A TELECOMMUNICATIONS NETWORK FOR DATA PROCESSING IN SCHOOLS: A MATHEMATICAL MODEL

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THESIS

This is to certify that the

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ABSTRACT

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by Rex Leroy Wood

Statement of the Problem

This study is concerned with the definition of a problem, quantifying the various properties that describe the components of the problem, suggesting a solution to the problem, and testing that solution. The problem simply defined is to configurate a computer system in which local school district offices, comprising the constituent school districts of the intermediate school district, Oakland Schools, Michigan, can send data over telephone wires to a single powerful computer, have that data processed and returned over the telephone wire to an output printer device.

Procedure

Quantifying the properties of the components involves recording in appropriate form, data about individual districts such as the number of students, the number of employees, the quantity of purchasing activity, and the calendar of various events taking into consideration the time of day, week, month and year. The solution suggested is in the form of electronic devices interconnected to constitute a telecommunications network. This network contains the elements of a computer, remote terminal devices located in local school district offices and the interconnecting communication lines. These quantified properties constitute a mathematical model. The test of the solution of the problem

is the simulation of the mathematical model. The study is further concerned with the interpretation of the results of the simulation.

Conclusions and Recommendations

The successful simulation of the mathematical model of data processing applications in schools using telecommunications facilities demonstrates that simulation is a technique that school administrators can use in their management roles. The computer output from the simulation run provides specific assistance to the staff of Oakland Schools and local district personnel in the definition and resolution of related problems. The model provides a base for configurating a system sensitive to changing demands of local school districts. Optimization of the system is possible through remodeling and repeated simulation runs. The flow diagrams and computer program in the appendixes provide adequate documentation for replication of the project.

Further attention by both school and technical personnel is needed to exploit the mathematical analysis tools to the benefit of educational administration.

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To the many superintendents, school business officials, principals and other school personnel in the constituent school districts of Oakland Schools for cooperation in the data collection phase of the project.

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CHAPTER I

INTRODUCTION

Statement of the Problem

This study is concerned with the definition of a problem, quantifying the various properties that describe the components of the problem, suggesting a solution to the problem, and testing that solution. The problem simply defined is to configurate a computer system in which local school district offices, comprising the constituent school districts of Oakland Schools[1], can send data over telephone wires to a single powerful computer, have that data processed and returned over the telephone wire to an output printer device. Quantifying the properties of the components involves recording in appropriate form, data about individual districts such as the number of students, the number of employees, the quantity of purchasing activity, and the calendar of various events taking into consideration the time of day, week, month and year. The solution suggested is in the form of electronic devices interconnected to constitute a telecommunications network. This network contains the elements of a computer, remote terminal devices located in local school district offices and the interconnecting communication lines. The test of the solution of the problem is the simulation of the mathematical model. The study is further concerned with the interpretation of the results of the simulation.

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[1]An intermediate school district in metropolitan Michigan.

Need for the Study

The Oakland Schools intermediate school district has provided a regional computer service for its constituent districts since 1961. The demands on the regional center for computer service has grown considerably in the ensuing five years. Longer range planning than present staffing permits has become increasingly evident. These demands are increasing as enrollments grow, as new programs are adopted and as agencies providing revenue demand more accountibility of funds.

The present facilities are being challenged to meet these growing demands. Two types of problems are of concern. One, punched card data is brought in for immediate processing; an appointment is necessary to avoid delays and wasted waiting time of local district personnel. It is becomming increasingly difficult to schedule these appointments. If sent in by a carrier, at least two days turn around time delays the time when the output is available to the local district. The other type of problem has to do with peak loads. Peak loads are primarily caused by high volume of input and output since the present system has only one input station and one printer output station. The basis need then, is to provide for transportation of data on a more economical and expeditious basis and to provide the system with multiple input and output stations. The queuing or waiting in line would be reduced for personnel. Jobs might be in queues but personnel would not be waiting for work to be completed away from their work station.

The Significance of the Study

Data processing techniques for the solution of problems of education are being explored at local, regional, state and national levels.

Many projects stimulated by the availability of federal grants have been and are being proposed for funding. These projects vary from local district projects to projects encompassing several contiguous states. The local district project, except in the largest of cities must, for lack of student or financial base, be limited. At the other extreme, the multi-state projects, although necessary and important, are too far removed from the day to day concerns of local district personnel.

This study attempts to demonstrate that on a regional basis, local school districts can pool their resources to a point of having a base sufficient to justify the establishment of an organization, adequately staffed, expertly trained and properly equipped to provide data processing services, sophisticated and extensive, but also serving the day to day mundane clerical functions of the employees of school districts.

Delimitation of the Study

As initially conceived this study would have encompassed all of the school districts of the state of Michigan recognizing the next echelon of administration. Although the state of the art of computer simulation is rapidly advancing, the program available at the time of model building was not adequate to accommodate the many variables and volumes necessary for the study on a state level. The limited background of the writer also precluded attempting to build a model of this magnitude. It was also relevant that the mathematical model have a basis of experience upon which to build. Therefore the study is limited to the constituent school districts of Oakland County. The study, or model components in terms of activities simulated, is further limited to those computer services presently automated in the constituency, plus the extension into some additional business office applications and into an information retrieval application. The information retrieval or file inquiry components of the model assumed that the other applications would build electronic files as data were processed throughout the year. For example, financial statements for management purposes or for reporting purposes would be available through the file inquiry application. It would be an output function, that is data would flow from the central computer to the remote terminal. It would not be necessary to send data in as the data would have been accumulated from the purchasing, accounts payable and payroll applications. Personnel records would also be on electronic files and could be updated through a message switching routine or retrieved through a file inquiry routine.

Data for the study has come from three basic sources. The first source, involving volumes, was the official reports of the local school districts to the state department of education. The data used from these sources were census figures, membership figures, and numbers of employees. A second source represented data collected by the members of the Teleprocessing Feasibility Study Committee[1]. The data collected by this group defined the purchasing activity and the accounts payable volumes. The purchasing activity data involved numbers of purchase orders, the distribution of the number of line items per purchase order and variance

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[1]The Teleprocessing Feasibility Study Committee was composed of the Director, Merlin Reeds of Oakland Schools; George Dexter, Birmingham; Byron Oliver, Farmington; Mel Staebler, Pontiac; Ferris Peabody, Royal Oak; James Smythe, Southfield; Nicholas Menghini, Waterford; and John Williams, Walled Lake. These seven members were appointed as middle management executives to conduct in depth studies within their respective districts and to present their recommendations for board of education action. The study was conducted during the period of September through December, 1965.

in purchasing by time of year. The third source of data was primarily the considered judgment of the writer. This judgment was frequently subjected to a critical analysis by members of the Teleprocessing Feasibility Study Committee. The writer's judgment was further conditioned by five year's experience in working closely with local school district teachers, counselors, principals, business administrators and superintendents in the development of applications to data processing. These data were primarily concerned with timing cycles. The basis for data is presented in the description of the programs branches in Chapter V.

Summary

The mathematical model of a teleprocessing network to serve an educational environment presented herein describes one situation, that is, one intermediate school district encompassing its constituent local school districts, and one set of particular procedures appropriate to the readiness of the personnel in that situation. The computer output from the simulation run of the model, when analyzed, serves as a management tool. First, the initial run reveals the weakness in the configuration. The weak points are identified and the magnitude of the weakness is revealed. Management can make the decision to live with the weaknesses, setting up appropriate rules to minimize the potential problems, or an alternate decision to reconfigurate to minimize the weaknesses can be made and the new model can be resimulated. Since computer runs are relatively inexpensive compared to a bad or poor configuration decision, the second or alternate decision seems desirable.

The computer run of the model described in this study is an actual first run of a suggested configuration of equipment to process certain specified applications or procedures. The findings or interpretations are based on this first run and not on repeated runs as would be desirable. The restraints of time and cost for computer runs precluded additional runs for purposes of this study.

The mathematical model, as a management tool, is operational and may be rerun with changes in variables at the discretion of management as the planning progresses for the development of the actual teleprocessing center.

Further, the model may be modified to accommodate any conceptually similar environment in any geographic area; indeed, the environment need not have any specific geographic boundaries. Further, the concept may be extended. The model currently is macroscopic in that the smallest time element is one-half second and the time period one year. In terms of timing, one-half second elements are large blocks of time to third generation computers. A new model focusing attention on peak periods of the month or year could give additional insight into the probable behavior of the system. Conceptually the model could be expanded to encompass the linkage of several computer centers each with its remote terminal devices, and the whole, perhaps linked to an even more powerful and sophisticated computer center.

These last two ideas are not presented with the thought of conclusions and recommendations but to assist the reader in understanding the level of utilization of the model.

In this study, simulation is employed to find and describe meaningful relationships among the many factors and variables that constitute the description of the mathematical model. Reruns would test and retest the sensitivity of controllable factors. This study is limited to the interpretation of the output of the simulation of one year of operation. Certain changes will be suggested by this interpretation. The technique is not suggested as a precise tool that will enable the executive to make an unqualified decision, but rather as a tool that will focus attention on the more crucial problem areas. Quantifying the input to the mathematical model as an exercise alone helps to bring the problems into focus.

Analyzing the output data further enlightens the executive or management team to a better understanding of the probable operating environment; its efficiencies and its limitations.

CHAPTER II

REVIEW OF THE LITERATURE

In 1963, Luton R. Reed[1] conducted a nationwide survey of the data processing systems in the public schools. Reed's survey identified 288 school[2] systems in the United States which had some type of data processing system in operation. One system[3] reported having data transmission equipment, but that same system did not report having a computer. This would seem to indicate a card-to-card communications device. Reed recognized the potential of data transmission in relation to the regional concept, "One aspect of data processing which makes it feasible for smaller school districts is the ability to transmit data electrically from outlying points to a central processing center."[4]

Grossman and Howe[5] in their text, Data Processing for Educators, indicate that one of the specific purposes of the California Research

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[1] Luton R. Reed, Data Processing Systems, A Guide for Educational Administrators. Central New York School Study Council, 1964.

[2] Ibid., 20.

[3] Ibid., 37.

[4] Ibid., 18.

[5] Alvin Grossman and Robert L. Howe, Data Processing for Educators. Chicago: Educational Methods, Inc., 1965.

and Development Center in Educational Data Processing is:

> "The conduct and support of simulation studies. --It is evident that certain types of complex decision processes can be performed by computer systems more efficiently than by humans. The potential of these techniques in education appears to be great. Efficient use of data would allow educators to make decisions and allow them to experiment with techniques and solutions before trying them in schools."

The preceding statement is the second of seven purposes of the Research and Development Center. The seventh purpose is the establishment of regional data processing centers. The regional center is perceived as the appropriate organization for handling all data processing for small districts, some processing for medium sized districts and certain specialized computing for the largest school district. The regional center would be a service organization providing those data processing services that the local districts could not provide for themselves.

As late as January, 1966, Business Publications International, introduced a new section entitled "Automation Educator" in its monthly magazine, Business Automation. A review of these sections fails to reveal any evidence that computer technology is being used in educational decision making. Neither the "Printout" sections listing new books and films nor the "Available Literature" sections which lists primarily vendor materials disclose any reference to publications covering the topic of using a mathematical analysis approach to problem solving for the educator.

In the non-education section, Senter Stuart writes on the topic: "Optimization - It Can Pay Off".[1] Although his presentation is business

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[1]Senter Stuart, "Optimization - It Can Pay Off," Business Automation, XIII, No. 3 (March, 1966), 46-49.

and industry oriented, certain conclusions are appropriate to the environment of the network described by this mathematical model. Relevant points made are:

1. Large and frequently repetitive tasks should be optimized even at considerable cost.
2. The cost factor of producing a report may be less consequential if the deadline for the report is critical. That is, optimize in spite of cost in some instances.
3. The output from the computer system should be appropriate to its use. Often times, management receives too much output.

Stuart focuses appropriate attention upon a problem faced by every data processing establishment. His concern is for optimizing the operations. Management is also necessarily concerned about the optimization of the configuration of the equipment in the third and fourth generation computer systems of which he speaks.

John W. Sullivan[1], in an address to the Florida Association of Educational Data Systems in February, 1965 entitled "Education and Automation" challenges educators to be better informed about present day technology. His challenge, "And may I suggest that any subject that I name that you do not know its proper utilization, that as a professional you could be classified by your administrator as being deficient!" He then lists the following as subjects about which educators should know

[1]John W. Sullivan, "Education and Automation," A Paper read before the Florida Association of Educational Data Systems, Boca Raton, Florida, February, 1965.

their utilization, advantages, capabilities and limitations:

1. Operations Research or Management Science Techniques, i.e., Queuing Theory, Linear Programming, PERT; to name just three.

2. Statistical sampling, including Bayesian Concept.

3. Scientific forecasting, including Hueristics.

4. Management Decision-Making by Exception.

5. Real Time Processing Similarities/Dissimilarities to Batch Processing.

6. Critical Path Methods of Cost, Scheduling, etc.

7. Single Information Flow Design Criteria.

8. Simulation and Game Theory.

9. Concept of Slack.

10. Retrieval, Linguistic and Algorithmic Procedures for Whole Document Processing, Automatic Abstracting, Indexing, etc.

Prior to recent months, periodicals devoted to education or even to educational data processing are notably silent in the use of computers in management decision roles. Change however is taking place. The subtopics: Pupil Management, Personnel Management, Physical Resource Management, and School District Planning are all included in the article "The Role of Computers in School Systems" in the January, 1966 issue of Monitor.[1] Trocchi indicates that PERT (Program Evaluation and Review Technique) can be used to control school construction. Since school construction is primarily contracted, few educators have become very knowledgeable of its usefulness even though the architectual and contracting firms have been using this technique to serve school districts.

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[1]Robert Trocchi, "The Role of Computers in School Systems", Monitor, IV, No. 6 (January, 1966), 6-9.

Schlaifer[1] points out the advantage of the high speed computer in 1959 prior to the advent of the relatively low cost third generation computers in seeking solutions to business problems. Most of the techniques listed by Sullivan were known and used in operations research prior to 1959 but most frequently by large organizations with specialists on their staffs. Today many of these techniques are available as tools in the form of programs written for computers.

Much of the literature in the field is the trade publications of the vendors of equipment, forms, and various kinds of services. These are promotional in nature and are slanted to topics indicating what is coming. Even advertising in many of the widely circulated magazines seeks to advise the executive of the new tools available to him to bring him current, concise, relevant information that he may make wise and timely decisions.

Lindsay[2] emphasizes that "Mathematical analysis is a tool to be used by management - not a substitute for it." He points up the need for the use of specialists in working with management to identify problems, defining relationships and interpreting results. Significantly he indicates that tools of mathematical analysis can be used in several ways:

1. To find the optimum combination of a very large number of interrelated factors.

2. To find the best solution, or at least a good solution, to problems involving uncertainty of future events.

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[1]Robert Schlaifer, Probability and Statistics for Business Decisions. New York: McGraw-Hill Book Company, Inc., 1959., 325.

[2]Franklin A. Lindsay, New Techniques for Management Decision Making, New York: McGraw-Hill Book Company, Inc., 1963., 2-3.

3. To find meaningful relationships among many interacting factors and to separate the important factors from the unimportant.

4. To develop ways of collecting and processing significant data at minimum cost.

5. To relate quantitatively the operational objectives of the individual segments of a business or government organization, or even of individual workers, to the over-all objectives of that organization.

6. To test the sensitivity of any given solution to changes in controlling factors.

Lindsay concludes, "It is my own belief that probability theory, simulation, and mathematical programming will have a major impact on management over the next few years."

CHAPTER III

BUILDING THE MODEL

Introduction

The proposed mathematical model was to be simulated according to a manufacturer's program. The specific program chosen was the General Purpose Systems Simulator II, a program available from International Business Machines Corporation.[1] Before proceeding to build the model, it is necessary to adopt the conventions, terminology and symbolism prescribed by the program.

One of the conventions is that a flow diagram must be drawn. (Appendix A) The flow diagram is a group of block type symbols connected by lines indicating the direction of movement of the traffic in the model. Units of traffic are introduced into the model at selected points of origin. The blocks through which the units of traffic move represent the kind of activity to be performed at each point. The respective positions of the blocks indicate the sequence of activities to be performed until the unit of traffic is completely serviced and exits from the model.

A clock time is associated with each unit of traffic, at its time of origin and at each block through which it moves.

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[1] ____________________, General Purpose Systems Simulator II, International Business Machines, Technical Publications Department, White Plains, New York, 1963.

Units of traffic to be serviced are called transactions. These transactions have certain properties that have a bearing on how they move through the system.

One such property is called transit time. It is the total elapsed time that a transaction remains in the model. This transit time is frequently modified in the model in order to measure portions of the transit time that are more meaningful than total elapsed time.

Parameters are values or properties that can be assigned to transactions. This enables the model builder to assign appropriate values to transactions as they move through the system. Parameters assigned to transactions may be set by the model builder or may be set dynamically by the simulator program.

The simulator program attaches a time priority to each transaction. The model builder or the simulator may assign or modify this priority as it moves through the system.

The transit time of a transaction is the sum of the action times at the blocks through which the transaction moves. The action time may be a constant, a variable or compound in nature. The action time is computed from two values, a mean time and a modifier. The expression 10:5 is translated by the program as an average of 10 time units plus or minus 5 time units. Each value of 5, 6, 7, ...15 have equiprobability of being the action time at a block having that action time specification.

A convention of the simulator program provides for the introduction of algebraic expressions into the model. These algebraic expressions have the code name Variable and are made up of one or more Systems Variables connected by the arithmetic signs of +, -, *, / where + is plus, - is

- is minus, * is multiply and / is divide. The System Variables are coded and defined as follows:

TABLE 1

SYSTEM VARIABLES

Mnemonic	Definition
Pn	Parameter n
M1	Transit time
D1	Delay time
Nn	Entry count, block n
Wn	Current count, block n
Fn	Facility status, facility n
Sn	Storage occupancy, storage n
Rn	Storage remainder, storage n
Qn	Queue length, queue n
C1	Clock time
Vn	Variable, number n
Xn	Stored value, cell n
TBn	Table mean of table n
Kn	Constant n
RN1	Random number
FNn	Function value, function n

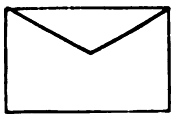
A storage can hold up to its rated capacity of transactions, the simulator keeps records on its status.

A facility can service only one transaction at a time, e.g., a bank teller is an example of a facility.

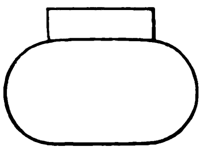
A queue is a waiting line. The simulator keeps records on its length and the time that each transaction spends in the queue.

Block Types and Purpose

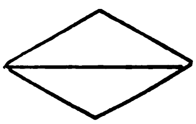
ADVANCE, computes an action time and determines the next block.



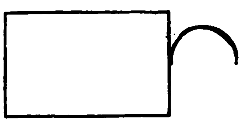
ASSEMBLE, reunites two parts of a previously split transaction.



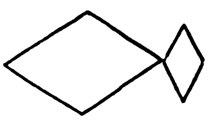
ASSIGN, assigns a value to a parameter of the transaction.



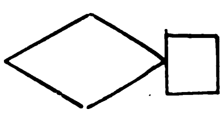
COMPARE, tests an environmental condition based on the value of two system variables.



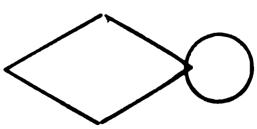
ENTER, places a transaction in a storage.



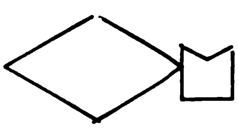
GATE (Facility), tests a facility for busy or not busy.



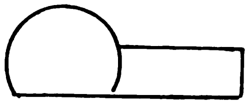
GATE (Logic), tests a switch for set or reset condition.



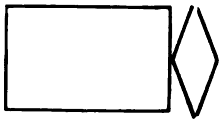
GATE (Storage), tests for full or empty status.



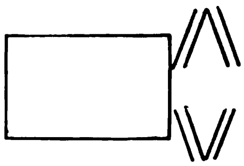
GATE (Match), transaction at a match or assembly block.



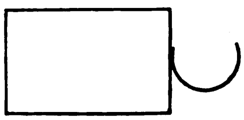
GENERATE, puts transactions into the system.



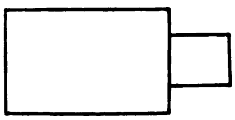
HOLD, uses a facility not being used by a prior transaction.



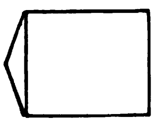
INTERRUPT, uses a facility, even interrupting a previous transaction using the facility with a HOLD or SEIZE block.



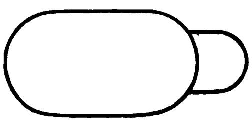
LEAVE, a transaction leaves a storage.



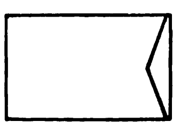
LOGIC, sets or resets a switch.



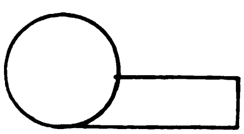
LOOP, returns to a previous block until the transaction has been in LOOP BLOCK value of X times.



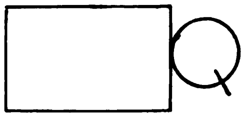
MARK, resets clock time of a transaction to zero.



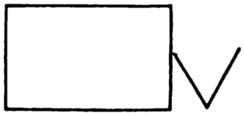
MATCH, tests the presence of a companion transaction at another MATCH block.



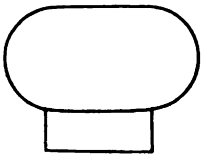
ORIGINATE, another way of putting a transaction into the system.



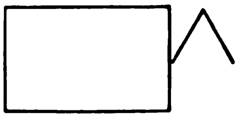
QUEUE, transactions remain in this block until accepted in the next, data is recorded on how many are in the queue and how long each remains.



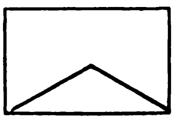
RELEASE, facility is made available to the next transaction seeking service.



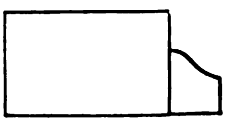
SAVEX, puts a value in a cell for future reference.



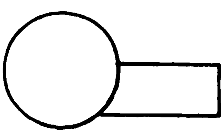
SEIZE, facility becomes dedicated to a transaction until **RELEASED** or **INTERRUPTED**.



SPLIT, divides a transaction into two parts to be routed along different paths, parts may be reassembled.



TABULATE, puts data being accumulated in table format for outputting purposes.



TERMINATE, transactions exit this block type.

Block Instruction Format

Location
MEAN
Modifier
Selection Mode

Associated with each block are numbers or terms that control the action of a unit of traffic while in the block, and its departure route.

The location is a number giving identity to the block unique in the entire system.

The mean represents the average amount of time that a transaction will remain in the block. The mean may be a variable or a number. The modifier controls the spread or the variance in the action time. The range in action time is the mean plus or minus the modifier.

The selection mode may be blank implying only one path leaving; it may be the term BOTH meaning that it will follow the first path if available, otherwise the second path will be taken. The selection mode could be ALL, meaning that several paths will be tested in sequence with the transaction taking the first available path. The selection mode could be a number. The number is a probability factor of taking the second path, otherwise the first path is followed.

Functions are sets of paired numbers that can be introduced into the simulation model. This makes it possible to insert extensive data in a rather simple format. Functions may be continuous or discrete. A continuous function provides for interpolation if an exact value is not recorded for the independent variable in the function. A discrete function does the equivalent of a direct table look up and can read only exact values recorded. An example of this is a function which records the number of students in a district to the district identification number.

Given the preceding conventions the flow diagram comprised of a number of blocks graphically represents the action that is to take place in the simulation of the model. To present the model to a computer for the sumulation run it is necessary to code each variable, function, table, block, etc., in a format acceptable to the computer program. This is accomplished by adhering to a set of coding rules and punching these data into standard eighty column cards. Appendix B is a complete print out of the mathematical model as presented to the computer for the simulation run. Each line with an * in the first print position is considered a comment and serves only to remind the programmer of the purpose of the adjacent instructions. All other lines of print are preceded by a number and have unique purposes in the model. Any greater detailed description would be technical and not relevant to most readers.

Appendixes A and B and the General Purposes Systems Simulator II Manual provide adequate documentation for the replication of this study. Changes in volumes, variables and parameters could be readily made for more depth analysis.

Summary

Johnson[1] writing in the Journal of Educational Psychology concludes: "Though at its outset a computer model is likely to oversimplify and indeed misrepresent, the model would provide a clearly defined base

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[1]M. Clemens Johnson, "Adaptive Computer Model", Journal of Educational Psychology, LV, No. 1, 66.

for future improvements and greater opportunities for precise communication. A concept and its operation which have been quantified would be better understood than verbal explanations alone."

The need to quantify as many of the factors of the environments as the model expects to simulate is a concept which must be at the forefront of the model builders thinking in order to minimize the dangers suggested by Johnson. Although the process of making improvements as a result of findings of each successive run can be performed repeatedly, a complex simulator model may require extensive manpower to evaluate output and to modify the computer input. The computer runs may be expensive if facilities are not readily available or if re-runs are made without adequate consideration of the expected returns in relation to the expense. Improved simulator programs and better price performance from computers in the future will reduce or eliminate this concern.

With these problems in mind, the model builder should also design the model to facilitate the process of changing specifications for reruns. With this capability it would be advantageous to "run the model" many times changing certain controlling parameters each time. Comparisons would reveal the relative influence of these parameters and would assist in more quickly arriving at an optimum model.

Experience in model building and an awareness by management personnel on the values of the technique in operational research will result in making more precise and meaningful data available to the model. This is Johnson's[1] thesis that "the model would provide a clearly defined base for future improvements."

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[1]Ibid.

CHAPTER IV

DESCRIPTION OF THE MATHEMATICAL MODEL

Introduction

The purpose of building a model in any endeavor is to provide the planners and builders of the eventual operational product with a better understanding of its potential capabilities, limitations and general characteristics. By building a product to scale (test model) in spatial dimensions and subjecting it to test conditions, engineers are able to predict with some degree of certainty the probable performance of the production model. The physical characteristics of the model are controlled (input) and recorded in precise mathematical terms. Results of tests of operational characteristics (output) are likewise measured, tabulated and correlated with input data. Engineering competency and statistical analysis of data guides the model designer in making changes in his model for subsequent testing purposes. Retest and redesign continues until performance is acceptable.

The model herein described is analogous to a physical model with the exception that as a mathematical model the physical characteristics are assumed. The model is "run" not in a wind tunnel, an aeronautics type laboratory; not on a test track, an automotive industry type laboratory, but simulated in a computer. The performance is recorded, tabulated and printed out at the conclusion of the computer simulation.

General Properties

The properties of this specific model can be enumerated as follows:

1. A system of a number of electronic devices are interconnected by telephone line linkage, the total being considered an entity. The total system as an entity has as a property the interrelationship of its parts. The total physical electronic devices as connected, including connecting wires, constitute the physical model as represented mathematically.
2. Each electronic device is also an entity. It has as properties its function in the system, its relative power (speed) in performing this function and a relationship to the system and its several parts. Each device is known as a facility. The purpose of the facility is to service appropriately the task assigned to it as the system operates in its totality. The facilities in this model are of two types. One facility is a computer or central processing unit. Essentially all activity in the system is routed through the central processing unit at least once during its life in the system. The other facility type is referred to as a remote terminal or terminal and is an input and output device. Its fundamental property is speed; the rate that it can send or receive data expressed as fifteen character messages. In the case of receiving, it also has the property of being able to print at a comparable speed. The model has three levels of terminals defined. Each terminal is defined according to the expected loading on it, or by decision of

the local district participant in the Teleprocessing Feasibility Study.

3. The school district is an entity that has as its properties a geographic location, a given number of students, a given number of secondary students, a given number of employees and either a given amount of business activity as determined by survey or an estimated amount based on a correlation with the number of employees. (Table 2) With each school district there is an associated facility, the facility being the terminal previously defined. It is noted here again that the property of a terminal is power in terms of speed. The properties of a district can be generalized as those characteristics which contribute to a loading on its associated facility.

4. The geographic area (Figure 1) served by the system is an entity that encompasses all of the several school districts that are associated with a terminal device. For purposes of consistency, this geographic area is said to be associated with the central processing facility.

   This geographic area will be referred to as the intermediate district. The school districts are referred to as constituent districts.

   A property of the intermediate district that is of importance then is the sum of the characteristics of the constituent districts that contribute to the loading on the total system. The word "sum" should not be considered in its simplest form here, but rather as a combination of an additive effect and an interaction effect.

TABLE 2

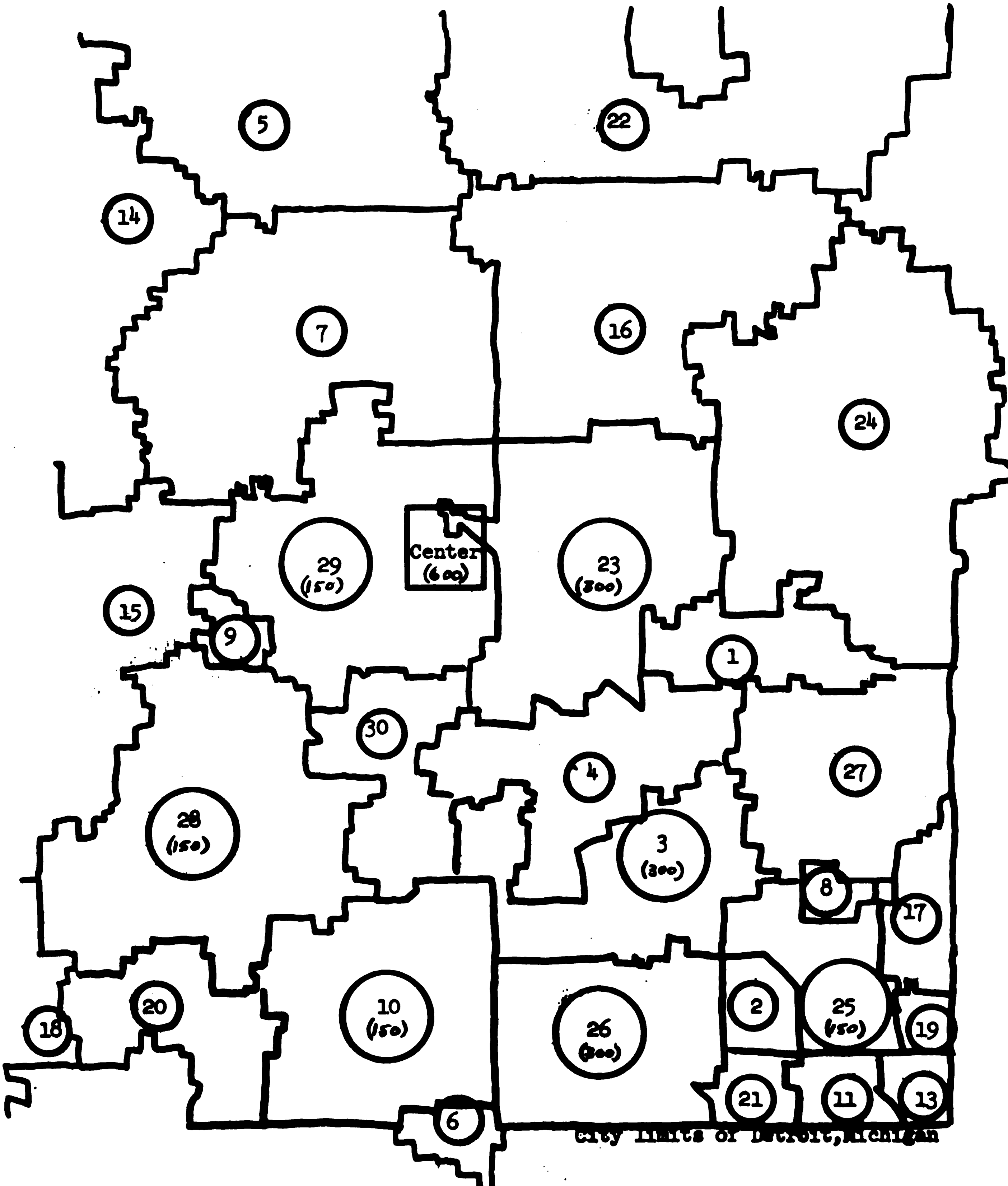
VOLUMES* BY DISTRICT

District	Code	Students* K-12	Students* 7-12	Employees*	Daily Purchasing **	Monthly Payables **
Avondale	01	3478	1467	208		
Berkley	02	8944	4098	558		
Birmingham	03	16110	7132	1231		
Bloomfield Hills	04	6821	3047	561		
Brandon	05	1498	635	88	9	200
Clarenceville	06	3815	1302	280		
Clarkston	07	5349	2046	331		
Clawson	08	4519	1704	287		
Dublin	09				1	1
Farmington	10	13430	5404	955	30	537
Ferndale	11	8248	3691	540		
	12				1	1
Hazel Park	13	8124	3328	522		
Holly	14	2838	1173	181		
Huron Valley	15	5427	2073	279		
Lake Orion	16	4384	1734	273		
Lamphere	17	5431	1563	367		
Lyon Township	18	2361	914	158		
Madison	19	4931	1713	296		
Novi	20	942	272	67		
Oak Park	21	7153	3122	678		
Oxford	22	2170	903	137		
Pontiac	23	23278	8864	1547	33	1000
Rochester	24	6459	2807	539		
Royal Oak	25	20069	8546	1333	26	750
Southfield	26	12865	5506	1134	24	504
Troy	27	4495	1894	274		
Walled Lake	28	8033	3569	566	10	208
Waterford	29	16413	6504	1105		
West Bloomfield	30	2642	1114	161		

* Source - Form A and D Reports to Michigan Department of Education, 1965.

** Source - Teleprocessing Feasibility Study Committee Survey.

Figure 1.



Oakland Schools - An Intermediate District of School Administration
See Tables 1 and 2 for local district codes and data

5. Applications or tasks to be performed consitute another set of entities that provide for the traffic through the model. General properties of these entities are those of initiating action in the model, of directing the pathway of each initiated action, and sharing the function of load determination with loading factors assigned by the constituent districts.

Specific Description

1. The total system assumed in this specific model contemplates a central computer with peripheral equipment adequate for file storage for the functions and loading presented in the model. For example, the kindergarten through twelfth grade enrollments totaled 212,000 in Oakland County, September, 1965.[1] Allowing one thousand characters of file storage for each student would require magnetic file storage of 212 million characters. Student accounting is the application expected to require the greatest amount of file storage, but if other applications boosted this requirement to a billion, this would not be prohibitive in the complex and powerful system assumed in the model. Further assumed in peripheral equipment would be different levels of accessibility to files, depending on the function and the times of day, week, month or year that these files would be used. Files would be temporarily moved to fast access areas during times of high utilization. Most input would originate at the remote terminals and most output developed would be returned to the same terminal. However, a 600 line per minute printer

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[1] Compiled from the official reports of local districts to the Department of Education, State of Michigan.

is assumed at the intermediate district for in house functions and for outputting grade reporting and student schedules if the input originates at one of the slower terminals and the remote fast terminal in an adjacent district is busy.

The total physical system then would have: a central computer, its on site electronic files, application and system control programs resident in the computer memory or filed for automatic retrieval, an on site fast printer, and thirty remote terminals. (Table 3) Three terminals would have power to print 300 lines per minute, four terminals could print at the rate of 150 lines per minute and the balance could print 15 lines per minute.

2. The parts of the physical system with the computer facility described are enumerated above. Each remote terminal would be associated with a school district. The power of the terminal assigned was determined on the basis of expected loading, equipment on the market, relative cost and the readiness of the district to exploit the power of the system. In the early phase of the model building, which was July to December of 1965, six-150 line per minute terminals were contemplated. Phase one of a two phase study involving seven of the largest districts upgraded this power by a total of 600 lines per minute for the system.

Each terminal would be equipped with a card reading device that would provide for sending input, in batch mode. Output could be punched card, printed, or both. System design would be expected to minimize the amount of input in relation to output. For example, to perform an accounts payable routine, vendor files and standard catalog files would be expected to provide names, addresses, descriptions, etc., with exceptions allowable. This would negate having to send massive volumes of data one way.

TABLE 3

TERMINAL FACILITIES

District	Code	Terminal Speeds: Line Per Minute	Assigned to Terminal No. ____	No. of Attached Terminal	No. of Attached 7-12 Students	Total 7-12 Load
Avondale	01	15	23			
Berkley	02	15	26			
Birmingham	03	300		3	6645	13777
Bloomfield Hills	04	15	03			
Brandon	05	15	29			
Clarenceville	06	15	10			
Clarkston	07	15	29			
Clawson	08	15	03			
Dublin	09	15	28			
Farmington	10	150		3	1574	6978
Ferndale	11	15	26			
	12	15	10			
Hazel Park	13	15	25			
Holly	14	15	29			
Huron Valley	15	15	28			
Lake Orion	16	15	23			
Lamphere	17	15	25			
Lyon Township	18	15	28			
Madison	19	15	25			
Novi	20	15	10			
Oak Park	21	15	26			
Oxford	22	15	29			
Pontiac	23	300		3	6008	14872
Rochester	24	15	23			
Royal Oak	25	150		3	6604	16150
Southfield	26	300		3	10811	16317
Troy	27	15	03			
Walled Lake	28	150		4	7670	11239
Waterford	29	150		4	4757	11261
West Bloomfield	30	15	28			

3. The specific school districts are the 29 constituent school districts of Oakland Schools Intermediate District. (Figure 1)

They are numbered 1 to 30 consistent with a coding system in use in the five year history of the present regional data center. Terminal or district twelve is really non-existent as that district was annexed to an adjoining district in 1961. District and terminal nine has no secondary students and does not enter into the grade reporting or student scheduling routines. Table 1 lists the number of employees, purchasing volume, accounts payable volume, number of students in kindergarten through twelfth grade, and number of students in seventh through twelfth grade.

These figures provide the basic variable input volumes into the system by district size.

It will be noted that terminal twelve will call for no loading based on size, however communications and file inquiries will be initiated from that terminal.

4. The geographic area associated with the central processing facility is the intermediate school district of Oakland Schools, approximately 900 square miles just northwest of Detroit. Its southeastern area through the central area is suburban, its northern and western areas are rural and small cities or villages. The constituent districts vary in size from under two square miles to over eighty square miles. Enrollments vary from under 1,000 students to over 23,000. Annual operating budgets range from under a half million to over twelve million dollars.

5. Specific applications built into the model are enumerated below. Some applications not specifically built into the model are assumed to be allowable within a related application or to be accomplished within the

file inquiry application. For example, inventory control could be an inherent part of purchasing and accounts payable with periodic reports emanating from the file inquiry routine. Detailed descriptions of the listed applications appear in the next chapter.

a. Network Communications
b. File Inquiry
c. Purchasing
d. Accounts Payable
e. Payroll
f. Student Master File Maintenance
g. Student Scheduling
h. Grade Reporting
i. Timekeeping

Timekeeping is a control function in the simulator program. It does not use any appreciable time in the model. A similar function in an operational model would require very little time.

CHAPTER V

PROGRAM BRANCHES OF THE MODEL

Introduction

As each application was developed in the model, it was the concern of the builder to initiate each unit of traffic at its appropriate time. The unit of traffic should move as the initiator, the local district operator, would prefer it to move within the limits of capability of the system and its affected parts. Priorities appropriate to the application and delay of a unit of traffic at any point in the system should be controlled. An amount of time sufficient to provide the service needed is exacted from each affected facility. It should be noted that units of traffic have widely varying characteristics. One type enters the system about every 3.2 minutes and remains only seconds unless delayed by lack of facilities to service it. Another type enters only once per year but is intermittently delayed between functions and will remain in the system several weeks. Several types exist between these extremes as will be described in detail under each application. A unit of traffic when introduced into the system is electronically stamped with an arrival time. When it leaves is known as its departure time. The elapsed time is transit time and in several instances the transit times were tabulated by the simulation program for analysis.

Another characteristic of a unit of traffic is the amount of use that it will make of the facilities. One type will make frequent use but only a minute or two at a time, while the other extreme is a unit of traffic that enters only once annually but uses several hours of terminal time, perhaps intermittently, and several minutes of computer time. Again the typical unit of traffic is between these two extremes.

Another important characteristic of a unit of traffic is the priority that is assigned to it. Priorities are established in two ways. With one, the model builder decides and assigns, or programs to have the simulator assign according to some condition. The second type of priority is determined by the amount of time a unit of traffic is delayed past its scheduled departure time from its present location in the system. If the model builder or the simulator program assigns a priority, that priority takes precedence over units of traffic just delayed by facilities being busy. In addition to these techniques, certain types of transactions are permitted to interrupt facilities even if engaged in servicing a high priority unit of traffic. However an interrupted facility may not be interrupted. This feature permits the flow of file inquiry type traffic between the parts of a larger batch type transaction.

In one instance, the loading that a unit of traffic puts on the system is calendar dependent. Purchasing is assumed to be four times normal in June and July and two times normal in May and August. In another case, student file maintenance is in a weekly cycle but only during the school year.

Units of traffic that are expected to stay in the system from one to several hours are structured to arrive in the system within the first four and one-half hours of the day. This minimizes the amount of unfinished batches remaining in the system from one day to the next. It is expected that the users of the remote terminals would behave in this way. If they did not, its effect would be to relieve the system from pressure as the alternative of more freedom would tend to even out the loading on the system.

The basis for assumptions that are made in the model building are many and varied, usually more than one would apply in each assumption. The bases for assumptions are as follows:

1. The writer's background knowledge of the behavior of the departments in the constituent school districts, particularly as it applies to applications now processed at the regional computer center.
2. Limited surveys conducted by participants in the Teleprocessing Feasibility Study.
3. Consensus of participants of the Teleprocessing Feasibility Study.
4. The writer's background knowledge of machine capabilities in handling particular types of applications.
5. Technical information supplied by the vendor (International Business Machines) systems engineer.
6. Personal interviews with Teleprocessing Feasibility Study participants and other school administrators.
7. Actual on-the-job experience by the writer in working at several levels with school district personnel in analyzing, designing, programming, and implementing data processing procedures in educational applications.
8. Bayesian theory of probability cited by Schaifler:[1]

"The theory of probability does not replace judg-

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[1]Robert Schaifler, Probability and Statistics for Business Decisions, New York: McGraw-Hill Book Company, Inc. 1959, 333.

> ment and experience. Its utility lies rather in the fact that it allows us to make more effective use of our judgment and experience by assigning probabilities to those events on which our experience and judgment bear most directly rather than to events which will actually determine costs but with which we have had relatively little direct experience."

Since the model is hypothetical, the only precisely reliable data that can be entered is that which has been tabulated in terms of counts: students, employees, etc. However, when the above bases for assumptions failed to being the problem into sharp focus, the most pessimistic assumptions were made.

Finally, this model, as with any model in its early stages, will at best yield only a macroscopic description of the characteristics of the final working production model. Optimization of a mathematical model would require several runs to determine the sensitivity of each of the many interacting variables. Ultimate optimization of a production model is beyond the scope of this study.

Network Communications

The purpose of this program application is twofold. First, as a daily routine and second as an intermittent routine.

It is anticipated that each morning, ten minutes of the day of each facility should be set aside for the following:

1. Center to terminal instructions.
2. Terminal to center problems.
3. Announcements of general interest to the local districts.
4. Other.

In the model, an eight hour day is assumed starting at 8:30 each morning. This routine would be performed at this time by the central processor every day unless the central processor was in a state of "interrupt" which is a highly improbable event. It would also be performed by every terminal not busy at that time, and in turn for those terminal facilities that were busy. Some terminals could be busy at 8:30 a.m. for other applications, but the probability is low.

The second purpose of network communications is another activity that the industry refers to as message switching. That is, any district could initiate the sending of a message to one, all or any mix of districts. This event is scheduled to occur eight times daily on a variable schedule of every hour, plus or minus half an hour.

Each of the eight units of traffic would put a five second loading on the computer and from one to three minutes of loading on each of from one to thirty terminals. Each terminal would average eight minutes of this type of communication daily. The central processor would require only forty seconds daily to serve this application.

Message content could be for any of the reasons listed under the 8:30 a.m. branch or any other reason.

This branch is not to be confused with file inquiry. In this application, messages originate outside the machinery network and do not get into files.

File Inquiry

File inquiry is another general purpose application and has two branches, each serving a different classification of problem. The first type would typically be a district asking to see or receive a single record of not more than a few hundred characters froms its central electronic file. The second type would be the request by a district for having a several page report generated and sent to its terminal.

Files to be accessed under this general purpose application could be any of the district files generated by the other special purpose applications.

The request to see a single record inquiry was programmed to enter the system every 3.2 minutes with a spread of 3.2 minutes. This means that a unit of traffic of this type would enter the system on the average of every 3.2 minutes, they could come in adjacent time units or be 6.4 minutes apart. This would result in an average of five file inquiries per day by each terminal. Each inquiry would use two minutes of terminal time and five seconds of central processor time. An average of ten minutes per day per terminal and twelve and one-half minutes of central processor time would be the overall loading.

A file inquiry requesting a several page report was estimated to be one per day per district. This was accordingly programmed to put a unit of traffic into the system every sixteen minutes on the average or from zero to thirty-two minutes apart. Loading per terminal per day would average ten minutes, varying five to fifteen minutes. The daily load on the computer would be thirty uses of an average of thirty seconds each, or fifteen minutes.

The Teleprocessing Feasibility Study Committee concurred in these assumptions by system but was critical of the lack of variance by district. It should be noted here that the districts with more powerful terminals could actually get equal reports in much less time or larger reports in the model as built. Output is a function of terminal power and this application ties up the terminal for a time element independent of the amount of output.

Purchasing

This branch of the model provides for a daily batch of purchase orders originating from each district terminal. The clock time of origin is distributed over a four and one-half hour time period. Fifty percent of these units of traffic are randomly originated between 9:00 a.m. and 10:00 a.m. Twenty-five percent are randomly originated between 10:00 a.m. and 11:30 a.m. The balance are originated between 11:30 a.m. and 1:30 p.m. This distribution is in keeping with the assumption that districts will wish to complete a batch process of this type during the same day.

Data for this procedure was collected by participants in the Teleprocessing Feasibility Study. Therefore, a table of relationships between number of employees and number of purchase orders originating daily was developed. For those districts providing data, the actual count of purchase orders entered the system. For those not represented, a table look up function was used to estimate the number. Since the data came from five of the ten largest districts, the smaller districts were put in the table at near the low of the sample of five. Districts with up to one hundred employees were estimated to have one to nine purchase orders daily directly proportional to the number of employees.

If employees numbered one hundred to five hundred fifty, daily purchase orders were set at nine also. All larger districts had greater purchasing activity as translated by the table look up function. (Table 4) The above discussion covers the distribution of arrival of batches and the number of purchase orders expected per batch.

TABLE 4

DISTRIBUTION OF NUMBER OF PURCHASE
ORDERS BY DISTRICT SIZE
(NUMBER OF EMPLOYEES)

Number of Employees	Volume of Purchase Orders
0-100	1-9
101-550	9
551-1000	10-30
1001-1160	24-29
1161-1300	24-25
1301-1800	26-33

Another concern is the amount of data necessary to process one purchase order. This concern divides itself into two parts. Can the purchase order be expedited by inputting a catalog number and a vendor number only, or will descriptive information be needed? This distribution was established by consensus of the participants of the Teleprocessing Feasibility Study as follows:

TABLE 5

DISTRIBUTION OF PROBABILITY OF VENDOR AND CATALOG ITEM
BEING STORED IN CENTRAL FILE AND ASSOCIATED NUMBER
OF MESSAGES REQUIRED FOR PROCESSING

		Catalog File	
		Yes	No
Vendor File	Yes	76.5 (2)	9.9 (6)
	No	8.5 (6)	5.1 (10)

These table values are derived from the following assumptions:

a. 85% of all items will be in the file.

b. 7% of all items will not be in file.

c. 8% will be for services not in file.

d. 90% of items will be from vendors on file.

e. 50% of non-file items will be from vendors on file.

f. 80% of services will be from vendors on file.

It will require one message to access either catalog or vendor file, five messages each if information is not on the file.

Minimum input would be if both the item and the vendor were on file, one message each or two messages. If neither were on file, five messages each or ten messages would be required. Combinations would require six messages each.

Since 85% of the items are assumed to be in the catalog and 90% will be from vendors on file, it is expected that 76.5% of the time (85% of 90%) only two messages would be required per line item on the purchase order.

The next consideration is for the number of line items per purchase order. A survey completed by the Teleprocessing Feasibility Study group resulted in the following table.

TABLE 6

FREQUENCY DISTRIBUTION OF LINE ITEMS PER PURCHASE ORDER

Number of Line Items Per Purchase Order	Frequency
1	40%
2	20%
5	20%
10	10%
20	5%
50	5%

The months studies were September and October, not heavy purchasing months. To incorporate a loading factor for summer purchasing, line items were multiplied by two during the months of May and August; by four during June and July. The respective means of numbers of line items per purchase order for these three periods are 6.7, 13.4 and 26.8.

Five variables have been discussed related to the purchasing branch.

a. Distribution of entry into the system.

b. Batch size by district.

c. Probability of items and vendors in file.

d. Distribution of the number of line items per purchase order.

e. Seasonal adjustment of loading.

Processing is by daily batch with inputting and outputting progressing by purchase order. The computer is interrupted for five seconds for each purchase order and the terminal utilization varies widely as determined by the five variables discussed above. The number of daily interruptions of the computer is estimated to be about four hundred. Total daily utilization for the computer for this procedure would then be about seventeen minutes.

Accounts Payable

The accounts payable routine reflects present behavior of local school district personnel in their dealing with vendors. A standard agreement that is common provides for a discount if bills are paid on or before the tenth of each month. This is usually extended if districts have a fixed monthly cycle that does not fall within these ten days. Also typical in the pattern is the fact that most boards of education meet during the first two weeks of the month in a business session, one purpose being to review and approve bills presented at that time. A few districts do pay on a regular basis throughout the month with approval of the board. Auditing is performed after the payment of bills. The reason for this mode of operation has been dictated by the peaking of the work load caused by processing during one brief period during the month. In an automated system this would not be necessary and it is assumed that all districts, large and small, would prefer the pattern that would consolidate accounts payable activities toward the first of the month. The freedom in the production model would permit processing at any time and divergence from the pattern would in fact relieve pressure on the system.

The assumption of restriction here is an attempt to display pressure on the system by movement from some present patterns to the present model pattern.

An assumption is made that boards of education will meet before the fifteenth of the month and that the fifteenth will fall on or after the tenth working day of the month. If these batches were to be processed according to an even distribution over the first six working days of the month, ths would allow for some time after the automated run for any additional preparation needed prior to board meetings. Boards of education rarely meet on Fridays and the first working day of a month could fall on any day of the week. Another factor, holidays, although not built into the model, directs us as model builders to provide for a "fudge" factor in time allowed to process this application. Independence Day in July, Labor Day in September, and New Year's Day would almost always present a disruption in normal schedules. Memorial Day and Good Friday could affect operational schedules.

The assumed mathematical model starts a fiscal year on a Monday, July 1. Day one of succeeding months will not be one hundred percent consistent with fact due to technical problems of representing the actual calendar in the mathematical model. The actual calendar based on a Monday, July 1 start yields a distribution of working days per month as follows:

One twenty-day month, four twenty-one day months, four twenty-two day months and three twenty-three day months. This distribution, disregarding holidays, was established as a function to determine or pick the first working day of each month. Attempts should be made in future models to relate the model to an exact calendar situation with holidays included. At this time, however, it is not seen as a radical weakness of the system.

The payroll application, to be explained next, is seen to have a weekly cycle and should be noted here as interacting at least once monthly with the accounts payable application. If the first day of the month falls on Wednesday, the day designated for payrolls, interaction would occur twice during that month.

Figure 2.

Illustration of Accounts Payable and Payroll Interaction with Working Day One Falling on Monday.

Mon.	Tues.	Weds.	Thurs.	Fri.
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22			

Figure 3.

Illustration of Accounts Payable and Payroll Interaction with Working Day One Falling on Wednesday.

Mon.	Tues.	Weds.	Thurs.	Fri.
		1	2	3
4	5	6	7	8
9	10	11	12	13

These illustrations reflect interaction of only two sizeable applications on the center and on the system as a total. In the first illustration, accounts payable for any one district has only a 16 2/3% probability of falling on Wednesday, payroll has a 50% probability. The probability of both events occurring on the same day is 8 1/3%. In the second illustration accounts payable has a 33 1/3% probability of falling on one of the two Wednesdays, a 50% probability exists that payroll would coincide with the same day. The probability of interaction by terminal if day one falls on Wednesday is 16 2/3%. Pursuing this line of thinking it can be demonstrated that throughout the year the probability is 10% that in an average month the payroll and accounts payable will fall on the same day. These are model probabilities, in a production environment personnel behavior would reduce these probabilities because of prior knowledge and experience. Further these probabilities concern interaction within the same day. Each action would have independent arrival times in the system, arriving according to the same probability within a four and one-half hour period from the beginning of the day. Their interaction within the day could range from zero to one completely overlapping the other, should one or the other fail to progress because of error.

An example of no interaction:

An accounts payable batch arrives at 9:30 a.m., sends data for ten minutes, processes data for three minutes, returns data for eighty minutes, the transaction is completed in ninety-three minutes including waits and interrupts. If the bi-weekly payroll arrives after 11:03 a.m. no interaction occurs.

An example of interaction:

A payroll batch arrives at 9:45 a.m. and sends data for ten minutes and at 9:55 a.m. it is waiting for the central processor. At 9:55 a.m. the central processor computes the payroll requiring five minutes. At 9:57 a.m. the accounts payable requiring fifteen minutes is sent in. At 10:00 a.m., payroll computing is complete, but outputting cannot proceed until 10:12 a.m. when the accounts payable batch is queued in a central file. Now the terminal is seized for outputting payroll and will hold for perhaps an hour. The central processor will compute and hold the accounts payable transaction but cannot return output until the payroll transaction is completed.

If we adopt the symbolism:

I_A = Acounts payable input

I_P = Payroll input

T_A = Accounts payable throughput, no error

T_{AE} = Accounts payable throughput, with error

T_P = Payroll throughput, no error

T_{PE} = Payroll throughput, with error

O_A = Accounts payable output

O_P = Payroll output

Then the following would be possible sequences with waits or queuing preceding any step.

I_A - T_A - O_A - I_P - T_P - O_P - this represents no interaction, each transaction would be mutually exclusive in time.

I_A - T_{AE} - I_P - T_P - T_A - O_P - O_A - this would be maximum interaction; first in, last out; last in, first out.

I_A - I_P - T_A - T_P - O_A - O_P - this would be a normal interaction; first in, first out; last in, last out.

Interaction is a vital concern of this study and the simulator program reflects all interactions in determining transit times of the thousands of units of traffic in the system; by tabulating the queues that build up indicating pressure points in the system. The discussion of the interaction of accounts payable with one other type of transaction, i.e., payrolls, illustrates how the system remains sensitive to the calendar, the clock and the traffic in the system. Further discussion of interaction logic in the description of the model would be redundant.

The origin of units of traffic in the accounts payable application has been reviewed with reference to the calendar and with the time of day. The next variable of concern is the volume. Data for input into this branch was collected by participants in the Teleprocessing Feasibility Study Group. All smaller local districts in the intermediate school district were assumed to have accounts payable input equal to the smallest of the large districts from which the sample was drawn.

This application also assumed that the output from purchasing would include pertinent information placed in central files that would be referred to at accounts payable time. The quantity of data needed from the remote terminal at accounts payable processing time would be minimal.

The volume of input was entered into the system with a table look up technique using data as indicated in Table 7.

TABLE 7

DISTRIBUTION OF NUMBERS OF ACCOUNTS PAYABLE VOUCHERS BY DISTRICT SIZE

No. of Employees	Volume of A/P (Vouchers)
0-100	1-200
101-550	201-208
551-1000	209-537
1001-1160	536-504
1161-1300	505-750
1301-1800	751-1000

The routine sends two-fifteen character messages in for each voucher needed in the batch, the computer assembles this data with data on file and returns twenty-fifteen character messages per voucher in the output phase of the routine. This is considered adequate to print required registers, control figures and voucher checks.

A sample:

A batch of five hundred vouchers would require one thousand messages for input. Approximately seventeen minutes of input time would be needed for the slower terminals, two minutes of computer time would be required and nearly three hours of output time would be needed on a terminal of this level. Total elapsed time if no queuing occurred would be about three hours and twenty minutes.

The input phase, the throughput phase and the output phase are discrete operations in this branch of the model. This differs from the purchasing routine in that purchasing seizes the terminal once, and holds throughout but seizes the computer once briefly for each purchase order.

One additional feature assumes that upon the completion of the throughput or processing phase, an audit trail would be sent to the terminal for control purposes. It further assumes that 10% of the batches are in error and the unit of traffic is returned to the process phase after an elapsed time of up to ten minutes is allowed for correction of this error. It would be at such a time that a payroll batch as discussed earlier might get into line ahead of accounts payable yielding a first in, last out situation.

Payroll

In the payroll branch we have the most experience to justify the data that enters into the model. The first payroll on our present regional data processing center was initiated in September of 1962. Between that date and January of 1966, eighteen additional local districts automated their payrolls and are currently being processed by the regional data processing center. There is one exception, Waterford School District has installed its own computer. Of the present eighteen school districts approximately one-half process their payrolls on one Wednesday and the other half of the school districts process on the following Wednesday. The mix of the size of the districts processing on Wednesdays has come by chance, and by chance has evened out quite well. The mathematical model also leaves this to chance. On the first payroll day in the model, fourteen districts are selected at random to be processed. On the following Wednesday the opposite fourteen districts are marked for processing. This procedure is then repeated on a bi-weekly basis insuring that each district is processed twenty-six times during the year. It is recognized that this is not a real life situation but it provides at this early stage of model building a chance to look at different types of interaction. Payroll days could have been set for each one of the twenty-eight districts. The temptation might have been to set equal loadings per week in which case the interaction would not have been real. The other temptation would have been to load one week unreasonably heavy and the other week light. Again this would not have been realistic. Allowing the matter to fall to chance once every two weeks insured a look at several kinds of mixes. Every school district in Oakland County is on a bi-weekly payroll period. The typical calendar of events in the payroll application is that time sheets or other evidence of attendance is forwarded from building level to district level offices on Monday following the Friday payroll ending period. Mondays and Tuesdays are devoted to organizing these source documents, updating the payroll punched card file and arriving at a control figure for this payroll batch. The batch then can usually be ready for computer input sometime between Tuesday afternoon and Wednesday. On the other end of the period, Friday morning is distribution time, checks need to be in the district mail to reach school employees at the respective buildings. Thursday then serves one of two purposes; first if there is any problem with the payroll it allows time to recover; second, Thursday is also available for preparation of the checks for circulation to the employees on the following day.

As in the previous two applications, payroll is handled in the model in a batch mode. That is, the payroll clerk in the local district prepares the payroll in punched card format and has it ready to transmit. Once it is started it continues transmitting until the complete file is stored at the center in a queue. These departure times are spread over a four and one-half hour period starting at nine o'clock on Wednesday morning. Approximately seven would leave district offices between 9:00 and 10:00 a.m. On the average three and one-half batches would leave between 10:00 and 11:30 a.m., and the remaining three and one-half would leave between 11:30 a.m. and 1:30 in the afternoon. The arrival time at the center would be a function of the departure time, the number of employees and the terminal speed at the district office where the batch originated. In the discussion of input flow there is departure time, transmitting time, and arrival time. Payroll batches have each been assigned priority six which is equal to accounts payable priority discussed in the earlier application. One payroll batch is a unit of traffic. Upon its arrival at the center it is stamped with a time and has a priority associated with this time. Its priority of six places it ahead of all transactions with assigned priority less than six. The computer notes the time and processes the batch in turn. Processing here means using all of the necessary information pertaining to each individual and the payroll as a total. Upon the completion of this processing, an audit trail is returned to the terminal for inspection by the payroll clerk. Up to ten minutes is allowed for this operator function of reviewing the audit trail. The model assumes that 10% will be bad runs. If the payroll is considered bad and rejected, up to one hour is allowed for the local district to recover and re-enter the system. Following the signal that a good payroll has been computed, the unit of traffic then awaits availability of the local district terminal to receive the output from the batch. Computer time is estimated at one hundred twenty employees per minute on the central processing. Returning output is straight forward but very time consuming as the assumption is made that ten times as much data will flow back to the district as is required to flow into the central processor. Voluntary deduction registers, check registers, and voucher checks are standard output for this routine.

The mathematical model as built and run assumes that all payroll output would flow back to the terminal of origin. In an operational model it is to be assumed that oftentimes small terminal users would choose to direct this high volume output to a faster terminal by prior arrangement.

As in the other applications it is assumed that as payroll batches progress through the quarter, fiscal and calendar year appropriate information will be retained on each employee. Also that an appropriate distribution of expenditures of salary accounts are automatically accomplished in the computer on days of the payroll batch processing.

What about government reports? Currently required are a quarterly report to the retirement fund board, and an annual routine reporting withholding statements to employees with copies going to the internal revenue. These two routines are not programmed specifically into the payroll branch or into an individual application. The ability to provide these reports would be an integral part of the system and could be generated centrally for purposes of speed or could be sent to local districts through the file inquiry routine.

The payroll applications require only about two percent of the computer time to handle the approximately 15,000 employees in the individual school districts. Loading on the individual terminals would vary considerably according to the size of the terminal and the size of the district. The large district with a small terminal would require several hours and the situation then likely would be deemed unsatisfactory. This problem was anticipated and will be discussed further in the interpretation of the results.

Student Master File

This is the first of three major branches in student record accounting included in the mathematical model. Child accounting records are initiated in Michigan at the time of the school census. This census is conducted between May 10 and May 31 each year. At that time the pertinent personal information is recorded for each child from 0-19 years of age. In the beginning this file would be loaded on to central electronic files. This branch of the model is concerned with the updating of the student record for those students actually in school. The volume for this branch is determined by the membership of the school. This file maintenance routine is considered to be a weekly batch process. It is expected that each district would update approximately 2.5% of its students records weekly throughout the forty week school year. This would be routine maintenance and not the type of updating that would come about through the grade reporting or student scheduling routines to be discussed in more detail in the next section. This activity is scheduled to be completely at random and occurring on the average once per week per district. The loading on the computer for this activity would be approximately forty-five minutes per week. The loading terminal would vary considerably. Large districts with small terminals such as Oak Park might require up to thirty minutes on a batch basis.

Timing estimates were based upon ninety characters of information being transmitted for each student file updated. It should be noted here that input only is considered in this routine. No output is anticipated.

File inquiries for summary reports would be expected to flow from the earlier described routine. Also the grade reporting and student scheduling routine have extensive reports flowing as output using these files as a source. The kindergarten through twelvth grade enrollments as of October, 1965 are the volumes that are used in the model. (Table 2)

Grade Reporting

In this routine ample evidence is available concerning the manner in which secondary schools behave in conducting their grade reporting procedures. The school year is typically blocked into six periods of six or seven weeks. Report cards are sent to parents sometime late in the week following the end of a marking period. In the model, Wednesday morning of the fifteenth, twenty-second, twenty-ninth, thirty-fifth, forty-second, and forty-ninth week following the start of the fiscal year were designated as the start of the grade reporting period. Batches were anticipated to arrive according to the following schedule of days: Wednesday - four, Thursday - eight, Friday - eight, Monday - four, and Tuesday - four. The arrival times within the day were anticipated according to an earlier described distribution which would anticipate the arrival early in the day in order to complete the batches within the same day.

Summarizing the last paragraph it will be noted that the grade reporting routine is spread over six periods of the school year. Within each period the individual batches are spread over five days with four or eight batches being processed on each of the days. Within the day the batches are distributed over a four and one-half hour period starting at 8:30 a.m. each morning.

From the information just presented it is apparent that four grade reporting routines will interact with the payroll days. These four districts might or might not be on payroll on that given week. The expected interaction would be two per grade reporting period. Outputting of grade reporting is extensive and this interaction is likely to result in queuing and delayed reports at least in some cases.

The distributions discussed to this point are concerned with the start of the batch from the local terminal. The transmission time is again a function of the terminal speed for any number of students for which records must be transmitted. Upon the completion of the sending of the input the batch waits in queue at the center for access to the computer for processing. Ninety characters of input for each student flows to the center. Considerable file organization is anticipated at this time to facilitate the continuous processing of other transactions in the system. The grade reporting batch is divided into twenty parts for processing by the computer. Primary concern at this time is with organizing the file in an appropriate order for outputting the report cards and class lists, the reports connected with the grade reporting period. Upon the completion of this compute phase, the output would be placed in a queue and wait to be outputted to the district.

In all previous activity output was returned to the terminal or origin. In this routine it is anticipated that four hundred characters of information for each student would be needed to print report cards and other data. Even for the smaller districts this would require hours on the slower type terminal. The decision was made to send the output from districts with small terminals to one of two places. The first choice would be to output on a fast terminal in a neighboring district.

At the time that the batch is ready to be outputted the fast terminal nearest the terminal of origin is tested for being busy. If busy, the central printer is tested for being busy. If the central printer is busy the batch then waits for either of these two devices and is outputted to the device that becomes available first.

The loading on the computer for this routine is approximately twelve hours to process about 85,000 secondary students. The loading on the terminal is complex and will be described in more detail in the interpretation of results. This is the first routine using the central printer and it is used then only for overflow.

Student Scheduling

In this routine the pattern of behavior of secondary school personnel is well known. For a period of the past four years local school principals and central computer personnel have worked together in arriving at a standard calendar of events in the student scheduling routine. As in other branches of the mathematical model the concern is with the entry of the various events into the model, the time necessary to process, and the time to return output to the point of origin or to the designated output terminal. In Oakland County, student scheduling has been for many districts a one-cycle operation with that cycle having its beginning in early spring and extending possibly until late August. A few of the school districts have scheduled by semester in which case there are two events during the year.

For this model the following assumptions are made: all districts will schedule for September 1, at the school year start with scheduling taking place for the full year. Each school will be scheduled twice, once during the spring for major planning purposes and again in mid-August allowing for the updating of requests by students resulting from spring failures or summer school changes. The spring activity is scheduled to start March 1 with input arriving from districts at the rate of one district per working day and spread over thirty working days following March 1. At the time of the arrival of input, the program will produce a potential conflict matrix and a complete summary report resulting from the input. In other words, working papers will be returned to the local school district upon receipt of the input.

Through-put or the actual placing of students in classes is scheduled to start April 1. The first attempts to schedule are distributed over the period April 1 to approximately May 15. Prediction for success of the scheduling is set at 33 1/3% meaning that on the average each school will have to be scheduled three times. In the event of a failure the school is rescheduled for processing from two hours to six days later. This allows the principal or other school personnel to make adjustments to the master schedule or make contact with students in order to increase the probability of success on the next run. Upon the successful completion of the through-put phase of student scheduling the batch is routed to the output portion of the grade reporting routine. As in the case of grade reporting, output would go back to the terminal of origin in the case of districts having large terminals but otherwise would go the district having a fast terminal nearest the point of origin, or to the central fast printer. This phase of student scheduling should be completed no later than June 15.

The next phase of student scheduling takes place the second and third weeks of August. It differs from phase one in two respects. The input is expected or considered to be at the center so that no input phase is required. The throughput phase is scheduled one hour apart for each district and is predicted to be 100% successful as it is primarily an updating of the spring scheduling routine. Upon the completion of the scheduling on the computer the batch is routed to the output phase of grade reporting as indicated earlier.

Summary

The balance of the routines in the model might be termed housekeeping routines. They serve to set appropriate signals in the model to set appropriate switches for examining the behavior of the various transactions in the model. For example, before any transaction may use a terminal device it must test to determine whether or not the terminal is busy. If the terminal is busy, that particular transaction is placed in a queue. The contents of this queue by terminal are measured and tabulated in the output from the simulation run. Likewise it is necessary to keep indicators set appropriately to determine the month of the year, the day of the month, the week and the day of the week. These housekeeping routines insure that the activity will flow through the system in the simulation run as nearly as possible describing the real life situation.

One additional discrete routine takes a sampling of the status of the terminal facilities every hour on the half hour. This means that forty times per week the environment is sampled to determine how busy the devices are. This information is tabulated and tables printed out at the end of the simulation run. The half hour point was picked instead of the hour point to avoid the constant start of the day in which all terminals would be busy in the network communication. If the hour point instead of the half hour point had been selected, once each day all thirty terminals would have been marked as busy. Therefore, the half hour point was chosen to get a random sampling of the business of the terminals.

Many different types of transactions have been described in the above sections. With much effort and with the aid of a calculating machine, actual loadings upon the computer and upon the several terminals could be totaled week by week to come up with an anticipated expected percentage of utilization. Such a procedure would be very time consuming and laborious and its accuracy would be subject to question. Further, no interaction among the transactions could be seen. Only time and experience will determine for certain how such an environment would behave. The simulation of this environment, however, should give clues as to the potential behavior. Procedures would be adjusted in order to make the model run more smoothly. In the simulation run determination would be made of those areas in which adjustment in behavior may become necessary, assuming configuration of a system with specifications set forth in the model.

CHAPTER VI

INTERPRETATION OF THE SIMULATION RUN

The Simulated Calendar

The natural calendar could start a July 1st to June 30th fiscal year on any working day of the week and that first working day could be July 1st, 2nd or 3rd. The assumption, purely for convenience was made that the model year would start on a Monday. Successive first days of the month would be entirely at random within the normal probability of the number of working days within a month falling between twenty and twenty-three days. Figure 4 illustrates the simulated calendar. The random generation of number of working days per month adequately distributed the first days of the month among the days of the week to provide a good mix of different situations throughout the simulation year. Significant cyclic operations are indicated on the calendar. To retain clarity daily and weekly applications, other than payroll, are not illustrated.

In the description of the student scheduling branch, June 15th was established as the latest day that spring student scheduling would be completed based upon a number of probability factors. The model simulated completion of the student scheduling as of June 3rd.

The calendar requires little interpretation. It provides a convenient reference for purposes of visualizing the environment as the various activities are being analyzed.

Figure 4.
C A L E N D A R

As Created By The Simulator

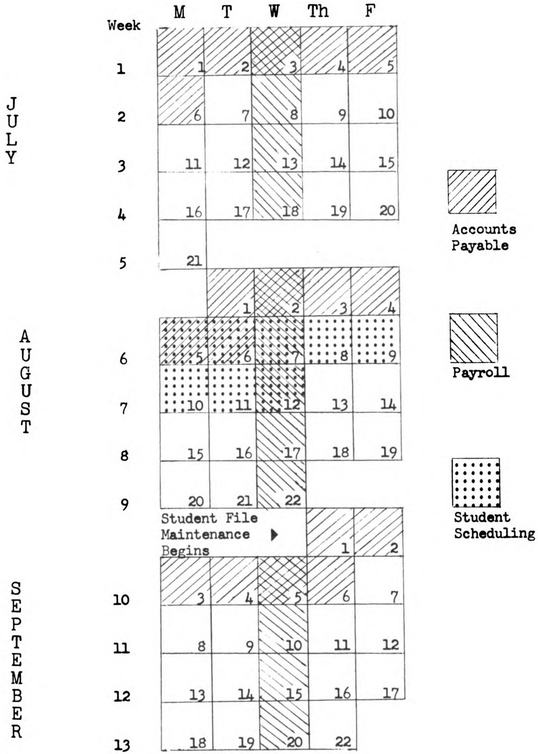


Figure 4. (con't.)

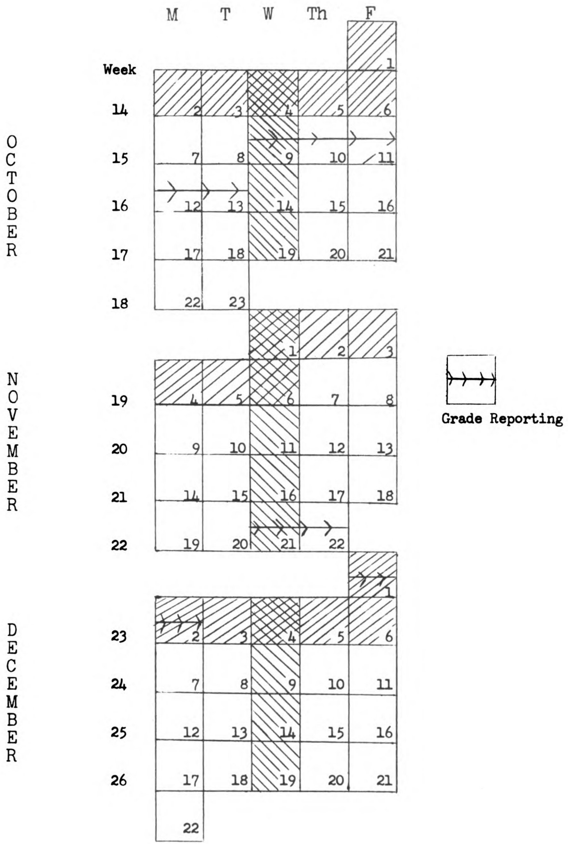


Figure 4. (con't.)

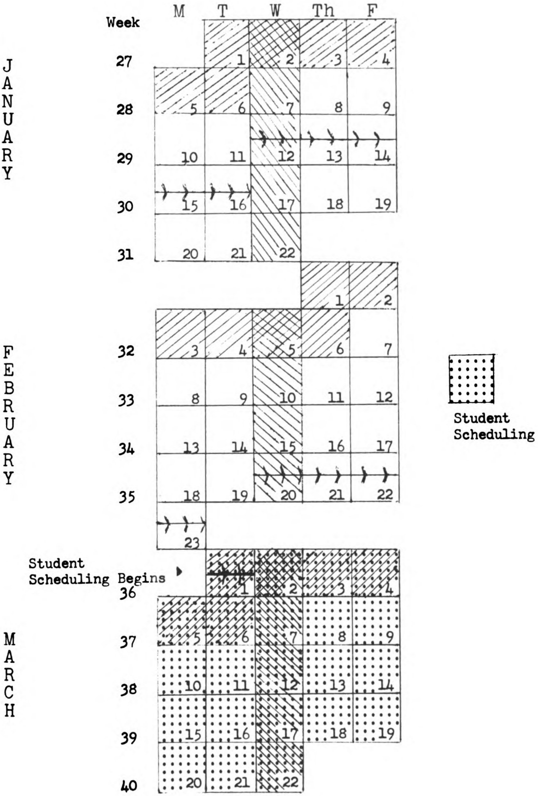
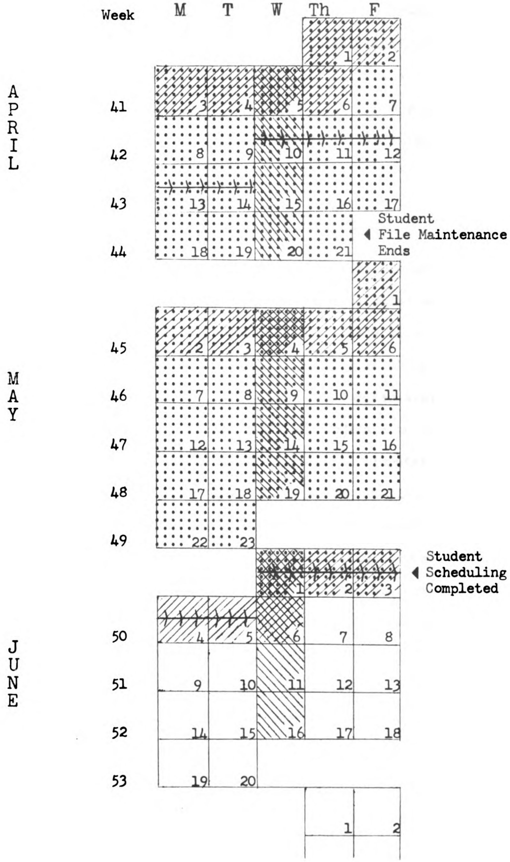


Figure 4. (con't.)



One branch of the simulator program sampled the status of the terminals hourly on the half-hour mark. Forty readings per week were tabled. The means of these tables by week ranged from a low of 2.4 to a high of 4.9. The 90th percentile ranged from 4 to 10. On the average throughout the year only three to four terminals would be busy at any one instant, the other twenty-six would be available for non-programmed use.

Facility Utilization

The concern for optimization in a teleprocessing environment would dictate that each facility have a high utilization while at the same time servicing the transactions entering the system with a minimum of delay. In the early phases of model building, average utilization on an annual basis was considered desirable, however, further analysis of the problem indicated that these results would not indicate on going behavior. Ideally, daily statistics would allow us to pinpoint probable pressures in the environment. A compromise of weekly statistics was dictated by economics. After the computer program was debugged, the simulation of the one year's operation required seventy-two minutes of time on an IBM 7904 computer at a cost of approximately ten dollars per minute. Many hours of an IBM 7040 computer time was used in debugging the mathematical model prior to the production run. These considerations dictated accepting the single run at this time. Even as this is being written there is a request to change the facility configuration and add two more program branches to the model and rerun. The weekly utilization tables, if published with this manuscript, would have required fifty-six tables. These have been omitted and represented graphically in Appendix C. The graphical representation does not include all of the information available in the tabled output from the computer but does focus attention on the activity at each facility. The graph represents utilizations at each facility for the entire year with information drawn from each of the fifty-six tables for each graph.

Utilization by type of terminal is of interest and will be discussed later. Figure 5 demonstrates another summarization of facility utilization. This graph demonstrates the range, variance, and mean of remote terminal facility utilization. The leftmost point in any week records the percentage of utilization of the least busy terminal, the rightmost point records the highest percentage for the week. The difference represents the range and is indicative of the variance. The X is the average utilization recorded for the thirty terminals. The low percentage points vary little from week to week but the terminals registering these low points are the terminals of the smaller districts. The high percentage points vary a great amount. The thirty-fourth week registered the lowest high percentage utilization of fifteen percent.

One of the most obvious relationships disclosed is the impact that grade reporting and student scheduling have on the environment. If a continuous line were drawn connecting each high percentage point week by week, the peaks would represent one or both of these activities. Each terminal registering these peaks are districts with high speed printers. This utilization is boosted by some outputting for smaller terminals. Outputting for smaller districts is shared by the central printer. (Figure 6.)

This illustration also demonstrates the impact of grade reporting and student scheduling outputting on the environment. It has been

Figure 5

```
                COMPOSITE       LOW TO HIGH        AVERAGE - X

                              PERCENTAGE BY WEEK.

     PERCENT   10         20         30         40         50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +         ****X**** *  *  *                       +
 02  +       *****X** *****                            +
 03  +       ****X**** *    *                          +
 04  +       ****X*******                              +
 05  +       ***  *X****    *   *                      +
 06  +       *****X ** * ** *                          +
 07  +       *******X** * **  **     *                 +
 08  +     *****X****     *                            +
 09  +      *****X**** *  * *                          +
 10  +      ******X* **  *** *                         +
 11  +      *****X*** *** *                            +
 12  +       ***X****** *                              +
 13  +       ***X**** **                               +
 14  +      *******X**  *** *    *                     +
 15  +      ******X* * **   *  * *                     +
 16  +        *******X** * **  ** *     *              +
 17  +       ***X****** * *                            +
 18  +      ******X* **** * ***                        +
 19  +      *  ***X***  **   *                         +
 20  +      ****X** * ***   *                          +
 21  +       ***X*** *  *                              +
 22  +        ***** *X*  ** ****    *                  +
 23  +      * * ******X*   ***  *  *   *               +
 24  +      ****X*  ** *   *                           +
 25  +      *****X**  ** * *                           +
 26  +       ***X**** **                               +
 27  +      ****  *X*****  *     *                     +
 28  +      ******X****   **  *                        +
 29  +       ** **** X*   * ***   *                    +
 30  +       ******X* **  * **   *      *              +
 31  +      *****X*** * * * *                          +
 32  +        ****X**** * **                           +
 33  +     ******X*** * ***                            +
 34  +      ****X****                                  +
 35  +       ***** ***X** ** *    * *  *               +
 36  +       *******X  *****                           +
 37  +        ******X  ***  *      *       *           +
 38  +      ******X****     *     *                    +
 39  +      * ** X ** * * * **                         +
 40  +       *****X*  *****                            +
 41  +       *******X** * **           *               +
 42  +      **********X * ****  *  *                   +
 43  +        ** *** X* *  **  *    *                  +
 44  +       *****X*** *****     *                     +
 45  +        *****X ***     *                         +
 46  +       ****X** * ***                             +
 47  +       ***X******* *                             +
 48  +       *** X**  ***                              +
 49  +      *  ** ***X** * ** *   *         *          +
 50  +       * *******X** * *  ** *        *           +
 51  +      ******X***  * *   *                        +
 52  +      *****X***  * *                             +
 53  +       *****X*** ****                            +
 54  +      ******X****** * *                          +
 55  +      ****X ***  *  *                            +
 56  +    *  ****X*****  **  *                         +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT   10         20         30         40         50
```

Figure 6

```
101 FAST PRINTER       FACILITY UTILIZATION.

                       PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5+++
 01   +*                                                +
 02   +*                                                +
 03   +*                                                +
 04   +*                                                +
 05   +*                                                +
 06   +******                                           +
 07   +*****************                                +
 08   +*                                                +
 09   +*                                                +
 10   +*                                                +
 11   +*                                                +
 12   +*                                                +
 13   +*                                                +
 14   +*                                                +
 15   +*************                                    +
 16   +**********                                       +
 17   +*                                                +
 18   +*                                                +
 19   +*                                                +
 20   +*                                                +
 21   +*                                                +
 22   +**********                                       +
 23   +************                                     +
 24   +*                                                +
 25   +*                                                +
 26   +*                                                +
 27   +*                                                +
 28   +*                                                +
 29   +**************                                   +
 30   +******                                           +
 31   +*                                                +
 32   +*                                                +
 33   +*                                                +
 34   +*                                                +
 35   +******************                               +
 36   +*********                                        +
 37   +*                                                +
 38   +*                                                +
 39   +*                                                +
 40   +*                                                +
 41   +***                                              +
 42   +*****************                                +
 43   +**********                                       +
 44   +******                                           +
 45   +**                                               +
 46   +******                                           +
 47   +***                                              +
 48   +***                                              +
 49   +***************                                  +
 50   +*********                                        +
 51   +*                                                +
 52   +*                                                +
 53   +*                                                +
 54   +*                                                +
 55   +*                                                +
 56   +*                                                +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5+++
      PERCENT  10        20        30        40        50
```

suggested that a model change directing all small district grade reporting and student scheduling to the central fast printer be made. This would have the effect of leveling out the peaks as demonstrated in Figure 5, but would boost the utilization of the central printer. In the actual operational environment options would be available. A discussion of the queuing problems will support the redirecting of the grade reporting and student scheduling output function.

Figure 7 records the percentage utilization of the computer. Aside from the two functions of grade reporting and student scheduling the loading by week has little variance; a low of twenty percent and a high of twenty-four percent. The effect of grade reporting and student scheduling is vividly demonstrated as is the interaction between these two operations beginning in the forty-first week. The peaks reach points ranging from forty percent to fifty-three percent but still could be considered safe. New applications should avoid cycles that would place heavy burdens on the system during these peaks. These peaks should be confirmed in an operational system and trends established so that management decisions involving the upgrading of equipment would be timely.

Appendix C is organized alphabetically by district. For discussion of facility utilization, it is appropriate to divide them into three groups. The first group, consisting of Birmingham, Farmington, Pontiac, Royal Oak, Southfield, Walled Lake, and Waterford each have high speed line printers. These terminals originate and receive in return all transactions involving their own local district data processing. In addition, they receive transactions from neighboring smaller school districts representing outputting functions of grade reporting and student

Figure 7

```
100   CENTER               FACILITY UTILIZATION.

                           PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +*********************                            +
 02   +********************                             +
 03   +********************                             +
 04   +*******************                              +
 05   +*********************                            +
 06   +**************************                       +
 07   +*******************************************      +
 08   +*******************                              +
 09   +*********************                            +
 10   +*********************                            +
 11   +**********************                           +
 12   +*********************                            +
 13   +**********************                           +
 14   +**********************                           +
 15   +*********************************                +
 16   +****************************************         +
 17   +**********************                           +
 18   +**********************                           +
 19   +**********************                           +
 20   +**********************                           +
 21   +*********************                            +
 22   +******************************************       +
 23   +********************************                 +
 24   +**********************                           +
 25   +**********************                           +
 26   +***********************                          +
 27   +***********************                          +
 28   +**********************                           +
 29   +*******************************************      +
 30   +*******************************                  +
 31   +**********************                           +
 32   +***********************                          +
 33   +**********************                           +
 34   +***********************                          +
 35   +**********************                           +
 36   +**********************                           +
 37   +*********************************************    +
 38   +******************************                   +
 39   +************************                         +
 40   +**********************                           +
 41   +*********************************                +
 42   +*****************************************************
 43   +*********************************************    +
 44   +********************************                 +
 45   +**************************                       +
 46   +*********************************                +
 47   +*****************************                    +
 48   +**************************                       +
 49   +***************************************          +
 50   +**********************************               +
 51   +*********************                            +
 52   +********************                             +
 53   +********************                             +
 54   +********************                             +
 55   +*******************                              +
 56   +********************                             +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

scheduling (see Table 3). The profiles of utilization of each of these seven demonstrate the sensitivity to grade reporting and student scheduling functions. All appear within a safe range even during peaks. Royal Oak management might wish to weigh the advantage of doubling printer speed or ruling out other districts gaining access to their printer. The problem is highlighted in the discussion on queuing.

The second group to be considered includes Berkley, Bloomfield Hills, Ferndale, Hazel Park, Oak Park and Rochester. Each of these districts was assigned fifteen line-per-minute terminals. The profiles of utilization for these districts indicate considerable variance from week to week although all remain in a safe range. This variance together with growth in volumes and the addition of applications might soon push utilization beyond a safe point. Also, as modeled, these terminals do rely on neighboring fast terminals for volume printing. This printing volume plus current levels of utilization suggest the need to consider upgrading terminal power for these districts.

The balance of the smaller districts or the third group all appear in a safe range. The reconfiguration suggested in the previous paragraph would even have a favorable influence for this group by providing additional printing power for the entire system.

Queuing Results

Each week from fifty to eighty units of traffic originated at each terminal in the system. The time of origin of each type was dependent upon the controls on that type in the model. Some were at quite specific times, others were almost completely at random and there were many degrees of control in between. The probability of a unit of traffic being serviced immediately was dependent upon the demands being made on the terminal. Is it in use? If so, how long? Are other units of traffic waiting to be serviced? If so, how many; how long; what priority?

During the first fifty-two weeks of the simulation, approximately 100,000 units of traffic were serviced at the terminal facilities. Table 8 records the distribution of waiting times for these transactions.

TABLE 8

DISTRIBUTION OF TERMINAL WAITS
FOR APPROXIMATELY 100,000 TRANSACTIONS

Minutes	%	Cumulative %
Less than ½	21.8	21.8
½-1½	40.8	62.6
1½-2½	10.6	73.2
2½-3½	6.1	79.3
3½-4½	3.0	82.3
4½-5½	2.2	84.5
5½-6½	1.9	86.4
6½-7½	1.8	88.2
7½-8½	1.2	89.4
8½-9½	1.8	91.2
9½-10½	1.1	92.3
10½-11½	.9	93.2
11½-12½	.9	94.1
12½-13½	.7	94.8
13½-14½	.6	95.4
14½-15½	.4	95.8
15½-16½	.6	96.4
Over 16½	3.4	99.8

Approximately 62,600 of these 100,000 transactions gained access to their respective remote terminals in less than one and one-half minutes. About 96,400 gained access within sixteen and one-half minutes. Over 3,400 transactions waited in excess of sixteen and one-half minutes. Would this be acceptable? Closer examination of the output data reveals isolated waits of two hours or more. Further analysis of queue statistics reveals that the transactions waiting in queues are predominantly file inquiry and network communication transactions. A fair share of other transactions are waiting but in an operational environment would be under greater control. Critical file inquiry and communication transactions would be given priorities in an operational environment to ease this problem.

The above arguments are presented as ways of accommodating restrictions. More appropriate to the present is the evidence for suggesting different facility specifications in certain parts of the configuration. The queuing problems of the districts with fast printers could be eliminated by the addition of limited purpose typewriter terminals. The small terminals could be dedicated to job rated applications such as file inquiry, summary reports and communication. The queues developed at the terminals of the medium size districts indicate a need to examine alternate facilities. A product gap in printer devices prevents specifying any particular printer speed at the present time but industry announcements of new equipment would indicate improvements are forthcoming soon.

Application queues were recorded at the terminals and at the computer for several of the applications. Queuing at the computer does not appear to be a problem. Maximum waiting lines rarely contain greater than two transactions, the exception occurring at grade reporting time when the length reached six on one occasion. Sizeable application queues do develop at the district terminals for the three applications of purchasing, file inquiry and communications. Each of these are daily applications and this queuing could be expected to develop at heavy batch processing times. These queue lengths emphasise the need for controls on accessibility and on priorities.

Program Applications

Getting a job completed within a reasonable time period is a concern of the school employee charged with a specific responsibility. There are appropriate times for each of a number of steps in the initiation, preparation, processing and completion of any given batch type job. It is extremely important in this mathematical model to determine if, in fact, the various phases were completed within appropriate time elements to serve a real life situation. Figures 8, 9, and 10 do reveal this evidence for three of the critical repetitive applications. The simulation calendar (Figure 4) supports this evidence and reveals evidence of meeting deadline dates for student scheduling and grade reporting.

One of the applications where time is critical is payroll. Nine o'clock Wednesday morning is marked as start time. Preferred results would be to complete the processing within the balance of the day. Figure 8 illustrates that this happened in the model about one-half of the payroll days. During the other weeks payroll processing overflowed to the next day, incidentally, conflicting with the daily 8:30 a.m. network communication application. Although overflow of the application occurred this often, only the computer and one or two terminals were involved by the overflow. The mean transit times for payroll batches varied from a low of one and one-half hours on the thirty-fourth week to three hours on the fourteenth and thirty-third week. Input specifications to the model set a .100 factor as probability of failure. In

Figure 8

DISTRIBUTION OF STATISTICS OF PAYROLL BATCH PROCESSING 14 BATCHES PER WEEK

X - AVERAGE TRANSIT TIME Z - 90 PERCENT COMPLETED
* - ELAPSED TIME FROM FIRST BATCH ARRIVAL TIME TO COMPLETION OF LAST BATCH
*S TO THE RIGHT OF 7 1/2 HOURS OVERFLOWED TO THE NEXT DAY

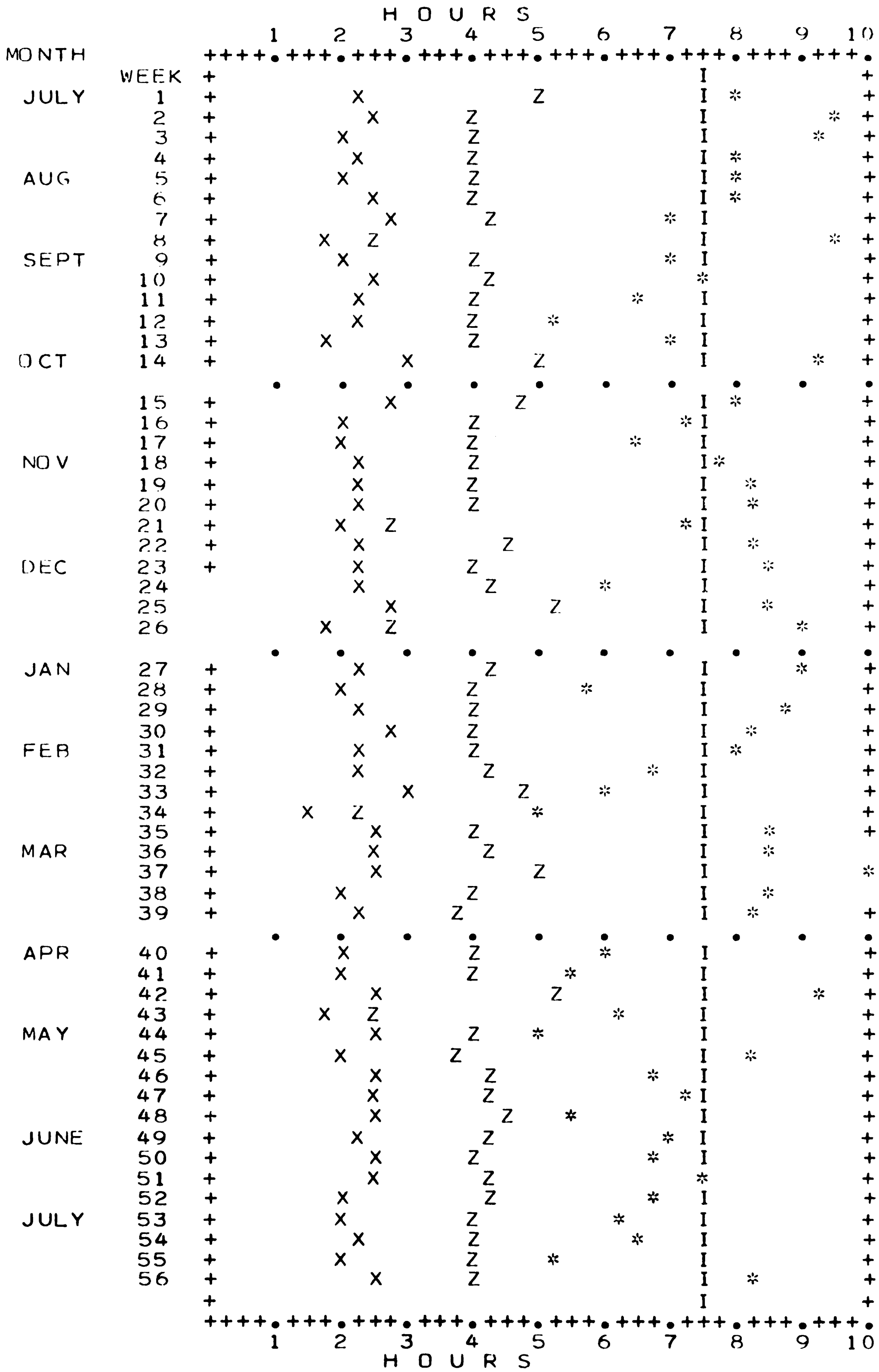


Figure 9

DISTRIBUTION OF STATISTICS OF ACCOUNTS PAYABLE
BATCH PROCESSING 30 BATCHES PER MONTH
X-AVERAGE TRANSIT TIME Z-90 PERCENT COMPLETED

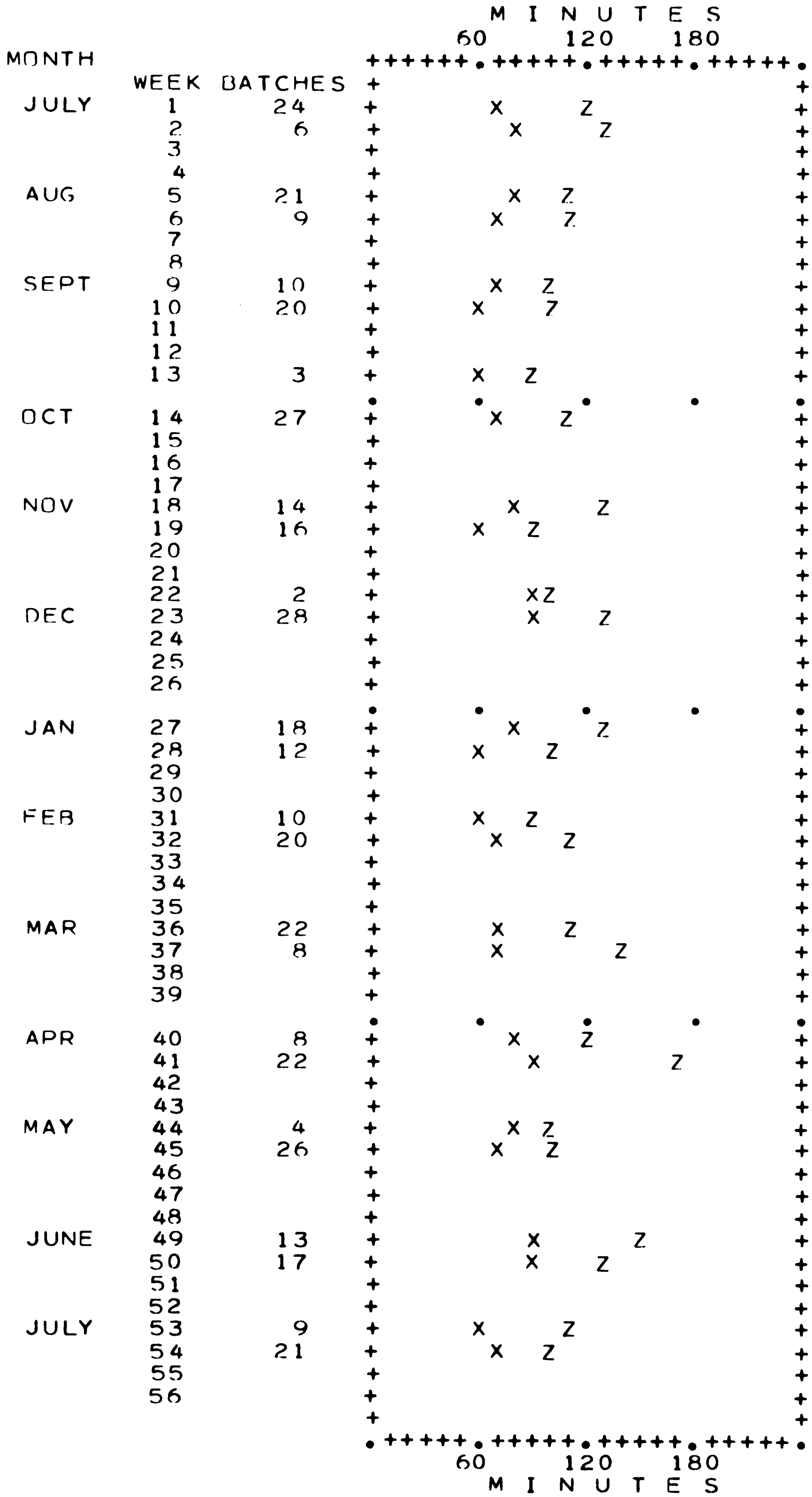


Figure 10

```
            DISTRIBUTION OF  STATISTICS   OF DAILY
              PURCHASE ORDER  BATCH PROCESSING
                    150 BATCHES PER WEEK
         X-AVERAGE TRANSIT TIME    Z-90 PERCENT COMPLETED
                     M I N U T E S
                   5   10   15   20   25
MONTH         +++++.++++.++++.++++.++++.++++.
        WEEK  +                             +
JULY       1  +        X     Z              +
           2  +        X     Z              +
           3  +         X    Z              +
           4  +       X      Z              +
AUG        5  +     X        Z              +
           6  +     X        Z              +
           7  +            X Z              +
           8  +     X   Z                   +
SEPT       9  +    X    Z                   +
          10  +     X   Z                   +
          11  +   X     Z                   +
          12  +    X    Z                   +
          13  +   X     Z                   +
                   .    .    .    .    .    .
OCT       14  +    X    Z                   +
          15  +     X   Z                   +
          16  +         Z X                 +
          17  +    X    Z                   +
NOV       18  +      X  Z                   +
          19  +   X     Z                   +
          20  +    X    Z                   +
          21  +   X     Z                   +
          22  +          X   Z              +
DEC       23  +           X  Z              +
          24  +   XZ                        +
          25  +   X     Z                   +
          26  +   X     Z                   +
                   .    .    .    .    .    .
JAN       27  +     X   Z                   +
          28  +     X   Z                   +
          29  +       X Z    Z              +
          30  +        XZ                   +
FEB       31  +    X    Z                   +
          32  +        XZ                   +
          33  +    X    Z                   +
          34  +   X     Z                   +
          35  +       X Z                   +
MAR       36  +          X   Z              +
          37  +      X  Z                   +
          38  +     X   Z                   +
          39  +    XZ                       +
                   .    .    .    .    .    .
APR       40  +     X   Z                   +
          41  +      X  Z                   +
          42  +          X   Z              +
          43  +           X  Z              +
MAY       44  +        XZ                   +
          45  +      X  Z                   +
          46  +    X    Z                   +
          47  +    X    Z                   +
          48  +      X       Z              +
JUNE      49  +       X      Z              +
          50  +             X     Z         +
          51  +      X       Z              +
          52  +       X      Z              +
JULY      53  +       X      Z              +
          54  +    X    Z                   +
          55  +     X   Z                   +
          56  +    X    Z                   +
              +                             +
              +++++.++++.++++.++++.++++.++++.
                   5   10   15   20   25
                     M I N U T E S
```

fifty-two weeks seven hundred eight payroll batches were processed; an estimated seventy-eight failed once delaying or prolonging process time. Seven or eight might have failed twice, perhaps one failed three times. These occurances would help to account for the few batches requiring five or more hours and for some of the overflow to the next day.

Figure 9 indicates the flow of the accounts payable batches through the model. This application was given a priority and would have to vie only with payroll for access to facilities. There is no apparent evidence that servicing of this application caused any significant pressure on the system. Most accounts payable batches entered and cleared the system in two hours or less.

The daily purchasing activity (Figure 10) rarely required more than fifteen minutes even during the summer months when data transmission was heavier from this application.

Summary

The computer output from the simulation run contained over five hundred pages of printed tables. The graphs and tables in this chapter and in Appendix C are summaries from many of these tables. Man months, if not man years, would be required to interpret these results in detail. At this point in time and preciseness of environmental description, spending that amount of time is not warranted. Further interpretation of these printouts will be helpful in arriving at a new configuration for resimulation purposes. Each district could weigh how the present configuration would perform for them, weigh the advantages of other facilities and arrive at a facility specification tailored to meet the local district requirements.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Introduction

The rate of development of the technology of automation is so rapid that possibilities considered remote at the beginning of this study nine months earlier show promise of becoming reality within the period of the next one to two years. The Teleprocessing Feasibility Study involving seven of the larger local school districts of Oakland Schools was conducted during the months of September through December of 1965. During the months of January through March, eleven of the remaining districts conducted similar studies involving the same applications but on a smaller scale due to their smaller student enrollments. Four additional districts are in the process of conducting independent studies to determine the feasibility of involvement in the teleprocessing network. At this writing each of the local districts is in various stages in its decisions to commit resources to the development of the teleprocessing network described by the mathematical model. Some, at least five districts, have passed board resolutions and included resources in the next fiscal budget to prepare for the establishment of the network. Other districts have board resolutions pending and still others are awaiting the outcomes of staff studies.

The appropriate timing of this study is self-evident. This initial simulation run presents significant data, not to make the final decisions but at present to better realize the factors in the decisions that need further study and analysis.

Conclusions

Mathematical model building and simulation in the field of education is in its infancy. This model of a teleprocessing network to serve an educational environment is but a sample of one. Extreme care should be taken not to generalize based upon such limited experience. Nevertheless, the complexity of the decisions facing today's educator and educational administrator mandates using more sophisticated techniques to clarify the issues.

As stated earlier, data presented in this study represents the output from a first simulation. Results should not be considered conclusive in every aspect, but the relationship between the parts can be tested further even if input data are only estimated. The first refinement of the model would adjust terminal power to overcome certain observed pressures in the system as determined by the first model run. The further refinement in the model would focus more closely on applications. Evidence from the computer output indicates that grade reporting presents one of the most significant pressures on the system. A series of questions might be asked. Should power of facilities be boosted to accommodate one problem application? Should constraints on accessibility be applied or increased? What are possible options and their respective costs? Further refinements in the simulator program to run the model could test the appropriateness of suggested model changes.

The cost of using the present simulator program to simulate the environment for full year cycles is relatively high. New programs promised by industry and new generation computers will diminish this problem but for the immediate future some attention should be given to building the model to study the environmental behavior in more detail over a shorter cycle. The present model develops weekly statistics for fifty-two weeks. This is needed to describe the cyclic activity that occurs relatively few times within the year. To supplement this overview, a technique to focus attention on the hour by hour or even minute by minute environment is needed.

The above statements refer to only a few conclusions that can be drawn from an analysis of the data generated by the model. Overall, the data generated verified that all program branches were functioning as specified and that transactions were being processed in an orderly fashion, given the various conditions assigned to each type of transaction. The importance of this can be emphasized by relating an occurance of one 'bad' run. The simulator program has a capacity of containing a maximum of one thousand transactions in all blocks at one time. In this particular 'bad' run, one type of transaction was entered properly but was held in a loop of just a few blocks in the flow diagram because of erroneous coding. Since these transactions could not leave, they continued to accumulate until the maximum of one thousand halted entry of any new transactions into the system until others had left. This occurred sometime in the simulated month of December. For the balance of the year one thousand transactions were in the model continuously. Output from that point forward was obviously bad, but the simulator continued to operate the model with these restrictions. The final run did yeild output that described the environment that the builder expected.

Conclusions related to individual districts, applications and configurations would necessitate involving local district personnel. Expectations of performance based on the present model, readiness to utilize program applications and budgetary considerations of each local district would contribute to conclusions and recommendations for each district.

Problem Areas

The electronic components assumed in the mathematical model are available from the computer vendors at the present time. The systems support to implement such an operational environment is also available at the present time. The commitment of industry to establish an implementation schedule will be a part of the bid specifications when invitations to bid are submitted to the vendors. This is a basic problem. Industry has not as yet committed technical staffs to developing programs oriented toward accommodating the needs of the education community in teleprocessing.

Computer programs to simulate mathematical models of the complexity of this model are not user oriented. Too much time elapsed between the beginning of model building and the computer simulation. Progress is being made in this area. School administrators in general lack knowledge, training and experience to exploit scientific management techniques as tools in management decisions. Industry provides technical training for top and middle management to exploit the advances in technology. The single fact that industry is producing at an all time high rate while maintaining low inventories attests to the success of their management training programs. The lack of a similar commitment to train school administrators to an understanding of the potential of automation in school management is a significant problem.

A related problem is the lack of adequately trained specialists to staff new roles that are currently developing in educational data processing.

Many of the problems are related to the single observation that technology as related to equipment is advancing at a rate faster than the consumer can implement. If the consumer is to gain ground a greater commitment to accomplish this end is needed.

Recommendations

For the immediate future, Oakland Schools and its constituent districts have available a scientific management tool that has the potential of aiding in the definition of a configuration of equipment to achieve the ends defined in the mathematical model. Modifications should be made in the model reflecting these new estimated and other known information. Better estimates of volumes are now available. Additional applications are needed in the model to accommodate the constituent districts.

Also for the immediate future, effort should be applied to upgrade simulation as a tool. First, to enable the user to prepare input with much less effort; second, to supplement the detailed computer output of the simulation run with summary reports. It would be especially valuable to have reports graphically displayed.

The educational community, including state departments of education, colleges and universities, intermediate and local districts should give attention to an appropriate training experience for present and future educational leaders in education.

Even before the mathematical model becomes in fact an operation model, it is known that it must remain flexible. It must be readily adaptible to changes in volumes, organizational patterns, new applications and any other influences on the environment. Data to build this model were difficult to obtain, some of the data are best estimates. This does not have to be the case in the future. The operational model can accumulate data relative to its own behavior, store that data, and periodically project what its future behavior will be based upon simulation runs using automatically accumulated precise historical information. Systems design personnel should include such plans in the comprehensive control program in the operational model.

Summary

Simulation has been demonstrated as a mathematical analytic tool for decision making. It has not been demonstrated that a solution can be found to a given problem but that mathematical model building can provide a vehicle for clearly defining the various factors of the problem. It can be used for testing the interrelationship of these factors, and for testing the sensitivity of behavior when changes occur in the various factors. This demonstration has been conducted in an educational administration environment. The demonstration has presented evidence that a teleprocessing network can bring the advantages of present day technology to children in school districts whether large or small. The demonstration has further presented evidence that this same technology can provide tools for management decisions in education as readily as other governmental agencies or business and industry.

APPENDIX A

FLOW CHARTS

OF

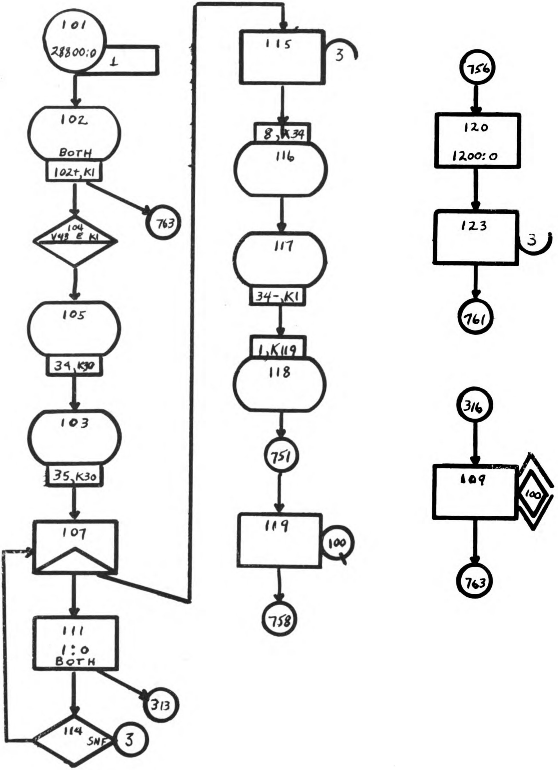
THE MATHEMATICAL MODEL:

A TELECOMMUNICATIONS NETWORK

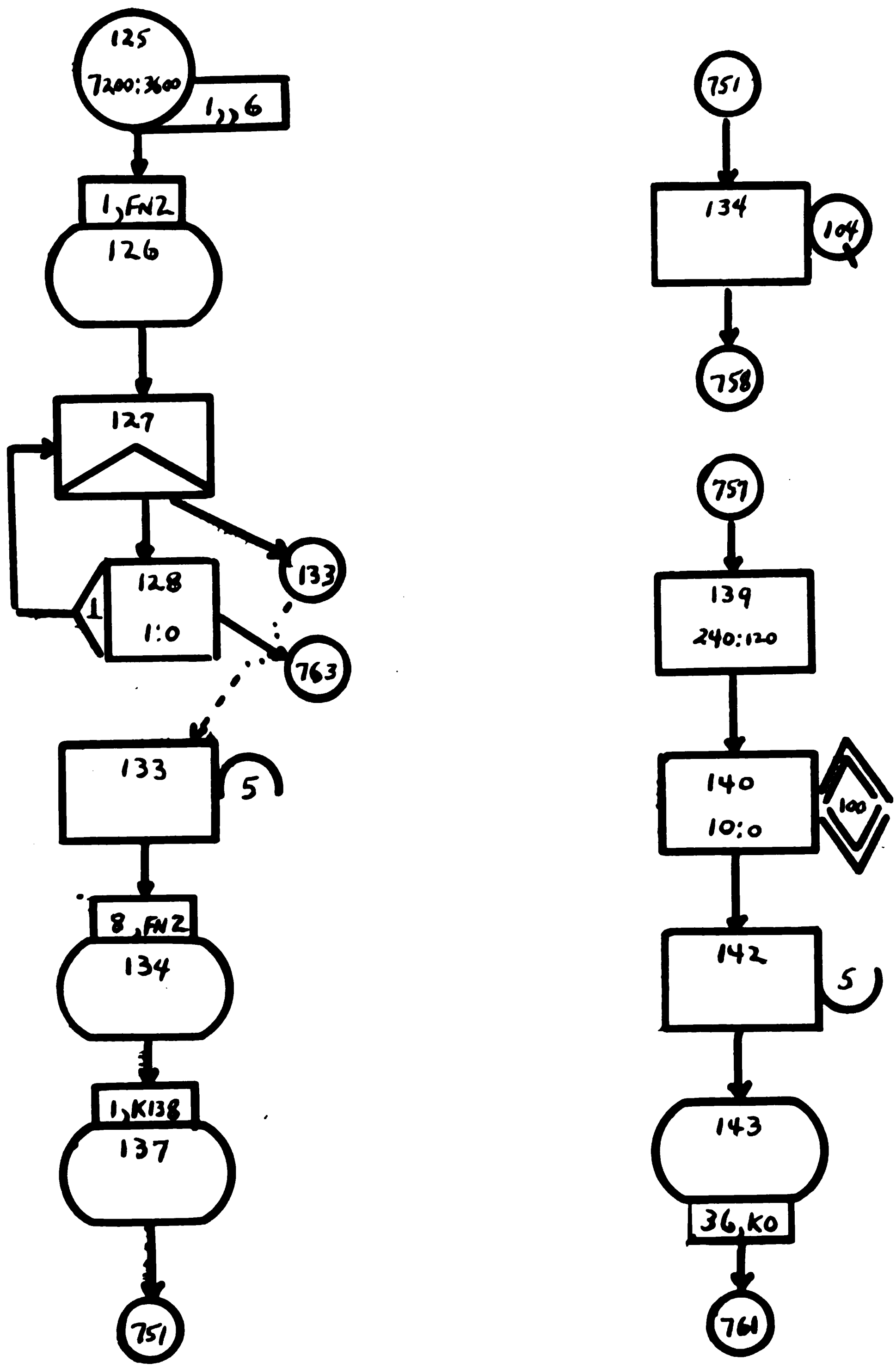
FOR

DATA PROCESSING IN SCHOOLS

NETWORK COMMUNICATIONS



NETWORK COMMUNICATIONS (continued)



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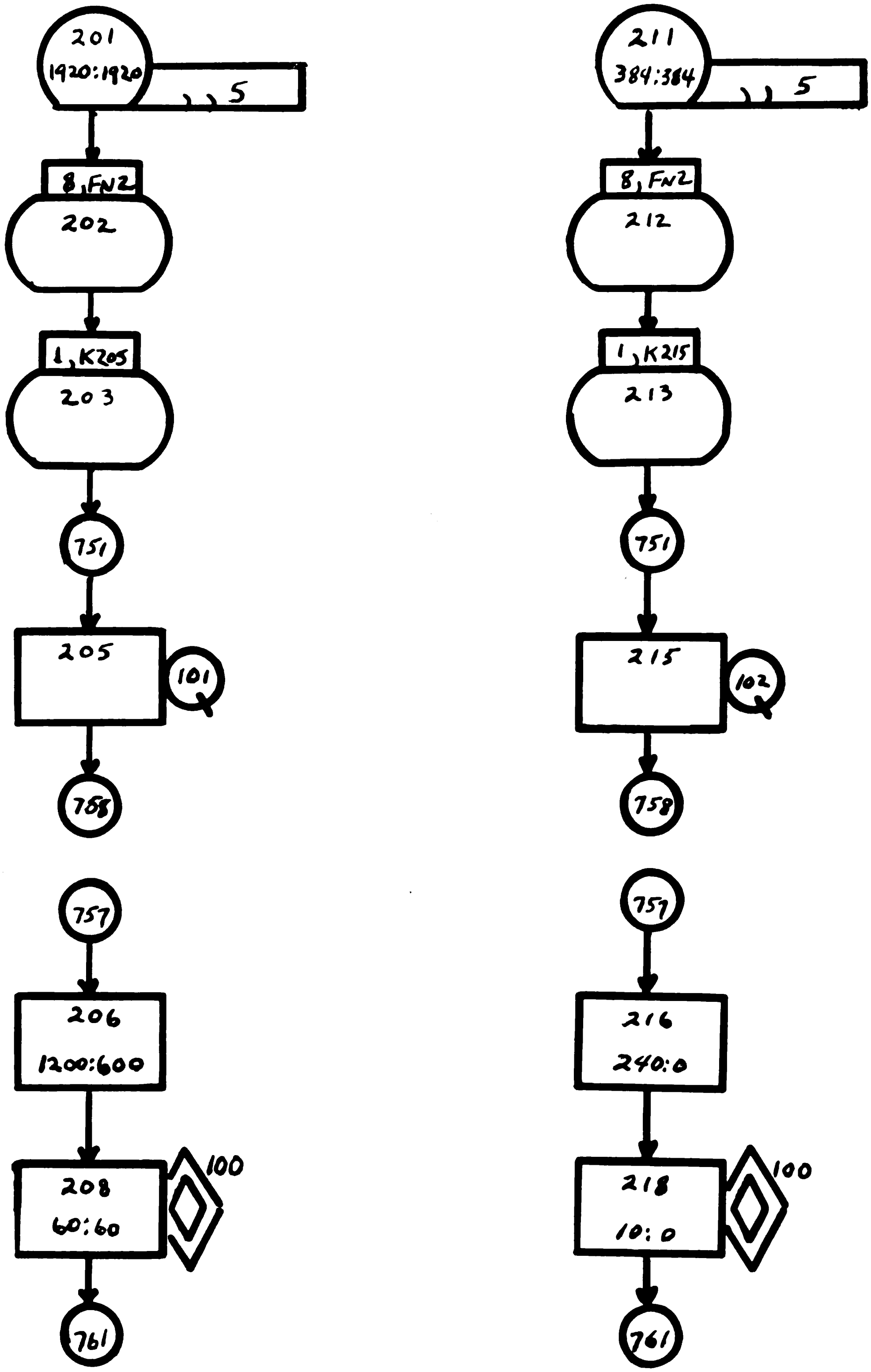
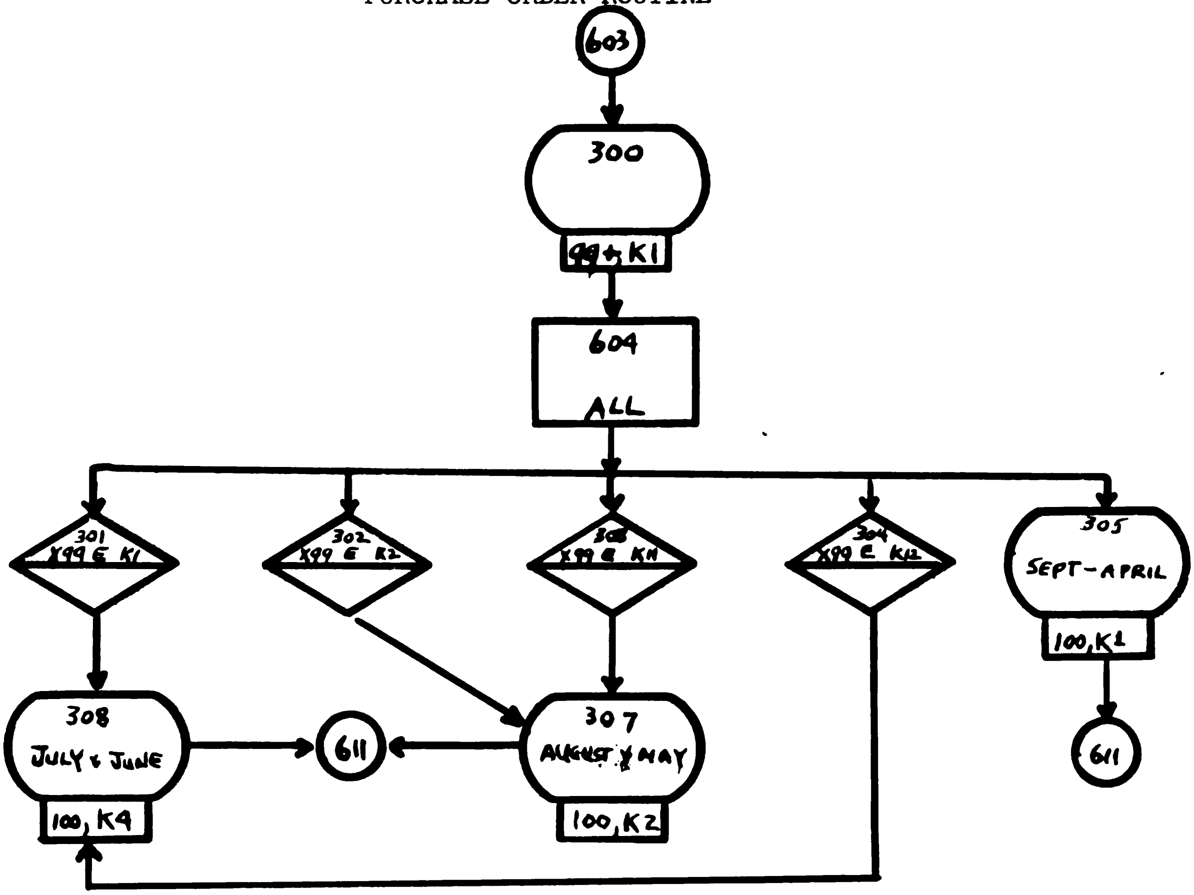


PURCHASE ORDER ROUTINE



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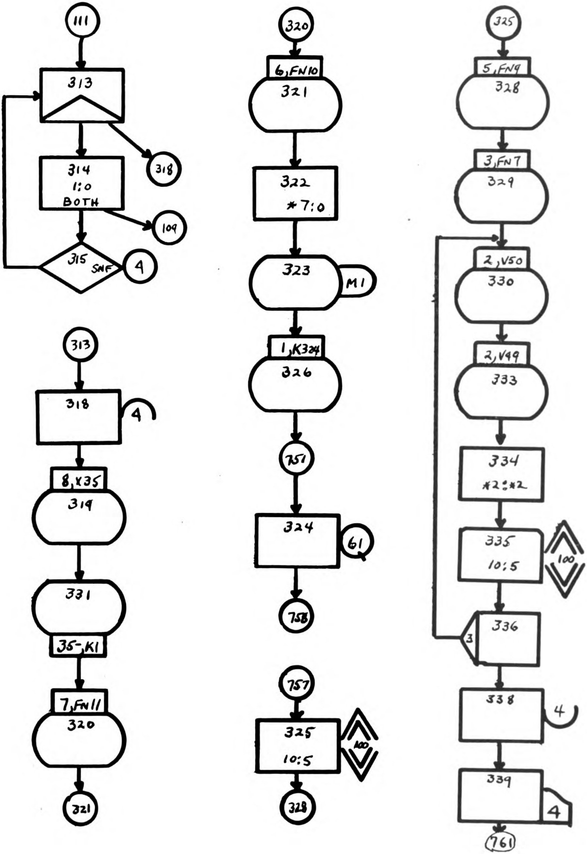
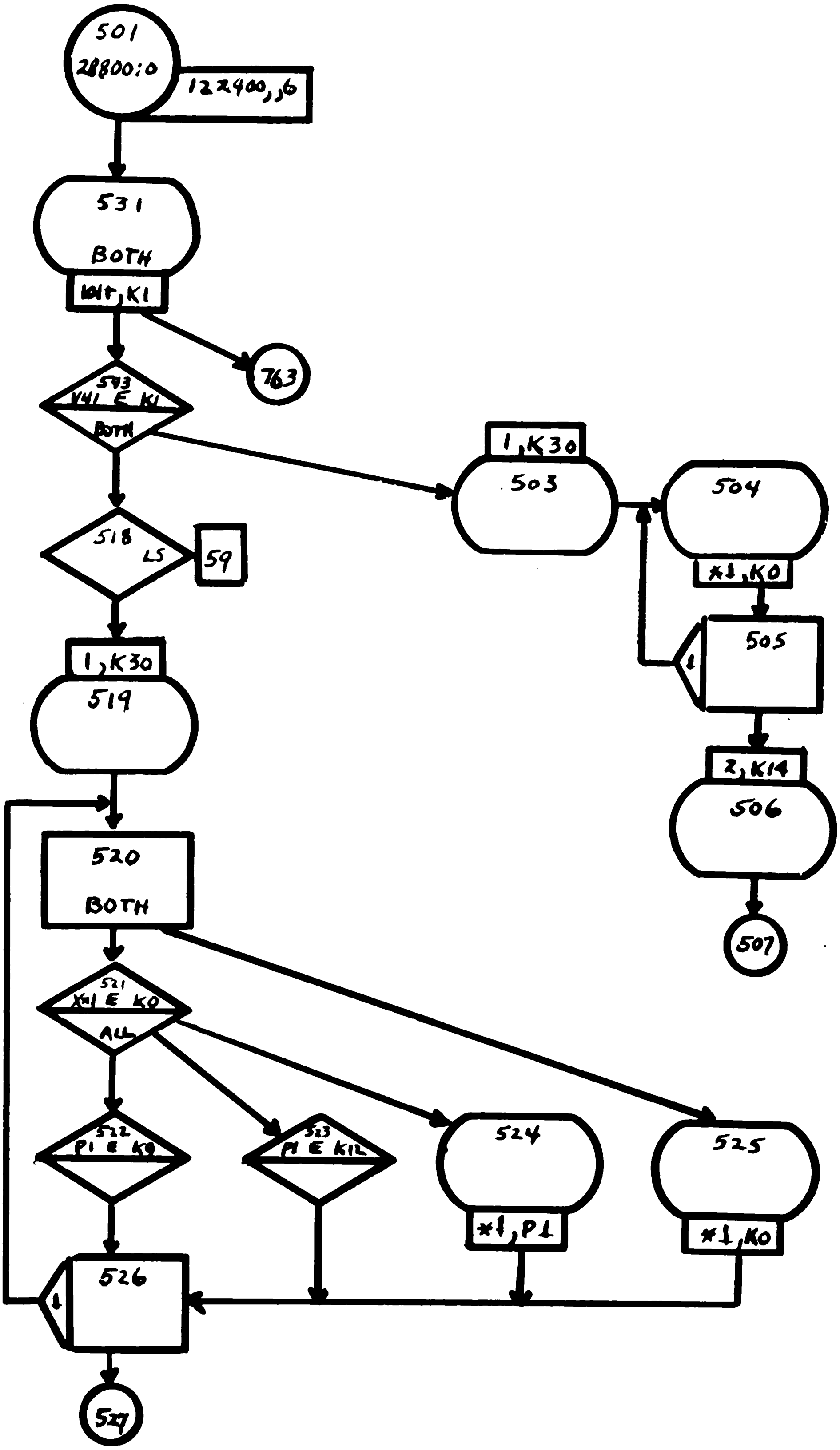


PAYROLL ROUTINE



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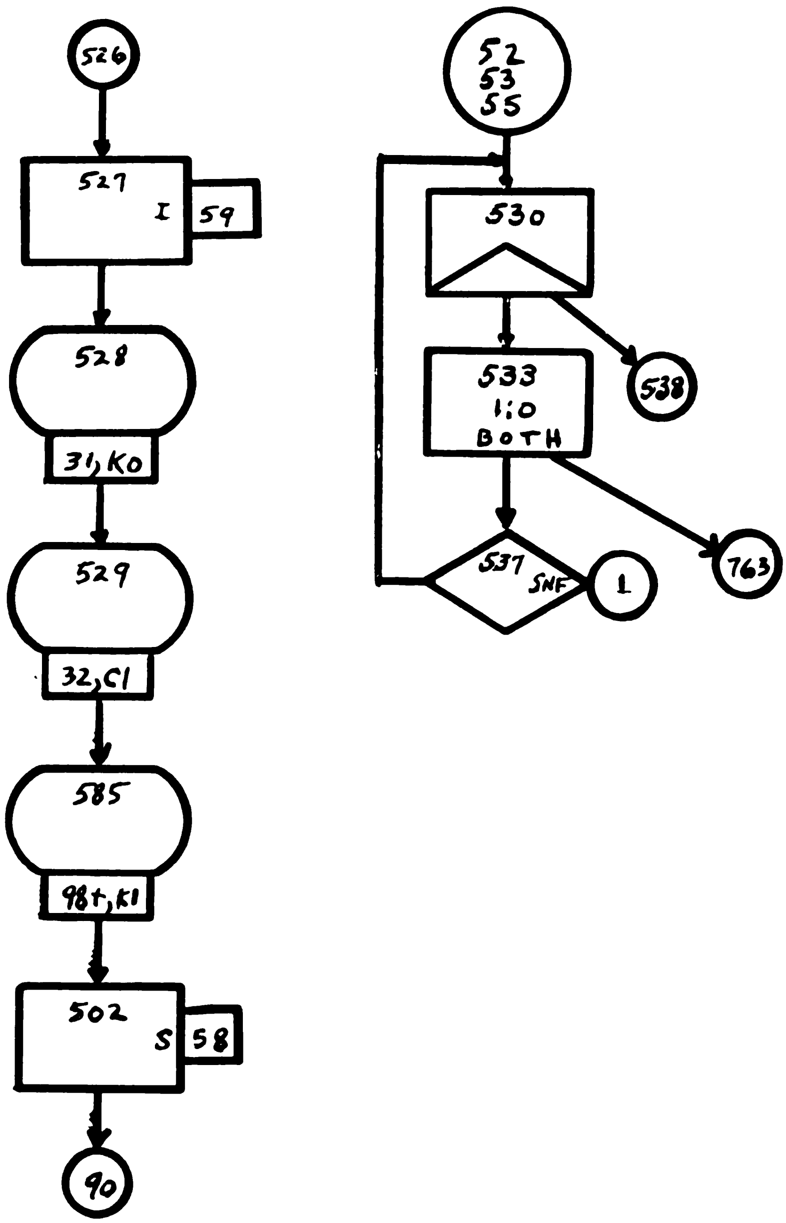

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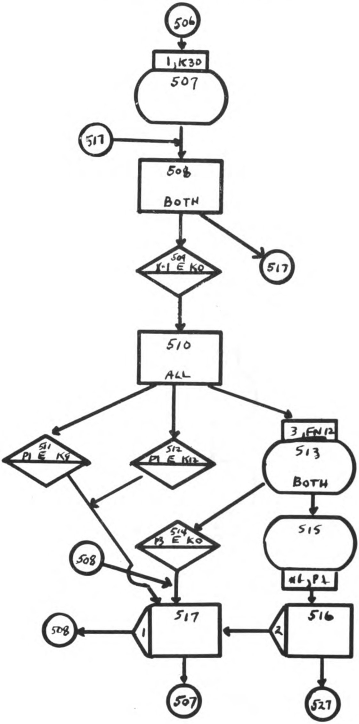

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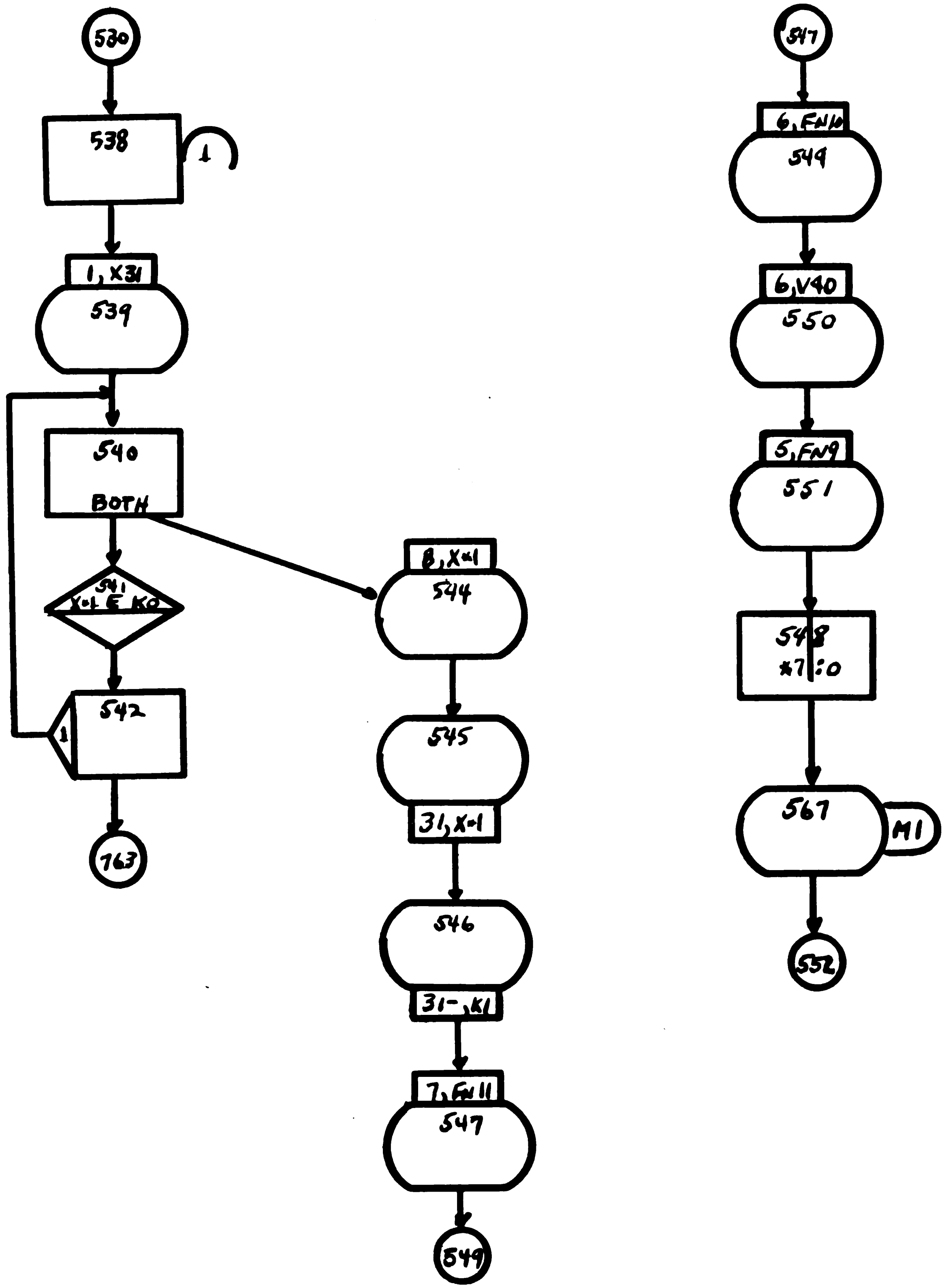

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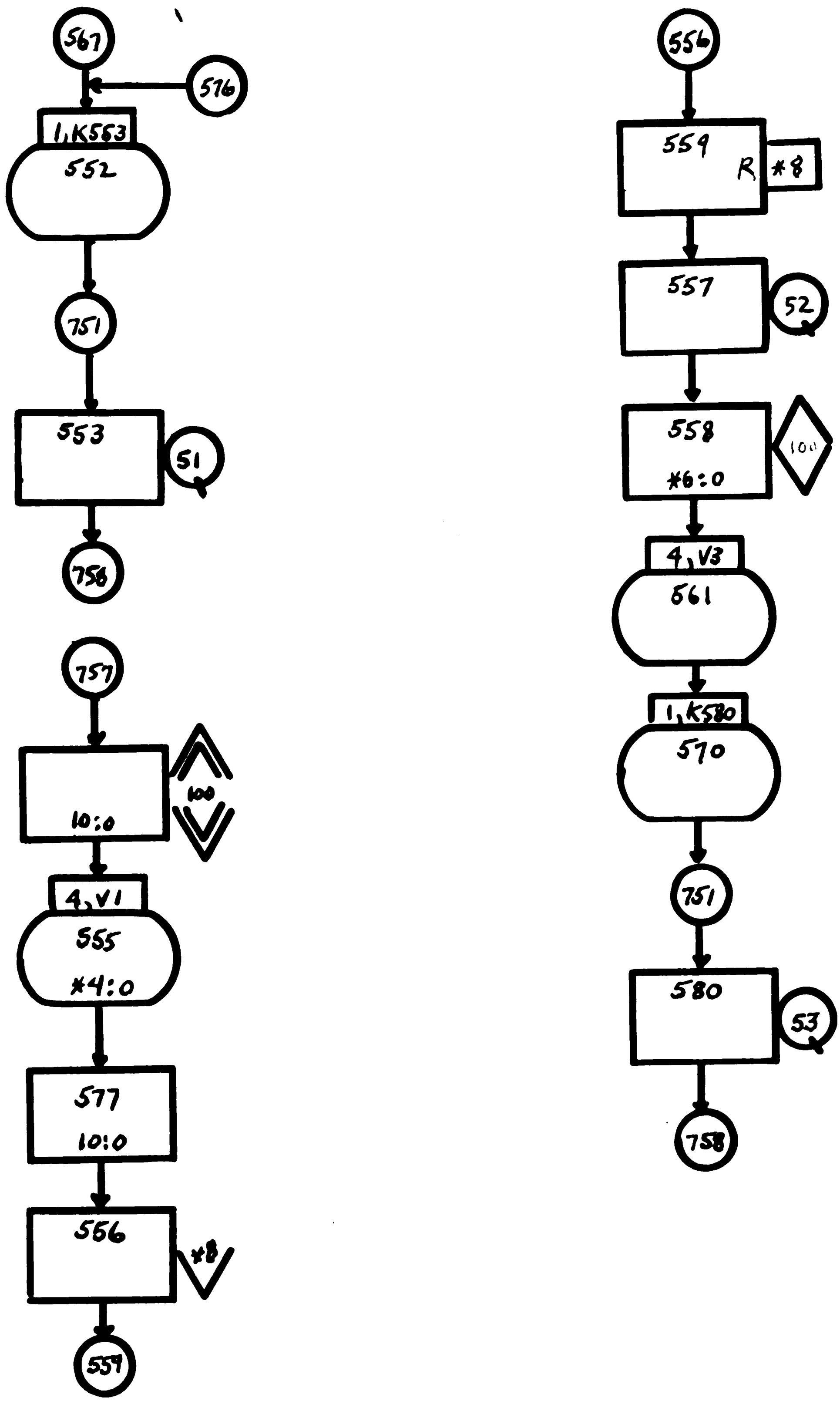

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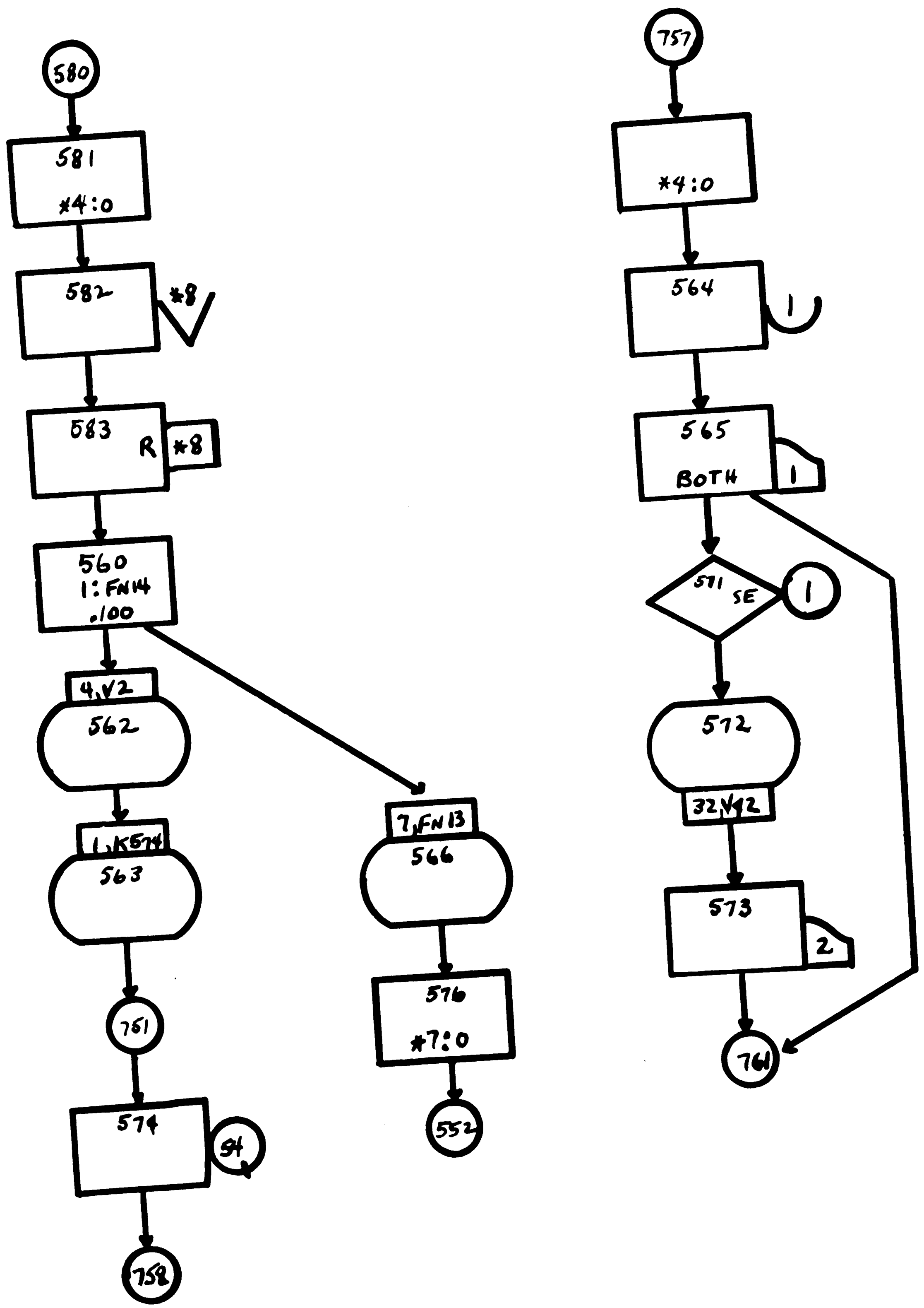
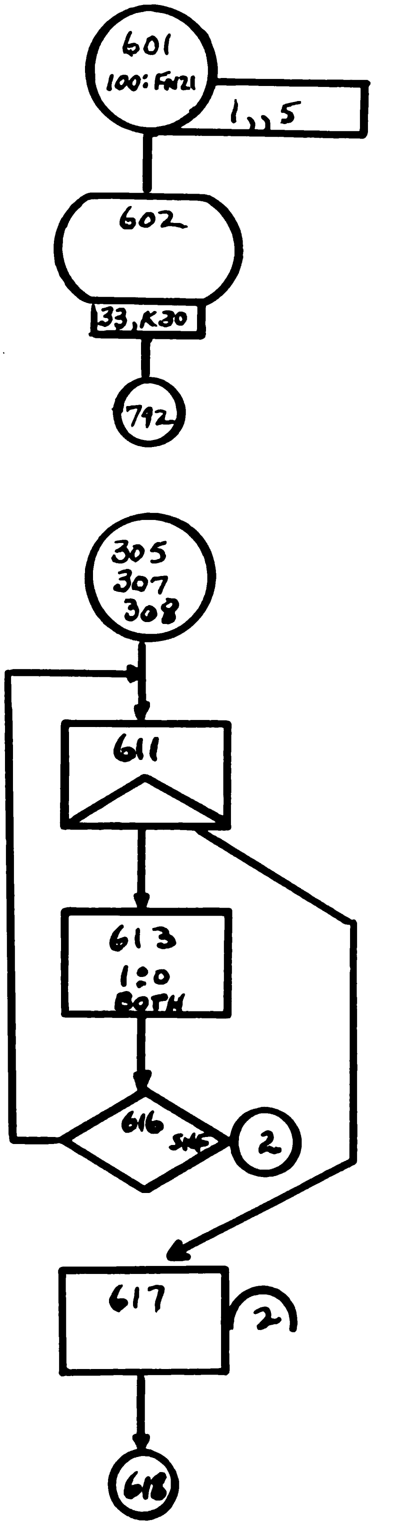
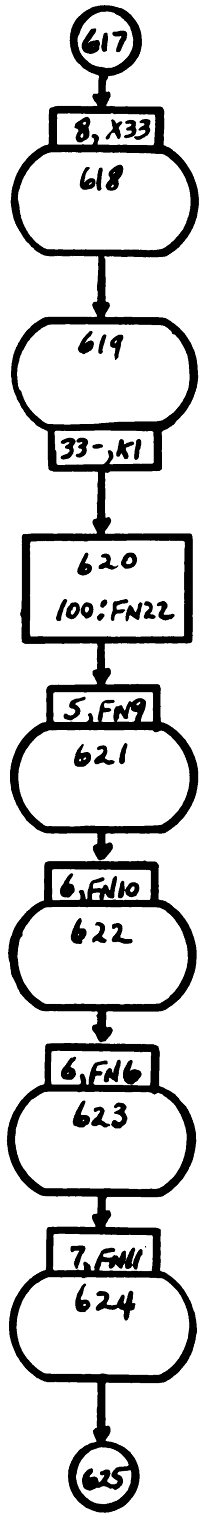


ACCOUNTS PAYABLE ROUTINE





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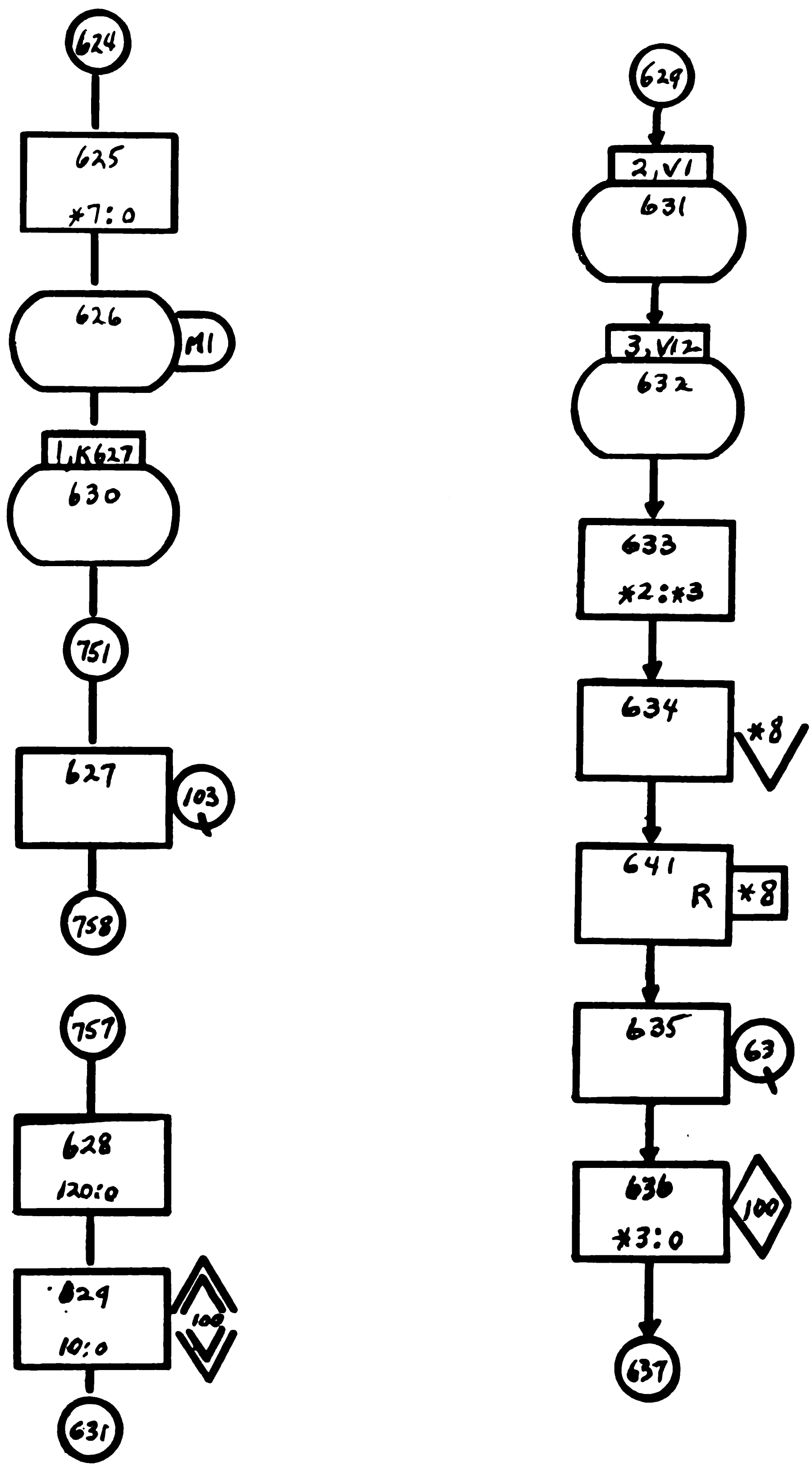

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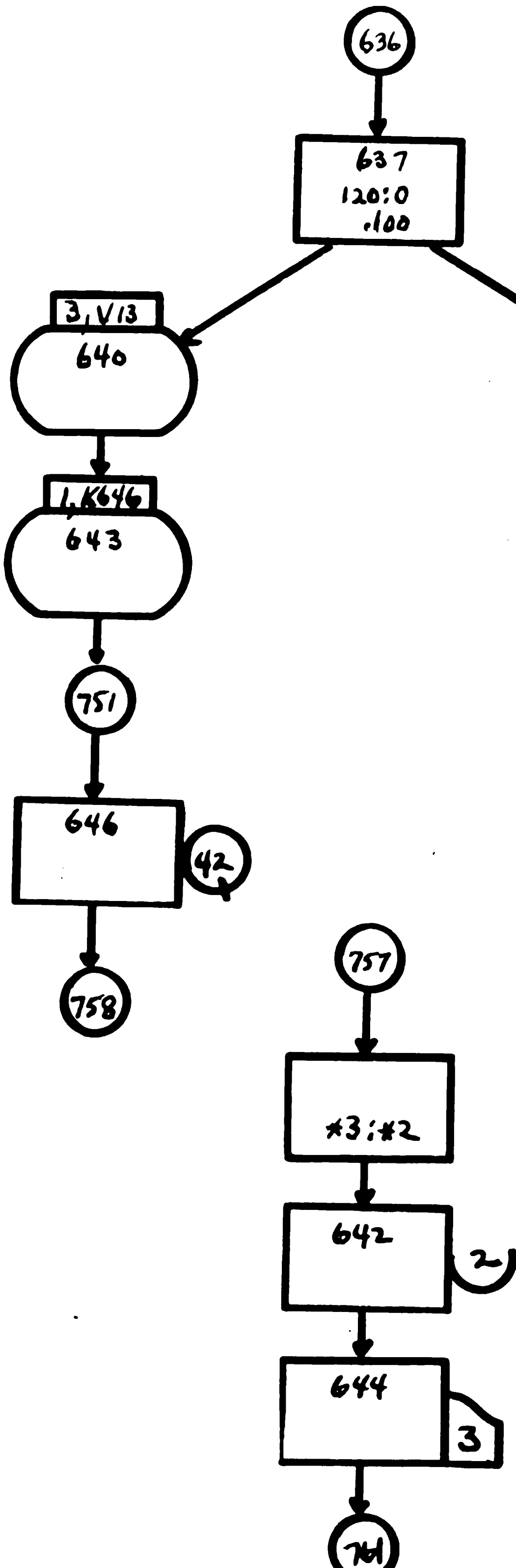
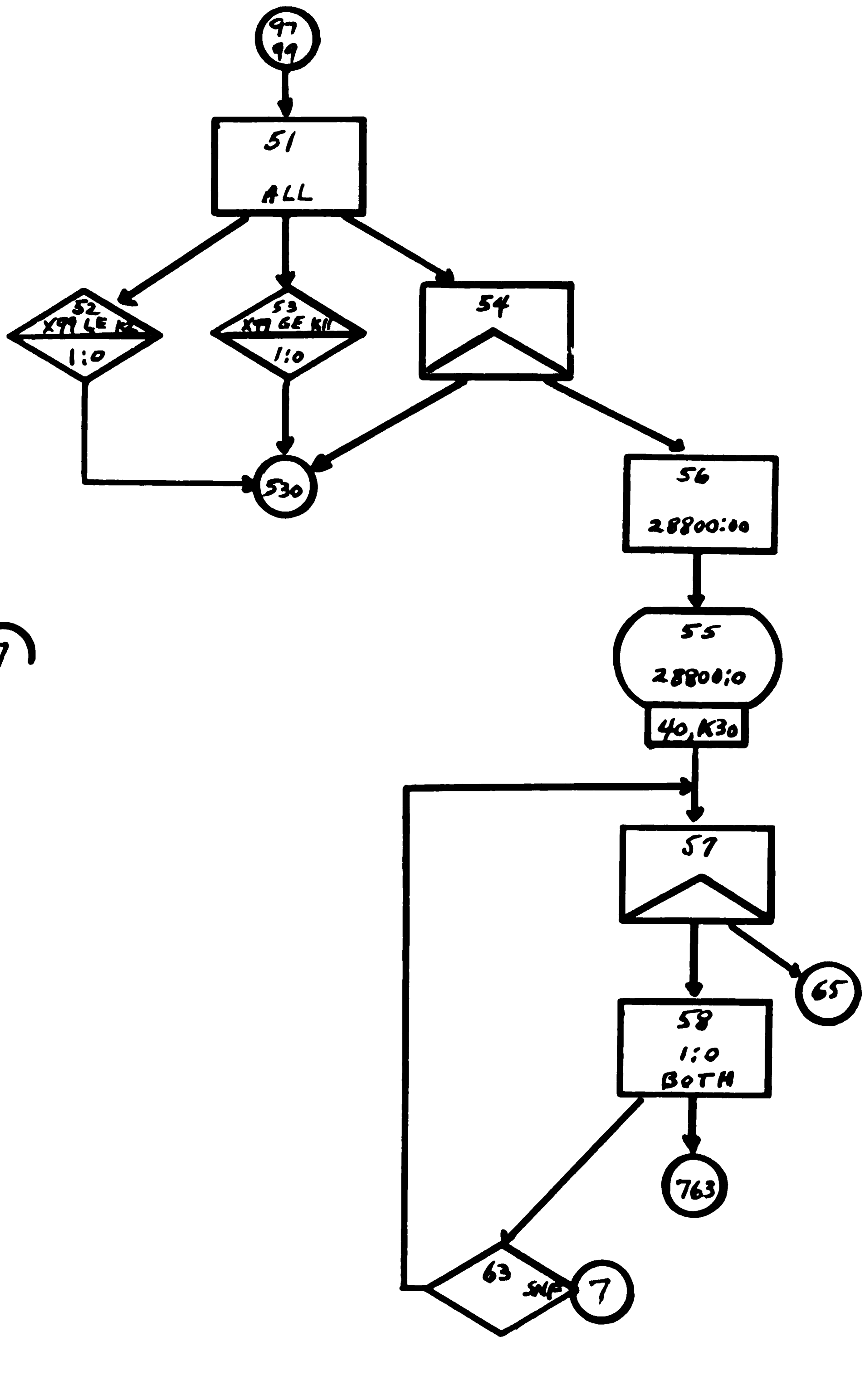


MASTER FILE UPDATE ROUTINE



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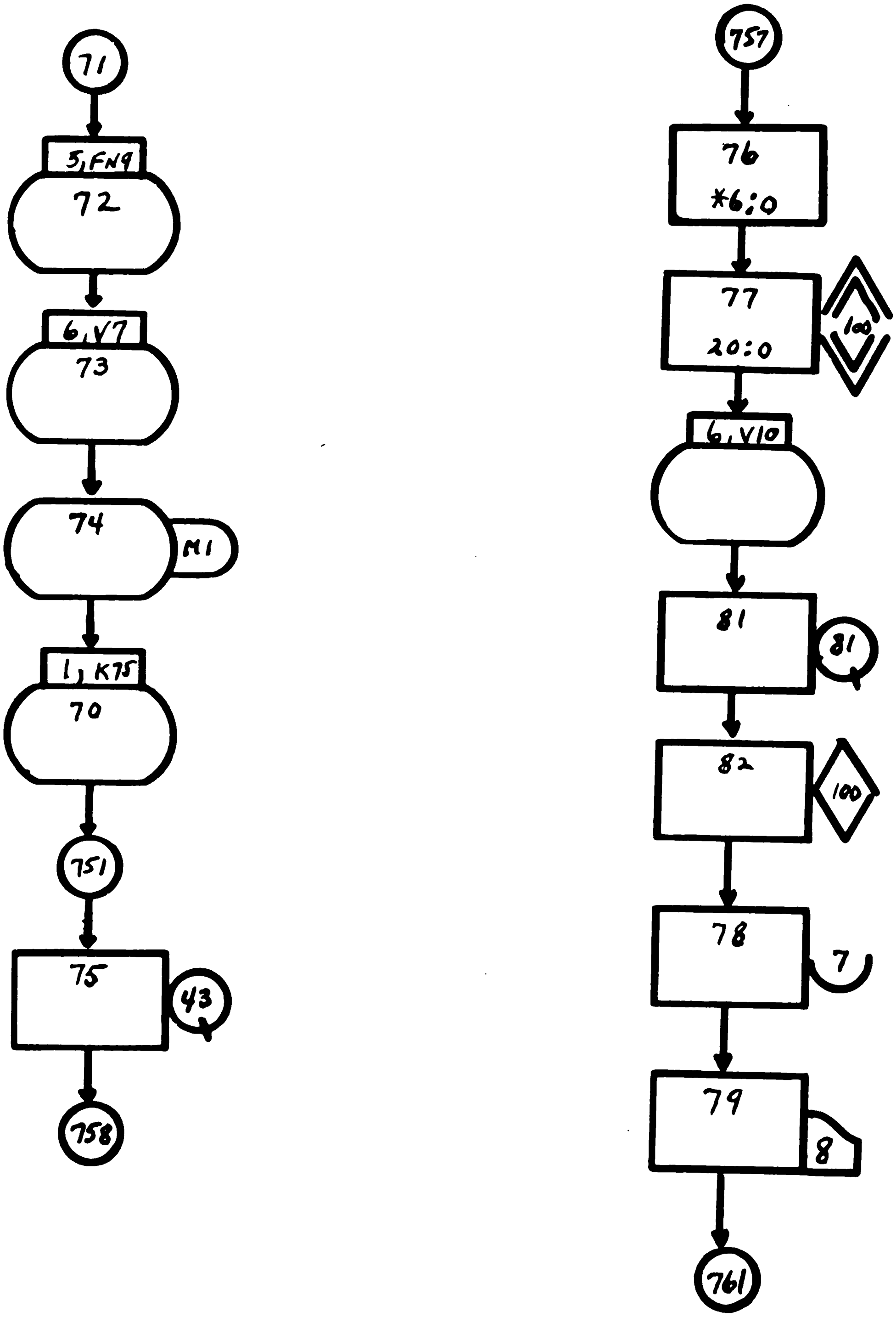
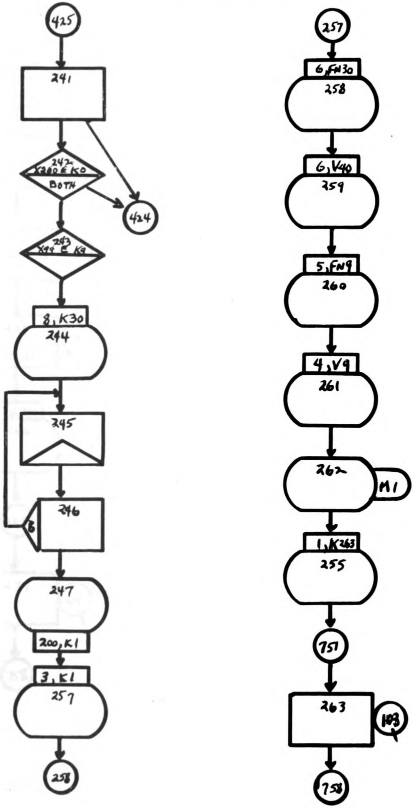


STUDENT SCHEDULING ROUTINE



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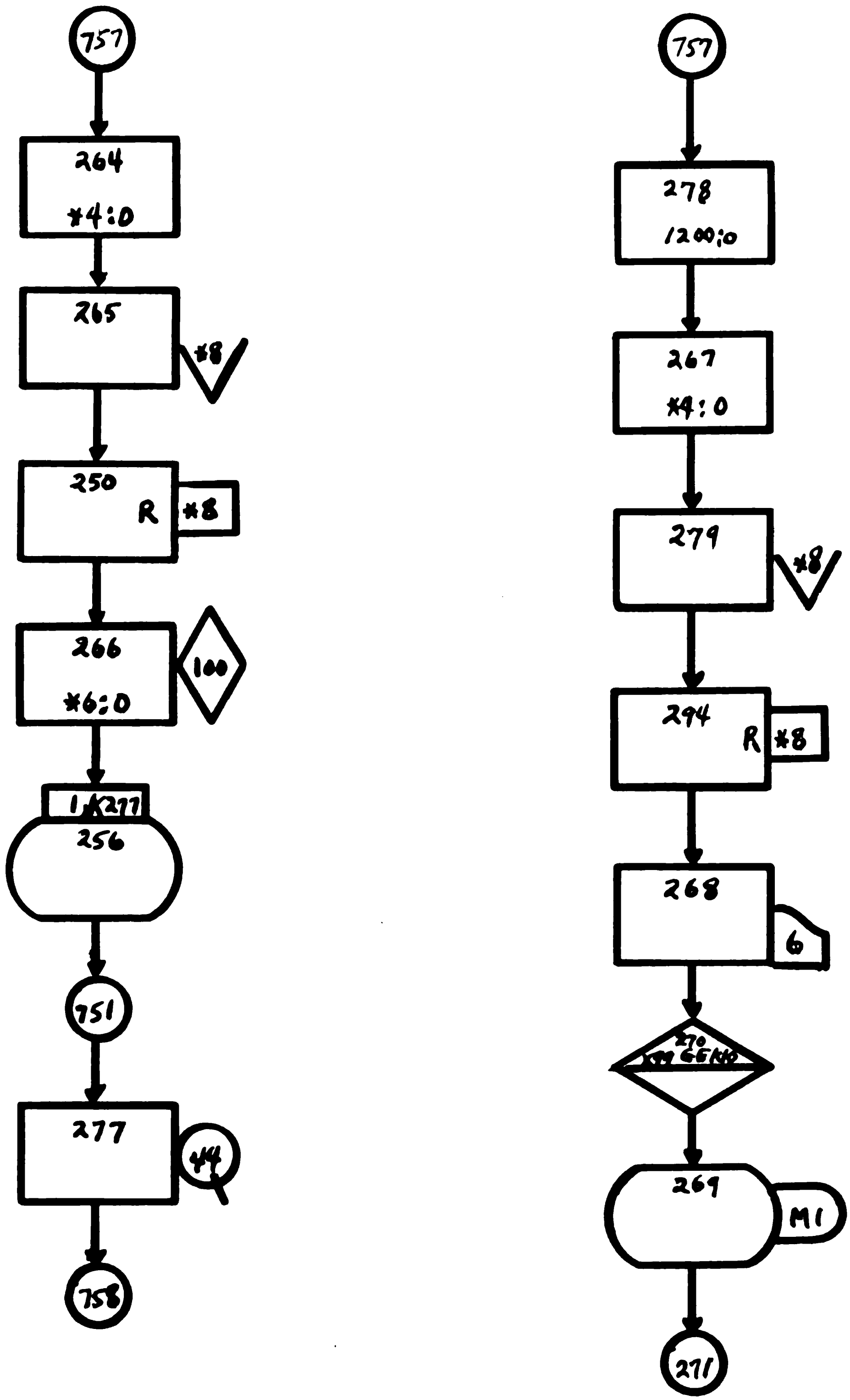

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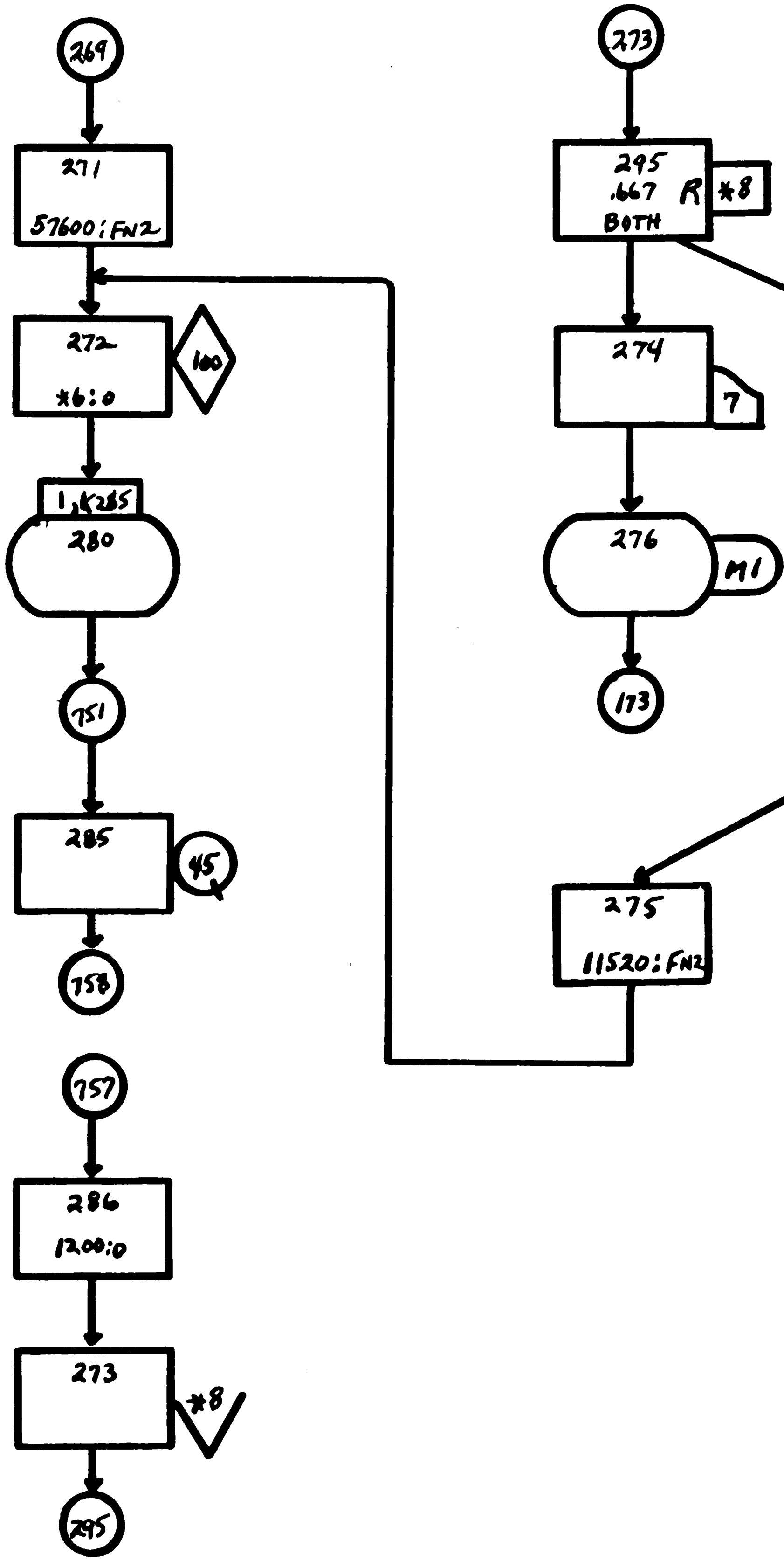
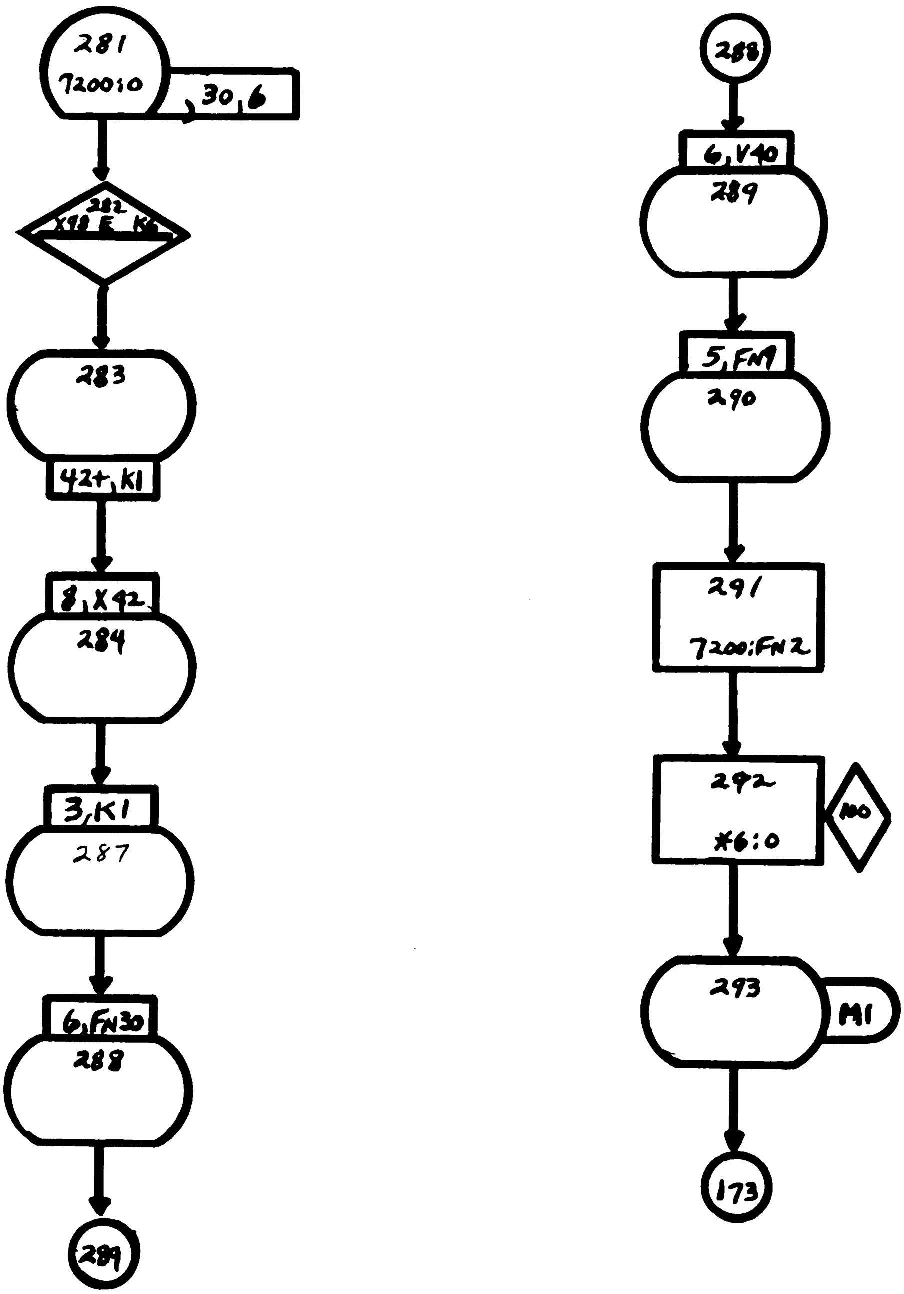
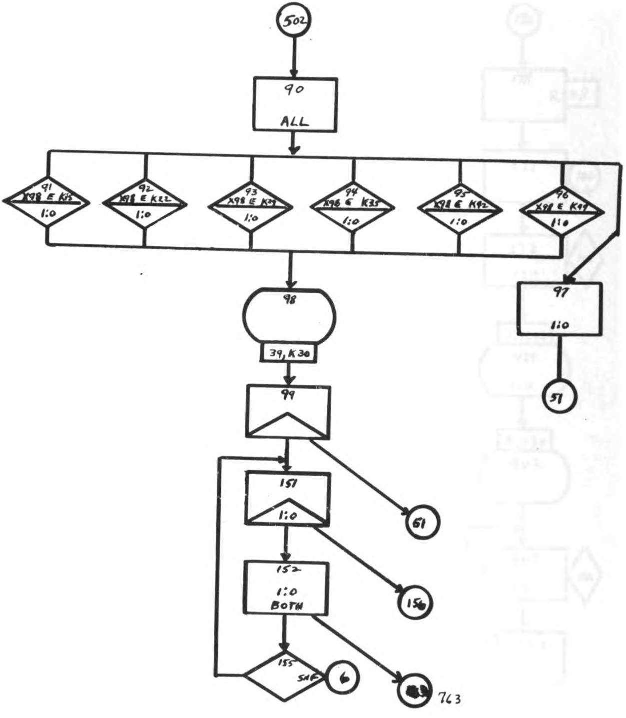


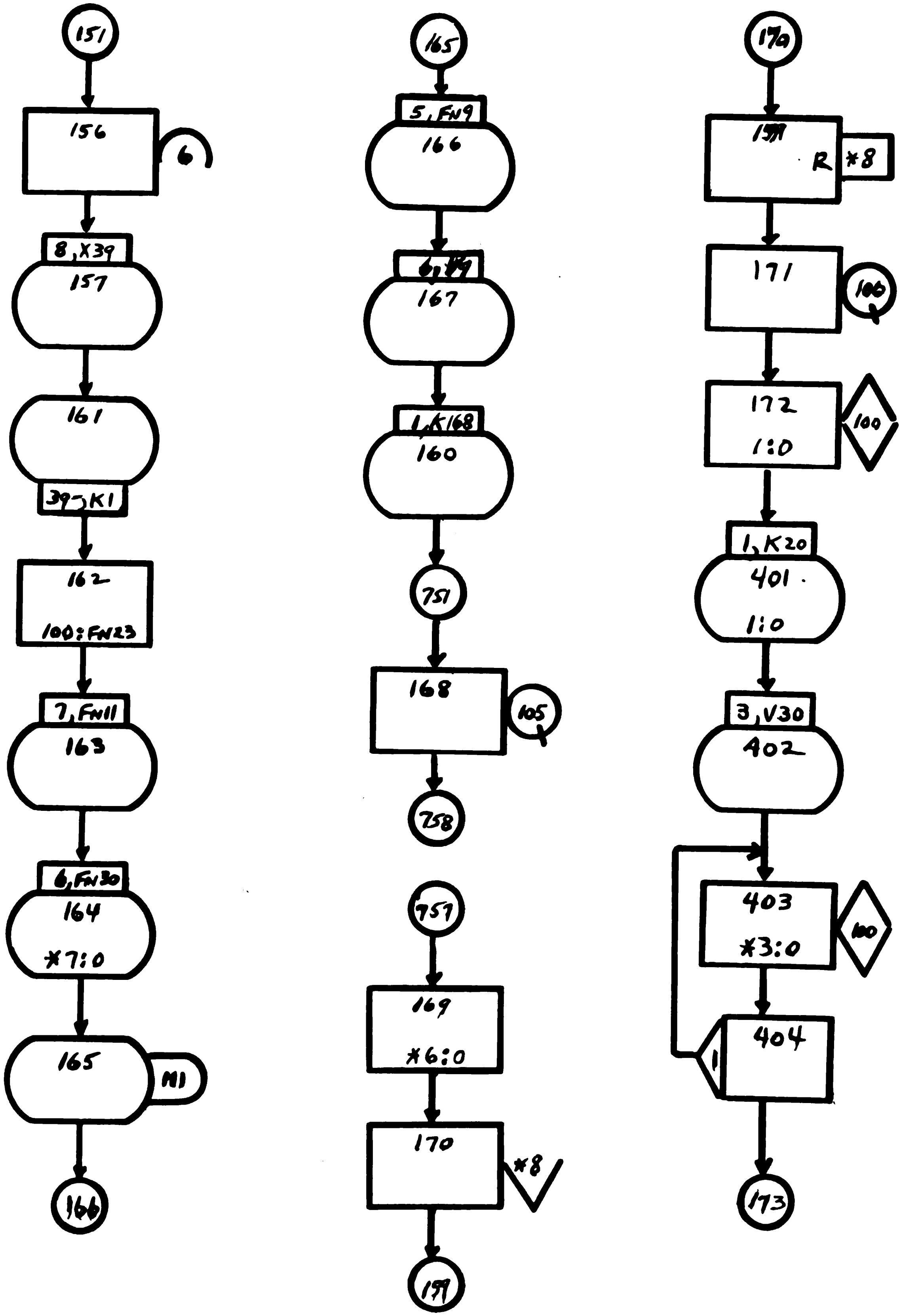
STUDENT SCHEDULING ROUTINE (continued)



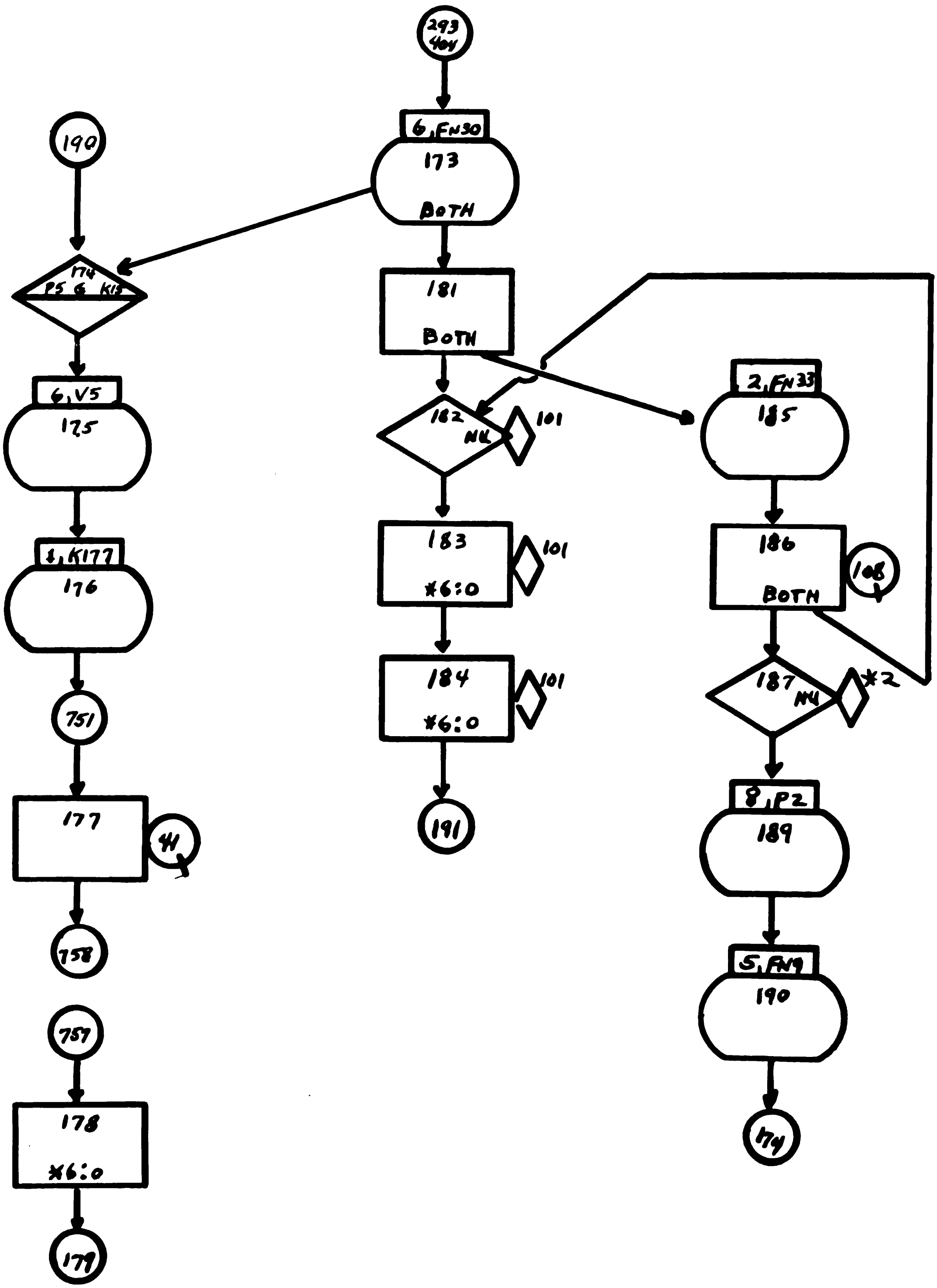
GRADE REPORTING ROUTINE



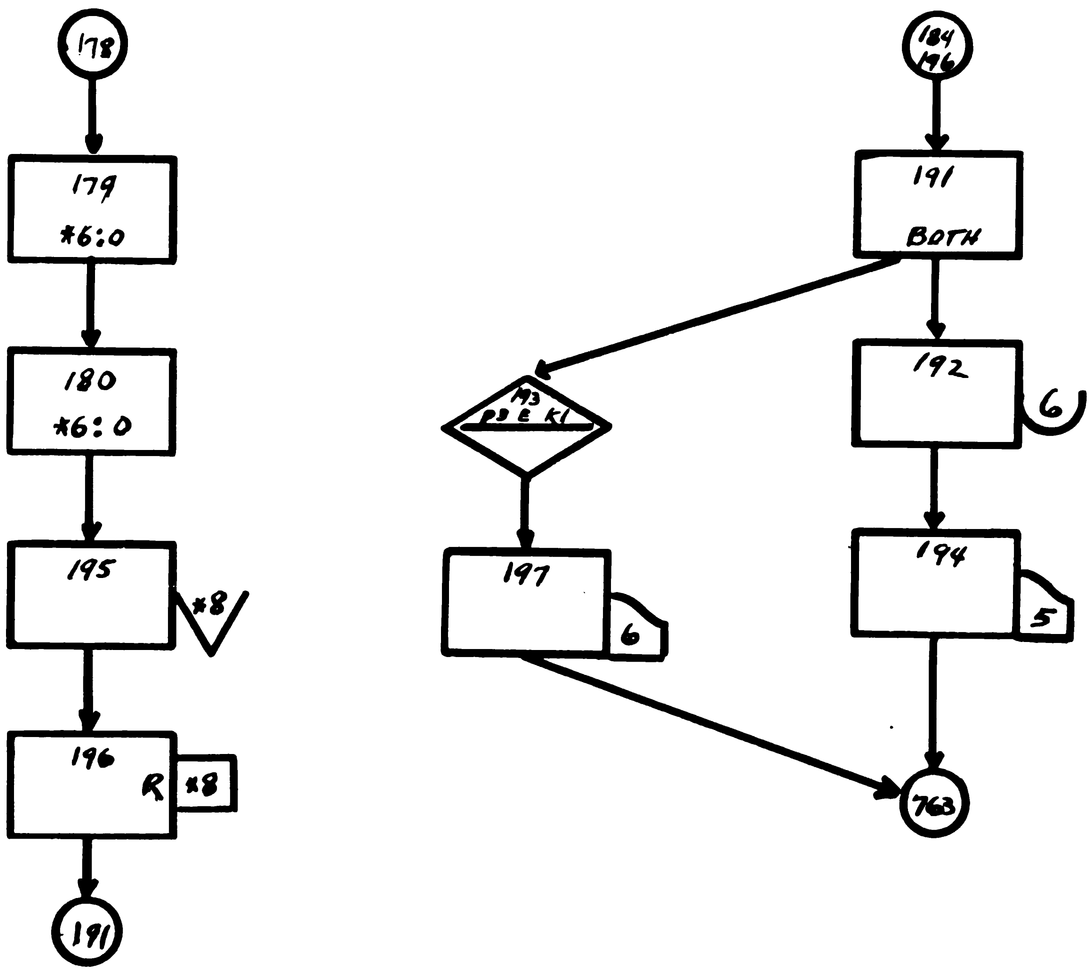
GRADE REPORTING ROUTINE (continued)



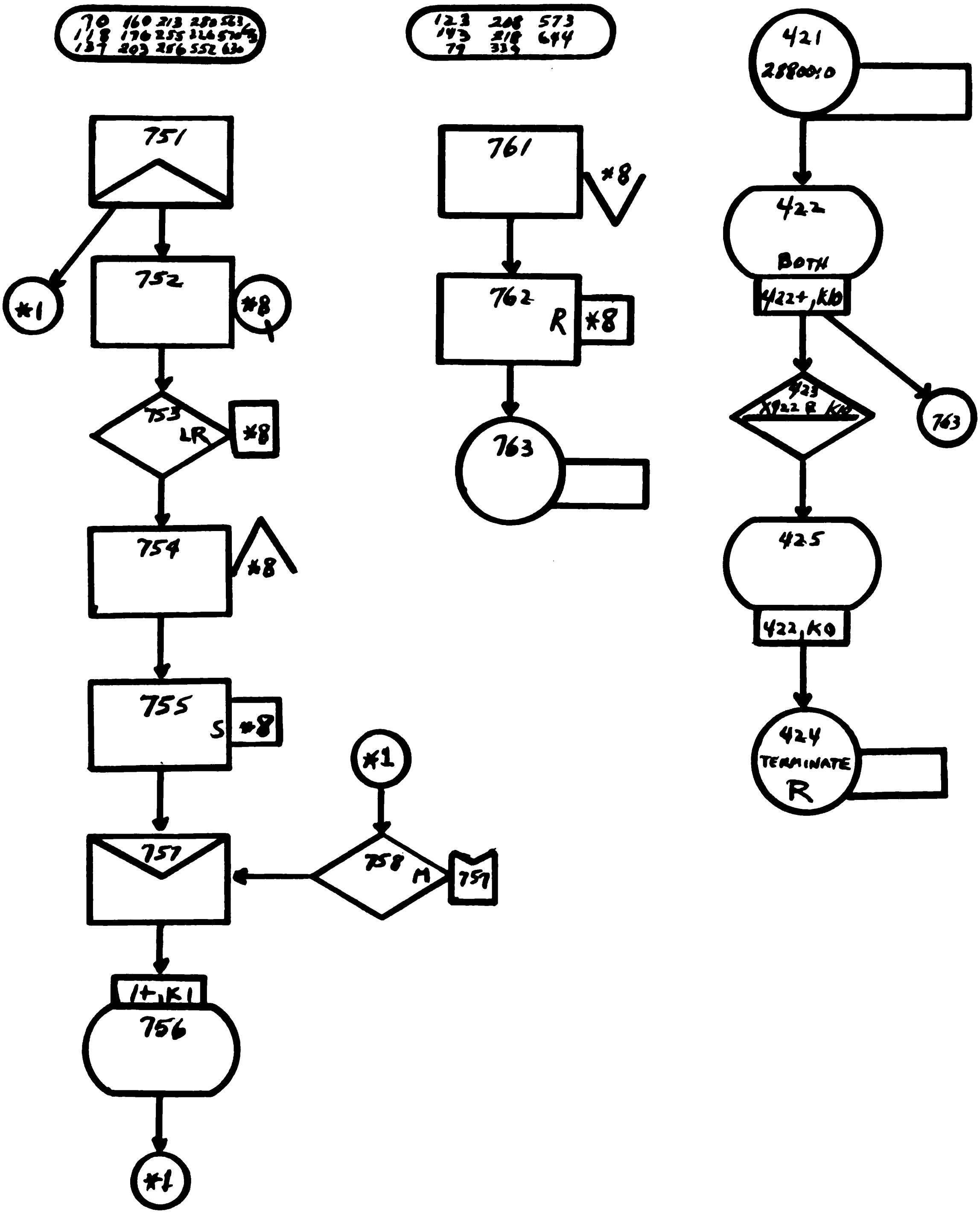
GRADE REPORTING ROUTINE (continued)



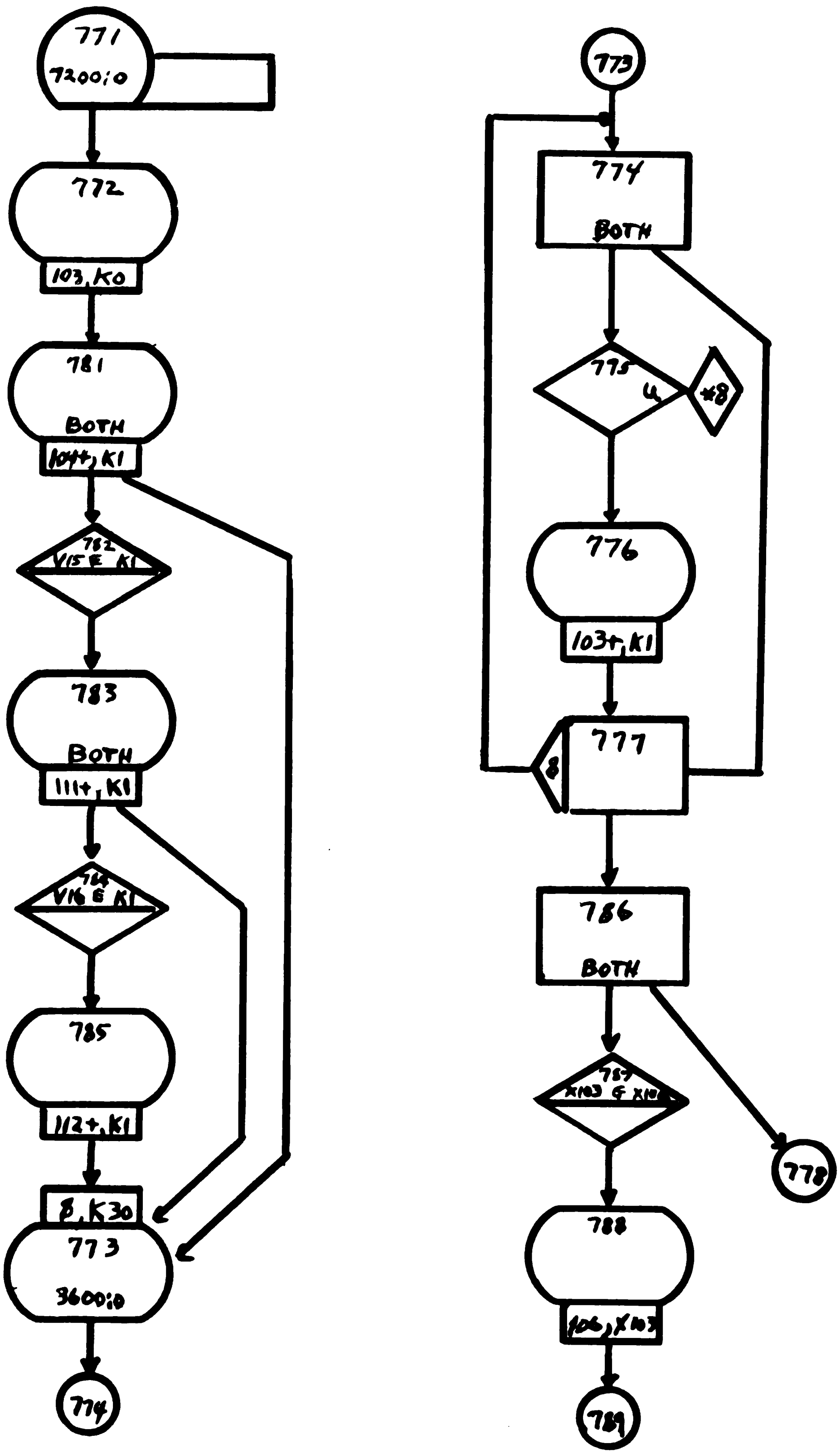
GRADE REPORTING ROUTINE (continued)



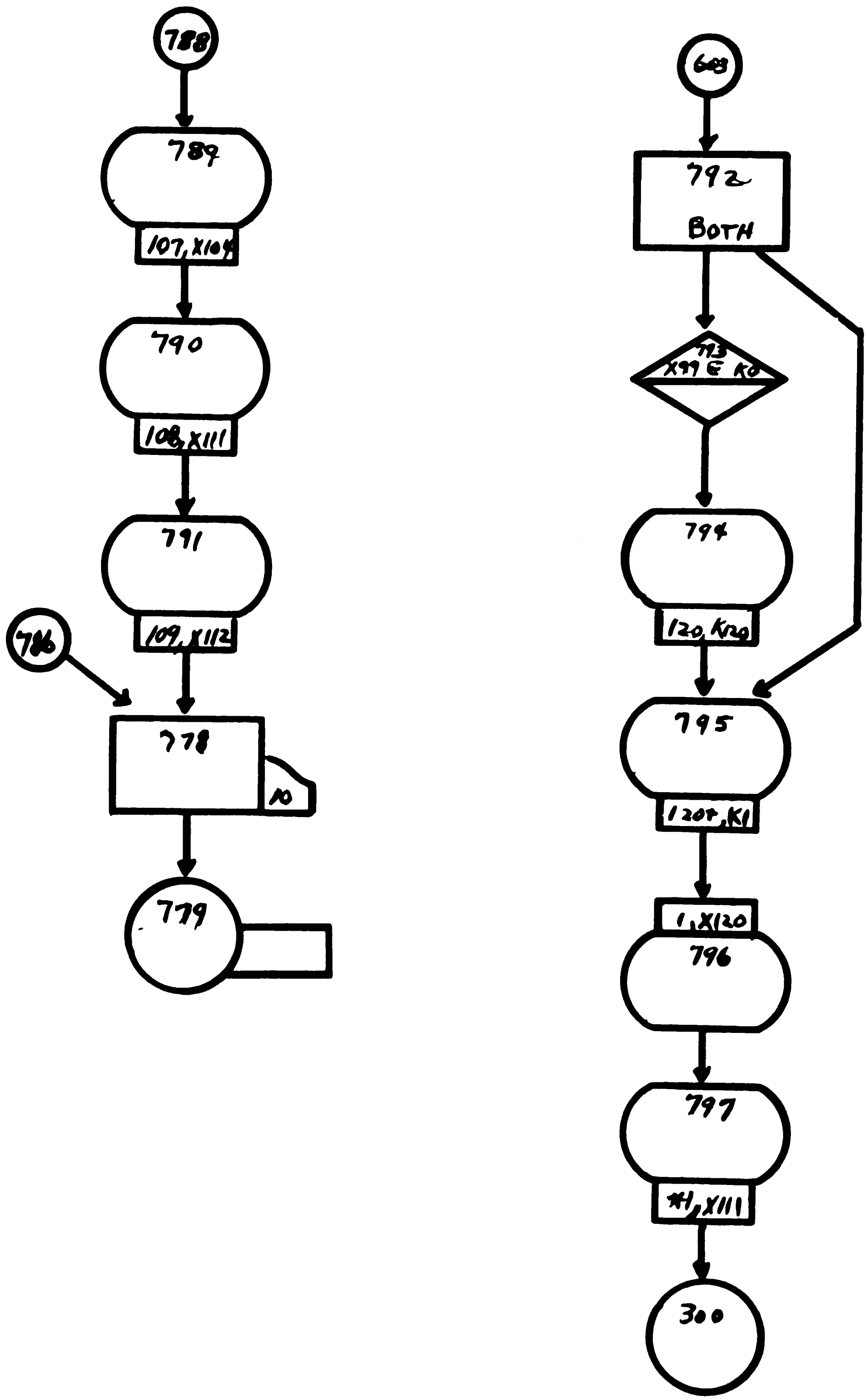
SUB-ROUTINES



TIMEKEEPING ROUTINE



TIMEKEEPING ROUTINE (continued)



APPENDIX B

THE COMPUTER PROGRAM

FOR

THE MATHEMATICAL MODEL:

A TELECOMMUNICATION NETWORK

FOR

DATA PROCESSING IN SCHOOLS

```
*      TITLE - PAGE OAKLAND SCHOOLS TELEPROCESSING NETWORK
*
*      PROGRAM - GENERAL PROGRAM SYSTEMS SIMULATOR II
*      1963 BY INT BUS MACH CORP.
*
*      PROGRAMMED BY REX WOOD, OAKLAND SCHOOLS, PONTIAC, MICHIGAN
*
*      TECHNICAL ASSISTANCE BY CHARLES HOOVER, IBM
*
*****************************************************************************************
*
*
*                         ABSTRACT OF THE PROGRAM
*
*            The table of contents enumerates several school business
*            office procedures and student accounting activities that many
*            school districts in Oakland County, Michigan now are systematically
*            processing on computers or other data processing hardware.  These
*            may be processed on the Oakland Schools Regional Center equipment,
*            locally owned or rented equipment, or through vendor facilities.
*
*                  Input data presently moves from local district to center
*            or vendor via mails, private auto, or common carrier.  The writer
*            attempts to describe an environment in which input data would
*            flow to a central computer over telephone lines, data would be
*            processed at the central computer and output data would be returned
*            via telephone lines to the local district.
*
*                  The task of defining the environment is that of equating
*            the volume of present paper work in these activities to an
*            environment in which local district personnel would present
*            a significant portion of this work to the computer for processing.
*            The system would be designed to reduce tedious repetive clerical
*            work, improve accounting procedures, provide management with
*            frequent management tools for decision making purposes, and
*            provide the educator with a significant research, programming
*            and scheduling tool.
```

The model is designed to be run or simulated for one year. This would be full cycle. Interaction of hourly, daily, weekly, bi-weekly, monthly, six week and annual activities would be observed. Of interest in the interaction is the loading on the facilities, when and how much queuing occurs, and if facilities can accomplish assigned work in reasonable periods of time.

Sensitivity of the model to different factors can be tested by reruns with these factors adjusted to other suitable values. What affect would a 20% increase in students and employees have on the operation of the model. This can be tested by one instruction change and rerun.

PROGRAM BRANCHES	BLOCK NUMBERS
1. Network communications	101-145
2. File inquiry - single question type	201-
File summary type	221
3. Purchasing	301-340
4. Payroll	501-578
5. Accounts Payable	601-646
6. Student master file maintenance	51- 81
7. Student scheduling Phase I	251-276
Student scheduling Phase II	281-292
8. Grade Reporting	90- 99
	151-199

```
*      Program Branches assembled to January 3, 1966 #1 through #8 census,
*      personnel records, cafeteria accounting, and many others to be
*      assembled at a later date.  The applications represent the mass data
*      flow for the applications to be developed initially meeting the
*      greatest needs of the near future.  Test scoring and reporting are
*      not included in the model as the input typically will flow through
*      an optical scanner currently not feasibly located at other than a
*      regional center.  Output from the testing routines would be printed
*      at center, sent out to terminal printers on second or third shift,
*      or sent out to terminals during times of low utilization during the
*      day shift.
*
*************************************************************************************
*
*      FUNCTION TABLE
*            No.   Purpose
*             2    Random selection of district number
*             6    Defines A/P volume using number of employees base
*             7    Defines P.O. volume using number of employees base
*             8
*             9    Terminal speed by district
*            10    Number of employees by district
*            11    Random clock starter 0-4.55 hour interval
*            12    Random pick of 14 terminals for processing payroll odd week
*            13    Random clock starter - 1 hour interval
*            14    Random clock starter 10 minute interval
*            15    Number of certified personnel
*            21    Identifies first day of the month
*            22    Picks first to sixth working day of the month
*            23    Random distribution of grade reporting routine
*            30    Number of secondary students
*            31    Defines a random length of messages for purchase orders
*                  dependent upon whether vendor, or item, or both are in file
*            32    Number of K-12 students
*            33    Assignment of fast terminal geographically
*            60    Random Distribution of number of line items per purchase
*                  order.  Range - 0 to 50 with a mean of 6.3
*
*************************************************************************************
```

```
*       STORAGE TABLE
*             No.   Purpose
*              1    Pools 14 payroll transactions weekly
*              2    Pools 30 accounts payable transactions monthly
*              3    Pools 30 transactions for daily network communications
*              4    Pools 30 transactions for daily purchase order batches
*              5    Stores up to 30 transactions for daily network communications
*              6    Stores 30 transactions at six week intervals for G.R.
*              7    Stores 30 transactions weekly for master file update batches
*
*******************************************************************************************
*
*       VARIABLE TABLE
*             No.   Purpose
*              1    Payroll messages %15 character.  With 10% overflow
*              2    Payroll messages in/out ratio - 1071
*              3    Payroll audit trail time
*              5    Calculates output time for grade reporting and student schedule
*              6    With V7 calculates input time for master file updating
*              7    Ditto
*              8    Calculates output time for G.R. and SS if printed at center
*              9    Calculates input time for grade reporting and scheduling
*             10    Divides enrollment by 40
*             12    Accounts payable input spread, and processing time
*             13    Accounts payable output time - 10 input time
*             15    Converts hour counter to days
*             16    Converts day counter to weeks
*             20    Converts transit time to minutes
*             30    Divides G.R. batch into 20 parts for CPU
*             40    Growth factor switch
*             41    Permits definition of one week.  N531/X10
*             42    Converts payroll process time from clock time units to minutes
*             43    Permits definition of one day
*             49    Used with X100 to seasonally adjust for purchase orders
*             50    Converts P.O. data to transmission time
*
*******************************************************************************************
```

```
*       QUEUE TABLE
*             No.   Purpose
*             1-30  Identified with district terminal
*              41   Grade reporting output - terminal wait
*              42   Accounts payable output - terminal wait
*              43   File Maintenance - terminal wait
*              44   Student scheduling matrix - terminal wait
*              45   Student scheduling throughput edit - terminal wait
*              51   Payroll batch arrives for processing
*              52   Payroll processed - wait time for output transaction
*              53   Accounts payable batch arrives
*              54   Accounts payable processed - wait for output
*              61   Purchase order routine, terminal wait
*              63   Accounts payable routine, central processor wait
*              81   File Maintenance - central processor wait
*             100   Network communications - 0830 terminal wait
*             101   Report inquiry
*             102   Single question inquiry
*             103   Accounts payable, terminal wait
*             104   Network communications, terminal wait
*             105   Grade reporting, terminal wait
*             106   Grade reporting, central processor wait
*             107   Student scheduling input, terminal wait
*             108   G.R. or SS output, waiting for geographic or central printer
*
**************************************************************************************
```

```
*     SAVEX LOCATIONS TABLE
*           No.   Purpose
*           1-30  Store payroll status of district
*            31   Counter for stepping through payroll initiator
*            32   Counter to save clock time Wednesdays at 9 A.M.
*            33   Counter for stepping through accounts payable initiation
*            34   Counter for identifying facilities for network communications
*            35   Counter for identifying facilities for purchase order routine
*            36   Counts daily network communication transactions
*            37   Hold random number assigned by function 2 (1-30)
*            39   Counter for identifying terminal for grade reporting
*            40   Counter for identifying terminal for master file updating
*            41   Counter for identifying terminal for student scheduling
*            98   Week Counter
*            99   Month Counter
*           100   Power factor for seasonal adjusting purchasing
*           101   Half day counter in payroll routine
*           102   Half day counter in communications routine
*           103   Counter for tabulating terminal status
*           104   Hour counter - total model
*           106   Count when facilities are busiest
*           107   Hour of busiest status - on the half hour
*           108   Day of busiest environment
*           109   Week of busiest environment
*           111   Day counter - total model
*           112   Week Counter - total model
*
***********************************************************************
```

```
*      LOGIC SWITCH TABLE
*            No.   Purpose
*            1-30  Identified with availibility of district terminal
*             58   Signals Wednesdays at 9 A.M.
*             59   Identifies odd or even week for payrolls
*             62   Signals start of month
*            101   Signals 8:30 A.M. daily
*            103   Signals Wednesdays of 15, 22, 29, 35, 42, and 49 weeks for G.R.
*            104   Signals months Sept. through April for master file updating
*
****************************************************************************************
*
*      TABLE OF TABLES
*            No.   Purpose
*             1    Tabulates transit time of payrolls in 15 minute intervals
*                  an 8 hour day
*             2    Tabulates total payroll job time for 14 districts from
*                  signal in A.M. to completion in P.M. or A.M. of next day
*             3    Tabulates transit time of accounts payable in 10 minute
*                  intervals over a 4 hour span
*             4    Tabulates transit time of each daily P.O. routine in 5
*                  minute intervals over an hour day
*             5    Tabulate grade reporting output time, half hour intervals
*             6    Tabulate student schedule input time, 15 minute intervals
*             7    Tabulate SS throughput time, 5 minute intervals
*             8    Tabulate master file update time, 5 minute intervals
*             9    Tabulate G.R. and SS output time on center printer, 10 minutes
*            10    Tabulate the status of terminals hourly
*
****************************************************************************************
```

```
*       CLOCK TIME UNITS EQUIVALENCE TABLE
*
*             1/2 second #          1 time unit
*               1 second #          2 time units
*               1 minute #        120 time units
*                 1 hour #      7,200 time units
*             8 hour day #     57,600 time units
*           40 hour week #    288,000 time units
*           52 week year # 14,976,000 time units
*
****************************************************************************************
*
*
*       TABLES, CAPACITIES, FUNCTIONS, VARIABLES
*
****************************************************************************************
*
*
*       TABLES
*
*             The function of tables and queue tables is to format the output of
*             the simulation run.  See index above for table descriptions
*
****************************************************************************************
```

*

1	Table	V20	0	15	32
2	Table	X32	3	15	32
3	Table	V20	0	10	32
4	Table	V20	0	5	32
5	Table	V20	0	30	32
6	Table	V20	0	15	32
7	Table	V20	0	5	32
8	Table	V20	0	5	32
9	Table	V20	0	10	32
10	Table	X103	1	1	28
11	Table	51	0	600	12
12	Table	52	0	600	12
13	Table	53	0	600	12
14	Table	54	0	600	12
15	Table	61	0	600	12
16	Table	62	0	600	12
17	Table	101	0	600	12
18	Table	102	0	600	12
19	Table	104	0	600	12
20	Table	105	0	600	12
21	Table	106	0	600	12
22	Table	107	0	600	12
23	Table	108	0	600	12
41	Table	41	0	600	12
42	Table	42	0	600	12
43	Table	43	0	600	12
44	Table	44	0	600	12
45	Table	45	0	600	12
81	Table	81	0	600	12

*

****

```
*       CAPACITIES
*
*
*             Capacities are used to store batches awaiting departure time into
*             the system as controlled by the program.
*
***********************************************************************************
*
  1     Capacity    14     Storage space for the 14 payroll batch transactions
  2     Capacity    30     Storage for 30 A/P batches.
  3     Capacity    30     Storage for network communications
  4     Capacity    30     Storage for 30 P.O. batches
  5     Capacity    30     Storage for intermittent network communication
  6     Capacity    30     Storage for grade reporting batches
  7     Capacity    30     Student master file maintenance batches
*
***********************************************************************************
*
*
*       FUNCTIONS
*
*             Functions are tables of paired numbers, X and Y, X being an
*             independent variable and Y being a dependent variable.  Examples
*             of use are: FN11 establishes departure times of various batches
*             (units of traffic) from terminals after a given point in time,
*             say, 0830 A.M. of a given day.  The function is continuous and
*             Y may take any value from 1 to 32768, 2 to the 15th power.
*             Another function example is: FN10 which records the number of
*             employees in each district.  This is actual data.  The function
*             is discrete and when referenced, an exact number is determined
*             for Y, i.e., the number of employees for that district.
*
***********************************************************************************
```

```
*
 2      Function    RN1   C3
 0      1     .967  30    .999  30
*       This function is used to randomly pick a district (terminal)
*
********************************************************************************
*
 6      Function    P6    C8
 0      1     100   200   550   208   1000  537   1160  504   1300  750
 1800   1000  2500  1500
*       Function 6 relates the A/P volume to the number of employees
*
********************************************************************************
*
 7      Function    P6    C8
 0      1     100   9     550   10    1000  30    1160  24    1300  26
 1800   33    2500  50
*       Independent variable is the number of employees
*       Dependent variable is the estimated number of P.O.'s in the daily batch
*       from a district of this size
*
********************************************************************************
*
 9      Function    P8    D30         Table of terminal speeds
 1      15    2     15    3     300   4     15    5     15    6     15
 7      15    8     15    9     15    10    150   11    15    12    15
 13     15    14    15    15    15    16    15    17    15    18    15
 19     15    20    15    21    15    22    15    23    300   24    15
 25     150   26    300   27    15    28    150   29    150   30    15
*
********************************************************************************
```

```
*
10      Function     P8   D30        Assignment of No. of employees
1       208    2     558  3    1231  4    561  5    88   6    280
7       331    8     287  9    0     10   955  11   540  12   0
13      522    14    181  15   279   16   273  17   367  18   158
19      296    20    67   21   678   22   137  23   1547 24   539
25      1333   26    1134 27   274   28   566  29   1105 30   161
*
***************************************************************************
*
11      Function     RN1  C4         Random clock starter 4.5 hour interval
0       1      .5    7200 .75  18000 .999 32768
*
***************************************************************************
*
12      Function     RN1  D2         Random pick of 14 terminals
.500    0      1.0   1
*
***************************************************************************
*
13      Function     RN1  C2         Random clock starter 1 hour
0       0      1.0   7200
*
***************************************************************************
*
14      Function     RN1  C2         Random clock starter 10 minute interval
0       0      1.0   1200
*
***************************************************************************
```

```
*
 15     Function      P8    D30          No. of certificated personnel
 1      142     2     428   3     834    4     339   5     61    6     180
 7      192     8     192   9     28     10    600   11    386   12    0
 13     349     14    116   15    211    16    167   17    230   18    103
 19     223     20    40    21    414    22    82    23    1037  24    280
 25     846     26    675   27    202    28    350   29    705   30    114
*
*****************************************************************************
*
 21     Function      RN1   D4           Identifies 1st. working day of month
 .083   11520 .417  12096 .750  12672 .999  13248
*
*****************************************************************************
*
 22     Function      RN1   D6
 .166   36      .333  612   .500  1188   .667  1764  .833  2340  .999  2916
*
*****************************************************************************
*
 23     Function      RN1   D5           Distributes grade reporting over 1 week
 .143   0       .429  576   .571  1152   .857  1728  .999  2304
*
*****************************************************************************
*
 30     Function      P8    D30          No. of secondary students
 1      1467    2     4098  3     7132   4     3047  5     635   6     1302
 7      2046    8     1704  9     0      10    5404  11    3691  12    0
 13     3328    14    1173  15    2073   16    1734  17    1563  18    914
 19     1713    20    272   21    3122   22    903   23    8864  24    2807
 25     8546    26    5506  27    1894   28    3569  29    6504  30    1114
*
*****************************************************************************
```

```
*
 31    Function     RN1  D5
 .765  30    .885   90   .920  150   .984  90    .999  150
*      The dependent variable is the message length of a given purchase order
*
*************************************************************************************
*
 32    Function     P8   D30         No. of students in K-12
 1     3478  2      8944 3     16110 4     6821  5     1498  6     3815
 7     5349  8      4519 9     0     10    13430 11    8248  12    0
 13    8124  14     2838 15    5427  16    4384  17    5431  18    2361
 19    4931  20     942  21    7153  22    2170  23    23278 24    6459
 25    20069 26     12865 27   4495  28    8033  29    16413 30    2642
*
*************************************************************************************
*
 33    Function     P8   D30         Assign fast terminals geographically
 1     23    2      26   3     3     4     3     5     29    6     10
 7     29    8      3    9     28    10    10    11    26    12    10
 13    25    14     29   15    28    16    23    17    25    18    28
 19    25    20     10   21    26    22    29    23    23    24    23
 25    25    26     26   27    3     28    28    29    29    30    28
*
*************************************************************************************
*
 60    Function     RN1  C7
 0     1     .400   1    .600  2     .800  5     .900  10    .950  20
 .999  50
*      Probability distribution of line items per purchase order
*
*************************************************************************************
```

```
*
*
*        VARIABLES
*
*              Variables are computational formula for converting known values
*              or environmental data to computed transit times, to modify the
*              environment, or to test the environment for decisions making, etc.
*
***************************************************************************************
*
 1    Variable   P6*K66/P5              No. of messages with 10% allowance
 2    Variable   K10*V1                 Output to input messages in 10/1 ratio
 3    Variable   K1500/P5               Calculate audit trail time
 5    Variable   P6*K400/P5             Calculates output time for G.R. and
                                        scheduling
 6    Variable   FN32*K4/K40            V6 and V7 calculates input time
 7    Variable   P6*K15/P5              For master file updating
 8    Variable   P6/K4                  Calculates output time G.R. and SS at center
 9    Variable   P6*K90/P5              Calculates input time for G.R and SS
10    Variable   FN32/K40               Divides enrollment of district by 40
12    Variable   P2/K10
13    Variable   P2*K10
15    Variable   X104%K8                Converts hours to days
16    Variable   X111%K5                Converts days to weeks
20    Variable   M1/K120                Converts Transit time to minutes
30    Variable   FN30/K20               Divides G.R. input by 20 for CPU
37    Variable   FN60
38    Variable   FN31*V37&K150&V37*K60
39    Variable   C1-X32
40    Variable   P6*K100/K100           Provides for growth factor
41    Variable   X101%K10
42    Variable   V39/K120
43    Variable   X102%K2                See 104, discards 1/2 transactions at B102
49    Variable   P2*K12/K20*X100
*
***************************************************************************************
```

```
*
*
*                 X100 contains 4 in June and July
*                               2 in May and August
*                               1 otherwise
*                 V49 - Seasonal adjustment of purchasing
 50    Variable   V38/P5
*                 FN31 distributes the probability of a line item
*                 purchase being in the file catalog and from a
*                 vendor in the file, both, either, neither, as follows:
*                 76.5%, 18.4%, and 5.1%
*                 FN60 assigns randomly a given number of line items
*                 to a purchase order.  The range of line items is
*                 1 to 50 with an average of 6.3
*                 K150 allocates 10-15 character messages of
*                 output for P.O. header information.  K60 allows
*                 4-15 character messages for each line item of
*                 output.
*                 P5 - Rate of transmission for given terminal
*                 V50 - Data length/speed - terminal time per P.O.
*
***********************************************************************************************
```

```
*           NETWORK COMMUNICATIONS
*       This phase reserves the time 830-840
*       each morning for network communications
*
************************************************************************************
*
*       NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
 101    Originate   1                       102         28800
 102    Savex       102&  K1          both  104   763
 104    Compare     V43   E     K1          105
 105    Savex       34    K30               103
 103    Savex       35    K30               107
 107    Split                               111   115
 111    Advance                       both  114   313   1
 114    Gate        SNF3                    107
*       Signal sent to purchase order routine to initiate daily activity there.
 115    Enter       3                       116
 116    Assign      8     X34               117
 117    Savex       34-   K1                118
 118    Assign      1     K119              751
*       Returned from split at 751
 119    Queue       100                     758
*       Returned from assembly at 757
 120    Advance                             123         1200  0
 123    Leave       3                       761
*       Sent to 761 for release of terminal, reset of logic switch and termination
*       Daily initiator routine returned from 316 - P.O. routine
 109    Interrupt   100                     763         1200  0
*       Sent to 763 for termination
*
************************************************************************************
```

```
*           Continuation of the communications network routine.
*           This phase generates a variable number of districts to receive
*           communications for an average of eight times daily.  Within each
*           block of time (one hour plus or minus one half hour) an average
*           of 15 districts will receive one message.  The network will process
*           120 messages daily, averaging 4 per district.
*           Cost in time - CPU-10 minutes daily.  Each terminal 8 minutes daily.
*
*****************************************************************************
*
*      NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
 125   Originate   1           6           126         7200  3600
 126   Assign      1     FN2               127
 127   Split                               128   133
 128   Loop        1                       127   763   1
 133   Enter       5                       134
 134   Assign      8     FN2               137
 137   Assign      1     K138              751
*      Returned from split at 751
 138   Queue       104                     758
*      Returned from assembly at 757
 139   Advance                             140         240   120
 140   Interrupt   100                     142         10
 142   Leave       5                       143
 143   Savex       36    KO                761
*      Sent to 761 for release of terminal, reset of logic switch and termination
*
*****************************************************************************
*
*      End of network communications routine
*
*****************************************************************************
```

```
*      Report inquiry - this phase assumes that an average of 1 report
*      will be requested daily from a district file in mass storage at the
*      center.  Each report will consume 0-1 minute of central processor time
*      and 5-15 minutes of terminal time.
*
*****************************************************************************
*
*      NAME       X     Y     Z     SEL   NBA   NBB   Mean time and module
 201   Generate               6           202         1920  1920  1 each 16
 202   Assign     8     FN2               203
 203   Assign     1     K205              751
*      Returned from split at 751
 205   Queue      101                     758
*      Returned from assembly at 757
 206   Advance                            208         1200  600
 208   Interrupt  100                     761         60    60
*      Sent to 761 for release of terminal, reset of logic switch and termination
*
*****************************************************************************
*
*
*      Single question inquiry - this phase assumes that each terminal will
*      request from 0-10 single question type file inquiries per day from
*      the center stored district files.  Each report will consume 2.5-7.5
*      seconds of central processor time and 2 minutes of terminal time.
*
*****************************************************************************
```

```
*
*       NAME         X      Y       Z      SEL    NBA    NBB    Mean time and module
 211    Generate                    6             212           384    384   1 each 3.23
 212    Assign       8      FN2                   213                        pick terminal
 213    Assign       1      K215                  751
*       Returned from split at 751
 215    Queue        102
*       Returned from assembly at 757
 216    Advance                                   218           240    0
 218    Interrupt    100                          761           10     0
*       Sent to 761 for release of terminal, reset of logic switch and termination
*       End of report inquiry routines
*
*************************************************************************************
*
*
*       This phase batches purchase orders at local district offices daily
*       and routes to the center for processing.  Located at the center are
*       direct access files of vendors and stock catalog items.  Also
*       encumbrance files by district that will be updated by this routine
*       for further reference later at receiving and at accounts payable time.
*
*************************************************************************************
*
*       From 603, the routine that generates the first day of a month.
*       The following blocks place a weighting factor in savex 100 for
*       seasonal adjustment of line items per purchase order.  August and
*       May have a weighting of 2, June and July have a weighting of 4,
*       all others have a weighting of 1.
*
*************************************************************************************
```

```
*
*       NAME        X      Y      Z      SEL    NBA    NBB    Mean time and module
 300    Savex       99     K1                   604
 604    Advance                          all    301    305
 301    Compare     X99    E      K1            308                  July
 302    Compare     X99    E      K2            307                  August
 303    Compare     X99    E      K11           307                  May
 304    Compare     X99    E      K12           308                  June
 305    Savex       100    K1                   611
 307    Savex       100    K2                   611
 308    Savex       100    K4                   611
 313    Split                                   314    318
 314    Advance                          both   315    109    1
 315    Gate        SNF4                        313
 318    Enter       4                           319
 319    Assign      8      X35                  331
 331    Savex       35-    K1                   320
 320    Assign      7      FN11                 321
 321    Assign      6      FN10                 322
 322    Advance                                 323           *7
 323    Mark                                    326
 326    Assign      1      K324                 751
*       Returned from split at 751
 324    Queue       61                          758
*       Returned from assembly at 757
*
*************************************************************************************
```

```
*
*      NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
 325   Interrupt   100                     328         10    5
 328   Assign      5     FN9               329
 329   Assign      3     FN7               330
 330   Assign      2     V50               333
 333   Assign      2     V49               334
 334   Advance                             335         *2    *2
 335   Interrupt   100                     336         10    5
 336   Loop        3                       330   338
 338   Leave       4                       339
 339   Tabulate    4                       761
*      Sent to 761 for release of terminal, reset of logic switch and termination
*
****************************************************************************
*
*
*      End of purchase order routine.
*
****************************************************************************
*
*
*            Payroll initiator routine
*                  Generate a signal to begin processing of 14 payroll-
*                  jobs and set-up to identify the 14 jobs with a
*                  unique school district number selected on a random basis.
*
****************************************************************************
```

```
*
*    NAME       X      Y     Z    SEL   NBA  NBB  Mean time and module
 501 Originate  122400       6          531       28800
 531 Savex      101&   K1         both  543  763
 543 Compare    V41    E     K1   both  518  503
 503 Assign     1      K30              504
 504 Savex      *1     K0               505
 505 Loop       1                       504  506
 506 Assign     2      K14              507
 507 Assign     1      K30              508
 508 Advance                      both  509  517
 509 Compare    X*1    E     K0         510
 510 Advance                      all   511  513
 511 Compare    P1     E     K9         517
 512 Compare    P1     E     K12        517
 513 Assign     3      FN12       both  514  515
 514 Compare    P3     E     K0         517
 515 Savex      *1     P1               516
 516 Loop       2                       517  527
 517 Loop       1                       508  507
*
*************************************************************************************
*
*    Above logic takes care of odd numbered weeks
*    Logic below takes care of even numbered weeks
*
*************************************************************************************
```

```
*
*       NAME        X      Y     Z      SEL   NBA   NBB   Mean time and module
 518    Gate        LS59                      519
 519    Assign      1      K30                520
 520    Advance                         both  521   525
 521    Compare     X*1    E     KO     all   522   524
 522    Compare     P1     E     K9           526
 523    Compare     P1     E     K12          526
 524    Savex       *1     P1                 526
 525    Savex       *1     KO                 526
 526    Loop        1                         520   527
*
*****************************************************************************************
*
*           30 Savex positions now contain districts that will be processed
*           during the even week.  Every district will be processed bi-weekly
*           but not regularly on the even or odd week.
*
*****************************************************************************************
```

```
*
*      NAME       X      Y     Z     SEL   NBA   NBB   Mean time and module
 527   Logic      159                      528                       switch
 528   Savex      31     K30               529
 529   Savex      32     C1                585                       clock time
 585   Savex      98&    K1                502
 502   Logic      S58                      90
 530   Split                               533   538
 533   Advance                       both  537   763   1
 537   Gate       SNF1                     530
*
*****************************************************************************
*
*          End of set up routine
*
*****************************************************************************
*
*                Assign Parameters      School district   P8
*                                       Start time        P7
*                                       Volume            P6
*                                       Terminal type     P5
*
*****************************************************************************
```

```
*
*       NAME        X     Y      Z     SEL   NBA   NBB   Mean time and module
 538    Enter       1                        539
 539    Assign      1     X31                540
 540    Advance                        both  541   544
 541    Compare     X*1   E      KO          542
 542    Loop        1                        540   763
 544    Assign      8     X*1                545
 545    Savex       31    X*1                546
 546    Savex       31-   K1                 547
 547    Assign      7     FN11               549
 549    Assign      6     FN10               550
 550    Assign      6     V40                551
 551    Assign      5     FN9                548
*
*****************************************************************************************
*
*             End of parameter assignment
*                   Begin actual work flow when parameter 7
*                   equals simulator clock time.
*
*****************************************************************************************
```

```
*
*       NAME          X      Y      Z      SEL    NBA    NBB    Mean time and module
 548    Advance                                   567           *7
 567    Mark                                      552
*       Transactions continue from 567 or return from 576
 552    Assign        1      K553                 751
*       Returned from split at 751
 553    Queue         51                          758
*       Returned from assembly at 757
 554    Interrupt     100                         555           10
 555    Assign        4      V1                   577           *4
 577    Advance                                   556           10
 556    Release       *8                          559
 559    Logic         R*8                         557
 557    Queue         52                          558
 558    Hold          100                         561           *6
 561    Assign        4      V3                   570
 570    Assign        1      K580                 751
*       Returned from split at 751
 580    Queue         53                          758                         is terminal
*       Returned from assembly at 757
 581    Advance                                   582           *4     0
 582    Release       *8                          583
 583    Logic         R*8                         560
 560    Advance                            .100   562    566    1      FN14  10 0/0
 562    Assign        4      V2                   563                         output
 563    Assign        1      K574                 751
*       Returned from split at 751
 574    Queue         54                          758                         is terminal
*       Returned from assembly at 757
*
*************************************************************************************
```

```
*
*       NAME         X     Y     Z     SEL   NBA   NBB   Mean time and module
 575    Advance                              564         *4    0
 564    Leave        1                       565
 565    Tabulate     1                 both  571   761               tab trans
 571    Gate         SE1                     572                     last one
 572    Savex        32    V42               573                     calculate
*       Sent to 761 for release of terminal, reset of logic switch and termination
 573    Tabulate     2                       761                     all time
 566    Assign       7     FN13              576                     restart
 576    Advance                              552         *7    0
*
************************************************************************************
*
*       End of payroll routine
*
************************************************************************************
*
*
*             Accounts payable start
*       This phase turns on signal to denote first working day of the month
*       according to distribution of actual calendar.  1-20 day month, 4-21
*       day months, 4-22 day months and 3-23 day months in a year.  Function 21
*       identifies the first day of the month.
*
************************************************************************************
```

```
*
*     NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
 601  Originate   1           5           602         100   FN21
 602  Savex       33    K30               792
*     First 6 working days of the month.  Logic switch 62 has been set
*     by blocks 601-3
 611  Split                               613   617
 613  Advance                       both  616   763   1
 616  Gate        SNF2                    611
 617  Enter       2                       618
*     Thirty A/P transactions (batches) now in store 2 awaiting
*     assignments.  Go to assignment routine.
*
******************************************************************************
*
*     Assignment of accounts payable batches
*     This phase sets up random flow of 30 A/P transactions
*     9 A.M. of day 1 to day 6 is selected by function 22.  Then function 11
*     distributes approximately 5 transactions per day over the working day.
*
******************************************************************************
```

```
*
*      NAME        X     Y      Z     SEL    NBA    NBB    Mean time and module
 618   Assign      8     X33                 619
 619   Savex       33-   K1                  620
 620   Advance                               621           100   FN22
 621   Assign      5     FN9                 622
 622   Assign      6     FN10                623
 623   Assign      6     FN6                 624
 624   Assign      7     FN11                625
 625   Advance                               626           *7    0
 626   Mark                                  630
*
**********************************************************************************
*
*      Go to execute
*      Execute accounts payable phase
*      Variable 1 and function 6 calculate A/P input volume
*      V12 defines a spread for input transmission, computer time.
*
**********************************************************************************
```

```
*
*      NAME         X      Y      Z      SEL    NBA    NBB    Mean time and module
 630   Assign       1      K627                 751
*      Returned from split at 751
 627   Queue        103                         758
*      Returned from assembly at 757
 628   Advance                                  629           120    0
 629   Interrupt    100                         631           10
 631   Assign       2      V1                   632
 632   Assign       3      V12                  633
 633   Advance                                  634           *2     *3
 634   Release      *8                          641
 641   Logic        R*8                         635
 635   Queue        63                          636
 636   Hold         100                         637           *3     0
 637   Advance                           .100   640    638    120
 640   Assign       3      V13                  643
 643   Assign       1      K646                 751
*      Returned from split at 751
 646   Queue        42                          758
*      Returned from assembly at 757
 647   Advance                                  642           *3     *2
 642   Leave        2                           644
 644   Tabulate     3                           761
*      Sent to 761 for release of terminal, reset of logic switch and termination
 638   Assign       7      FN14                 639
 639   Advance                                  630           *7     0
*
*****************************************************************************************
```

```
*
*    NAME        X      Y      Z      SEL   NBA   NBB  Mean time and module
*    Student accounting branches of model January 2, 1966
*          Master file updating
*          Student scheduling - 2 phases spring and late August
*          Grade reporting - secondary grades only - 6 times annually.
*          The master file updating would reference the census file, however,
*          the model assumes the once a year major update not via
*          telecommunications.
*
*******************************************************************************
*
*          Master file updating routine
*          This routine assumes that each student file would require an average
*          of 90 characters of additions or changes per year exclusive of
*          information flowing from other routines - census, grade reporting and
*          student scheduling.  This routine would complement these other student
*          accounting routines.
*
*          All students K-12 on the master file - 225,000 estimate
*          updating starts Sept. 1 and ends May 1.
*          Weekly batches equal to enrollment/40 arrive at random.
*
*          Signal arrives from block 97 or 99
*          Departure times are random Thursday A.M. to Wednesday noon next.
*
*******************************************************************************
```

```
*
*     NAME         X      Y      Z      SEL    NBA    NBB    Mean time and module
 51   Advance                           all    52     54
 52   Compare      X99    LE     K2            530           1               terminate
 53   Compare      X99    GE     K11           530           1               May - August
 54   Split                                    56     530
 56   Advance                                  55            28800 0
 55   Savex        40     K30                  57            28800 0
 57   Split                                    58     65
 58   Advance                           both   63     763    1
 63   SNF7                                     57
 65   Enter        7                           66
 66   Assign       8      X40                  67
 67   Savex        40-    K1                   71            8      FN11
 71   Assign       6      V6                   72                           V6-FN32*K4/K40
 72   Assign       5      FN9                  73
 73   Assign       6      V7                   74                           V7-P6*K15/P5
 74   Mark                                     70
 70   Assign       1      K75                  751
*     Returned from split at 751
 75   Queue        43                          758
*     Returned from assembly at 757
 76   Advance                                  77            *6
 77   Interrupt    100                         80            20
 80   Assign       6      V10                  81                           V10-FN32/K40
 81   Queue        81                          82
 82   Hold         100                         78            *6     *6
 78   Leave        7                           79
 79   Tabulate     8                           761
*     Sent to 761 for release of terminal, reset of logic switch and termination
*
*************************************************************************************
```

```
*
*   NAME         X     Y     Z     SEL   NBA   NBB   Mean time and module
*            Student scheduling routine phase 1-phase 11 occurs in August
*            100,000 students from 28 districts to be scheduled
*            input arrival occurs March 1 - April 15.
*            Throughput advances from April 1 to May 15.  Success probability
*            in this phase is assumed to be 1/3.  The latest completion date
*            would be May 15 and 18 days.  The output advances after successful
*            run via the grade reporting output routine.  Completion not later
*            than June 15.
*            The input routine includes receiving, editing, tally and matrix of
*            potential conflicts.  Tally and matrix and input are returned to
*            terminal and stored for throughput.  Scheduling is batched as one
*            job or transaction per terminal.
*
*************************************************************************************
*
*   Enters from block 425
*
*   NAME         X     Y     Z     SEL   NBA   NBB   Mean time and module
241 Advance                        both  242   424
242 Compare      X200  E     K0    both  243   424
243 Compare      X99   E     K9          244
244 Assign       8     K30               245
245 Split                                246   257
246 Loop         8                       245   247   1
247 Savex        200   K1                424
257 Assign       3     K1                258         57600 FN2
258 Assign       6     FN30              259                    No. of sec. students
259 Assign       6     V40               260                    growth factor
260 Assign       5     FN9               261                    terminal speed
261 Assign       4     V9                262                    V9-P6*K90/P5
262 Mark                                 255
255 Assign       1     K263              751
*
*************************************************************************************
```

```
*
*     NAME      X     Y     Z     SEL   NBA   NBB   Mean time and module
*     Returned from split at 751
 263  Queue     107                     758
*     Returned from assembly at 757
 264  Advance                           265         *4          imput time
 265  Release   *8                      250
 250  Logic     R*8                     266
 266  Hold      100                     256         *6    0
 256  Assign    1     K277              751
*     Returned from split at 751
 277  Queue     44                      758
*     Returned from assembly at 757
 278  Advance                           267         1200  0
 267  Advance                           279         *4    0
 279  Release   *8                      294
 294  Logic     R*8                     268
 268  Tabulate  6                       270
*
*************************************************************************
*
*           Throughput phase of student scheduling
*
*************************************************************************
```

```
*
*       NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
 270    Compare     X99   GE    K10         269
 269    Mark                                271
 271    Advance                             272         57600 FN2   throughput April
*             Previous block delays processing of student scheduling from 1-30 days.
 272    Hold        100                     280         *6
 280    Assign      1     K285              751
*       Returned from split at 751
 285    Queue       45                      758
*       Returned from assembly at 757
 286    Advance                             273         1200  0
 273    Release     *8                      295
 295    Logic       R*8               .667  274   275
*             Previous block predicts successful run ratio of 1/3.  Unsuccessful
*             run is rescheduled for processing from 2 hours to 6 days later.
 274    Tabulate    7                       276
 276    Mark                                173
*       Returned for rescheduling 1.6 hours to 6 days later
 275    Advance                             272         11520 FN2
*             Go to grade reporting output routine.
*
*********************************************************************************************
*
*             End of phase 1 student scheduling routine.
*
*********************************************************************************************
*
*             Phase 11 student scheduling routine August 15-18
*             Updating of spring scheduling but reflecting addition of students,
*             students moving away and election changes.
*
*********************************************************************************************
```

```
*
*     NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
281   Generate          30    6           282         7200
282   Compare     X98   GE    K6          283
283   Savex       42&   K1                284
284   Assign      8     X42               287
287   Assign      3     K1                288                   not grade reporting
288   Assign      6     FN30              289
289   Assign      6     V40               290
290   Assign      5     FN9               291
291   Advance                             292         7200  FN2
292   Hold        100                     293         *6
293   Mark                                173
*
*           Go to grade reporting output routine
*           End of phase 11 student scheduling routine.
*
*****************************************************************************
*
*           Grade reporting routine
*           This routine picks Wednesday mornings of the 15th, 22nd, 29th, 35th,
*           42nd, and 49th weeks following the start of the fiscal year as the
*           start of a 5 day period for processing report cards.
*           The distribution assumes 4 districts will start processing on Wednesday
*           8,8,4,4, on the following days ending the Tuesday of the following week
*           the count in block 536 equals the week count.
*
*****************************************************************************
*
*     Weekly signals arrive here from 502, redirected to 51 and back to 530.
*
*****************************************************************************
```

```
*
*      NAME      X     Y     Z     SEL   NBA   NBB   Mean time and module
 156   Enter     6                       157
 157   Assign    8     X39               161
 161   Savex     39-   K1                162
 162   Advance                           163         100   FN23  5 day distribution
 163   Assign    7     FN11              164                     4.55 hr distribution
 164   Assign    6     FN30              165         *7
 165   Mark                              166
 166   Assign    5     FN9               167
 167   Assign    6     V9                160                     V9-P6*K90/P5
 160   Assign    1     K168              751
*      Returned from split at 751
 168   Queue     105                     758                     terminal wait
*      Returned from assembly at 757
 169   Advance                           170         *6    0
 170   Release   *8                      159
 159   Logic     R*8                     171
 171   Queue     106                     172                     CPU wait
 172   Hold      100                     401         1           CPU time start
 401   Assign    1     K20               402         1
 402   Assign    3     V30               403                     V30-FN30/K20
 403   Hold      100                     404         *3    0
 404   Loop      1                       401   173
 173   Assign    6     FN30        both  174   181               No. of students
 174   Compare   P5    G     K15         175
 175   Assign    6     V5                176                     V5#P6*K400/P5
 176   Assign    1     K177              751
*      Returned from split at 751
 177   Queue     41                      758
*      Returned from assembly at 757
*
****************************************************************************
```

```
*
*        NAME        X      Y      Z      SEL    NBA    NBB    Mean time and module
 178     Advance                                 179           *6    0
 179     Advance                                 180           *6    0
 180     Advance                                 195           *6    0
 195     Release     *8                          196
 196     Logic       R*8                         191
 181     Advance                          both   182    185
 182     Gate        NU101                       183
 183     Hold        101                         184           *6    0
 184     Hold        101                         191           *6    0
 185     Assign      2      FN33                 186
 186     Queue       108                  both   187    182
 187     Gate        NU*2                        189
 189     Assign      8      P2                   190
 190     Assign      5      FN9                  174
 191     Advance                          both   193    192
 193     Compare     P3     E      K1            197
 197     Tabulate    6                           763
 192     Leave       6                           194
 194     Tabulate    5                           763
*
*             End of grade reporting routine and student scheduling output.
*
*****************************************************************************************
*
*
*        Subroutine to wait for, then seize terminal.
*
*        Arrivals from 118-137-203-213-326-552-570-563-630-643-70-255-256-280-160-176
*
*****************************************************************************************
```

```
*
*       NAME          X      Y      Z      SEL    NBA    NBB    Mean time and module
 751    Split                                     *1     752
*
*       1 values - 119-138-205-215-324-553-580-574-627-646-75-263-277-285-168-177
*
 752    Queue         *8                          753
 753    Gate          LR*8                        754
 754    Seize         *8                          755
 755    Logic         S*8                         757
 757    Assemble      2                           756
 756    Assign        1&     K1                   *1
*
*       Same as *1 above plus 1.
*
 758    Gate          M757                        757
*
*************************************************************************************
*
*       Subroutine to release terminal and reset logic switch.
*
*       Arrivals from - 123-143-208-218-339-573-644-79
*
*************************************************************************************
*
*       NAME          X      Y      Z      SEL    NBA    NBB    Mean time and module
 761    Release       *8                          762
 762    Logic         R*8                         763
 763    Terminate
*
*************************************************************************************
```

```
*
*     NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
*
*     Timekeeper routine
*
*     Assumes year starts on Monday morning.
*           The time keeper routine generates a transaction every hour on the
*     hour.  Savex 103 is zeroed for counting the number of busy facilities.
*     104 is incremented 1 each hour.  Remainder division is performed by
*     variable 15 to tag count of days in X111.  Remainder division is performed
*     by variable 16 to tag count of weeks in X112.  Parameter 8 is set to 30
*     and the status of each facility is checked hourly.  Count is maintained
*     in X103 and the greatest count is saved in X106.  Each time X103 exceeds
*     X106 a save routine is performed.  The hour, day, and week is saved
*     in X107, X108, X109 respectively.
*
****************************************************************************************
```

```
*
*       NAME        X     Y     Z     SEL   NBA   NBB   Mean time and module
 771    Generate    1                       772         7200  0
 772    Savex       103   K0                781
 781    Savex       104&  K1          both  782   773
 782    Compare     V15   E     K1          783
 783    Savex       111&  K1          both  784   773
 784    Compare     V16   E     K1          785
 785    Savex       112&  K1                773
 773    Assign      8     K30               774         3600  0
 774    Advance                       both  775   777
 775    Gate        U*8                     776
 776    Savex       103&  K1                777
 777    Loop        8                       774   786
 786    Advance                       both  787   778
 787    Compare     X103  G     X106        788
 788    Savex       106   X103              789
 789    Savex       107   X104              790
 790    Savex       108   X111              791
 791    Savex       109   X112              778
 778    Tabulate    10                      779
 779    Terminate
*
*****************************************************************************
*
*       A supplemental timing log is kept between blocks 603 and 300 by blocks
*       792 through 797.  The 1st day of each month is tagged and stored in
*       savex locations 121 through 132.
*
*****************************************************************************
```

```
*
*       NAME          X      Y      Z      SEL    NBA    NBB    Mean time and module
 792    Advance                            both   793    795
 793    Compare       X99    E      KO            794
 794    Savex         120    K120                 795
 795    Savex         120&   K1                   796
 796    Assign        1      X120                 797
 797    Savex         *1     X111                 300
*
************************************************************************************
*
*
*           Following routine's function is to signal 5 P.M. Friday
*           evening -- the end-of-the-week -- and thereby cause the
*           statistics for the week just ended to be summarized by the
*           simulator program.
*
************************************************************************************
*
*       NAME          X      Y      Z      SEL    NBA    NBB    Mean time and module
 421    Originate                                 422           28800
 422    Savex         422&   K1            both   423    763
 423    Compare       X422   E      K10           425
 425    Savex         422    KO                   241
 424    Terminate     R
*
************************************************************************************
*
*           End-of-model.  Following control cards cause the simulator
*           to run for one week, produce a weekly summary of all
*           processing and reset to start another week.  Every four weeks
*           a checkpoint of the model is saved by use of the saves
*           control cards.
*
************************************************************************************
```

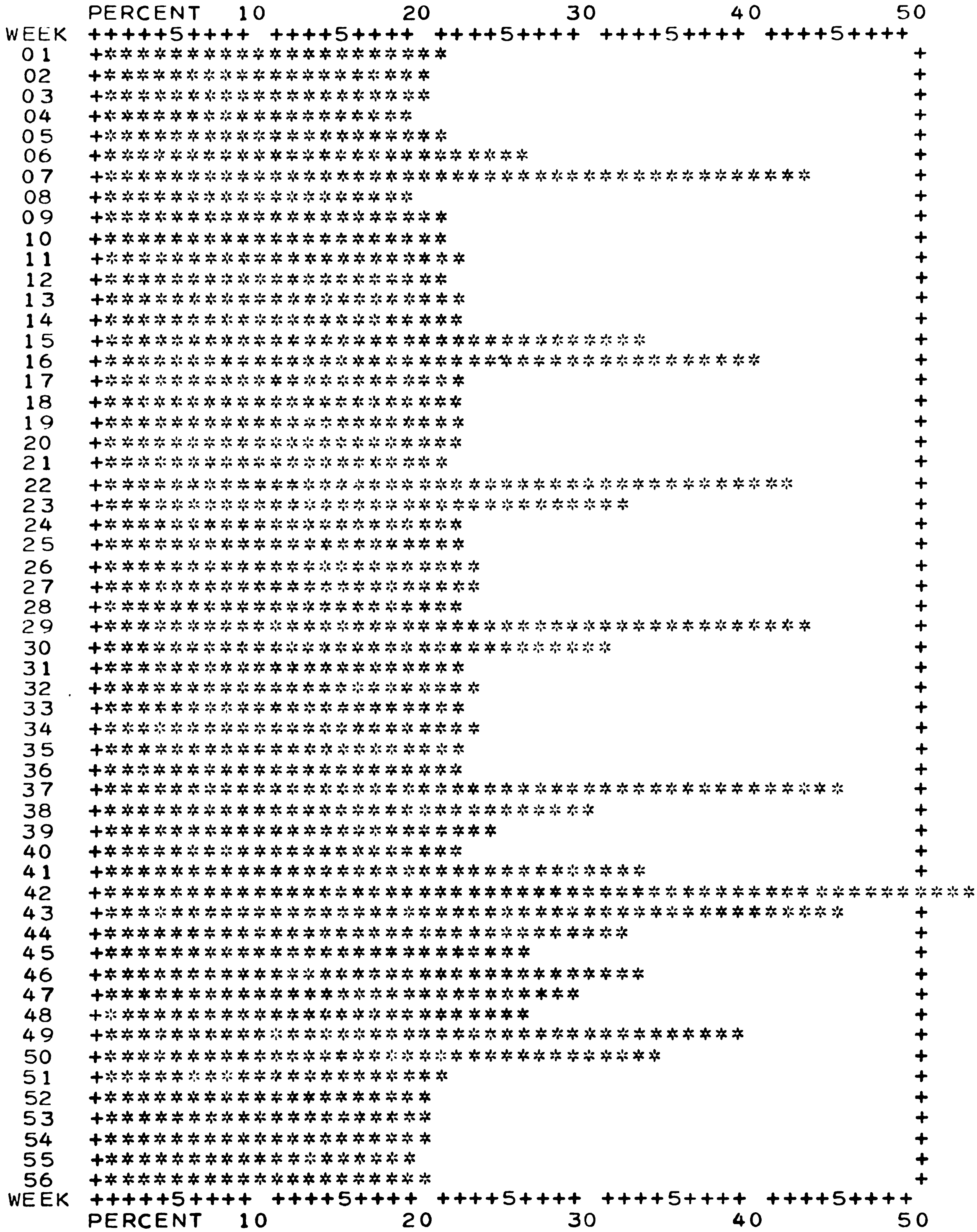
APPENDIX C

FACILITY UTILIZATION

GRAPHS

100 CENTER FACILITY UTILIZATION.

PERCENTAGE BY WEEK.



```
101 FAST PRINTER        FACILITY UTILIZATION.

                             PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +*                                                +
 02  +*                                                +
 03  +*                                                +
 04  +*                                                +
 05  +*                                                +
 06  +******                                           +
 07  +*****************                                +
 08  +*                                                +
 09  +*                                                +
 10  +*                                                +
 11  +*                                                +
 12  +*                                                +
 13  +*                                                +
 14  +*                                                +
 15  +*************                                    +
 16  +**********                                       +
 17  +*                                                +
 18  +*                                                +
 19  +*                                                +
 20  +*                                                +
 21  +*                                                +
 22  +**********                                       +
 23  +************                                     +
 24  +*                                                +
 25  +*                                                +
 26  +*                                                +
 27  +*                                                +
 28  +*                                                +
 29  +**************                                   +
 30  +******                                           +
 31  +*                                                +
 32  +*                                                +
 33  +*                                                +
 34  +*                                                +
 35  +******************                               +
 36  +*********                                        +
 37  +*                                                +
 38  +*                                                +
 39  +*                                                +
 40  +*                                                +
 41  +***                                              +
 42  +*****************                                +
 43  +**********                                       +
 44  +******                                           +
 45  +**                                               +
 46  +******                                           +
 47  +***                                              +
 48  +***                                              +
 49  +***************                                  +
 50  +*********                                        +
 51  +*                                                +
 52  +*                                                +
 53  +*                                                +
 54  +*                                                +
 55  +*                                                +
 56  +*                                                +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

```
01     AVONDALE              FACILITY UTILIZATION.

                              PERCENTAGE BY WEEK.

     PERCENT   10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +*************                                    +
 02  +*************                                    +
 03  +************                                     +
 04  +**********                                       +
 05  +*************                                    +
 06  +************                                     +
 07  +**************                                   +
 08  +***********                                      +
 09  +*************                                    +
 10  +************                                     +
 11  +************                                     +
 12  +**************                                   +
 13  +********                                         +
 14  +****************                                 +
 15  +*************                                    +
 16  +*************                                    +
 17  +*************                                    +
 18  +*********                                        +
 19  +************                                     +
 20  +************                                     +
 21  +*************                                    +
 22  +*********                                        +
 23  +******************                               +
 24  +*********                                        +
 25  +********                                         +
 26  +*************                                    +
 27  +***************                                  +
 28  +*******                                          +
 29  +**************                                   +
 30  +*************                                    +
 31  +************                                     +
 32  +*************                                    +
 33  +********                                         +
 34  +*************                                    +
 35  +*********                                        +
 36  +*******************                              +
 37  +**************                                   +
 38  +***************                                  +
 39  +*********                                        +
 40  +***********                                      +
 41  +***********                                      +
 42  +***************                                  +
 43  +*************                                    +
 44  +*************                                    +
 45  +**************                                   +
 46  +*************                                    +
 47  +********                                         +
 48  +**************                                   +
 49  +*****************                                +
 50  +****************                                 +
 51  +*********                                        +
 52  +**************                                   +
 53  +***********                                      +
 54  +****************                                 +
 55  +*************                                    +
 56  +*******                                          +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT   10        20        30        40        50
```

```
02    BERKLEY           FACILITY UTILIZATION.

                        PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +***********************                          +
 02   +************                                     +
 03   +**********                                       +
 04   +*******************                              +
 05   +************                                     +
 06   +*********************                            +
 07   +*****************                                +
 08   +*********                                        +
 09   +***********                                      +
 10   +**********************                           +
 11   +*********                                        +
 12   +*******************                              +
 13   +******************                               +
 14   +**************                                   +
 15   +******************                               +
 16   +******************                               +
 17   +********************                             +
 18   +**************                                   +
 19   +************                                     +
 20   +*******************                              +
 21   +**********                                       +
 22   +*************************                        +
 23   +***************************                      +
 24   +**********                                       +
 25   +**********************                           +
 26   +***********                                      +
 27   +**********                                       +
 28   +**********************                           +
 29   +*****************                                +
 30   +*********************                            +
 31   +*********************                            +
 32   +*************                                    +
 33   +*******************                              +
 34   +**********                                       +
 35   +*********************                            +
 36   +*********************                            +
 37   +******************                               +
 38   +*************************                        +
 39   +*********                                        +
 40   +******************                               +
 41   +***************                                  +
 42   +******************************                   +
 43   +**********                                       +
 44   +*******************                              +
 45   +*************                                    +
 46   +*******************                              +
 47   +********                                         +
 48   +******************                               +
 49   +****************                                 +
 50   +**************************                       +
 51   +**********                                       +
 52   +********************                             +
 53   +*************                                    +
 54   +******************                               +
 55   +**********                                       +
 56   +*********************                            +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

```
03   BIRMINGHAM        FACILITY UTILIZATION.

                       PERCENTAGE BY WEEK.

     PERCENT  10         20         30         40         50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5+++
 01  +***********                                      +
 02  +**********                                       +
 03  +**********                                       +
 04  +*********                                        +
 05  +************                                     +
 06  +*********************                            +
 07  +************                                     +
 08  +*******                                          +
 09  +***********                                      +
 10  +************                                     +
 11  +**********                                       +
 12  +*********                                        +
 13  +***********                                      +
 14  +*********                                        +
 15  +**********                                       +
 16  +***********************                          +
 17  +********                                         +
 18  +***********                                      +
 19  +***********                                      +
 20  +***********                                      +
 21  +*********                                        +
 22  +********************                             +
 23  +*************                                    +
 24  +************                                     +
 25  +***********                                      +
 26  +*********                                        +
 27  +**********                                       +
 28  +**********                                       +
 29  +*************************                        +
 30  +**********                                       +
 31  +***********                                      +
 32  +*********                                        +
 33  +*********                                        +
 34  +*********                                        +
 35  +*********************                            +
 36  +*********                                        +
 37  +*********                                        +
 38  +***********                                      +
 39  +************                                     +
 40  +***********                                      +
 41  +************                                     +
 42  +*********************                            +
 43  +**********************                           +
 44  +**********                                       +
 45  +**********                                       +
 46  +**********                                       +
 47  +*********                                        +
 48  +*********                                        +
 49  +********************                             +
 50  +***************                                  +
 51  +***********                                      +
 52  +************                                     +
 53  +****************                                 +
 54  +*********                                        +
 55  +**********                                       +
 56  +**********                                       +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10         20         30         40         50
```

```
04    BLOOMFIELD HLS    FACILITY UTILIZATION.

                        PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +****************                                 +
 02   +*********************                            +
 03   +************                                     +
 04   +*******************                              +
 05   +************************                         +
 06   +************                                     +
 07   +*********************                            +
 08   +**********                                       +
 09   +**********                                       +
 10   +************************                         +
 11   +*******************                              +
 12   +***********                                      +
 13   +*********                                        +
 14   +*********************                            +
 15   +******************                               +
 16   +***************                                  +
 17   +******************                               +
 18   +***********                                      +
 19   +*********************                            +
 20   +**********                                       +
 21   +********************                             +
 22   +****************                                 +
 23   +**********************                           +
 24   +**********                                       +
 25   +**********                                       +
 26   +*****************                                +
 27   +*********                                        +
 28   +*************************                        +
 29   +************************                         +
 30   +**********                                       +
 31   +***********                                      +
 32   +**********************                           +
 33   +*****************                                +
 34   +********                                         +
 35   +****************                                 +
 36   +**********************                           +
 37   +*********                                        +
 38   +*******************************                  +
 39   +**********                                       +
 40   +*******************                              +
 41   +******************                               +
 42   +*******************                              +
 43   +*****************                                +
 44   +******************                               +
 45   +**************                                   +
 46   +********************                             +
 47   +***********                                      +
 48   +******************                               +
 49   +*************************                        +
 50   +*************                                    +
 51   +*********************                            +
 52   +**********                                       +
 53   +********                                         +
 54   +*********************                            +
 55   +********                                         +
 56   +*******************                              +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

```
05   BRANDON           FACILITY UTILIZATION.

                       PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +****************                                 +
 02  +***********                                      +
 03  +***********                                      +
 04  +*********                                        +
 05  +**********                                       +
 06  +************                                     +
 07  +**********                                       +
 08  +*********                                        +
 09  +************                                     +
 10  +************                                     +
 11  +************                                     +
 12  +**********                                       +
 13  +**********                                       +
 14  +*************                                    +
 15  +***********                                      +
 16  +***********                                      +
 17  +**********                                       +
 18  +**********                                       +
 19  +************                                     +
 20  +**********                                       +
 21  +*********                                        +
 22  +***********                                      +
 23  +*************                                    +
 24  +***********                                      +
 25  +********                                         +
 26  +*********                                        +
 27  +*********                                        +
 28  +***************                                  +
 29  +**************                                   +
 30  +********                                         +
 31  +**********                                       +
 32  +***********                                      +
 33  +**********                                       +
 34  +********                                         +
 35  +***********                                      +
 36  +*********                                        +
 37  +************                                     +
 38  +***********                                      +
 39  +**********                                       +
 40  +****************                                 +
 41  +**********                                       +
 42  +********                                         +
 43  +**********                                       +
 44  +****************                                 +
 45  +***********                                      +
 46  +**********                                       +
 47  +**********                                       +
 48  +*********                                        +
 49  +***********                                      +
 50  +************                                     +
 51  +************                                     +
 52  +************                                     +
 53  +**************                                   +
 54  +**********                                       +
 55  +*********                                        +
 56  +**********                                       +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

```
06    CLARENCEVILLE     FACILITY UTILIZATION.

                         PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5+++
 01  +*************                                     +
 02  +*******************                               +
 03  +**********                                        +
 04  +*****************                                 +
 05  +***************                                   +
 06  +*************                                     +
 07  +*********                                         +
 08  +*************                                     +
 09  +************                                      +
 10  +**************                                    +
 11  +**********                                        +
 12  +**************                                    +
 13  +**************                                    +
 14  +*************                                     +
 15  +****************                                  +
 16  +************                                      +
 17  +*********                                         +
 18  +****************                                  +
 19  +***************                                   +
 20  +*********                                         +
 21  +*************                                     +
 22  +*************                                     +
 23  +*************                                     +
 24  +****************                                  +
 25  +**************                                    +
 26  +************                                      +
 27  +*************                                     +
 28  +**************                                    +
 29  +*****************                                 +
 30  +*********                                         +
 31  +**********                                        +
 32  +*****************                                 +
 33  +*********                                         +
 34  +**************                                    +
 35  +********                                          +
 36  +******************                                +
 37  +************                                      +
 38  +**************                                    +
 39  +*********                                         +
 40  +********************                              +
 41  +*************                                     +
 42  +**********************                            +
 43  +****************                                  +
 44  +*********                                         +
 45  +*************                                     +
 46  +****************                                  +
 47  +***************                                   +
 48  +********                                          +
 49  +********************                              +
 50  +********                                          +
 51  +****************                                  +
 52  +*************                                     +
 53  +**********                                        +
 54  +******************                                +
 55  +**********                                        +
 56  +****************                                  +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

```
07    CLARKSTUN           FACILITY UTILIZATION.

                          PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +******************                               +
 02  +**********                                       +
 03  +***************                                  +
 04  +********                                         +
 05  +**********                                       +
 06  +******************                               +
 07  +*********                                        +
 08  +***************                                  +
 09  +********                                         +
 10  +*********************                            +
 11  +*****************                                +
 12  +********                                         +
 13  +********                                         +
 14  +********************                             +
 15  +**********                                       +
 16  +**********************                           +
 17  +********                                         +
 18  +******************                               +
 19  +*******                                          +
 20  +*****************                                +
 21  +****************                                 +
 22  +*********                                        +
 23  +************************                         +
 24  +*******                                          +
 25  +*****************                                +
 26  +**********                                       +
 27  +**********                                       +
 28  +*****************                                +
 29  +*************                                    +
 30  +*****************                                +
 31  +***********                                      +
 32  +**************                                   +
 33  +*****************                                +
 34  +********                                         +
 35  +**************                                   +
 36  +***************                                  +
 37  +*************                                    +
 38  +*************************                        +
 39  +*******                                          +
 40  +****************                                 +
 41  +***************                                  +
 42  +**************                                   +
 43  +*******************                              +
 44  +********                                         +
 45  +*************                                    +
 46  +**************                                   +
 47  +***********                                      +
 48  +*****************                                +
 49  +***********                                      +
 50  +*********************                            +
 51  +***************                                  +
 52  +***********                                      +
 53  +****************                                 +
 54  +*************                                    +
 55  +***************                                  +
 56  +**********                                       +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

```
08   CLAWSON              FACILITY UTILIZATION.

                          PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +************                                     +
 02  +*******************                              +
 03  +****************                                 +
 04  +************                                     +
 05  +**************                                   +
 06  +*************                                    +
 07  +*********                                        +
 08  +**************                                   +
 09  +**********                                       +
 10  +****************                                 +
 11  +***************                                  +
 12  +***********                                      +
 13  +********                                         +
 14  +*******************                              +
 15  +**************                                   +
 16  +***************                                  +
 17  +********                                         +
 18  +**************                                   +
 19  +**************                                   +
 20  +*************                                    +
 21  +*************                                    +
 22  +************                                     +
 23  +****************                                 +
 24  +*********                                        +
 25  +*********                                        +
 26  +*************                                    +
 27  +****************                                 +
 28  +**********                                       +
 29  +**************                                   +
 30  +**************                                   +
 31  +************                                     +
 32  +************                                     +
 33  +***************                                  +
 34  +*********                                        +
 35  +************************                         +
 36  +*************                                    +
 37  +***********                                      +
 38  +**************                                   +
 39  +***************                                  +
 40  +***********                                      +
 41  +**************                                   +
 42  +*******************                              +
 43  +****************                                 +
 44  +************                                     +
 45  +************                                     +
 46  +**************                                   +
 47  +*********                                        +
 48  +*************                                    +
 49  +**********                                       +
 50  +***********************                          +
 51  +****************                                 +
 52  +*************                                    +
 53  +******************                               +
 54  +*******                                          +
 55  +**********                                       +
 56  +**************                                   +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

```
09   DUBLIN               FACILITY UTILIZATION.

                          PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +**********                                        +
 02  +********                                          +
 03  +*********                                         +
 04  +********                                          +
 05  +*********                                         +
 06  +*********                                         +
 07  +********                                          +
 08  +*********                                         +
 09  +**********                                        +
 10  +********                                          +
 11  +*******                                           +
 12  +*********                                         +
 13  +**********                                        +
 14  +*******                                           +
 15  +********                                          +
 16  +***********                                       +
 17  +**********                                        +
 18  +*********                                         +
 19  +**********                                        +
 20  +*******                                           +
 21  +*********                                         +
 22  +*********                                         +
 23  +*******                                           +
 24  +*********                                         +
 25  +***********                                       +
 26  +********                                          +
 27  +********                                          +
 28  +*********                                         +
 29  +********                                          +
 30  +*********                                         +
 31  +********                                          +
 32  +**********                                        +
 33  +************                                      +
 34  +*******                                           +
 35  +********                                          +
 36  +**********                                        +
 37  +**********                                        +
 38  +*********                                         +
 39  +*******                                           +
 40  +**********                                        +
 41  +*********                                         +
 42  +*********                                         +
 43  +*********                                         +
 44  +********                                          +
 45  +**********                                        +
 46  +********                                          +
 47  +********                                          +
 48  +********                                          +
 49  +*******                                           +
 50  +********                                          +
 51  +********                                          +
 52  +*******                                           +
 53  +*********                                         +
 54  +********                                          +
 55  +********                                          +
 56  +*******                                           +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

10 FARMINGTON FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +************                                     +
 02   +*************                                    +
 03   +*************                                    +
 04   +***********                                      +
 05   +************                                     +
 06   +***********                                      +
 07   +*************************                        +
 08   +***********                                      +
 09   +*********                                        +
 10   +***********                                      +
 11   +************                                     +
 12   +***********                                      +
 13   +*********                                        +
 14   +**********                                       +
 15   +********                                         +
 16   +***************************                      +
 17   +**********                                       +
 18   +**********                                       +
 19   +*************                                    +
 20   +**********                                       +
 21   +************                                     +
 22   +**********                                       +
 23   +***************************                      +
 24   +***********                                      +
 25   +*************                                    +
 26   +********                                         +
 27   +**************                                   +
 28   +**********                                       +
 29   +************************                         +
 30   +***********                                      +
 31   +*********                                        +
 32   +*********                                        +
 33   +*********                                        +
 34   +**********                                       +
 35   +*****************************                    +
 36   +***********                                      +
 37   +***********                                      +
 38   +**********                                       +
 39   +*********                                        +
 40   +***********                                      +
 41   +***********                                      +
 42   +*************                                    +
 43   +********************************                 +
 44   +********                                         +
 45   +**********                                       +
 46   +***********                                      +
 47   +************                                     +
 48   +*********                                        +
 49   +******************************************       +
 50   +**********                                       +
 51   +***************                                  +
 52   +********                                         +
 53   +*********                                        +
 54   +************                                     +
 55   +***********                                      +
 56   +**********                                       +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

11 FERNDALE FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +****************                                 +
 02   +******************                               +
 03   +***********                                      +
 04   +*******************                              +
 05   +*********                                        +
 06   +***********************                          +
 07   +*********************                            +
 08   +********                                         +
 09   +***************                                  +
 10   +********************                             +
 11   +******************                               +
 12   +**********                                       +
 13   +************                                     +
 14   +***********************                          +
 15   +****************************                     +
 16   +***********                                      +
 17   +**********                                       +
 18   +************************                         +
 19   +******************                               +
 20   +***********                                      +
 21   +********                                         +
 22   +*********************                            +
 23   +******************************                   +
 24   +*********                                        +
 25   +********************                             +
 26   +*********                                        +
 27   +******************                               +
 28   +*************                                    +
 29   +*****************                                +
 30   +*****************                                +
 31   +*************                                    +
 32   +**********************                           +
 33   +********************                             +
 34   +********                                         +
 35   +**********************                           +
 36   +********************                             +
 37   +***********                                      +
 38   +*****************                                +
 39   +*****************                                +
 40   +**********                                       +
 41   +************************************             +
 42   +*****************                                +
 43   +**********                                       +
 44   +******************                               +
 45   +************                                     +
 46   +******************                               +
 47   +********                                         +
 48   +*****************                                +
 49   +******************                               +
 50   +***********************                          +
 51   +***********                                      +
 52   +******************                               +
 53   +*******************                              +
 54   +************                                     +
 55   +******************                               +
 56   +*******                                          +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

```
12    XXX                  FACILITY UTILIZATION.

                           PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +**********                                       +
 02  +**********                                       +
 03  +*********                                        +
 04  +***********                                      +
 05  +********                                         +
 06  +*********                                        +
 07  +********                                         +
 08  +**********                                       +
 09  +*******                                          +
 10  +********                                         +
 11  +********                                         +
 12  +********                                         +
 13  +********                                         +
 14  +*******                                          +
 15  +*******                                          +
 16  +**********                                       +
 17  +************                                     +
 18  +********                                         +
 19  +*********                                        +
 20  +*******                                          +
 21  +*********                                        +
 22  +*********                                        +
 23  +*********                                        +
 24  +*******                                          +
 25  +********                                         +
 26  +*********                                        +
 27  +*******                                          +
 28  +********                                         +
 29  +********                                         +
 30  +**********                                       +
 31  +********                                         +
 32  +*********                                        +
 33  +******                                           +
 34  +**********                                       +
 35  +************                                     +
 36  +********                                         +
 37  +********                                         +
 38  +*******                                          +
 39  +*********                                        +
 40  +*********                                        +
 41  +**********                                       +
 42  +*******                                          +
 43  +**********                                       +
 44  +**********                                       +
 45  +*********                                        +
 46  +*********                                        +
 47  +*********                                        +
 48  +*********                                        +
 49  +**********                                       +
 50  +**********                                       +
 51  +*******                                          +
 52  +*********                                        +
 53  +*********                                        +
 54  +**********                                       +
 55  +********                                         +
 56  +*****                                            +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

13   HAZEL PARK   FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +**************                                   +
 02   +********************                             +
 03   +******************                               +
 04   +**********                                       +
 05   +************************                         +
 06   +********                                         +
 07   +*******************                              +
 08   +*********                                        +
 09   +*********                                        +
 10   +**********************                           +
 11   +***********                                      +
 12   +****************                                 +
 13   +**********                                       +
 14   +*********************                            +
 15   +*******************                              +
 16   +**************                                   +
 17   +*********                                        +
 18   +*********************                            +
 19   +************                                     +
 20   +******************                               +
 21   +********                                         +
 22   +************************                         +
 23   +**************                                   +
 24   +******************                               +
 25   +********************                             +
 26   +**********                                       +
 27   +****************                                 +
 28   +*********************                            +
 29   +***********                                      +
 30   +************************                         +
 31   +************                                     +
 32   +*******************                              +
 33   +*****************                                +
 34   +***********                                      +
 35   +************************                         +
 36   +*************                                    +
 37   +********************************                 +
 38   +**********                                       +
 39   +*****************                                +
 40   +********                                         +
 41   +*************                                    +
 42   +***************************                      +
 43   +**********                                       +
 44   +**********************                           +
 45   +****************                                 +
 46   +**********                                       +
 47   +***********                                      +
 48   +******************                               +
 49   +******************************                   +
 50   +***********                                      +
 51   +*******************                              +
 52   +************                                     +
 53   +*********                                        +
 54   +***********************                          +
 55   +********                                         +
 56   +******************                               +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

14 HOLLY FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
      PERCENT   10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +****************                                 +
 02   +***********                                      +
 03   +*************                                    +
 04   +***********                                      +
 05   +*****************                                +
 06   +**********                                       +
 07   +*************                                    +
 08   +********                                         +
 09   +************                                     +
 10   +************                                     +
 11   +*********                                        +
 12   +*************                                    +
 13   +*********                                        +
 14   +**************                                   +
 15   +********                                         +
 16   +*************                                    +
 17   +************                                     +
 18   +*********                                        +
 19   +***************                                  +
 20   +*******                                          +
 21   +***********                                      +
 22   +***********                                      +
 23   +************                                     +
 24   +**********                                       +
 25   +**********                                       +
 26   +************                                     +
 27   +**************                                   +
 28   +**************                                   +
 29   +*************                                    +
 30   +************                                     +
 31   +***********                                      +
 32   +*************                                    +
 33   +*******                                          +
 34   +*************                                    +
 35   +***************                                  +
 36   +***************                                  +
 37   +***********                                      +
 38   +****************                                 +
 39   +*********                                        +
 40   +************                                     +
 41   +*************                                    +
 42   +************                                     +
 43   +*************                                    +
 44   +***********                                      +
 45   +******************                               +
 46   +***********                                      +
 47   +***********                                      +
 48   +************                                     +
 49   +*************                                    +
 50   +**************                                   +
 51   +**************                                   +
 52   +************                                     +
 53   +*********                                        +
 54   +***************                                  +
 55   +***********                                      +
 56   +**********                                       +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT   10        20        30        40        50
```

```
15    HURON VALLEY      FACILITY UTILIZATION.

                        PERCENTAGE BY WEEK.

      PERCENT  10         20         30         40         50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +***************                                   +
 02   +*************                                     +
 03   +***************                                   +
 04   +**********                                        +
 05   +************                                      +
 06   +***************                                   +
 07   +**********                                        +
 08   +**************                                    +
 09   +****************                                  +
 10   +***********                                       +
 11   +******************                                +
 12   +********                                          +
 13   +***************                                   +
 14   +*************                                     +
 15   +*********                                         +
 16   +*****************                                 +
 17   +**************                                    +
 18   +***********                                       +
 19   +************                                      +
 20   +***************                                   +
 21   +**********                                        +
 22   +****************                                  +
 23   +*************                                     +
 24   +****************                                  +
 25   +**********                                        +
 26   +***************                                   +
 27   +*****************                                 +
 28   +************                                      +
 29   +**************                                    +
 30   +*****************                                 +
 31   +***************                                   +
 32   +************                                      +
 33   +***********                                       +
 34   +***************                                   +
 35   +******************                                +
 36   +**************                                    +
 37   +**************                                    +
 38   +*********                                         +
 39   +***************                                   +
 40   +*********                                         +
 41   +****************                                  +
 42   +***********************                           +
 43   +**************                                    +
 44   +*********                                         +
 45   +*****************                                 +
 46   +***********                                       +
 47   +**************                                    +
 48   +*********                                         +
 49   +*****************                                 +
 50   +**************                                    +
 51   +****************                                  +
 52   +**********                                        +
 53   +***********                                       +
 54   +******************                                +
 55   +**************                                    +
 56   +**********                                        +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10         20         30         40         50
```

16   LAKE ORION   FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
      PERCENT   10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +*************                                    +
 02   +***************                                  +
 03   +***********                                      +
 04   +**************                                   +
 05   +************                                     +
 06   +************                                     +
 07   +**************                                   +
 08   +************                                     +
 09   +**************                                   +
 10   +*************                                    +
 11   +***************                                  +
 12   +*********                                        +
 13   +**********                                       +
 14   +****************                                 +
 15   +****************                                 +
 16   +*************                                    +
 17   +***************                                  +
 18   +*******                                          +
 19   +*************                                    +
 20   +************                                     +
 21   +**************                                   +
 22   +***********                                      +
 23   +******************                               +
 24   +*********                                        +
 25   +*************                                    +
 26   +**********                                       +
 27   +******************                               +
 28   +*********                                        +
 29   +*********                                        +
 30   +******************                               +
 31   +**************                                   +
 32   +************                                     +
 33   +*********                                        +
 34   +***************                                  +
 35   +**************                                   +
 36   +******************                               +
 37   +**************                                   +
 38   +**********                                       +
 39   +***********************                          +
 40   +***********                                      +
 41   +******************                               +
 42   +*******************                              +
 43   +**************                                   +
 44   +**********                                       +
 45   +******************                               +
 46   +***********                                      +
 47   +**********                                       +
 48   +**************                                   +
 49   +****************                                 +
 50   +****************                                 +
 51   +************                                     +
 52   +***************                                  +
 53   +***************                                  +
 54   +*************                                    +
 55   +**********                                       +
 56   +************                                     +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT   10        20        30        40        50
```

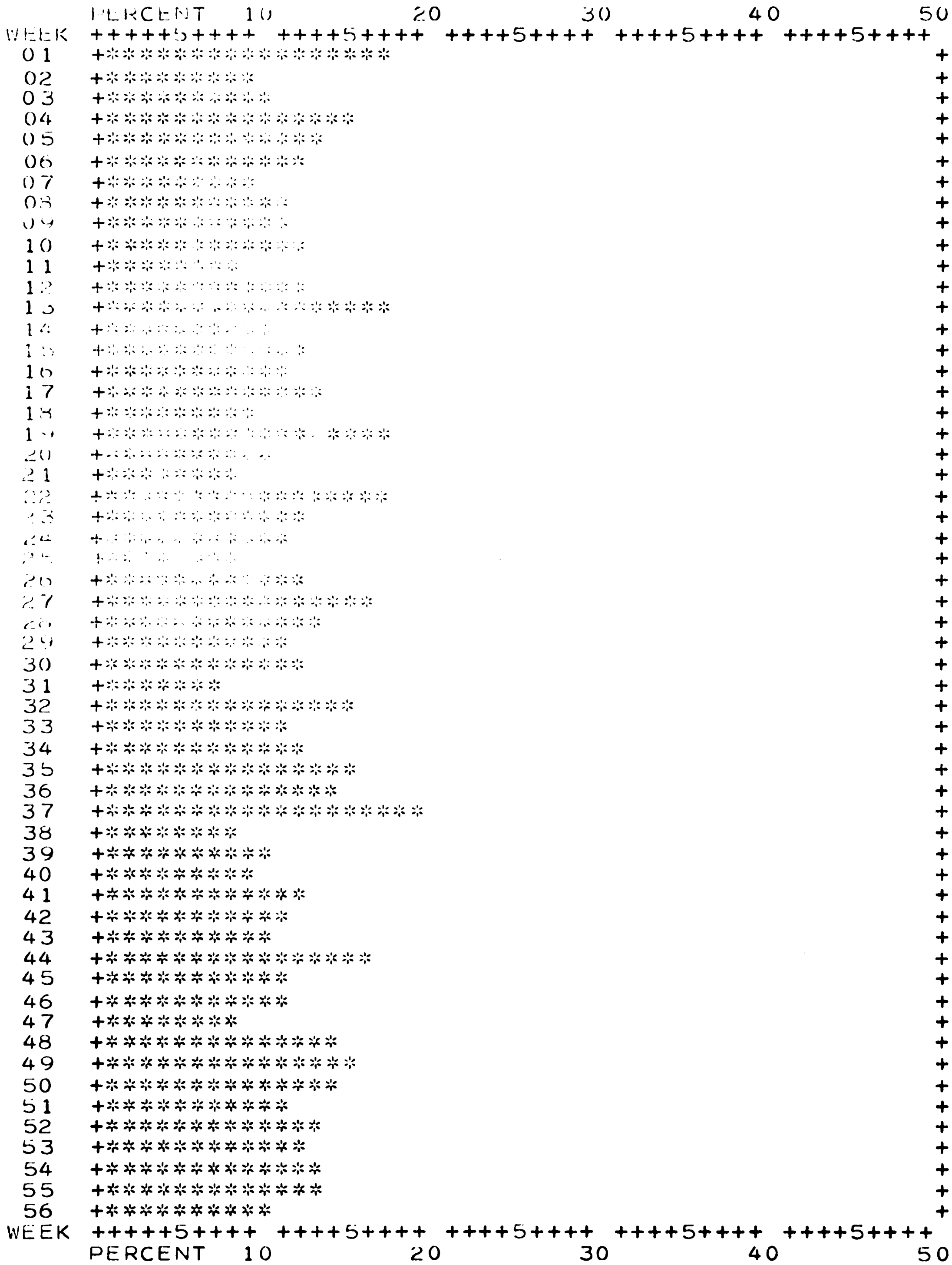
17 LAMPHERE FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
       PERCENT  10         20         30         40         50
WEEK   +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01    +***********                                       +
 02    +********************                              +
 03    +******************                                +
 04    +**********                                        +
 05    +**************                                    +
 06    +****************                                  +
 07    +****************                                  +
 08    +***********                                       +
 09    +*********************                             +
 10    +*******                                           +
 11    +*********                                         +
 12    +***************                                   +
 13    +***********                                       +
 14    +*******************                               +
 15    +************                                      +
 16    +**************                                    +
 17    +****************                                  +
 18    +************                                      +
 19    +**************                                    +
 20    +**********                                        +
 21    +****************                                  +
 22    +***********                                       +
 23    +**************                                    +
 24    +***************                                   +
 25    +********                                          +
 26    +*****************                                 +
 27    +**************                                    +
 28    +****************                                  +
 29    +**************                                    +
 30    +***************                                   +
 31    +*****************                                 +
 32    +*********                                         +
 33    +**************                                    +
 34    +********                                          +
 35    +**************                                    +
 36    +******************                                +
 37    +***********                                       +
 38    +**************                                    +
 39    +************************                          +
 40    +***********                                       +
 41    +***************                                   +
 42    +****************                                  +
 43    +*********                                         +
 44    +***************                                   +
 45    +*************                                     +
 46    +****************                                  +
 47    +*****************                                 +
 48    +**********                                        +
 49    +**********                                        +
 50    +******************                                +
 51    +*************                                     +
 52    +***************                                   +
 53    +***********                                       +
 54    +*****************                                 +
 55    +*********                                         +
 56    +***************                                   +
WEEK   +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
       PERCENT  10         20         30         40         50
```

18 LYON TOWNSHIP FACILITY UTILIZATION.

PERCENTAGE BY WEEK.



```
19   MADISON HTS        FACILITY UTILIZATION.

                        PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +********************                             +
 02  +*************                                    +
 03  +**************                                   +
 04  +****************                                 +
 05  +*************                                    +
 06  +************                                     +
 07  +**********                                       +
 08  +**************                                   +
 09  +******************                               +
 10  +*********                                        +
 11  +*************                                    +
 12  +**********                                       +
 13  +**************                                   +
 14  +***************                                  +
 15  +****************                                 +
 16  +************                                     +
 17  +**********                                       +
 18  +*******************                              +
 19  +*********                                        +
 20  +***************                                  +
 21  +*************                                    +
 22  +***********                                      +
 23  +**********************                           +
 24  +*********                                        +
 25  +*******                                          +
 26  +***************                                  +
 27  +*************                                    +
 28  +**************                                   +
 29  +**************                                   +
 30  +***************                                  +
 31  +**********                                       +
 32  +*********************                            +
 33  +**************                                   +
 34  +***********                                      +
 35  +*******************                              +
 36  +***********                                      +
 37  +************                                     +
 38  +*****************                                +
 39  +**************                                   +
 40  +********                                         +
 41  +********************                             +
 42  +*********************                            +
 43  +*********                                        +
 44  +*************                                    +
 45  +******************                               +
 46  +************                                     +
 47  +***************                                  +
 48  +**********                                       +
 49  +**************                                   +
 50  +******************                               +
 51  +****************                                 +
 52  +***********                                      +
 53  +***********                                      +
 54  +*****************                                +
 55  +**************                                   +
 56  +*************                                    +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

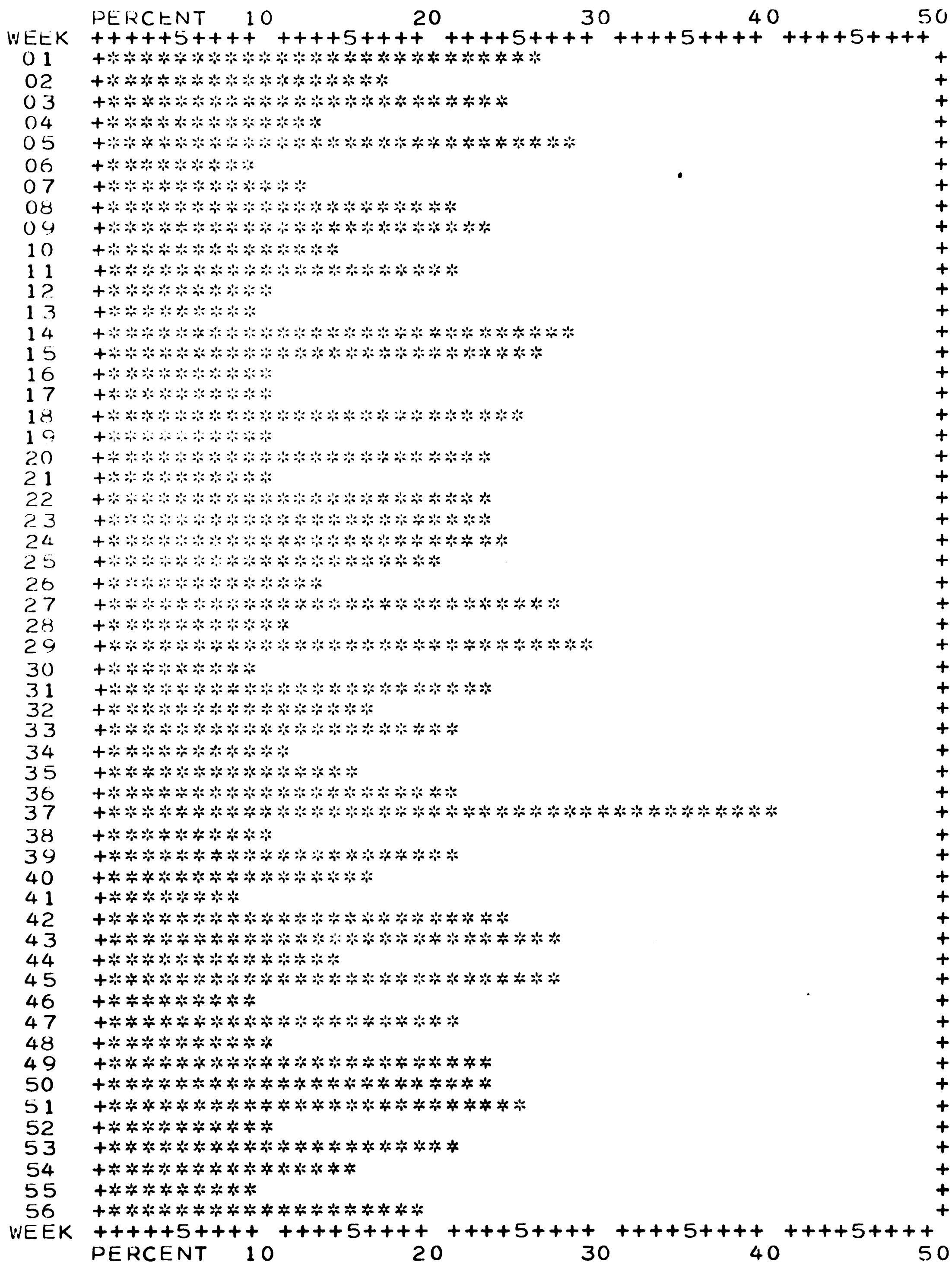
20   NOVI   FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +************                                     +
 02  +********                                         +
 03  +********                                         +
 04  +************                                     +
 05  +***************                                  +
 06  +**********                                       +
 07  +*********                                        +
 08  +*********                                        +
 09  +**********                                       +
 10  +**********                                       +
 11  +**********                                       +
 12  +********                                         +
 13  +*********                                        +
 14  +*************                                    +
 15  +*********                                        +
 16  +*********                                        +
 17  +***********                                      +
 18  +********                                         +
 19  +*********                                        +
 20  +**********                                       +
 21  +*********                                        +
 22  +*********                                        +
 23  +************                                     +
 24  +*********                                        +
 25  +**********                                       +
 26  +**************                                   +
 27  +**********                                       +
 28  +**********                                       +
 29  +********                                         +
 30  +***********                                      +
 31  +**********                                       +
 32  +************                                     +
 33  +***********                                      +
 34  +************                                     +
 35  +************                                     +
 36  +*************                                    +
 37  +************                                     +
 38  +***********                                      +
 39  +**********                                       +
 40  +************                                     +
 41  +*************                                    +
 42  +**********                                       +
 43  +**********                                       +
 44  +********                                         +
 45  +*************                                    +
 46  +************                                     +
 47  +********                                         +
 48  +**********                                       +
 49  +**********                                       +
 50  +************                                     +
 51  +*********                                        +
 52  +************                                     +
 53  +***************                                  +
 54  +********                                         +
 55  +*******                                          +
 56  +********                                         +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

21 OAK PARK FACILITY UTILIZATION.

PERCENTAGE BY WEEK.



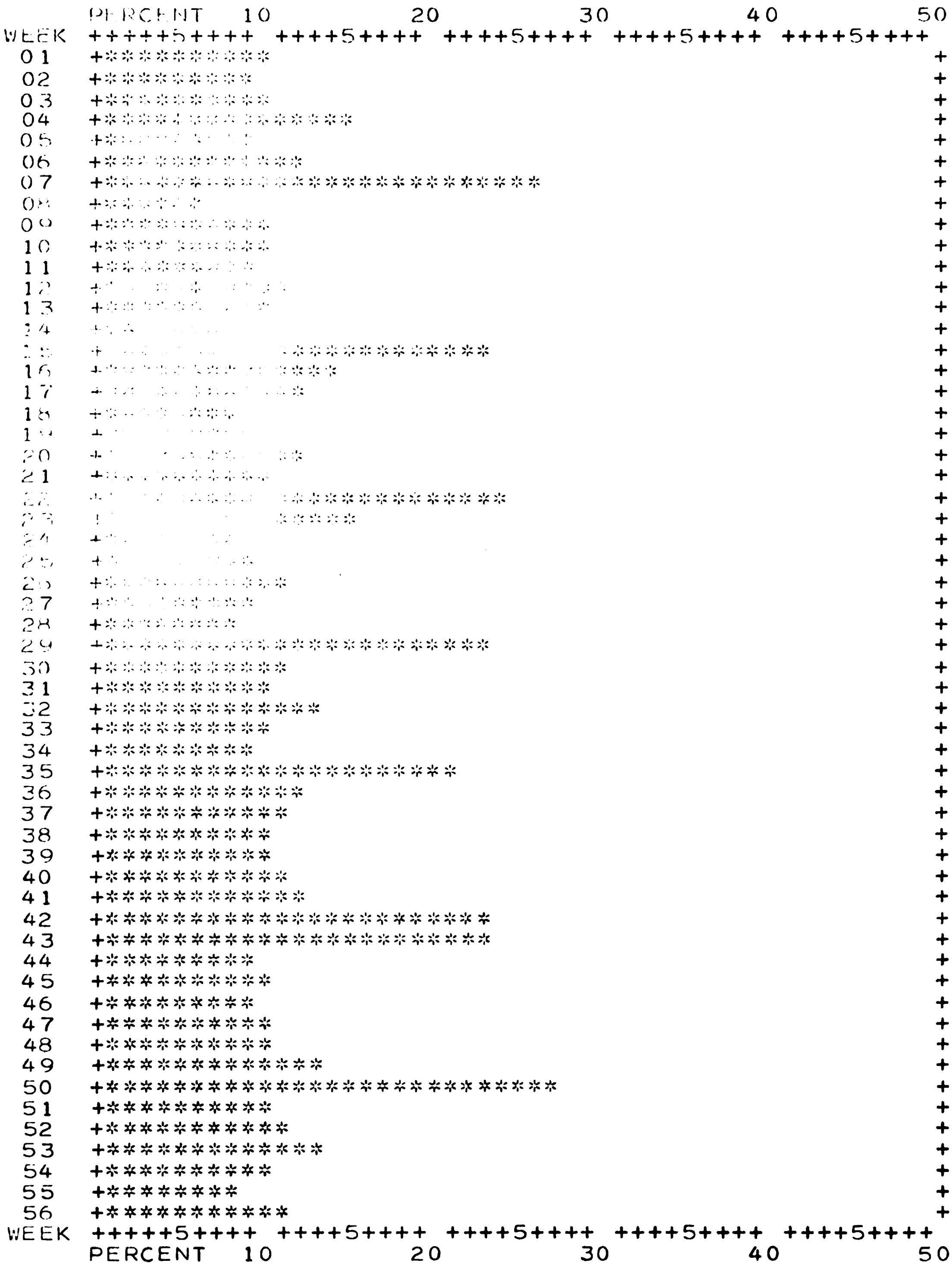
```
22    OXFORD                  FACILITY UTILIZATION.

                              PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +***************                                  +
 02   +*********                                        +
 03   +***********                                      +
 04   +*************                                    +
 05   +**********                                       +
 06   +****************                                 +
 07   +***********                                      +
 08   +*************                                    +
 09   +***********                                      +
 10   +****************                                 +
 11   +*********                                        +
 12   +**********                                       +
 13   +*********                                        +
 14   +**********                                       +
 15   +**********                                       +
 16   +*****************                                +
 17   +*********                                        +
 18   +*****************                                +
 19   +***********                                      +
 20   +********                                         +
 21   +**********                                       +
 22   +************                                     +
 23   +***********                                      +
 24   +**********                                       +
 25   +************                                     +
 26   +************                                     +
 27   +***************                                  +
 28   +************                                     +
 29   +************                                     +
 30   +*********                                        +
 31   +***********                                      +
 32   +************                                     +
 33   +**********                                       +
 34   +***********                                      +
 35   +********                                         +
 36   +*******************                              +
 37   +**********                                       +
 38   +********                                         +
 39   +*********                                        +
 40   +***********                                      +
 41   +********************                             +
 42   +************                                     +
 43   +************                                     +
 44   +**************                                   +
 45   +****************                                 +
 46   +**********                                       +
 47   +*************                                    +
 48   +*********                                        +
 49   +*************                                    +
 50   +*************                                    +
 51   +*************                                    +
 52   +**********                                       +
 53   +***************                                  +
 54   +*******                                          +
 55   +**********                                       +
 56   +*******                                          +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

23 PONTIAC FACILITY UTILIZATION.

PERCENTAGE BY WEEK.



```
24    ROCHESTER            FACILITY UTILIZATION.

                           PERCENTAGE BY WEEK.

      PERCENT   10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
01    +*************                                     +
02    +*********************                             +
03    +************                                      +
04    +******************                                +
05    +************                                      +
06    +********************                              +
07    +*****************                                 +
08    +**********                                        +
09    +******************                                +
10    +*************                                     +
11    +*******                                           +
12    +*****************                                 +
13    +******************                                +
14    +************                                      +
15    +*******                                           +
16    +**************************                        +
17    +*********                                         +
18    +***********************                           +
19    +*********************                             +
20    +***********                                       +
21    +*********                                         +
22    +**************************                        +
23    +**************                                    +
24    +******************                                +
25    +******************                                +
26    +*********                                         +
27    +*********************                             +
28    +************                                      +
29    +*********                                         +
30    +***********************                           +
31    +*******************                               +
32    +**************                                    +
33    +*********************                             +
34    +*********                                         +
35    +****************                                  +
36    +********************                              +
37    +**********************                            +
38    +************                                      +
39    +*******************                               +
40    +********************                              +
41    +*********************                             +
42    +**************                                    +
43    +************                                      +
44    +*********************                             +
45    +*************                                     +
46    +*******************                               +
47    +******************                                +
48    +********                                          +
49    +******************                                +
50    +******************                                +
51    +*********                                         +
52    +********************                              +
53    +********************                              +
54    +************                                      +
55    +*********************                             +
56    +*********                                         +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT   10        20        30        40        50
```

```
25    ROYAL OAK           FACILITY UTILIZATION.

                          PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +*************                                    +
 02   +************                                     +
 03   +*********                                        +
 04   +*********                                        +
 05   +*************                                    +
 06   +**********                                       +
 07   +********************************                 +
 08   +************                                     +
 09   +************                                     +
 10   +***********                                      +
 11   +**************                                   +
 12   +**********                                       +
 13   +*********                                        +
 14   +***********                                      +
 15   +*************                                    +
 16   +**********************************               +
 17   +***********                                      +
 18   +***********                                      +
 19   +***********                                      +
 20   +*******                                          +
 21   +***********                                      +
 22   +****************                                 +
 23   +**********************************               +
 24   +********                                         +
 25   +*******                                          +
 26   +***********                                      +
 27   +********                                         +
 28   +*************                                    +
 29   +*********************                            +
 30   +***********************************              +
 31   +************                                     +
 32   +************                                     +
 33   +********                                         +
 34   +**************                                   +
 35   +*******************************                  +
 36   +******************                               +
 37   +**********                                       +
 38   +*********                                        +
 39   +************                                     +
 40   +***********                                      +
 41   +**************                                   +
 42   +************                                     +
 43   +*********************************************************
 44   +***********                                      +
 45   +*************                                    +
 46   +**********                                       +
 47   +***********                                      +
 48   +*********                                        +
 49   +***********                                      +
 50   +*****************************************        +
 51   +**********                                       +
 52   +*********                                        +
 53   +*********                                        +
 54   +************                                     +
 55   +********                                         +
 56   +*************                                    +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

26 SOUTHFIELD FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
     PERCENT  10         20         30         40         50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +**********                                          +
 02  +************                                        +
 03  +********                                            +
 04  +********                                            +
 05  +*********                                           +
 06  +***********                                         +
 07  +*****************                                   +
 08  +*********                                           +
 09  +*********                                           +
 10  +**********                                          +
 11  +***********                                         +
 12  +***********                                         +
 13  +*********                                           +
 14  +********                                            +
 15  +**********                                          +
 16  +****************                                    +
 17  +**********                                          +
 18  +************                                        +
 19  +**********                                          +
 20  +**********                                          +
 21  +*********                                           +
 22  +************************                            +
 23  +***********                                         +
 24  +********                                            +
 25  +**********                                          +
 26  +**********                                          +
 27  +************                                        +
 28  +***********                                         +
 29  +************************                            +
 30  +**********                                          +
 31  +*******                                             +
 32  +**********                                          +
 33  +*********                                           +
 34  +************                                        +
 35  +*****************                                   +
 36  +*********                                           +
 37  +***********                                         +
 38  +***********                                         +
 39  +**********                                          +
 40  +***********                                         +
 41  +*************                                       +
 42  +**********                                          +
 43  +****************                                    +
 44  +********************                                +
 45  +************                                        +
 46  +**********                                          +
 47  +*********                                           +
 48  +**********                                          +
 49  +**********************                              +
 50  +*************                                       +
 51  +*********                                           +
 52  +*********                                           +
 53  +**********                                          +
 54  +**********                                          +
 55  +********                                            +
 56  +********                                            +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10         20         30         40         50
```

27 TROY FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
     PERCENT  10                  20                  30                  40                  50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +***************                                  +
 02  +******************                               +
 03  +*********                                        +
 04  +*****************                                +
 05  +*************                                    +
 06  +***************                                  +
 07  +**************                                   +
 08  +********                                         +
 09  +**********                                       +
 10  +*****************                                +
 11  +*********                                        +
 12  +***************                                  +
 13  +**********                                       +
 14  +****************                                 +
 15  +*************                                    +
 16  +*************                                    +
 17  +*********                                        +
 18  +****************                                 +
 19  +*************                                    +
 20  +********                                         +
 21  +*********                                        +
 22  +***************                                  +
 23  +************************                         +
 24  +********                                         +
 25  +**************                                   +
 26  +********                                         +
 27  +****************                                 +
 28  +**********                                       +
 29  +*****************                                +
 30  +*************                                    +
 31  +**************                                   +
 32  +**************                                   +
 33  +**********                                       +
 34  +***************                                  +
 35  +***************                                  +
 36  +*************                                    +
 37  +*****************                                +
 38  +************                                     +
 39  +*********                                        +
 40  +************                                     +
 41  +********************                             +
 42  +**************                                   +
 43  +**********************                           +
 44  +********                                         +
 45  +**************                                   +
 46  +*********                                        +
 47  +****************                                 +
 48  +*********                                        +
 49  +***************                                  +
 50  +*******************                              +
 51  +***************                                  +
 52  +**********                                       +
 53  +**************                                   +
 54  +**************                                   +
 55  +********                                         +
 56  +************                                     +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10                  20                  30                  40                  50
```

```
28   WALLED LAKE       FACILITY UTILIZATION.

                       PERCENTAGE BY WEEK.

     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +**********                                       +
 02  +************                                     +
 03  +*********                                        +
 04  +************                                     +
 05  +********                                         +
 06  +*********                                        +
 07  +**********************                           +
 08  +*********                                        +
 09  +********                                         +
 10  +********                                         +
 11  +********                                         +
 12  +**********                                       +
 13  +**********                                       +
 14  +*******                                          +
 15  +*********                                        +
 16  +********************                             +
 17  +**********                                       +
 18  +*********                                        +
 19  +*********                                        +
 20  +*********                                        +
 21  +**********                                       +
 22  +**************************                       +
 23  +***********                                      +
 24  +**********                                       +
 25  +********                                         +
 26  +************                                     +
 27  +********                                         +
 28  +***********                                      +
 29  +*********************                            +
 30  +**********                                       +
 31  +*************                                    +
 32  +**********                                       +
 33  +*********                                        +
 34  +*********                                        +
 35  +**********                                       +
 36  +********************                             +
 37  +*************                                    +
 38  +**********                                       +
 39  +**********                                       +
 40  +*********                                        +
 41  +***********                                      +
 42  +***************************                      +
 43  +**************                                   +
 44  +************                                     +
 45  +*********                                        +
 46  +********                                         +
 47  +************                                     +
 48  +*******************                              +
 49  +******************                               +
 50  +**************                                   +
 51  +*********                                        +
 52  +********                                         +
 53  +*********                                        +
 54  +***********                                      +
 55  +*********                                        +
 56  +*******                                          +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

29 WATERFORD FACILITY UTILIZATION.

PERCENTAGE BY WEEK.

```
     PERCENT  10        20        30        40        50
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01  +***********                                      +
 02  +********                                         +
 03  +***********                                      +
 04  +********                                         +
 05  +********                                         +
 06  +***************                                  +
 07  +*************************                        +
 08  +**********                                       +
 09  +*********                                        +
 10  +**********                                       +
 11  +*********                                        +
 12  +**************                                   +
 13  +***********                                      +
 14  +***********                                      +
 15  +******************                               +
 16  +*****************************                    +
 17  +**********                                       +
 18  +**************                                   +
 19  +**********                                       +
 20  +********                                         +
 21  +**********                                       +
 22  +*******************************                  +
 23  +***********                                      +
 24  +**********                                       +
 25  +**********                                       +
 26  +*********                                        +
 27  +*************                                    +
 28  +**********                                       +
 29  +**************                                   +
 30  +****************************                     +
 31  +**********                                       +
 32  +************                                     +
 33  +**********                                       +
 34  +***********                                      +
 35  +**********************************               +
 36  +**************                                   +
 37  +**********                                       +
 38  +***********                                      +
 39  +*********                                        +
 40  +*************                                    +
 41  +*************                                    +
 42  +******************************                   +
 43  +*************                                    +
 44  +*****************************                    +
 45  +**************                                   +
 46  +************                                     +
 47  +************                                     +
 48  +*********                                        +
 49  +***********                                      +
 50  +******************************                   +
 51  +**********                                       +
 52  +********                                         +
 53  +************                                     +
 54  +**********                                       +
 55  +**************                                   +
 56  +*********                                        +
WEEK +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
     PERCENT  10        20        30        40        50
```

```
30    WEST BLOOMFLD     FACILITY UTILIZATION.

                        PERCENTAGE BY WEEK.

      PERCENT  10        20        30        40        50
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
 01   +*****************                                +
 02   +**************                                   +
 03   +***********                                      +
 04   +**********                                       +
 05   +****************                                 +
 06   +**********                                       +
 07   +***********                                      +
 08   +**********                                       +
 09   +*************                                    +
 10   +*************                                    +
 11   +************                                     +
 12   +********                                         +
 13   +*************                                    +
 14   +**************                                   +
 15   +************                                     +
 16   +**************                                   +
 17   +**********                                       +
 18   +**********                                       +
 19   +***************                                  +
 20   +**********                                       +
 21   +*************                                    +
 22   +**********                                       +
 23   +***************                                  +
 24   +**********                                       +
 25   +**********                                       +
 26   +************                                     +
 27   +*****************                                +
 28   +**********                                       +
 29   +*************                                    +
 30   +***********                                      +
 31   +************                                     +
 32   +*************                                    +
 33   +*************                                    +
 34   +**********                                       +
 35   +************                                     +
 36   +***************                                  +
 37   +*************                                    +
 38   +**********                                       +
 39   +************                                     +
 40   +*****************                                +
 41   +*********                                        +
 42   +************                                     +
 43   +**************                                   +
 44   +**********                                       +
 45   +****************                                 +
 46   +**********                                       +
 47   +*********                                        +
 48   +*************                                    +
 49   +***************                                  +
 50   +***************                                  +
 51   +***********                                      +
 52   +*************                                    +
 53   +*********                                        +
 54   +*************                                    +
 55   +***********                                      +
 56   +*********                                        +
WEEK  +++++5++++ ++++5++++ ++++5++++ ++++5++++ ++++5++++
      PERCENT  10        20        30        40        50
```

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