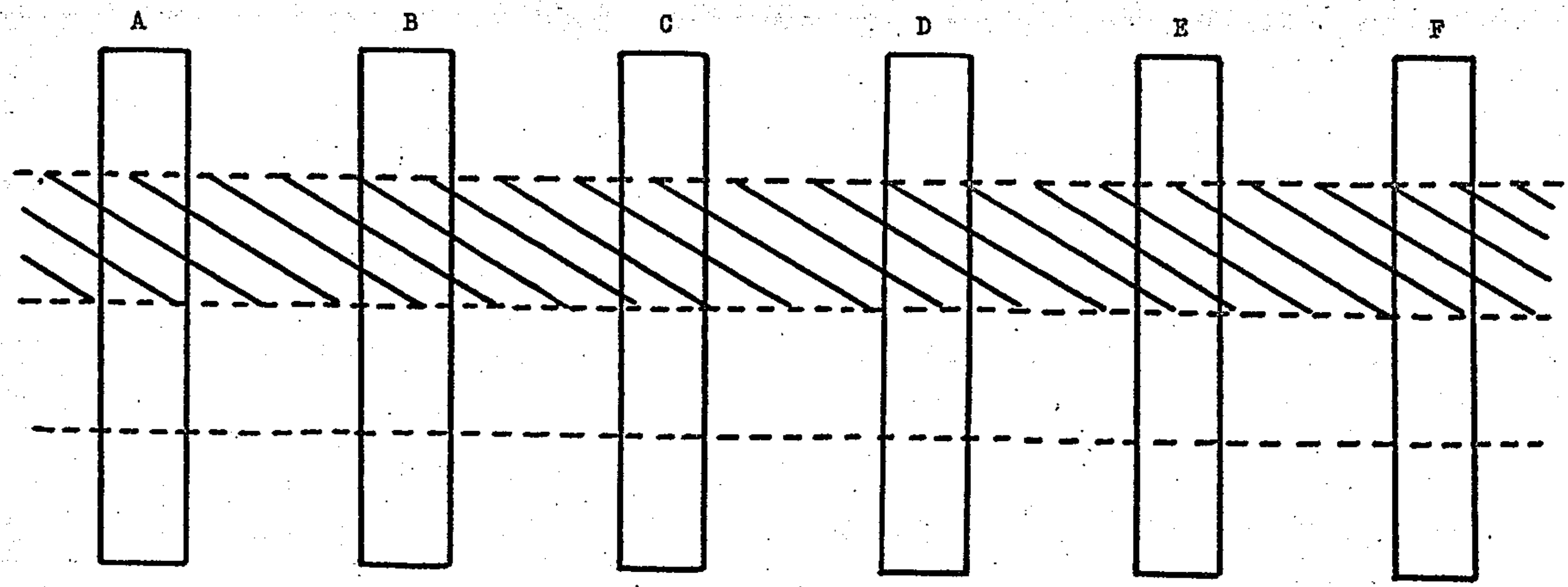

A
B
C
D
E
F
Actual sales this period.
Cumulative sales to date. (beginning of period).
Cumulative sales forecast. (end of period)
Number of weeks since forecst was updated.
Total cumulative deviations squared.
Deviations this period.

FIGURE (10).



i). Take shaded section into core store leaving rest in back-up store and perform the operations on that section.

ii). Replace the section into the back-up store after the operation and then bring down the next section, etc.

FIGURE (11).

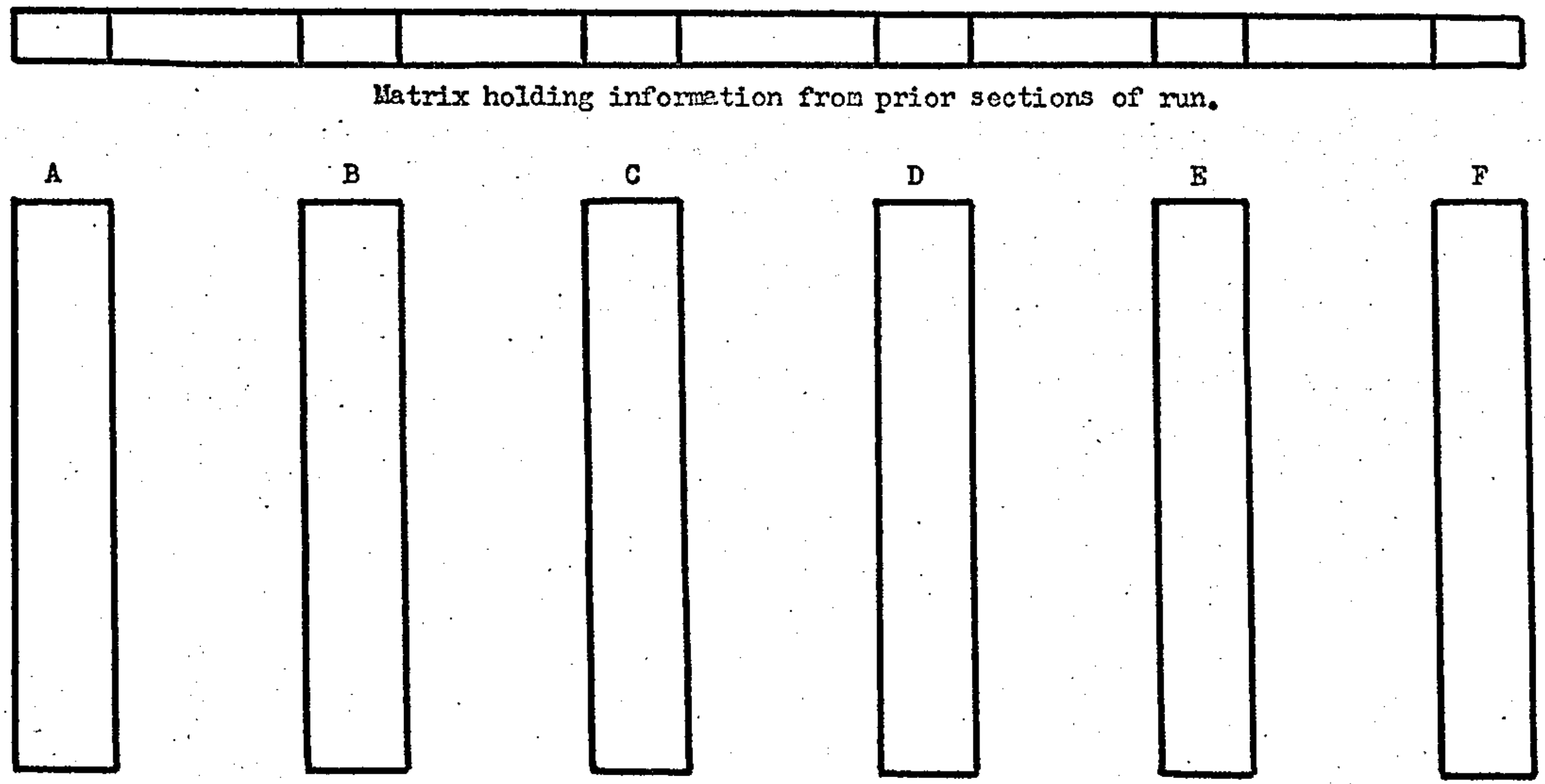

Matrix holding information from prior sections of run.
A
B
C
D
E
F

FIGURE (12).

STEP 1.

Build up sales to date;

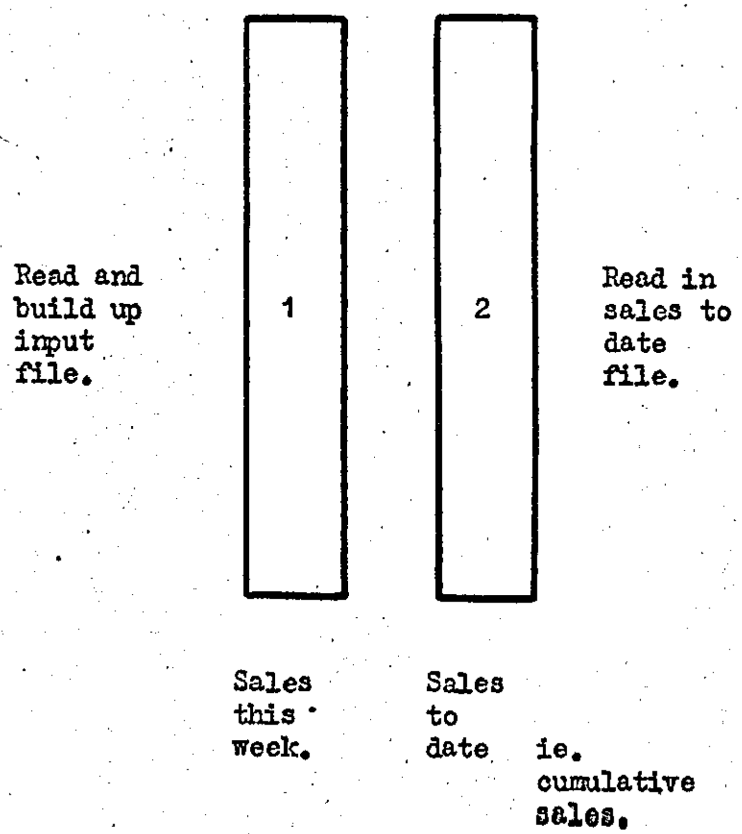


FIGURE (13.1).

STEP 3.

Build up new difference file;

Take the difference between file 2 and file 5 item by item and place in the corresponding position in file 4, overwriting file 4.

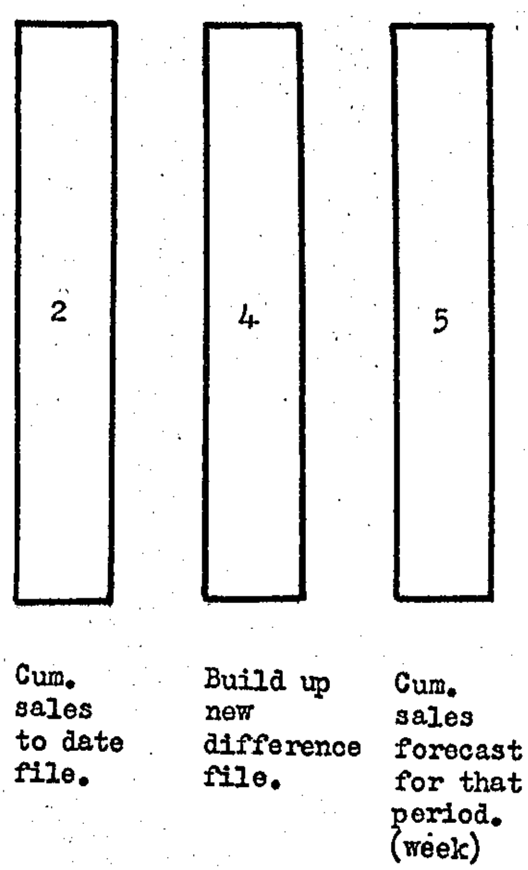


FIGURE (13.3).

STEP 2.

Build up cumulative difference file;

Add the square of items in file 4 to items already stored in file 3, item by item.

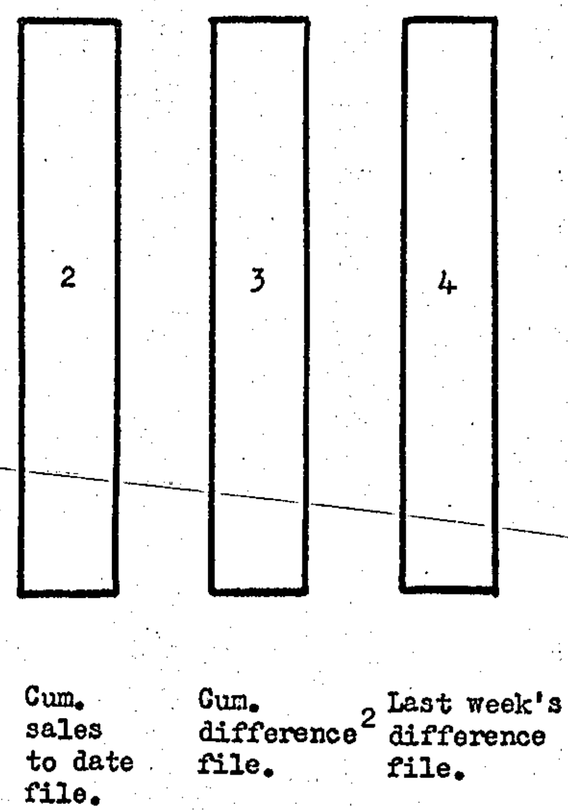


FIGURE (13.2).

STEP 5.

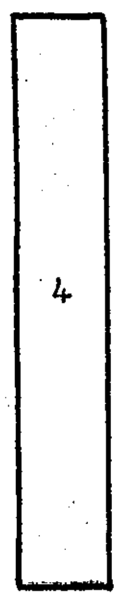
Compute confidence limits;

Multiply the result obtained from step 4 by each of the constants supplied by the company management. eg. Warning limit at 1.97, and action limit at 3.00, or other such figures as the company management may require.

STEP 6.

Check this week's deviations;

Compare file 4, item by item, against the two values computed in step 5. Punch out any file 4 greater values.



This week's difference file.

STEP 7.

Estimate accuracy;

Punch out the values obtained in steps 4 and 5.

FIGURE (13.5).

STEP 4.

Compute standard deviation;

Total the squares of the items in file 4, and add this to the total of the values in file 3. Then divide this figure by the figure obtained from counting the number of entries in file 4 and adding this value to the total of the entries in file 6. The square root of this value gives us our estimated standard deviation.

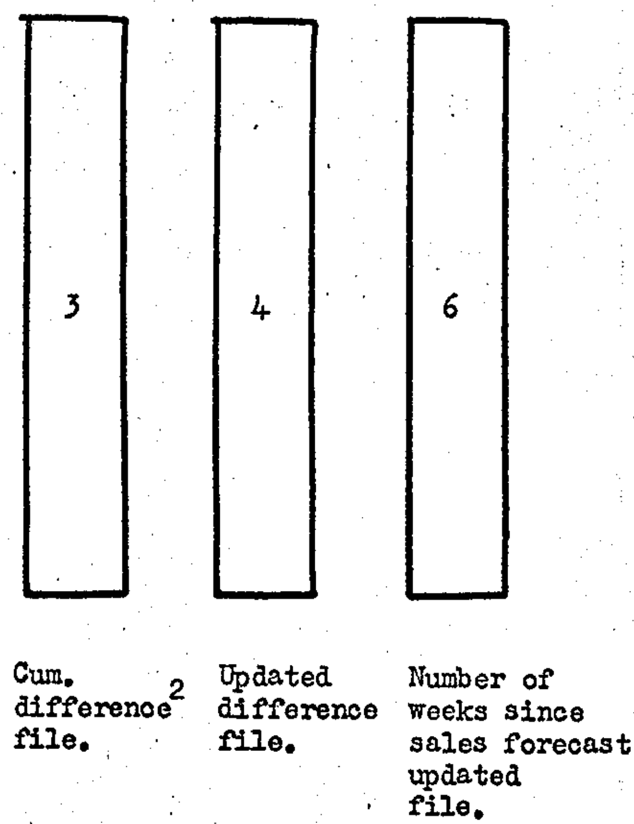


FIGURE (13.4).

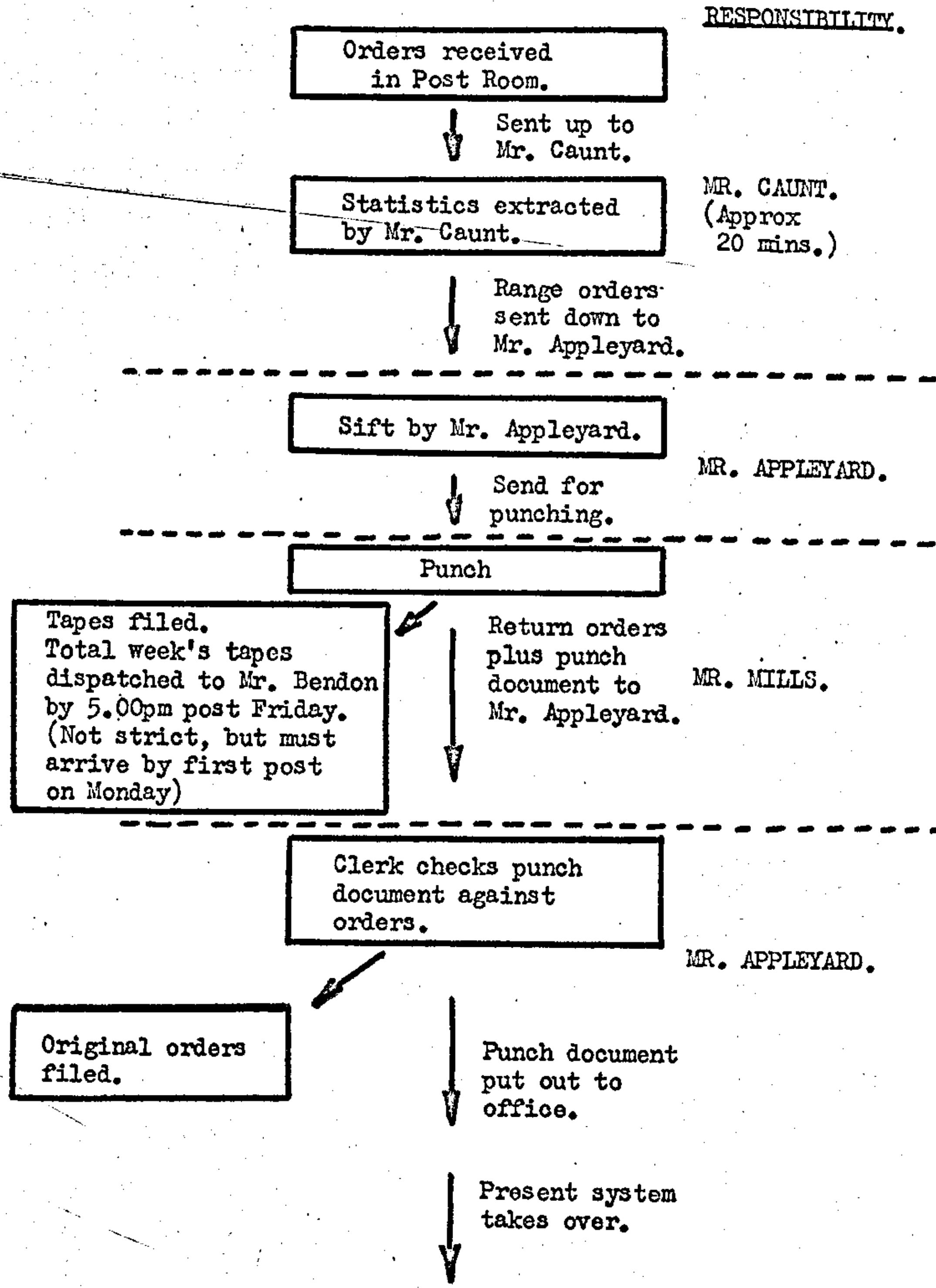

RESPONSIBILITY.
Orders received in Post Room.
Sent up to Mr. Caunt.
Statistics extracted by Mr. Caunt.
MR. CAUNT. (Approx 20 mins.)
Range orders sent down to Mr. Appleyard.
Sift by Mr. Appleyard.
Send for punching.
MR. APPLEYARD.
Punch
Tapes filed.
Total week's tapes dispatched to Mr. Bendon by 5.00pm post Friday.
(Not strict, but must arrive by first post on Monday)
Return orders plus punch document to Mr. Appleyard.
MR. MILLS.
Clerk checks punch document against orders.
MR. APPLEYARD.
Original orders filed.
Punch document put out to office.
Present system takes over.

FIGURE (14).

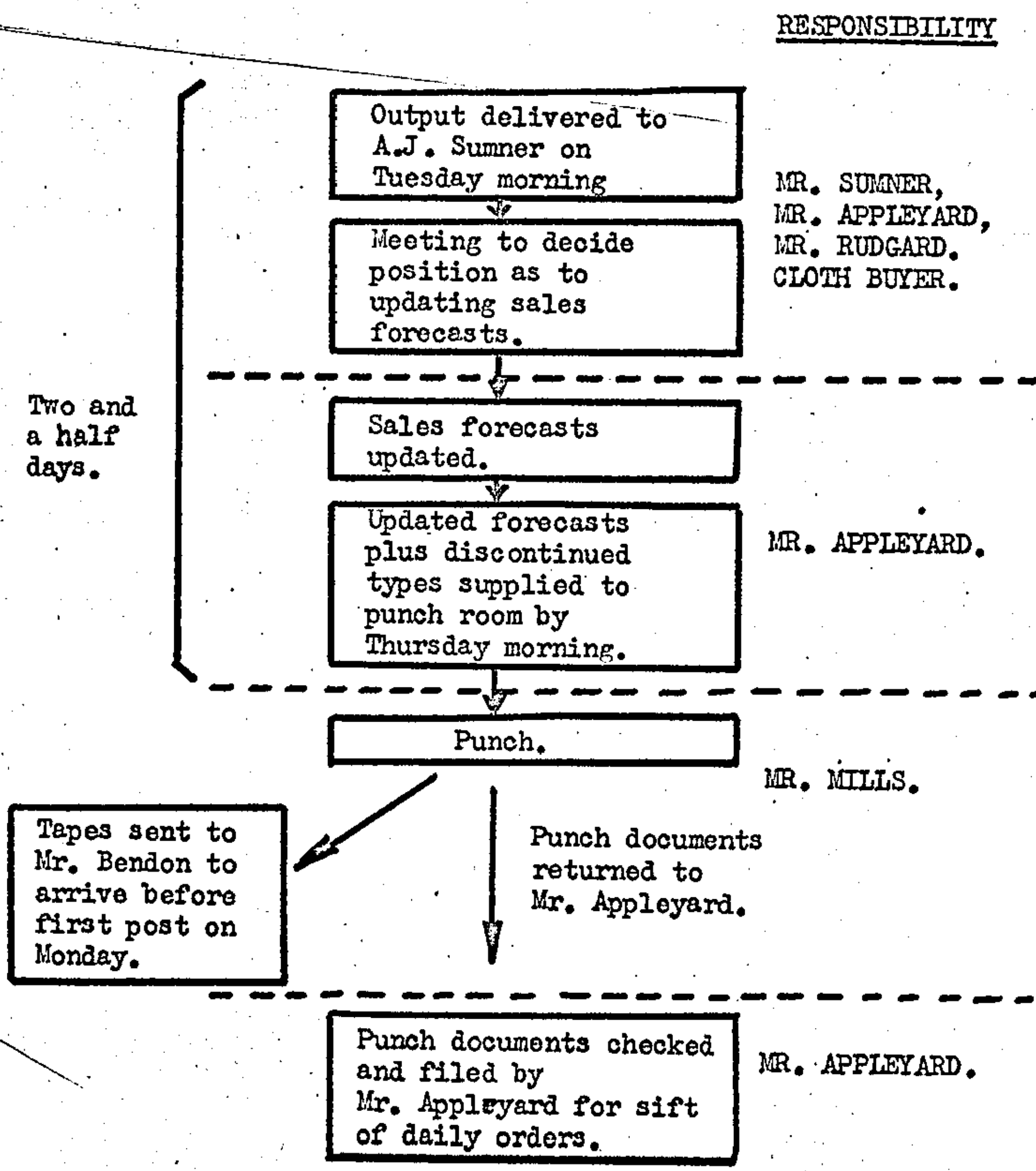

RESPONSIBILITY
Output delivered to A.J. Sumner on Tuesday morning
Meeting to decide position as to updating sales forecasts.
MR. SUMNER, MR. APPLEYARD, MR. RUDGARD. CLOTH BUYER.
Two and a half days.
Sales forecasts updated.
Updated forecasts plus discontinued types supplied to punch room by Thursday morning.
MR. APPLEYARD.
Punch.
MR. MILLS.
Tapes sent to Mr. Bendon to arrive before first post on Monday.
Punch documents returned to Mr. Appleyard.
Punch documents checked and filed by Mr. Applеyard for sift of daily orders.
MR. APPLEYARD.

FIGURE (15).

MONDAY MORNING RUN.

Order of jobs;

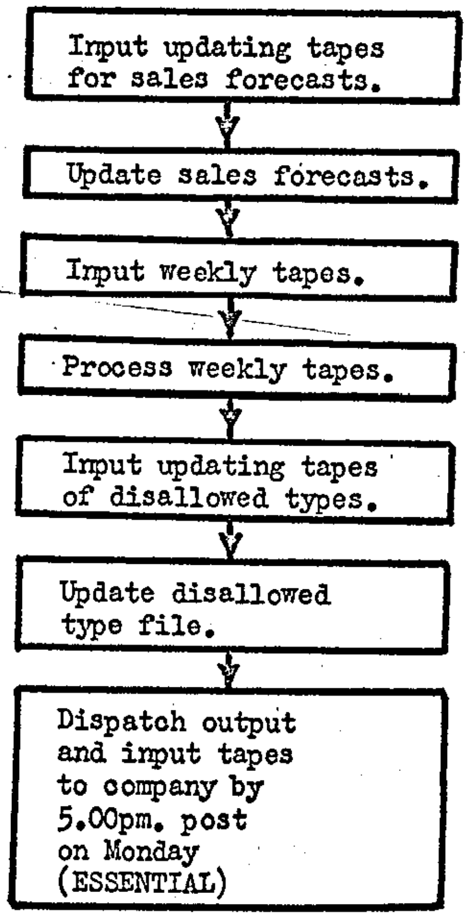


FIGURE (16).

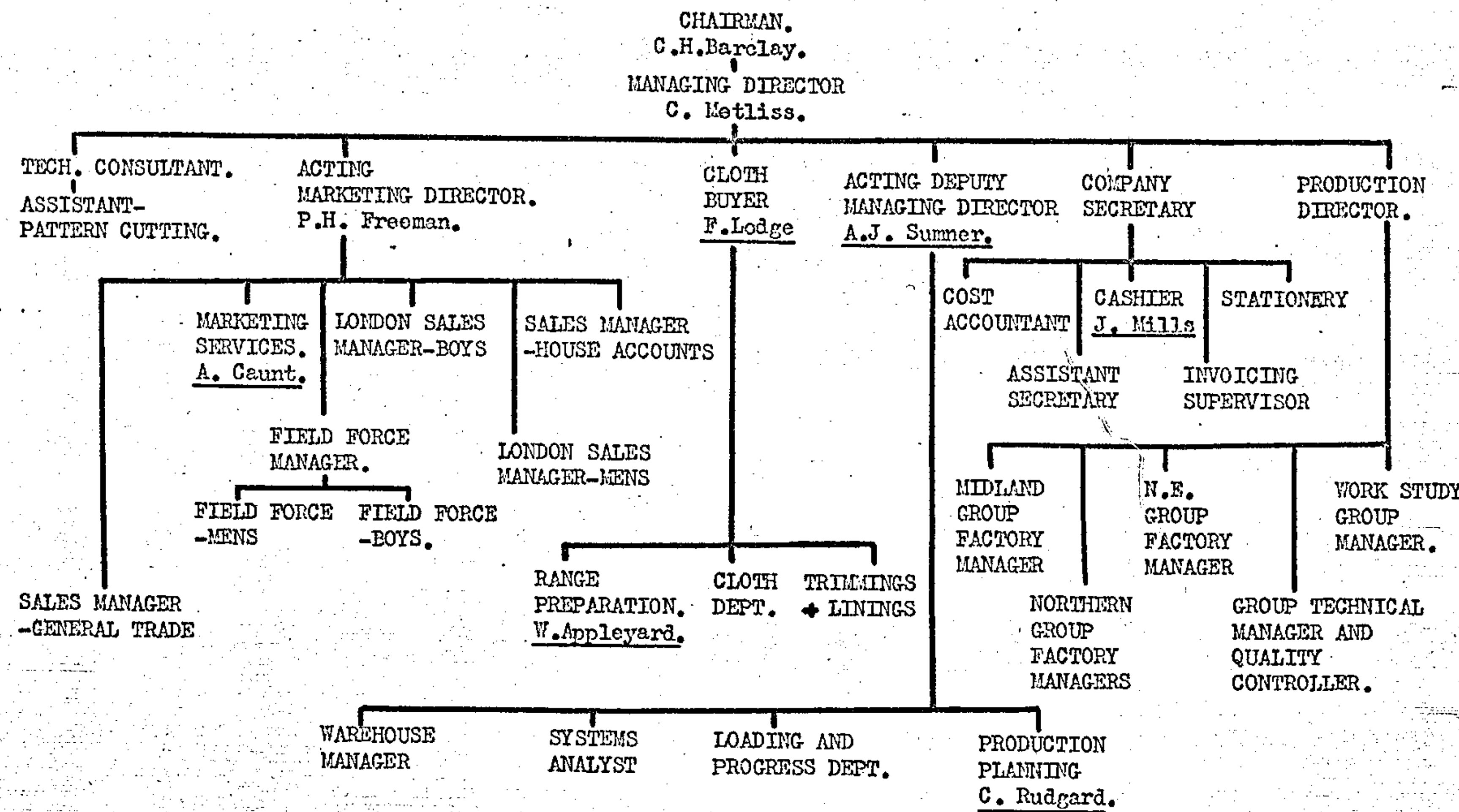

CHAIRMAN.
C.H.Barclay.
MANAGING DIRECTOR
C. Metliss.
TECH. CONSULTANT.
ASSISTANT-
PATTERN CUTTING.
ACTING
MARKETING DIRECTOR.
P.H. Freeman.
CLOTH
BUYER
F.Lodge
ACTING DEPUTY
MANAGING DIRECTOR
A.J. Sumner.
COMPANY
SECRETARY
PRODUCTION
DIRECTOR.
MARKETING
SERVICES.
A. Caunt.
LONDON SALES
MANAGER-BOYS
SALES MANAGER
-HOUSE ACCOUNTS
FIELD FORCE
MANAGER.
LONDON SALES
MANAGER-MENS
FIELD FORCE
-MENS
FIELD FORCE
-BOYS.
SALES MANAGER
-GENERAL TRADE
RANGE
PREPARATION.
W.Appleyard.
CLOTH
DEPT.
TRIMMINGS
+ LININGS
COST
ACCOUNTANT
CASHIER
J. Mills
STATIONERY
ASSISTANT
SECRETARY
INVOICING
SUPERVISOR
MIDLAND
GROUP
FACTORY
MANAGER
NORTHERN
GROUP
FACTORY
MANAGERS
N.E.
GROUP
FACTORY
MANAGER
GROUP TECHNICAL
MANAGER AND
QUALITY
CONTROLLER.
WORK STUDY
GROUP
MANAGER.
WAREHOUSE
MANAGER
SYSTEMS
ANALYST
LOADING AND
PROGRESS DEPT.
PRODUCTION
PLANNING
C. Rudgard.

FIGURE (17).

APPENDIX 3.

Correspondence.

TO See Distribution List
FROM Mr. A.J. Sumner
DATE 14th July, 1966.

INTER-DEPARTMENTAL MEMO

Range Order Analysis

Loughburough University

Loughburough University have a Management Studies Faculty which undertake practical projects in industry. I have arranged for one of their graduate staff (Mr. Heyhurst) to examine the problem of range order analysis which will be part of his thesis for his M.Sc. He will be joining us on Monday, 18th July and will share Mr. Linley's office. His brief will be as follows:

1. To determine how we can analyse incoming range orders so that comparisons can be made with our cloth availability and production capacity forecasts.

2. How this order analysis can be used for forecasting the total season's sales.

He is programmed to complete this work by the end of August so that it can be given practical application during the range selling season, September/October.

I should be grateful if everyone gives him full co-operation in his activities.

A.J. Sumner

Distribution List

Mr. D. Linley
Mr. C.R. Farrar
Mr. W. Appleyard
Mr. A. Caunt

Mr. C. Metliss } for information
Mr. P.H. Freeman }

FIGURE (18).

27th July, 1966.

J. Bendon, Esq.,
[redacted]
London, W.C.1.

Dear James,

As you know, we have been able to avail ourselves of the services of Mr. Hayhurst, who is doing some original work on the subject of order analysis, sales forecasting, and production planning for us. I enclose a copy of my original memo on this subject which details his brief in broad terms.

If I may expand on this, what we are trying to do is to arrive at a method of order analysis and sales forecasting that allows us to maximise the market potential at any moment of time, bearing in mind the restraints of cloth availability, production capacity and stock levels, etc.

The work that Mr. Hayhurst has so far done has produced some very interesting thoughts as to how we might tackle this problem, but the following facts emerge:

1. that any system we need is likely to be very sophisticated and must, therefore, involve the use of a computer,

2. that it will be impossible to introduce this kind of system in time for the next selling season in September and,

3. that we have very inadequate data on which to arrive at the basic concepts involved.

It is, however, already clear that no matter how far we progress with Mr. Hayhurst's suggestions, a vital first step is the computerisation of order receipt and analysis. Mr. Hayhurst will be writing to you separately to expand his thoughts on the matter.

FIGURE (19).

It is very important that we go quickly on this so that we can take into account next season's selling. I have no doubt that even though it is difficult, you will help us find a way of achieving this, and the work you have already done on the sales ledger should prove valuable when analysing orders.

Yours sincerely,

A.J. Sumner

27th July, 1966.

J. Bendon, Esq.,
[redacted].,
London, W.C.1.

Dear Mr. Bendon,

Further to Mr. Sumner's letter of today's date, I herewith enclose a brief draft of our initial proposals for your perusal, prior to the meeting on August 5th.

Yours faithfully,
[redacted]

G. Hayhurst

FIGURE (20.1)

27th July, 1966.

RANGE ORDER ANALYSIS PROPOSALS.

The problem is basically one of the computation of statistically significant variations from forecast sales which can be implemented immediately.

It is necessary to store the sales forecast in a backing store, possibly in the form of a 2-D matrix of size equal to the number of lines by the number of weeks per season (approx. 12).

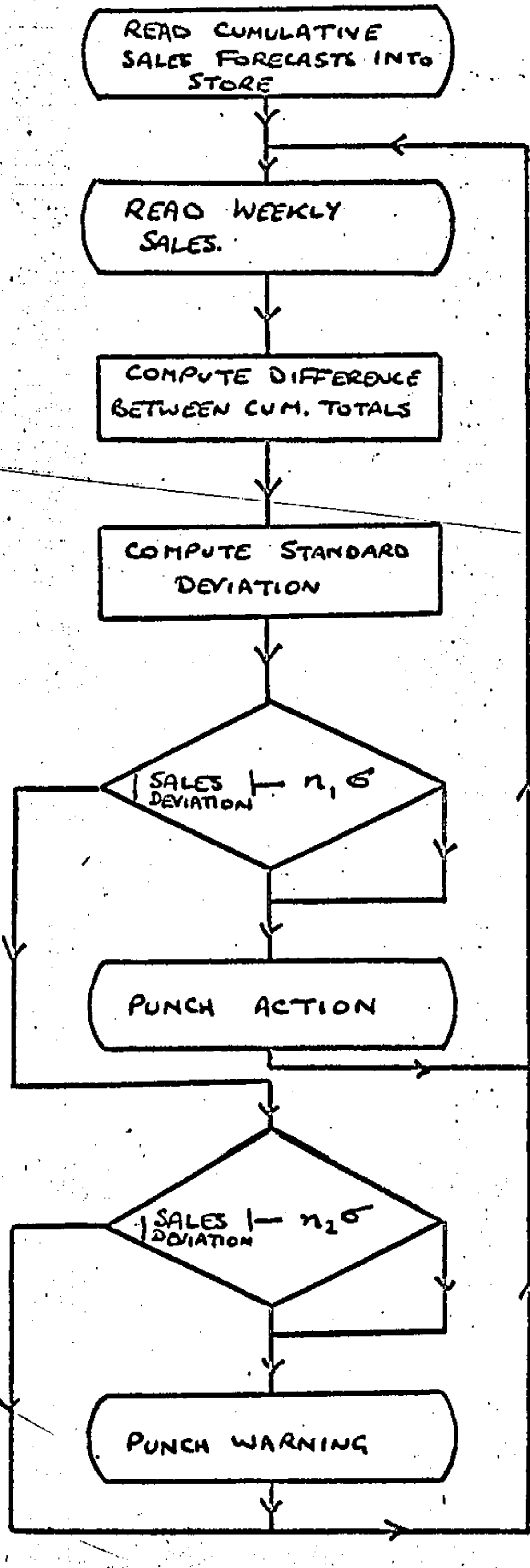
We could possibly punch our weekly sales on our N.C.R. punch-verifier unit, then send this down to you for comparison with our weekly sales forecast. The resulting deviations being accumulatively collected and the standard deviation to date worked out. The new deviations being then checked against multiples of the newly obtained standard deviation figure with the larger deviations being punched out, and returned to the [redacted] Management. The system roughly following the flow chart overleaf.

The [redacted] Management will then make decisions on receipt of this information, which will require the updating of the sales forecast store to new values supplied by [redacted] together with the deletions from the cumulative deviation file corresponding to the updated matrix row. The process of weekly sales comparison being continued with the updated system.

The problem, as I see it, is primarily one of "House-keeping" at your end.

G. HAYHURST.

FIGURE (20.2).



READ CUMULATIVE SALES FORECASTS INTO STORE
READ WEEKLY SALES.
COMPUTE DIFFERENCE BETWEEN CUM. TOTALS
COMPUTE STANDARD DEVIATION
|SALES DEVIATION| ⊢ $n_1 \sigma$
PUNCH ACTION
|SALES DEVIATION| ⊢ $n_2 \sigma$
PUNCH WARNING

FIGURE (20.3).

G. Hayhurst.

11th August, 1966.

R.A. Fawthrop, Esq.,
Department of Industrial Engineering
and Management,
University of Technology,
Loughborough,
Leicestershire.

Dear Mr. Fawthrop,

I am pleased to confirm the discussions which took place at our meeting on Friday last and my subsequent discussions with Mr. Hayhurst.

1. It was decided that the sales forecast and order analysis methods being developed by Mr. Hayhurst in connection with our range selling programme, are unlikely to be computerised in time for the next selling season in September, 1966. It was, therefore, decided he should continue his work by planning to implement these ideas for the following selling season occurring next February/ March, 1967.

2. As part of his programme, Mr. Hayhurst will prepare a timetable and description of the steps necessary to implement these methods, both of which have been discussed and agreed in principle by Mr. J. Bendon.

3. It was agreed that Mr. Hayhurst should operate in Leeds for approximately a further two weeks so that he may complete the above tasks and also prepare his thesis which he anticipates would be in a form that would provide the information specified in paragraph 2 above.

Thank you for your continuing help.

Yours truly,

A.J. Sumner

FIGURE (21;).

G. Hayhurst, Esq.,
[redacted]
LEEDS 1.

19th July, 1966

Dear Mr. Hayhurst,

Following our telephone conversation yesterday afternoon, I am enclosing a descriptive brochure on the GE-415. The configuration which we have comprises:

GE-415 Central Processor		
16 K words core storage		
6 magnetic tape units 1	-	40 Kc
1 card reader	-	900 cpm
1 card punch	-	100 cpm
1 paper tape reader	-	500 cps
1 paper tape punch	-	150 cps
1 line printer	-	1200 lpm
1 console typewriter	-	15 cps

A full range of software is available including:

FORTRAN IV
COBOL '61
Sort and Merge
RPG
LP, CPM, PERT etc.
Mathematical library
Utility library

I trust this gives you the information you need, but please do not hesitate to contact me for any further details.

Yours sincerely,

James Bendon

FIGURE (22).