THE DEVELOPMENT OF A MANPOWER PLANNING MODEL

by

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ABSTRACT

In recent years a number of personnel planning techniques and manpower models have been developed to improve long range planning in the personnel field. A review of the literature on manpower planning revealed that models had been developed to consider quite specific problems and that the quantitative techniques had considered only a very simple manpower structure.

The simplicity of the existing models, together with the widely varying assumptions upon which the models were based, indicated that the factors to be included in a general manpower planning model required investigation.

The investigation demonstrated that one of the major weaknesses of the existing models was their failure to include provision for promoting employees through a hierarchical structure. The decision was made to construct a forecasting model which included this feature together with the other factors required to forecast labour requirements for production workers and non-professional staff positions.

A model was constructed to reflect these factors and a computer programme written for the model. Initial investigations with the model indicated that promotions increased exponentially as turnover increased, and that the timing of hiring decisions depended upon the training times in the

organizational structure. The conclusion of this investigation was that the hierarchical structure would be required in a general model. The existing models may be underestimating the time lags and training costs by failing to consider promotions.

The study concluded with an analysis of the problems that would be encountered in constructing a more complex model and in adding cost-optimizing features to it.

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CHAPTER I

INTRODUCTION

The increasing organizational complexity of society has led to the development of decision-making procedures and techniques in a number of areas. For many years, while progress was being made in other fields, manpower utilization decisions were based on bar charts and other simple graphical techniques. Recently, a number of investigators have realized the potential for new developments in this field. This has led to the development of methods for making manpower planning decisions under certain, well specified, conditions.

I. THE PROBLEM

Statement of the Problem. The purpose of this study was to (1) investigate the factors to be considered in a general manpower planning model, (2) construct a general model which could be used for manpower planning by a number of organizations, (3) investigate the effects of certain parameters on the manpower system.

Importance of the Study. As corporations grow in size and diversity of operations and try to cope with new markets and rapid technological change, sophisticated long range plans become increasingly important. Governments must plan, build and maintain complex administrative services in a large

number of fields. Because of the overriding importance of personnel, manpower planning is an important component of any aggregate planning system.

Manpower planning is also becoming important as a field by itself. The increasing complexity of many industrial operations has led to the need for a fully trained work force at all times. The increasing rate of technological change and the specialization required for many jobs has made it difficult to hire personnel with the requisite skills and has placed greater demands on industrial training. The undesirable location of some operations has led to a continuing shortage of skilled personnel in certain industries. Thus, whether manpower planning is to be considered as part of an aggregate plan or as a separate entity, it is extremely important to both corporate and governmental organizations.

Limitations of the Study. Manpower planning has been defined to include a specification of the kinds and numbers of men required to accomplish the organization's objectives; a forecast, from current personnel inventories, of how well the future needs can be met; and, by comparing needs to supply, the formulation of plans for recruiting, assigning and developing personnel.[1] This study was limited to the forecasting aspects of manpower planning. The specification

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[1]W.R. Dill, D.P. Gaver and W.L. Weber, "Models and Modelling for Manpower Planning," Management Science, XIII, No. 4, (December, 1966), pp. 142.

of hiring requirements, the hiring process and training were not investigated except as they relate to the forecasting procedure. Because the study was limited to the forecasting aspects of planning, individual characteristics of the workers were neglected. The worker was considered strictly as a member of a group exhibiting certain characteristics related to their employment.

II. CHAPTER OUTLINE AND DEFINITION OF TERMS

Chapter Outline

The remainder of this chapter is devoted to the definition of special terms used in the study and to a review of existing manpower models. Chapter II contains a detailed discussion of the factors to be considered in building a general manpower planning model. A simulation model, which would be applicable to certain non-managerial employees, is developed in Chapter III. Chapter IV contains a few brief examples of the model's decisions together with a discussion of the effects of several major parameters. The study concludes with a comparison of the general model to other types and a discussion of the future developments in the use of manpower planning models.

Definitions of Terms

Job Category. A group of tasks for which training is required. The job in the organization must be grouped

according to the training required and the position of the job in the organization's hierarchical structure.

Labour Force Required. The "labour force required" is the number of personnel desired for each job category in each future decision period.

Regular Labour Force. The "regular labour force" is the number of fully trained employees available for work at the present time.

Training Delay. The "training delay" is defined as the time lapse between when the decision is made to hire or promote a worker and when the worker joins the regular work force. It includes both the time lag in hiring and the training time.

Labour Pool. The "labour pool" is the maximum number of employees that may be hired in a decision period.

Labour Turnover. For the purposes of this study "labour turnover" considers only the employees who voluntarily terminate their employment. The "turnover rate" is actually the quit rate and does not include personnel who are discharged or laid off.

III. A REVIEW OF EXISTING MODELS

A number of manpower planning models have been constructed and reported in the literature. In most instances these models have been developed to deal with specific and rather limited situations. Several of the more detailed

models are discussed below, together with a brief outline of other models which have considered the manpower function.

Gotterer's Model

One of the more general models was built by Gotterer to consider the effects of delays in labour force changes. The model was a computer simulation of a company producing a standardized product and consisted of a simple production-distribution system (Figure I-1) together with a personnel system (Figure I-2).[2] Although a detailed description of the model was not available it was apparent that the following assumptions were made:

1. The quit rate was a function of the lay-off rate.

2. All employees were engaged in the same type of work, i.e., there was no hierarchical structure for production workers.

3. Delays occurred in recruiting, hiring and laying-off of personnel.

4. A number of assumptions were made regarding the productivity of employees during the training and termination periods.

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[2]Malcolm H. Gotterer, A Study of the Effects of Delays in Changes in a Work Force, in Symposium on Simulation Models: Methodology and Applications to the Behavioral Sciences, Austin C. Hoggatt and Frederick E. Balderston, editors, (Cincinnati, Ohio: South-Western Publishing Co., 1963), pp. 192 - 202.

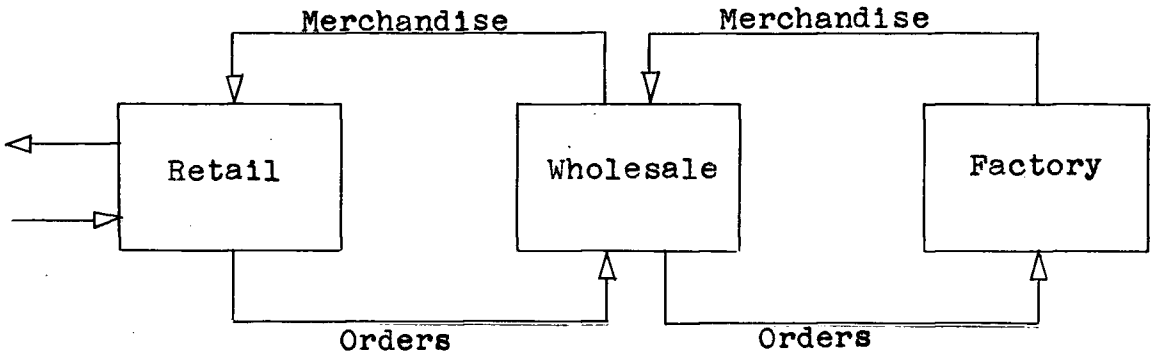

Figure I-1

Production-Distribution System

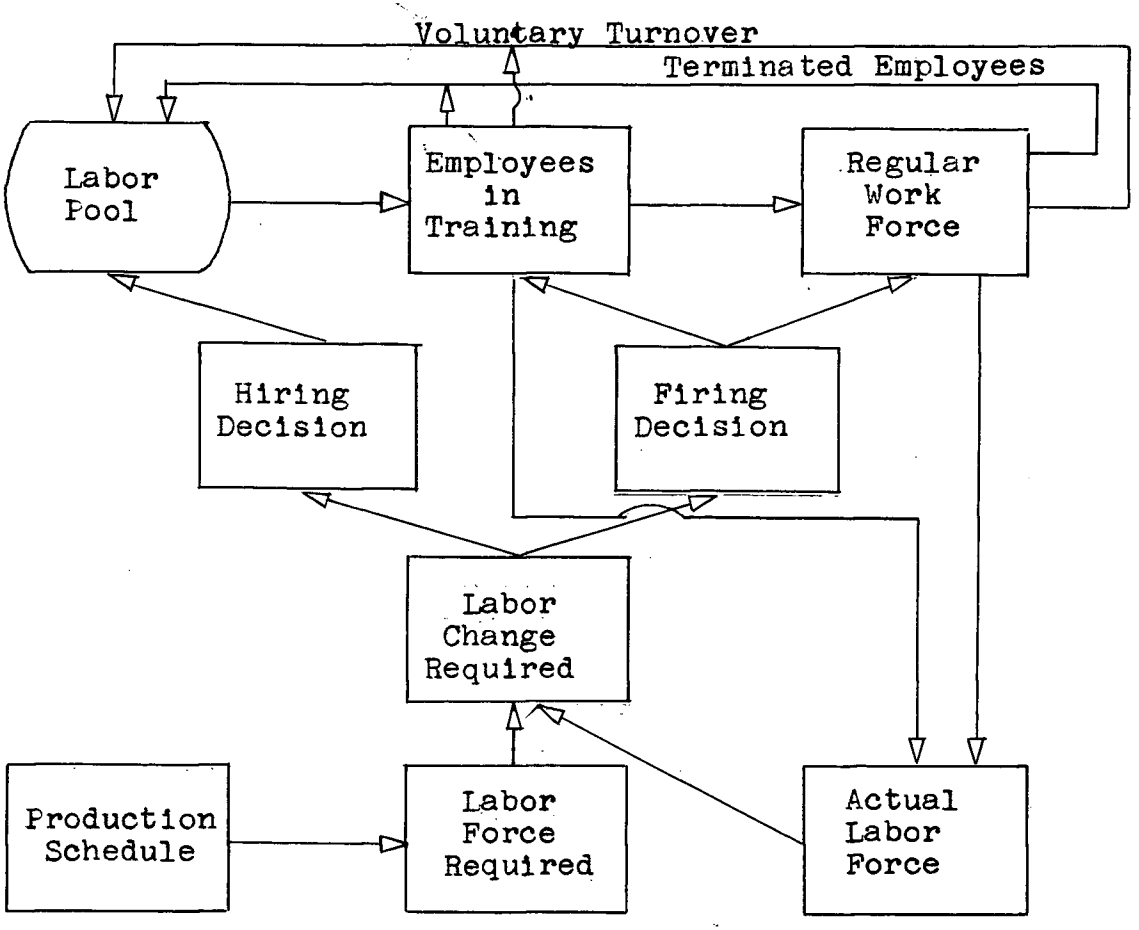

Figure I-2

Personnel System

Forrester's Model

Forrester has developed a manpower planning model as a component of an aggregate planning system.[3] The model was strongly oriented towards the problem of adjusting the work force to meet production and inventory requirements. Forrester assumed that the work force was employed on one type of work and included provision for hiring, training and laying-off personnel. Because the model was to represent a one job category situation there was no provision for promoting the worker or for providing the worker with additional training after he entered the work force. A major limitation of the model was that it assumed that employees only left the work force when they were laid off. The possibility of a worker quitting was not considered.

Nemhauser's Model

The problem of hiring, training and scheduling telephone operators led to the development of a manpower model for this purpose.[4] Although this was a rather specific case, the assumptions provided some guidelines towards developing a general model. The major assumptions were as follows:

1. All employees were engaged in the same type of work.

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[3]Jay W. Forrester, Industrial Dynamics, (Cambridge, Massachusetts: M.I.T. Press, 1961), pp. 208 - 251.

[4]George L. Nemhauser and Henry L.W. Nuttle, "A Quantitative Approach to Employemtn Planning," Management Science, XI, No. 8, (June, 1965), pp. 155 - 165.

2. The resignation rate was a function of the length of service.

3. New employees were trained by other employees who had to be relieved from their usual duties.

4. Hires and losses during the month occurred at a constant rate.

5. The length of the training period and the number of instructors per student was constant.

Although not specifically stated, Nemhauser seemed to neglect the effect of hiring delays, the possibility of the worker being laid off, and the productivity of the trainees. Despite these limitations the study was generally indicative of the problems and the factors that must be considered in a general model.

Aggregate Production Models

A number of techniques have been developed in recent years to cope with the problems of aggregate production planning[5] (i.e., production-inventory-work force systems). Because the writers were mainly concerned with the development of the technique, rather than its application, their treatment of the manpower planning aspects has been rather cursory. All the techniques assumed a homogeneous work force, neglected the time lags in the decisions and neglected

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[5]For example, Linear Decision Rules, Linear Programming and Parametric Production Planning. The application of the techniques to manpower planning are discussed in Chapter V.

the probability of a worker quitting. Consequently, they would be of little use to manpower planning in their present form.

Theoretical Models

In addition to the empirical models mentioned above, considerable research has been done with mathematical models of the personnel function. Dill reported that models based on Markov chains can be reasonably accurate. In the same report, Dill and his co-workers developed a number of mathematical models to consider rigid and flexible hierarchical structures, promotion by seniority, promotion by ability and so on. In all instances the probability of quitting was assumed to be an exponential function of the length of service in a particular position.

Despite the conceptual validity of these models there would be a number of difficulties in applying them to practical situations. Time delays, the effect of trainees on productivity, and lay-offs are not considered. Until models are developed to treat a number of factors which are important in short-term planning their applicability is restricted to the investigation of theoretical relationships and to long range studies of large groups such as military personnel.

Conclusions.

The empirical models developed to date were constructed

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[6]Dill, Gaver and Weber, op.cit., pp. 144.

to consider specific problems. The overriding question was whether one or more of these models could be applied to general manpower planning situations.

The main limitation of the existing models is that they consider the work force to be a homogenous group of workers employed in the same task. This is in marked contrast to the organizational structure of many organizations. In most cases workers are employed in a number of tasks which require different training and experience. It is also common practice for there to be opportunities for employees to advance to more senior positions in the organization. In order to realistically represent this in a model, provision must be made to promote and train employees as the more senior employees quit.

The investigation of the existing models also demonstrated that widely varying assumptions have been made with regard to turnover and training. While these assumptions were presumably valid for the particular situation, they provide little information on the criteria and assumptions required in a general model.

CHAPTER II

CONSIDERATIONS IN A GENERAL MANPOWER MODEL

The purpose of this chapter is to investigate the factors that should be considered in developing a manpower planning model. Throughout the discussion of these factors, the basic criteria are that (1) the resulting model must be a realistic simulation of actual events and (2) the information required must be readily obtainable by the organization. Aspects of the model that are relatively straightforeward or dependent upon management policy are discussed briefly. The complex aspects of the model are discussed more thoroughly, particularly with regard to the measurement of these factors by the organization.

The remainder of the chapter has been sub-divided into three major sections. The first considers the factors involved in determining work force levels. The second considers the aspects of bringing an employee into the work force and the third, the factors which cause him to leave it.

I. DETERMINATION OF WORK FORCE LEVELS

Labour Force Required

The first requirement for a manpower planning model is information regarding the labour force requirements for future time periods. This information is the only variable

which is entirely exogenous to the manpower system and can be thought of as the basic input to the system. If the manpower model is a sub-system within a larger system of the firm, the information is generated by the production-inventory-sales sub-systems and fed into the manpower model. If, as in the present case, the manpower model is a separate entity unrelated to a larger system, the labour force requirement is a true exogenous variable. It may be related to future production requirements if the objective is to analyze the effect of the variable on production and costs under certain conditions. Alternatively, if the objective is to study the effect of changes in the labour force under varying conditions or policies, specification of the pattern and size of the changes in the labour force would be sufficient.

In either situation, the following information is required to satisfy the objectives of a realistic model based on obtainable data.

Size of Labour Force. The number of workers required in each future time period must be specified. If the labour force is based upon future production requirements, worker productivity must be implicitly considered in determining the labour force required. In instances where productivity can be measured, the labour force required can be readily calculated once production requirements are known. In other cases productivity is immeasurable and the decision-maker must rely on past experience in determining the labour force.

Depending upon the purpose of the model and the degree of sophistication desired, the labour force could be specified as a deterministic or probabilistic figure.

Job Categories. The manpower models reported to date have all considered the workers to be employed in the same type of work. In some cases the employees actually were in one job category[1] but in most instances the investigators were dealing with a multi-job plant and neglected this aspect entirely. While this omission simplified the models it also produced an undesirable effect. By neglecting the job hierarchy, the training delays and costs associated with promotions were overlooked. If the firm was subject to a large change in labour requirements or high turnover rates, the effect could be considerable. A detailed manpower model should consider the hierarchical nature of the organization by containing provision for a number of job categories.

Absenteeism. Another factor which must be considered in estimating future manpower requirements is absenteeism and illness. The fraction of the labour force that is unavailable for work due to illness can be estimated on the basis of past experience. Expected absenteeism is more complex since the rate depends on worker morale, job satisfaction[2] and

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[1]George L. Nemhauser and Henry L. W. Nuttle, "A Quantitative Approach to Employment Planning," Management Science, XI, No. 8, (1965), pp. 155 - 165.

[2]Victor H. Vroom, Work and Motivation, (New York, John Wiley & Sons, Inc., 1964), pp. 178 - 180.

work group stability. Major changes in any of these factors affect the absence rate and make historical data of limited usefulness in determining future rates. Since the decision-maker is constrained by the subjectivity of these factors it is suggested that historical data be used in the initial runs of the model. If the model predicts a period of high turnover, the expected absence rate should be adjusted.

Regular Labour Force

The regular labour force is defined as the group of fully trained employees available for work during the planning period. The basic information required from the firm is the number of workers in each job category at the present time. Since the operation of the model consists of comparing this "Regular Labour Force" group to the labour requirements in future periods, other information is also required. Depending upon the type of model being constructed, the workers' seniority, training, productivity or other factors may have to be specified. These information requirements are discussed in relation to the other aspects of the manpower model.

II. ENTERING THE WORK FORCE

Labour Pool

The labour pool is defined as the number of workers that are available for employment at "entrance" positions in the hierarchical structure during a certain period of time.

The term "entrance positions" is used to indicate a job category for which workers can be hired. In many industrial organizations, seniority constraints limit the entrance positions to the lowest job category in the hierarchy and to positions, such as journeyman tradesman, which require formal training.

Despite the lack of consideration given by other investigators to the question of labour supply in manpower planning, the supply problem is second only to the problem of forecasting labour demand in the firm. If the manpower model is to be used to analyze the effects of a large increase in the work force or the effects of high turnover rates it is necessary to have some limitation on the maximum number of workers which can be hired in a certain time period.

In studies such as Gotterer's[3] and Nemhauser's[4] there was little need for a supply constraint in analyzing their immediate problems. The first study was concerned with the effects of hiring under varying circumstances rather than being a practical model of real situations. The latter study dealt with a one category situation with relatively short training periods and unskilled workers. In such cases it

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[3]Malcolm H. Gotterer, A Study of the Effects of Delays in Changes in a Work Force, in Symposium on Simulation Models: Methodology and Applications to the Behavioral Sciences, Austin C. Hoggatt and Frederick E. Balderston, editors, (Cincinnati, Ohio: South-Western Publishing Co., 1963), pp. 192 - 202. (Hereafter referred to as Effects of Delays).

[4]Nemhauser and Nuttle, op. cit.

was reasonable to assume that the labour supply would be so great relative to demand that a constraint was unnecessary. On the other hand, Forrester's study of an electronics firm was an instance where a supply constraint would appear to be desirable.[5] Although it was a one category study the workers were semi-skilled and required a moderately long training period.[6]

Despite the failure of these investigators to mention the problem of a restricted labour supply in their publications, it is improbable that they failed to consider it in building their models. In all likelihood, they realized the difficulty in obtaining objective data on the supply and preferred to risk unrealistic hiring rates under certain conditions rather than introduce subjective data into their model. In a general model, however, it would be desirable to include a labour supply constraint in order to investigate the effect of different labour pool sizes on the work force and on total costs. The constraint also helps to emphasize the fact that there is a limit to the supply of labour and to encourage future investigators to research this side of the problem.

A number of factors must be considered in estimating

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[5]Jay W. Forrester, Industrial Dynamics, (Cambridge, Massechusetts: M.I.T. Press, 1961), pp. 208 - 251.

[6]Ibid., pp. 231.

the size and the changes in the firm's labour pool. In a long-term study, demographic changes in the labour market and changing participation rates for the labour force must be considered. Government policies on minimum wages, labour laws, social security, immigration and employment influence the long-term labour supply. The policies of the organization and other labour users with respect to wages, fringe benefits and training, also affect the labour supply. Unfortunately the effect of policy changes and economic conditions on the firm's labour supply are difficult to determine. For the purposes of manpower planning, a subjective estimate of the labour supply can be made based on past hiring experience and forecasts of possible changes in the near future. The supply can then be varied and the sensitivity of manpower levels and costs relative to these changes can be determined.

Hiring

The hiring function plays a twofold role in manpower planning. The hiring decision is triggered by the information that future manpower requirements are greater than the manpower available at that time. Personnel must be recruited and selected for the openings and receive the required training at some time prior to when they are required for production work. One of the prime effects of hiring on the model is to introduce the time delay required for recruitment and selection.

The other effect of the hiring process is to determine the number and quality of the future employees in the organization. The labour pool from which the firm hires is not a specific number of people but a spectrum with the size of the pool increasing as quality requirements decrease. If an organization is hiring few men, relative to the size of the labour pool, it will be able to hire high calibre men within a short time. As the number of desired hires increases, the firm will find that it must either accept lower calibre employees or expand its labour pool by increasing its recruiting efforts and thereby increasing the time delay.

Thus the hiring process appeared to be a complex function of the labour supply, the number to be hired, the job requirements, the characteristics of the applicants and the hiring time. A review of the literature revealed that the efforts to date have concentrated on matching the applicants to the jobs available but have not included the other factors. Gotterer's study considered the effect of hiring delays on total costs but did not attempt to include the other aspects of the hiring process.

In view of the present state of knowledge on the hiring process, a manpower model would have to rely on the organization's personnel records. The hiring time could be determined from these records together with an estimate of the future effect of the preceeding factors. The quantity-quality relationship could be subjectively estimated if there

is strong evidence to suggest that it will change. Otherwise it should be assumed to be constant.

Training

Training, within the organizational setting, has been defined as:

> That process which, under company auspices, seeks in a planned, coordinated, and continuous manner to develop in all employees those understandings, skills, and attitudes, which will maximize individual present and future efficiency and the effectiveness of the overall company organization.[7]

By this definition, the scope of training is as broad as the needs and philosophy of the organization. It includes orientation training of new employees, retraining of older employees caused by changes in production patterns or technology, brush-up courses to increase the efficiency of existing personnel and job skills training at any level in the organization.

While it is beyond the scope of this presentation to delve into the intricacies of developing and instituting effective training programmes, the areas where the training function impinges upon manpower planning must be investigated.

Types of Training. Although there are many different types of training programmes, they may be divided into two basic types for the purpose of the manpower planning model.

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[7]Frank A. DePhilips, William A. M. Berliner and James J. Cribbin, Management of Training Programs, (Homewood, Illinois, Richard D. Irwin, Inc., 1960), pp. 6.

The first group includes programmes in which the trainee does not affect production while being trained. Off-the-job programmes such as lectures, plant tours, discussion groups, correspondence courses and so on, together with programmes where the trainee is on the job with an experienced worker but where there is no increase in production due to the trainee, are the most common cases in this group. A good example of the latter type of programme is found in processing plants where a trainee is placed with another operator and learns the job by observing and assisting the operator. When he is sufficiently trained he assumes the operator's job and the operator is transferred to another section of the plant.

The other basic group of training programmes are the type where the trainee affects production while being trained. Apprenticeship training and most shop training programmes are examples of this group.[8] Another example is Nemhauser's study of telephone operators. In this study, production workers were taken off their jobs to operate a formal training programme. Thus there was a negative relationship between the number of trainees and the number available for production jobs.[9]

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[8]Dale Yoder, Personnel Management and Industrial Relations, (3rd. ed., New York, Prentice-Hall, Inc., 1948), pp. 260 - 262.

[9]Nemhauser and Nuttle, op.cit., pp. 158.

The reasons behind the division of training programmes into two groups, depending upon the contribution of the trainee to production, lies in the nature of the problems which these types of training resolve. The general aim of training is to provide a skilled, efficient work force of a certain size at some future point in time. This objective can be accomplished by the "zero contribution" types of training. The decision regarding the number of workers to be hired and trained is directly related to the number of trained workers that are expected to be available in the future. This number, in turn, depends on the number of experienced workers currently in the work force and the number that are currently being trained. A decision of this nature depends on historical data and is independent of future decisions.

In contrast to the "zero contribution" types of training, the treatment of "contribution" types of training requires a special technique. Because the "contribution" type affects production levels during the training period, the number of production workers required in some future period depends on the number being trained during that period. This situation, where current and future promotion decisions are interrelated is known as the "deterministic sequential decision problem".[10] Dynamic programming techniques are

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[10]G. Hadley, Nonlinear and Dynamic Programming, (Reading, Massachusetts, Addison-Wesley Publishing Company, Inc., 1964), pp. 375 - 379.

required to solve this type of decision problem.

Regardless of how the trainees are grouped, the following information is required for manpower planning: (1) the number being trained, (2) their job category, and (3) the training time. If a cost optimizing model is being constructed, information must be obtained regarding the training costs. In the case of "contribution" types of training, the benefits of increased production during the training period would also have to be considered.

Determination of Training Time. Another major aspect of the training problem is the delaying effect due to training or the training time. For the purposes of manpower planning the training time to be used in the model is the standard training time for a particular job within the organization. Since this delaying effect is relatively important, the factors involved in determining it should be analyzed. The following discussion investigates the factors which affect training times and the problem of measuring it in certain situations.

Training, in its broadest sense, is a learning process. Therefore it may be thought of as an activity whereby the individual not only acquires, but also retains and utilizes certain skills, habits and attitudes. DePhilips describes this learning process as proceeding through four stages.[11]

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[11]DePhilips, Berliner and Cribbin, op.cit., pp. 69.

The first stage is one of "unconscious incompetance" in which the trainee is unaware of his lack of knowledge. As training commences, the trainee enters the second stage where he becomes aware of his ignorance and of the need for training. The initial training period is characterized by an incomplete understanding of the job and an expenditure of energy that is out of proportion to the difficulty of the task. With further training the trainee enters a third stage where he has a clearer understanding of the task, better coordination, and a reduction in trial and error learning. After a period of time the trainee proceeds to a fourth and final stage where he not only has a complete understanding of relationships between all aspects of the task but also has a sense of accomplishment in a job well done. These four stages are illustrated in Figure II-1.

It must be noted that these training stages and the associated learning curve consider the total learning process. In all likelihood, sensory-motor (skill) learning proceeds more rapidly than either conceptual or associational learning. An example of the learning curves for the various learning processes is shown in Figure II-2.

The hypothesis of different learning rates creates a number of difficulties in determining the training time for a particular job. The trainee tends to feel that he is sufficiently trained when he can "do the job." Usually this is when the sensory-motor aspects of the task have been

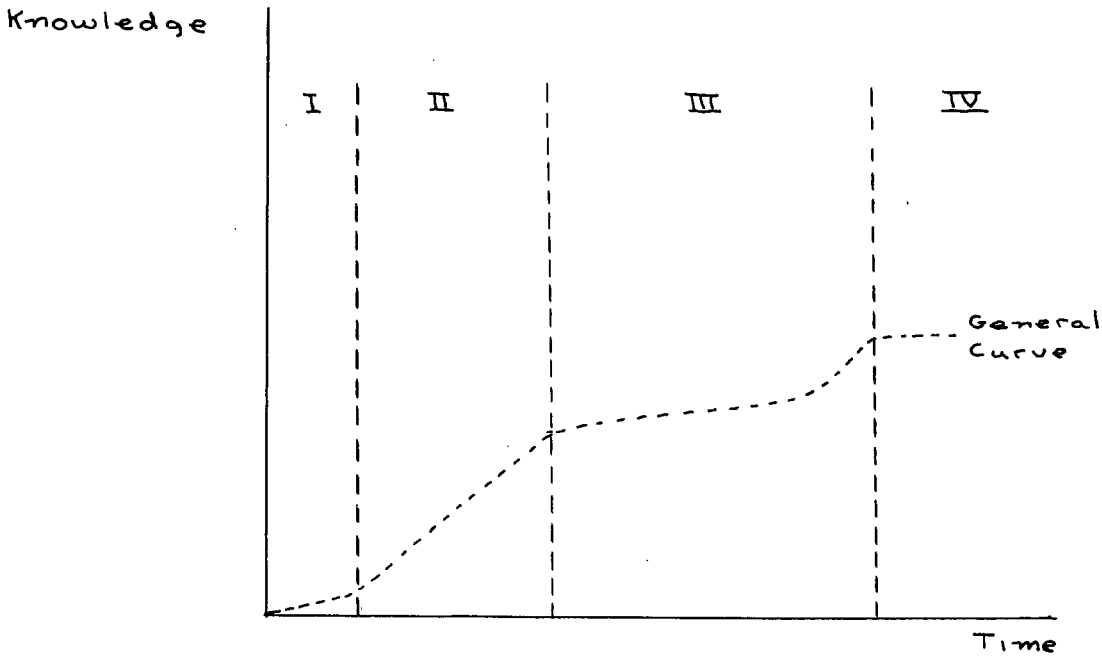

Figure II-1

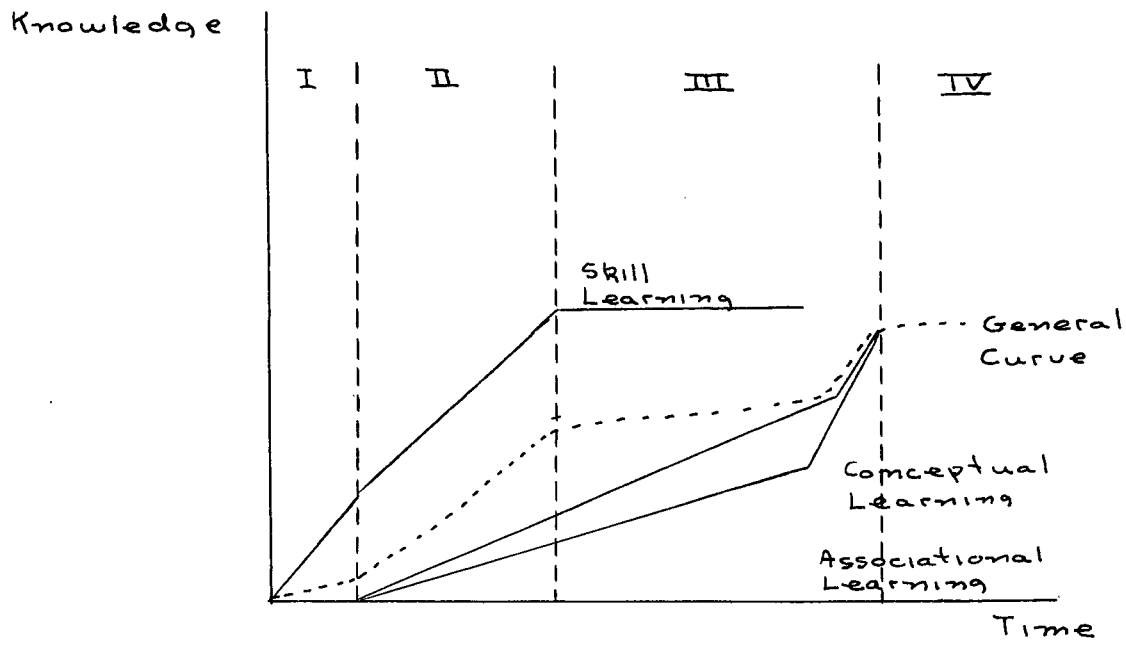

Figure II-2

Typical Learning Curves

learned. Since the sensory-motor elements are easily recognized and easily measured, management may also be led to believe that the worker is trained when he reaches this stage. In the example shown in Figure II-2, this would be early in stage III. In many industrial jobs sensory-motor skills override the other skills to such an extent that the worker is quite well trained. In other areas, such as the processing industries, the employee is far from being an experienced worker at this time.

Another major factor in determining training time is the method of learning. Knowledge acquired in a logical manner is retained longer than learning by rote. It has also been found that a task that is learned well is retained longer and better than one that has barely been learned during training.[12]

On the basis of the discussion thusfar, it can be seen that the factors affecting training time are many and complex. In general terms, however, it can be said that the training time for a particular job is a function of (1) the types of learning processes and the relative importance of each to the job, (2) the method of learning, (3) the stage of learning which must be attained in order to perform the job, (4) the frequency with which knowledge is used, and (5) the ability of the person being trained.

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[12]DePhilips, Berliner and Cribbin, op.cit., pp. 112-117.

Measuring Training Time. The standard criterion for judging if a person has been adequately trained is whether or not he can do the job. In many instances, especially where the learning is associational or conceptual in nature, individual productivity cannot be measured. Usually the training time is judged to be the time when the learning rate reaches an intermediate plateau, i.e., at a point where the trainee appears to have stopped learning. At this point it appears to both the trainee and the supervisor that the trainee is capable of doing the job. This factor, combined with the lack of quantitative methods for measuring the trainee's knowledge, often leads to training being curtailed before the worker is fully trained. On the other hand, if the job requires considerable skill learning or individual production can be measured, the training time is usually considered to be the time taken for the individual to attain the average output of experienced operators.

Neither of these criteria should be accepted for general use if they can be avoided. In instances where individual productivity cannot be measured, a subjective criterion must be used. If the subjective judgement is made considering the above-mentioned factors rather than simply when the trainee appears to know the sensory-motor aspects, the judgement may be quite accurate.

In cases where individual productivity is measurable, the costs and benefits of training may be considered. The

concept that training time is the length of time required to attain the average output of experienced workers has been justified on the basis that any output below this level is unporfitable.

Clearly this is not the case. Whether or not a worker is profitable depends on his contribution to production and is independent of the average production of his co-workers. The "average production" criterion must be rejected for three reasons: (1) it is unrelated to profit, (2) it neglects to consider that the trainees are still learning when they complete their training programme, (to train workers until they reach this level may result in abnormally long training times and place the slower learners under unnecessary pressure), and (3) unless the trainee's productivity falls off after the training programme, all trainees will become "above average" workers. This will raise the average productivity and may cause the firm to be undully selective in recruiting and promoting employees.

Having resolved that average productivity is an unsatisfactory measurement of training time, a new criterion must be developed. Winthrop has led the way in this respect by developing a learning curve procedure for the acceptance and paying of apprentices.[13] He develops a curve of unit

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[13]Henry Winthrop, "Management Decision Technique in the Classification of Employee Skills", Management Technology, II, (December, 1962), pp. 101 - 107.

cost versus output and determines the break-even point for various market prices of the product. It is then possible to determine which apprentices to reject and how profitable they are at each level of output. The same technique could also be applied to determining the length of training required before the trainee becomes profitable to the firm. Although neither Winthrop's article nor a similar study by Taylor[14] deal specifically with marginal analysis, it is obtainable from the unit cost versus hourly output and hourly output versus training time curves. If the changes in unit cost and training time for a certain change in the output rate can be measured, the benefit of additional training time at this particular output can be determined. The benefit can be compared to the cost and training terminated when the marginal cost exceeds the marginal benefit. Thus the learning curve procedure meets the requirements of marginal analysis and is a relatively easy and practical procedure for determining the optimal training time when productivity can be measured.

Promotions

One of the major differences between a general model and the models reported in previous studies is that a general

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[14]Marvin L. Taylor, "The Learning Curve - A Basic Cost Projection Tool", Management Information-A Quantitative Accent, Thomas H. Williams and Charles H. Griffin, editors, (Homewood, Illinois: Richard D. Irwin, Inc., 1967), pp. 497 - 501.

model must include provision for a hierarchical organization structure. A job hierarchy, by its very nature, implies that there are opportunities for employees to advance from one job to another. Thus the model must make provision for promoting the employee and training him as he progresses from one job category to another.

The promotion decision is essentially the same as the hiring decision. The difference is that, where the hiring decision indicated the need to bring workers in from the labour pool, the promotion decision indicates the need to bring workers up from a lower job category. Thus the promotion decision is entirely internal and dependent soley upon the organization's requirements and their promotion policies.

The policy of the organization regarding promotions depends on the type of work which the labour force performs. Many industrial organizations have a policy of promoting their present employees and only hiring for the lowest job category. Others, because of the nature of the work or the costs of training, prefer to hire experienced workers when they can, and only promote employees when absolutely necessary. Between these two extremes there could be a number of criteria for the fraction of the labour requirement that is to be hired and the fraction that is to be promoted.

The decision to promote an individual worker may also be based on a number of factors. In many unionized plants, total seniority or a combination of total seniority and

plant seniority may be the only acceptable criterion for promotion. In other organizations promotions may be based on seniority in a particular job or on the worker's ability.

From the view-point of a general discussion, provision for promotions to occur must be included in the model together with the policies and criteria that are used to determine how the worker is to be promoted.

III. LEAVING THE WORK FORCE

The third major group of aspects to be considered in a manpower model are the factors and forces which cause an employee to leave the work force. The ensueing discussion is sub-divided into the three major causes of an employee leaving the work force. The employee may leave voluntarily (quit), he may leave at the request of the employer due to some fault of the employee (be discharged), or he may leave at the request of the employer but through no fault of his own (be laid off). Since voluntary termination is the most common cause of termination, as well as the most complex, it is discussed in considerable detail. Discharges and lay-offs are relatively straightforward decisions. The former is independent of the model while the latter, like the hiring decision, is entirely dependent upon the other factors in the model.

Effects of Terminations

Terminations, whether they be voluntary or involuntary,

have a considerable effect upon the organization. First, a termination results in the employer losing his investment in the worker. Not only is there the cost of hiring and training a new employee, but also the new employee is likely to be less productive than the one he replaces. Second, the introduction of new employees and promotion of more senior men disrupts the established work groups and leads to increased confusion in the organization. This lowers the group's productivity and may lead to increased absenteeism[15] and turnover.[16] Third, if the termination is voluntary there is likely to be a considerable time-lag between the decision to quit and the actual resignation.[17] During this time period the employee's contribution is likely to be less than that of the average worker.

In summary, terminations of any kind affect the organization's costs and production. The effect on hiring and training can be easily represented in the manpower model. The effect of normal levels of terminations is reflected in the productivity and absentee coefficients that are used in

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[15]John B. Fox and Jerome F. Scott, Absenteeism: Management Problem, (Boston, Harvard University Graduate School of Business Administration, 1957).

[16]Elton Mayo and George F.F. Lombard, Teamwork and Labor Turnover in the Aircraft Industry of Southern California, (Boston, Harvard University, Graduate School of Business Administration, 1957).

[17]Wayne L. McNaughton, "When the Employee Decides to Quit", Personnel, XXXII, (May, 1956), pp. 525 - 532.

the model. Changes in the termination rate cannot be readily treated unless the organization has sufficient information to relate these changes to productivity and absenteeism.

Determinants of Turnover

Theoretical Indicators. A vast number of studies have been made concerning the factors that determine turnover rates. For the purposes of this discussion, the research studies were sub-divided into three groups; biographical studies, psychological studies, and economic studies. The biographical studies have indicated that relationships exist between turnover rates and age, sex, marital status (responsibility), previous job history, previous wages, and so on. The fact that other studies have found no correlations between any of the above factors and turnover leads one to doubt their general applicability. This view is substantiated by both Schuh[18] and Hulin[19] who report that, while biographical factors may affect turnover in certain cases, general conclusions cannot be made.

Studies of the relationships between a number of psychological factors and labour turnover have been more successful. Schuh has recently reviewed all the published

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[18]Allen J. Schuh, "The Predictability of Employee Tenure: A Review of the Literature", Personnel Psychology, XX, No. 2, (Summer, 1967), pp. 133 - 152.

[19]Charles L. Hulin, "Job Satisfaction and Turnover in a Female Clerical Population", Journal of Applied Psychology, L, No. 4, (August, 1966), pp. 280 - 285.

tests on the effect of these factors on turnover. He reports that in particular situations intelligence, aptitude, personality and interests affect tenure. The only factors that were positively related in all cases were job satisfaction and work group relations.[20]

It must be realized, however, that these factors only consider the forces which tend to make the worker stay with the firm. A number of other factors, such as relative wage levels and opportunity elsewhere, tend to force the worker to leave. The complexity of these economic factors have restricted the studies to aggregate situations. Vroom reported that turnover increases as unemployment decreases.[21] Harker found that turnover in the United States closely followed the level of business activity in 20 out of 22 years between 1935 and 1957.[22] While these economic studies provided well correlated indicators of changes in labour turnover rates in an aggregate sense, there would be difficulties in applying them to a specific organization.

In summary, the factors which are good general indicators of turnover are difficult to measure and even more difficult to relate to specific turnover rates. Fortunately,

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[20]Schuh, op.cit.,

[21]Victor H. Vroom, Work and Motivation, (John Wiley and Sons, Inc., New York, 1964), pp. 178.

[22]John B. Harker, "Business Activity and Turnover", Personnel Journal, XXXVI, No. 5, pp. 183 - 184.

a turnover indicator need not be based on theoretical concepts. Empirical indicators, if they can be found, are satisfactory for manpower planning. The following sections discuss several empirical indicators which have been used in other manpower models.

Turnover as a Function of Employment Stability. One of the basic assumptions of Gotterer's model is that the rate at which employees resign is a function of the stability of employment. Specifically he assumes that the turnover rate is two percent when employment stability is a maximum and increases in proportion to the percentage of the labour force being laid off.[23] While this criterion may be a good indicator in some cases, it cannot be recommended for general use. Empirical evidence indicates that a firm which is expanding its labour force finds that many of the men they hire quit within a short time.[24] Undoubtedly this is due to improper selection, placement, and training, but is is a fact which must be considered. According to Gotterer's decision rule the firm should have extremely low turnover rates if employment is expanding or stable. Thus, Gotterer's rule is not applicable under these conditions. Even when there are lay-offs the rule does not necessarily apply. Studies by Mayo[25]

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[23]Gotterer, op.cit., pp. 193.

[24]Norman R. F. Maier, Psychology in Industry, (3rd. ed.), (Boston, Houghton Mifflin Co., 1965), pp. 624.

[25]Mayo and Lombard, op.cit.,

and Fox[26] indicate that turnover is likely to increase when a firm is laying off workers. They found that the causes of the increased turnover and absenteeism were the uncertainty, irregularity and confusion that the lay-offs produced rather than the lay-offs themselves. Once these causes were identified and policies implemented to minimize them, the researchers found that the relationship between turnover and lay-offs ceased to exist. Therefore, it appears that Gotterer's decision rule need not be applicable when the work force is contracting and is not applicable if the work force is expanding.

Turnover as a Function of Length of Service. Another commonly used indicator of turnover is the length of service of the employee either in total or with respect to his present position. There is strong empirical evidence to support the assumption that turnover is a function of the worker's length of service with the firm. Maier cites a study of a public service corporation where turnover rates depended upon the length of service more than it depended upon other measurable factors. The British Columbia Telephone Company reports that the turnover of telephone operators is well correlated to the length of service.[28] The writer's experience in the

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[26]Fox and Scott, op.cit.,

[27]Maier, op.cit., pp. 624.

[28]Personal communication with Mr. D.M. Carter, Personnel, British Columbia Telephone Company, Vancouver, B. C.

mining industry also substantiates this assumption. In contrast to this evidence, research in the armed forces shows that there is a correlation between turnover and the length of service in a particular position.[29]

The differences between the conflicting evidence can be reconciled if the characteristics of the groups are considered. Most unskilled and semi-skilled workers are employed in positions where there are limited opportunities for advancement. In many of these jobs, advancement is based on the worker's seniority with the organization. Furthermore, alternative job opportunities are usually at the same or lower skill levels and the worker cannot move to a higher job category by going to another employer. Under these conditions the worker is unlikely to be by-passed when promotions are determined or to feel that he is missing out on better opportunities elsewhere. The effect of these factors on the employee's decision to quit should be minimal.

The factors which are likely to affect turnover are the biographical and psychological factors discussed previously. Except in times of mass unemployment the labour force available to a firm is made up of young people seeking their first job and those who have quit a previous employer. The young worker entering the labour force probably has little work

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[29]W.R. Dill, D.P. Gaver and W.L. Weber, "Models and Modelling for Manpower Planning", Management Science, XIII, No. 4, (December, 1966), pp. 142 - 167.

experience and few responsibilities. If he finds that he doesn't like the type of work he quits and seeks alternative employment. The main factor affecting this decision is the time that it takes the work to discover that he dislikes the work. Although this time will vary between individuals the relationship between turnover and total length of service is evident. The youth now joins the second group that constitute the labour supply, those who have quit their previous job. The worker now repeats the hiring, time lapse, quitting procedure until he finds satisfactory employment.

Two items in this process are worthy of note. First, a large number of the men hired by an organization are subject to time-oriented leaving forces. The length of service in the firm will measure these forces. Second, because of the tendency to quit shortly after hiring, a firm may have to hire several employees before they find one that stays with the firm. This has severe implications upon the firm that wants to expand its work force or that fails to provide the necessary conditions and benefits to retain its senior employees.

The second group of employees to be considered includes managerial, professional and military personnel. Promotion is based more on merit than seniority and the employee can move either horizontally or upward when he takes another job. For this group, the length of service with the organization is likely to be less important than present and future

opportunities for advancement. Since an individual is normally uncertain of how his superiors rate him and what his opportunities are within the firm, he seeks out a criterion which allows him to measure this. In many instances the criterion is the length of service in his present job relative to that of his reference group.[30] If the individual feels that he is being promoted rapidly there is a tendency for him to stay with the organization. If, on the other hand, he feels that he is being left behind, there will be a tendency for him to seek opportunities elsewhere.

In summary, it appears that length of service can be a satisfactory indicator of turnover. If the group is composed of semi-skilled or skilled workers or low level clerical personnel the total length of service with the firm should be used. If the group is composed of professional personnel the length of service in the job category should be used. In either case the indicators would have to be adjusted for changes in the age and sex composition of the work force, economic conditions, and job satisfaction levels.

Discharges

Besides leaving the work force voluntarily a worker may be forced to leave by being discharged. Although the discharge rate is usually quite low and the decision is made

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[30]Dill, Gaver and Weber, op.cit., pp. 163.

independently of manpower requirements it should be considered in the model. Despite the lack of published evidence, it is reasonable to expect that newly hired employees are more likely to be discharged than more senior workers. Personal traits such as incompetance, emotional instability and insubordination may not be detected before the worker is hired but will become evident shortly afterwards and cause the worker to be discharged. Other discharges are due to specific actions of the employee or to traits which develop after he is hired. In total, the rate is likely to be a function of the length of service for junior employees and constant for more senior personnel. Under these conditions a constant rate independent of both the hiring rate and length of service may be satisfactory. Discharges could be treated in the model by adjusting the labour force requirement to include a discharge coefficient.

Lay-offs

The third way in which employees leave the work force is by being laid off. This decision is also made by the organization but, in contrast to discharges, the decision depends entirely upon the future requirements of the firm. The manpower model could be built to cope with any number of policy constraints which would affect the timing of the lay-offs and the number of workers affected. A time lag between the decision and the lay-off would be required since the

organization must inform the workers of the impending lay-off. Information is also required with regard to the decision criteria for lay-offs. If the criterion is either total seniority or job seniority it could be readily handled in the model. Depending on company policy, constraints might be introduced so that there would be no lay-offs if the workers were to be recalled within a short time or if only a few men were to be laid off. Since the lay-off decision is generated by the model and is not subject to the external environment any decision criterion and constraint could be introduced providing that the necessary information is available.

The procedure for treating employees who are laid off also depends on company policy. If the workers are not subject to re-call by the employer, then they can be considered to leave the work force completely when they are laid off. If the workers are subject to re-call, then provision must be made to re-introduce the worker to the same job category without going through the training programme. Provision must also be made for the laid-off employees to sever his relations with the employer and a criterion developed to determine the probability of a laid off employee quitting. Although there are no published studies on the factors influencing a laid off employee to quit, a historical study would be possible if the organization had a pattern of

laying-off and recalling employees. In all likelihood the quit rate is related to the length of the lay-off, the expected length of the lay-off, other opportunities, and the value of the accrued benefits foregone.

CONCLUSIONS

Basic Requirements of a General Model

The investigation of the requirements in a general model demonstrated that the following factors must be considered in any manpower planning model:

1. A forecast of future labour requirements.
2. Information on the present labour force.
3. A hierarchical organization structure.
4. Provision for time lags whenever hiring or training occurs.
5. A labour pool from which the employees are hired.
6. Provision for labour turnover.
7. Provision for hiring and promoting employees.
8. Provision for laying-off and demoting employees.

Specific Models

The investigation of the general requirements in a manpower planning model also indicated that several types of models could be constructed. The basic differences between these types arose through the effect of training on production and the quit rate relationship. If the trainees

did not affect production, simulation techniques would be applicable. Alternatively, if production was affected, dynamic programming would be required. There were also two basic ways to treat the quit rate function. It has been hypothesized that the quit rate depended on the length of service with the employer if the employee could not improve his position by changing jobs. It was also hypothesized that the quit rate would be a function of the length of service in a particular job if the employee could improve his position by changing employers. These four types of models, together with an outline of the types of employees the models would treat, are illustrated in Figure II-3.

The Type I model, (non-managerial employees, no effect on production) includes all processing and assembly-line jobs. Type II (non-managerial employees, trainees affect production) includes job-shop workers, maintenance workers, telephone operators and so on. Type III includes all types of managerial and military personnel who are subject to training on the job. Type IV includes the same group but training is divorced from the job. The formal management training schools operated by some of the larger corporations illustrate the Type IV model.

If the labour force were divided into four groups according to these criteria, the Type I and Type II models would contain the largest number of workers. The majority of the models developed to date have been constructed to

TYPE I

- Quit Rate depends on length of service
- Production is independent of the number of trainees
- Examples

  assembly-lines
  processing industries
  apprentice programmes

TYPE II

- Quit Rate depends on length of service
- Production depends on the number of trainees
- Examples

  job-shops
  maintenance workers

TYPE III

- Quit Rate depends on time in job category
- Production depends on the number of trainees
- Examples

  military personnel
  most managerial jobs

TYPE IV

- Quit Rate depends on time in job category
- Production is independent of the number of trainees
- Examples

  formal training of managerial employees

Figure II-3

Alternative Types of Models

consider a specific sub-group of the Type I model or some variation of it. Unfortunately, these models have not considered all the relevant factors necessary for their use in most Type I situations. For example, Forrester neglected turnover entirely while Gotterer considered turnover to be related to the lay-off rate. Both of them neglected to consider a hierarchical structure. Nemhauser's model for scheduling telephone operators (a Type II sub-group), while correct for telephone operators, did not include a job hierarchy.

In view of these limitations it was decided to construct a new model which would include the basic requirements of the general model.

The Type I group was selected as the basis for the model for two reasons. First, this group of non-managerial employees is the largest group in most organizations. Second, the model can be constructed without using dynamic programming techniques. Because dynamic programming is a cost-optimizing procedure, cost equations would have been required for each relationship in the model. It was not the purpose of this study to investigate the size, shape and interrelationship of the cost functions in a manpower system. A study of this sort would have impinged upon a number of aggregate production planning techniques and led away from the original purpose of the study.

CHAPTER III

DEVELOPMENT OF THE MODEL

The purpose of this chapter was to develop a working model of the manpower planning function which could be used for organizational planning or for research into the effect of manpower structures on the personnel function. On the basis of the considerations discussed in Chapter II, the model was developed to analyse the segment of the work force in which:

1. The employee is subjected to leaving forces that can be approximated as a function of their length of service with the employer.

2. The employee does not affect the organization's productivity while he is being trained.

I. ASSUMPTIONS

A number of assumptions were made in order to develop a foundation for the model. The general criteria used in making these assumptions were that the model must be a realistic representation of the system and the information required must be readily available to the organization.

General Assumptions

The following assumptions were made because

the organization does not normally have the information required to treat the factors in a different manner. The assumptions would be required in any objective manpower model.

1. Because the forecast considers workers who have yet to be hired, the workers are considered as members of a group. Individual characteristics are neglected.

2. All employees in a job category have equal productivity.

3. All employees have equal ability.

4. Worker productivity is known and constant.

Simplifying Assumptions

A number of simplifying assumptions were made in constructing the model. The general purpose of these assumptions was to deliniate a specific model type and to remove a number of minor factors from the model.

Quitting. The probability of a worker quitting during a time period was assumed to be a function of the worker's length of service in the organization at the start of the time period. As mentioned previously, it was thought that this assumption was necessary if the model was to be used for manpower planning below the managerial level.

Labour Requirements. Future labour requirements were assumed to be known with certainty. The reason for assuming deterministic labour requirements was that the model was considered as separate from production and inventory

models. If the model were to be combined into an aggregate model or if optimizing techniques were being used, probabilistic data might be desirable. This could be readily introduced to the model by way of the Monte Carlo technique.

Firing. The number of workers discharged during a decision period was assumed to be negligible. Since the number discharged would be considered in either the labour requirement or the quit rate, the model was unaffected by this assumption.

Illness, Accidents and Absenteeism. It was assumed that the number of workers unavailable for work due to illness, accidents and absenteeism was negligible. In actual practice the labour requirement would be adjusted to consider the expected number of workers unavailable due to these factors.

Specific Assumptions

In addition to the simplifying assumptions which deliniated and simplified the model, a number of specific assumptions were made. In general these were required to provide the organizational policies for promotion. In a few instances assumptions were made to avoid the constraints of the computer language (FORTRAN). All these assumptions could be easily changed if they were found to be inapplicable to the organization being studied.

Basis for Promotion. It was assumed that workers were

to be promoted on the basis of their length of service with the organization. The effect of this assumption was to determine who was to be promoted and, therefore, to determine the composition of the regular work force in the future. The composition, in turn, determined the number that would quit at each job category and the promotions required to fill these vacancies. In actual practice the promotion criterion would be a function of the worker's ability and his seniority. Because the model was a forecasting device, ability was assumed to be equal for all workers. Under these conditions seniority was the prime criterion for promotion. If a more subjective criterion, such as ability, was used in practice to determine who was to be promoted it would affect the individual worker but would have little effect on the number of men promoted.

In some organizations the length of service in a particular job has been suggested as the criterion. This assumption could be used in the present model by keeping records of worker's promotions. The modification would only be necessary if an existing organization wanted to initiate manpower planning. If the organization used the model from the time it started (i.e., when all employees had zero service) the end result would be identical to promoting by length of service in the firm.

Promotion Constraint. It was assumed that workers must be presently employed at the next lower job category in order to be eligible for promotion. The effect of this

assumption was to constrain the number eligible for promotion and prevent an unrealistic number of promotions from occurring.

A constraint was introduced to limit the fraction of the labour force that could be promoted in any one time period. Thus if the decision-maker felt that promoting more than fifty percent of a group would be detrimental to the organization he could introduce a constraint of this size. When the requirements exceeded the constrained supply the difference would be reported as a shortage. The results could then be analyzed and a decision made to promote the extra workers required, to tolerate the shortage or to promote additional workers in earlier periods. Provision was made to specify the constraint for each job category.

Quit Rate for Trainees. The probability of a trainee quitting was assumed to be the same as the probability for a member of the regular work force.

Hiring. It was assumed that workers would only be hired for the lowest job category and that the requirements in higher categories would be met entirely by internal promotions. The assumption was made in order to avoid considering the cost implications of hiring skilled employees versus training. The assumption also clarified the basis for promotion. If employees were hired for higher job categories they would be eligible for promotion to the next category even though they had less seniority than other workers. With the present assumption, employees in higher job categories

are always more senior.

The assumption that workers can only be hired for the lowest job category is realistic for the type of organization under consideration. In most industrial organizations the production workers are unskilled or semi-skilled. The type of work differs between plants and consequently employees must receive some training within the plant in order to be able to perform their job. It is also common for those plants, whether unionized or not, to consider seniority in determining promotions. The hiring assumption is valid under these conditions. Another type of employee is the specially-trained skilled worker such as a journeyman tradesman. In most instances, workers are not promoted into this group. In effect they are a separate, one-level hierarchy.

The remaining group, which includes skilled production workers and clerical personnel, may be either hired or promoted from within. The assumption of hiring only at the lowest level would not be entirely applicable unless the organization had an inviolate rule of promotion from within the organization.

Training Time. It was assumed that all workers being promoted to or hired for a job category would receive equal training. Although this assumption would only be strictly correct if all employees had equal ability and equal experience, it was a good approximation and was consistant with the previous assumptions.

Demotions and Lay-offs. The demotion and lay-off aspects of manpower forecasting are neglected in the model. In many organizations the work force is either stable or increasing. In others, where the work force is steadily decreasing, the organization relies on natural attrition to decrease the force rather than suffer the costs of demotions. Under either of these circumstances a demotion or lay-off procedure is unnecessary. Nevertheless there are organizations with seasonal fluctuations in their labour requirements and these groups should be considered in a general model.

In contrast to the hiring and promotion procedure where the policy considerations are fairly uniform, lay-off and demotion procedures are subject to a number of varied constraints. As mentioned in Chapter II, demotions could be from each category or by total seniority. Workers laid off could be subject to rehiring and a separate quit rate used. A constraint could be introduced so that lay-offs would not occur unless the number to be laid off exceeded a certain size. Because of the sizable intangible costs incurred by lay-offs the organization might be reluctant to lay-off or demote employees for short periods of time. None of these considerations are universally applicable. Specific organizations may have policies which incorporate any combination of factors. Rather than select a particular sub-set of policies for the model it was decided to omit the demotion and lay-off aspects entirely.

Training Time Limitation. It was assumed that a training delay would exist in the lowest job category. The primary reason for the assumption was that the FORTRAN computer language was unable to handle a variable with the subscript "0" (zero). If there were no training delay when workers were hired, the workers would have to be advanced from length of service "zero" to length of service "one" in the Labour Force Update procedure. This could only have been accomplished by making the model considerably more complex and by artifically advancing the time periods in order to treat input data at time period "zero".

The training delay has been defined to include all time lags between the promotion decision and when the employee started work. Even if training was not required, a delay would occur in the lowest category due to the time consumed in recruiting and selecting new employees. Therefore the assumption was thought to be realistic for most organizations.

Calculation Procedure. In order to define a specific calculation procedure it was assumed that (1) all hiring, promotions and training occur at the start of the time period, (2) employees quit at an even rate throughout the time period. Thus, if an average of 100 workers were required to meet production forecasts, and if 10 workers were expected to quit, the labour force would be 105 men at the start of the period and 95 at the end.

Hiring Constraint. A hiring constraint was introduced

to limit the number that could be hired in any period. It was assumed that the size of the constraint would vary for different time periods.

II. NOMENCLATURE

The following terms were used in the construction and description of the model.

T	=	the current decision period.
J	=	the future time period.
I	=	total length of service with the organization.
K	=	number of job categories.
JMAX	=	time horizon of the programme.
IMAX	=	most senior length of service group.
KMAX	=	highest position in organization hierarchy.
DEL(K)	=	training delay in category K.
P(I)	=	probability of staying to next time period given length of service - I.
HMAX(J)	=	maximum number of hires allowed in period J.
G(K)	=	fraction of employees in category K that are available for promotion.
R(K,J)	=	work force required in category K at time J.
MEN(K,I,J)	=	regular labour force in category K with seniority I at time J.
TR(K,I)	=	labour force being trained for category K.
PPSTAY(K,I)	=	the probability of a worker with seniority I and in job category K staying through the training period.

RPRO	=	number of promotions required.
AVPRO	=	number of employees available for promotion.
J 1	=	the time period which must be considered when promoting for period J.
PHIRE	=	number of hires desired.
HIRE	=	actual number hired at time J.
EXMEN	=	the number of workers in a regular work force that are expected to stay to the end of period J.
RETR	=	the extra number of workers required at the start of period J to satisfy the labour force requirement in that period.
SHORT	=	the expected shortage in category K at time J.
TMEN(K,J)	=	the total number of workers in category K at the end of period J.
TPRO(K,J)	=	the total number of workers promoted to satisfy the requirements of category K at time J.
QUITS(K,J)	=	number of workers quitting category K in period J.
NWORK	=	the average number of workers available for work after promotions and quits have been considered.

III. BUILDING THE MODEL

General Perspective

The manpower model is essentially a forecasting device based on the number of workers currently available in each job category, future labour requirements, the quit rate and the organizations policies. Because the calculations in

a particular decision period affect the lower job categories the decision period must be far enough into the future to allow these adjustments to take place. The time difference between the current time and the decision period must be equal to the sum of the time lags for each category below the one being considered. For example, assume that there are two job categories with training delays of two months each. In time period T = 1, the decision period for category K = 2 is period J = T + DEL(1) + DEL(2) = 5. When K = 1 is considered, J = T + DEL(1) = 3. This may be shown in graphical form as follows:

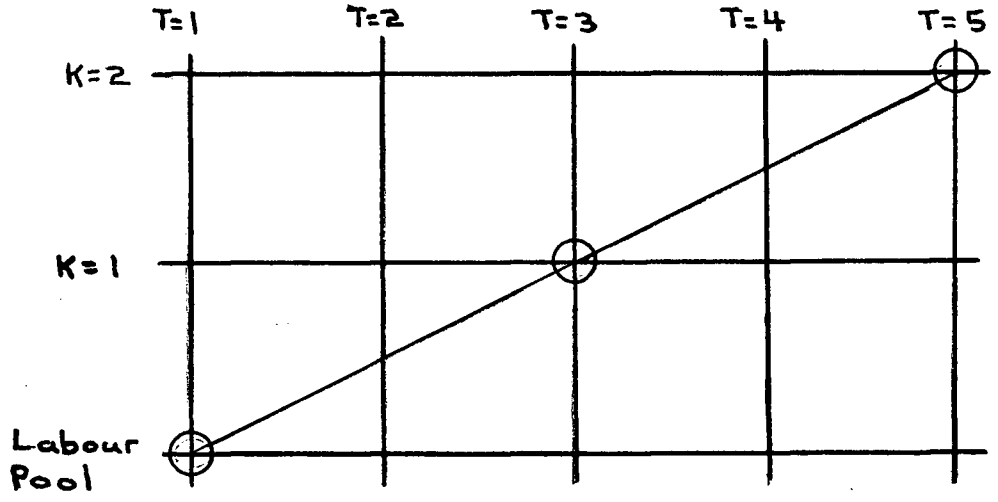


Figure 3-1

Timing of Decisions

Basic Equations

Before proceeding to a discussion of the movement of workers between job categories at various time periods the basic relationships in each decision node (i.e., for a particular K and J) must be discussed. The interactions at a decision node are illustrated in Figure 3-2.

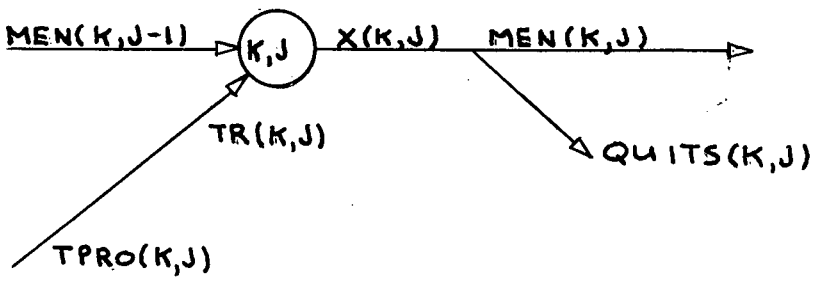


Figure 3-2

Typical Decision Node

K	=	job category number.
J	=	decision period number.
P(J)	=	probability of staying through period J.
R(K,J)	=	average number of workers required.
MEN(K,J-1)	=	number of workers at the end of period J-1.
X(K,J)	=	number of workers required at the start of period J.
QUITS(K,J)	=	number of workers quitting during period J.
TR(K,J)	=	number of promotions required to satisfy the requirement.
TPRO(K,J)	=	number of workers to be promoted from category K-1.

Assuming that the probability of staying depends on the decision period rather than worker seniority, the basic relationships may be written as follows:

3 - 1 $$X(K,J) = MEN(K,J-1) + TR(K,J)$$

3 - 2 $$QUITS(K,J) = (1-P(J))*X(K,J)$$

3 - 3 $$MEN(K,J) = P(J)*(X(K,J))$$

3 - 4 $$TPRO(K,J) = TR(K,J)/P(J-DEL(K))*---*P(J-1)$$

If employees are assumed to quit at a constant rate during the period then;

3 - 5 $$R(K,J) = X(K,J) + MEN(K,J)/2$$

Since MEN(K,J-1), P(J), AND R(K,J) are known the basic equations may be solved in the following manner: From equations 3-3 and 3-5,

$$R(K,J) = X(K,J) + P(K)*(X(K,J))/2$$

Therefore

$$X(K,J) = 2*R(K,J)/(1 + P(J))$$

The other equations may now be solved

3 - 1 $$TR(K,J) = X(K,J) - MEN(K,J-1)$$

3 - 2 $$QUITS(K,J) = (1 - P(J))*X(K,J)$$

3 - 3 $$MEN(K,J) = P(J)*X(K,J)$$

3 - 4 $$TPRO(K,J) = TR(K,J)/P(J-DEL(K)*---*P(J-1)$$

Sample Calculation

The use of these equations in a sample calculation will serve to demonstrate how they are used in the manpower

model. Assume that there are two job categories with training delays DEL(1) = 1 and DEL(2) = 2. When T = 1, the decision nodes for the job categories are:

$$K = 1 \qquad J = T + DEL(1)$$
$$= 1 + 1$$
$$= 2$$
$$K = 2 \qquad J = T + DEL(1) + DEL(2)$$
$$= 1 + 1 + 2$$
$$= 4$$

The decision nodes are (1,2) and (2,4). Information is required for MEN(K,J-1), R(K,J) and P(J=1, JMAX) where JMAX is the last decision period.

Let MEN(2,3) = 50
MEN(1,1) = 100
R(2,4) = 60
R(1,2) = 100
P(J) = 0.90 for all time periods.

Consider the highest job category (Decision node (2,4)),

$$X(K,J) = 2*(R(K,J))/(1 + (P(J))$$
$$X(2,4) = 2(60)/(1 + .90)$$
$$X(2,4) = 63$$
$$TR(2,4) = X(2,4) - MEN(2,3)$$
$$= 63 - 50$$
$$= 13$$

$$TPRO(2,4) = TR(2,4)/(P(2)*P(3))$$
$$= 13 /(.9*.9)$$
$$= 16$$
$$QUITS(2,4) = (1 - P(4))*X(2,4)$$
$$= (1 - .9)*63$$
$$= 6$$
$$MEN(2,4) = P(4)*X(2,4)$$
$$= .9*63$$
$$= 57$$

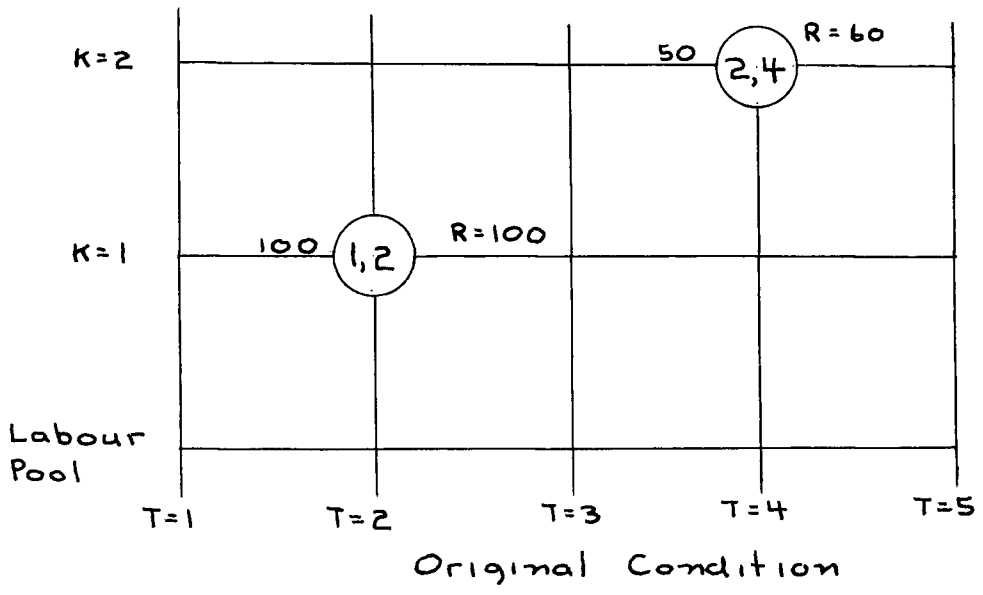
Assuming that the employees quit at an even rate throughout the period the average number of men available for work is:

$$NWORK = MEN(2,4) + QUITS(2,4)/2$$
$$= 57 + 6/2$$
$$= 60$$

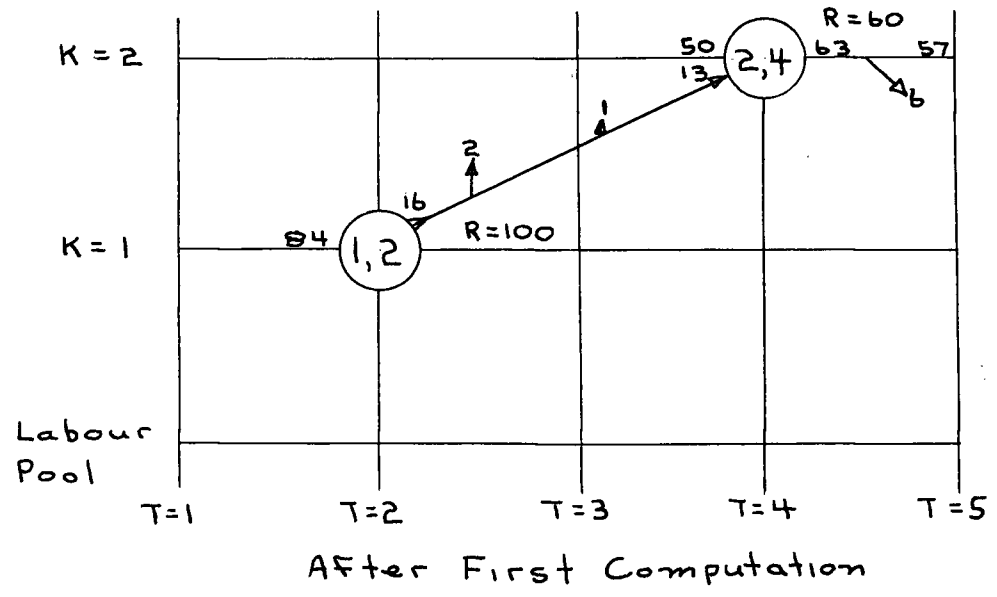
As would be expected this is the same as R(2,4), the work force required. Since 16 men were promoted from MEN(1,1) the revised number of men in MEN(1,1) is (100 - 16) or 84 men. The number who quit during training is TPRO(2,4) - TR(2,4) or 3 men. The initial conditions together with the result of the first calculations are illustrated in Figure 3-3.

The next job category (K=1) may now be considered.

$$X(1,2) = 2(R(1,2))/(1 + P(2))$$
$$= 2(100)/(1 + .90)$$
$$= 105$$



Original Condition



After First Computation

Figure 3-3

Sample Calculation

$$TR(1,2) = X(1,2) - MEN(1,1)$$
$$= 105 - 84$$
$$= 21$$

Since K = 1, TPRO is the number hired

$$TPRO(1,2) = TR(1,2)/P(1)$$
$$= 21/.90$$
$$HIRE = 23$$
$$QUITS(1,2) = (1 - P(2))*(1,2)$$
$$= (1 - .9)*105$$
$$= 11$$
$$MEN(1,2) = P(2)*X(1,2)$$
$$= .9*105$$
$$= 94$$
$$NWORK = MEN(1,2) + QUITS(1,2)/2$$
$$= 94 + 11/2$$
$$= 100$$

This completes the calculation for T = 1. The entire procedure is then repeated for a number of time periods as illustrated in Figure 3-4.

The General Model

The construction of a general manpower planning model involved the programming of the manpower calculation equations with the quit rate as a function of the length of service. The policy assumptions and constraints discussed previously were introduced into the model. The model is

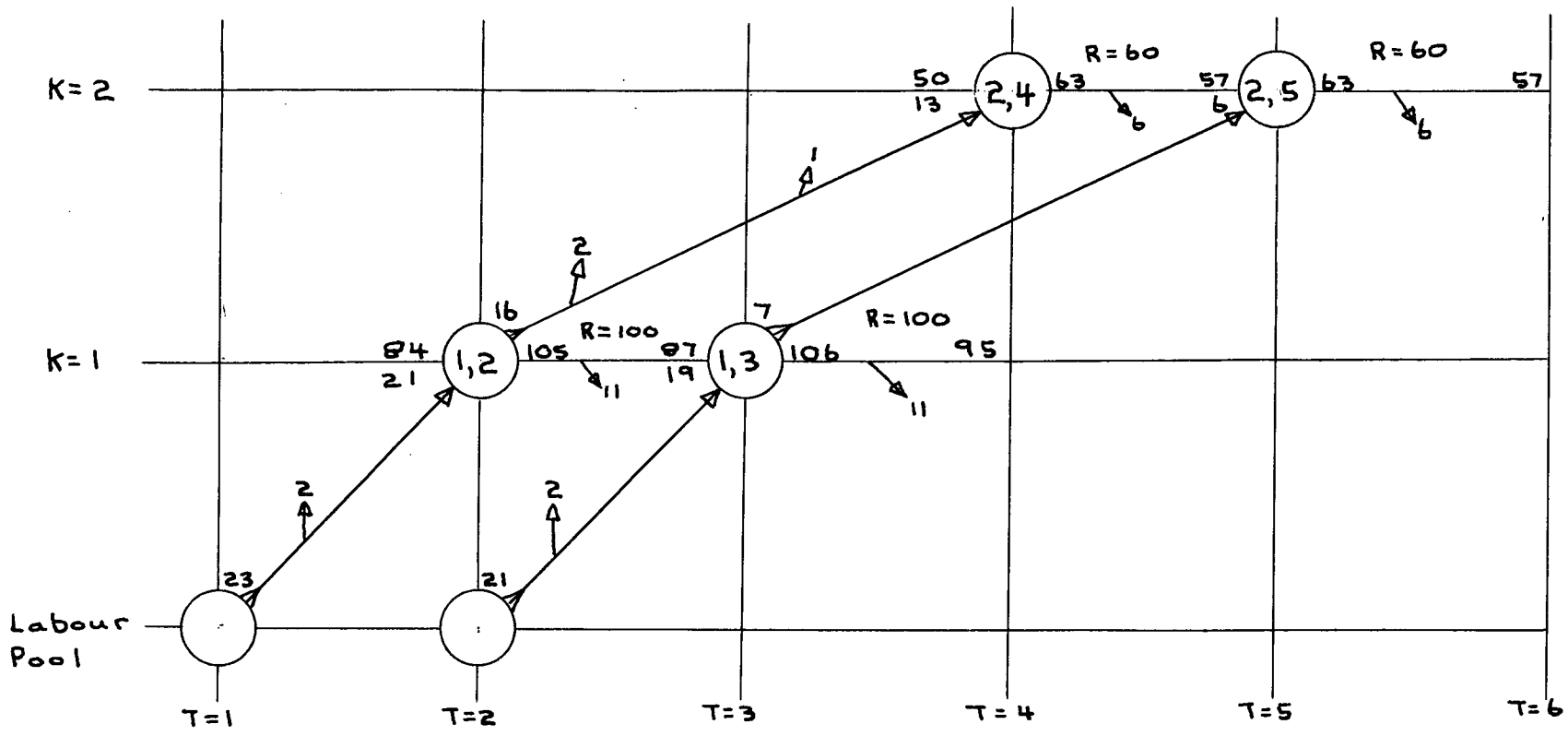


Figure 3-4

Sample Calculation for Two Time Periods

described in simplified flow charts on the following pages. Detailed flow charts and a listing of the computer programme are included in Appendix A.

The FORTRAN "DO" statement was used in the flow charts to reduce the number of pages required and to simplify the drawings. Unless otherwise noted, the processing operation referred to in the "DO" statement immediately follows the statement. The traditional flow charting technique and the modified style used in this study are illustrated below.

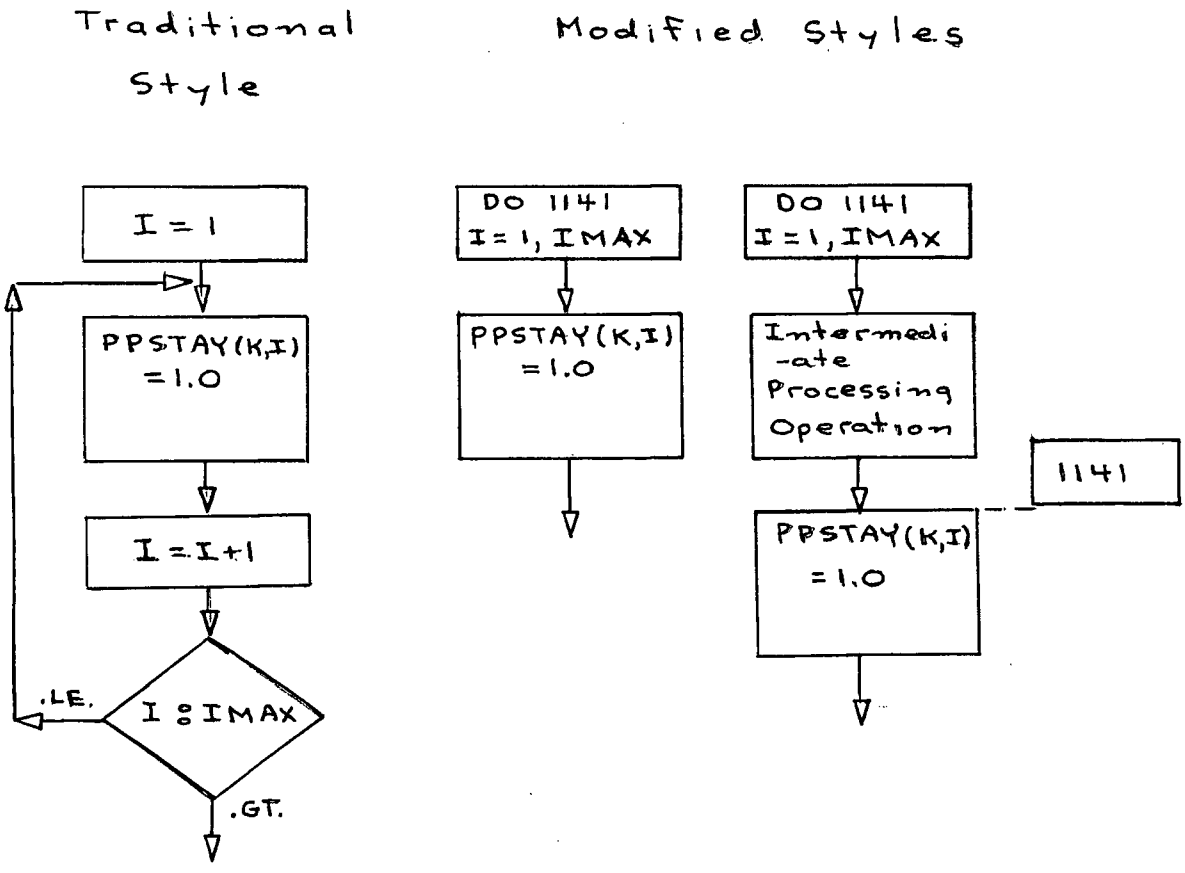
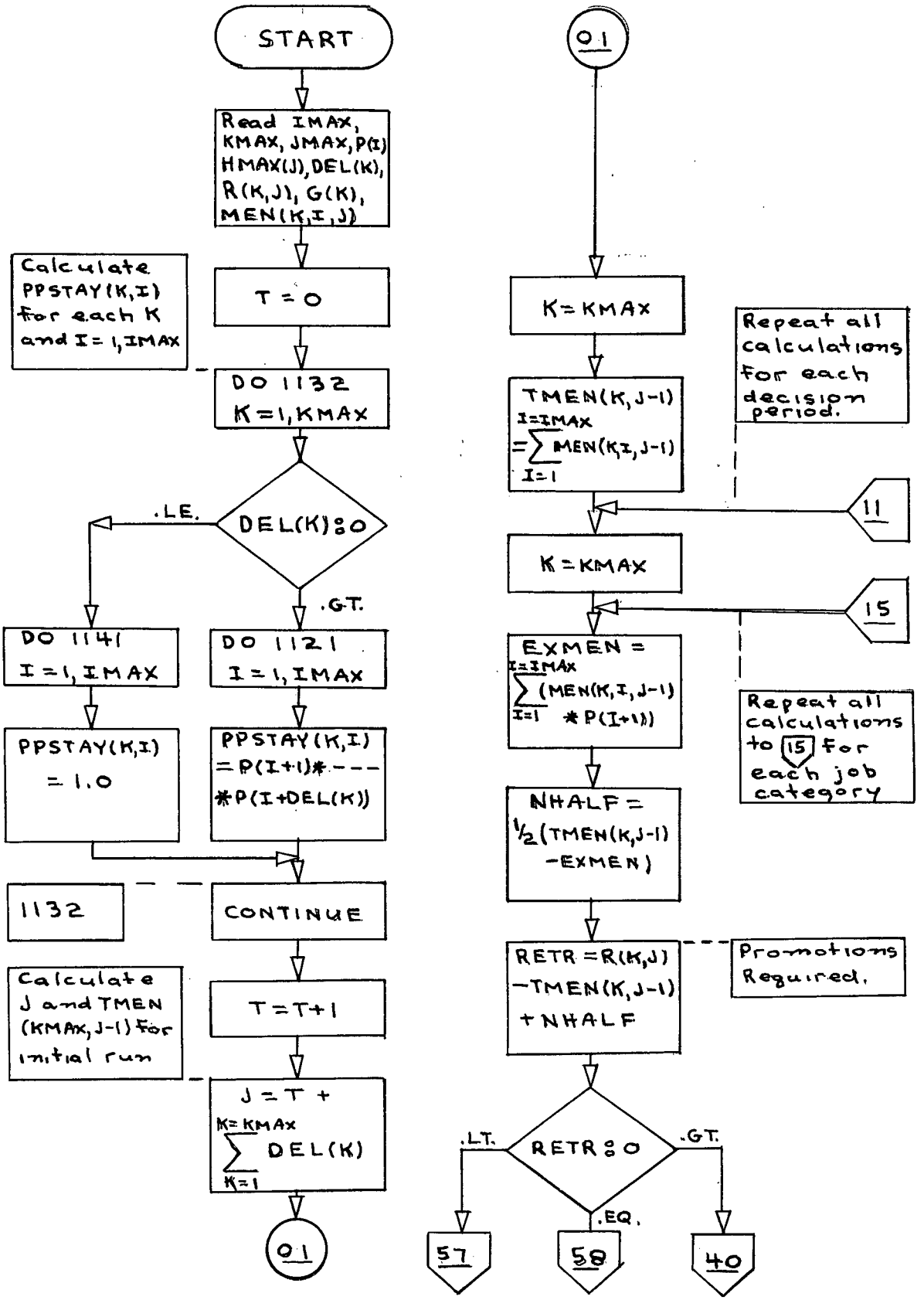
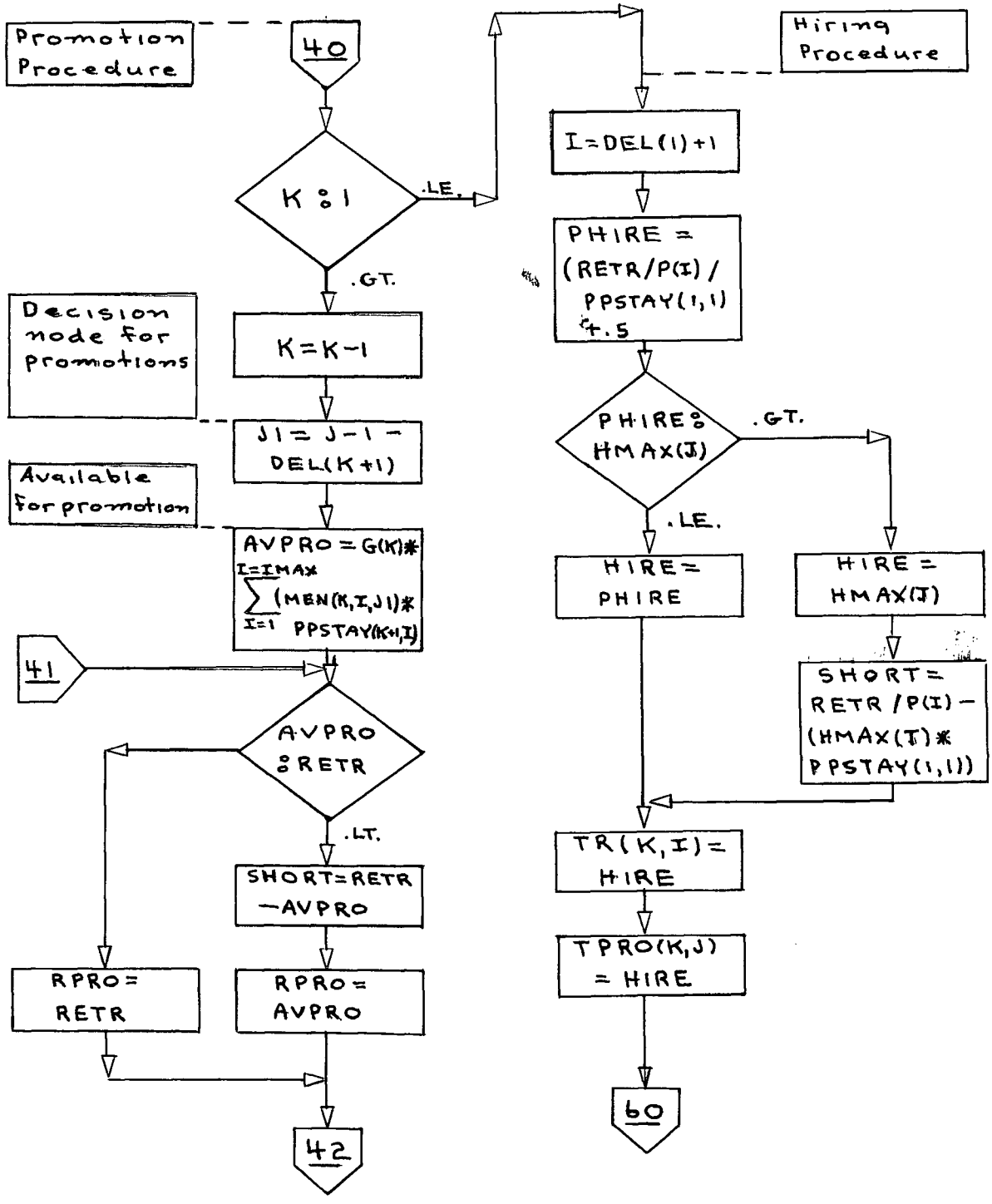
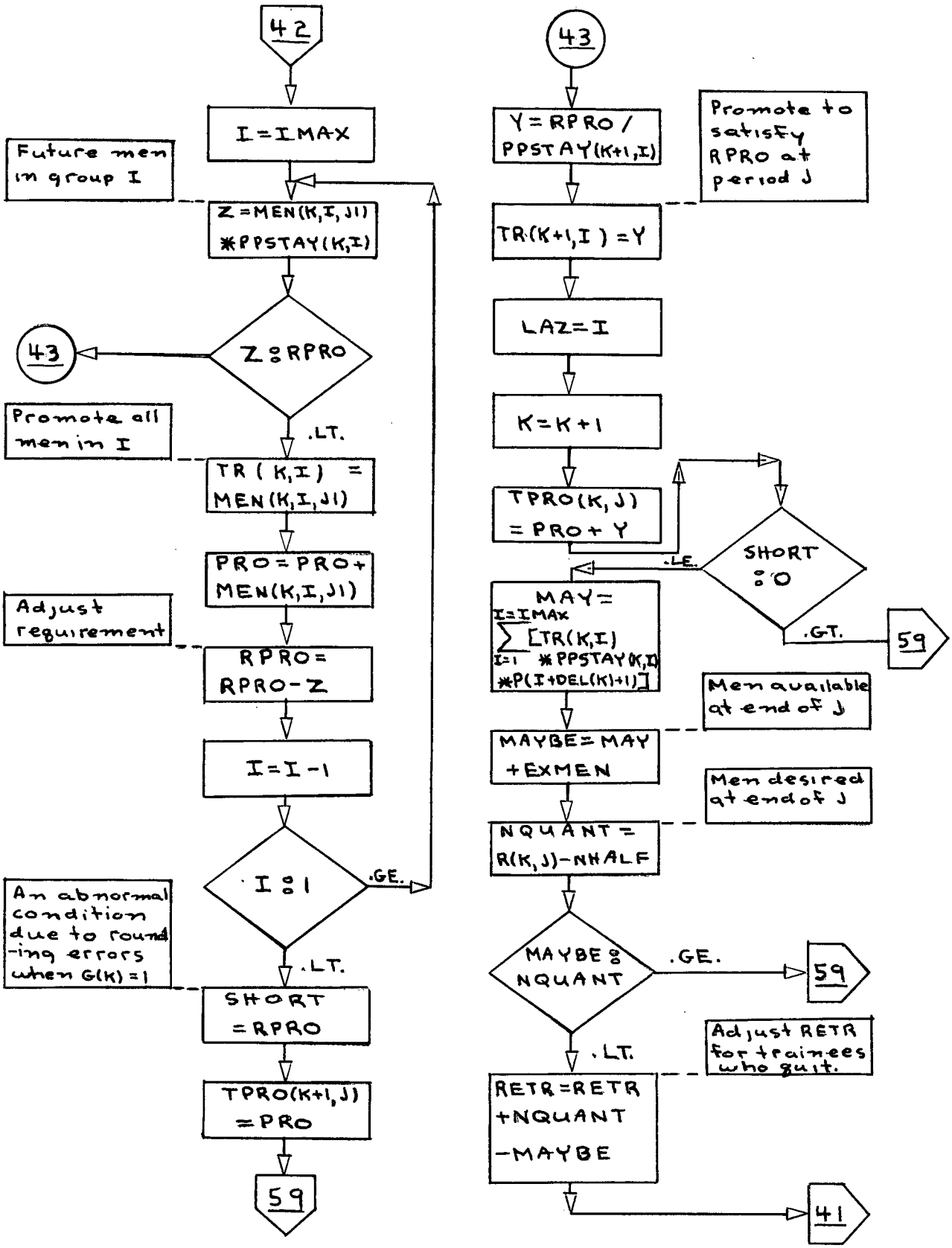


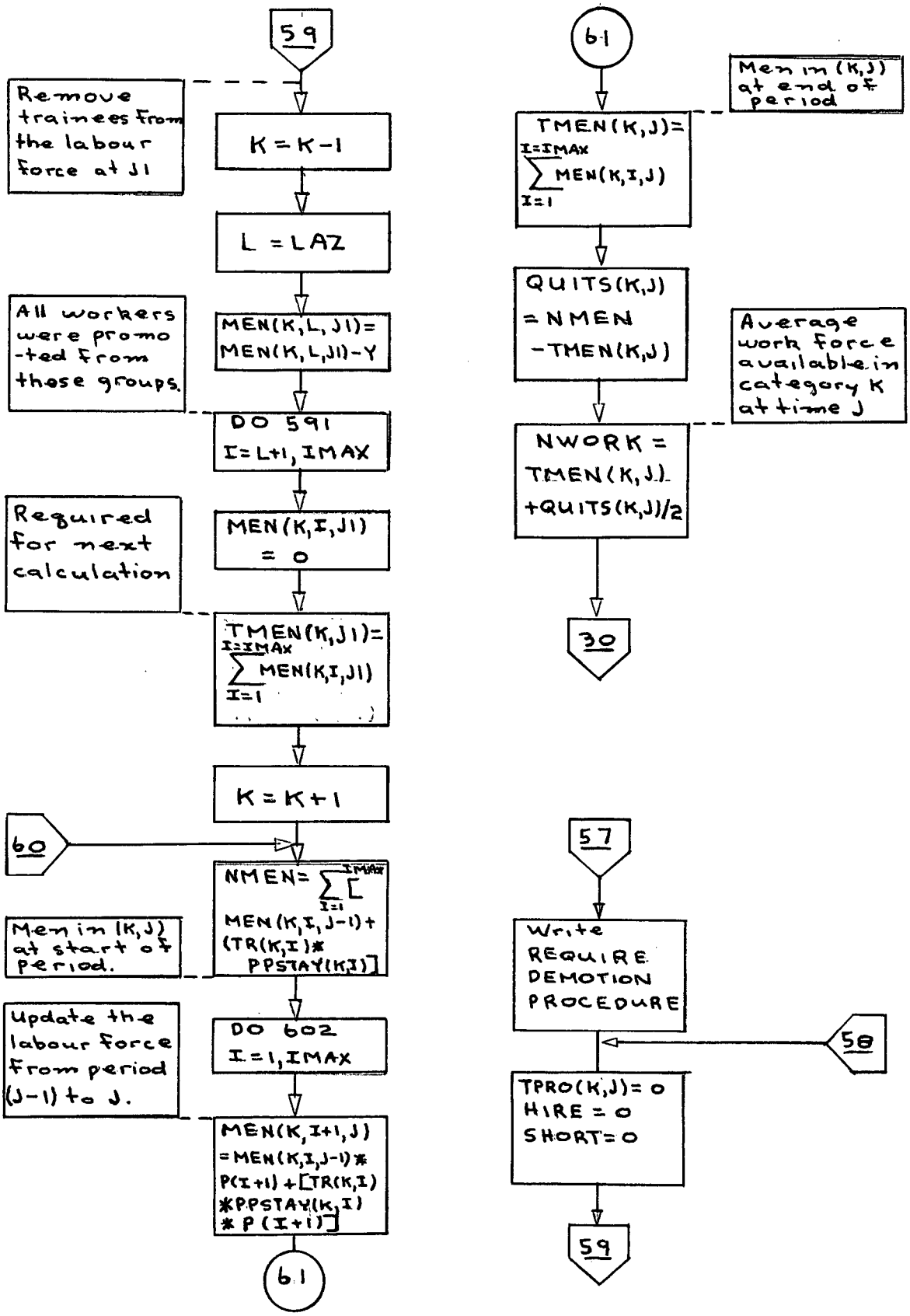
Figure 3-5

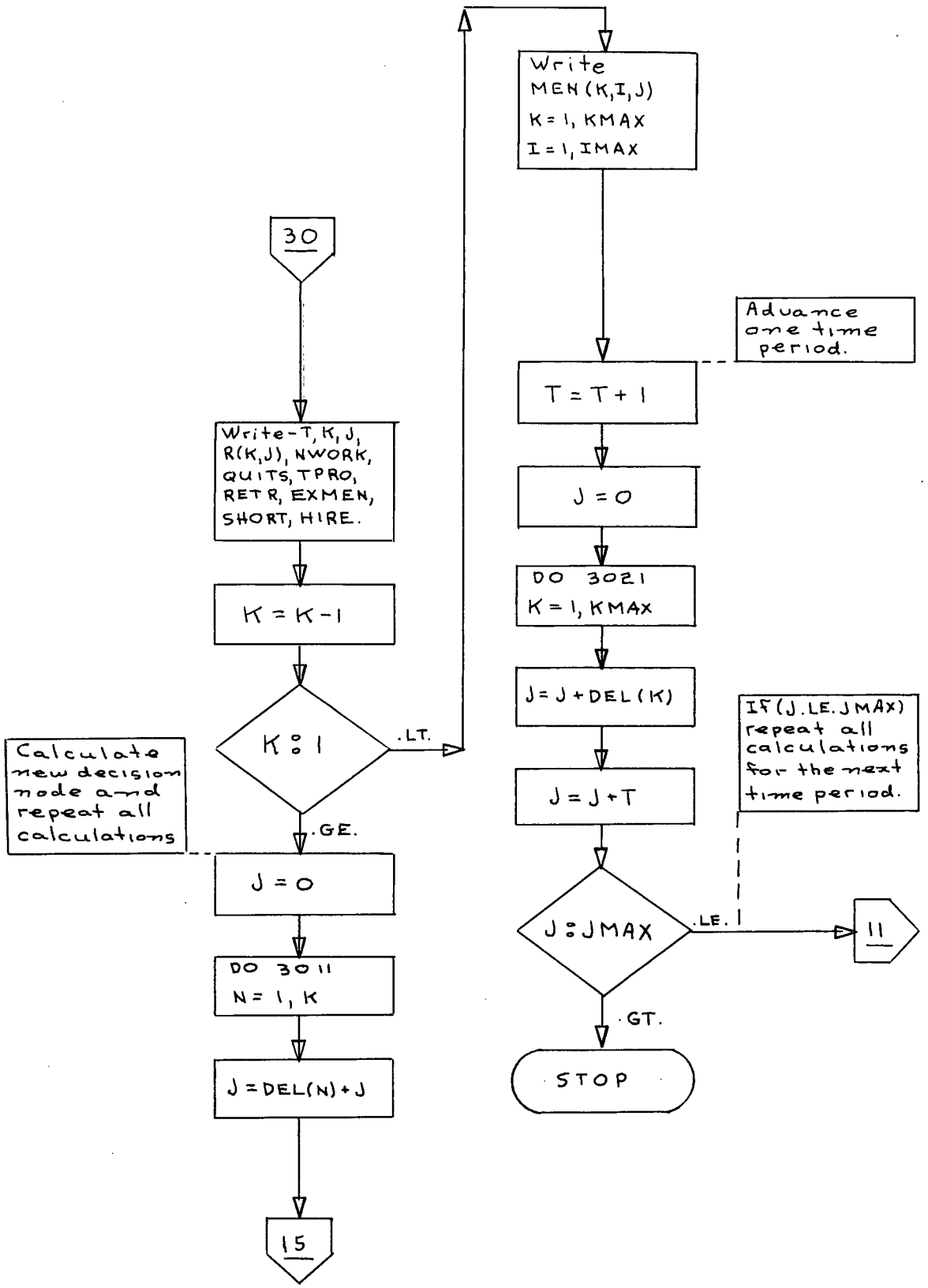
Modified Flow Charting Technique


START
Read IMAX, KMAX, JMAX, P(I) HMAX(J), DEL(K), R(K,J), G(K), MEN(K,I,J)
Calculate PPSTAY(K,I) for each K and I = 1, IMAX
T = 0
DO 1132 K = 1, KMAX
DEL(K) .LE. 0
.GT.
DO 1141 I = 1, IMAX
PPSTAY(K,I) = 1.0
DO 1121 I = 1, IMAX
PPSTAY(K,I) = P(I+1)* --- *P(I+DEL(K))
1132
CONTINUE
Calculate J and TMEN (KMAX, J-1) for initial run
T = T+1
J = T + K=KMAX Σ K=1 DEL(K)
01
01
K = KMAX
TMEN(K,J-1) I=IMAX = Σ I=1 MEN(K,I,J-1)
Repeat all calculations for each decision period.
11
K = KMAX
15
EXMEN = I=IMAX Σ I=1 (MEN(K,I,J-1) * P(I+1))
Repeat all calculations to 15 for each job category
NHALF = 1/2 (TMEN(K,J-1) - EXMEN)
RETR = R(K,J) - TMEN(K,J-1) + NHALF
Promotions Required.
RETR ? 0
.LT.
.EQ.
.GT.
57
58
40


Promotion Procedure
40
K ≟ 1
.LE.
.GT.
Decision node for promotions
K=K-1
J1 = J-1 - DEL(K+1)
Available for promotion
AVPRO = G(K)* Σ (MEN(K,I,J1)* PPSTAY(K+1,I)) I=1 to IMAX
41
AVPRO ≟ RETR
.LT.
SHORT=RETR -AVPRO
RPRO= RETR
RPRO= AVPRO
42
Hiring Procedure
I=DEL(1)+1
PHIRE = (RETR/P(I)/ PPSTAY(1,1) +.5
PHIRE ≟ HMAX(J)
.GT.
.LE.
HIRE= PHIRE
HIRE = HMAX(J)
SHORT= RETR/P(I) - (HMAX(J)* PPSTAY(1,1))
TR(K,I)= HIRE
TPRO(K,J) = HIRE
60


42
I=IMAX
Future men in group I
Z=MEN(K,I,J1) *PPSTAY(K,I)
Z ? RPRO
43
.LT.
Promote all men in I
TR(K,I) = MEN(K,I,J1)
PRO=PRO+ MEN(K,I,J1)
Adjust requirement
RPRO= RPRO-Z
I=I-1
I ? 1
.GE.
An abnormal condition due to round-ing errors when G(K)=1
.LT.
SHORT =RPRO
TPRO(K+1,J) =PRO
59
43
Y=RPRO / PPSTAY(K+1,I)
Promote to satisfy RPRO at period J
TR(K+1,I)=Y
LAZ=I
K=K+1
TPRO(K,J) =PRO+Y
.LE.
SHORT ? 0
.GT.
59
MAY= I=IMAX ∑ [TR(K,I) I=1 *PPSTAY(K,I) *P(I+DEL(K1+1)]
Men available at end of J
MAYBE=MAY +EXMEN
Men desired at end of J
NQUANT= R(K,J)-NHALF
MAYBE ? NQUANT
.GE.
59
.LT.
Adjust RETR for trainees who quit.
RETR=RETR +NQUANT -MAYBE
41


59
Remove trainees from the labour force at J1
K = K-1
L = LAZ
All workers were promo-ted from these groups.
MEN(K,L,J1)= MEN(K,L,J1)-Y
DO 591 I=L+1, IMAX
Required for next calculation
MEN(K,I,J1) = 0
TMEN(K,J1)= I=IMAX ∑ I=1 MEN(K,I,J1)
K = K+1
60
NMEN= I=IMAX ∑ I=1 [MEN(K,I,J-1)+ (TR(K,I)* PPSTAY(K,I)]
Men in (K,J) at start of period.
Update the labour force from period (J-1) to J.
DO 602 I=1, IMAX
MEN(K,I+1,J) =MEN(K,I,J-1)* P(I+1) +[TR(K,I) *PPSTAY(K,I) * P(I+1)]
61
61
Men in (K,J) at end of period
TMEN(K,J)= I=IMAX ∑ I=1 MEN(K,I,J)
QUITS(K,J) = NMEN -TMEN(K,J)
Average work force available in category K at time J
NWORK = TMEN(K,J) +QUITS(K,J)/2
30
57
Write REQUIRE DEMOTION PROCEDURE
58
TPRO(K,J)= 0
HIRE = 0
SHORT= 0
59


Write
MEN(K,I,J)
K=1, KMAX
I=1, IMAX
Advance one time period.
T=T+1
J=0
DO 3021
K=1, KMAX
J=J+DEL(K)
J=J+T
IF(J.LE.JMAX) repeat all calculations for the next time period.
J.JMAX
.LE.
11
.GT.
STOP
30
Write-T, K, J, R(K,J), NWORK, QUITS, TPRO, RETR, EXMEN, SHORT, HIRE.
K=K-1
K.1
.LT.
Calculate new decision node and repeat all calculations
.GE.
J=0
DO 3011
N=1, K
J=DEL(N)+J
15

Summary

The model developed in this chapter was constructed to forecast manpower requirements in situations where the trainees did not affect the production rate. The assumptions upon which the model was based were made for one of three reasons.

1. General assumptions regarding ability and productivity were made because the organization would not have the information to assess these factors.

2. Simplifying assumptions were made to delineate a model that would be applicable to non-managerial personnel.

3. Specific assumptions were made to define organizational policies and the criteria for hiring and promotion.

These assumptions were combined with the manpower equations to form a manpower forecasting model. The model was designed so that the size of the system parameters could be varied without modifying the programme.

CHAPTER IV

OPERATION OF THE MODEL

The manpower forecasting model described in Chapter III was thoroughly checked out for possible errors in logic or in programming. Once these errors were corrected, a number of computer runs were performed. These runs were of two types. The first type was to demonstrate how the model worked under various condisions. The second type was directed at the investigation of how some paramenters, specifically the quit rate and the training time, affected the model. The results of these studies are described in the following sections.

I. SAMPLE CALCULATIONS

The purpose of this study was to demonstrate how the model performed a set of calculations.

Input Data. The general input data for this study was as follows:

Number of job categories - 5.

Labour Force Requirement - 250, 200, 150, 100, 50, for job categories one to five respectively.

Regular Labour Force - 250, 200, 150, 100, 50 for job categories one to five respectively.

Labour Force seniority - 1.

Promotion Constraint - 0.5

Labour Pool Size - 500 per time period.

Time Horizon - 24

Training Delay - 1,1,2,2,3 for job categories one to five respectively.

Probability of Staying - a quit function which peaked when the length of service was six months and seventeen months was used. This function is shown as the "medium" level quit rate in Figure 4-1, page 78.

In order to demonstrate the ability of the model to adjust to variations in the system, the input data was modified in the following manner:

1. The labour force required in category four in time periods eight, nine and ten was increased from 100 to 200.

2. The maximum number of workers that could be hired in time period two was reduced from 500 to 20.

The calculations produced by the model in the first four time periods are shown in Table 1.

Period One. Inspection of Table I reveals that the model adjusted the work force so that the average number of production workers (NWORK) equalled the labour force requirements (R(K,J)) for the time period. Because it was assumed that employees would only be hired and promoted at the start of the period while employees quit at an even rate, the number of workers at the end of the period (EXMEN) is less than the initial labour force. This decrease in the work force is

TABLE I

SAMPLE CALCULATION OUTPUT DATA

DECISION PERIOD	JOB CAT.	TIME PER	REQ.	NWORK	TMEN	QUIT	TPRO	RETR	SHORT	HIRE
1	5	10	50	51	50	1	1	1	0	0
1	4	7	100	100	99	2	2	2	0	0
1	3	5	150	151	149	3	4	4	0	0
1	2	3	200	200	198	4	6	6	0	0
1	1	2	250	251	248	5	9	9	0	9
2	5	11	50	50	49	2	1	1	0	0
2	4	8	200	162	158	7	74	104	37	0
2	3	6	150	154	151	6	91	82	0	0
2	2	4	210	208	203	9	109	105	0	0
2	1	3	250	156	152	7	20	116	96	20
3	5	12	50	51	49	3	4	3	0	0
3	4	9	200	199	193	12	59	51	0	0
3	3	7	150	149	144	9	71	61	0	0
3	2	5	200	198	192	12	77	72	0	0
3	1	4	250	253	249	7	185	181	0	185
4	5	13	50	50	48	4	4	3	0	0
4	4	10	200	200	191	17	23	19	0	0
4	3	8	150	149	143	12	41	34	0	0
4	2	6	200	197	189	16	59	55	0	0
4	1	5	250	250	245	10	66	65	0	66
5	5	14	50	51	48	5	7	5	0	0
**** REQUIRE DEMOTION PROCEDURE****										
5	4	11	100	175	166	18	0	-75	0	0
5	3	9	150	150	142	15	18	14	0	0
5	2	7	200	200	190	19	41	38	0	0
5	1	6	250	251	245	12	54	53	0	54
8	5	17	50	50	48	4	5	4	0	0
****REQUIRE DEMOTION PROCEDURE***										
8	4	14	100	110	105	9	0	-9	0	0
8	3	12	150	150	143	13	16	14	0	0
8	2	10	200	199	188	21	42	37	0	0
8	1	9	250	251	244	14	57	56	0	57
9	5	18	50	51	49	3	5	4	0	0
9	4	15	100	100	97	6	3	3	0	0
9	3	13	150	150	145	9	16	14	0	0
9	2	11	200	197	187	20	40	36	0	0
9	1	10	250	251	244	14	55	54	0	55

reflected in the number of hires required and the number of quits. A total of fifteen workers quit in the time periods under consideration while only nine were hired. Nevertheless the work force requirements in each job category were met. (In most cases the workers available (NWORK) do not exactly equal the requirement due to rounding off errors in the programme.)

Period Two. The calculations for the second time period were upset due to several factors. The work force required in job category four was increased from one hundred to two hundred men. The promotion constraint on category three restricted the number available for promotion to half the 149 men in category three at the end of period five. Seventy-four men were promoted from category three to category four. These promotions were insufficient to meet the requirement and the labour force shortage was calculated. It should be noted that although seventy-four men were promoted out of category three the two month training time resulted in eleven of the seventy-four quitting during training. The actual shortage that occurred in category four at time period eight was thirty-seven men.

The model then proceeded to the next category (three) and promoted the necessary men to satisfy the requirement. Rounding off errors resulted in there being a difference of four between the requirement and the number at work. (150 versus 154).

In category two the labour force requirement was increased to 210 men. Because of the large number promoted from category two to category three, 109 men had to be promoted into category two to meet the requirement.

A constraint had been placed on the system so that no more than twenty men could be hired in period two. As illustrated in the last line of the period two data, twenty men were hired but this was insufficient to fill the vacancies caused by the promotions and a ninety-six man shortage resulted.

In summary, the results are what one would expect. If an attempt is made to increase the labour force by 110 men when only 20 can be hired, a shortage will result. The interesting point is that, due to the training delays for the various job categories, a work force increase at category four in time period eight causes a shortage to develop at category one in time period three.

Periods Three and Four. The next set of calculations indicate the decisions made in period three. The hiring constraint was relaxed and a sufficient number were hired and promoted to alleviate the shortages. The work force required and the force available are again in balance. The decisions made in period four also hold the work force in balance.

Period Five. The labour force required in category four at time period eleven was reduced from two hundred workers to one hundred. This meant that there was an excess in

category four and the demotion procedure would be required to adjust the work force.

Periods Eight and Nine. It can be seen from Table I that there was still an excess of men in category four. This excess was gradually being reduced as the workers were promoted to category five and as the workers in category four quit. Period nine demonstrates a return to the normal situation once the excess is used up.

II. EFFECT OF PARAMETERS ON THE MODEL

The effect of changing some of the model parameters was also investigated. The first group of studies considered the effect of different quit rates on the number of workers hired, the number promoted, the number that quit and the work force structure. The second group of studies considered the effect of training time on the same factors.

Effect of Quit Rate

The effect of the quit rate on the manpower system was investigated by running the model with three different quit rates while the other factors remained constant.

Input Data. The input data for these studies was the same as in the previous study except that a one month training delay was used for all job categories and the promotion constraint was removed, i.e., G(K) = 1.0.

The three quit rates were specified as "low", "medium"

and "high". The "medium" rate was twice the "low" rate and the "high" was twice the "medium" rate. The shape of the quit function and the absolute size of the three rates are illustrated in Figure 4-1.

Output Data and Analysis. The computed results from the three runs were analyzed by totalling the number of promotions determined in each time period. It must be noted that, because the model considers a future decision period in making the calculation, this is not the total number that would actually be promoted in the time period. The promotions were plotted against time for each of the three quit rates as shown in Figure 4-2. The total number of hires and quits were plotted in a similar manner as shown in Figures 4-3 and 4-4 respectively.

All three graphs show a general trend for the number of promotions, quits and hires to vary with the probability of the worker quitting. This trend is due to the fact that the work force started out with one month's seniority. If the worker's seniority had been different or if they had been in a number of seniority groups the tendency to follow the quit rate probability would have been less pronounced.

In spite of this limitation, which mainly affects the earlier time periods, the effect of the different quit rates is quite noticable. The graphs all show that the number of workers hired or promoted increases more than the quit rate. For example, in time period eighteen, changing the quit rate

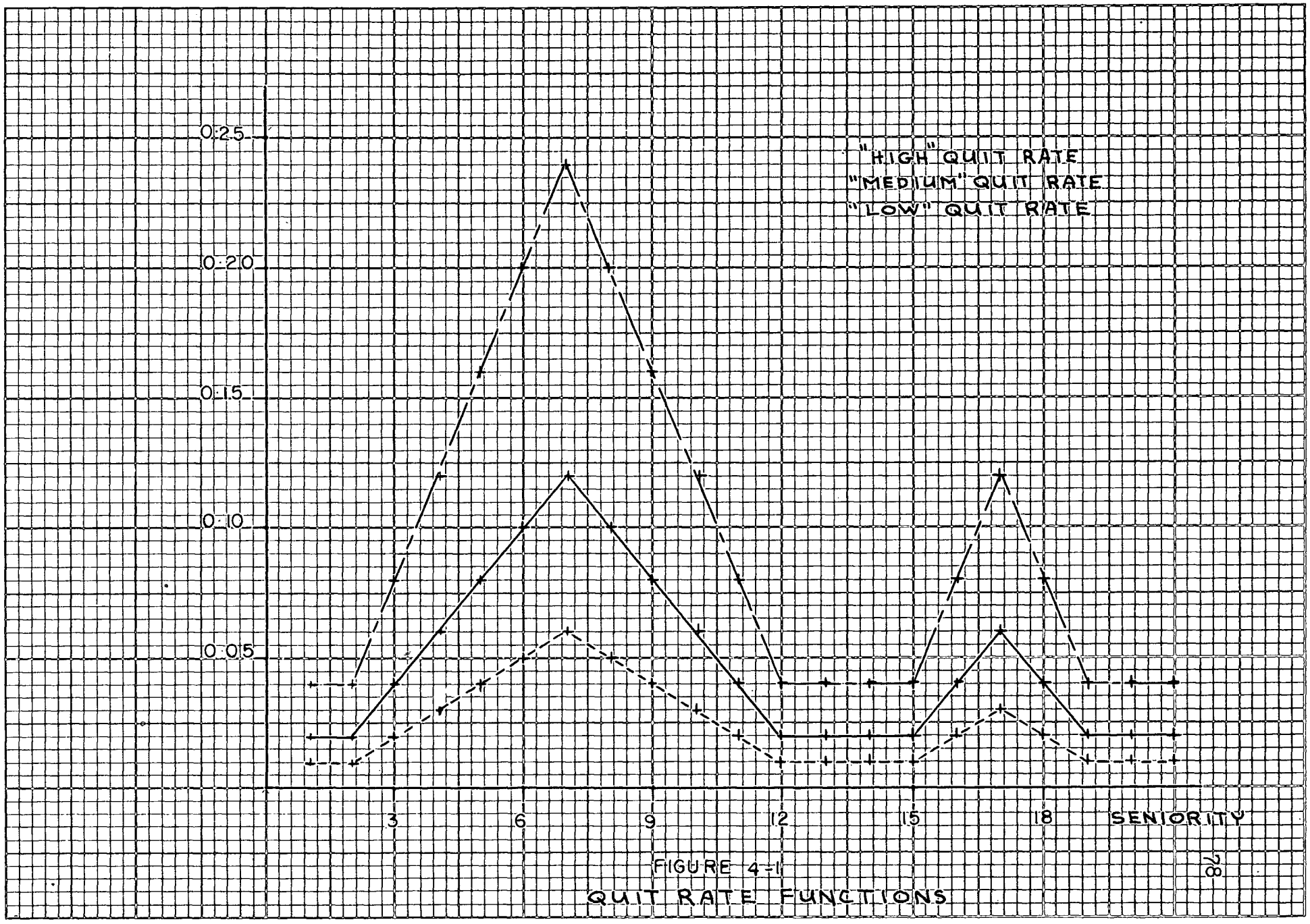


FIGURE 4-1
QUIT RATE FUNCTIONS

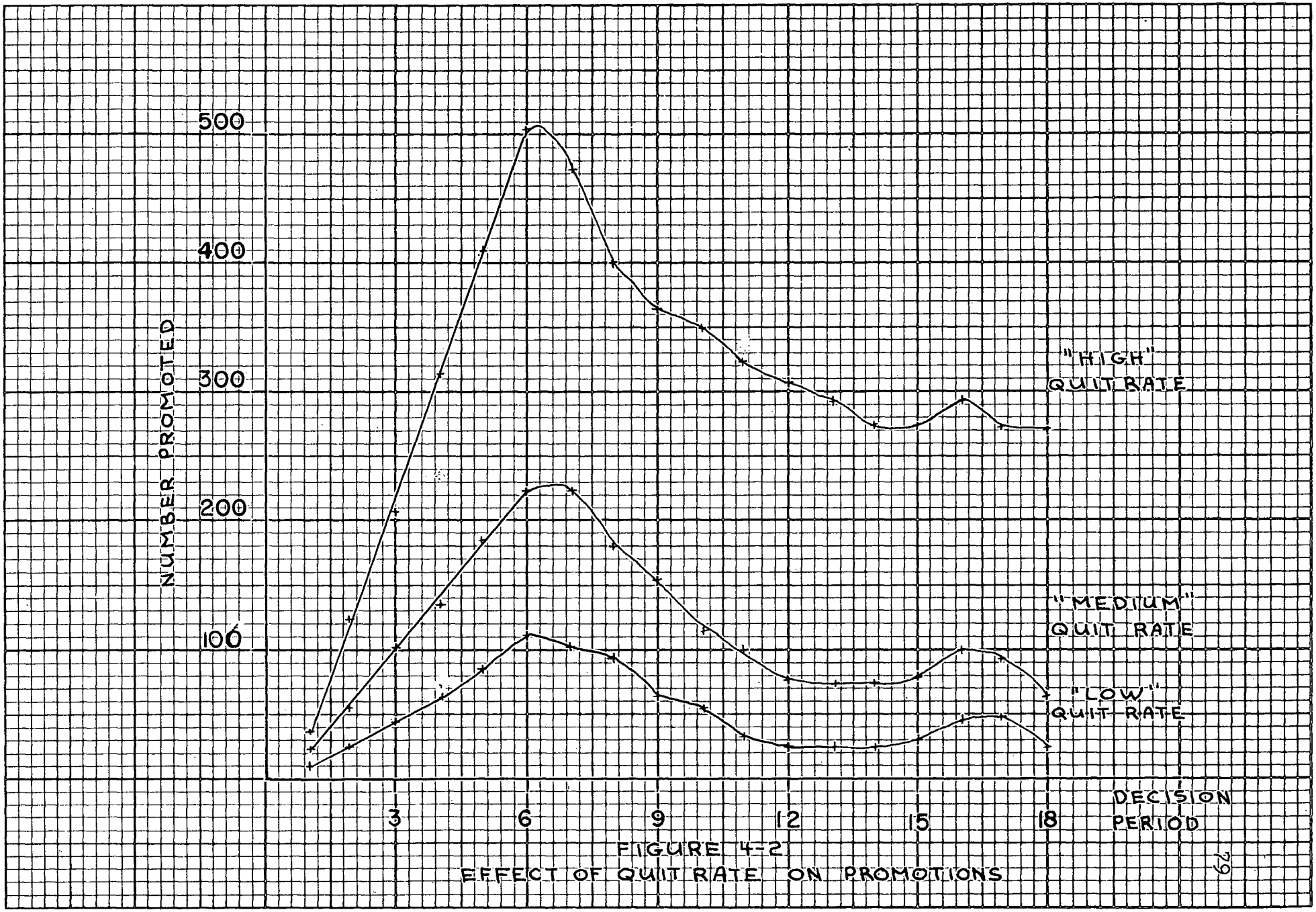


FIGURE 4-2
EFFECT OF QUIT RATE ON PROMOTIONS

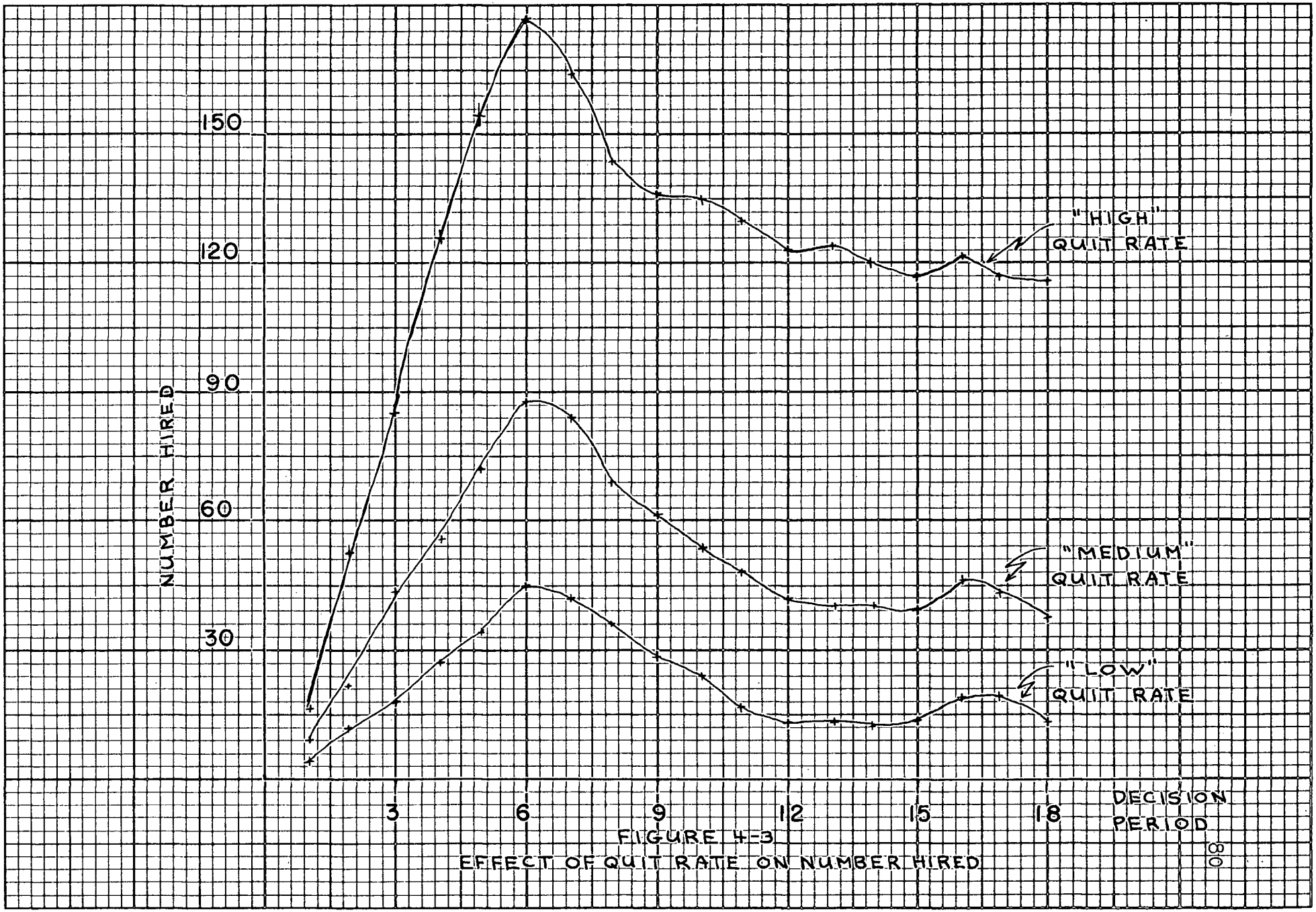


FIGURE 4-3
EFFECT OF QUIT RATE ON NUMBER HIRED

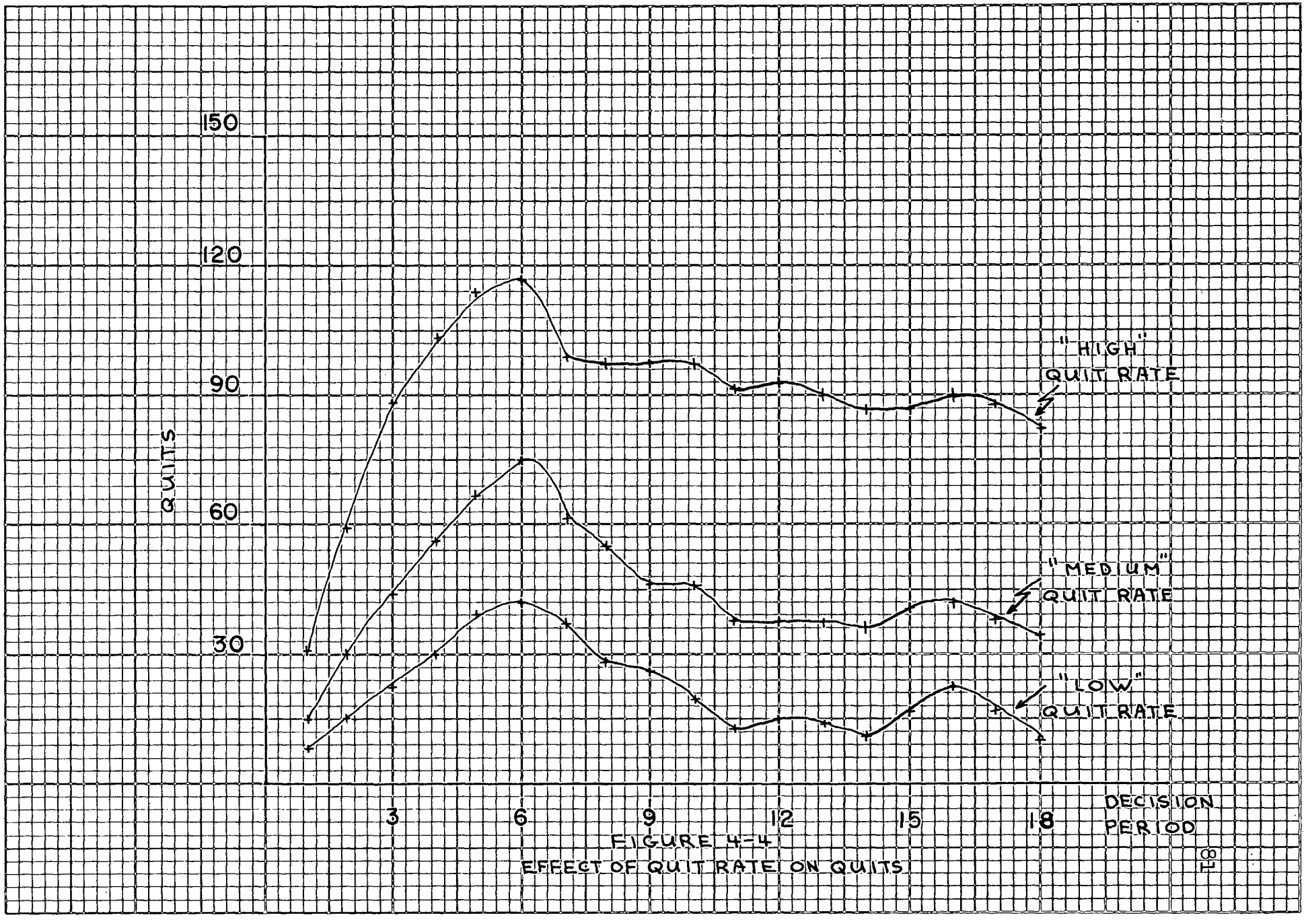


FIGURE 4-4
EFFECT OF QUIT RATE ON QUITS

from the "low" to the "medium" level (a two-fold increase) increases the number hired from 13 to 38, the number promoted from 25 to 73 and the quits from 10 to 34. Doubling the quit rate from the "medium" to the "high" level produces the same relative increase in the hires and quits but an even larger increase in the number promoted. The affect of the quit rate on these factors is shown in Figure 4-5. From this graph it can be seen that as the quit rate increases the number of quits increases linearly, the number hired increases slightly faster and the number of promotions increase exponentially.

Effect of Training Time

The effect of training time on the manpower system was investigated by varying the training delay while other factors were held constant.

Input Data. The input data for this study was the same as in the previous studies except that (1) the "medium" level quit rate was used, (2) the labour force seniority was one month for category one, two months for category two and so on. The training delays were specified as one month and two months in the first and second runs respectively. It was assumed that the delay would be the same for each job category.

Output Data and Analysis. The total number of hires, quits and promotions were determined as the previous investigation and are shown in Figures 4-6, 4-7, and 4-8

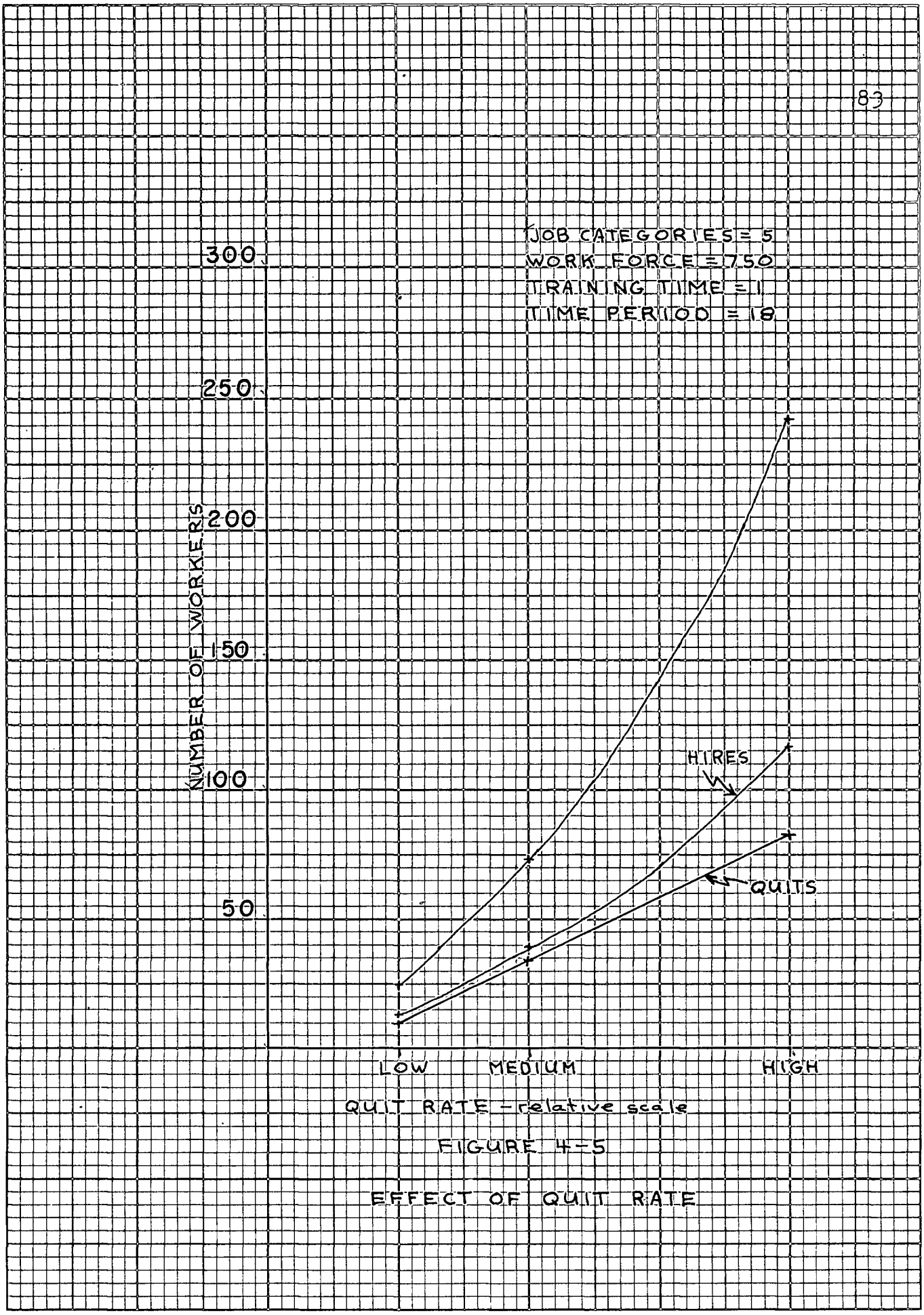


FIGURE 4-5

EFFECT OF QUIT RATE

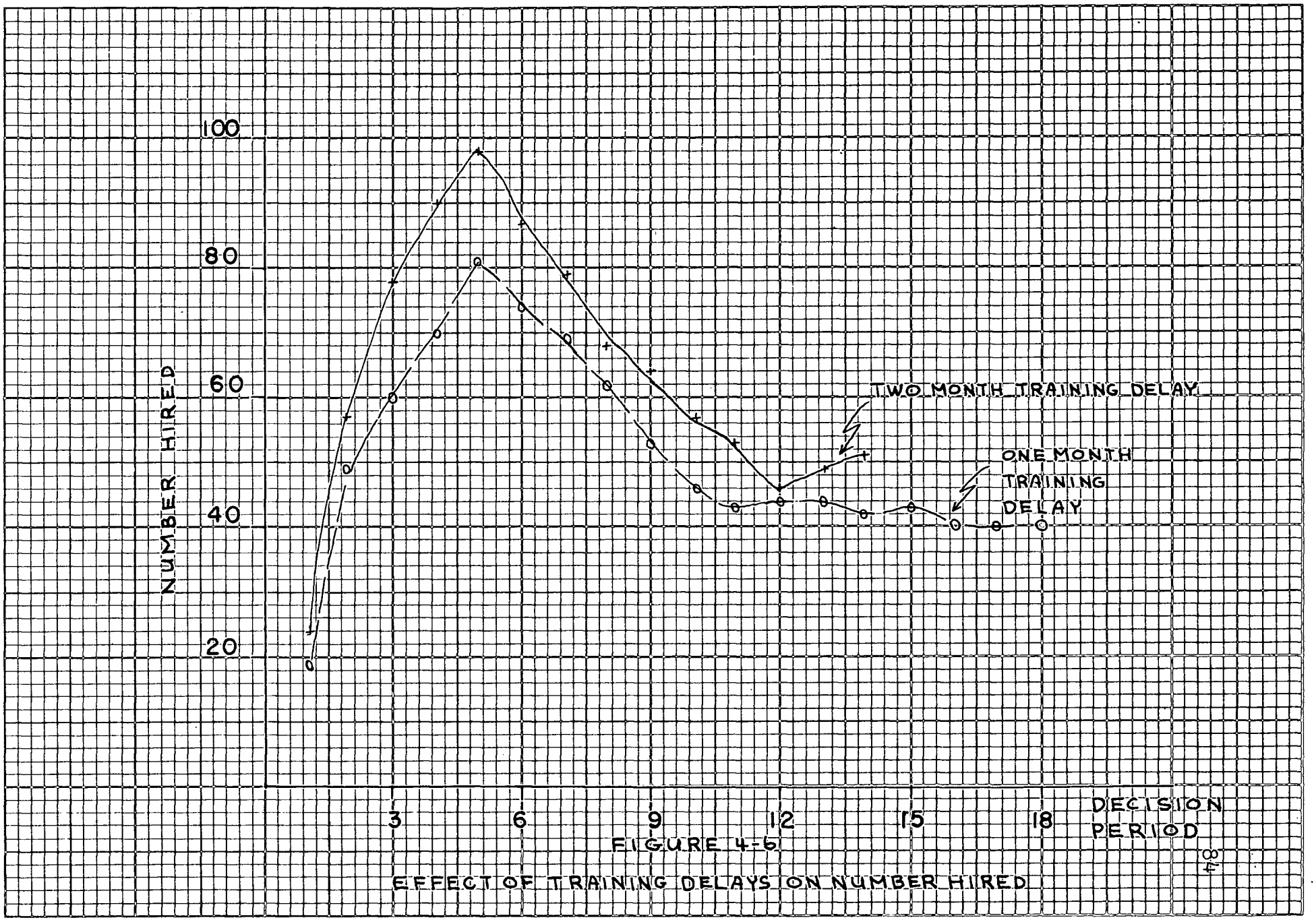


FIGURE 4-6

EFFECT OF TRAINING DELAYS ON NUMBER HIRED

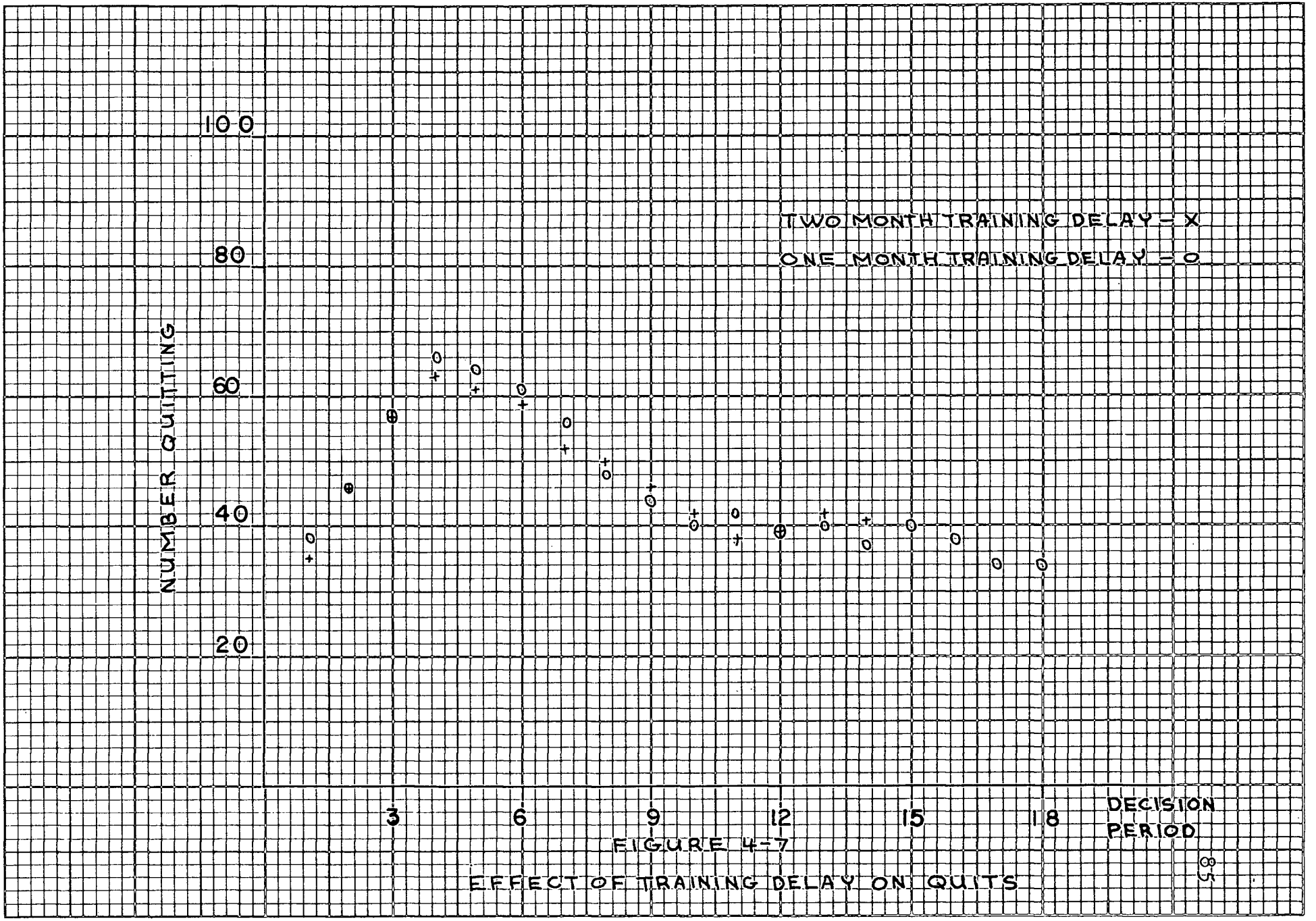


FIGURE 4-7

EFFECT OF TRAINING DELAY ON QUITS

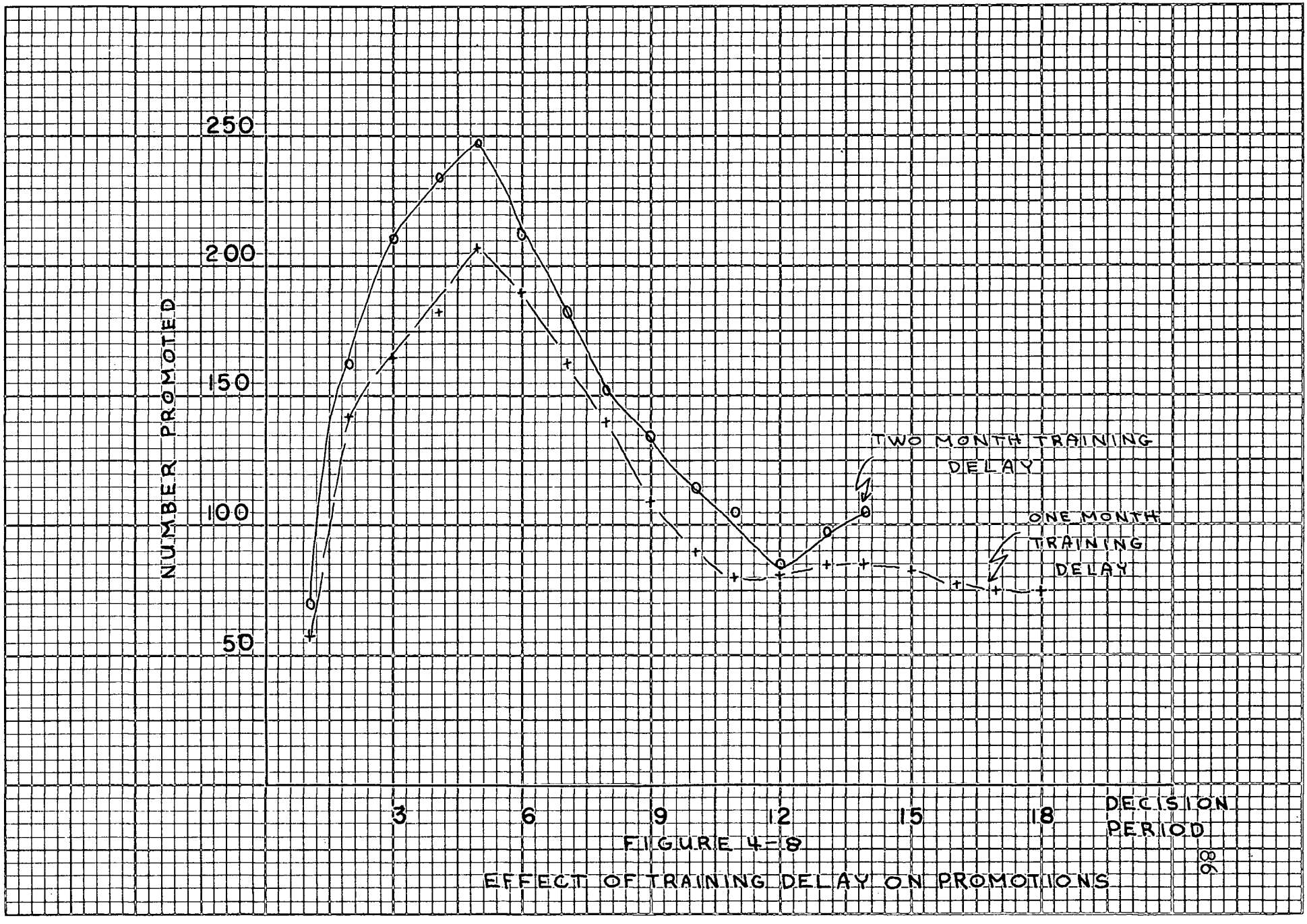


FIGURE 4-8

EFFECT OF TRAINING DELAY ON PROMOTIONS

respectively. On the basis of this information it would appear that the size of the training delay has little effect on the number that quit. The effect of the training delay on the number promoted and hired was more noticable. As would be expected, a longer training time meant that more employees would be in training at any one time. The reason for the higher rates of change, both when promotions were increasing and decreasing, was not clear but it appeared to be related to the seniority distribution of the initial labour force. The variation in the number hired is due to the variation in the number of workers being trained.

Conclusions

The test runs indicated that the model had been properly constructed to simulate the assumed conditions and policies. Preliminary investigations indicated that the size of the quit rate function had a much greater effect on the number of promotions than on the other factors.

CHAPTER V

AREAS FOR FUTURE DEVELOPMENT

The areas requiring further development were divided into three groups.

1. Developments which could be incorporated into the existing model.

2. Construction of a cost-optimizing manpower model.

3. Integration of the manpower model into aggregate production planning techniques.

I. DEVELOPMENT OF THE EXISTING MODEL

The manpower forecasting model developed in this study was a simple model of the manpower function based on the most probable relationships for personnel below the managerial level. These relationships, and the reasons for them, have been discussed in Chapter III under the heading "Specific Assumptions". In several cases, alternative assumptions could have been made and would have produced a more complex model. The primary benefit of including some of these alternatives in the model would be to describe the policies of specific organizations. The inclusion of alternatives would also enable the organization to investigate the effects of various policies on its personnel structure. A number of alternate policies, which could be included in the model,

will now be considered.

Quit Rate. The probability of an employee quitting was assumed to be a function of the total length of service and independent of whether an individual was working or being trained. If the quit rate was a function of the length of service in a particular position, the model would have to be modified so that the "I" subscript in MEN(K,I,J) referred to the elapsed time since the worker was promoted. A different quit rate for trainees could be introduced by specifying another P(I) function in the PPSTAY(K,I) calculation. The quit rate could also be related to the different job categories or to seasonal factors by adding additional subscripts.

Hiring. It was assumed that workers were hired for the lowest job category and that the hiring constraint was a function of time. In order to hire workers for job categories other than K = 1, a criterion for hiring and promoting workers would be required. For example, the criterion might be that workers would be promoted if they were available and that the extra workers required would be hired from outside the organization. The hiring constraint would have to be specified for both the job category and the time period. The training delay for the new hires would have to be stipulated and an additional PPSTAY(K,I) calculated for this group.

The hiring constraint could be altered independently of the hiring procedure. Besides being specified for each

job category, it could be made a function of the hiring rate in past periods by subscripting the HIRES figure. An equation to weight HMAX over a number of periods would also be required.

Promotions. Promotions were assumed to depend upon plant seniority. If it was desirable to promote according to job category seniority while maintaining the quit rate as a function of total seniority an additional subscript would be required. Because FORTRAN names can only have three subscribed variables, the MEN(K,I,J) name would have to be changed. This could be accomplished by specifying a name, such as MEN 1, etc., which would indicate the job category that the men were in. An additional subscript, such as job category seniority, could then be added to the regular labour force.

Training Delay. A training delay in the first job category was assumed to occur due to the time lag between the decision to hire and the time when the new employees started to work. Although it is improbable that this assumption would need to be changed, it could be avoided by artifically advancing the time periods and seniority records by one time period.

Labour Requirement. The organization was assumed to be flexible enough to permit it to hire and promote employees at the start of each time period. As employees quit, the size of the labour force would decrease and the force would

be adjusted at the start of the following period to maintain an average production rate.

This procedure would not be entirely suitable for organizations who wished to maintain a steady labour force throughout the period. The employees would have to be hired, promoted and trained so that the change in labour force (NCHANG) was satisfied at the start of the period and the number to compensate for terminations were introduced during the period.

An illustration of the promotion and quit patterns and their effect on the size of the labour force is shown in Figure 5-1. The diagram shows that the total number of promotions and quits is not affected by the desired labour force so long as the same average number of workers are employed during the period. The constant labour force case could be introduced into the model by specifying the number of trainees required (RETR) as being equal to (NCHANG + NLEAVE) and by specifying the average number of workers (NWORK) as being equal to the labour force at the end of the period (TMEN(K,J)).

Demotions and Lay-offs. The procedure for demoting and laying-off workers in the model is essentially the reverse of the procedure for hiring and promoting. The demotion decision occurs when the number of workers available exceeds the requirement in a particular period. The workers are demoted by removing them from the regular labour force in

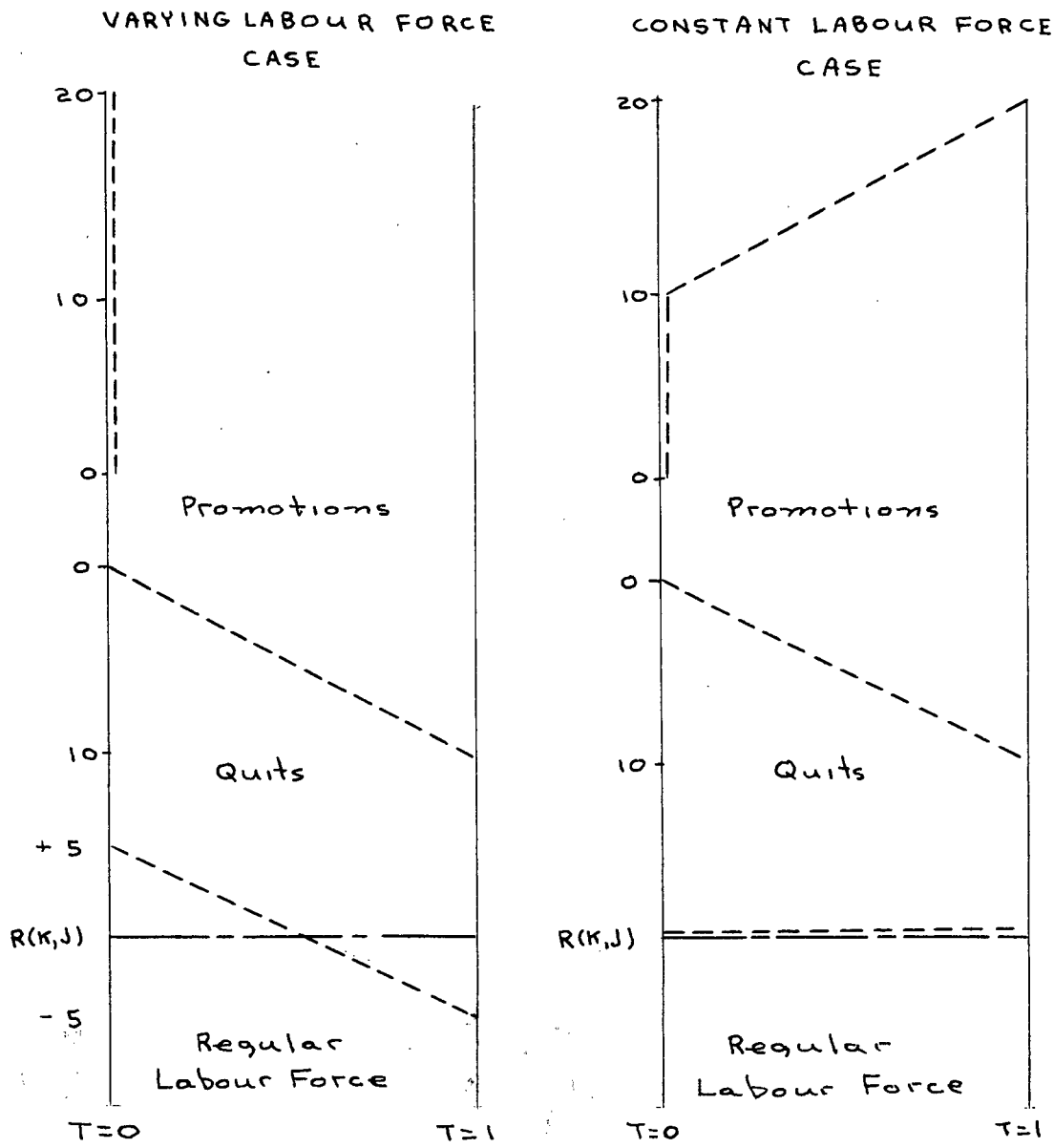


Figure 5-1

Effect of Alternative Promotion Patterns on the Regular Work Force

accordance with the organization's policy. For example, if demotions are based on seniority, the least senior employees would be demoted first. A record of the number of workers demoted, their job category, their seniority and the time period must be kept so that the workers can be introduced into a lower job category at the proper time period.

The decision to lay off workers requires an additional step if these workers must be re-hired before new employees are hired. In this case, the workers must be stored in a "lay-off pool" and recalled from this pool in preference to hiring new employees. Provision should also be made for the laid-off worker to sever his relationship with the firm.

In summary, modifying the model to include provision for demoting and laying-off workers does not present any real problems. These procedures were not included in the original model because the policies and criteria for the decisions vary between different organizations.

Productivity and Labour Requirements. The decision-maker was assumed to be able to forecast the organization's labour requirements. In order to make this forecast the decision-maker must make an implicit assumption regarding the productivity of the individuals in the work force. The model developed in the study assumed that experienced and trained, inexperienced workers were equally productive. This would not occur unless the worker had been trained until he attained his maximum contribution to production.

The effect of increasing productivity with experience could be represented in the model by specifying the labour force requirement in terms of "worker equivalents". Records would have to be kept for the length of service in each job category. Promotions would be based upon the number of "worker equivalents" required in each period. One of the problems in adding variable productivity to the present model is that, as the workers become more experienced, there is a possibility that their productivity will increase faster than the workers quit or are promoted. This would lead to an excess of "workers equivalents" and some employees would be demoted or laid off. A model could be constructed to avoid demotions by considering present and future decisions simultaneously. The model would require a set of cost functions and a dynamic programming formulation of the manpower equations.

II. A COST-ORIENTED MODEL

The next step in increasing the sophistication of the model is to include cost information. The addition of cost equations to the present model would provide a useful tool for analyzing the relative importance of hiring and training costs under various conditions. The model could also be used for assessing cost fluctuations as the size of the labour force changed and for forecasting operating budgets. If the model was expanded to include the other policy variables mentioned in the preceeding section the effect of

various sets of policies could be evaluated in terms of dollars rather than men.

Cost Optimization. The inclusion of cost equations would also make the model amenable to a number of optimizing techniques. Hanssmann and Hess have applied linear programming to manpower planning.[1] Holt and his co-workers developed a procedure for optimal planning when costs were quadratic rather than linear functions.[2] Both reports assumed a homogeneous, one job category work force and that employees could only leave the work force by being laid off. Nevertheless, the fundamentals of the techniques should be applicable to more complex manpower models.

The most promising optimizing technique for manpower planning appears to be dynamic programming. In addition to cost optimization, the technique can solve sequential decision problems.[3] This would permit a considerably more elaborate model to be constructed because it would allow present and future conditions to be evaluated simultaneously. Trainee

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[1]Fred Hanssmann and Sidney W. Hess, "A Linear Programming Approach to Production and Employment Scheduling," Management Technology, I, (January, 1960), pp. 46 - 51.

[2]Charles C. Holt, Franco Modigliani and Herbert A. Simon, "A Linear Decision Rule for Production and Employment Scheduling", Analyses of Industrial Operations, Edward H. Bowman and Robert B. Fetter, editors. (Homewood, Illinois, Richard D. Irwin, Inc., 1959), pp. 169 - 199.

[3]G. Hadley, Nonlinear and Dynamic Programming, (Reading, Massachusetts, Addison-Wesley Publishing Company, Inc., 1960), pp. 375.

productivity and the effect of experience on production rates could be included in the model. An additional advantage to a dynamic programming formulation of the model lies in the use of the model in a number of investigations. Optimal scheduling of the work force would lead to lower labour costs, The analysis of policy considerations would be improved because the model would determine the optimal schedule for each set of policies.

Cost Equations. The main difficulty in developing a cost oriented manpower model is the identification and measurement of relevant costs. Gaudet has published a comprehensive report concerning the determination of recruitment, selection, indoctrination, and severance costs.[4] The major problem in these areas is to separate the relevant costs from the total costs of the personnel department. Gaudet discusses some of the procedures which might be used to determine the average cost per employee and the use of a "selection ratio" procedure for determining total costs. The selection ratio procedure is actually of limited usefulness because different recruitment methods and different numbers of applicants for various jobs cause the ratios to vary.[5] The advent of high speed data processing has led to the development of

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[4]Frederick J. Gaudet, Labour Turnover: Calculation and Cost, (New York, American Management Association, 1960).

[5]Ibid., pp. 42.

procedures for keeping accurate records on the number of applicants at various stages in the hiring process.[6] The use of these procedures by an organization would enable it to keep accurate records of the tangible costs in the hiring and severance processes.

The manpower model must also consider the effect of turnover on the production departments. Inexperienced personnel will generally affect the quantity and quality of the product, cause increased scrap losses, require increased supervision, increase maintenance costs, and increase the number of accidents. The tangible portions of these costs are not separated from total production costs in most accounting systems. The intangible portions of these costs together with the effect which turnover has on other employees and on the company's public image are even more difficult to estimate. To complicate matters still further, the costs must be estimated over various production levels in order to formulate the cost equations.

A major consideration is the relative importance of accurate costs. Bock has suggested that many of the intangible costs are likely to be negligible within the normal

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[6]International Business Machines Ltd., General Information Manual - Personnel Records, (Manual No. E20-8032. Endicott, New York, International Business Machines Ltd., 1966).

[7]Robert H. Bock, "Measuring Cost Parameters in Inventory Models," Management Technology, IV, (June, 1964) pp. 59 - 71.

operating range and that others can be subjectively estimated by management.[7] In some instances the estimation of tangible costs may be slightly less stringent than accounting practice would dictate. Kriebel's study of the empirical problems in obtaining costs indicated that various statistical techniques could be used to estimate the linear decision rule cost coefficients.[8] He also suggested that, in many cases, it might be easier to increase the number of cost equations rather than attempt to fit poorly correlated costs to standardized equations.[9] A number of investigators have found that accurate cost estimation was not required for aggregate planning problems because the total cost curve was relatively flat near the optimal solution.[10]

In summary, it is apparent that the identification and measurement of manpower costs is the most difficult problem in developing a cost oriented manpower model. There are indications that accurate costs may not be mandatory. The shape of the cost functions and the relative importance of these functions should be investigated when a cost oriented model is constructed.

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[8]Charles H. Kriebel, "Coefficient Estimation in Quadratic Programming Models," Management Science, XIII, No. 8, (April, 1967), pp. 473 - 486.

[9]Ibid., pp. 485

[10]These investigations are discussed in the following Section.

III. AGGREGATE PRODUCTION PLANNING

The present model, either with or without the cost optimizing aspects, is a useful planning tool. Organizations such as government bodies, are essentially service organizations and are capable of doing their aggregate planning with a manpower model. Industrial organizations, on the other hand, must consider sales levels, inventories and the work force in their aggregate plans. For this type of organization the manpower model is a component of the overall system and must be integrated with production and inventory models.

The purpose of this section is to briefly discuss a number of techniques which are applicable to this problem of aggregate planning in industrial organizations.

Simulation

The simulation approach to aggregate planning involves the determination and formulation of inventory, production and work force policies in the same manner as the manpower model was developed in this study. A simple model may contain a dozen or so equations relating the various levels, rates, and delays.[11] On the other hand, a detailed study may require hundreds of equations to describe the intricate interactions

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[11]See Stanford L. Optner, Systems Analysis for Business and Industrial Problem Solving, (Englewood Cliffs, N.J., Prentice-hall, Inc., 1965), pp. 372 - 394.

in the firm.[12]

The basic objective of the simulation approach is to develop empirical relations which represent the system being studied. Once these relations have been determined, the effect of various rates, delays and policies can be investigated and the system improved by selecting factors which reduce costs.

The advantage of simulation is that almost any situation may be represented in the model. The disadvantage is that the relations which represent the system under one set of conditions may not be the true relations. Changing the conditions may yield one set of results in the model and quite another in the actual system.

Analytical Techniques

A number of analytical and heuristic techniques have been adapted to or developed for the aggregate planning problem. The common advantage of these approaches is that they produce optimal or near-optimal results. The common disadvantage is that the models are considerably more restricted than they are with simulation procedures. Before discussing the specific techniques, their common limitations must be considered.

Limitations. The analytical techniques currently

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[12]Jay W. Forrester, Industrial Dynamics, (Cambridge, Massachusetts, M.I.T. Press, 1961), pp. 208 - 251.

available consider a two variable system. The two variables, whose scheduling constitutes the problem, are the aggregate production rate and the work force. Because production is only considered in the aggregate sense, a common production unit must be determined. Furthermore, limiting the system to a two variable decision rules out the consideration of changes in product mix, labour mix or production sequences. The effect of these limitations is to restrict the use of the techniques to relatively simple industrial plants where a common denominator for production can be found and where the interaction of product mix is relatively unimportant.

Algorithmic Techniques. Linear programming has been successfully applied to the aggregate planning problem. The basic technique has been described by Hanssmann and Hess and involved the modification of the cost functions from a piece wise linear relationship to true linear form.[13] In a recent article, Orrbeck carried the problem a step further by adjusting the production function to include variable productivity as the worker's experience increased.[14]

Linear programming has two basic weaknesses as an aggregate planning tool. First, the costs must be specified as linear relations. Second, optimal results can only be

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[13]Hanssmann and Hess, op.cit., pp. 48 - 49.

[14]M.G. Orrbeck, D.R. Schuette, and H.E. Thompson, "The Effect of Worker Productivity on Production Smoothing," Management Science, XIV, No. 6, (February, 1968), pp. 332 - 342.

obtained if the forecasts are made with certainty. Hanssmann and Hess state that the deviations should not be significant for reasonably good forecasts.[15] They also suggest that inventory costs are the only costs affected by uncertainty and that the "cost of uncertainty" can be obtained by comparing expected inventory costs to the costs under deterministic conditions.[16]

A second technique, the linear decision rule, was developed specifically for the aggregate production planning problem.[17] The basic assumption of the linear decision rule technique was that all cost functions could be approximated by quadratic equations. The optimal solution was obtained by solving the set of linear equations obtained when the partial derivatives of total cost with respect to each period work force and inventory were set equal to zero. The use of quadratic cost functions was justified by two reasons. First, it was suggested that in many instances the cost relations were probably non-linear and increased rapidly outside the normal operating range. The second reason for quadratic equations was that an optimal solution could be obtained from uncertain production forecasts.

A major factor in the use of the linear decision rule

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[15]Hanssmann and Hess, op.cit., pp. 50.

[16]Ibid., pp. 50 - 51.

[17]Holt, Modigliani and Simon, op.cit., pp. 170.

was the effect of inaccurate costs on the final solution. A number of investigators have found that the total cost curve for a system is relatively flat near the optimal solution.[18] Holt's initial studies indicated that if the decision rule coefficient were incorrect by a factor of two, i.e., 100 percent over or 50 percent under, total costs increased by 11 percent.[19]

The theory behind the accuracy problem was subjected to rigorous analysis by VanDePanne and Bosje.[20] The analysis showed that small errors in the cost coefficients had little effect in the short term but the errors were cumulative and produced severe distortions if an infinite planning horizon was considered. Thus it would appear that accurate coefficient estimation was not mandatory and that a rigorous analysis of the cost components was not required with the linear decision rule.

Heuristic Techniques. A number of heuristic techniques have been developed to solve aggregate planning problems. The basic premise behind these techniques was that, if the total cost curve was relatively flat, a "good" solution could

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[18]Charles C. Holt, et.al., Planning Production, Inventories and Work Force, (Englewood Cliffs, N.J., Prentice-Hall, Inc., 1960), pp. 65 - 66.

[19]Holt, Modigliani and Simon, op.cit., pp. 184.

[20]C. Van DePanne and J. Bosje, "Sensitivity Analysis of Cost Coefficient Estimates: The Case of Linear Decision Rules for Employment and Production," Management Science, IX, No. 1, (October, 1962), pp. 82 - 107.

which was close to the "optimal" solution. Bowman suggested that the cost coefficients for the decision rules be derived from management's past decisions rather than from the cost model.[21] Bowman based this decision on the premise that management subjectively estimates coefficients in their normal decisions. He suggested that experienced managers were probably good coefficient estimators and that their costs fluctuated due to variance in decision making rather than biased estimates.[22] He found that formal estimation of the coefficients produced improved performance but that the results were not as good as those obtained by the linear decision rule.[23]

A slightly different approach to coefficient estimation was taken by Jones in the development of the parametric production planning technique.[24] Rather than estimate the coefficients, Jones developed the production and work force decision rules with parameters for the desired change and relative weighting of future periods. The solution was obtained by searching the four dimensional universe of

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[21]Edward H. Bowman, "Consistancy and Optimality in Management Decision Making," Management Science, IX, No. 5, (January, 1963), pp. 310 - 321.

[22]Ibid., pp. 320.

[23]Ibid., pp. 316.

[24]Curtis H. Jones, "Parametric Production Planning," Management Science, XII, No. 11, (July, 1967), pp. 843 - 865.

possible parameters to select a set of parameters which gave the lowest costs. When the approach was applied to a number of situations it was found to yield results which were comparable to Holt's linear decision rule and to linear programming with certain forecasts. Jones also found that the approach was decidedly superior to linear programming if uncertain forecasts were included. The result of this investigation also supported Bowman's hypothesis that the consistency with which coefficients were used was an important determinant of the relative optimality of the results.[25]

Taubert has recently investigated the applicability of a number of search techniques to the aggregate scheduling problem.[26] The basic approach was to convert Holt's linear decision rules into a twenty dimension response surface. The surface was explored by conjugate gradient, variable metric and pattern search methods. Taubert reported that the methods sought out a minimum point on the surface which approximated the results of the linear decision rule.

Comparison of Techniques. A comparison between simulation and analytical techniques was not possible because the same firms have not been studied. The analytical techniques, however, were compared to each other. Bowman

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[25]Jones, op.cit., pp. 856.

[26]William H. Taubert, "A Search Decision Rule for the Aggregate Scheduling Problem," Management Science, XIV, No. 6, (February, 1968), pp. 343 - 359.

compared the costs obtained by his "managerial coefficients" procedure to the results obtained by Holt. In three cases, where the cost reductions were relatively small, Bowman's procedure produced comparable results. In a fourth case, a paint factory, Bowman did not obtain the large cost reduction obtained by Holt.[27] The parametric production planning technique was applied to the paint factory and produced results which differed from the linear decision rule by $933 on a two million dollar cost base.[28] Jones also compared the technique to a linear programming solution for a hypothetical firm. He found that parametric planning produced eight percent higher than linear programming with certain forecasts and eight percent lower than linear programming with uncertain forecasts.[29]

In summary, it would appear that the heuristic techniques yield results which are not appreciably different from algorithmic techniques with complete certainty. The time savings obtained by utilizing a heuristic approach, together with the ability of Jones' technique to consider uncertainty and realistic cost functions would indicate that parametric production planning may be the best approach to future planning problems.

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[27]Bowman, op.cit., pp. 316.

[28]Jones, op.cit., pp. 852.

[29]Ibid., pp. 852.

CHAPTER VI

CONCLUSIONS

The study showed that a number of investigators have constructed manpower forecasting models. Several models were developed solely for manpower planning purposes. Other models, the majority of the ones investigated, were developed to consider manpower planning as part of the aggregate production planning decision. The diversity of model types and the wide range of assumptions made in previous studies suggested that the factors to be considered in a general model required investigation.

The investigation demonstrated that the following factors should be included in a general manpower planning model.

1. A forecast of future labour requirements.
2. Information on the present labour force.
3. A hierarchical organization structure.
4. Provision for time lags whenever hiring or training occurs.
5. A labour pool from which the employees are hired.
6. Provision for labour turnover.
7. Provision for hiring and promoting employees.
8. Provision for laying-off and demoting employees.

When these considerations were compared to the existing

models it was found that none of the models included a hierarchical organization structure and that many did not adequately consider time delays or the labour turnover relationship. A decision was made to construct a forecasting model which would include the relevant factors, particularly a hierarchical structure. The investigation showed that two types of forecasting models could be built. A simulation model would be applicable if the forecasting decision was based on information pertaining to the current period. A dynamic programming model would be necessary if the forecasting decision depended upon a balancing of present and future decisions. A dynamic programming formulation of the model would have required the development of cost relationships so that optimal decisions could be obtained. Because the study had been restricted to the investigation and development of the Industrial Relations aspects of the model, the cost aspects were beyond the scope of the study. Rather than construct a model based upon inadequately investigated cost equations, the decision was made to construct a simulation model. The effect of this decision was to restrict the model to organizations where the number of trainees did not appreciably affect production.

In order to further deliniate the model a number of assumptions were made to specify the organization's hiring, promotion and training policies. A set of equations were developed to demonstrate the fundamental calculation which

determined the number of promotions and quits in each time period. The equations were then included in the model and the model was programmed for solution by computer. Test calculations were made to demonstrate how the model worked and to investigate how different quit rates and training times affected the number of workers hired and promoted.

The model showed that as the quit rate increased the number of quits increased linearly, the number hired increased slightly faster and the number promoted increased exponentially. Increasing the training time increased the number of promotions but did not affect the number of hires or quits.

Because the model was developed and programmed to consider a set of the more probable policy assumptions it was lacking the flexibility to treat other policy conditions. The nature of these policy alternatives were investigated and the procedures for changing the model to include them were described.

The most fertile area for future developments in manpower forecasting appeared to be in the construction of a dynamic programming model. In addition to removing the restriction on trainee productivity, dynamic programming would produce a cost-optimizing model that could either be used by itself or integrated into a large aggregate planning model. Despite the indication that approximate cost information would yield near optimal results the interrelationship of costs with the manpower function would appear to warrant

investigation before or during the construction of a cost-optimizing model.

The investigation of the factors which should be included in a general model revealed that there were several areas that require further research. The size of the labour supply available to the organization can only be subjectively estimated. In view of the labour shortage in certain industries and regions a study might be initiated to determine the factors affecting the supply of labour to the firm. Another area in the hiring process that should be investigated is the effect of the hiring rate on the ability of the workers hired. A number of psychological tests are available to measure worker aptitudes, but as far as could be determined, they have not been used in this type of study.

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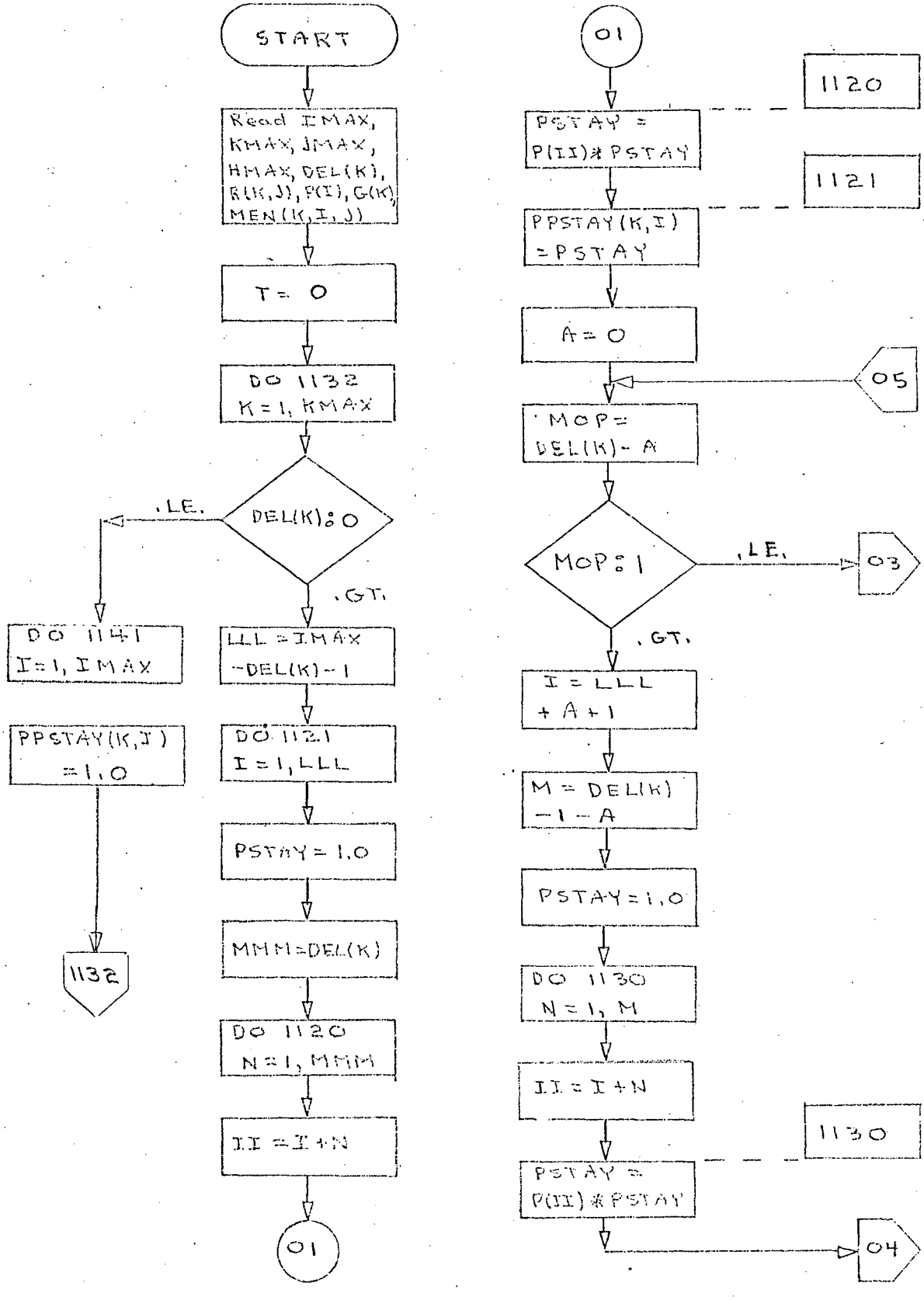
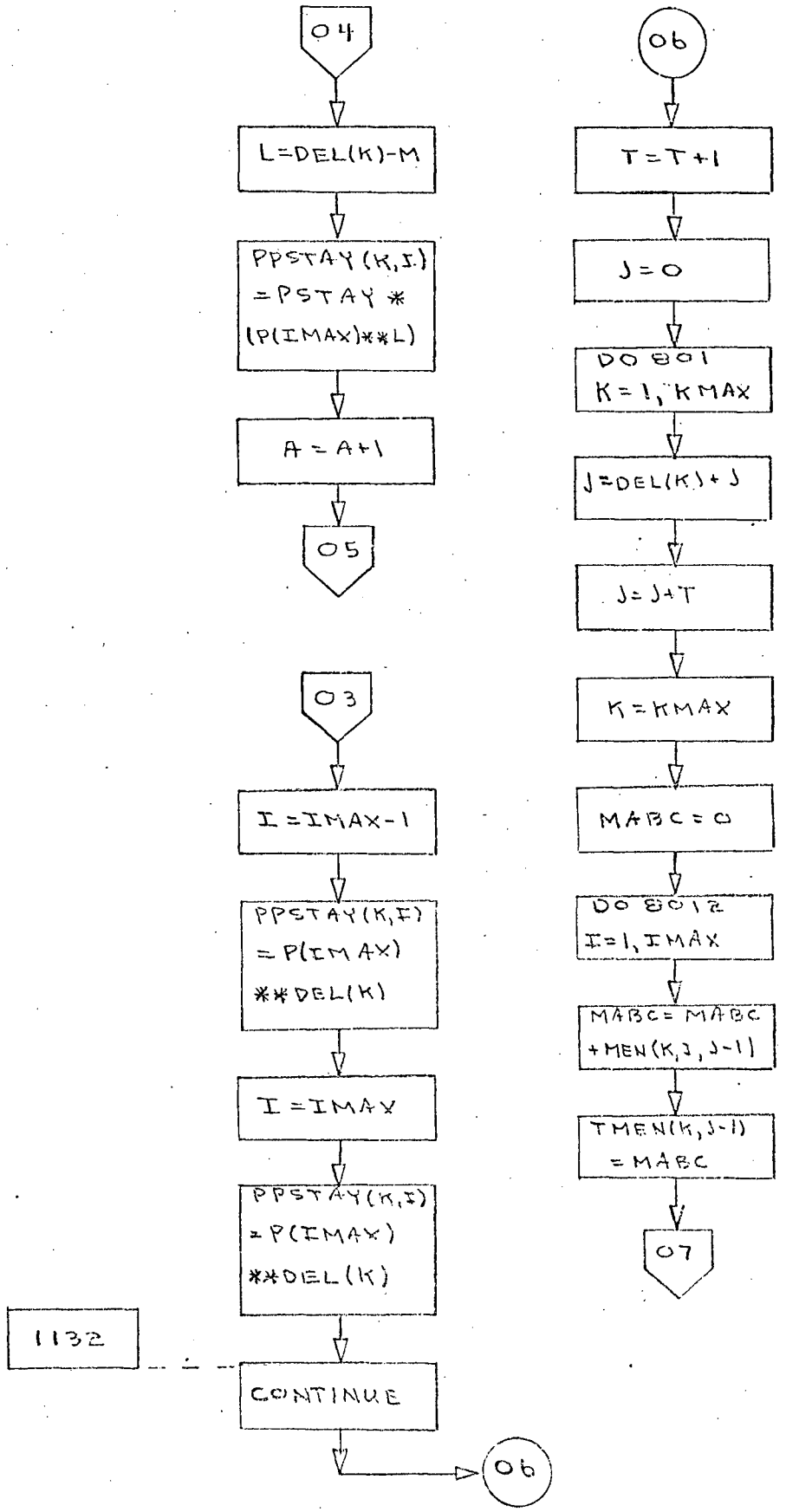
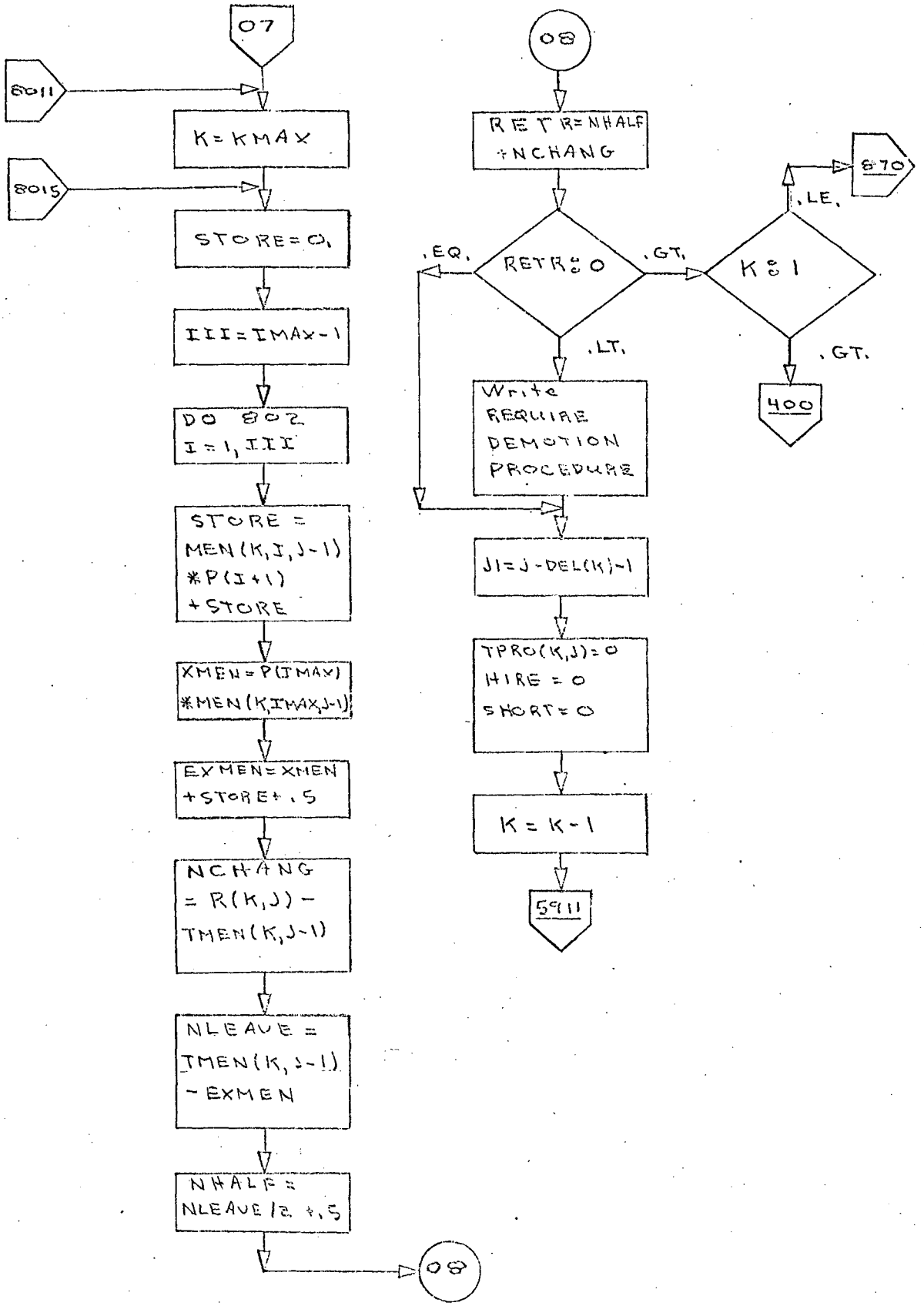
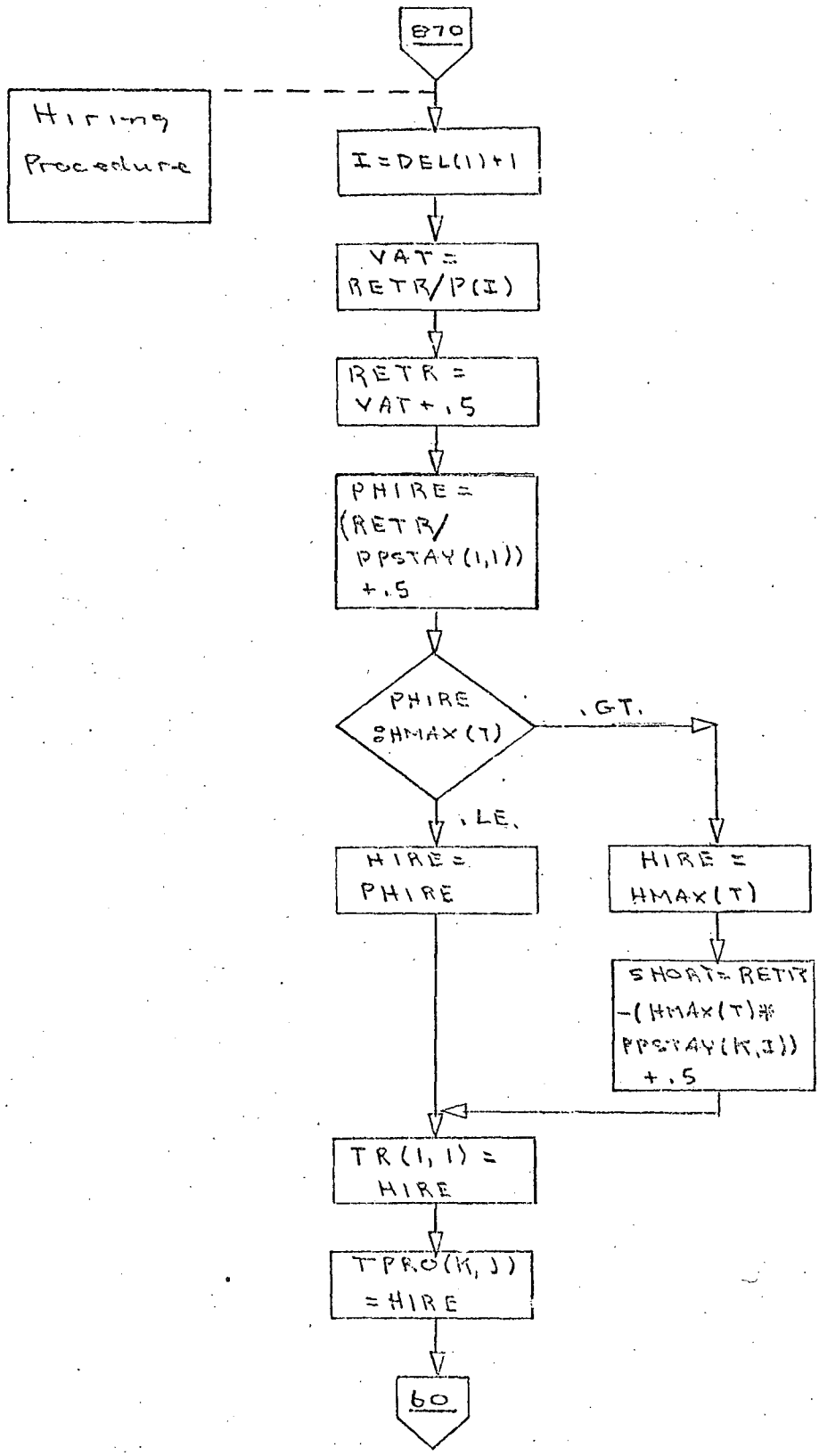
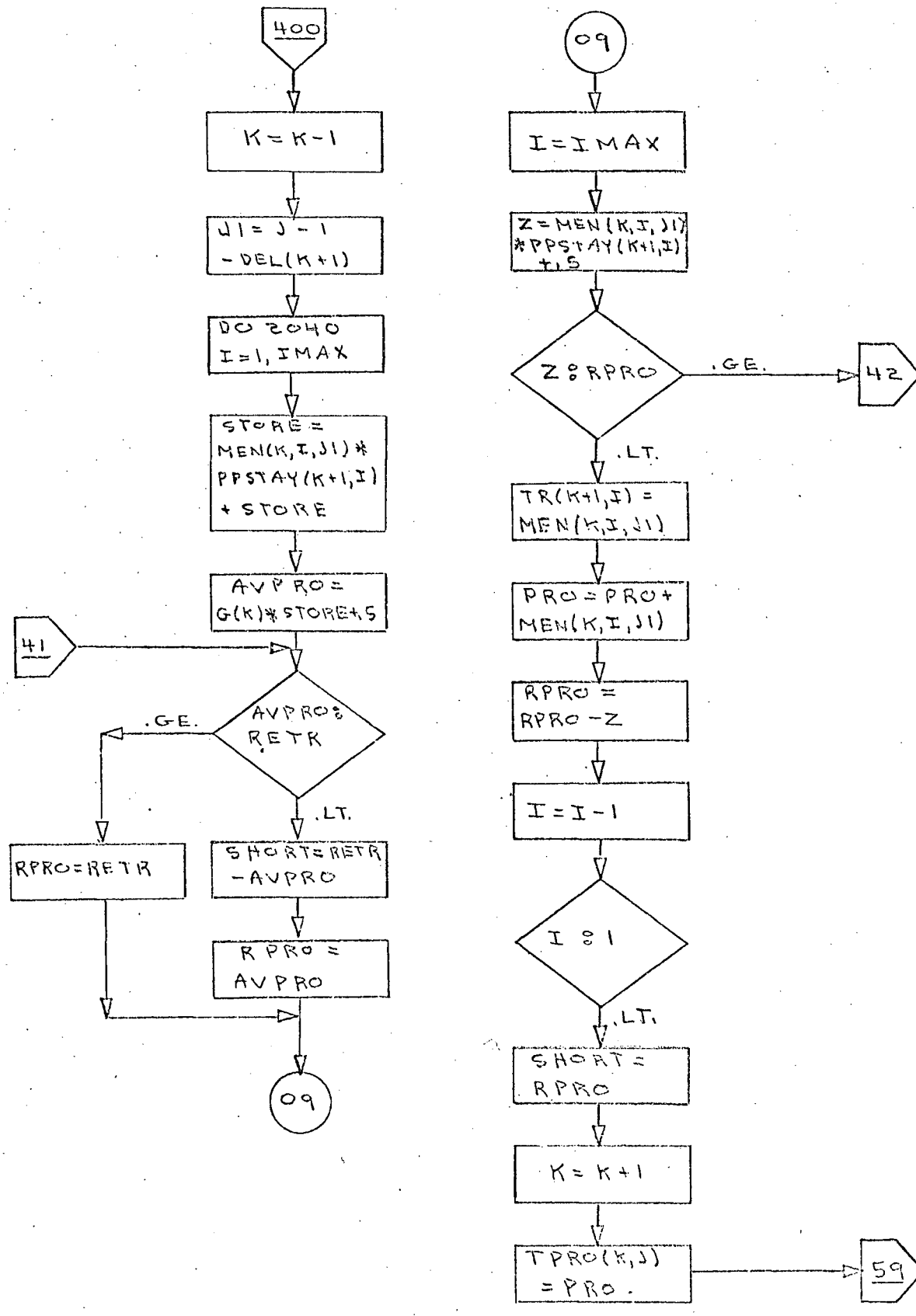
APPENDIX

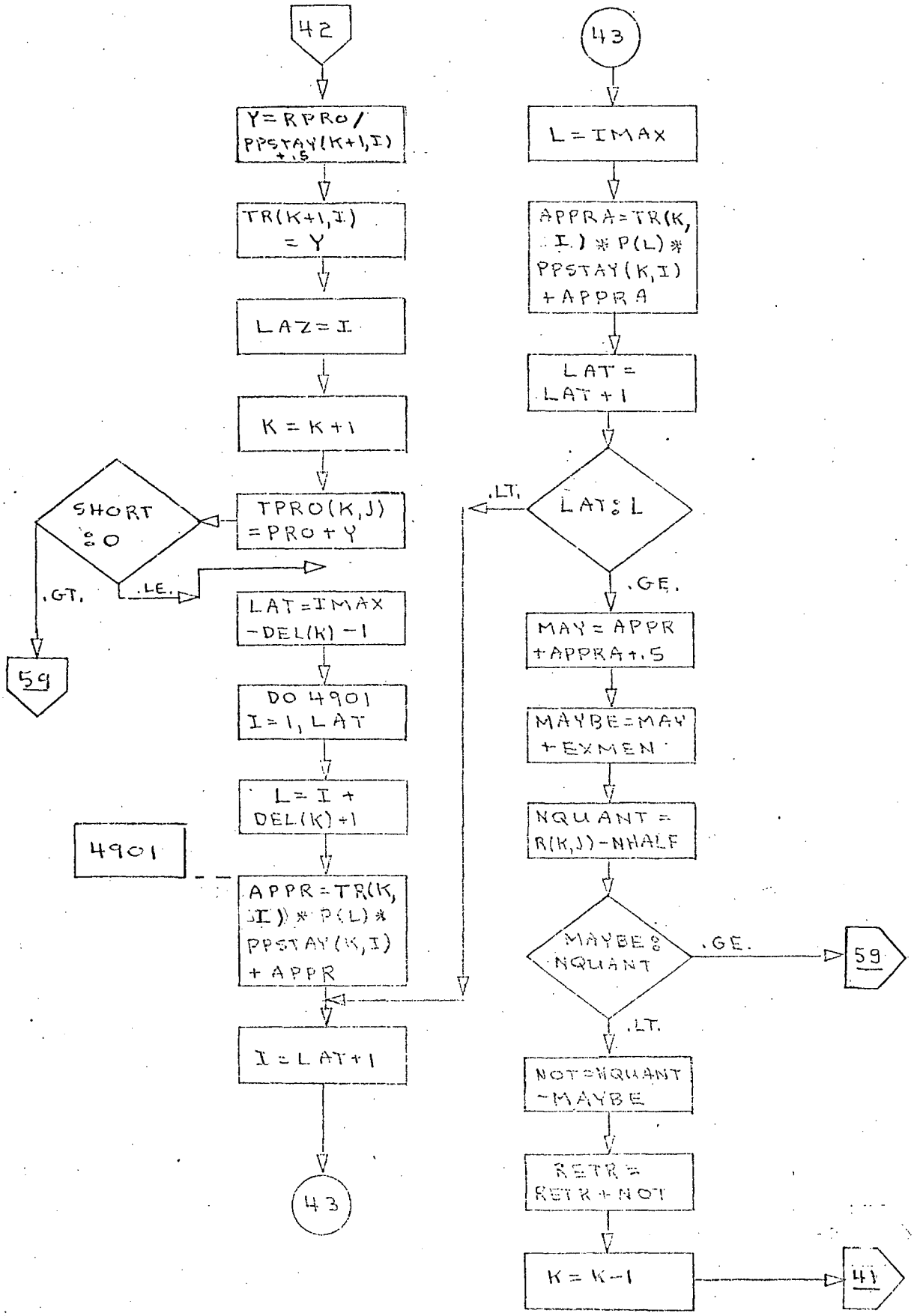

START
Read IMAX, KMAX, JMAX, HMAX, DEL(K), R(K,J), P(I), G(K), MEN(K,I,J)
T = 0
DO 1132 K=1, KMAX
DEL(K): 0
.LE.
.GT.
DO 1141 I=1, IMAX
PPSTAY(K,I) = 1.0
1132
LLL = IMAX - DEL(K) - 1
DO 1121 I=1, LLL
PSTAY = 1.0
MMM = DEL(K)
DO 1120 N=1, MMM
II = I+N
01
01
1120
PSTAY = P(II) * PSTAY
1121
PPSTAY(K,I) = PSTAY
A = 0
05
MOP = DEL(K) - A
MOP: 1
.LE.
03
.GT.
I = LLL + A + 1
M = DEL(K) - 1 - A
PSTAY = 1.0
DO 1130 N=1, M
II = I+N
1130
PSTAY = P(II) * PSTAY
04

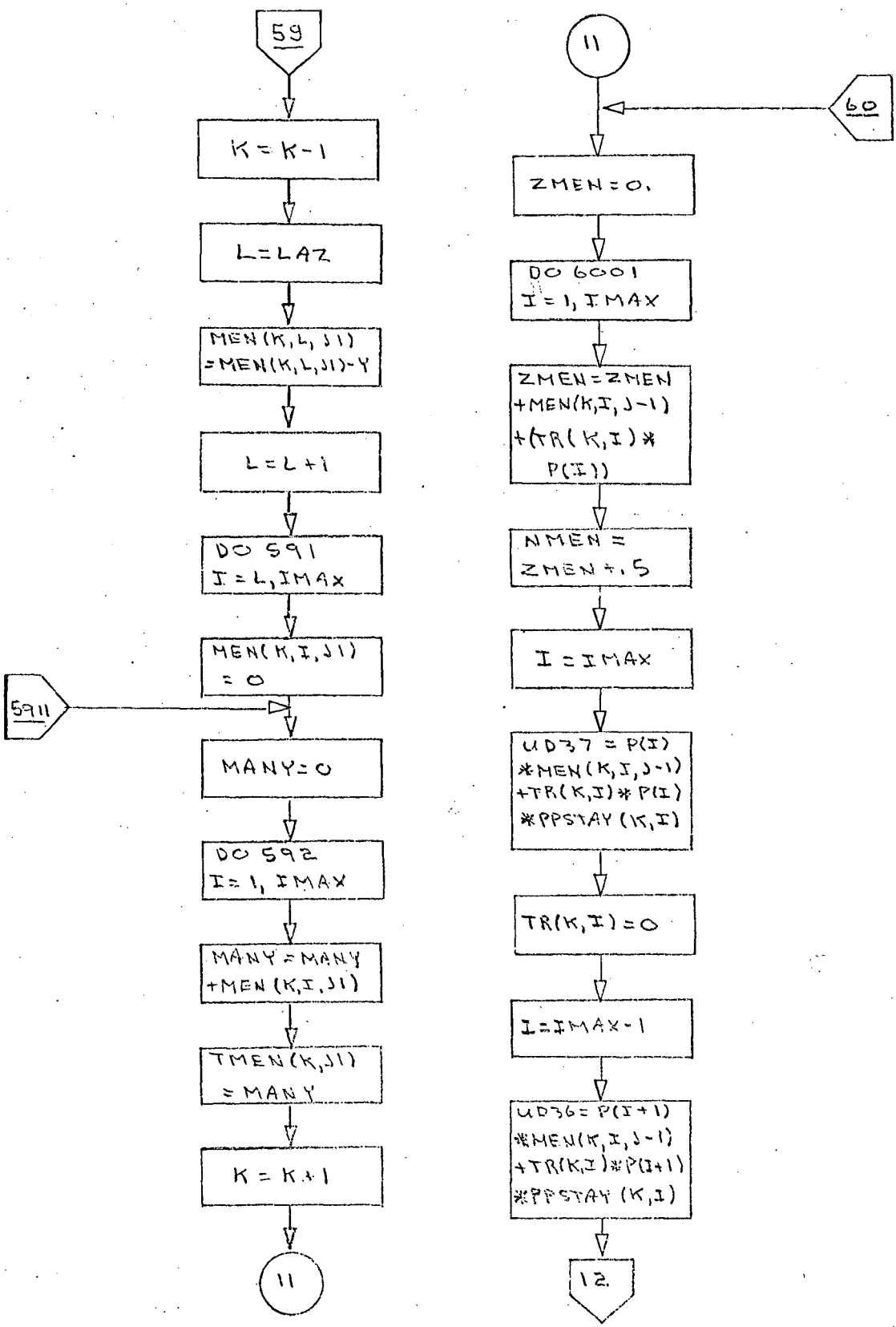

04
L=DEL(K)-M
PPSTAY(K,I)
=PSTAY *
(P(IMAX)**L)
A=A+1
05
03
I=IMAX-1
PPSTAY(K,I)
=P(IMAX)
**DEL(K)
I=IMAX
PPSTAY(K,I)
=P(IMAX)
**DEL(K)
1132
CONTINUE
06
06
T=T+1
J=0
DO 801
K=1, KMAX
J=DEL(K)+J
J=J+T
K=KMAX
MABC=0
DO 8012
I=1, IMAX
MABC=MABC
+MEN(K,J,J-1)
TMEN(K,J-1)
=MABC
07

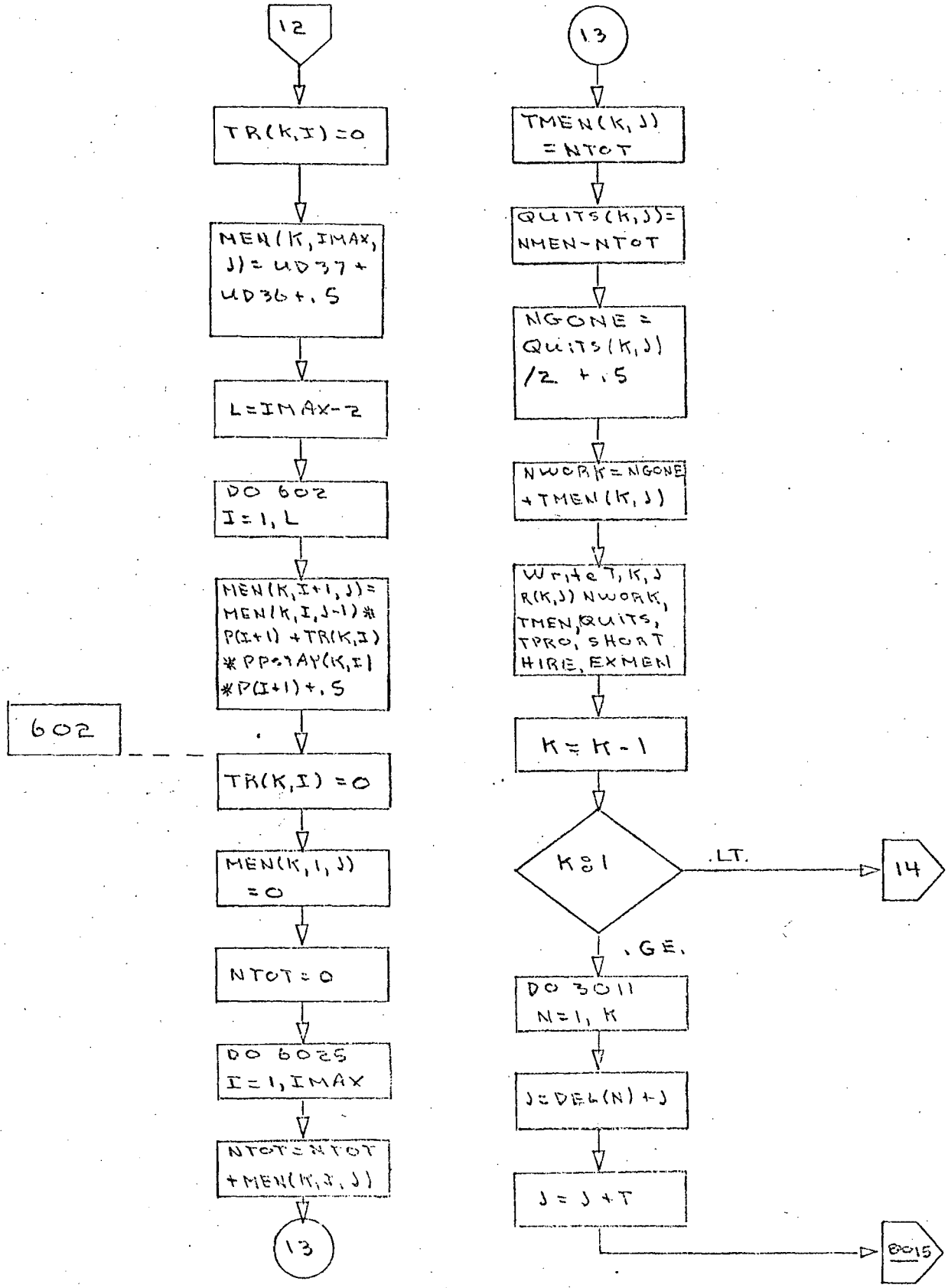

07
8011
8015
K=KMAX
STORE=0.
III=IMAX-1
DO 802
I=1,III
STORE =
MEN(K,I,J-1)
*P(I+1)
+STORE
XMEN=P(IMAX)
*MEN(K,IMAX,J-1)
EXMEN=XMEN
+STORE+.5
NCHANG
=R(K,J)-
TMEN(K,J-1)
NLEAVE=
TMEN(K,J-1)
-EXMEN
NHALF=
NLEAVE/2.+.5
08
08
RETR=NHALF
+NCHANG
RETR=0
.EQ.
.GT.
.LT.
K=1
.LE.
.GT.
870
400
Write
REQUIRE
DEMOTION
PROCEDURE
JI=J-DEL(K)-1
TPRO(K,J)=0
HIRE=0
SHORT=0
K=K-1
5911

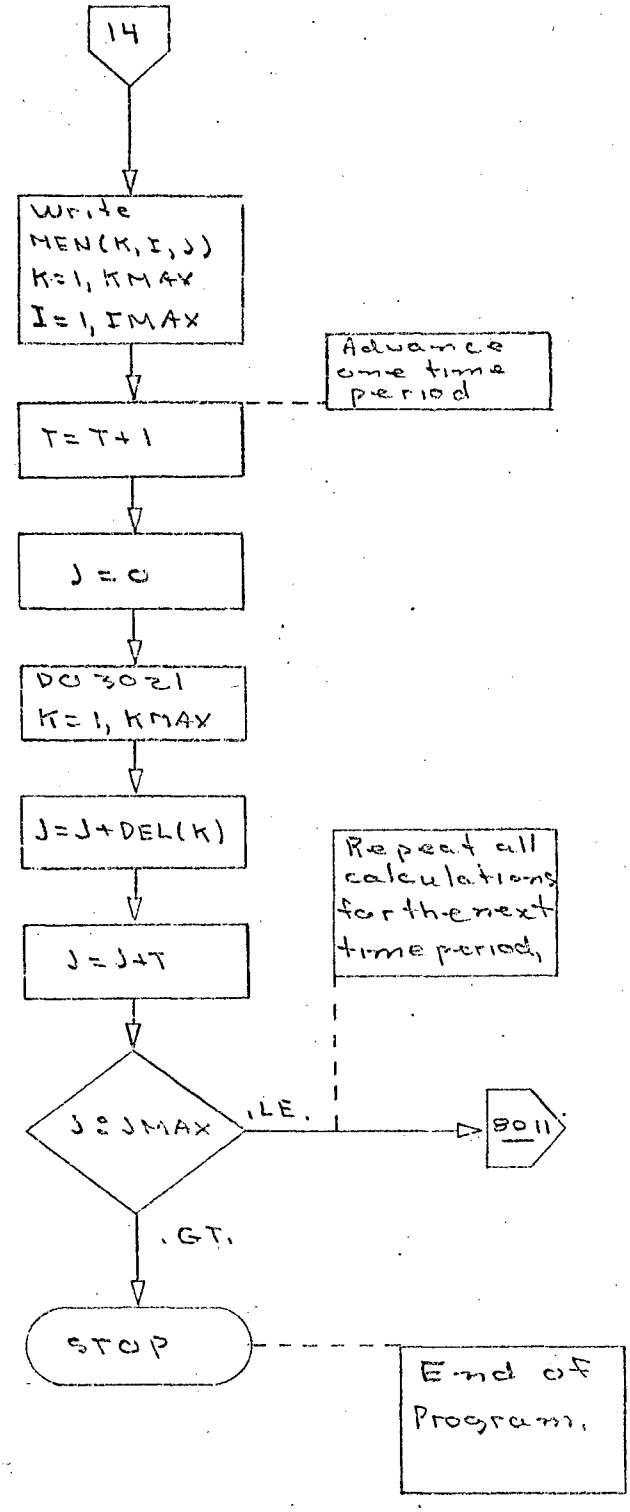

870
Hiring Procedure
I=DEL(1)+1
VAT=RETR/P(I)
RETR=VAT+.5
PHIRE=(RETR/PPSTAY(1,1))+.5
PHIRE .GT. HMAX(T)
.LE.
HIRE=PHIRE
HIRE=HMAX(T)
SHORT=RETR-(HMAX(T)*PPSTAY(K,I))+.5
TR(1,1)=HIRE
TPRO(K,J)=HIRE
60


400
K=K-1
J1=J-1
-DEL(K+1)
DO 2040
I=1,IMAX
STORE=
MEN(K,I,J1)*
PPSTAY(K+1,I)
+STORE
AVPRO=
G(K)*STORE+S
41
AVPRO≥
RETR
.GE.
.LT.
RPRO=RETR
SHORT=RETR
-AVPRO
RPRO=
AVPRO
09
09
I=IMAX
Z=MEN(K,I,J1)
*PPSTAY(K+1,I)
+S
Z≥RPRO
.GE.
42
.LT.
TR(K+1,I)=
MEN(K,I,J1)
PRO=PRO+
MEN(K,I,J1)
RPRO=
RPRO-Z
I=I-1
I≥1
.LT.
SHORT=
RPRO
K=K+1
TPRO(K,J)
=PRO.
59


42
Y=RPRO/PPSTAY(K+1,I)+.5
TR(K+1,I)=Y
LAZ=I
K=K+1
SHORT .LT. 0
TPRO(K,J)=PRO+Y
.GT.
.LE.
59
LAT=IMAX-DEL(K)-1
DO 4901 I=1,LAT
4901
L=I+DEL(K)+1
APPR=TR(K,I)*P(L)*PPSTAY(K,I)+APPR
I=LAT+1
43
43
L=IMAX
APPRA=TR(K,I)*P(L)*PPSTAY(K,I)+APPRA
LAT=LAT+1
LAT .LT. L
.GE.
MAY=APPR+APPRA+.5
MAYBE=MAY+EXMEN
NQUANT=R(K,J)-NHALF
MAYBE .GE. NQUANT
59
.LT.
NOT=NQUANT-MAYBE
RETR=RETR+NOT
K=K-1
41


59
K = K-1
L=LAZ
MEN(K,L,J1) =MEN(K,L,J1)-Y
L=L+1
DO 591 I=L,IMAX
MEN(K,I,J1) = 0
5911
MANY=0
DO 592 I=1,IMAX
MANY=MANY +MEN(K,I,J1)
TMEN(K,J1) = MANY
K = K+1
11
11
60
ZMEN=0.
DO 6001 I=1,IMAX
ZMEN=ZMEN +MEN(K,I,J-1) +(TR(K,I)* P(I))
NMEN = ZMEN+.5
I = IMAX
UD37 = P(I) *MEN(K,I,J-1) +TR(K,I)*P(I) *PPSTAY(K,I)
TR(K,I)=0
I=IMAX-1
UD36= P(I+1) *MEN(K,I,J-1) +TR(K,I)*P(I+1) *PPSTAY(K,I)
12.


12
TR(K,I)=0
MEN(K,IMAX,J)=UD37+UD36+.5
L=IMAX-2
DO 602 I=1,L
MEN(K,I+1,J)=MEN(K,I,J-1)*P(I+1)+TR(K,I)*PP=1AP(K,I)*P(I+1)+.5
602
TR(K,I)=0
MEN(K,1,J)=0
NTOT=0
DO 6025 I=1,IMAX
NTOT=NTOT+MEN(K,I,J)
13
13
TMEN(K,J)=NTOT
QUITS(K,J)=NMEN-NTOT
NGONE=QUITS(K,J)/2.+.5
NWORK=NGONE+TMEN(K,J)
Write T,K,J R(K,J) NWORK, TMEN,QUITS, TPRO, SHORT HIRE, EXMEN
K=K-1
K≤1
.LT.
14
.GE.
DO 3011 N=1,K
J=DEL(N)+J
J=J+T
8015


14
Write
MEN(K,I,J)
K=1, KMAX
I=1, IMAX
Advance one time period
T=T+1
J=0
DO 3021
K=1, KMAX
J=J+DEL(K)
J=J+T
Repeat all calculations for the next time period
J ≤ JMAX
.LE.
9011
.GT.
STOP
End of Program.