COMPUTER SIMULATION

of a

POLICE EMERGENCY RESPONSE SYSTEM

Norbert Hauser

Gilbert R. Gordon

Julius Surkis

A Report Prepared for the United States Department of Justice

Law Enforcement Administration

Grant No. 030

POLYTECHNIC INSTITUTE OF BROOKLYN

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PREFACE

In 1966, the Department of Justice's Office of Law Enforcement Assistance sponsored a project entitled "Formulation of a General Computer Model to Study the Operation of Police Departments" at the Polytechnic Institute of Brooklyn.

After exploring several areas, including the operation of a precinct, recruiting and personnel policies, and an overall approach to law enforcement in New York City, one critical function, communications and response was chosen for detailed analysis. Several computer models were developed, tested, and modified, resulting in three simulation programs described in this report.

Dr. Daniel J. Duffy developed the initial proposal in consultation with Justice Department and New York City Police Department personnel. He served as project director during the first year. In September 1967, Dr. Duffy left Brooklyn Polytechnic to become Vice President of Academic Affairs at New York State University's Maritime Academy. Dr. Norbert Hauser, senior researcher on the project became director, adding Messrs. Gilbert R. Gordon and Julius Surkis, both members of Polytechnic's teaching staff, to the group.

Messrs. Robert Roda and Michael Tirabassi, graduate students, each spent one year on the project collecting data, writing and testing computer programs. Mr. R. S. Shah also made major programming contributions on a part-time basis. Mr. Lawrence Parks, although not a member of the team, became interested in the subject and developed a model of the dynamics of crime prevention vs. criminal apprehension in partial fulfillment of his master's degree requirements.

The New York City Poice Department participated in this study by providing access to records, permission to observe and collect data, and by answering questions. Deputy Inspector Kanz and Captain Becker of the Communications Center, Deputy Inspector Lustig, 20th Precinct Commander, and Deputy Inspector Ravins, Planning Bureau Chief, consistently offered friendly cooperation. Lieutenant Sherrid, who originally served as liason officer, became a consultant to the project after his retirement from the Police Department.

It is hoped that this report will be of use to law enforcement agencies throughout the country, not as a finished package which can be implemented immediately, but as an indication of how computer simulation can be used in resource allocation.

Brooklyn, N. Y.
September, 1969

Norbert Hauser
Gilbert R. Gordon
Julius Surkis

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CHAPTER I

INTRODUCTION

The urgency of studying police response systems was clearly demonstrated through the recent work done by the members of the Science and Technology Taskforce of the President's Commission on Law Enforcement and the Administration of Justice.* A study was conducted in Los Angeles observing the occurrence of incidents in two districts. The results showed that a decrease in police response time was correlated with increased probability of criminal apprehension.

A decrease in response time can be achieved by changes in the response system structure. This requires a thorough analysis of the response system. The resulting models can be used to evaluate various alternative policies within given constraints of limited funds, manpower, equipment, union agreements, political exigencies, etc. Alternatively, models may predict the degree of performance improvement resulting from increases in manpower, mechanization, redeployment of resources from one sector to another. Requests for additional funds supported by estimates of resulting benefits can be evaluated objectively and compared with competing requests.

The objective of the effort reported here is to describe and analyze the response system of an actual police department in a large urban area, New York City. Starting with the next chapter, this report is devoted to a detailed emergency response system, the logical structure of several computer simulation models, their implementation in the General Purpose Simulation System (GPSS), and a discussion of some simulation results. The remainder of this chapter will briefly describe the underlying concepts of modeling and simulation.

---

*The Challenge of Crime In A Free Society, President's Commission On Law Enforcement and Administration of Justice, U.S. Government Printing Office, 1967.

Models

A model is a representation of some process or "system." It may be concrete as, for example, a small scale model of a machine, or abstract as, for example, a set of equations describing the movement of an aircraft during landing. It may range from precise, quantitative, well thought out, tested and verified, to vague, intuitive, qualitative. It may be deterministic - change in temperature as gas is compressed, or stochastic - the odds of a certain event's occurrence under given circumstances. Since a model never incorporates all of the system's characteristics - if it did, it would no longer be a model but a replica - the all-purpose model does not and cannot exist. Instead, a model is designed to answer specific questions, make specific predictions, respond to specific inputs. Conclusions based on assumptions other than those within the model are unwarranted, and may actually be worse than unsubstantiated guesses.

It is important to realize that the use of models is not confined to scientists and engineers, but that all decisions in our daily lives are based on some kind of models. These may be intuitive, qualitative, and so deeply ingrained that we are not consciously aware of them. For example, a person driving an automobile does so with the aid of a fairly complex dynamic interactive model which programs his movements with relation to position, velocity and direction of vehicles and pedestrians on the road. The model may fail with disastrous consequences, for several reasons: (a) an important component - a car pulling out of a parking space - is left out, (b) a critical parameter - speed of an approaching vehicle while passing a truck - is wrongly estimated, (c) a component's behavior changes unexpectedly - a blowout causes a car to swerve, or (d) unexpected interactions - the swerving car causes other vehicles to change directions or speed suddenly. One reason for the relatively low number of road accidents is the human brain's ability to make rapid changes in its models. This is one important advantage man still has over the most sophisticated electronic device. A computer may execute or solve a model with far greater speed and accuracy than man, but - at least at the present state of knowledge - it cannot modify the structure of its models without human intervention. Since this report deals with a particular type of computer-run model, it is essential to realize that its effectiveness depends on a thorough understanding of the structure, assumptions, accuracy, and pertinence of information that went into the model. Furthermore, the detailed description that follows is intended to encourage potential users to introduce changes which will make the model more representative of their particular situation. Under no circumstances should a decision maker expect to be able to "plug in" somebody else's model without prior critical examination.

Before leaving this subject, one more analogy may be useful. In searching for a fugitive suspect, police frequently construct a model, a sketch which hopefully reproduces some of the suspect's characteristic features. Such a model requires a combination of two types of inputs: (a) knowledge of the suspect's characteristics supplied by witness, and (b) skill to convert this knowledge into a sketch. Seldom, if ever, can one person meet both requirements. Instead, an interactive process of questioning, interpretation, tentative evaluation, revision, etc. takes place until the witness is satisfied.

Similar interactions take place between the analyst and the substantive expert in constructing a computer model of an existing or proposed system. The analyst may have an advantage over the artist by being able to observe personally an actual system, but the substantive expert should insist on "recognizing the sketch" before actually using a model. One purpose of this report is to demonstrate that, even though the computer requires specialized skills generally not found among top decision makers, computer models can be described in terms recognizable and subject to challenge by persons intimately familiar with the process being modeled. A significant byproduct of such interchange between analyst and decision maker is that it forces the latter to examine and explicitly state the assumptions underlying his own picture (model) of the system under consideration. Frequently this will give him new insights, which, in turn, may produce improvements without actually running the model on a computer in its present form.

Simulation*

Simulation involves the manipulation and observation of a model in a real or synthetic environment. Such a model ideally represents the essential characteristics, without frills or irrelevancies, of the system under investigation. In constrast with analytic models which are solved (exactly or approximately), simulation models are run. The analyst observes, gathers pertinent data, draws appropriate conclusions, introduces changes, and repeats this procedure until he has gained sufficient insight. The mass of data to be processed, and the desire to compress time, i.e. simulate years of operation in seconds or minutes, make a high speed computer an essential ingredient in most simulations.

Purposes of Simulation

Among the applications of simulation are:

1. Analysis of complex systems. This may involve:
   a. estimation of parameters
   b. observation of system behavior
   c. exploration of effect of changes in structure, parameters, environment
   d. sensitivity analyses

The system under study may be
   a. already in existence
   b. partially operative
   c. nonexistent

For example, the introduction of a computer into a communication system may be simulated and experimented with before the computer is available. In fact, such analysis will help determine whether a computer is necessary and, if so, what configuration will be most useful.

2. Demonstration. Complex systems which have been designed by

*This section is based on a chapter of Volume I of "Computers in Engineering Design Education," published by The University of Michigan, written by one of the authors of this report.

analytical and empirical methods can frequently be demonstrated to non-technical personnel, management, or customers by simulation.

3. Training. Where training in the real system environment may be dangerous or costly, simulation may offer a realistic substitute. Examples are simulated airplane cockpits, radar networks, communcation systems, and war games.

Alternatives to Simulation

Broadly speaking, methods useful in system analysis and designed may be classified into three categories:

1. Analytical
2. Simulation
3. Experimentation on real system.

The methods are listed in order of increasing realism, ease of verification, testing, and understanding by management.

Unfortunately the order is also of decreasing power, generality, elegance, and efficiency.

Analytical methods, when applicable, are most powerful and efficient. They frequently indicate explicitly whether an optimal solution exists, whether it is unique, and may even lead us systematically to such solution. However, nature frequently has to be distorted beyond recognition to fit into a model amenable to analytical solution. Systems involving human interactions do not readily lend themselves to analytic approaches.*

Direct experimentation, at the other extreme, may be necessary because of the difficulty in abstracting a meaningful model of any kind. For example, while preliminary experiments in agricultural or medical research may be performed in the laboratory, tests on the real systems - the land or the human body - are eventually necessary. This example illustrates two disadvantages of direct experimentation: time and danger.

*Nevertheless, attempts in this direction may lead to insights not otherwise apparent. Comprehensive analytical models are developed by A. Blumstein and R. Larson in "Models of a Total Criminal Justice System," Operations Research, 17 No. 2, March-April 1969, 199-232.

In a police setting, the undesirability of extensive experimentation - varying force sizes, radically changing assignments to precincts, shifts, trying different patrol routes and ratios of automobile to scooter to foot patrol - is obvious. Public safety depends too much on successful police operation to risk failure of an experiment. In addition, responses to circumstances that currently do not exist, but may reasonably be expected in the future - changes in population mix, crime patterns - as well as riots or other emergencies cannot be developed by direct experimentation. There is great need for a police "wind tunnel" that permits experimentation without risk, in a short time, under circumstances that do not exist now but may appear in the future.

Computer simulation provides such a vehicle, offering a combination of advantages (and disadvantages) of the other two approaches. In addition to permitting realistic models that need not conform to restrictive mathematical necessities it does not require an explicitly stated criterion function or "figure of merit." A decision maker may clearly prefer result A to result B without committing himself as to how many units of objective 1 he is willing to sacrifice for an additional unit of objective 2.

In terms of experimentation, the analyst may hold every variable constant but the ones under consideration - a condition which can only be approximated in the laboratory, and which is unattainable in real life. In stochastic simulations, the seemingly impossible task of reproducing random events identically is accomplished by producing, according to definite rules, sequences of pseudo-random numbers which although perfectly predictable, exhibit almost every other characteristic of randomness.

Programming Languages

The great disadvantage of computer simulation used to be the tedium and cost of model development and verification. With standard procedure-oriented languages such as FORTRAN or ALGOL, programming a simulation can be an overwhelming burden. This is particularly true for processes in which events take place parallel in time. Accounting for proper time sequencing, randomly fluctuating delays, processing times, waiting times in service queues, etc., is not only difficult, but so tediuos as to discourage most analysts who are not also professional programmers. On the other hand, employment of a programmer inserts a source of distortion between the analyst and computer. In their desire to attain programming efficiency, programmers may unintentionally change the logic of a situation without the analyst's knowledge.

Several powerful simulation languages have recently been developed which allow the analyst to describe his problem or process model in a manner closely related to its logic. By far the most popular one is IBM's General Purpose Simulation System (GPSS)*, which is the language used in this report. This language automatically provided for all the accounting and housekeeping functions of a simulation, leaving the analyst free to concentrate on the problem being simulated.

The following chapters of this report include (1) a verbal description with diagrams of the system being modeled, (2) detailed verbal descriptions and logic diagrams of the various component models, (3) listings and sources of input data, (4) model experimentation results, (5) discussion of results, and (6) detailed descriptions and block diagrams of computer programs and computer printouts of programs and results of runs.

*General Purpose Simulation System/360 User's Manual, International Business Machines Corporation, White Plains, 1967.

CHAPTER 2

DESCRIPTION OF SYSTEM TO BE MODELED

System Structure

In the context of this study, the system is defined as the phase of police operations and resources that concerns itself with the response to requests for police assistance. It can be viewed as consisting of three interrelated subsystems:

1. Input Processing
2. Resource Assignment and Dispatching
3. Field Response and Disposition

The first two subsystems are sometimes referred to as the command and control subsystem. (Figure 1)

Input Processing

The input to the response system is initiated by the incidents that require police assistance. These are reported by various media:

a. by the police--using radio or telephone
b. by the public--using telephone
c. by alarm systems
d. by other departments--using telephone

The majority of requests for police assistance and service consists of telephone calls received at the Police Communications Center. The requests for assistance cover: felonies, misdemeanors, disturbances, ambulance calls, and other calls. The pertinent information on the request (time received, location, request type) is recorded. This requires accurate and efficient personnel. The data is then relayed to the second subsystem.

Resource Assignment and Dispatching

On the basis of data recorded on the request, a decision is made concerning the assignment of field resources. In most cases a patrol car is sent. The selection of a particular unit to respond to the request

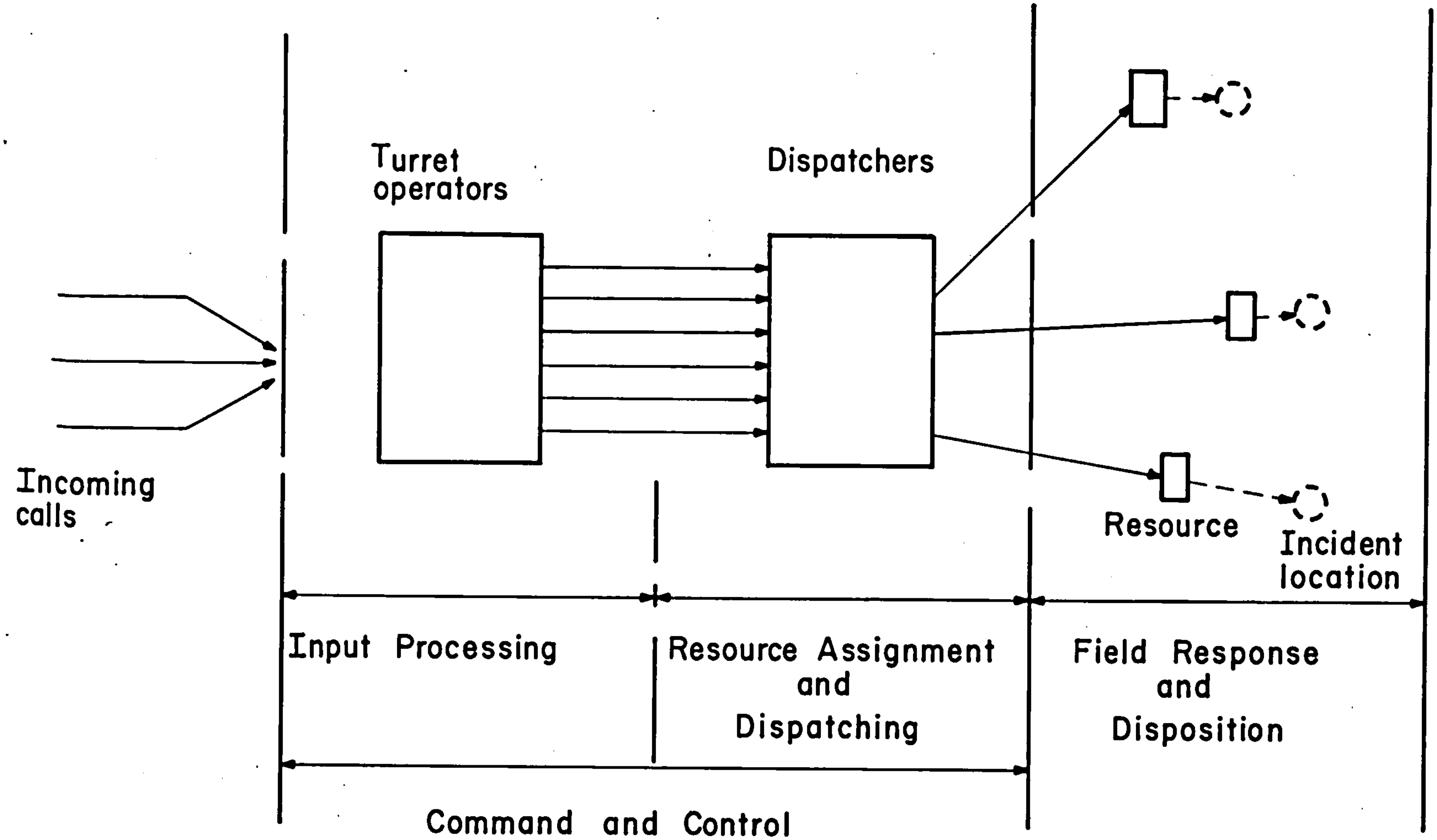


Figure 1

POLICE RESPONSE SYSTEM

depends on the deployment and availability of resource units in the field. The unit closest to the request location is asked to respond.

Field Response and Disposition

The assigned unit proceeds to the designated location, attends to the matter at hand, and reports to the dispatcher via radio upon completion of its assignment.

DETAILED SYSTEM DESCRIPTION*

Input Processing

All telephone calls for police assistance come into the Police Communications Center in Lower Manhattan. The incoming calls are answered by two groups of operators. (Group I and Group II turret operators). Group I turret operators process only those calls that require police assistance.

If a Group I turret operator is available, he answers the call and determines whether it belongs in the emergency or non-emergency category. If it is an emergency call, he obtains the pertinent information on the request and records it on a CRD-7 form. A conveyor belt carries these forms to the dispatchers. If it is a non-emergency call (a complaint or a call requesting information), he transfers it to the Group II turret. Group II turret operators answer all non-emergency calls plus call which found the Group I operators busy. If both groups are busy, the call waits until a Group II turret operator becomes available. All calls which find the Group I turret operators busy are handled by the Group II operators ahead of non-emergency calls.

Resource Assignment and Dispatching

New York City is divided into police divisions each of which contains four to six contiguous precincts. Each precinct is divided into twelve to twenty sectors to which various field resource units are assigned. Each division has a dispatcher and one radio frequency at the Communications Center to contact and communicate with the field units of that division.

*As it was in early 1968.

For efficiency and speed in communication, a master dispatcher is assigned to a group of divisions. He receives the CRD-7 form on the conveyor belt, determines division, precinct and sector of the request, and records it on the form. Then he hands the slip to the appropriate division dispatcher.

The dispatcher has a large map of his division in front of him with lights indicating field units in service. He attempts to reach an available field unit closest to the request location and relays the pertinent information to a police officer in that unit.

<u>Field Response and Disposition</u>

The assigned field unit travels to the requested location. The disposition of the case depends on the request characteristics. If the request concerns a felony, additional resources may be summoned, ambulances may be required; all these affect the disposition. If a suspected perpetrator is apprehended, an arrest is made, which increases the disposition time considerably. On the other hand, unfounded calls or minor disturbances may only require a very short disposition time.

After completing the disposition of the case, the field unit notifies the dispatcher that the assignment is complete and that the unit is back in service. Figure 2 summarizes the system description.

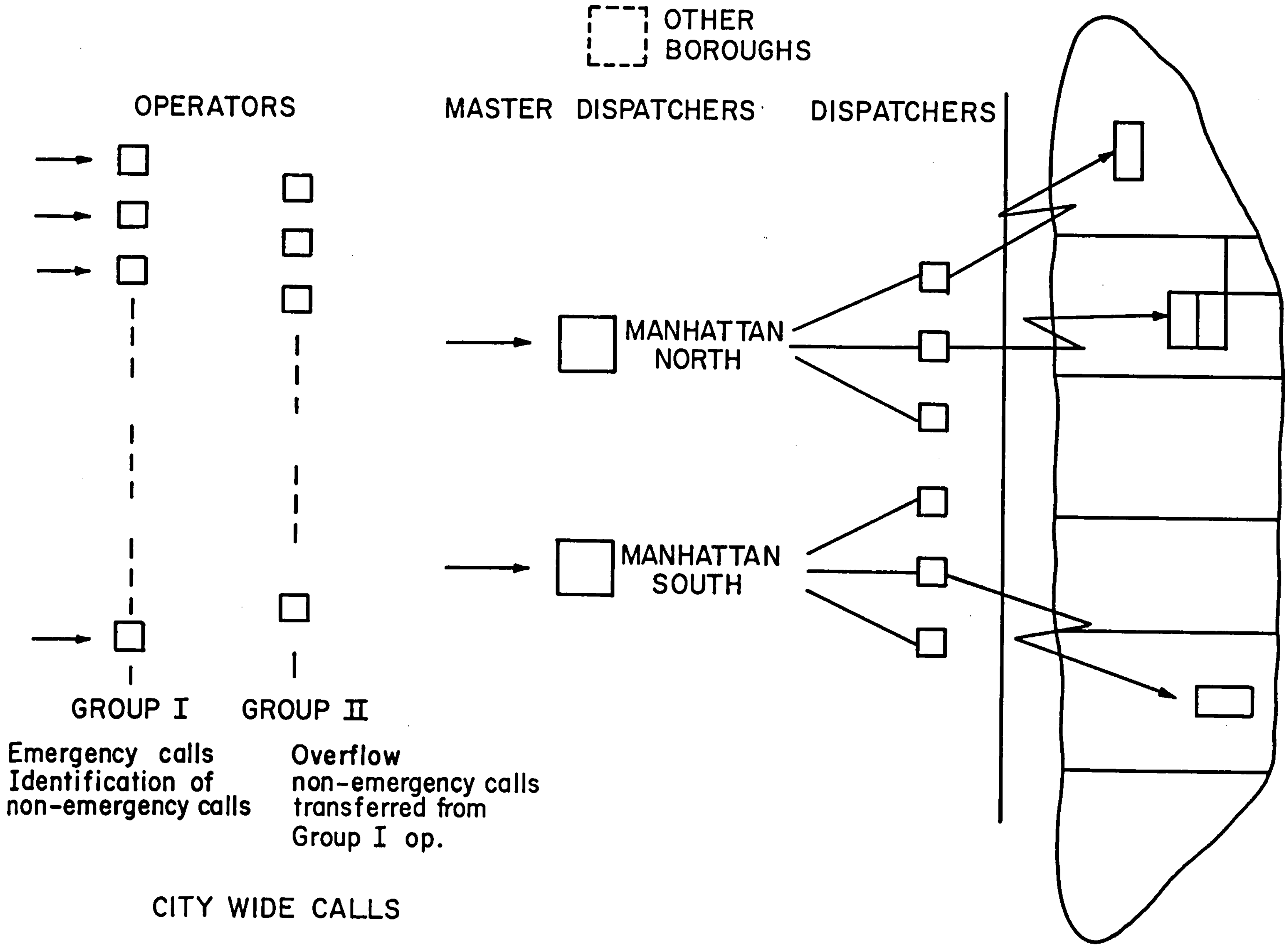


Figure 2

N.Y.C. POLICE RESPONSE SYSTEM

CHAPTER III

MODEL DESCRIPTIONS

Model Development

The initial model developed in this project concerned itself with the Communication Center as it existed prior to 1968. This model considers a single group of turret operators, no master dispatcher, only two dispatchers for all of Manhattan, and an ambulance dispatcher. It is included within this report since it represents the initial effort in the project. It may also be of interest to police departments with similar configurations.

The work on the initial model provided deeper insight into the operations of the police response system. It became evident that the resource assignment and the dispatching function were not independent of the field resource status. It was also clear that the field resource status had a major bearing on the overall response time of the police system. Thus, a more realistic view of the New York police response system could be accomplished by incorporating both the field resources and communication center functions.

In 1967, plans for reorganizing the Police Communication Center were released. They provided for the present set-up as described in the introductory section. It was decided to structure future models on the basis of the reorganized system.

From the experience gained in the initial phase, it became clear that the input processing could be viewed independently of the other two functions. Therefore, two separate models were developed:

1. The Turret Board Model (Input Processing)
2. The Dispatching-Field Resource Model (Resource Assignment and Dispatching - Field Response and Disposition)

This is a more efficient procedure than combining all three functions in one model. From a simulation point of view, since the output from the Turret Board Model provides the input to the Field Response Model, the two models can be run independent of each other, saving appreciable computer time without compromising quality of results.

TURRET BOARD MODEL

Description

The model represents the operation of the input processing sector of the Communications Center. This sector can be viewed as an independent subsystem since it is unaffected by what happens in the two other sectors: resource assignment and dispatching, field response and disposition. For a given configuration of personnel at the turret boards and a given arrival rate of calls to the communication center, the model proceeds as follows:

Calls according to the specified arrival rate are generated. Each call is assigned a type (emergency, non-emergency) according to the given percentage distribution of emergency and non-emergency calls. The model then determines the availability of a Group I turret operator. If one is available, he responds to the call. Since the model has assigned the appropriate call type, (emergency, non-emergency) the Group I turret operator designated to answer the call responds accordingly:

If it is a non-emergency call, the operator spends a random amount of time, in accordance with a given distribution, to identify it as a non-emergency call. The model then releases the Group I turret operator and refers the call to the Group II turret operators.

If the call is an emergency, the Group I turret operator requires some amount of time to converse and record the pertinent information. The time spent is determined from the distribution specified in the model. The Group I turret operator is then released and the call processing is complete. If the model finds all Group I turret operators busy at the arrival of a call, the call is transferred to the Group II turret. Priority is assigned to these transferred calls so that they are answered before the identified non-emergency calls waiting for Group II response.

These two types of calls, the identified non-emergency calls and calls which found Group I operators busy, are handled by the Group II turret operators in the following manner:

The model checks the availability of Group II turret operators; if one is available, he answers the call. If it is an emergency call, he responds spending a random amount of time according to a specified distribution. At the completion of this time, the Group II turret operator is released and the processing on the call is complete. If the call is non-emergency, the Group II turret operator spends a random amount of time indicated by the distribution corresponding to the response required for non-emergency calls. When all Group II turret operators are busy, calls transferred to them must wait (queue). Calls that found Group I turret operators busy, will be handled ahead of identified non-emergency calls.

All telephone conversations take a random amount of time. Each type, however, is distributed over a different range. Thus, the time required by a Group I turret operator to determine that a call is non-emergency will usually take less than that required by a Group II operator to dispose of such a call. The model, therefore, provides a specific time distribution, obtained from actual observations, for the duration of each type of call.

Figure 3 summarizes the model's logic.

The processing of calls in the above described manner is simulated over a period of time specified by the user. During the run, various statistics are gathered. These are useful in evaluating the performance of the system under the given input conditions. These are enumerated in the Basic Output section of this chapter.

Basic Input to the Model

The Turret Board Model of the Communication Center requires the following input information:

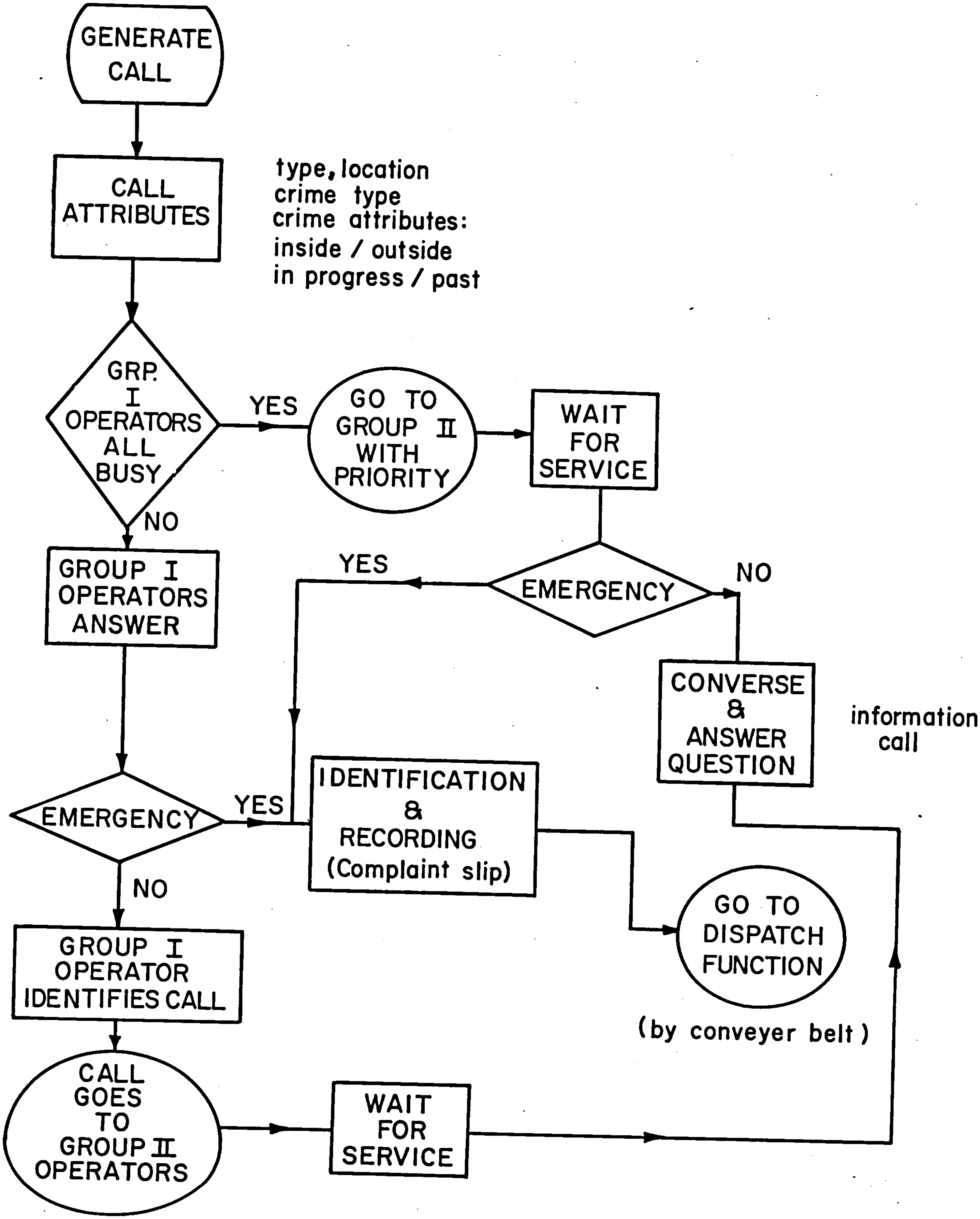


Figure 3

POLICE RESPONSE SYSTEM
INPUT PROCESSING

1. The arrival distribution of calls
2. Time distribution to identify non-emergency calls
3. Time distribution to respond to non-emergency calls
4. Time distribution to process emergency calls
5. Percentage of emergency and non-emergency calls
6. Number of Group I and Group II turret board operators

Basic Output of the Model

The Turret Board Model of the Communications Center produces the following output:

I. For each group of Turret Operators:

1. The average number busy
2. Maximum number of operators busy
3. The average utilization (and idle time) of operators
4. Number of calls handled
5. Average call handling time

II. For incoming calls:

1. Total processing time distribution for emergency calls
2. Waiting time distribution for emergency calls transferred to Group II turret operators
3. Time until processing starts on non-emergency calls (including identification by Group I turret operators and waiting time at Group II).

Results of experimentation on this model are discussed in Chapter V. A detailed explanation of the GPSS program with flow charts and complete listing of code and computer printout of results, is in Appendix A.

DISPATCHING AND FIELD RESPONSE MODEL

Description

This model represents the selection, assignment, and dispatching of field resources, the field response after dispatching, and the final disposition of the request which initiated the call. While the model structure is general and applies to all of New York City, it was limited to the Borough of Manhattan in this particular version to conserve computer time.

Some of the significant assumptions defining the scope of the model are:

1. Every call for police assistance initiates the dispatch of a single unit of field resource.
2. Different resources are dispatched depending on the type of call.
3. Priority dispatching depends on the type of call and other characteristics.
4. There is no resource interchange between divisions.
5. Multiple resource dispatching is not provided for.

The model generates calls which are assigned an emergency, non-emergency status, and point of origin if the request is an emergency call. From this point on, only Manhattan emergency calls are considered.* The crime or request type characteristics are assigned from appropriate distributions. These characteristics describe whether the crime or request is inside or outside, in progress or past. Then the call goes through the turret boards, spending an amount of time selected from a distribution generated by the Turret Board Model described earlier. Serious crimes in progress are assigned priority in terms of handling. The information pertaining to the request is then taken to the appropriate master dispatcher by a conveyor belt, where it may have to wait. High priority requests are handled first. After processing by the master dispatcher, the request is forwarded to the dispatcher responsible for the division in which the request originated, where it waits until the dispatcher is able to attend to it. The dispatcher cannot complete the handling of a request if all field resources are busy. The time it takes for the dispatcher to reach a field unit by radio is also accounted for by the model. The model then

*Non-emergencies do not require dispatching of field resources. As previously mentioned, this demonstration model was restricted to Manhattan. Other boroughs could easily be substituted or added.

assigns the time it takes for the field unit to reach the scene of the request. If the crime was in progress when reported, the model decides whether or not an arrest is made. This arrest probability depends on the time it took the field resource to respond to the call. The model accumulates this elapsed time from the moment the call is initiated up to the arrival of the field unit at the scene. The disposition is then determined by taking into account the request type and whether or not an arrest was made. After dispositions the field unit reports back to the dispatcher.

The above-described procedures are summarized in Figures 4 and 5.

The model simulates the dispatching and field disposition of the Police Response System over a time span specified by the user during which various statistics are gathered to aid the user in evaluating the performance of the system. These are enumerated in the Basic Output section of of this chapter.

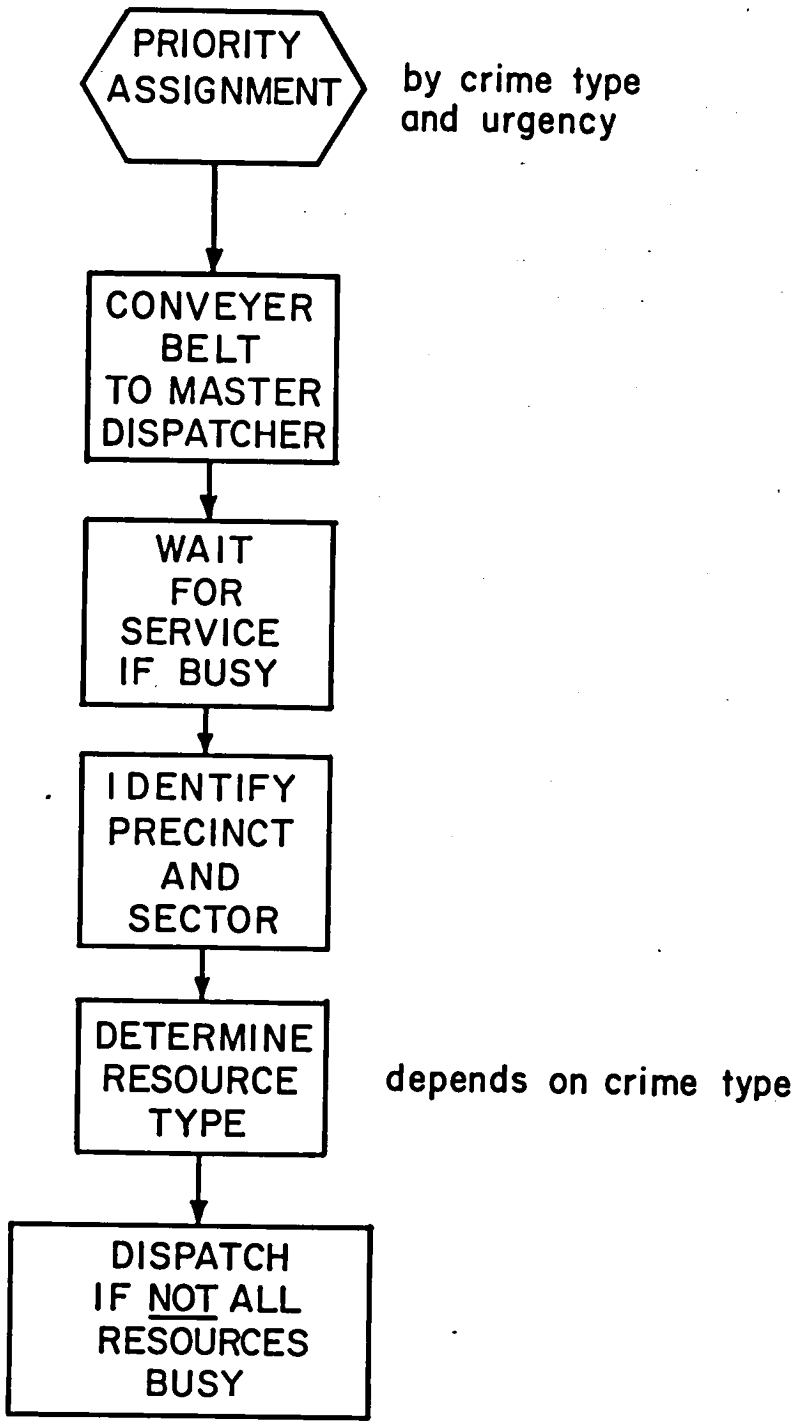


Figure 4

POLICE RESPONSE SYSTEM

RESOURCE ASSIGNMENT AND DISPATCHING

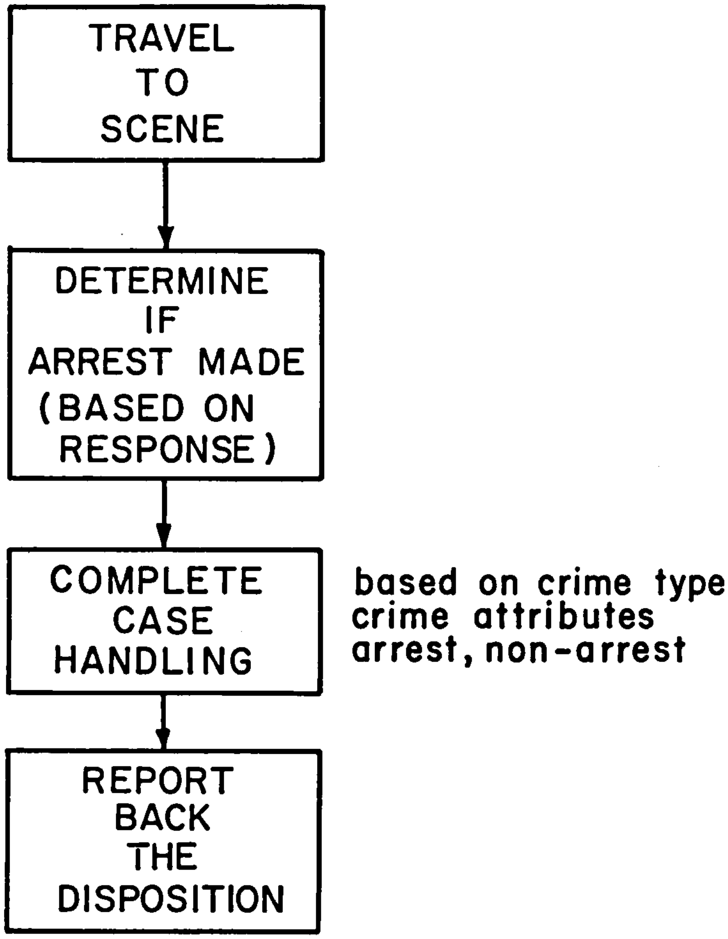


Figure 5

POLICE RESPONSE SYSTEM

FIELD RESPONSE AND DISPOSITION

Basic Input to the Model

The model requires the following distributions:

1. Time spent at the turret boards by an emergency call. (This distribution can be obtained from Table 2 of the Turret Board Model.)

2. Location and nature of call. (This input provides information concerning the breakdown of incoming calls as follows:)

a. Non-emergency calls and Non-Manhattan emergency calls.
b. Emergency calls from Manhattan Divisions (Six Divisions in Manhattan)

3. Type of Request

Given that the call is an emergency from a division in Manhattan, the frequency breakdown for various requests must be supplied:

a. murder, rape
b. felonious assault, robbery
c. burglary, grand larceny
d. grand larceny motor vehicles
e. ambulance request
f. misdemeanor
g. offense
h. non-crime request

Such a breakdown has to be supplied for each division.

4. Percent of time that request types (or crime types) occur inside or outside.

5. Percentage of time that reported crimes are in progress or past (not applicable to ambulance calls and non-crime requests)

6. Mean radio reach time as a function of resource utilization (a relationship between the number of free field units and the time it takes to reach a unit is assumed)

7. The mean travel time of a field unit to the request location as a function of resource utilization

8. Resources assigned by request type.

9. Arrest probability expressed as a function of response time

10. Mean disposition time expressed as a function of request type and arrest status

Basic Output of the Model

The following output statistics are produced:

I. For each dispatcher and master dispatcher:

1. Average utilization
2. Number of calls handled
3. Average time per call

II. For each group of field resources:

1. Average number in use
2. Average utilization (and idle time)
3. Number of calls using the resources
4. Average time in use per call

III. For all queues in the system:

1. Maximum contents
2. Average contents
3. Average time spent in queue
4. Average time spent in queue for those calls that had to wait

IV. For incoming calls:

1. Distribution of time to reach dispatcher
2. Distribution of time until dispatch. Separate tables by division and priority and a summary for all calls.
3. Distribution of time until scene reached (response time). Separate tables by division and priority and a summary for all calls.

4. Distribution of time until disposition completed (time spent in system). Separate tables by division and priority a summary for all calls.

Results of experimentation on this model are discussed in Chapter V. A detailed explanation of the GPSS program, with flow charts and complete listing of code and computer printout of results, is in Appendix B.

PRELIMINARY COMMUNICATION CENTER MODEL

Description

This model represents the Communications Center as it operated prior to the reorganization which took place during 1968. The Communications Center answered only calls from Manhattan. There was only one turret. In addition to answering calls and filling out forms for emergency calls, the turret operators were required to determine the precinct for the call, perform other clerical operations, and notify the precinct house of the call. There were no master dispatchers, and two dispatchers served all of Manhattan.

The model considers the turret board, the Manhattan North dispatcher and the ambulance dispatcher.

Calls are generated from an input distribution which include emergency, emergency with ambulance, and non-emergency calls. If a turret board operator is available, the call is handled, otherwise it waits.

Different telephone handling times are assumed for the three types of calls. Depending on the call type, the following procedures are performed:

If the call is an emergency, the call slip is sent to the dispatcher, and the turret operator spends time notifying the appropriate precinct and performs additional clerical work on the call.

If the call is an emergency with required ambulance, a copy of the call slip goes to the dispatcher and another copy is forwarded to the ambulance dispatcher. Then the turret operator proceeds to notify the appropriate precinct as in the emergency call case.

If the call is of the non-emergency type, no further operations are performed. The model only treats the Manhattan North patrol car dispatcher. However, the ambulance dispatcher handles calls for all Manhattan. The Manhattan North calls go to the dispatcher; if he is busy, they queue. The dispatcher (patrol car or ambulance) spends time reaching the appropriate resource. Then the patrol car spends time disposing of the case and reports back to the dispatcher. The same holds for the ambulance.

Basic Input to the Model

The preliminary Communication Center Model requires the following distributions:

1. The arrival rate of calls
2. Telephone handling times for different types of calls
3. Time to notify precinct
4. Radio reach times for patrol car and ambulance dispatchers
5. Disposition times for patrol cars and ambulances
6. Report-back times
7. Percentage of call types

Basic Output of the Model

The model produces the following output statistics:

I. For the Turret Operators:

1. Average number of operators busy
2. Maximum number busy
3. Average utilization (and idle time) of operators
4. Number of calls handled
5. Average call handling time

II. For the Dispatchers:

1. Average utilization (and idle time)
2. Average call handling time
3. Average number of calls in queue
4. Average waiting time of calls

III. Distributions:

1. Time between call and dispatcher
2. Time between call and completion of dispostion

Results of experimentation on this model are discussed in Chapter V. A detailed explanation of the GPSS program, with flow charts and complete listing of code and computer printout of results, is in Appendix C.

MODELING DESIGN

The modeling of a complicated urban system must be motivated by significant aspects of the system that one wishes to emphasize. In this case, the variables of major interest were response times, and utilization of personnel and equipment. It is clear that the Police Response System can be viewed as a complex queueing system. GPSS was chosen as the simulation language, since it is designed to facilitate the construction of simulation models of such service systems.

The various elements of the system must be examined to determine their effect on the system variables of interest. The elements of the Police Response System are turret board operators, master dispatchers, dispatchers (each with a radio frequency for contacting field units assigned to his division), and field units of various types (cars, scooters). These elements affect various components of response time and these components must also be delineated.

The components of response are the following:

1. Time spent by the turret operator conversing and recording information.
2. Time for conveyor belt to carry information to master dispatcher.
3. Time master dispatcher spends determining precinct and sector.
4. Time to dispatch of field unit (radio reach time).
5. Time for field unit to travel to the scene of the complaint.

Two other time components for handling the request, although not components of response time, are important. These are:

6. Time for field unit to dispose of the request.
7. Time for field unit to report back to dispatcher.

The importance of these components will become clear in the course of the discussion. Of course, all waiting times for service elements constitute important time components, but these are inherent to any queueing simulation and need not be considered here.

Some of these time components can accurately be modeled as purely random variables whose distribution is specified in the model. This is the case for Items 1, 2, 3, and 7 since their distributions are unaffected by other elements of the system.

The time required for the dispatcher to reach and dispatch a field unit was observed to be dependent upon the state of the system. If all field units are available, he need only contact the field unit assigned to the sector from which the request originated. As the number of the field units assigned to requests increases, the time required to locate a unit to respond to a request increases. This component was modeled as a family of distributions whose parameters varied as a function of field resource utilization. This dynamic interaction requires a more careful modeling of the field resource utilization and clarifies the need to consider Items 6 and 7 above. Since data on the specific nature of the distributions were unavailable and difficult to obtain, the family of distributions used in the model were exponential with the mean expressed as a function of field utilizations.

Similarly, the time to reach the scene is related to field resource utilization. The greater the number of field units assigned to requests, the greater the probability of a unit at a greater distance from the scene being assigned. Again data were unavailable and difficult to collect, and this component was also modeled as a family of exponential distributions with the mean expressed as a function of field resource utilization.

The need to model the field resource utilization requires a careful analysis of disposition times (Item 6). There are many factors which affect the time required to handle a request. The two most important factors are the type of request and whether or not an arrest is made. It was therefore important to model arrests. Studies have shown that one of the most important factors in whether or not an arrest is made, given a crime in progress, is the response time. The factors of in-progress or past, and the probability of arrest as a function of response time were also incorporated. Other factors may also affect disposition times, such as crimes occuring inside or outside. The disposition times were modeled as a family of exponential distributions with the mean as a function of request type and whether or not an arrest is made. Seven categories of request types are defined in the model.

These concepts incorporate into the model many of the dynamic interactions of the Police Response System.

An important point, which leads to increased simulation efficiency, is the fact that time components connected with turret board processing are not dynamically related to the Dispatching and Field Response sectors of the system. Given an arrival rate of calls and a level of personnel on the turret boards, processing can be described purely as a random variable having a probability distribution in no way affected by the state of the dispatchers or field units. Conversely, none of the time components connected with the Dispatching and Field Response segments of the system are influenced by the state of the Turret Board Sector. This allows for decoupling the simulation model. A Turret Board Model simulates turret board processing only. The second model incorporates the turret board processing time as a probability distribution obtained from the output of the Turret Board Model.

This decoupling proves efficient for a number of reasons. Turret board experimentation can be performed without incurring the time required to simulate dispatching and field response each time.

Then, dispatching and field response runs can be made assuming a fixed level of turret board personnel. Since these are the desired types of runs, the savings in time can be significant. A second important factor is that the Turret Board Model requires the processing of all call types, whereas the Dispatching and Field Response Model simulates emergency calls only.

CHAPTER IV

DATA COLLECTION AND ANALYSIS

In any large simulation, difficulties arise in data collection and reduction. It can readily be seen that data problems in a public service organization like the police department are immense. Since the diversity and immediate nature of their operations preclude detailed data accumulation and reduction, only skeletal data is recorded and stored. However, efforts are underway to increase the scope of data for management decisions and modeling.

For the models discussed in this report, some of the data needed was either unavailable or required a major data collection and reduction effort.

Since the basic objective of this study was to develop and demonstrate the use of simulation models, the lack of "accurate" data should be considered of a secondary nature. However, the models pinpoint the type of data necessary to structure simulation models. Thus in designing management information schemes for police activity, the type of data required for simulation models can be reduced and generated as a byproduct of these routine management reports.

The data used in the models are of a reasonable nature since whenever assumptions were made, they were deduced from related available data.

The data collection and reduction effort consisted of the following activities:

1. actual data collection
2. review of police records and reports
3. discussions with police officials

1. Actual Data Collection:

This phase of data collection was comprised of determining call handling times as they arrived at the police communications center. The data pertain to a Friday evening in March (3-28-68).

The turret board operators were observed and call types (emergency, emergency with ambulance, non-emergency) and duration were recorded. It was not possible to monitor or count all calls that came to the communications center at the time.

From the data collected the following call duration distributions were obtained:

1. Emergency Calls (Figure 29)
2. Emergency with Ambulance (Figure 30)
3. Non-emergency Calls (Figure 31)

These distributions form the basis for the call duration times used in the Turret Board Model. (Figures 32, 33)

During the same evening the dispatchers were also observed to obtain data on radio reach times. It is extremely difficult to obtain quantitative data due to the level of activity in the dispatching area. These observations were useful in forming an impression for the distribution relating radio reach times to resource utilization. (At approximately 50% utilization the mean radio reach time was 25 seconds).

2. <u>Data From Records and Reports</u>

From discussions and the study of yearly data it was established that a Friday evening in July would be a representative time to study peak period demands on the police response system. July 21, 1967 was chosen as the day for which police records (CRD-7 slips) would be studied.

From these records, number of emergency calls and ambulance requests by division and by time of day were tabulated for Manhattan and Brooklyn. Number of daily calls from the other boroughs was also recorded.

This information was used in establishing the origin and frequency of emergency calls. The data also aided in determining the frequency of one request type ambulance calls.

From "The Statistical Report of Crime and Related Activity NYC Police Department (July 1967)", divisional crime frequency counts as well as frequency of crimes committed inside and outside were extracted.

From 20th Precinct (Manhattan) Management Reports, disposition times on crime types were obtained.

a. <u>Data from Police Records July 21, 1967</u>

The CRD-7 slips were tabulated by division (Manhattan) by hour for emergency and ambulance calls. The data are recorded and displayed in the following manner.

Column 1:	Hour of day
Column 2:	Number of emergency calls not including ambulance requests
Column 3:	Number of abulance calls
Column 4:	Total number of emergency calls (sum of columns 2 and 3)
Column 5:	Hourly percent of daily emergency calls (column 4 divided by daily total of column 4 expressed as percent)
Column 6:	Percent ambulance calls (column 3 divided by column 4 expressed as percent)

1st. Div. (1,4,5,6,7)

Hour	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.
Midnte.	13	3	16	5.1	18.8
1 a.m.	9	-	9	3.1	-
2 a.m.	9	1	10	3.4	10.0
3 a.m.	7	1	8	2.7	12.5
4 a.m.	3	1	4	1.4	25.0
5 a.m.	4	-	4	1.4	-
6 a.m.	1	-	1	.34	-
7 a.m.	2	-	2	.68	-
8 a.m.	5	2	7	2.4	28.6
9 a.m.	8	1	9	3.1	11.1
10 a.m.	9	5	14	4.8	35.7
11 a.m.	8	3	11	3.7	27.3
Noon	7	4	11	3.7	36.4
1 p.m.	10	3	13	4.4	23.1
2 p.m.	6	3	9	3.1	33.3
3 p.m.	10	2	12	4.1	16.7
4 p.m.	12	3	15	5.1	20.0
5 p.m.	9	4	13	4.4	30.8
6 p.m.	14	3	17	5.8	17.8
7 p.m.	17	10	27	9.2	37.0
8 p.m.	15	5	20	6.8	25.0
9 p.m.	12	2	14	4.8	14.3
10 p.m.	18	5	23	7.8	21.8
11 p.m.	19	5	24	8.2	20.8
	227	66	293		

TABLE 1

2nd. Div. (9,10,13,14)

Hour	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.
Midnte.	24	3	27	5.8	11.1
1 a.m.	8	1	9	1.9	11.1
2 a.m.	11	2	13	2.8	15.4
3 a.m.	9	2	11	2.4	18.2
4 a.m.	7	-	7	1.5	-
5 a.m.	4	-	4	.9	-
6 a.m.	6	1	7	1.5	14.3
7 a.m.	10	1	11	2.4	9.1
8 a.m.	12	4	16	3.5	25.0
9 a.m.	11	4	15	3.2	26.7
10 a.m.	17	5	22	4.8	22.7
11 a.m.	8	1	9	1.9	11.1
Noon	11	4	15	3.2	26.7
1 p.m.	22	5	27	5.8	18.5
2 p.m.	19	5	24	5.2	20.8
3 p.m.	24	9	33	7.1	27.2
4 p.m.	25	9	34	7.4	26.5
5 p.m.	22	4	26	5.6	15.4
6 p.m.	19	4	23	5.0	17.4
7 p.m.	22	7	29	6.3	24.2
8 p.m.	13	2	15	3.2	13.3
9 p.m.	24	5	29	6.3	17.2
10 p.m.	25	7	32	6.9	21.8
11 p.m.	24	-	24	5.2	-
	377	85	462		

TABLE 2

DISTRIBUTION OF CALLS

Hour	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.
	3rd. Div. (16,17,18)				
Midnte.	10	1	11	5.0	9.1
1 a.m.	7	2	9	4.1	22.2
2 a.m.	6	2	8	3.7	25.0
3 a.m.	5	2	7	3.2	28.6
4 a.m.	2	-	2	.9	-
5 a.m.	2	-	2	.9	-
6 a.m.	3	1	4	1.8	25.0
7 a.m.	3	-	3	1.4	-
8 a.m.	7	-	7	3.2	-
9 a.m.	6	2	8	3.7	25.0
10 a.m.	9	-	9	4.1	-
11 a.m.	6	1	7	3.2	14.3
Noon	3	1	4	1.8	25.0
1 p.m.	9	-	9	4.1	-
2 p.m.	12	4	16	7.3	25.0
3 p.m.	8	5	13	6.0	38.2
4 p.m.	7	2	9	4.1	22.2
5 p.m.	7	2	9	4.1	22.2
6 p.m.	11	1	12	5.5	8.4
7 p.m.	13	1	14	6.4	7.1
8 p.m.	4	-	4	1.8	-
9 p.m.	10	5	15	6.9	33.3
10 p.m.	14	1	15	6.9	6.7
11 p.m.	21	-	21	9.6	-
	185	33	218		

TABLE 3

Hour	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.
	4th. Div. (19,20,22,23)				
Midnte.	18	1	19	4.8	5.3
1 a.m.	13	3	16	4.0	18.8
2 a.m.	3	1	4	1.0	25.0
3 a.m.	2	1	3	.8	33.3
4 a.m.	6	-	6	1.5	-
5 a.m.	3	4	7	1.8	57.1
6 a.m.	4	1	5	1.3	20.0
7 a.m.	6	1	7	1.8	14.3
8 a.m.	7	4	11	2.8	36.4
9 a.m.	13	-	13	3.3	-
10 a.m.	10	5	15	3.8	33.3
11 a.m.	11	7	18	4.5	38.9
Noon	14	2	16	4.0	12.5
1 p.m.	12	4	16	4.0	25.0
2 p.m.	17	5	22	5.5	22.7
3 p.m.	18	6	24	6.0	25.0
4 p.m.	36	7	43	10.8	16.3
5 p.m.	25	4	29	7.3	13.8
6 p.m.	18	3	21	5.3	14.3
7 p.m.	15	6	21	5.3	28.6
8 p.m.	13	3	16	4.0	18.8
9 p.m.	18	3	21	5.3	14.3
10 p.m.	21	3	24	6.0	12.5
11 p.m.	21	1	22	5.5	4.5
	324	75	399		

TABLE 4

DISTRIBUTION OF CALLS

	5th. Div. (24,26,30,34)					6th. Div. (25,28,32)				
Hour	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.
Midnite	13	4	17	3.9	23.5	17	2	19	4.3	10.5
1 a.m.	15	5	20	4.6	25.0	25	4	29	6.6	13.8
2 a.m.	11	2	13	3.0	15.4	9	-	9	2.1	-
3 a.m.	5	-	5	1.2	-	4	-	4	.9	-
4 a.m.	9	1	10	2.3	10.0	6	-	6	1.4	-
5 a.m.	9	1	10	2.3	10.0	5	-	5	1.1	-
6 a.m.	4	-	4	.9	-	5	3	8	1.8	37.5
7 a.m.	4	1	5	1.2	20.0	6	3	9	2.1	33.3
8 a.m.	6	2	8	1.8	20.0	8	3	11	2.5	27.3
9 a.m.	16	2	18	4.2	11.1	8	3	11	2.5	27.3
10 a.m.	10	2	12	2.8	16.7	9	2	11	2.5	18.2
11 a.m.	12	4	16	3.7	25.0	17	6	23	5.2	26.1
Noon	10	3	13	3.0	23.1	10	3	13	3.0	23.1
1 p.m.	15	4	19	4.4	21.0	17	10	27	6.1	37.0
2 p.m.	10	1	11	2.5	9.1	20	9	29	6.6	31.0
3 p.m.	17	4	21	4.8	19.0	8	2	10	2.3	20.0
4 p.m.	26	2	28	6.5	7.1	19	9	28	6.4	32.2
5 p.m.	21	3	24	5.5	12.5	24	5	29	6.6	17.2
6 p.m.	26	9	35	8.1	25.7	21	6	27	6.1	22.2
7 p.m.	21	2	23	5.3	8.7	25	3	28	6.4	10.7
8 p.m.	27	4	31	7.2	12.9	20	2	22	5.0	9.1
9 p.m.	25	5	30	6.9	16.7	26	4	30	6.8	13.3
10 p.m.	29	6	35	8.1	17.1	20	13	33	7.5	39.4
11 p.m.	22	3	25	5.8	12.0	14	4	18	4.1	22.2
	363	70	433			343	96	439		

TABLE 5 TABLE 6

DISTRIBUTION OF CALLS

ALL MANHATTAN

Hour	# Radio Calls	# Amb. Calls	Total	Hourly %	% Amb.
Midnite	95	14	109	4.9	12.8
1 a.m.	77	15	92	4.1	16.3
2 a.m.	49	8	57	2.5	14.0
3 a.m.	32	6	38	1.7	15.8
4 a.m.	33	2	35	1.6	5.7
5 a.m.	27	5	32	1.4	15.6
6 a.m.	23	6	29	1.3	20.7
7 a.m.	31	6	37	1.6	16.2
8 a.m.	45	15	60	2.7	25.0
9 a.m.	62	12	74	3.3	16.2
10 a.m.	64	19	83	3.7	22.9
11 a.m.	62	22	84	3.7	26.2
Noon	55	17	72	3.2	23.6
1 p.m.	85	26	111	4.9	23.4
2 p.m.	84	27	111	4.9	24.3
3 p.m.	85	28	113	5.0	24.8
4 p.m.	125	32	157	7.0	20.4
5 p.m.	108	22	130	5.8	16.9
6 p.m.	109	26	135	6.0	19.3
7 p.m.	113	29	142	6.3	20.4
8 p.m.	92	16	108	4.8	14.8
9 p.m.	115	24	139	6.2	17.3
10 p.m.	127	35	162	7.2	21.6
11 p.m.	121	13	134	6.0	9.7
	1819	425	2244		

TABLE 7

DISTRIBUTION OF CALLS

TOTAL COUNT BY BOROUGHS

BOROUGH	EMERGENCY	EMERGENCY WITH AMBULANCE	TOTAL
MANHATTAN	1,819	425	2,244
BROOKLYN	1,491	441	1,932
BRONX	836	227	1,063
QUEENS	1,075	225	1,300
RICHMOND	288	26	314

TABLE 8

b. Divisional Crime and Related Activities From Police Reports

To obtain data on divisional police activity in the Borough of Manhattan, "The Statistical Report of Crime and Related Activity, New York City Police Department (July 1967)" was used:

Division 1	No. in July 1967	
Murder and Rape	10	
Robbery and Felonious Assault	202	
Burglary and Grand Larceny	1,185	
Grand Larceny Motor Vehicles	154	
Misdemeanors	1,889	
Offenses	721	
		4,161

Division 2		
Murder and Rape	17	
Robbery and Felonious Assault	379	
Burglary and Grand Larceny	2,245	
Grand Larceny Motor Vehicles	200	
Misdemeanors	1,784	
Offenses	452	
		5,077

Division 3	No. in July 1967	
Murder and Rape	8	
Robbery and Felonious Assault	234	
Burglary and Grand Larceny	1,646	
Grand Larceny Motor Vehicles	135	
Misdemeanors	1,716	
Offenses	852	
		4,591
Division 4		
Murder and Rape	14	
Robbery and Felonious Assault	340	
Burglary and Grand Larceny	1,606	
Grand Larceny Motor Vehicles	164	
Misdemeanors	1,833	
Offenses	728	
		4,683
Division 5		
Murder and Rape	22	
Robbery and Felonious Assault	439	
Burglary and Grand Larceny	1,194	
Grand Larceny Motor Vehicles	135	
Misdemeanors	2,055	
Offenses	181	
		4,024
Division 6		
Murder and Rape	33	
Robbery and Felonious Assault	891	
Burglary and Grand Larceny	1,208	
Grand Larceny Motor Vehicles	114	
Misdemeanors	1,801	
Offenses	305	
		4,352
	Total All Manhattan	26,888

TABLE 9

The information presented so far was used to arrive at the following input distributions and parameters:

1. Breakdown of total calls into emergency calls by division in Manhattan and other calls. (non-emergency)
2. Breakdown of emergency calls by request type by division in Manhattan.
3. Total number of peak hour calls.

From the total monthly Manhattan felonies (Table 9) an attempt was made to determine the number of peak hour crime request calls. These constitute request types 1 through 4 and 6, 7. These are the only request types reported in figures given in Table 9.

From Table 7, the peak hour was determined to be between 10 pm and 11 pm. The number of emergency calls during this peak hour was 162 (7.2% of daily total).

An estimate of daily crime-request calls was made, 867 calls. This assumes that there is no significant daily variation throughout the month on crime requests.

To obtain peak hour crime request calls:

$$(867)\ (0.072) = 63 \text{ calls}$$

Total number of emergency calls are made of crime requests, non-crime requests (request type 8) and ambulance requests.

For ambulance calls during the peak hour 20% was used. (actual for July 21, 1967, 21.6%)

The non-crime request percentage was calculated indirectly as follows:

$$63+(A+N)162=162$$

A = Fraction of ambulance requests = 0.2

N = Fraction of non-crime requests

Solving for N, we obtain

$$N = .411$$

40% was used for non-crime requests during the peak hour.

Using these percentages we can estimate total number of emergency calls for the month for Manhattan.

These are calculated as follows:

Crime request calls (Table 9) are divided by 1-(A+N) give monthly emergency calls.

Monthly Emergency Calls

Div. 1	Div. 2	Div. 3	Div. 4	Div. 5	Div. 6
10,400	12,680	11,470	11,710	10,050	10,880

TABLE 10

These monthly calls can be used to calculate an estimate of peak hour emergency calls by division. (Results rounded to next higher integer).

Div. 1	Div. 2	Div. 3	Div. 4	Div. 5	Div. 6
25	30	27	28	24	26

TABLE 10 A

To obtain the breakdown of total calls into emergency calls by division in Manhattan and other calls, the percent non-emergency calls has to be estimated.

After discussion with police officials, this was set at 30% of all incoming calls.

In addition, the percent of non-Manhattan emergency calls have to be assumed. This was approximated by studying the boroughs of Manhattan and Brooklyn. In Manhattan 7.27% of daily emergency calls occurred during the peak hour and in Brooklyn 8.2% of daily emergency calls occurred during the peak hour. An estimate for peak-hour emergency calls were made for the other boroughs taking 7.7% of daily emergency calls during the peak hour.

Manhattan		162	
Brooklyn		159	
Queens		100	1300 X .077
Bronx		82	1063 X .077
Richmond		24	31.4 X .077
	Total	527	

The total number of calls was estimated by using total number of emergency calls and the percent of non-emergency calls (30%):

$$\frac{527}{1-.30} = 750 \text{ calls}$$

To calculate emergency calls as a percent of all calls by division, figures of Table 10 A must be divided by total number of calls (750).

Emergency call Percentages for Manhattan

Div. 1	Div. 2	Div. 3	Div. 4	Div. 5	Div. 6
3.3	4.0	3.6	3.7	3.2	3.5

Note: Non-emergency 30%

Non-Manhattan emergency 48.7%

Using the figures of Table 10 and the appropriate divisional crime type breakdowns in Table 9, the breakdown of emergency calls by request type for each division can be obtained.

BREAKDOWN OF % CRIME TYPE REQUESTS

CRIME TYPE	DIV. 1 NO.	DIV. 1 %	DIV. 2 NO.	DIV. 2 %	DIV. 3 NO.	DIV. 3 %	DIV. 4 NO.	DIV. 4 %	DIV. 5 NO.	DIV. 5 %	DIV. 6 NO.	DIV. 6 %
Murder & Rape	10	.10	17	.13	8	.07	14	.12	22	.22	33	.30
Robbery & Fel. Assault	202	1.9	379	3.0	234	2.0	340	2.9	439	4.4	891	8.2
Burglary & Grand Larceny	1185	11.4	2245	17.7	1646	14.3	1606	13.7	1194	11.9	1208	11.1
Grand Larceny M.V.	154	1.5	200	1.6	135	1.2	164	1.4	135	1.3	114	1.0
Misdemeanors	1889	18.2	1784	14.1	1716	15.0	1833	15.6	2055	20.3	1801	16.4
Offenses	721	6.9	452	3.6	852	7.4	728	6.2	181	1.8	305	2.8
Total Emergency Calls	10,400		12,680		11,710		11,710		10,050		10,880	

TABLE 11

Note: The ambulance request percentage was set at 20 and other non-crime request percentage was set at 40. The mean inter-arrival time for all incoming calls is calculated from:

$$3600 \text{ sec/hr} \div 750 \text{ calls} = 4.8 \text{ seconds}$$

CHAPTER V

MODEL EXPERIMENTATION

Turret Board Model

A set of simulation runs was made to demonstrate some of the possible application areas of the model. The objective of these runs was to explore the performance of the system under varying input levels and under varying manpower levels.

The input levels selected were:

Average Interarrival Time

(Time between calls)

3.0 sec.	(1200 calls per hour)
4.8 sec.	(750 calls per hour)
6.0 sec.	(600 calls per hour)

For each of the above input levels runs were made where the number of operators in Group II remained constant (20) and the number of Group I operators was varied.

The results were summarized as follows:

1. Average utilization of Group I operators (Figure 6)
2. Average utilization of Group II operators (Figure 7)
3. Number of operators in Group II busy 95% of the time (Figure 8)
4. Maximum number of operators busy on Turret II (Figure 9)
5. Sum of maximum number of operators busy on Turret I and Turret II (Figure 10)
6. Cumulative distributions of time that emergency calls spent in the system (Figures 11-13)
7. Per cent of emergency calls that had to wait. (For 3.0 second interarrival time only). (Figure 14)

The average utilization figures give an insight to the effect of varying the number of Group I operators under different inter-arrival times.

Figure 8 indicates the estimated number of Group II operators that would be needed to provide service without delay 95% of the time for a given number of Group I turret operators.

Figure 9 indicates the number of Group II operators needed to service without delay all of the incoming calls.

The cumulative distributions pertaining to time spent in the system by emergency calls for 5, 11, 18 Group I turret operators do not indicate much variation.

For a heavy incoming load of calls (1200 calls/hr.), the effect of increasing the number of Group I turret operators is clearly shown in Figure 14.

A second set of simulation runs were made with a constant level of manpower (20) but allocated in different patterns among the two turret boards.

The patterns used were:

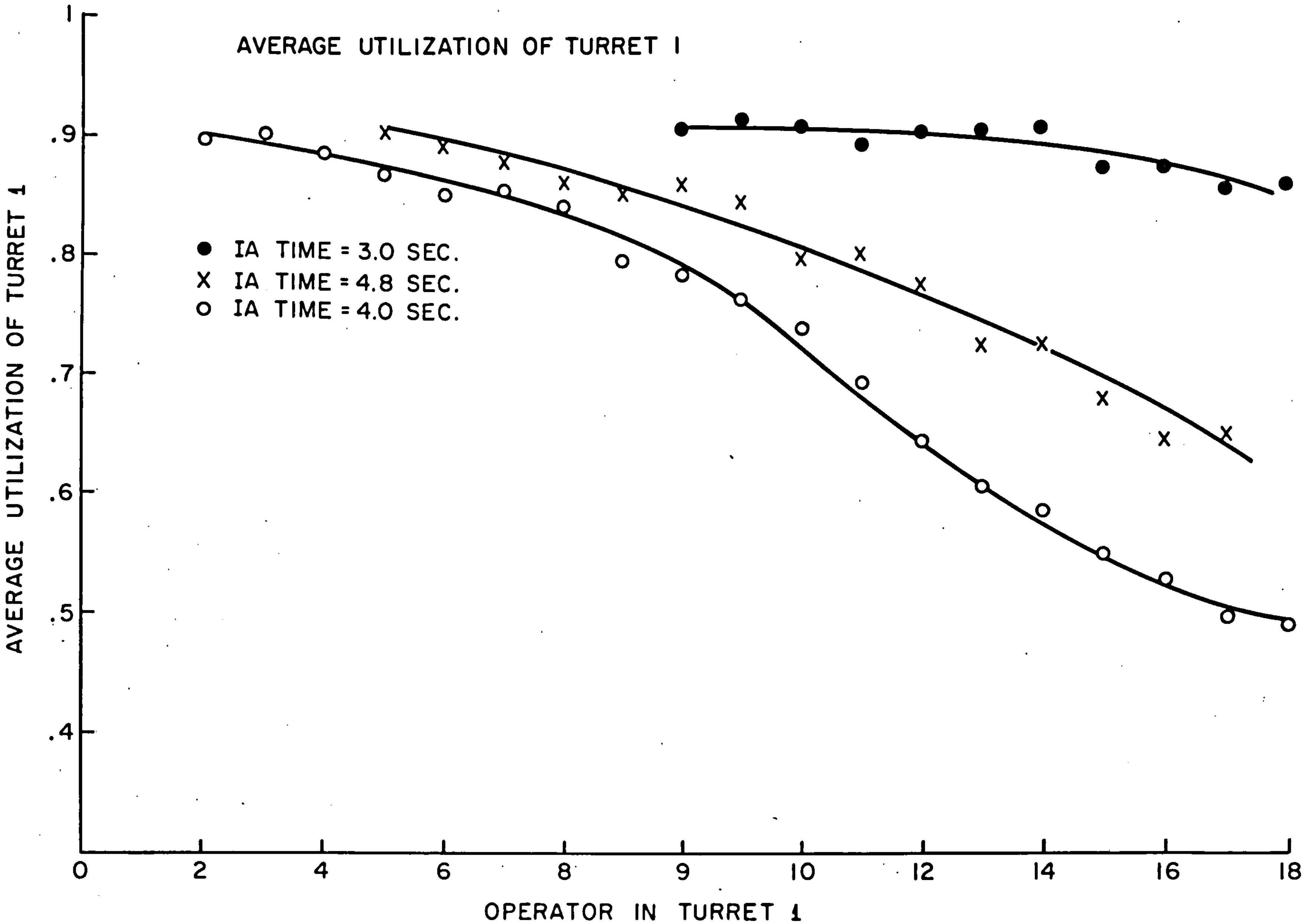
	Turret I	Turret II
1.	5	15
2.	8	12
3.	12	8
4.	15	5

The hourly arrival rate of calls: 750

Attention was focussed on:

a. Percent of emergency calls that waited (Figure 15)
b. Mean waiting time for emergency calls that waited (Figure 16)
c. Mean waiting time for non-emergency calls (including identification time) (Figure 17)

FIGURE 6


AVERAGE UTILIZATION OF TURRET I
● IA TIME = 3.0 SEC.
X IA TIME = 4.8 SEC.
O IA TIME = 4.0 SEC.
AVERAGE UTILIZATION OF TURRET 1
1
.9
.8
.7
.6
.5
.4
0
2
4
6
8
9
10
12
14
16
18
OPERATOR IN TURRET 1

AVERAGE UTILIZATION OF TURRET 2

FIGURE 7

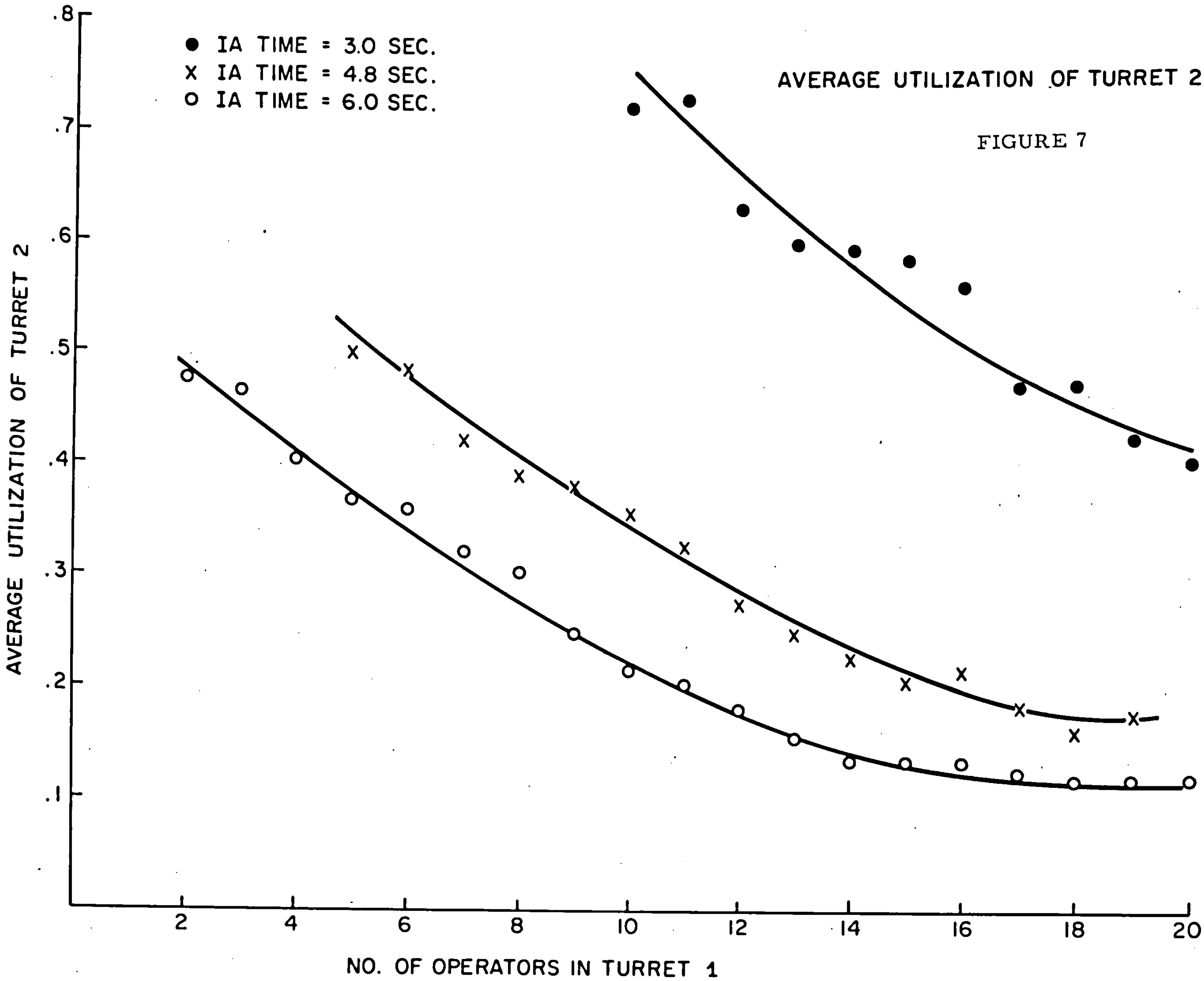
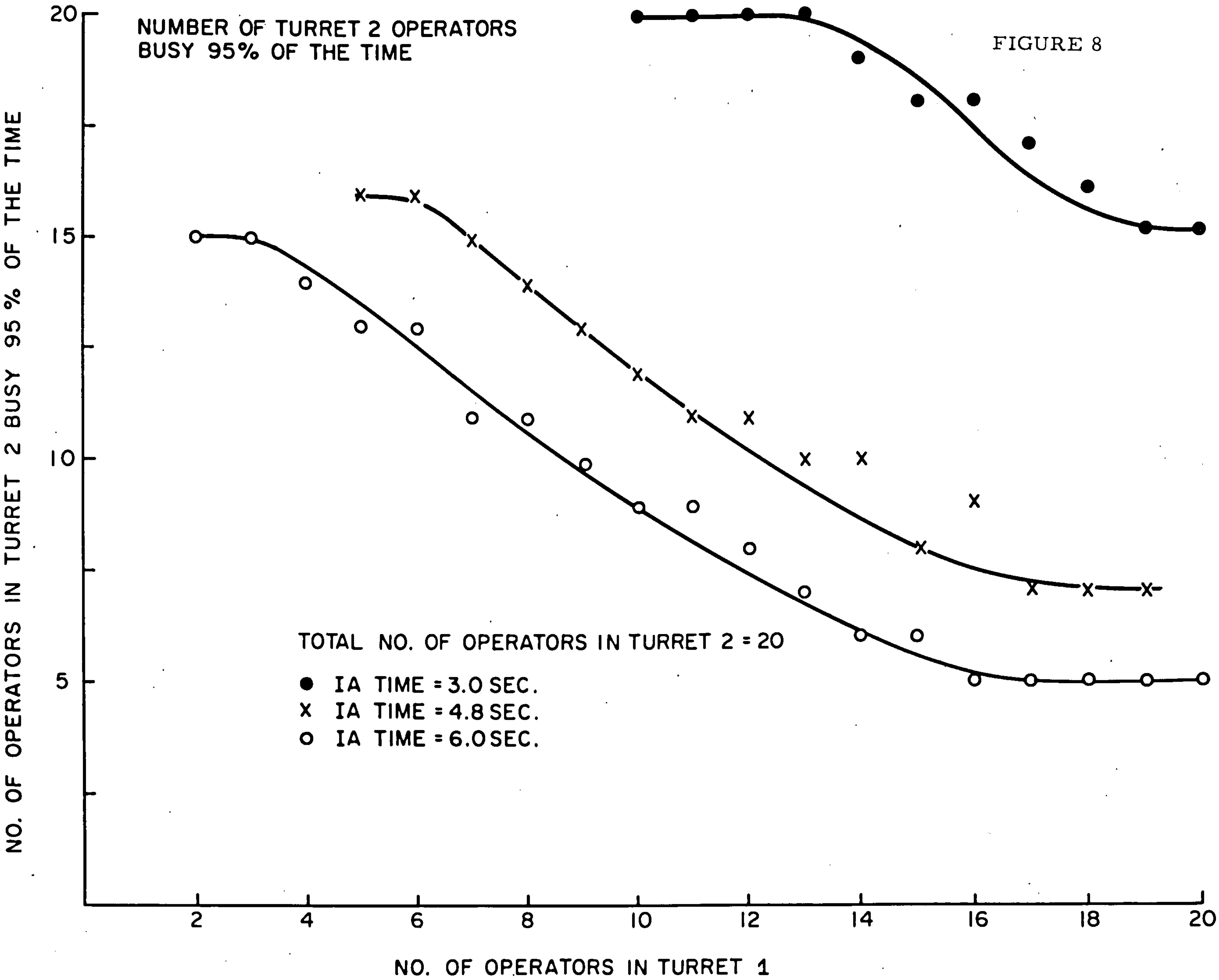


FIGURE 8


NUMBER OF TURRET 2 OPERATORS
BUSY 95% OF THE TIME
TOTAL NO. OF OPERATORS IN TURRET 2 = 20
● IA TIME = 3.0 SEC.
x IA TIME = 4.8 SEC.
o IA TIME = 6.0 SEC.
NO. OF OPERATORS IN TURRET 2 BUSY 95 % OF THE TIME
20
15
10
5
2
4
6
8
10
12
14
16
18
20
NO. OF OPERATORS IN TURRET 1

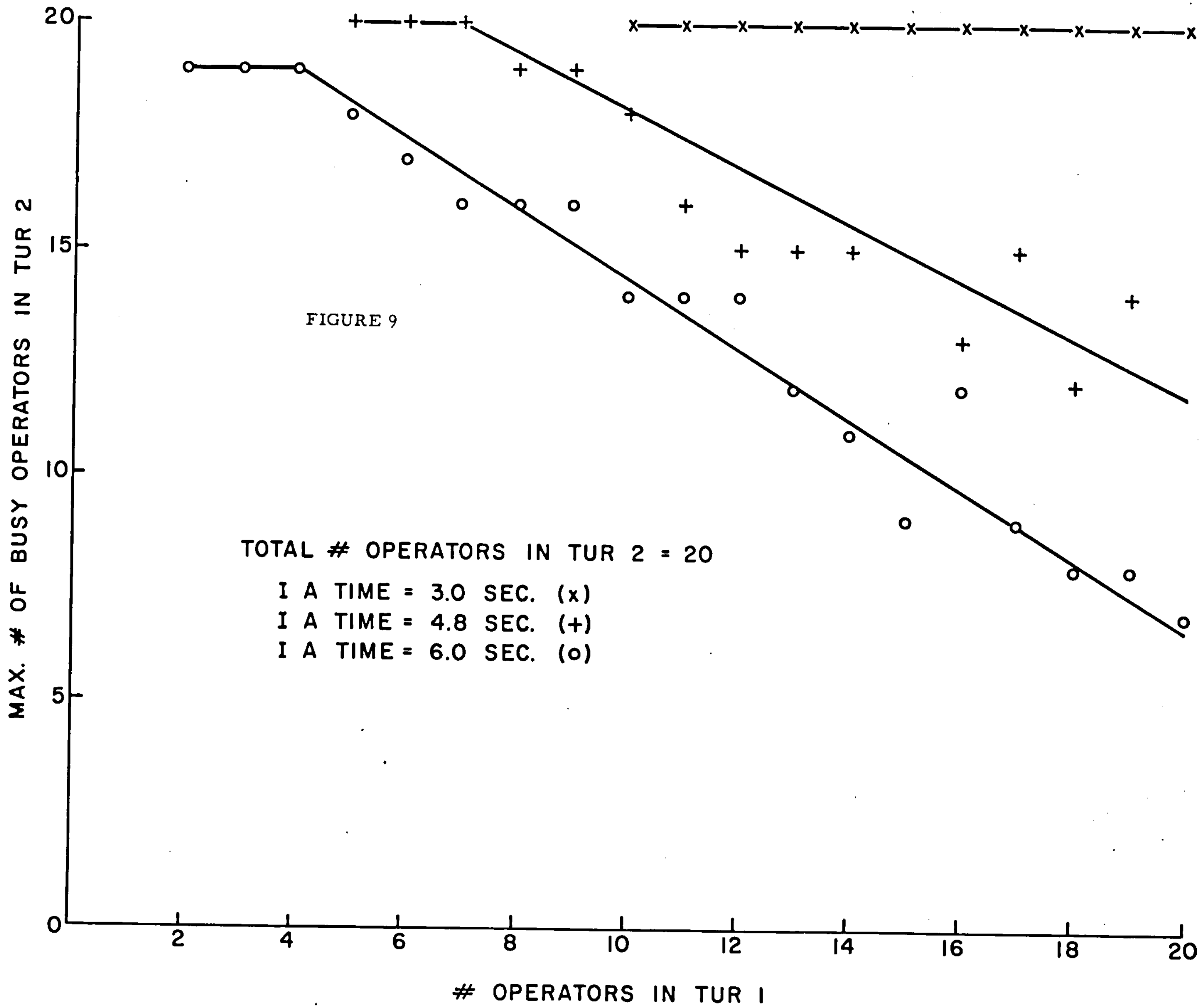
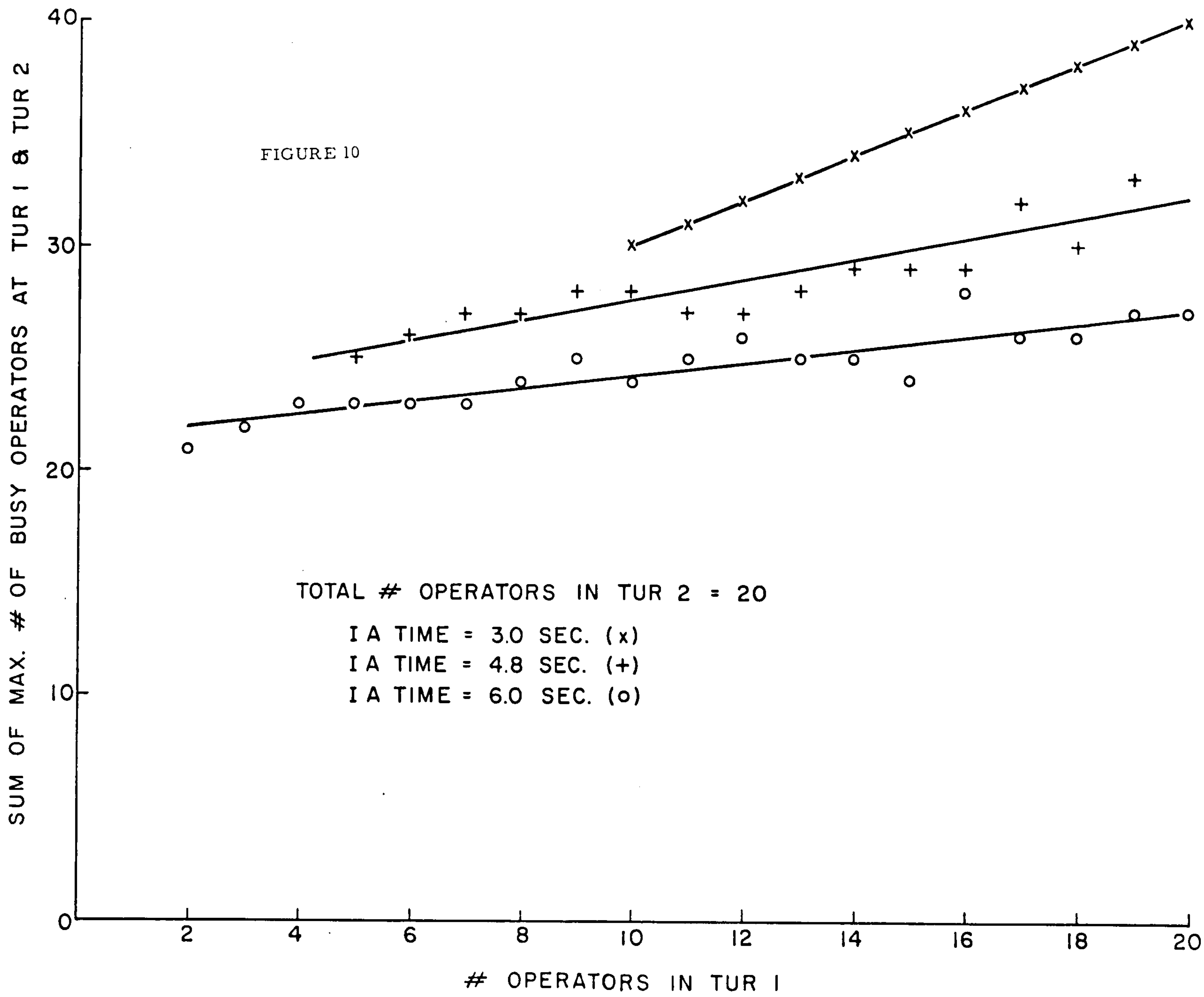

20
15
10
5
0
2
4
6
8
10
12
14
16
18
20
MAX. # OF BUSY OPERATORS IN TUR 2
OPERATORS IN TUR I
TOTAL # OPERATORS IN TUR 2 = 20
I A TIME = 3.0 SEC. (x)
I A TIME = 4.8 SEC. (+)
I A TIME = 6.0 SEC. (o)

FIGURE 9

FIGURE 10



40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
SUM OF MAX. # OF BUSY OPERATORS AT TUR 1 & TUR 2
OPERATORS IN TUR 1
TOTAL # OPERATORS IN TUR 2 = 20
I A TIME = 3.0 SEC. (x)
I A TIME = 4.8 SEC. (+)
I A TIME = 6.0 SEC. (o)

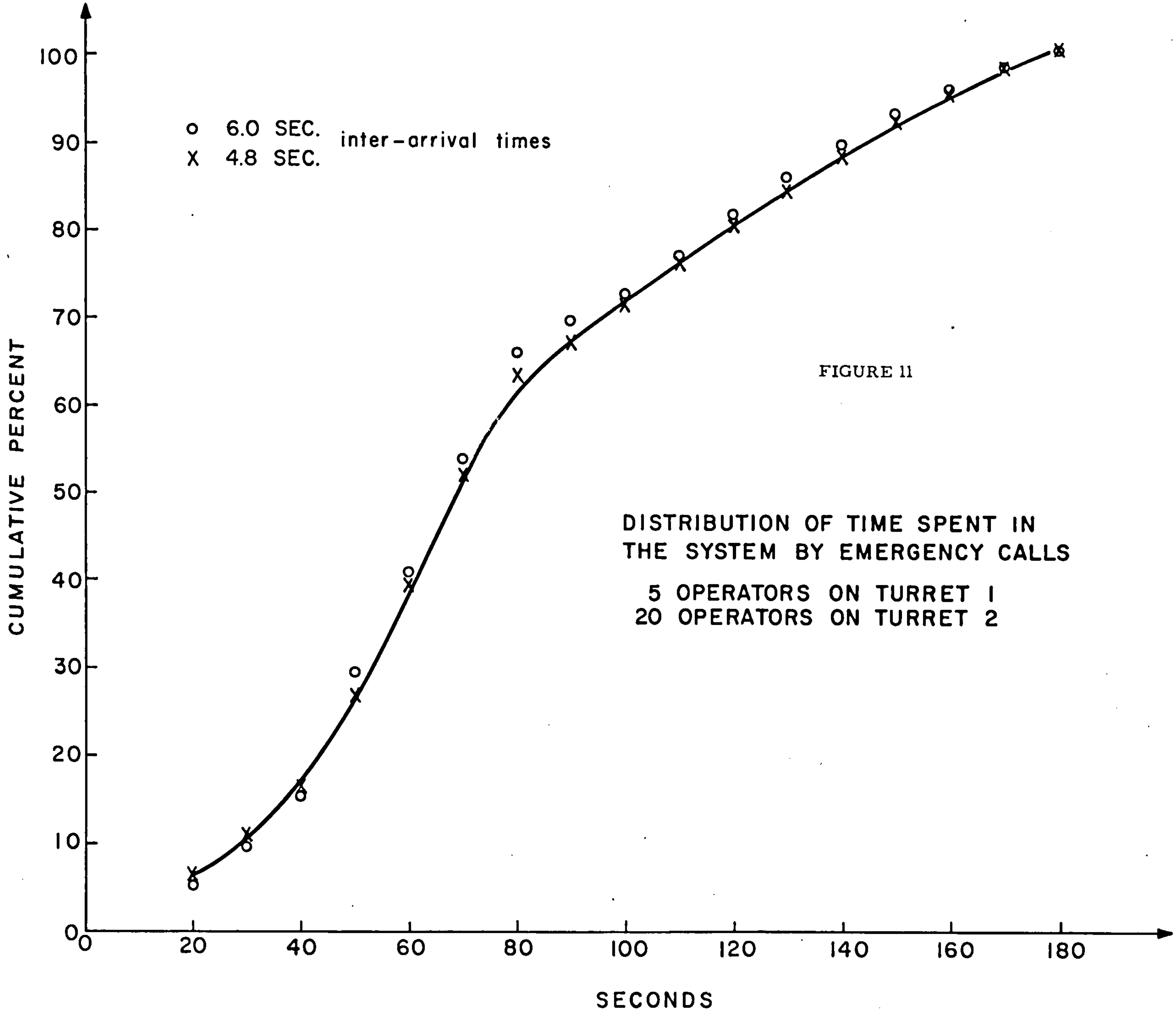
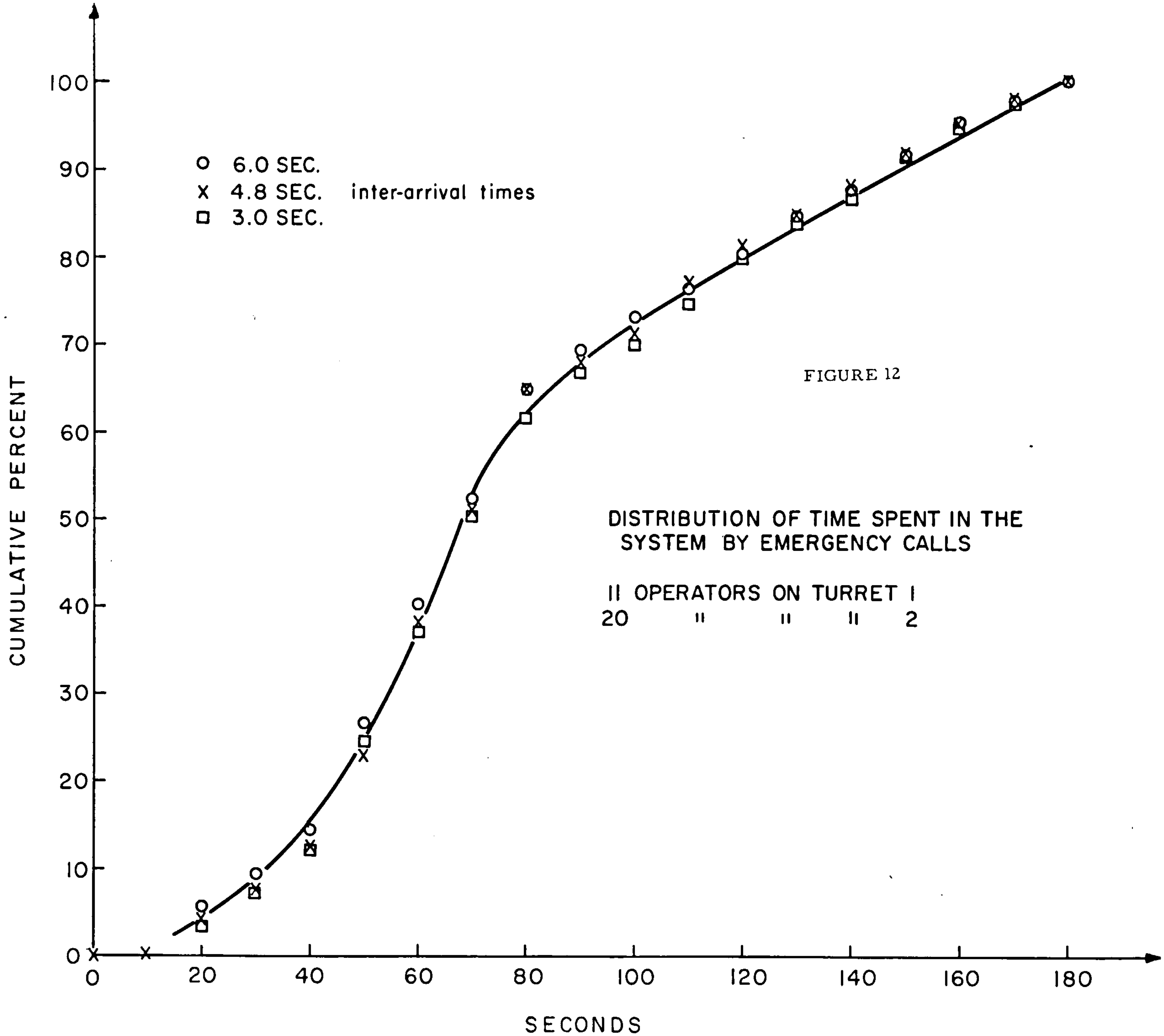

DISTRIBUTION OF TIME SPENT IN
THE SYSTEM BY EMERGENCY CALLS
5 OPERATORS ON TURRET 1
20 OPERATORS ON TURRET 2
o 6.0 SEC.
X 4.8 SEC.
inter-arrival times
CUMULATIVE PERCENT
SECONDS
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180

FIGURE 11



o 6.0 SEC.
x 4.8 SEC. inter-arrival times
□ 3.0 SEC.
DISTRIBUTION OF TIME SPENT IN THE SYSTEM BY EMERGENCY CALLS
11 OPERATORS ON TURRET 1
20 " " " 2
CUMULATIVE PERCENT
SECONDS
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180

FIGURE 12

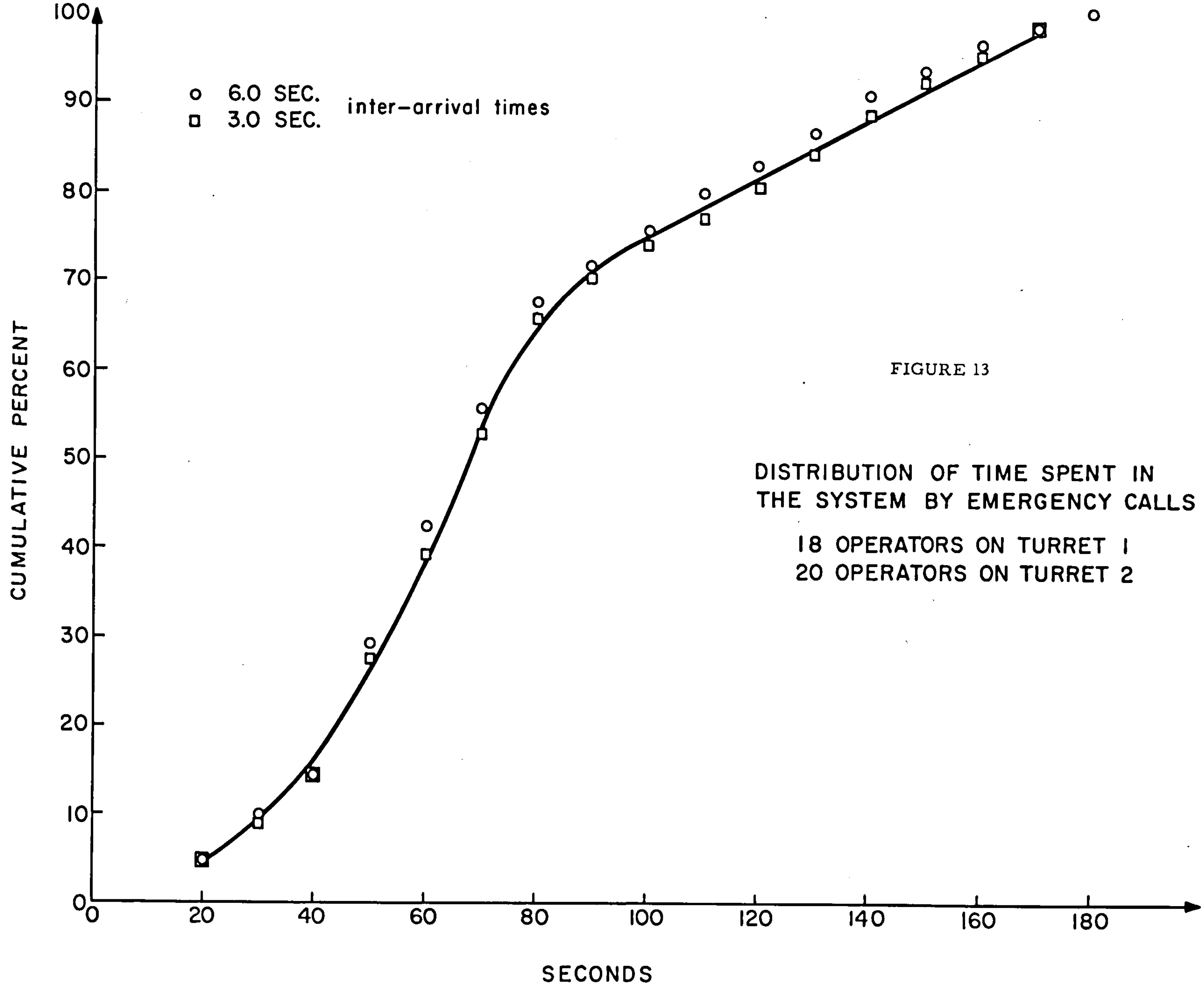


FIGURE 13

DISTRIBUTION OF TIME SPENT IN THE SYSTEM BY EMERGENCY CALLS

18 OPERATORS ON TURRET 1
20 OPERATORS ON TURRET 2

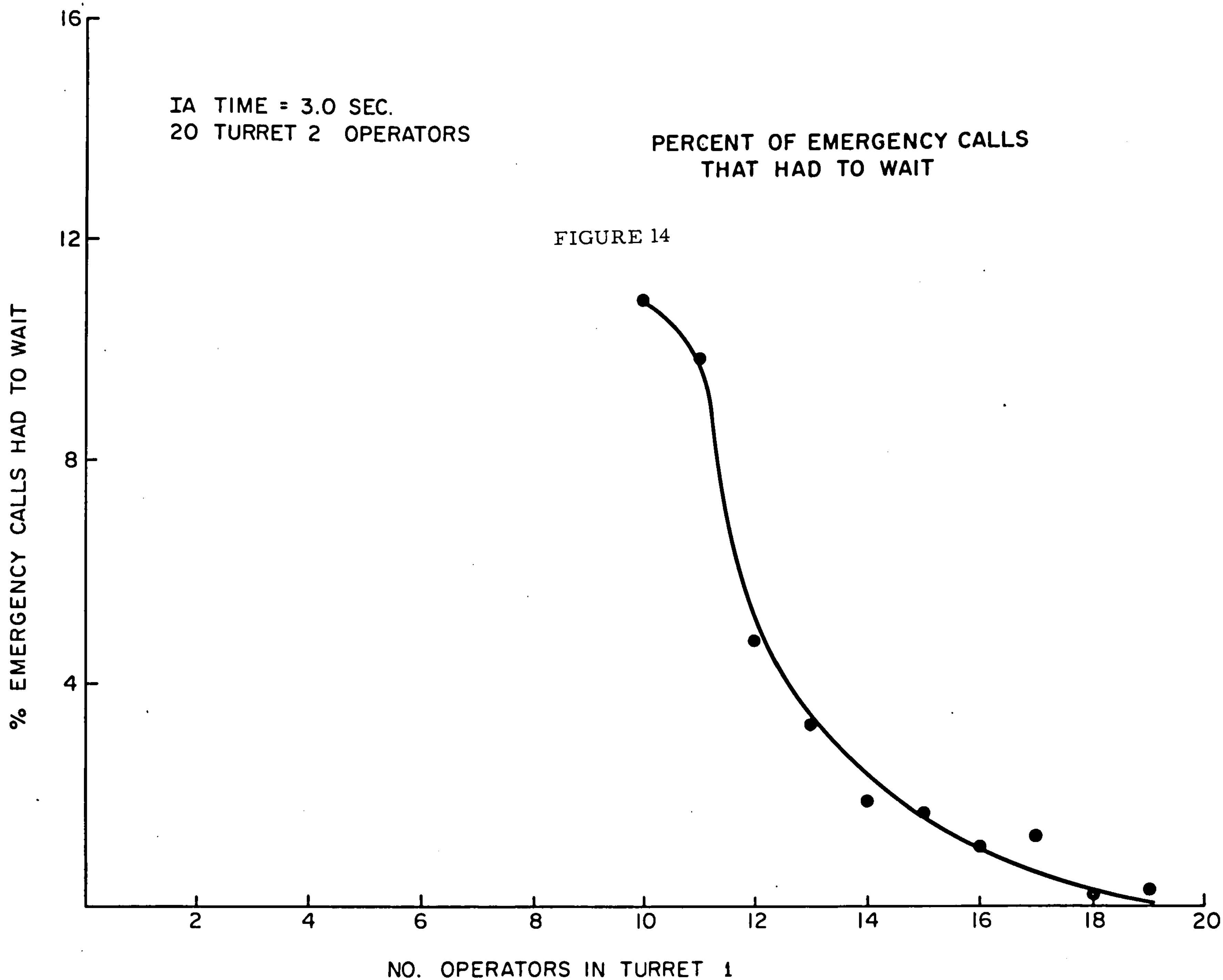

IA TIME = 3.0 SEC.
20 TURRET 2 OPERATORS
PERCENT OF EMERGENCY CALLS
THAT HAD TO WAIT
16
12
8
4
% EMERGENCY CALLS HAD TO WAIT
2
4
6
8
10
12
14
16
18
20
NO. OPERATORS IN TURRET 1

FIGURE 14

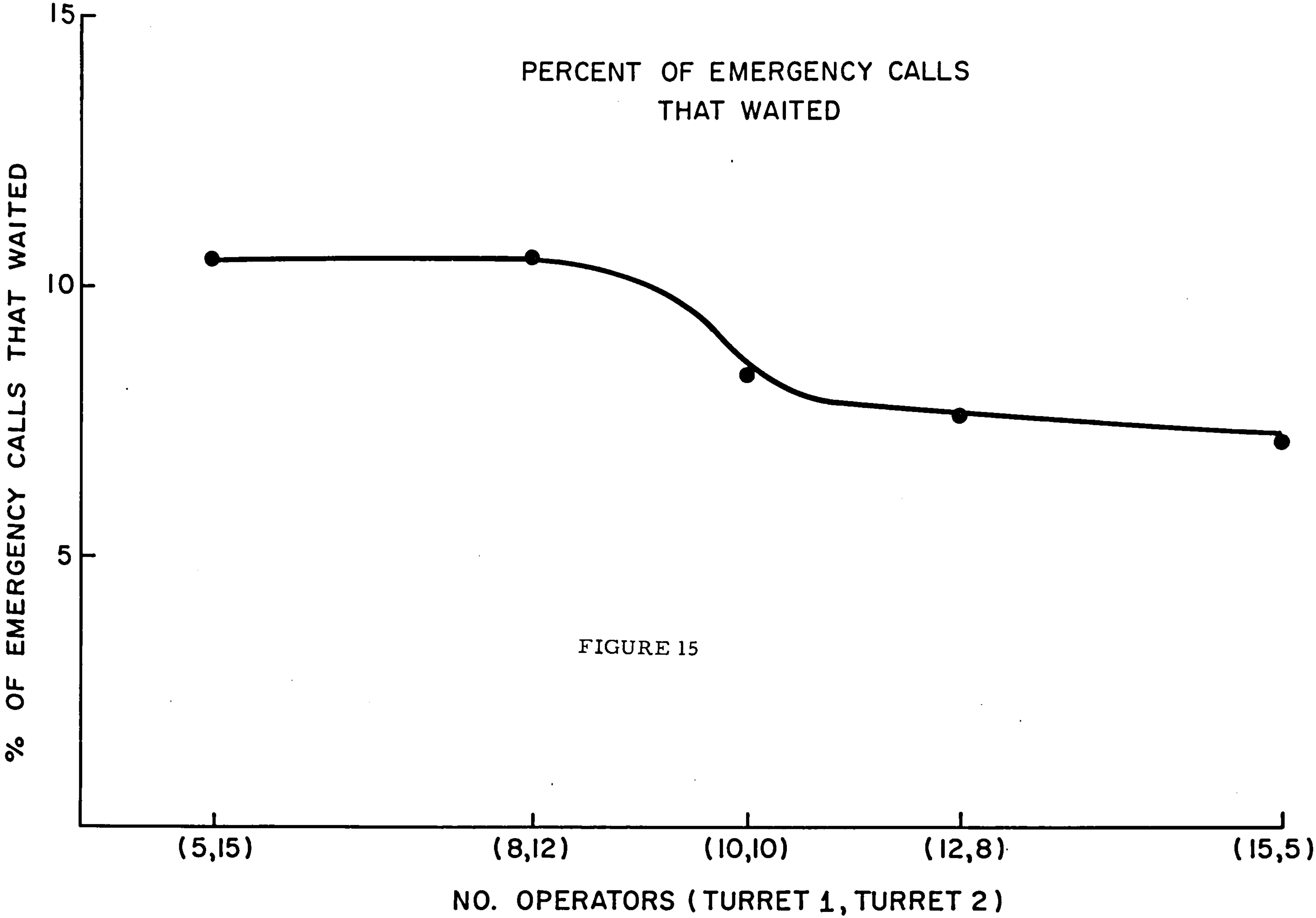

PERCENT OF EMERGENCY CALLS
THAT WAITED
% OF EMERGENCY CALLS THAT WAITED
15
10
5
(5,15)
(8,12)
(10,10)
(12,8)
(15,5)
NO. OPERATORS (TURRET 1, TURRET 2)

FIGURE 15

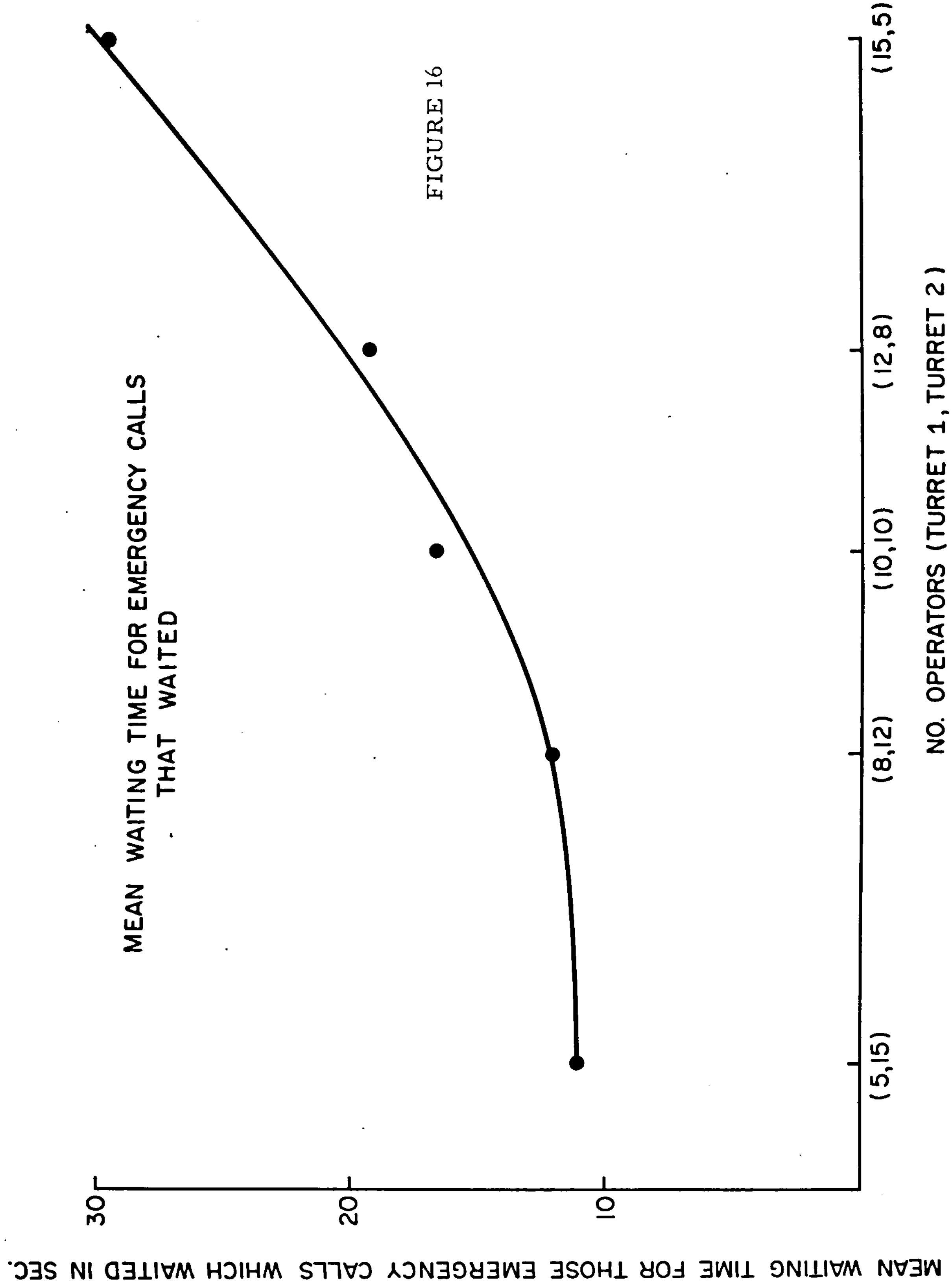

MEAN WAITING TIME FOR EMERGENCY CALLS THAT WAITED
MEAN WAITING TIME FOR THOSE EMERGENCY CALLS WHICH WAITED IN SEC.
30
20
10
NO. OPERATORS (TURRET 1, TURRET 2)
(5,15)
(8,12)
(10,10)
(12,8)
(15,5)

FIGURE 16

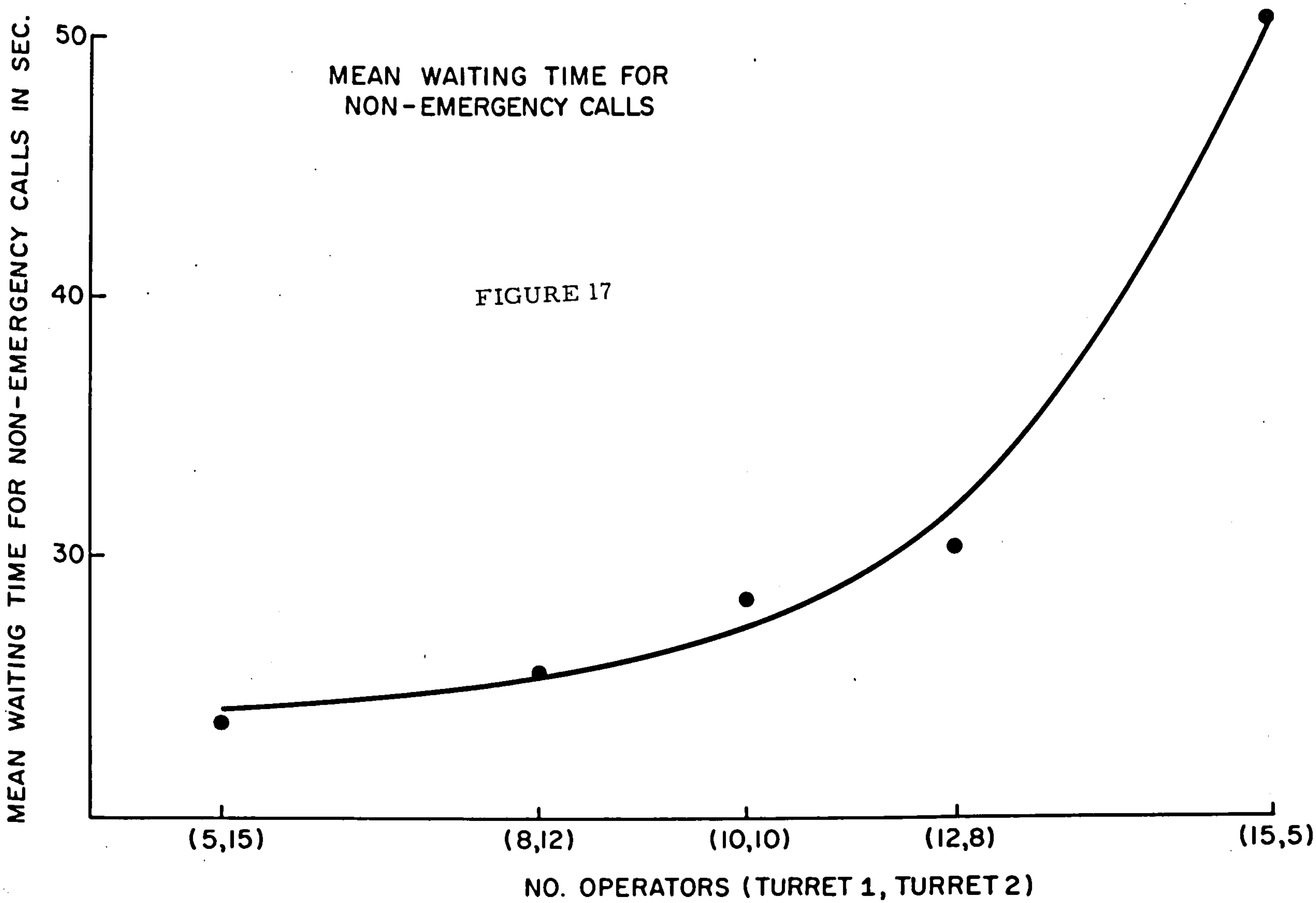

MEAN WAITING TIME FOR
NON-EMERGENCY CALLS
MEAN WAITING TIME FOR NON-EMERGENCY CALLS IN SEC.
50
40
30
(5,15)
(8,12)
(10,10)
(12,8)
(15,5)
NO. OPERATORS (TURRET 1, TURRET 2)

FIGURE 17

Response System Model

The primary purpose of the simulation runs made with the response system model was to investigate the effect of varying resource levels on the response time. These experiments were for a 4.8 second inter-arrival time (750 calls per hour). The first set of runs utilizes a single resource type: cars. An equal number of cars was allocated to each division.

The following levels were used:

Resource Levels
100
80
65
50
35

The cumulative distributions of response time for the above resource levels are given in Figure 18.

The average response time for all Manhattan for varying resource levels is given in Figure 19; for individual divisions, Figure 20.

The average utilization of dispatchers and the average waiting time at the dispatchers for various resource levels are given in Figures 21 and 22.

To illustrate the flexibility of the model, a second resource type (scooter) was added and similar runs were made. (Figures 23-28).

Again, equal resources were allocated to each division.

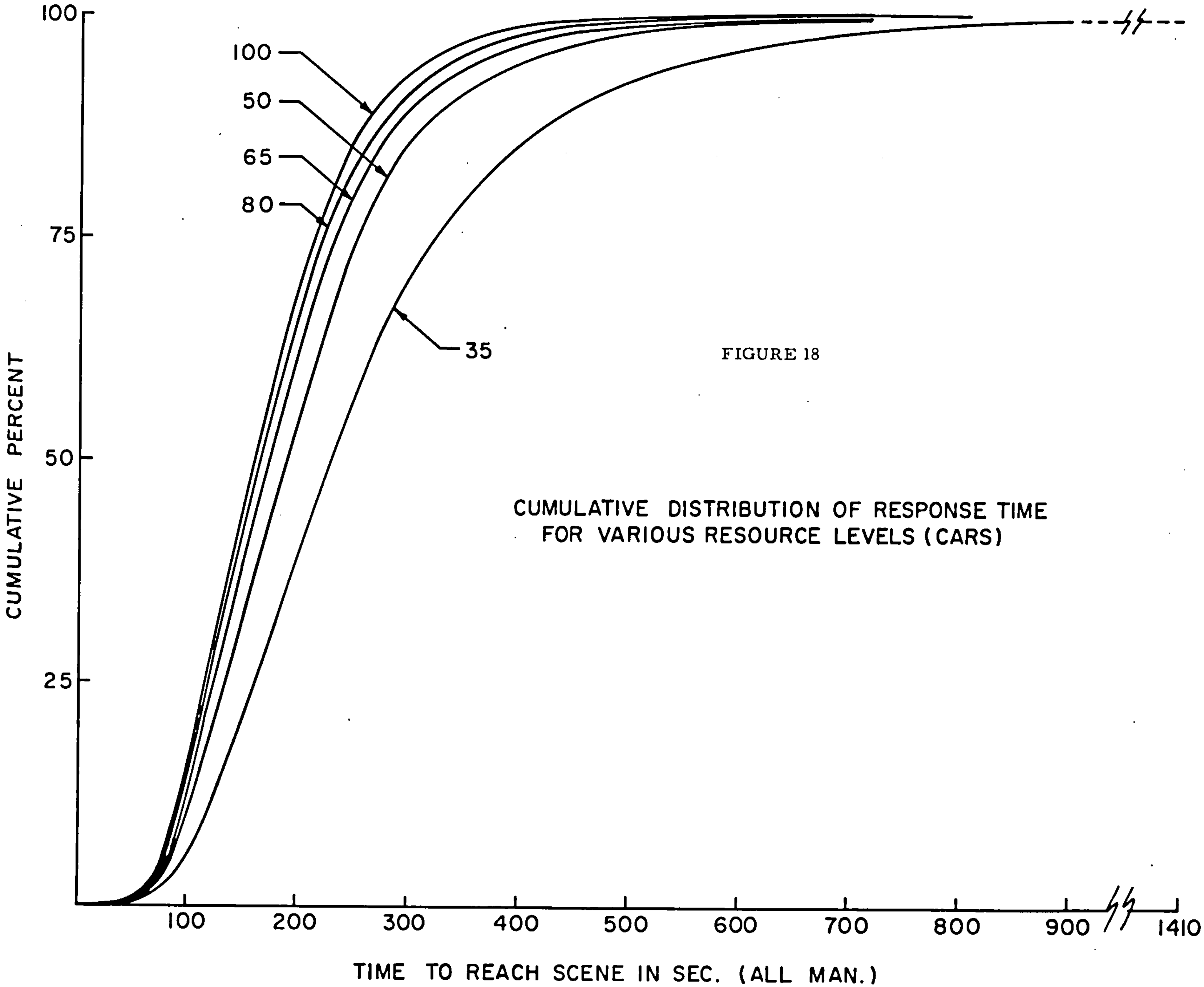


FIGURE 18

CUMULATIVE DISTRIBUTION OF RESPONSE TIME
FOR VARIOUS RESOURCE LEVELS (CARS)

FIGURE 19

AVERAGE RESPONSE TIME
FOR VARIOUS RESOURCE LEVELS
(CARS)

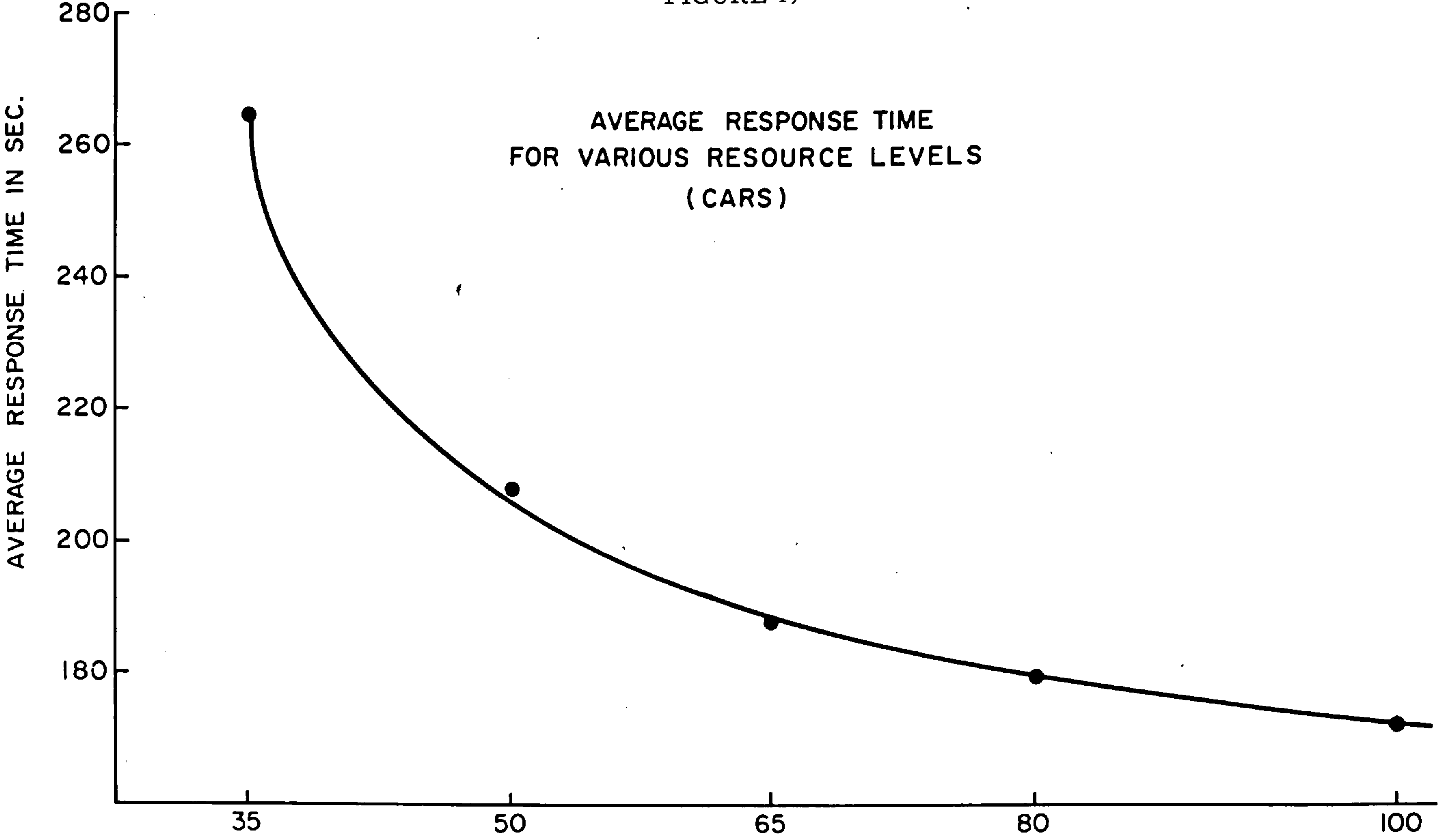
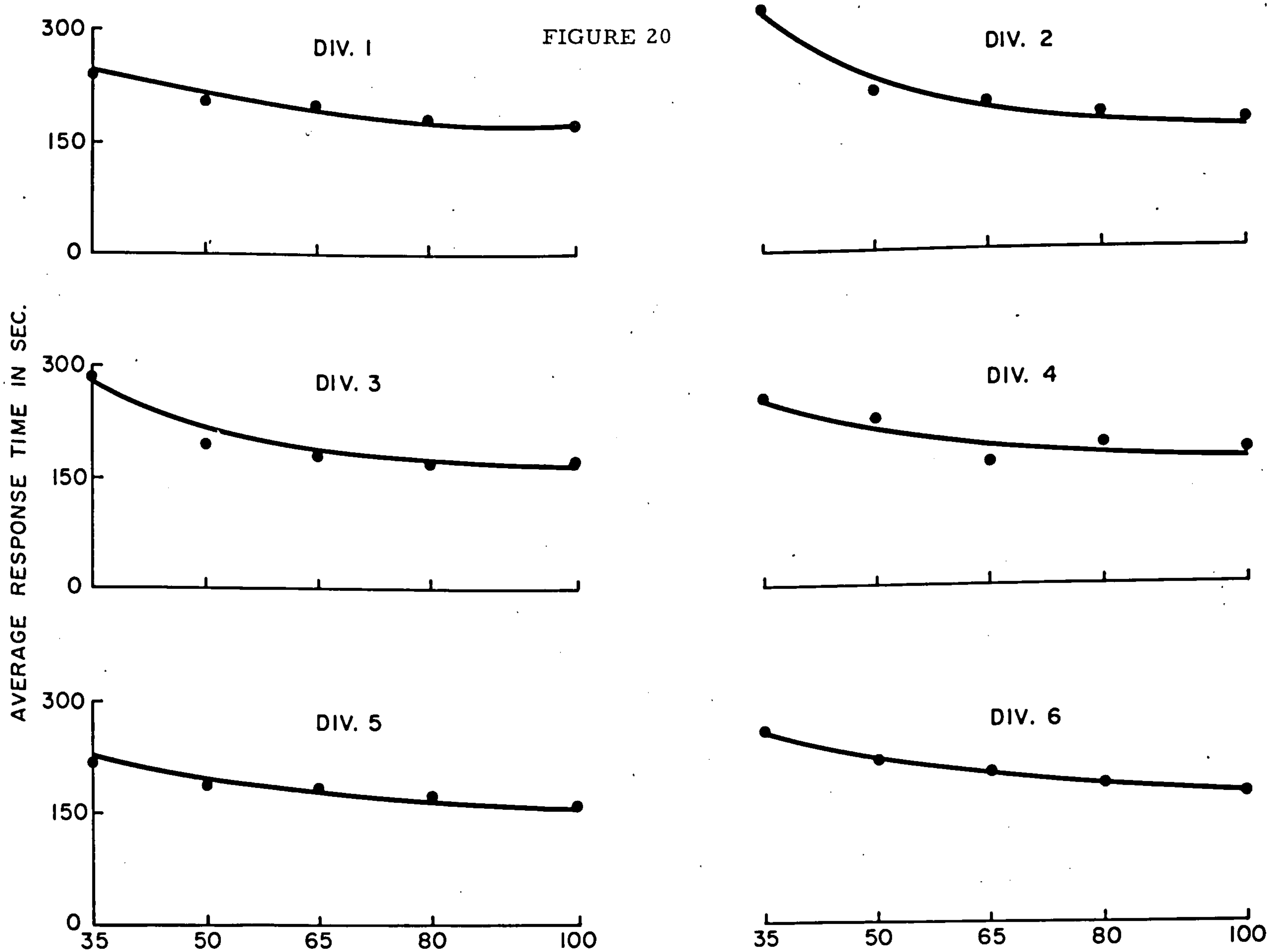
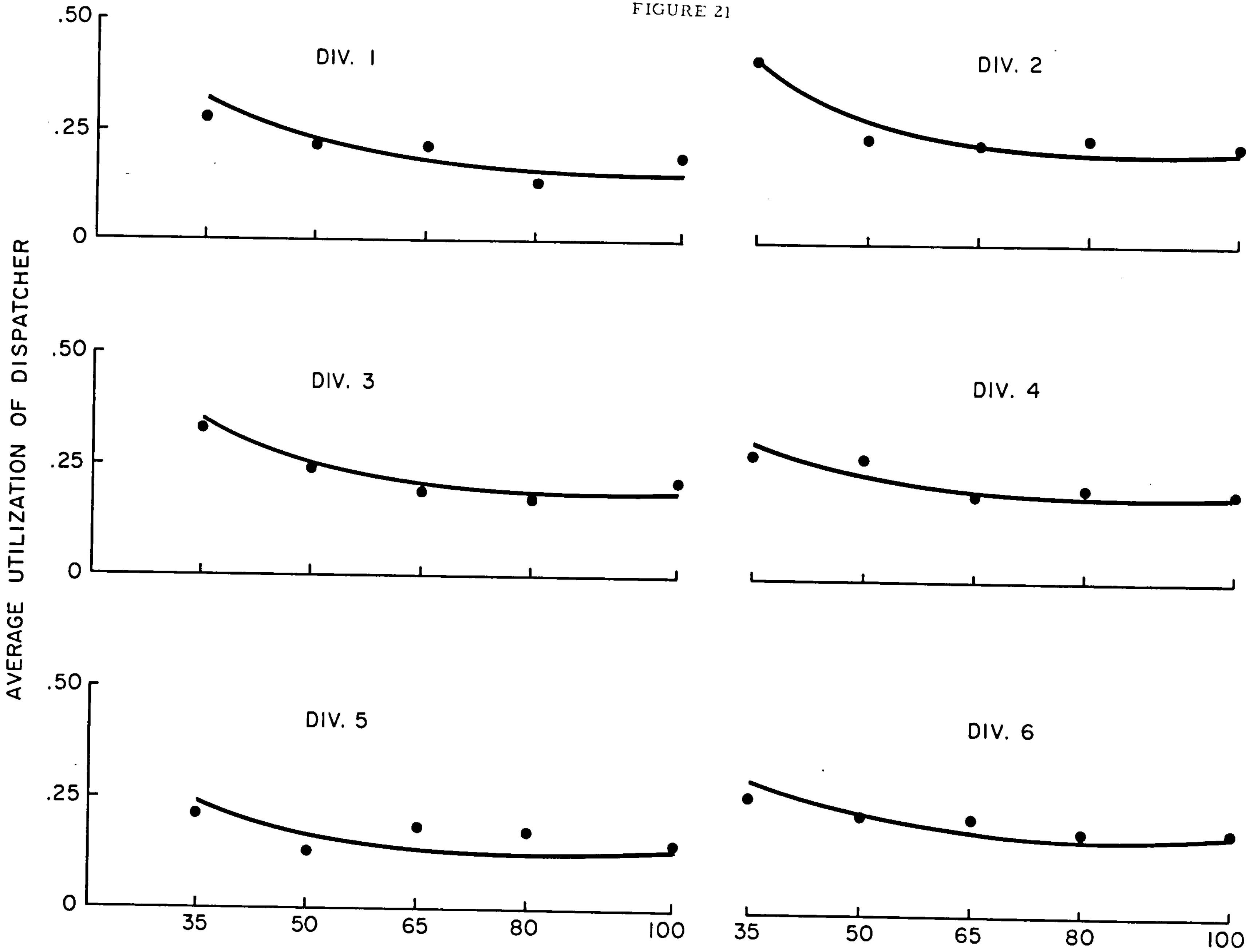


FIGURE 20



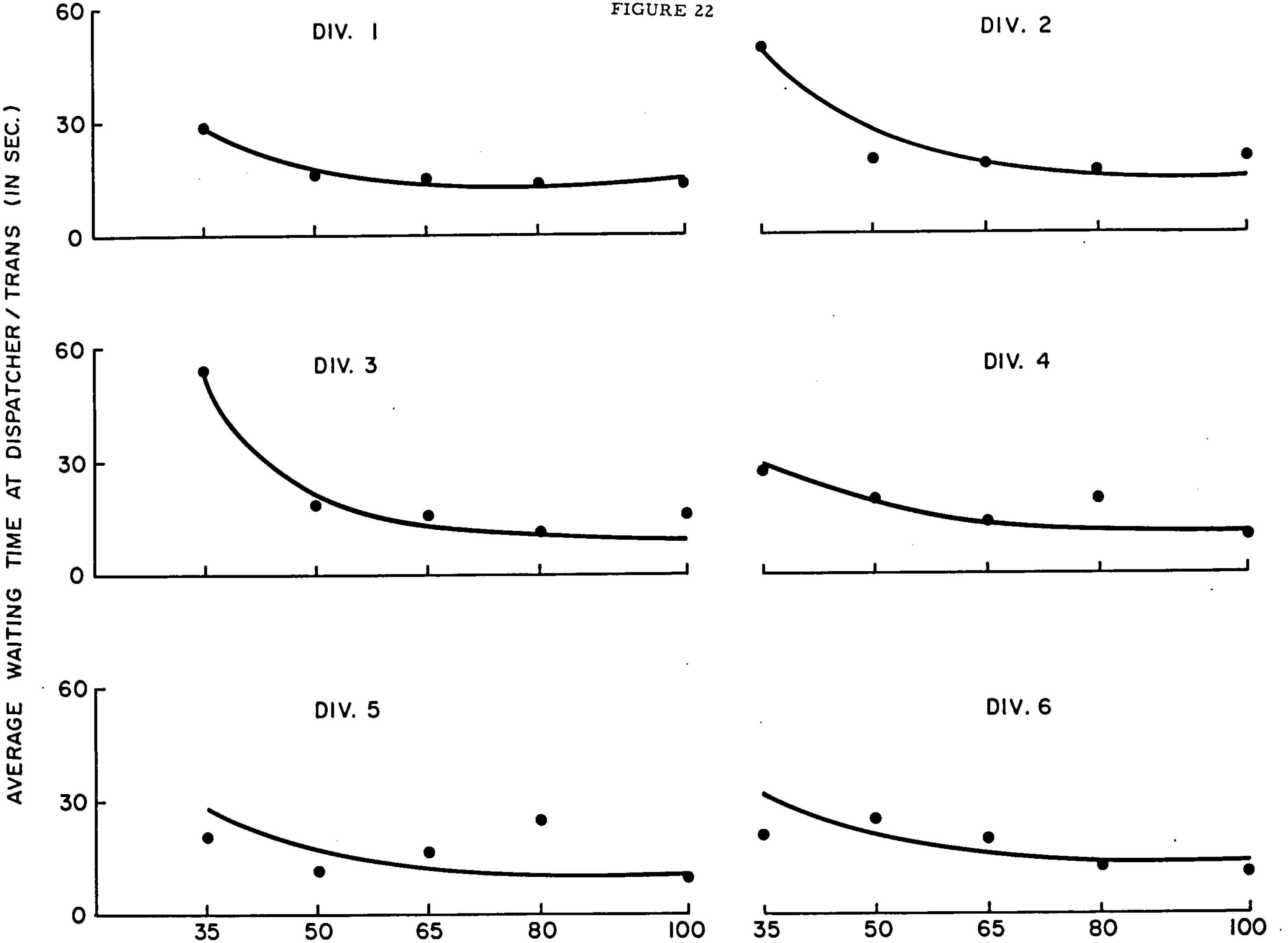
AVERAGE RESPONSE TIME FOR EACH DIVISION VARIOUS RESOURCE LEVELS (CARS)

FIGURE 21



AVERAGE UTILIZATION OF DISPATCHER FOR VARIOUS RESOURCE LEVELS (CARS)

FIGURE 22



AVERAGE WAITING TIME AT DISPATCHER / TRANS. VARIOUS RESOURCE LEVELS (CARS)

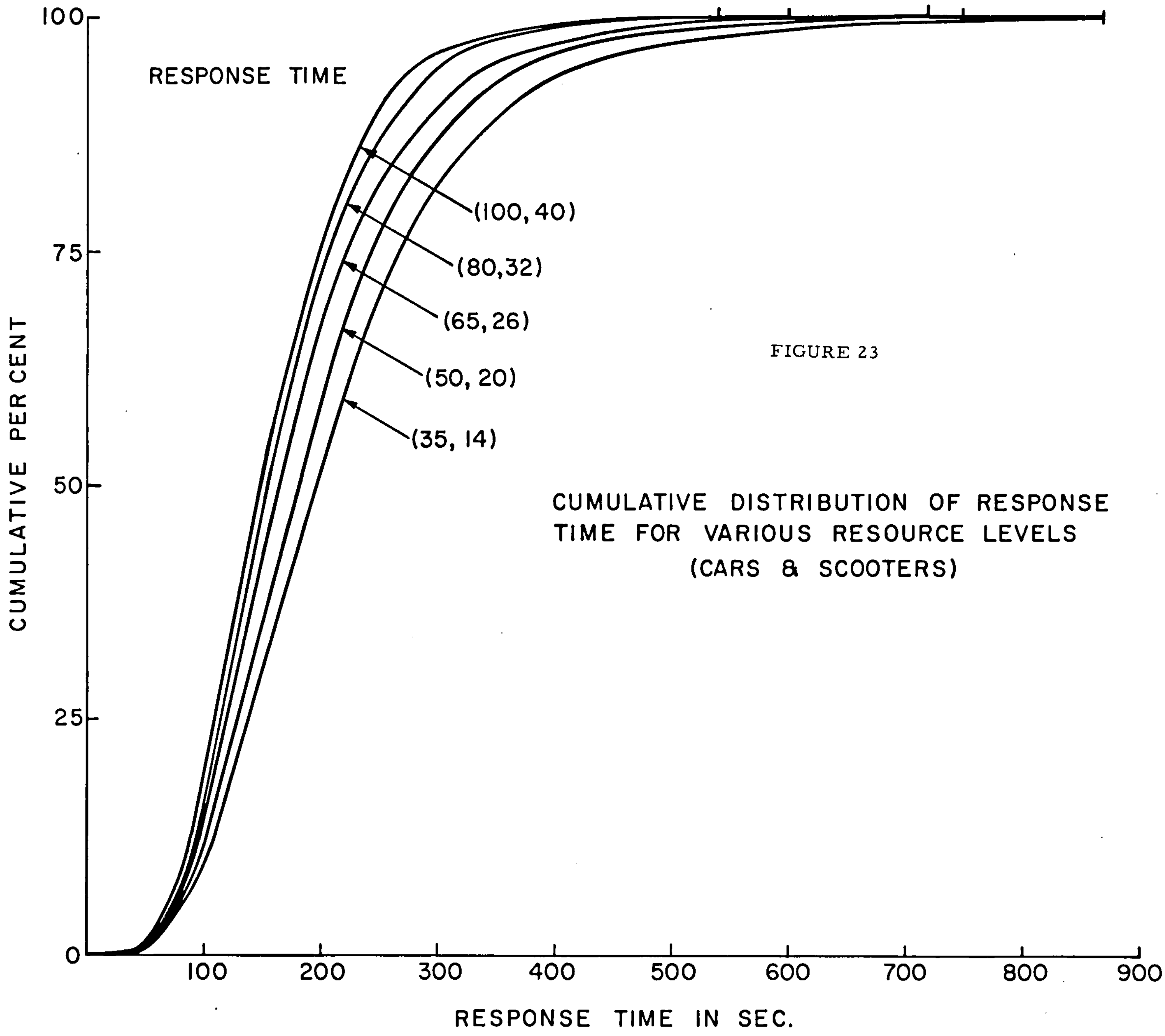


FIGURE 23

CUMULATIVE DISTRIBUTION OF RESPONSE TIME FOR VARIOUS RESOURCE LEVELS (CARS & SCOOTERS)

FIGURE 24

AVERAGE RESPONSE TIME
FOR VARIOUS RESOURCE LEVELS
(CARS & SCOOTERS)

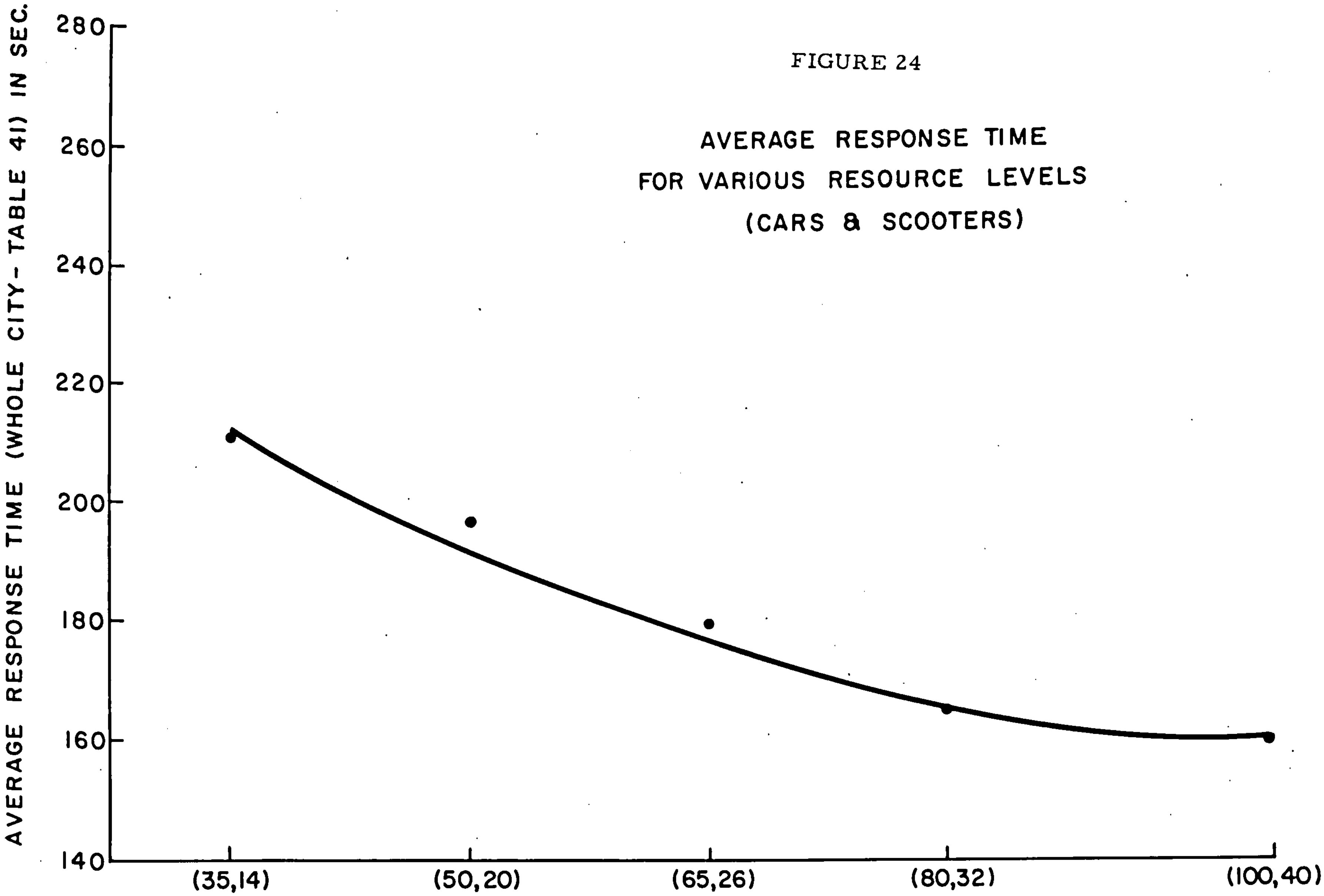


FIGURE 25

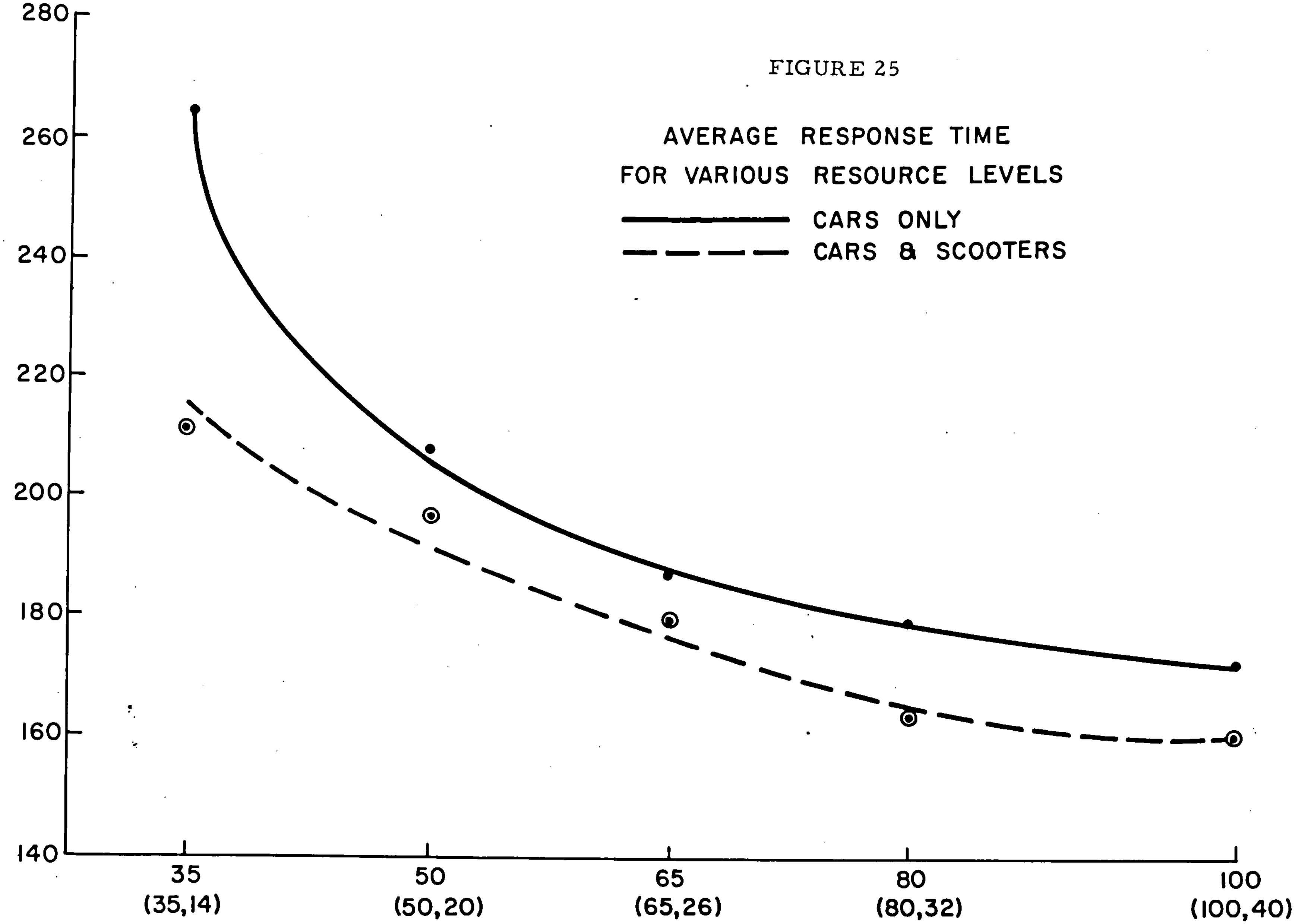
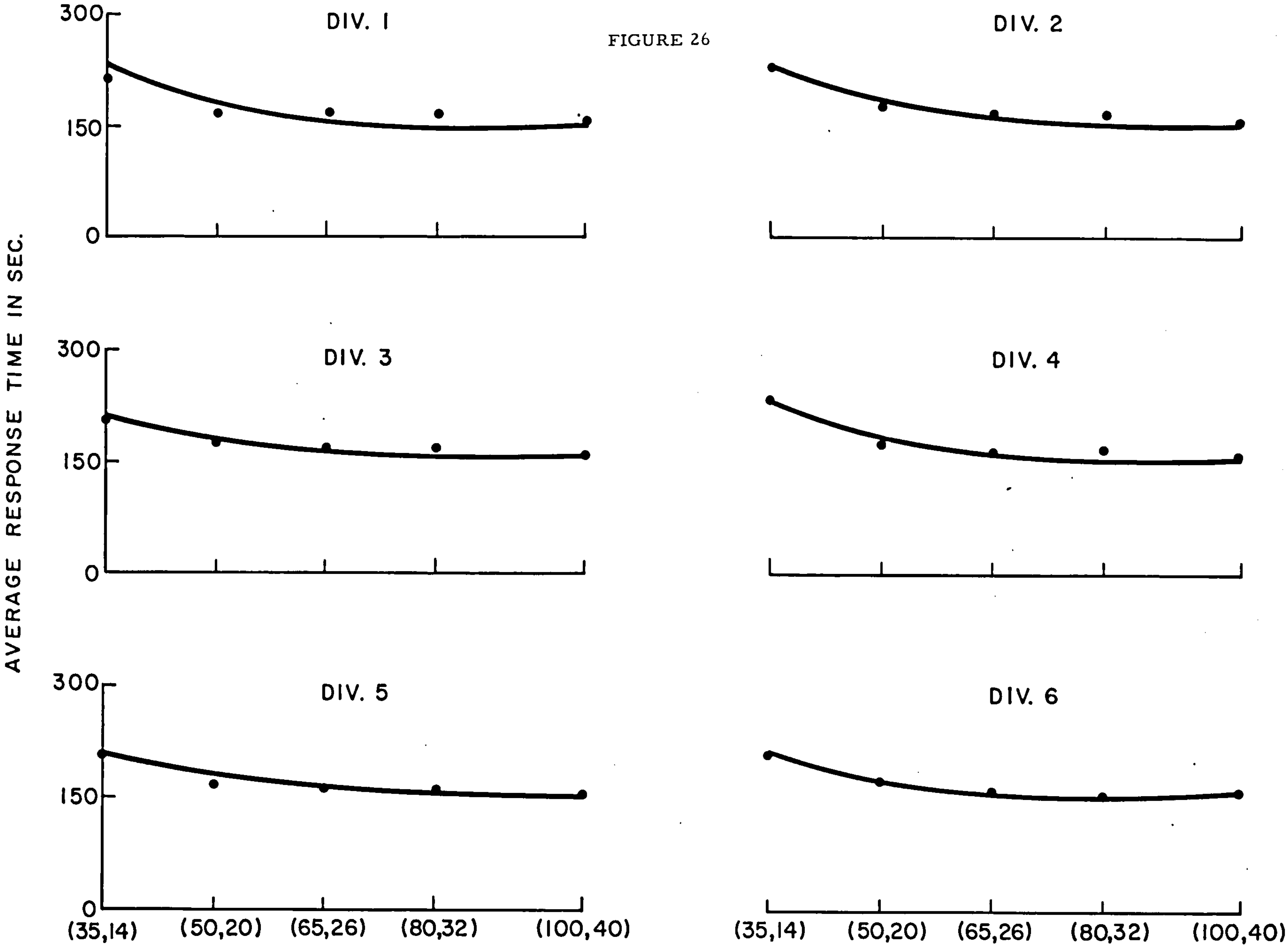
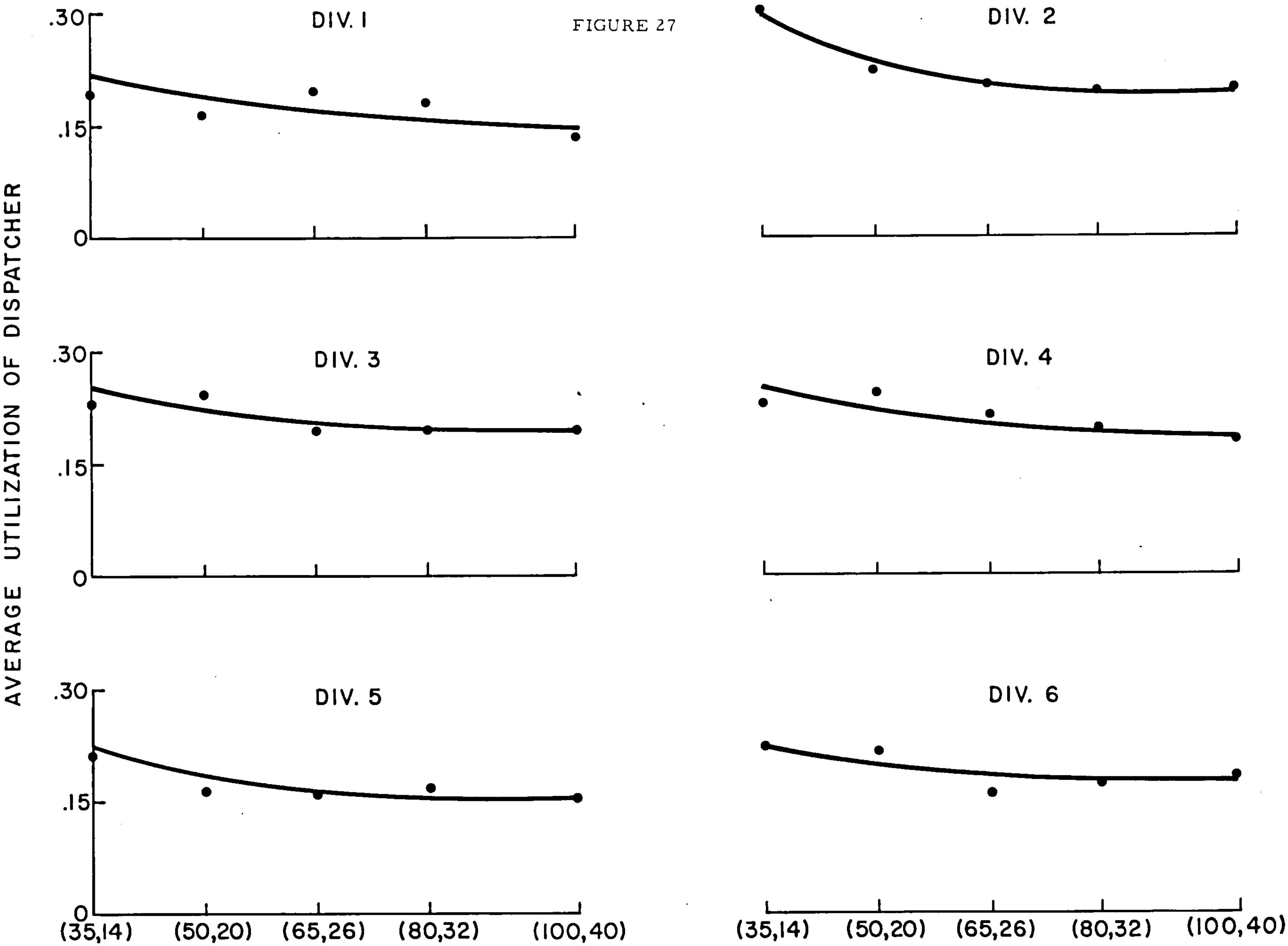

AVERAGE RESPONSE TIME
FOR VARIOUS RESOURCE LEVELS
CARS ONLY
CARS & SCOOTERS
280
260
240
220
200
180
160
140
35
(35,14)
50
(50,20)
65
(65,26)
80
(80,32)
100
(100,40)

FIGURE 26



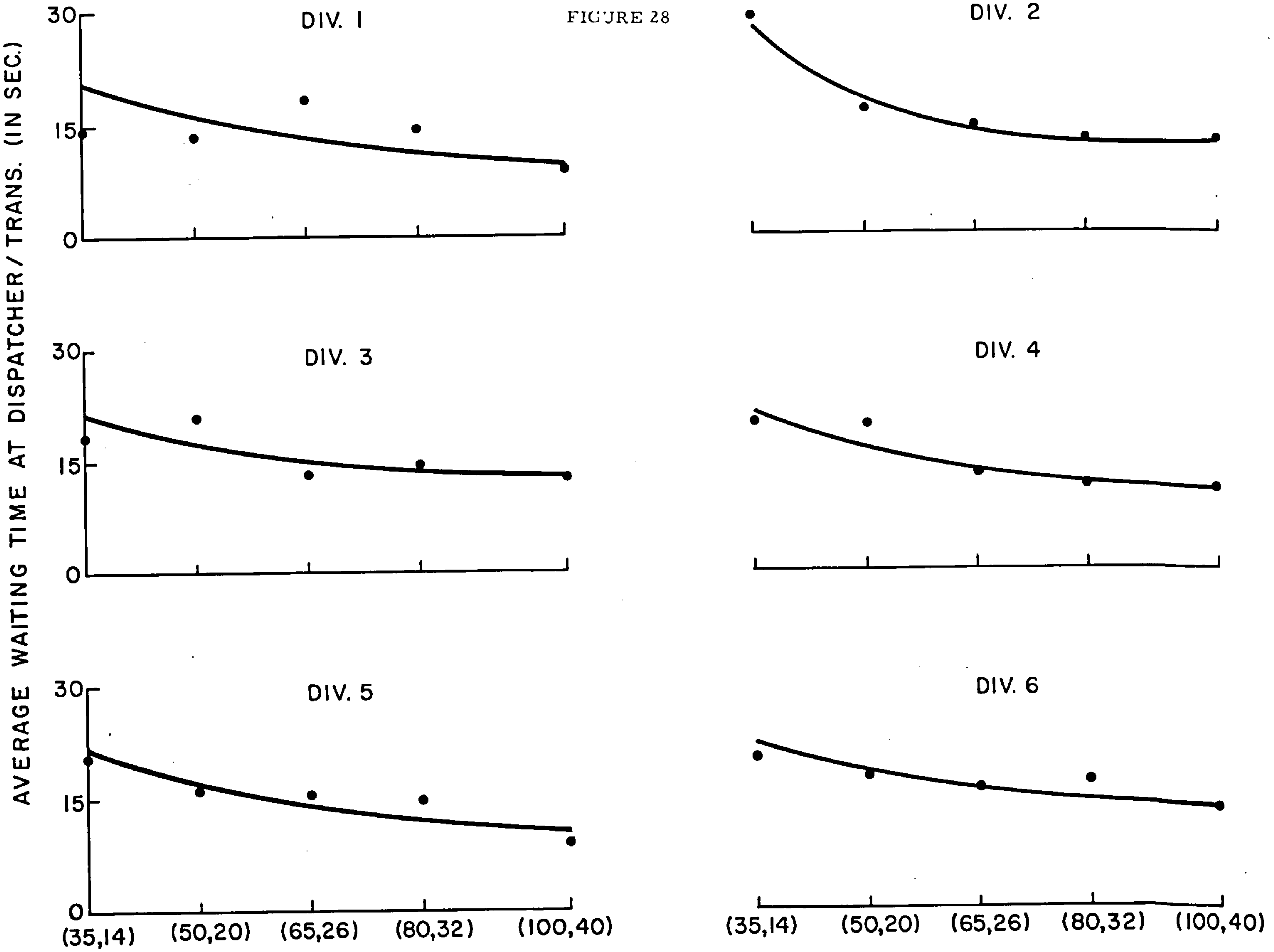
AVERAGE RESPONSE TIME FOR EACH DIVISION VARIOUS RESOURCE LEVELS (CARS & SCOOTERS)

FIGURE 27



AVERAGE UTILIZATION OF DISPATCHER FOR VARIOUS RESOURCE LEVELS (CARS & SCOOTERS)

FIGURE 28



AVERAGE WAITING TIME AT DISPATCHER / TRANS. VARIOUS RESOURCE LEVELS (CARS & SCOOTERS)

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The curves displayed in the previous chapter should be looked upon as the kind of information obtainable from computer simulation. The models reported here address themselves to questions such as

> ...for a given rate of calls, how many switchboard operators are required to process all emergency calls with waiting time not exceeding 30 (or 15) seconds? (The answer could be more than the current switchboard capacity.)
>
> ...for a given rate of calls, and a given number of turret operators, what is the average waiting time per call? How many calls need not wait at all? How many must wait more than one minute? What fraction of time are all operators busy? What fraction of time are more than two idle?
>
> ...what contribution, in terms of reduced waiting time, could one (two, three...) additional turret operator (dispatcher, vehicle) make?

Slight program modifications could permit questions relating to non-existing, but possibly desirable configurations and procedures, such as

> ...if a computer is introduced into the system, how are waiting and processing times, personnel and equipment utilization affected?
>
> ...alternatively, how much additional personnel (if any) could accomplish similar results?
>
> ...for a given amount of money, which alternative among competing proposals would be most effective?
>
> ...how much additional money would be required to reach a given level of performance?

In the runs conducted for this report, arriving calls were assumed to be exponentially distributed. This is consistent with experience on similar calls reported in the literature. However, this assumption is not essential to any of the models described. GPSS allows the substitution of any distribution by any other distribution, observed or theoretical, simply by replacing the pertinent program cards. The relevant distributions are clearly labeled in the program printouts of Appendices A through C.

In conclusion, simulation requires a decision maker to describe a system under study in complete, unambiguous terms. An analyst translates such a description into computer language. The decision maker then is able to ask a series of "What will happen if..." questions. These questions must be consistent with the information structure put into the model. The answers will be the logical consequences of the data, rules, and logic of the model.

Only the decision maker can decide whether a given model is adequate for his purposes. He does this by asking a series of questions and evaluating each answer in light of his experience and judgment. Frequently this leads to a series of model adjustments. It is dangerous for one organization to use another organization's models without verification of its validity under the new circumstances. Similarly, a model may no longer be appropriate in the situation for which it was developed if conditions have changed appreciably.

The purpose of this report is to demonstrate the suitability and usefulness of computer simulation in the analysis and design of large scale police activities and systems. It describes three prototype models, based on information obtained in a real police environment. It then shows the kind of information that can be extracted with the help of a computer.

The authors welcome comments and questions from interested persons or organizations.

APPENDIX A

COMPUTER PROGRAM - TURRET BOARD MODEL

The following discussion refers to the program printout at the end of this Appendix. Some familiarity with GPSS/360 is assumed.

INPUT

STORAGES

The Group I and Group II turret operators are represented in the model by STORAGEs labelled TUR 1 and TUR 2. The capacities of these STORAGEs correspond to the number of operators at each turret board.

FUNCTIONS

FUNCTION 1 - Cumulative distribution of time spent in conversing and supplying information for non-emergency calls.

FUNCTION 2 - Cumulative distribution of time spent in conversing, obtaining information and recording the details for emergency calls.

FUNCTION 3 - The fraction of calls which are emergency and non-emergency. A functional value of 0 corresponds to an emergency call and a value of 1 to a non-emergency call. The function is coded as a discrete cumulative distribution.

FUNCTION 4 - Cumulative distribution of interarrival times for calls coming into the Communications Center. At present, these are assumed to be exponentially distributed, with the mean value supplied by the user.

OUTPUT

TABLES

TABLE 2 - This table yields the distribution of time spent in the system by emergency calls.

TABLE 3 - This table gives the distribution of time spent waiting for a Group II turret operator by emergency calls which found the Group I

turret operators busy.

TABLE 4 - This table corresponds to the distribution of time until a non-emergency call is handled. It includes identification by a Group I turret operator if this has occurred.

TABLE 5 - This table yields the distribution of the number of Group I turret operators that are busy. The system is sampled every three seconds to determine the number of busy operators.

TABLE 6 - This table is similar to TABLE 5 but concerns the number of busy operators in Group II.

General Logic

Calls are randomly generated by the GENERATE block, labelled GEN, with any desired mean interarrival time from an exponential distribution. Call type (emergency (0), non-emergency (1) is assigned randomly to PARAMETER 1 using FUNCTION 3. The Group I turret operators are checked to determine if they are all busy by a GATE block. If they are all busy, the call is sent to PRGP2. If not, it takes a Group I turret operator (ENTER block). A TEST block interrogates PARAMETER 1 to determine the nature of the call. If it is an emergency call (P1=0), the call is sent to PROC1. Non-emergency calls are identified by Group I turret operators, within 10 to 20 seconds uniformly distributed, and spend this time in the ADVANCE block. Then the Group I turret operator is released and the call is sent to NEMG2. Emergency calls (sent to PROC1) undergo a time delay to represent the conversation time and recording of information. This time is randomly selected from FUNCTION 2. The Group I turret operator is then released (LEAVE block), a statistic is entered into TABLE 2 (TSMAN) and the call is terminated.

Calls which found the Group I turret operators busy are sent to PROC1 where a PRIORITY is assigned to them. This is done to assure that they will be-handled before the identified non-emergency calls sent to the Group II operators, in case there is a queue. At NEMG2 the calls queue (if all Group II turret operators are busy) and are answered when a Group II turret operator is available. PARAMETER 1 is tested to determine if the call is non-emergency and if so, it is sent to NOEMG. An entry is made in TABLE 3 for emergency calls. The call undergoes a time delay randomly selected from FUNCTION 2 to represent conversation time and the recording of information. The Group II turret operator is then released (LEAVE block) and the call is sent to TSMAN where TABLE 2 is compiled; and the call is then terminated. TABLE 4 is tabulated for non-emergency calls sent to NOEMG. There is a delay to represent conversation time and time necessary to supply information. The time is randomly selected from FUNCTION 1. The Group II turret operator is then released and the call terminated. The block labelled TIMER is a timing routine that controls the length of the run in terms of simulated time. The system generates a transaction at a predetermined interval (in this model a transaction is generated every three seconds). The inquiry made by this transaction generates TABLEs 5 and 6. (Number of operators busy on each one of the turret boards). After performing certain bookkeeping operations for printout purposes, the transactions count in determining the run length. The run length is controlled by the START card which indicates how many of these timing transactions should occur before the run is completed and a printout occurs.

FIGURE 29

EMERGENCY CALLS CONVERSATION TIMES
(3-28-68)

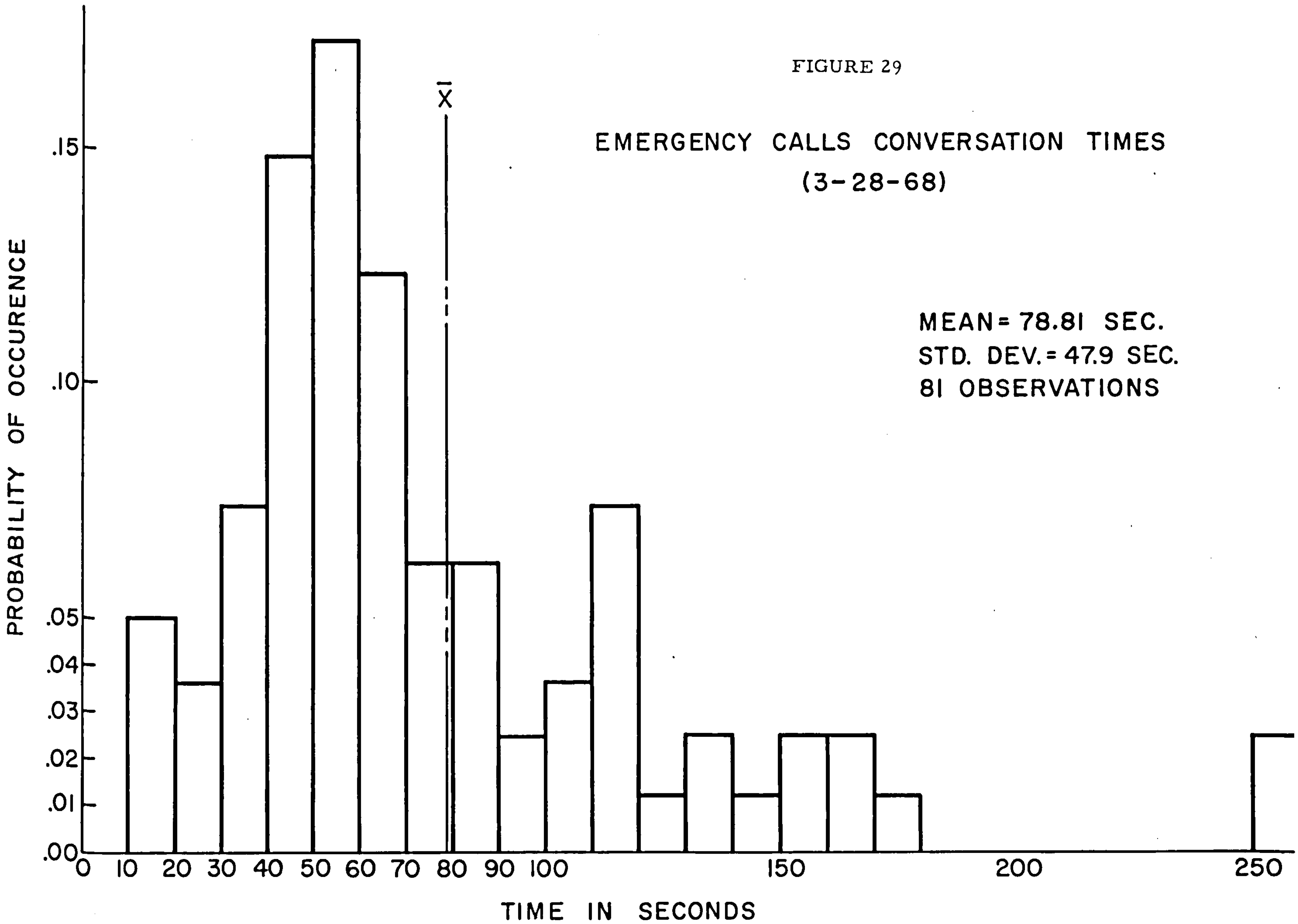


FIGURE 30

EMERGENCY CALLS REQUESTING AMBULANCE
CONVERSATION TIMES
(3-28-68)

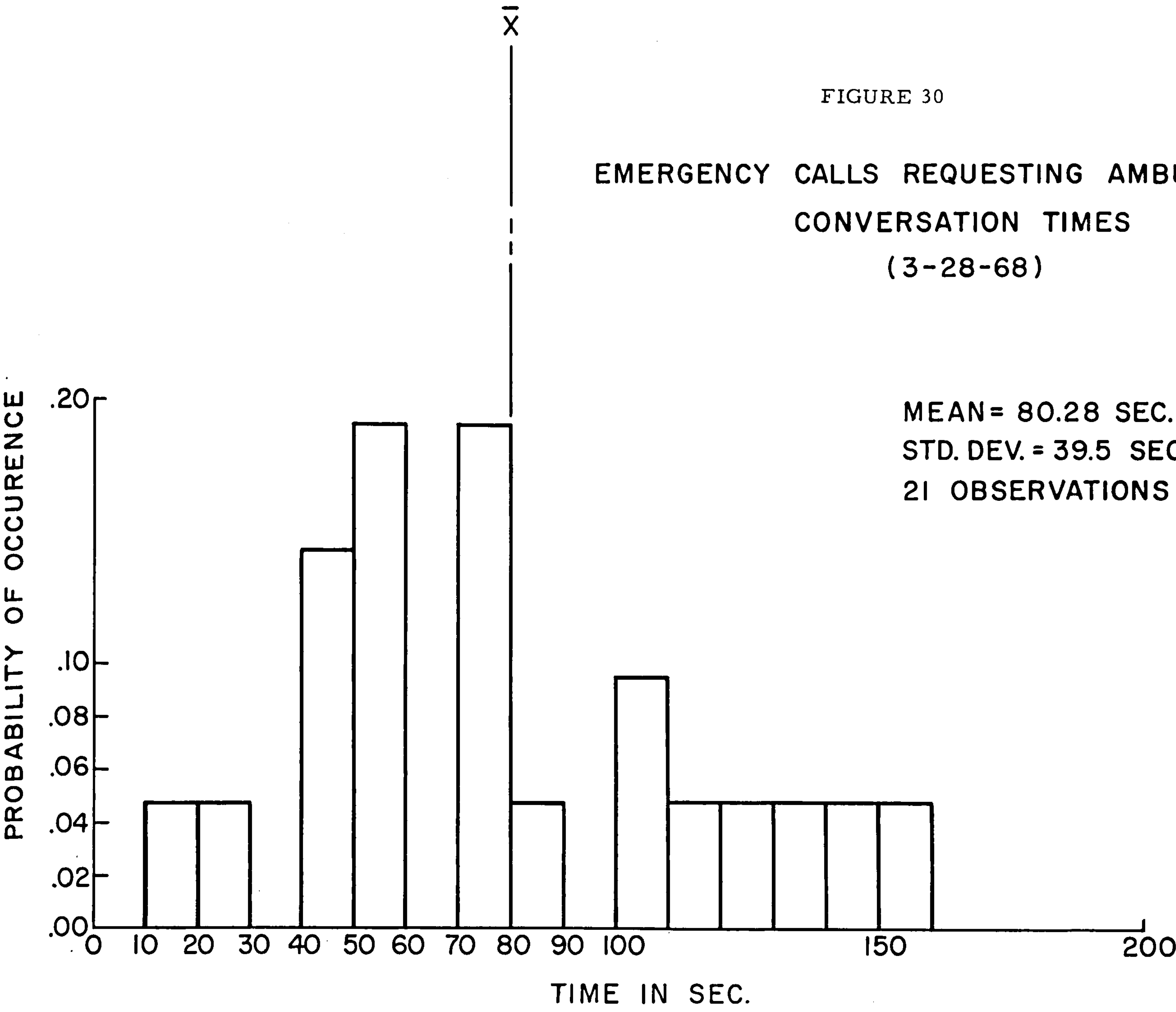
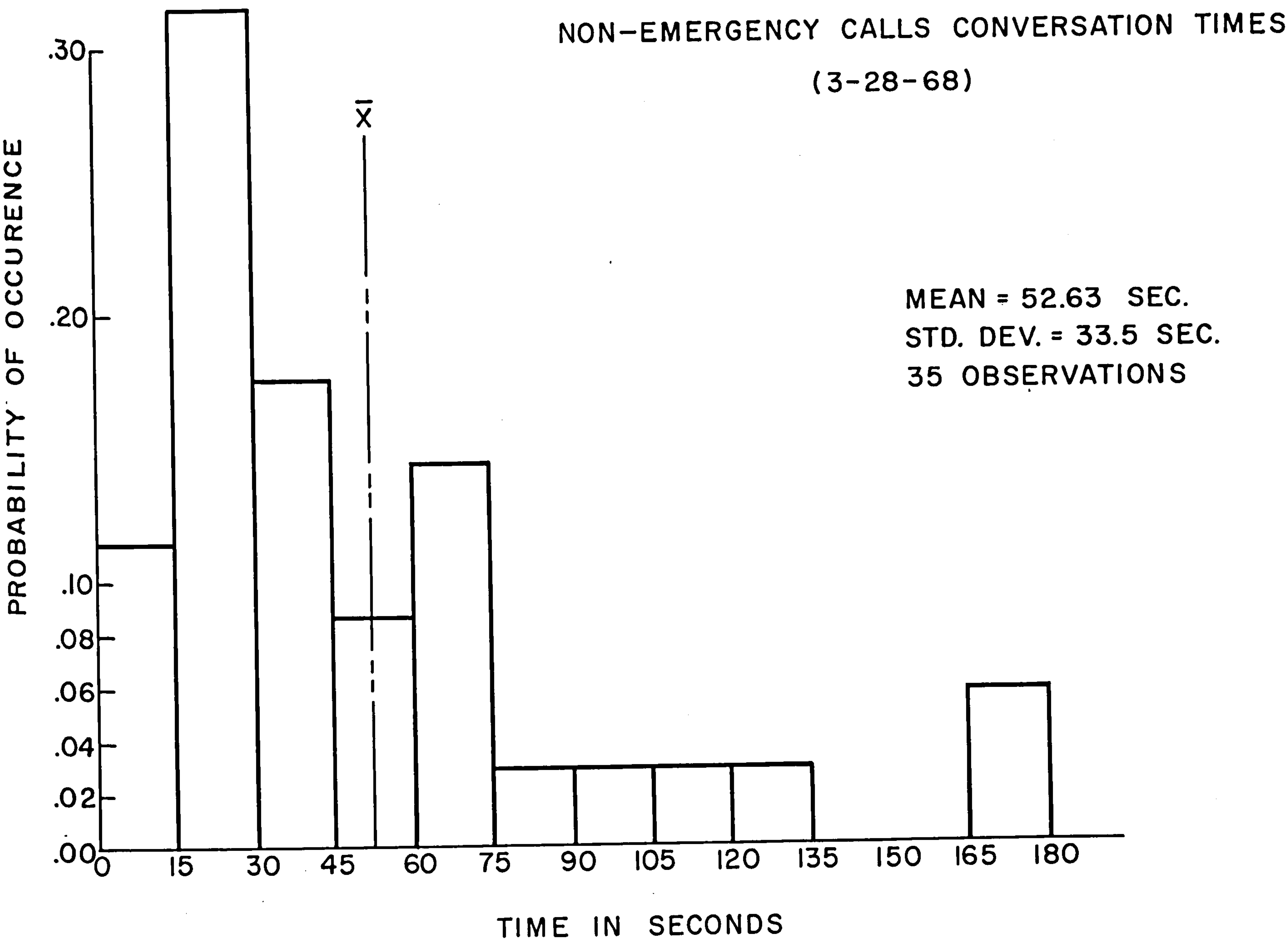


FIGURE 31


NON-EMERGENCY CALLS CONVERSATION TIMES
(3-28-68)
MEAN = 52.63 SEC.
STD. DEV. = 33.5 SEC.
35 OBSERVATIONS
X̄
PROBABILITY OF OCCURENCE
.30
.20
.10
.08
.06
.04
.02
.00
0
15
30
45
60
75
90
105
120
135
150
165
180
TIME IN SECONDS

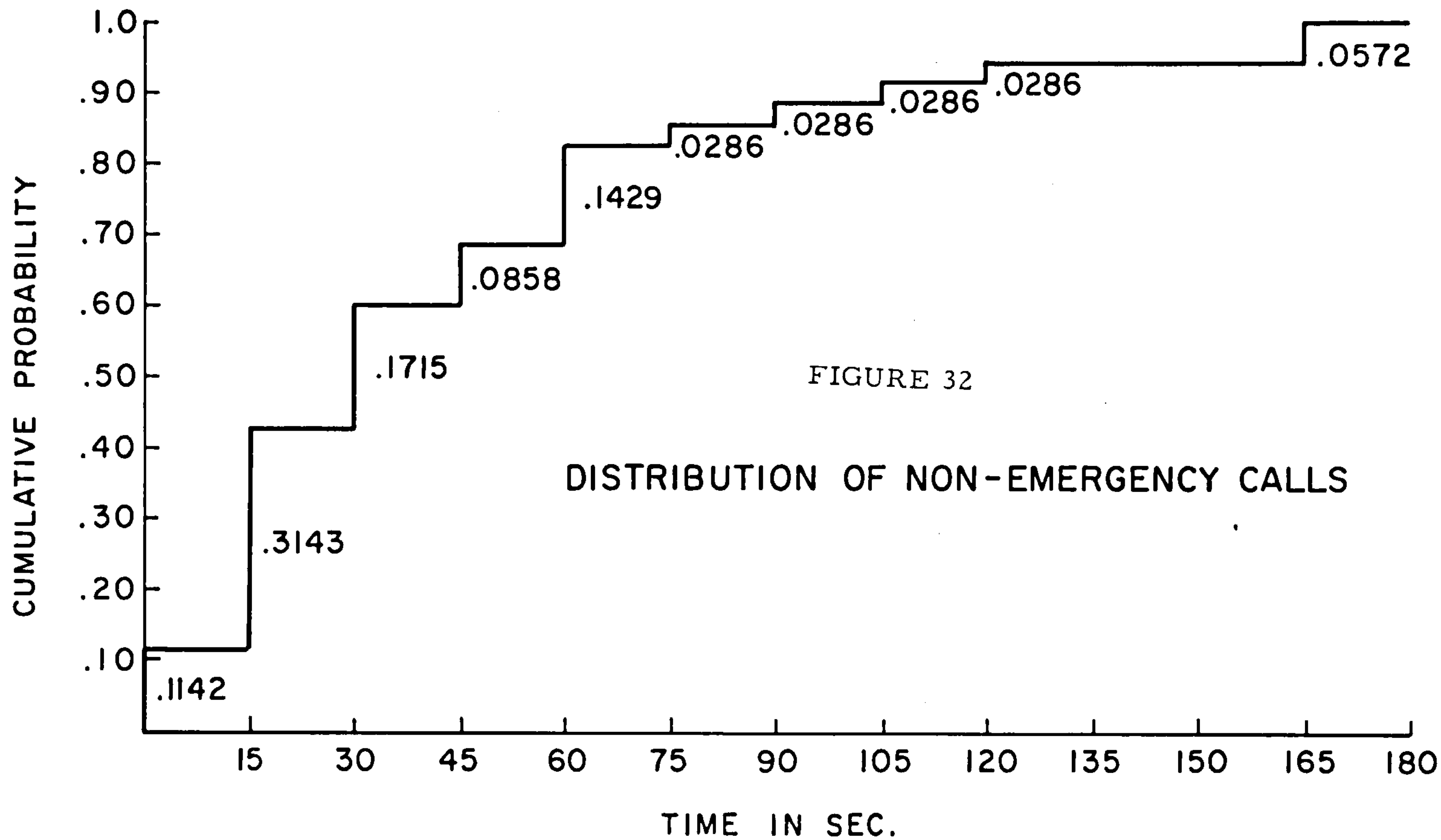


FIGURE 32

DISTRIBUTION OF NON-EMERGENCY CALLS

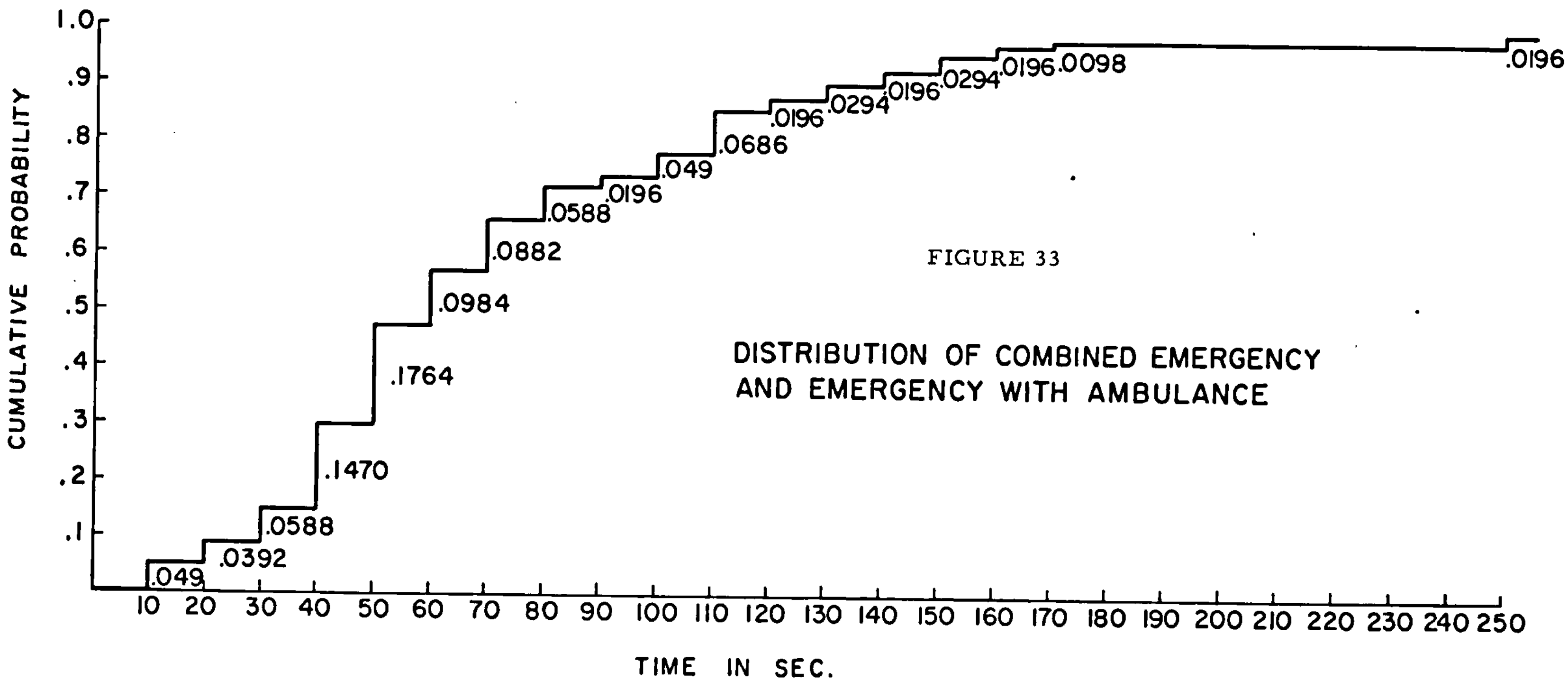


FIGURE 33

DISTRIBUTION OF COMBINED EMERGENCY AND EMERGENCY WITH AMBULANCE

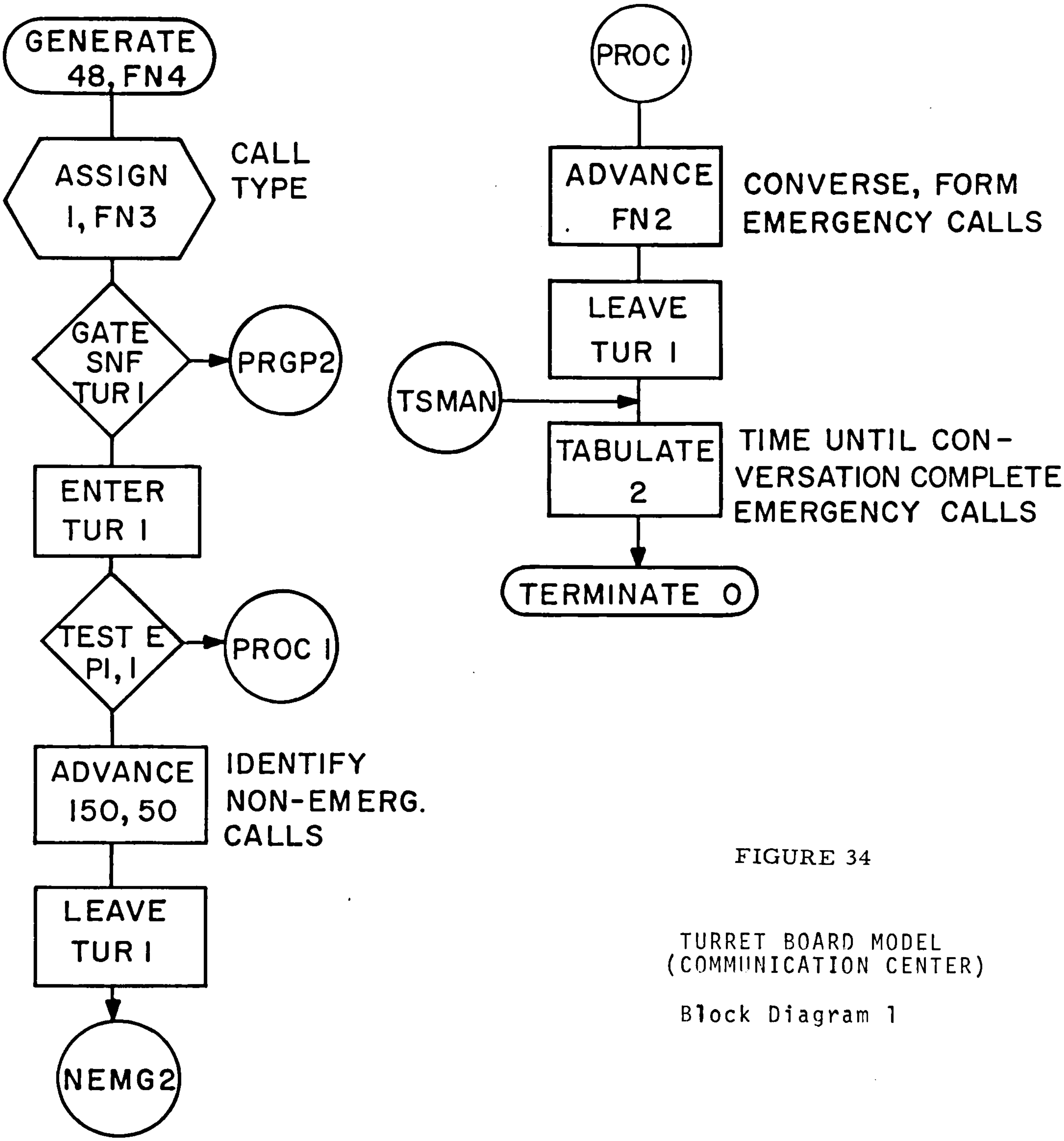
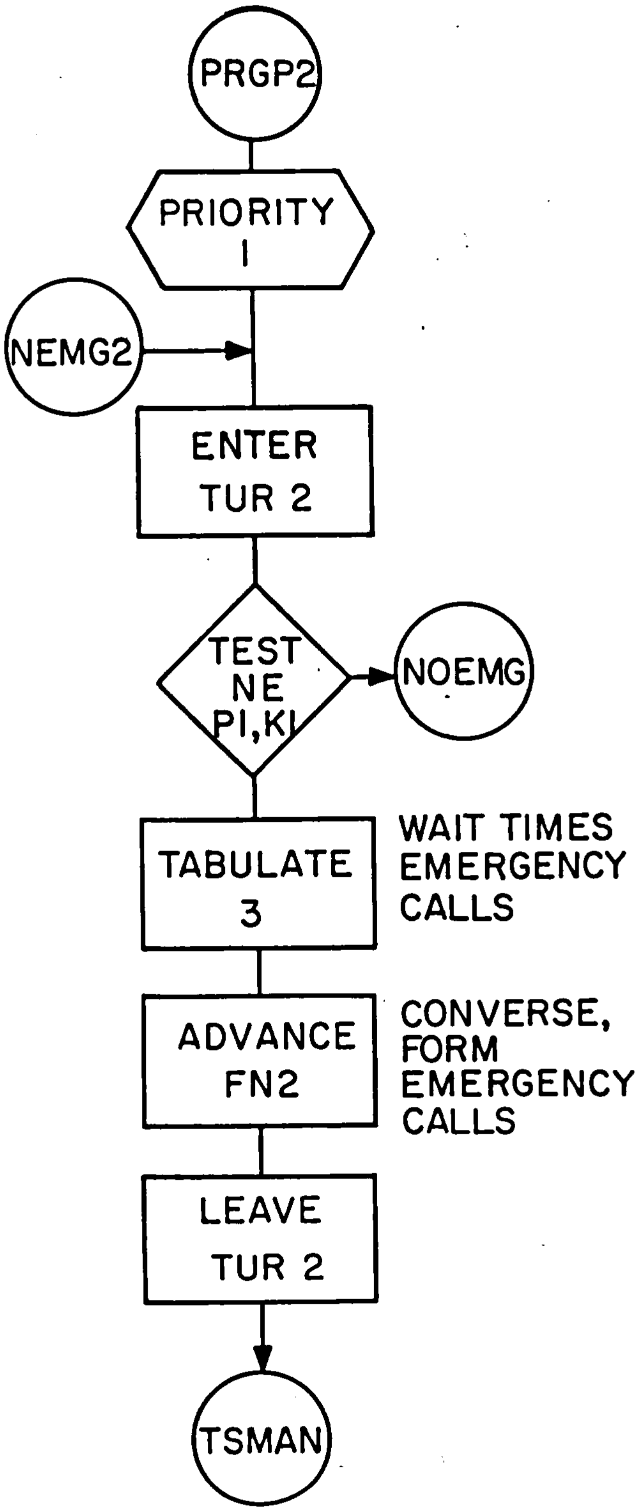
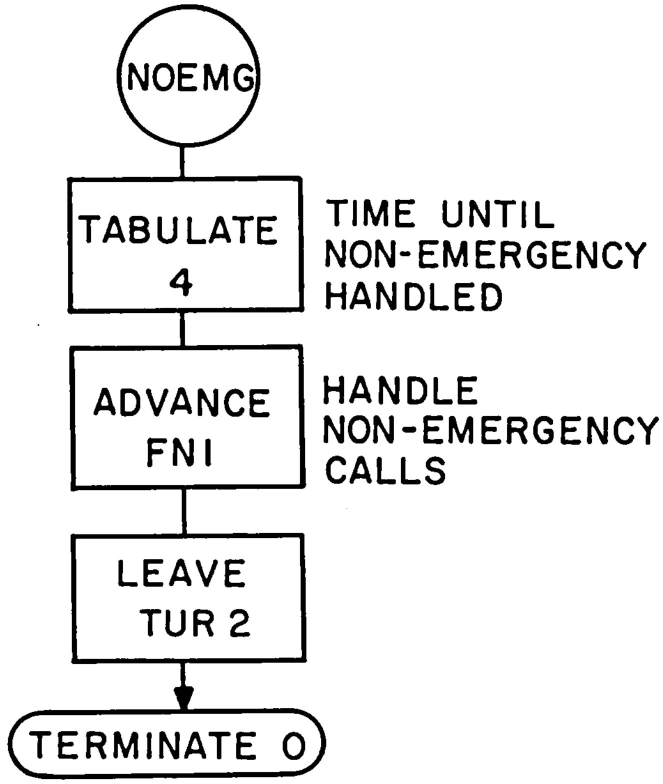


FIGURE 34

TURRET BOARD MODEL
(COMMUNICATION CENTER)

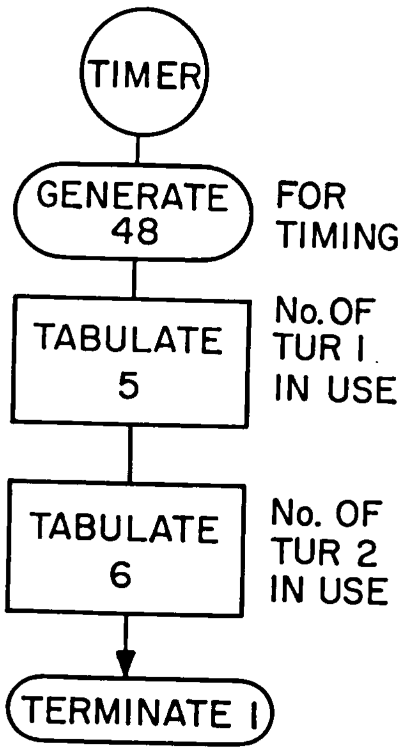
Block Diagram 1





TURRET BOARD MODEL
(COMMUNICATION CENTER)

Block Diagram 2



TURRET BOARD MODEL
(COMMUNICATION CENTER)

Block Diagram 3

```
BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G                  COMMENTS                                  CARD
                                                                                                   NUMBER
        *      SIMULATE                                                                              1
        TUR1   STORAGE    10                                                                         2
        TUR2   STORAGE    10                                                                         3
        2      TABLE      M1,0,100,30          TIME TO COMPLETE CONVER.-EMERG CALLS                  4
        3      TABLE      M1,0,50,30           WAITING TIMES - EMG CALLS(TUR2 ONLY)                  5
        4      TABLE      M1,0,50,50           TIME UNTIL NON-EMG CALLS HANDLED                      6
        5      TABLE      S$TUR1,0,1,22        NO OF BUSY OP IN TUR1                                 7
        6      TABLE      S$TUR2,0,1,22        NO OF BUSY OP IN TUR2                                 8
        1      FUNCTION   RN1,C6               TIME TO PROC NON EMERGENCY CALLS                      9
        0      0     .1   150   .6    450      .8287 600   .9145 1200  1.0   1800                   10
        2      FUNCTION   RN2,C6               CONVERSE & FORM - EMERGENCY CALLS                    11
        0      100  .1470 400   .657  800      .92   1500  .98   1700  1.0   1800                   12
        3      FUNCTION   RN3,D2               CALL TYPE -  0-EMG, 1-NON EMG                        13
        .7     0     1.0  1                                                                         14
        4      FUNCTION   RN4,C24              EXPO FN                                              15
        0      0     .1   .104  .2    .222     .3    .355  .4    .509  .5    .69                    16
        .6     .915  .7   1.2   .75   1.38     .8    1.6   .84   1.83  .88   2.12                   17
        .9     2.3   .92  2.52  .94   2.81     .95   2.99  .96   3.2   .97   3.5                    18
        .98    3.9   .99  4.6   .995  5.3      .998  6.2   .999  7.0   .9997 8.0                    19
1       GEN    GENERATE   48,FN4               CALL COMES IN                                        20
2              ASSIGN     1,FN3                TYPE OF CALL, DISTRICT                               21
3              GATE SNF   TUR1,PRGP2                                                                22
4              ENTER      TUR1                 GROUP 1 TURRET OPERATORS                             23
5              TEST E     P1,1,PROC1           IS CALL NON EMERGENCY                                24
6              ADVANCE    150,50               IDENTIFY NON EMERGENCY CALLS                         25
7              LEAVE      TUR1                 GROUP 1 OPERATORS                                    26
8              TRANSFER   ,NEMG2               GO TO GP2 OPERATORS                                  27
9       PROC1  ADVANCE    FN2                  HANDLE EMERGENCY CALLS                               28
10             LEAVE      TUR1                                                                      29
11      TSMAN  TABULATE   2                                                                         30
12             TERMINATE  0                                                                         31
        * CALLS WHICH FOUND GROUP 1 TURRET OPERATORS BUSY                                           32
13      PRGP2  PRIORITY   1                    ASSIGN PRIORITY                                      33
        * CALLS HANDLED BY GROUP 2 TURRET OPERATORS                                                 34
14      NEMG2  ENTER      TUR2                 GROUP 2 TURRET OPERATORS                             35
15             TEST NE    P1,K1,NOEMG          TEST FOR EMERG CALLS                                 36
16             TABULATE   3                    WAIT TIME OF EMG CALLS TABULATED                     37
        *                                      TUR2 EMG CALLS ONLY                                  38
17             ADVANCE    FN2                  HANDLE EMERGENCY CALLS                               39
18             LEAVE      TUR2                                                                      40
19             TRANSFER   ,TSMAN                                                                    41
20      NOEMG  TABULATE   4                    TIME UNTIL NON EMG CALLS HANDLED                     42
21             ADVANCE    FN1                  HANDLE NON EMERGENCE CALLS                           43
22             LEAVE      TUR2                                                                      44
23             TERMINATE  0                                                                         45
24      TIMER  GENERATE   48                   1 XACT EVERY 4.8 SEC.                                46
25             TABULATE   5                    TABULATE S$TUR1                                      47
26             TABULATE   6                    TABULATE S$TUR2                                      48
27             TERMINATE  1                                                                         49
               INITIAL    X1,6                 TIME AT THE END OF 1ST RUN IN X1                     50
               INITIAL    X2,10                TUR1 CAPACITY IN X2                                  51
               INITIAL    X3,10                TUR2 CAPICITY IN X3                                  52
               START      75                   6 MINUTES TO SET UP INITIAL COND                     53
               RESET                                                                                54
               INITIAL    X1,120               TIME AT THE END OF 2ND RUN IN X1                     55
```

19809

```
          START     1500           RUN O 2 HOURS
     *
     *
          REPORT
          EJECT
          TEXT      STATISTICS AFTER A RUN OF =X1,2/XXX= MINUTES
          SPACE     1
          TEXT      CAPACITY OF TURRET 1 = =X2,2/XX=
          TEXT      CAPACITY OF TURRET 2 = =X3,2/XX=
          SPACE     1
     STO  INCLUDE   S1-S2/1,2,3,4,5,6,7,8
          SPACE     2
          TEXT      TIME TO CCMPLETE CONVERSATION - EMERGENCY CALLS
     TAB  INCLUDE   T2/1,2,3,4,10,11,12,13
          SPACE     1
          TEXT      WAITING TIMES - EMERGENCY CALLS (TURRET 2 ONLY)
     TAB  INCLUDE   T3/1,2,3,4,10,11,12,13
          SPACE     1
          TEXT      TIME UNTIL NON-EMERGENCY CALLS HANDLED
     TAB  INCLUDE   T4/1,2,3,4,10,11,12,13
          SPACE     1
          TEXT      FREQUENCY DISTRIBUTION OF TURRET 1
     TAB  INCLUDE   T5/1,2,3,4,10,11,12,13
          SPACE     1
          TEXT      FREQUENCY DISTRIBUTION OF TURRET 2
     TAB  INCLUDE   T6/1,2,3,4,10,11,12,13
     *
     * GRAPHS FOR TABLES 2,5 AND 6
     *
     *
     * TURRET 1 OCCUPENCY - TABLE 5 FREQUENCY DISTRIBUTION IN PER CENT
     *
          EJECT
          GRAPH     TP,5
          ORIGIN    50,10
          X         ,9,1,0,1,11
          Y         0,5,8,5
     51   STATEMENT 8,30,TURRET 1 OCCUPENCY
     39   STATEMENT 9,45,TABLE 5 FREQUENCY DISTRIBUTION IN PER CENT
     2    STATEMENT 37,8,PER CENT
     2    STATEMENT 38,8,OF TOTAL
     45   STATEMENT 54,30,NO CF OPERATORS IN TURRET 1
          ENDGRAPH
     *
     * TURRET 2 OCCUPENCY - TABLE 6 FREQUENCY DISTRIBUTION IN PER CENT
     *
          EJECT
          GRAPH     TP,6
          ORIGIN    50,10
          X         ,9,1,0,1,11
          Y         0,5,8,5
     51   STATEMENT 8,30,TLRRET 2 OCCUPENCY
     39   STATEMENT 9,45,TABLE 6 FREQUENCY DISTRIBUTION IN PER CENT
     2    STATEMENT 37,8,PER CENT
     2    STATEMENT 38,8,OF TOTAL
     45   STATEMENT 54,30,NO OF OPERATORS IN TURRET 2
          ENDGRAPH
```

```
*
*  TIME TO COMPLETE CONVERSATION FOR EMERGENCY CALLS -
*  TABLE 2 CUMULATIVE PER CENT
*
          EJECT
          GRAPH        TD,2
          ORIGIN       50,10
          X            ,,4,0,1,25
          Y            0,20,5,9
   36     STATEMENT    4,49,TIME TO COMPLETE CONVERSATION FOR EMERGENCY CALLS
   47     STATEMENT    5,30,TABLE 2 CUMULATIVE PER CENT
   2      STATEMENT    41,6,   CUM
   2      STATEMENT    42,6,PER CENT
   45     STATEMENT    54,30,TIME (IN TENTH OF A SECOND)
          ENDGRAPH
*
          END
```

RESET
INITIAL X1,120
START 1500

STATISTICS AFTER A RUN OF 120 MINUTES

CAPACITY OF TURRET 1 = 10
CAPACITY OF TURRET 2 = 10

STORAGE	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	ENTRIES	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
TUR1	10	8.385	.838	1042	579.453	9	10
TUR2	10	6.314	.631	782	581.387	10	10

TIME TO COMPLETE CONVERSATION - EMERGENCY CALLS
TABLE 2
ENTRIES IN TABLE 1002 MEAN ARGUMENT 794.082 STANDARD DEVIATION 425.000 NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE
0	0	.00	.0
100	1	.09	.0
200	58	5.78	5.8
300	51	5.08	10.9
400	44	4.39	15.3
500	105	10.47	25.8
600	122	12.17	38.0
700	120	11.97	49.9
800	120	11.97	61.9
900	40	3.99	65.9
1000	44	4.39	70.3
1100	50	4.99	75.3
1200	39	3.89	79.2
1300	47	4.69	83.9
1400	32	3.19	87.1
1500	49	4.89	92.0
1600	30	2.99	95.0
1700	29	2.89	97.9
1800	19	1.89	99.8
1900	0	.00	99.8
2000	2	.19	100.0

REMAINING FREQUENCIES ARE ALL ZERO.

WAITING TIMES - EMERGENCY CALLS (TURRET 2 ONLY)
TABLE 3
ENTRIES IN TABLE 299 MEAN ARGUMENT 41.812 STANDARD DEVIATION 92.000 NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE
0	210	70.23	70.2
50	24	8.02	78.2
100	21	7.02	85.2
150	13	4.34	89.6
200	6	2.00	91.6
250	11	3.67	95.3
300	5	1.67	96.9
350	2	.66	97.6
400	3	1.00	98.6
450	0	.00	98.6
500	4	1.33	100.0

REMAINING FREQUENCIES ARE ALL ZERO

TIME UNTIL NON-EMERGENCY CALLS HANDLED
TABLE 4

ENTRIES IN TABLE 475 | MEAN ARGUMENT 151.126 | STANDARD DEVIATION 155.125 | NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE
0	111	23.36	23.3
50	8	1.68	25.0
100	11	2.31	27.3
150	138	29.05	56.4
200	141	29.68	86.1
250	16	3.36	89.4
300	9	1.89	91.3
350	6	1.26	92.6
400	10	2.10	94.7
450	3	.63	95.3
500	5	1.05	96.4
550	2	.42	96.8
600	3	.63	97.4
650	2	.42	97.8
700	0	.00	97.8
750	1	.21	98.1
800	2	.42	98.5
850	2	.42	98.9
900	1	.21	99.1
950	0	.00	99.1
1000	2	.42	99.5
1050	1	.21	99.7
1100	1	.21	100.0

REMAINING FREQUENCIES ARE ALL ZERO

FREQUENCY DISTRIBUTION OF TURRET 1

TABLE 5

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	
1500	8.396	1.550	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE
0	0	.00	.0
1	0	.00	.0
2	2	.13	.1
3	3	.19	.3
4	27	1.79	2.1
5	43	2.86	4.9
6	125	8.33	13.3
7	176	11.73	25.0
8	300	19.99	45.0
9	363	24.19	69.2
10	461	30.73	100.0

REMAINING FREQUENCIES ARE ALL ZERO

FREQUENCY DISTRIBUTION OF TURRET 2

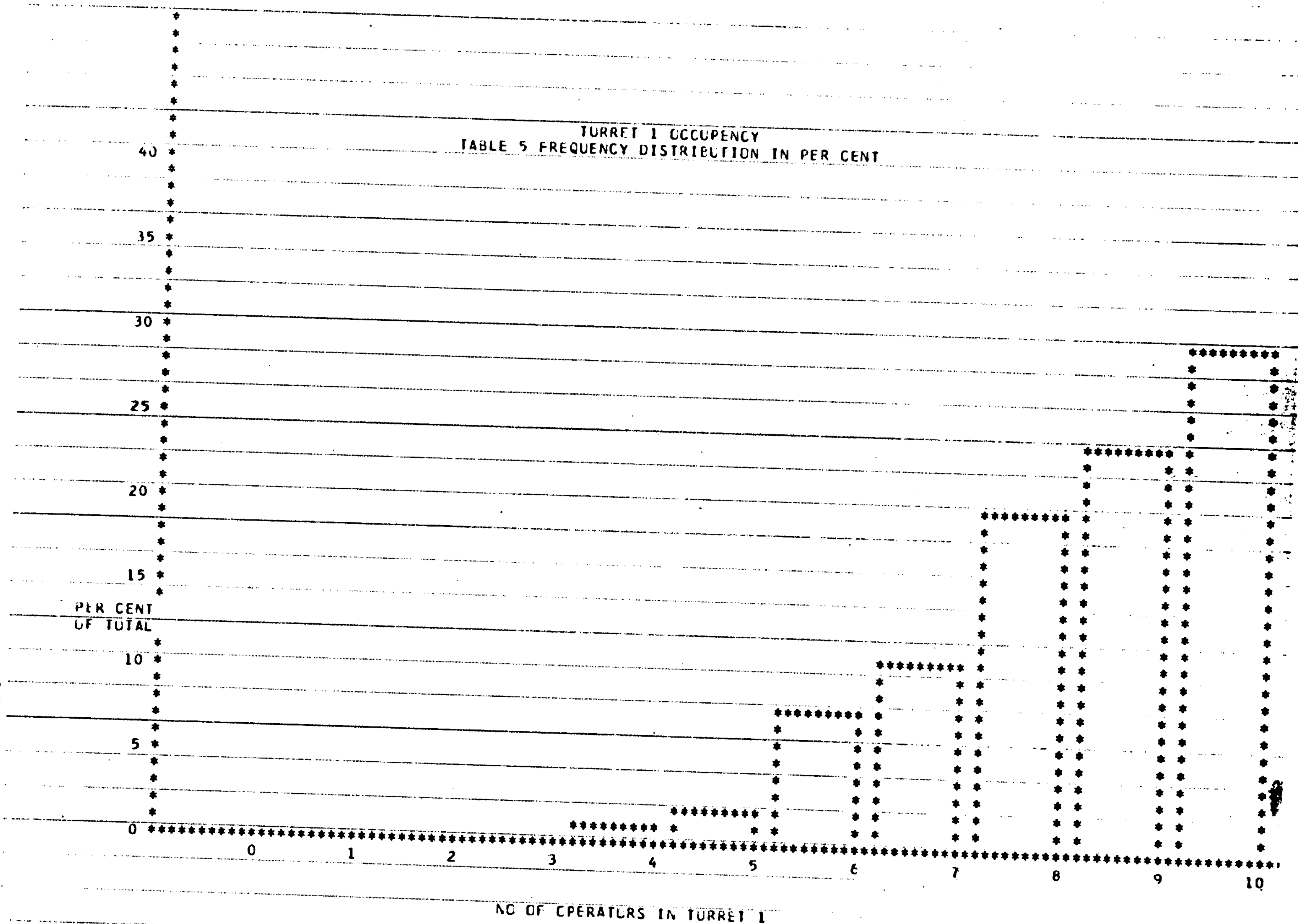
TABLE 6

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	
1500	6.300	2.695	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE
0	9	.59	.5
1	33	2.19	2.7
2	81	5.39	8.1
3	126	8.39	16.5
4	171	11.39	27.9
5	205	13.66	41.6
6	208	13.86	55.5
7	152	10.13	65.6
8	109	7.26	72.9
9	75	4.99	77.9
10	331	22.06	100.0

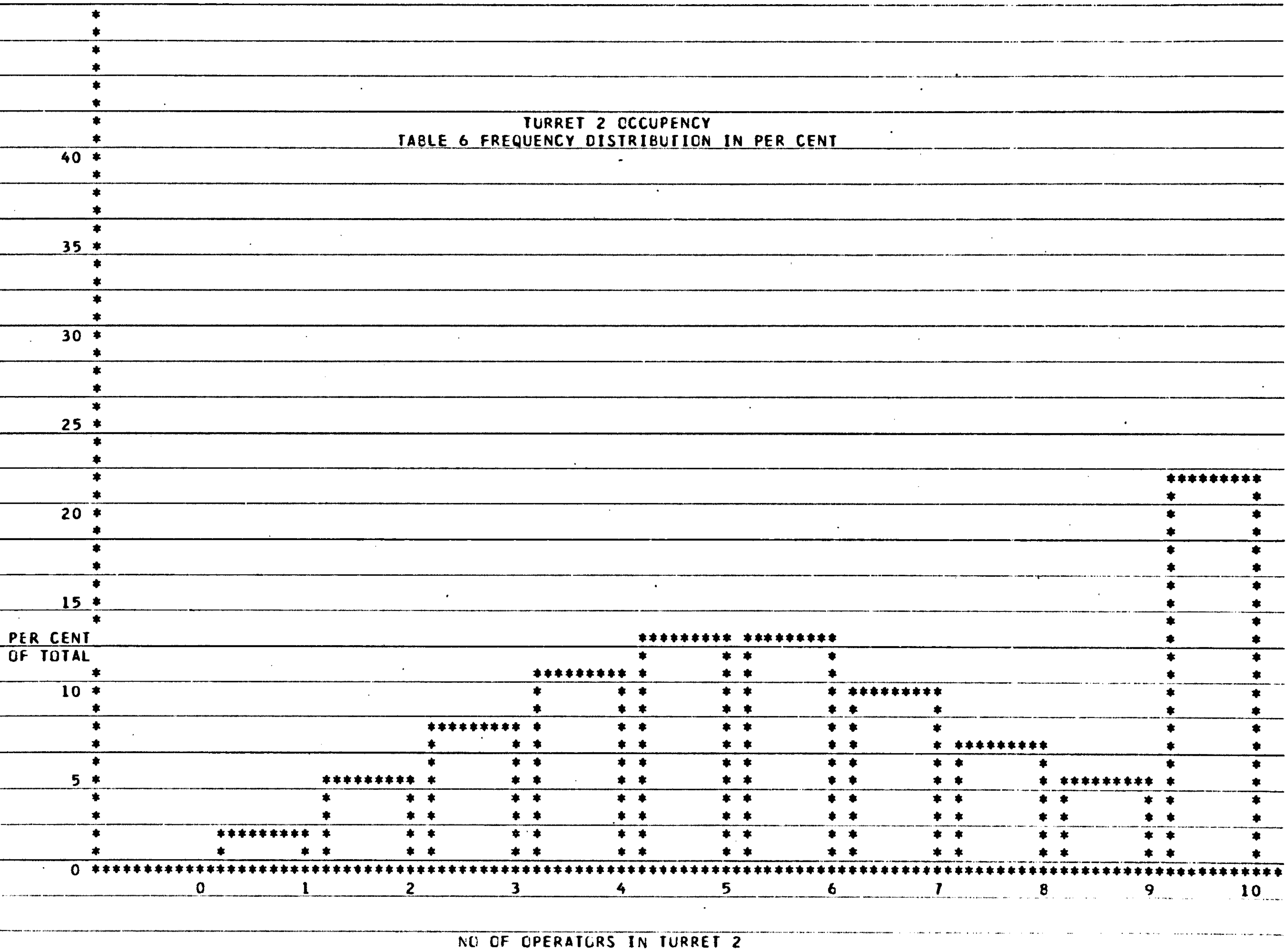
REMAINING FREQUENCIES ARE ALL ZERO

TURRET 1 OCCUPENCY
TABLE 5 FREQUENCY DISTRIBUTION IN PER CENT

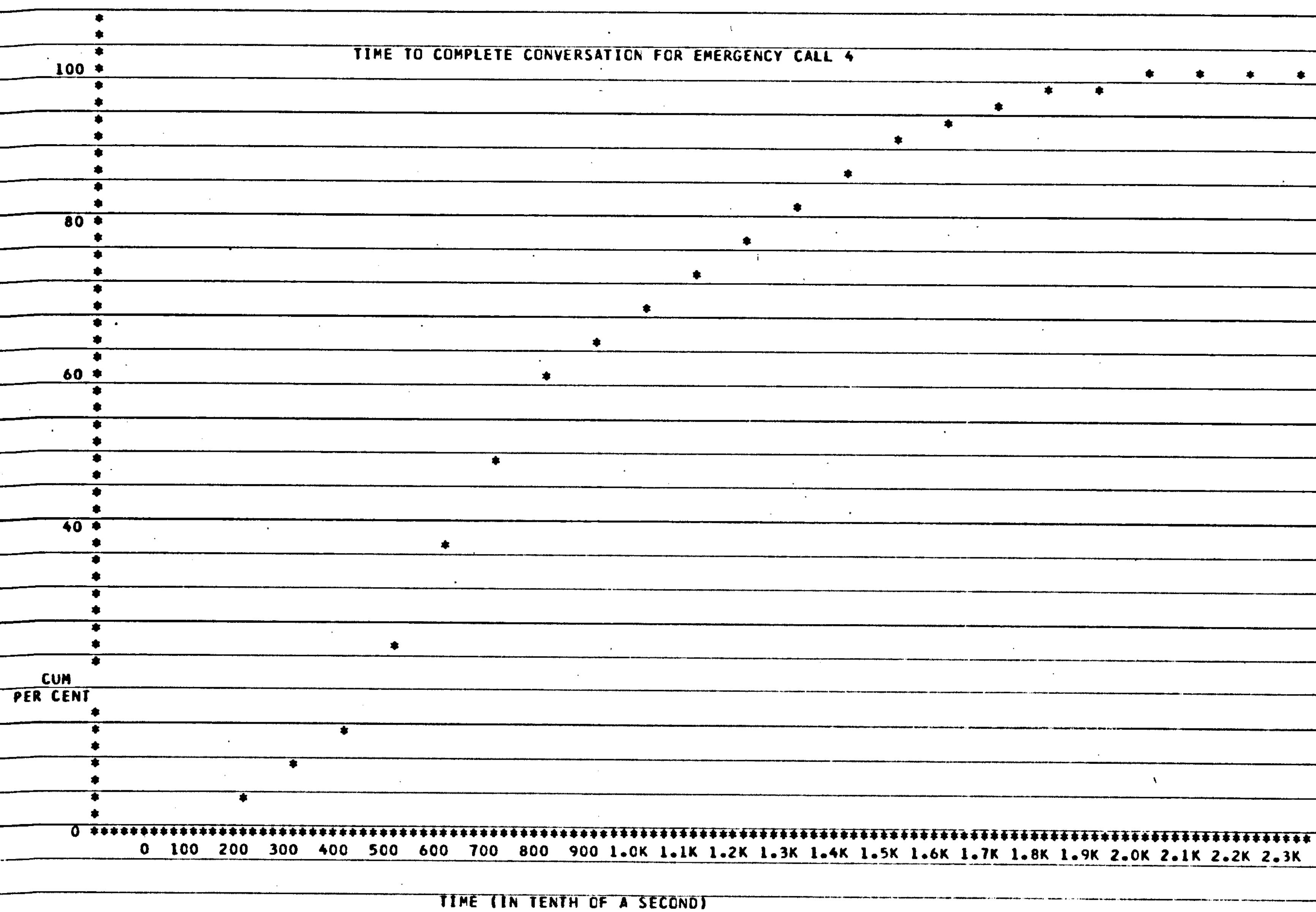


TURRET 2 OCCUPENCY - TABLE 6 FREQUENCY DISTRIBUTION IN PER CENT

1 19823



TIME TO COMPLETE CONVERSATION FOR EMERGENCY CALLS -
TABLE 2 CUMULATIVE PER CENT



APPENDIX B

COMPUTER PROGRAM - RESPONSE SYSTEM

The following is a detailed narrative of the program logic of the Response System Model viewed from a GPSS point of view. Familiarity with the GPSS/360 language is assumed.

First the definitions and correspondences of major entities used in the discussion are given. This is followed by the definition and description of distributions used and special output produced. Then the logic of the program is discussed.

INPUT

FACILITIES	(Label and/or No.)	DEFINITION
DSPH 1	(1)	Division 1 Dispatcher
DSPH 2	(2)	Division 2 Dispatcher
DSPH 3	(3)	Division 3 Dispatcher
DSPH 4	(4)	Division 4 Dispatcher
DSPH 5	(5)	Division 5 Dispatcher
DSPH 6	(6)	Division 6 Dispatcher
MSDSO	(7)	Master Dispatcher-Manhattan South
MSDNO	(8)	Master Dispatcher-Manhattan North
STORAGES		
CAR 1	(9)	Division 1 Cars
CAR 2	(10)	Division 2 Cars
CAR 3	(11)	Division 3 Cars
CAR 4	(12)	Division 4 Cars
CAR 5	(13)	Division 5 Cars
CAR 6	(14)	Division 6 Cars
SCTR 1	(15)	Division 1 Scooters
SCTR 2	(16)	Division 2 Scooters
SCTR 3	(17)	Division 3 Scooters
SCTR 4	(18)	Division 4 Scooters
SCTR 5	(19)	Division 5 Scooters
SCTR 6	(20)	Division 6 Scooters

USER CHAINS		DEFINITION
DSPH 1	(1)	Calls Waiting for Division 1 Dispatcher
DSPH 2	(2)	Calls Waiting for Division 2 Dispatcher
DSPH 3	(3)	Calls Waiting for Division 3 Dispatcher
DSPH 4	(4)	Calls Waiting for Division 4 Dispatcher
DSPH 5	(5)	Calls Waiting for Division 5 Dispatcher
DSPH 6	(6)	Calls Waiting for Division 6 Dispatcher
DSPH 7	(7)	Calls Waiting for Man.So. Master Dispatcher
DSPH 8	(8)	Calls Waiting for Man.No. Master Dispatcher
RPBK 1	(9)	Report back calls waiting for Div.1 Dispatcher
RPBK 2	(10)	Report back calls waiting for Div.2 Dispatcher
RPBK 3	(11)	Report back calls waiting for Div.3 Dispatcher
RPBK 4	(12)	Report back calls waiting for Div.4 Dispatcher
RPBK 5	(13)	Report back calls waiting for Div.5 Dispatcher
RPBK 6	(14)	Report back calls waiting for Div.6 Dispatcher

QUEUES		CONTENTS
DSPH 1	(1)	Div. 1 calls to be dispatched waiting for Dispatcher
DSPH 2	(2)	Div. 2 calls to be dispatched waiting for Dispatcher
DSPH 3	(3)	Div. 3 calls to be dispatched waiting for Dispatcher
DSPH 4	(4)	Div. 4 calls to be dispatched waiting for Dispatcher
DSPH 5	(5)	Div. 5 calls to be dispatched waiting for Dispatcher
DSPH 6	(6)	Div. 6 calls to be dispatched waiting for Dispatcher
DSPSO	(7)	Man. So. calls waiting for master dispatcher
DSPNO	(8)	Man. No. calls waiting for master dispatcher

FUNCTIONS

FUNCTION 1 - Distribution of time spent at the turret boards by emergency calls. This function is obtained from TABLE 2 of the Turret Board Model.

FUNCTION 3 - Defines the fraction of incoming calls which are non-emergency, non-Manhattan emergency, and emergency calls for each Division of Manhattan. The function is coded as a cumulative distribution with the following values:

1 - 6 - Manhattan Division 1 - 6 Emergency
7 - Non-Manhattan Emergency and Non-Emergency
(Figure 35)

FUNCTIONS 4-9 - These functions give the probability of the request types by Division. FUNCTION 4 corresponds to Division 1, FUNCTION 5 to Division 2, etc. The function values are as follows:

1. Murder, rape
2. felonious assault, robbery
3. burglary, grand larceny
4. grand larceny - motor vehicle
5. ambulance request
6. misdemeanor
7. offense
8. non-crime request

For each Division, the fraction of incoming emergency calls which fall into each category is given. The functions are coded as cumulative distributions. (Figures 36-41)

FUNCTION 10 - This function gives the probability that the crime has occurred inside. Numbers are coded in parts per 1,000. (Figure 42)

FUNCTION 11 - This function gives the probability of the crime still being in progress at the time of the call, for each request type. Since request types 5 and 8 are not crimes, they have probabilities of zero. The probabilities are given in parts per 1,000. (Figure 43)

FUNCTION 12 - This function gives the mean radio reach time as a function of field resource utilization. It is assumed that time to reach a field unit by the dispatcher increases as utilization of the field resource increases. The utilization is given in parts per 1,000. (Figure 44)

FUNCTION 13 - This function gives the mean car travel time to reach the scene of the request as a function of car utilization in the field. The utilization is shown in parts per 1,000. (Figure 45)

FUNCTION 14 - This function is similar to Function 13 except mean scooter travel time to reach the scene of the request is given.

FUNCTION 16 - This function gives the type of resource to be assigned to each request type. Cars are represented by a 0 functional value; scooters by a 1.

FUNCTION 17 - This function defines the probability of arrest (given a crime in progress) as a function of response time. It is assumed that as response time decreases, probability of arrest increases. (Figure 46)

FUNCTION 18 - This function gives the average disposition time for each request type. It is assumed that disposition times differ significantly if an arrest is made. Therefore, the function look-up is coded as follows:

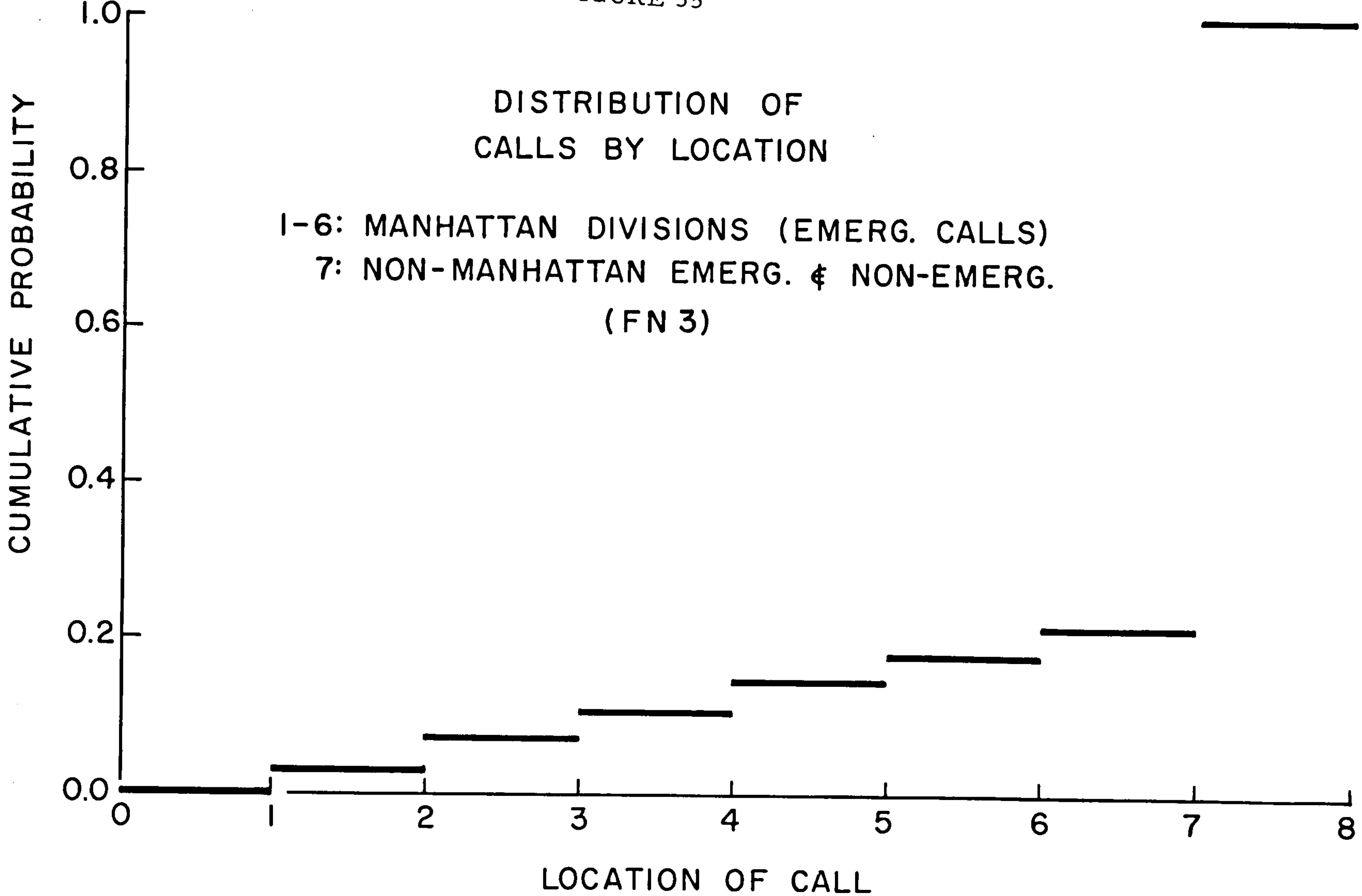
Units digit - request type (1-8)
tens digit - 1 if arrest, 0 if non-arrest

Example

01 is murder or rape without an arrest
11 is murder or rape with an arrest made.

FUNCTION 20 - This is the cumulative exponential distribution.

FIGURE 35



DISTRIBUTION OF
CALLS BY LOCATION
1-6: MANHATTAN DIVISIONS (EMERG. CALLS)
7: NON-MANHATTAN EMERG. & NON-EMERG.
(FN 3)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
LOCATION OF CALL

FIGURE 36

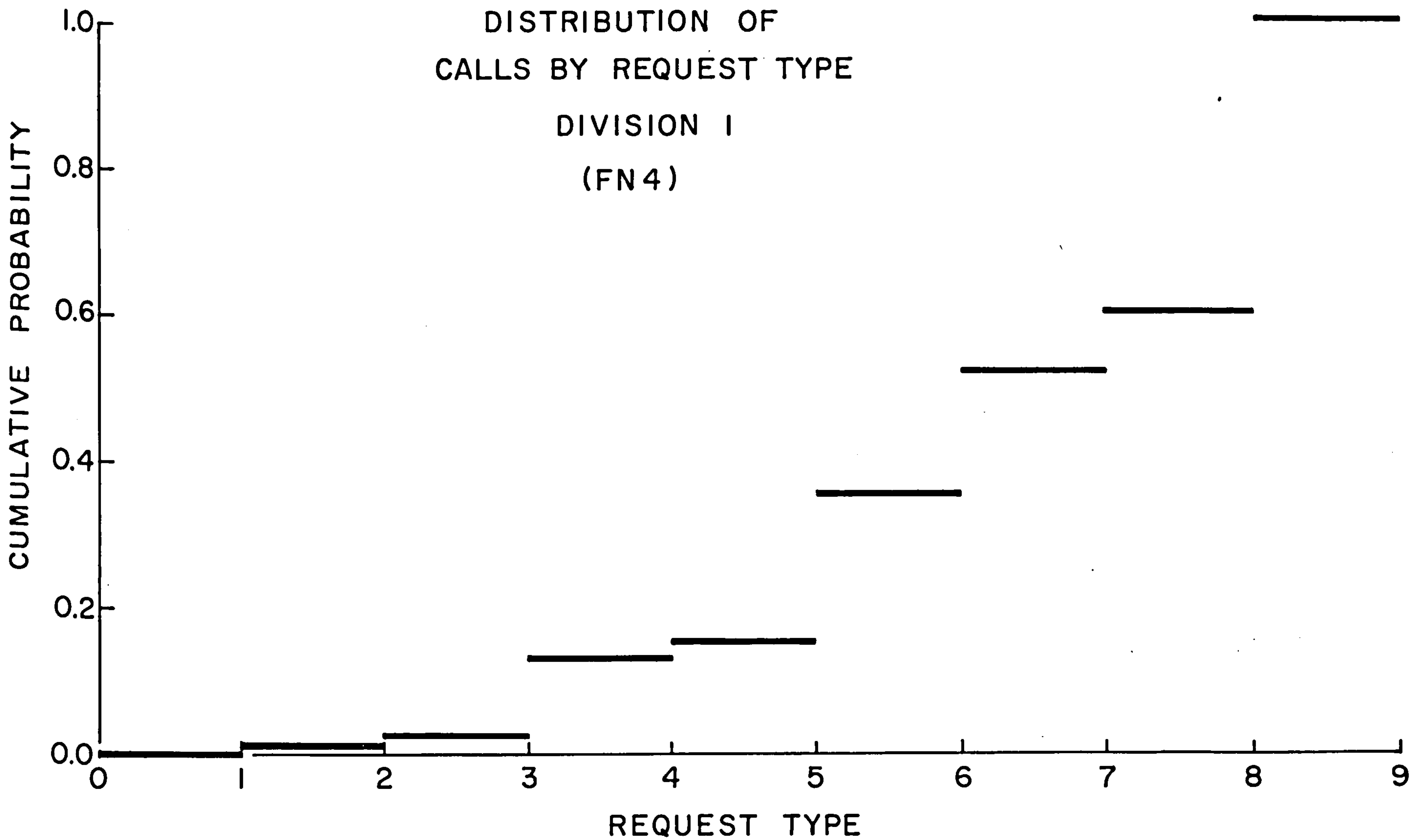

DISTRIBUTION OF
CALLS BY REQUEST TYPE
DIVISION I
(FN4)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
REQUEST TYPE

FIGURE 37

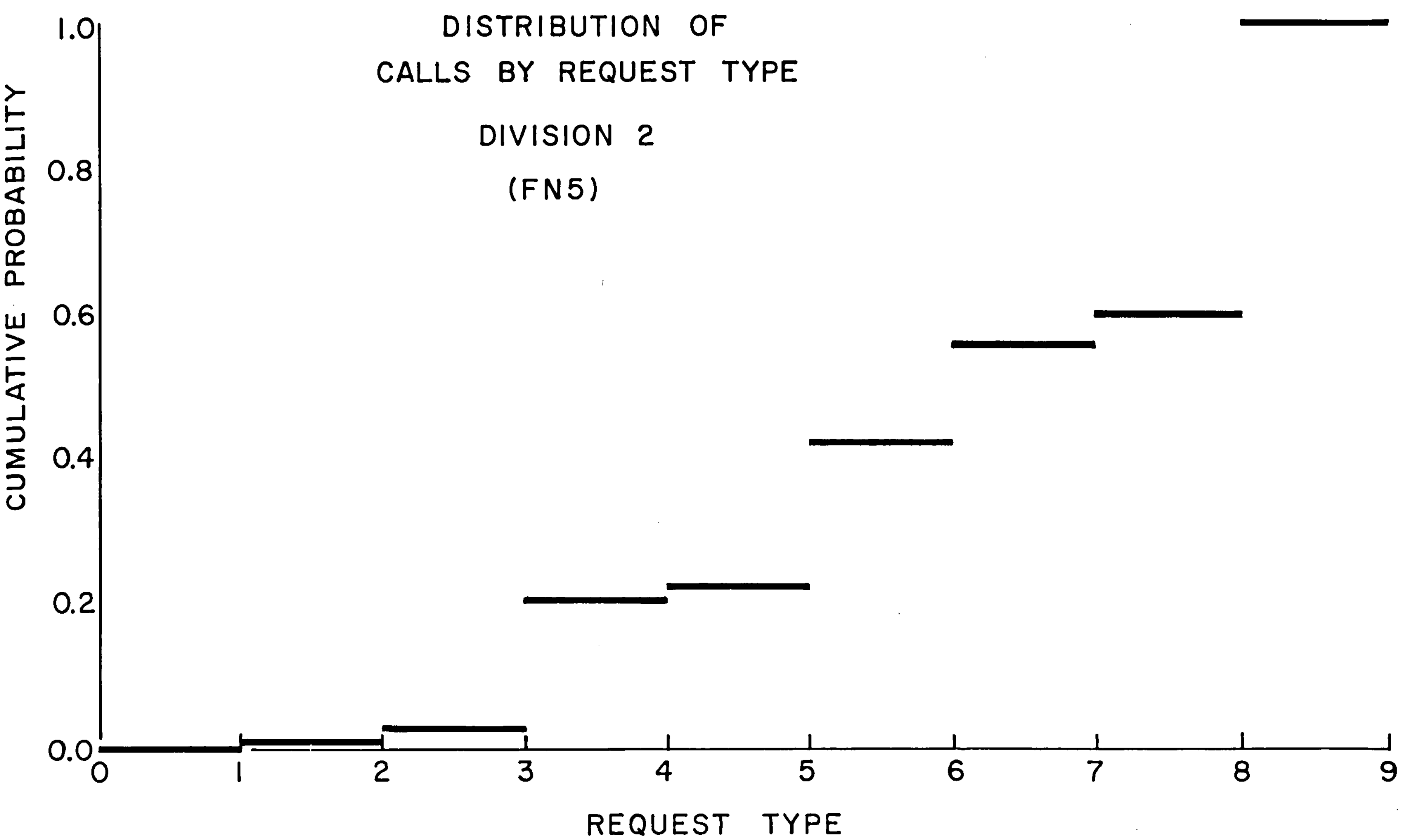

DISTRIBUTION OF
CALLS BY REQUEST TYPE
DIVISION 2
(FN5)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
REQUEST TYPE

FIGURE 38

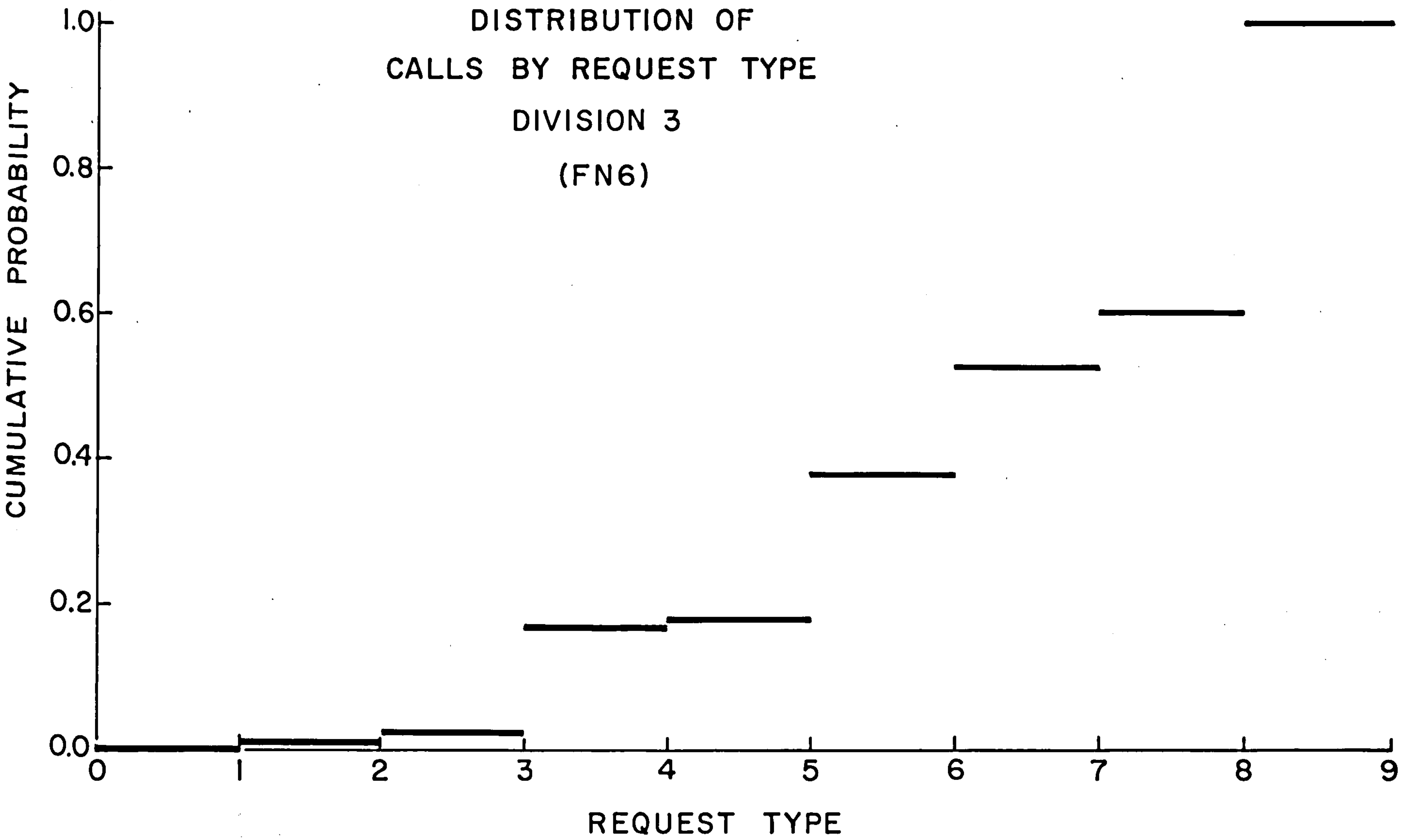

DISTRIBUTION OF
CALLS BY REQUEST TYPE
DIVISION 3
(FN6)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
REQUEST TYPE

FIGURE 39

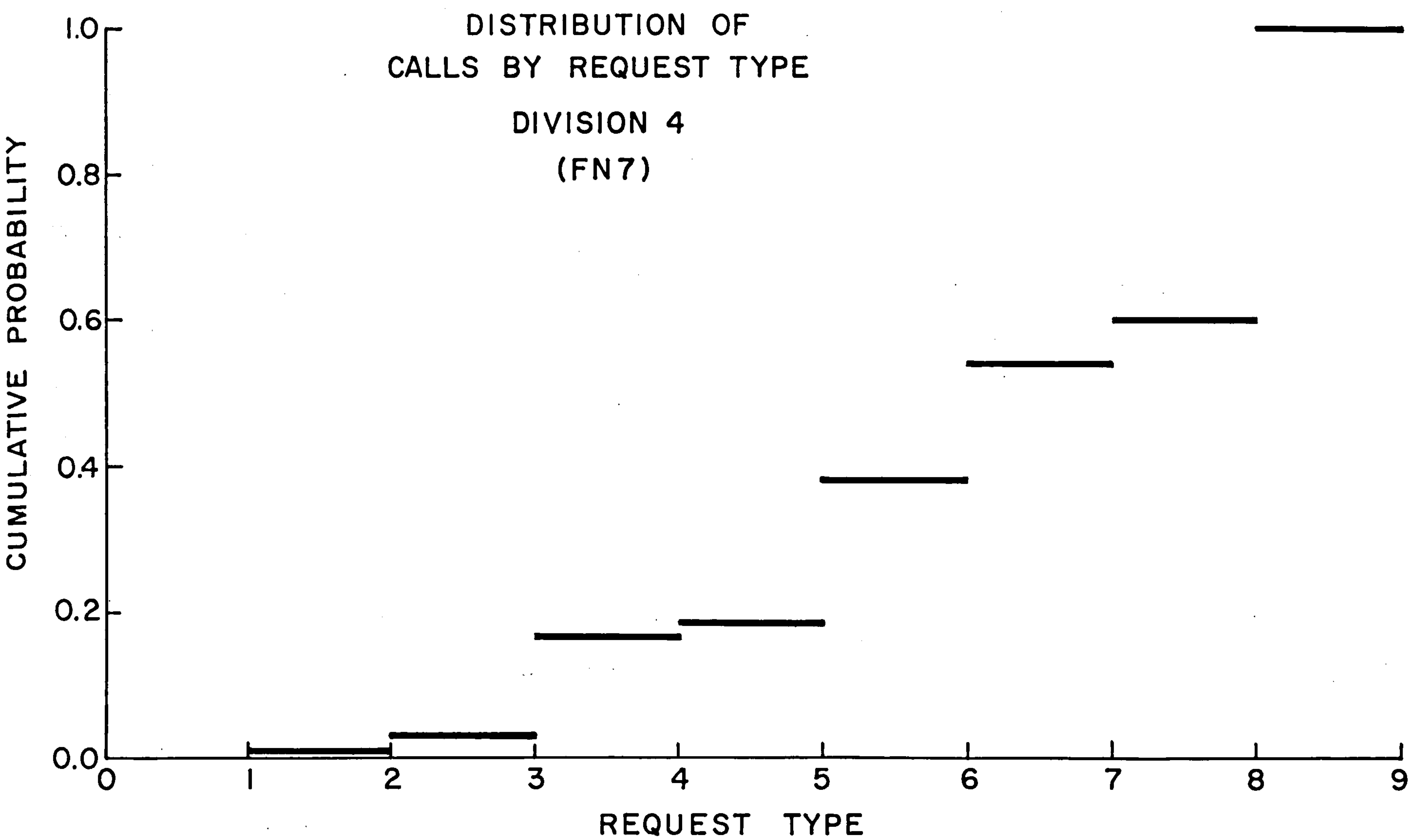
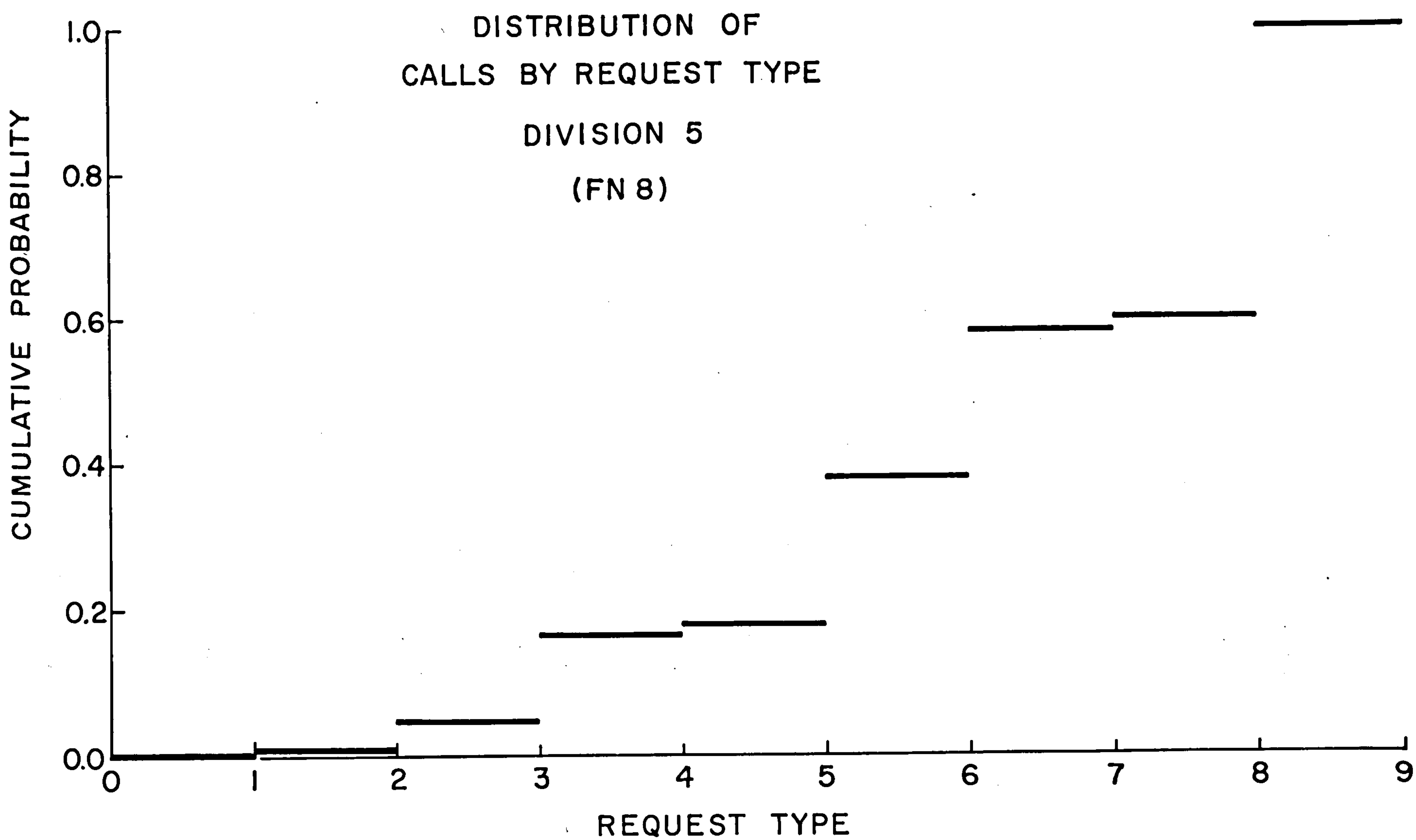

DISTRIBUTION OF
CALLS BY REQUEST TYPE
DIVISION 4
(FN7)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
REQUEST TYPE

FIGURE 40



DISTRIBUTION OF
CALLS BY REQUEST TYPE
DIVISION 5
(FN 8)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
REQUEST TYPE

FIGURE 41

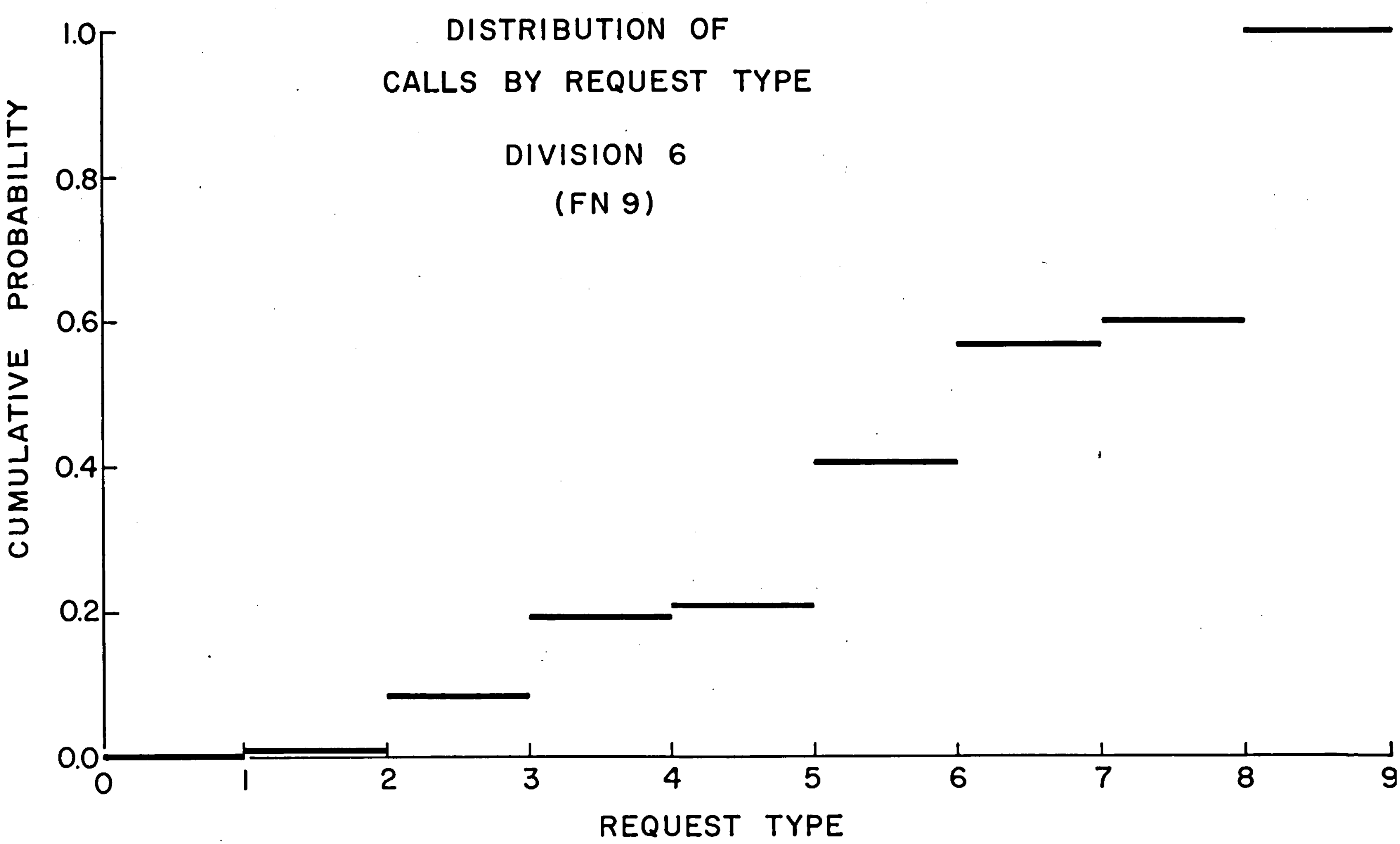

DISTRIBUTION OF
CALLS BY REQUEST TYPE
DIVISION 6
(FN 9)
CUMULATIVE PROBABILITY
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
REQUEST TYPE

FIGURE 42

PROBABILITY OF
CALLS OCCURRING INSIDE
BY REQUEST TYPE
(FN 10)

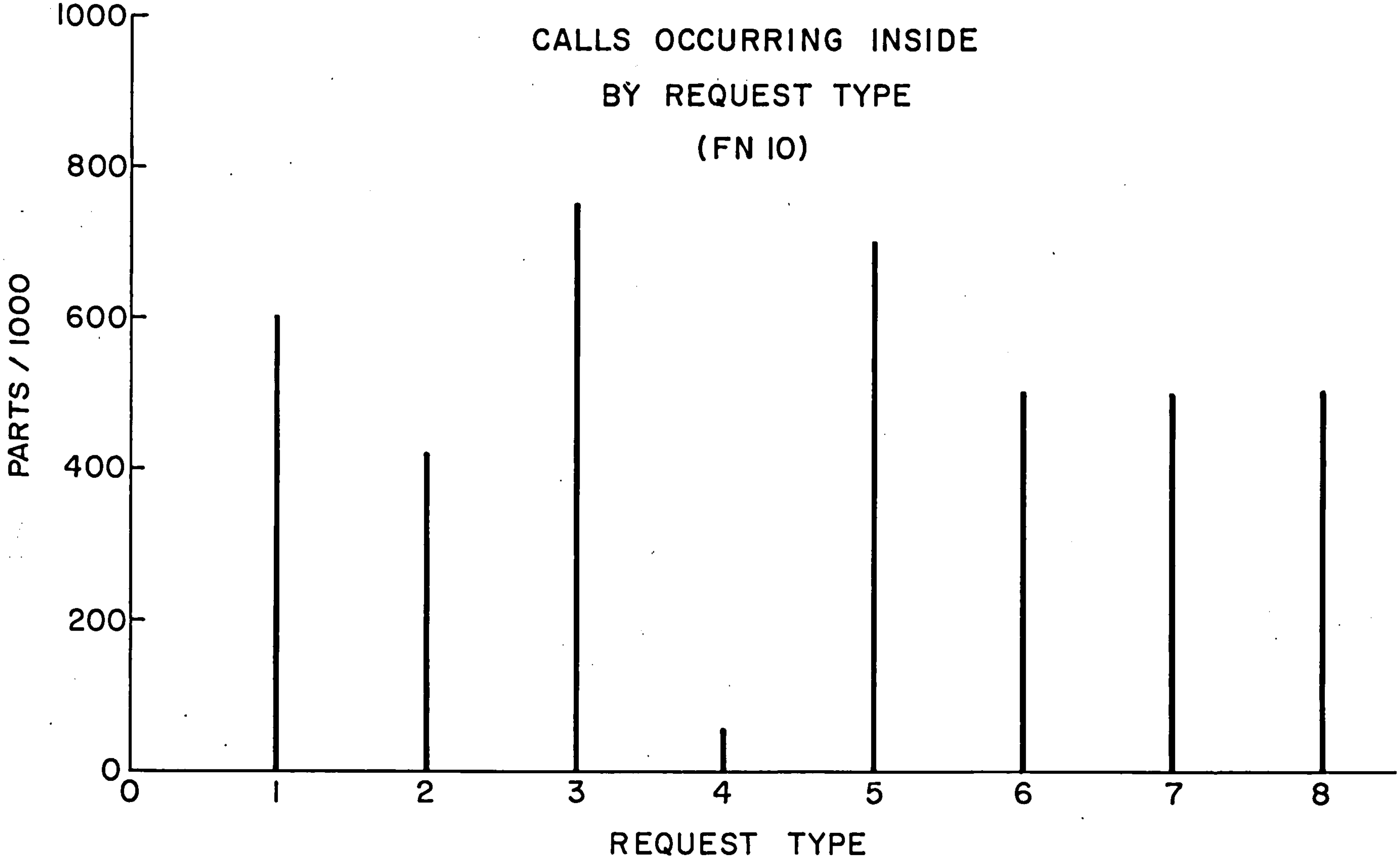


FIGURE 43

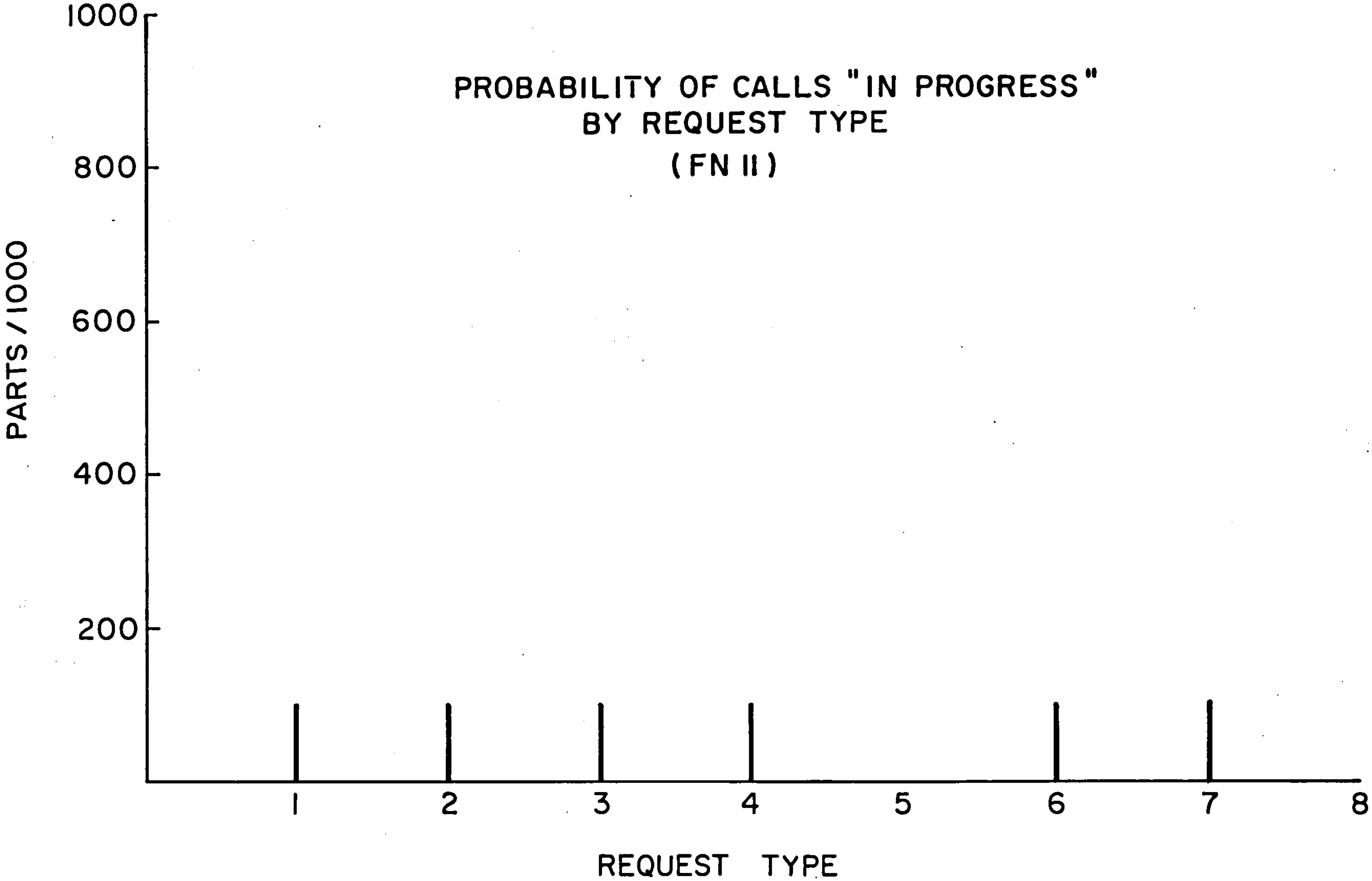

PROBABILITY OF CALLS "IN PROGRESS"
BY REQUEST TYPE
(FN II)
1000
800
600
400
200
PARTS / 1000
1
2
3
4
5
6
7
8
REQUEST TYPE

FIGURE 44

MEAN RADIO REACH TIME: ϕ (RESOURCE UTILIZATION)
(FN 12)

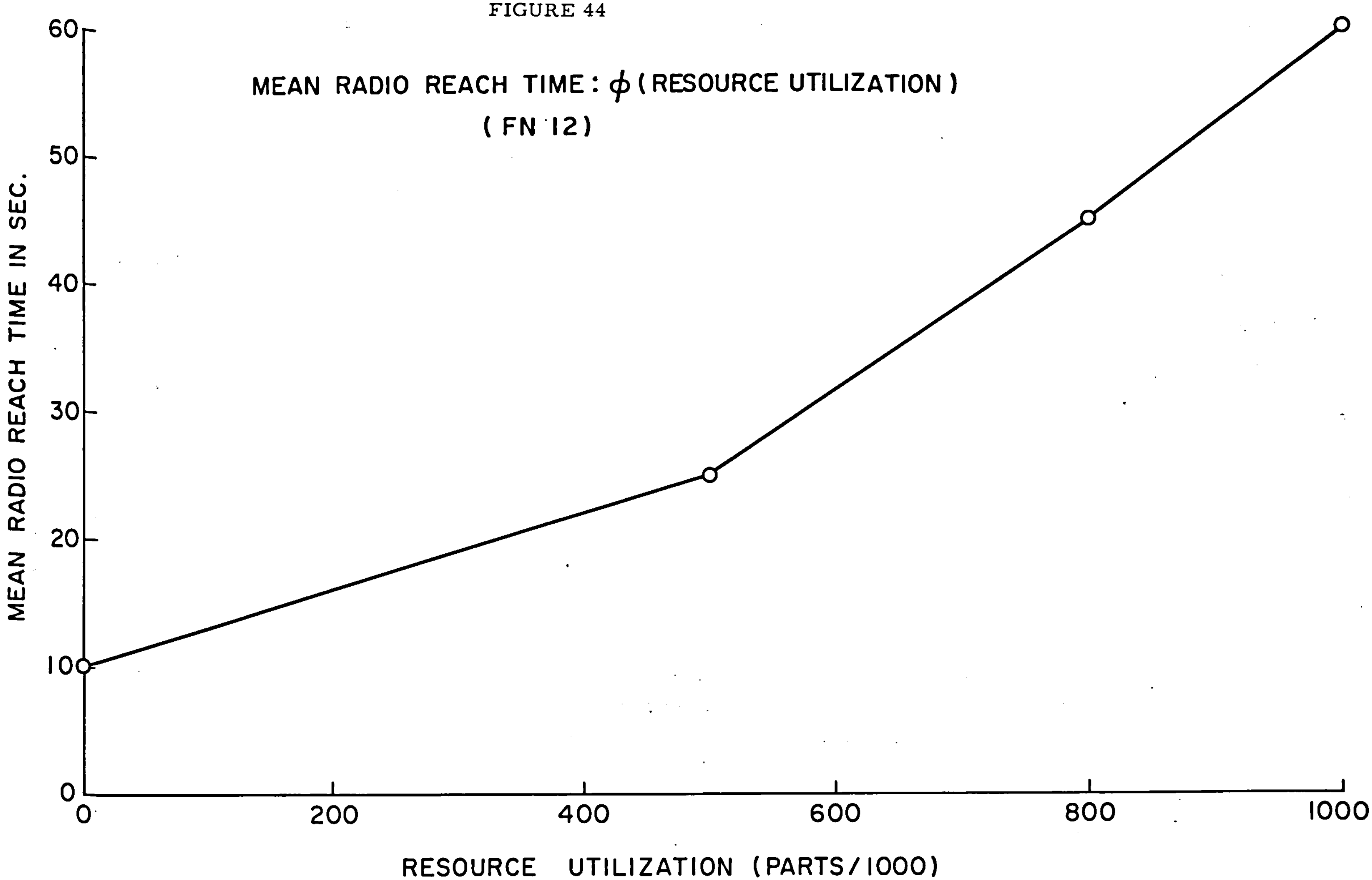


FIGURE 45

MEAN CAR (SCOOTER) TRAVEL TIME: ϕ(CAR(SCOOTER) UTILIZATION)
(FN13, FN14)

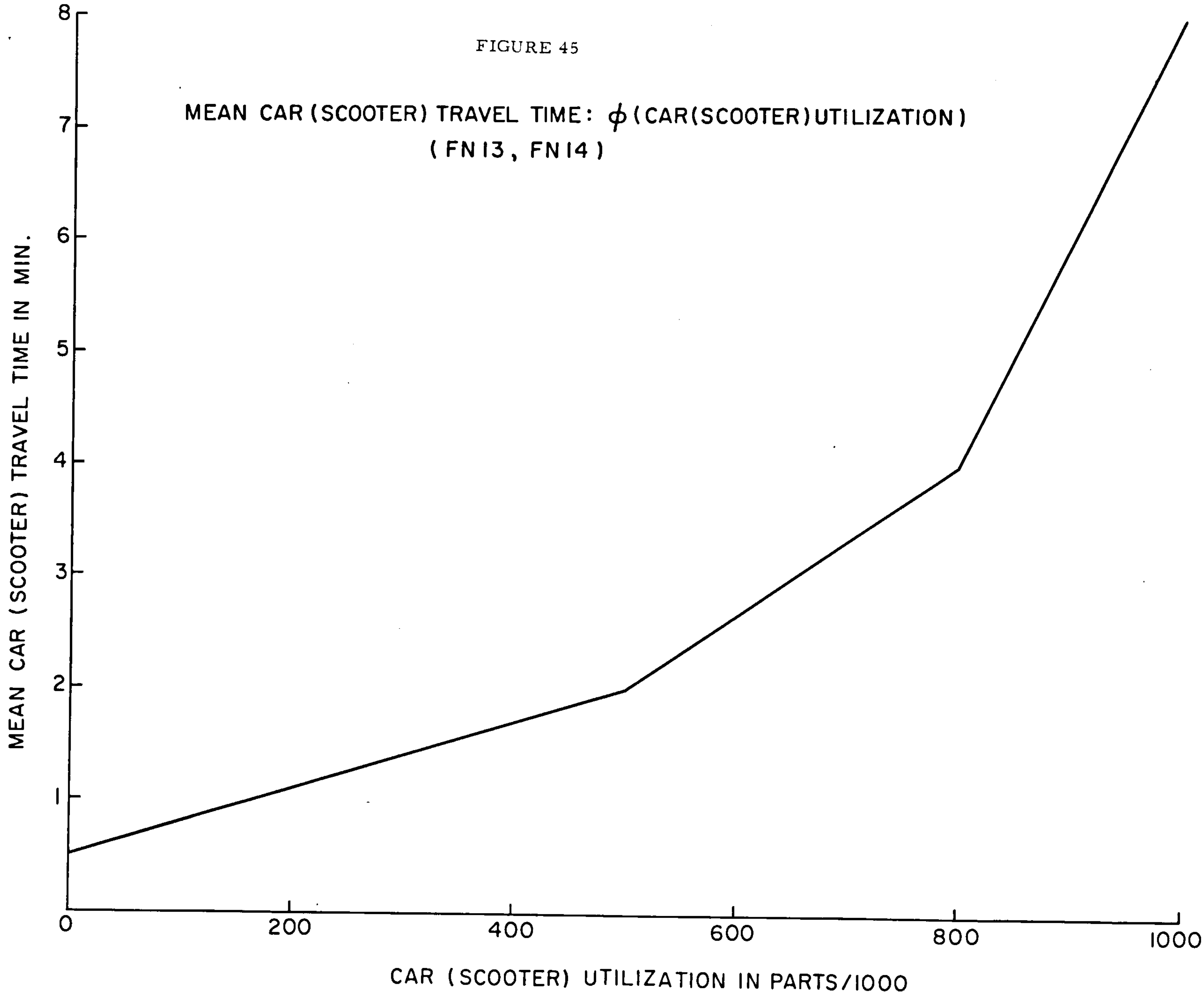
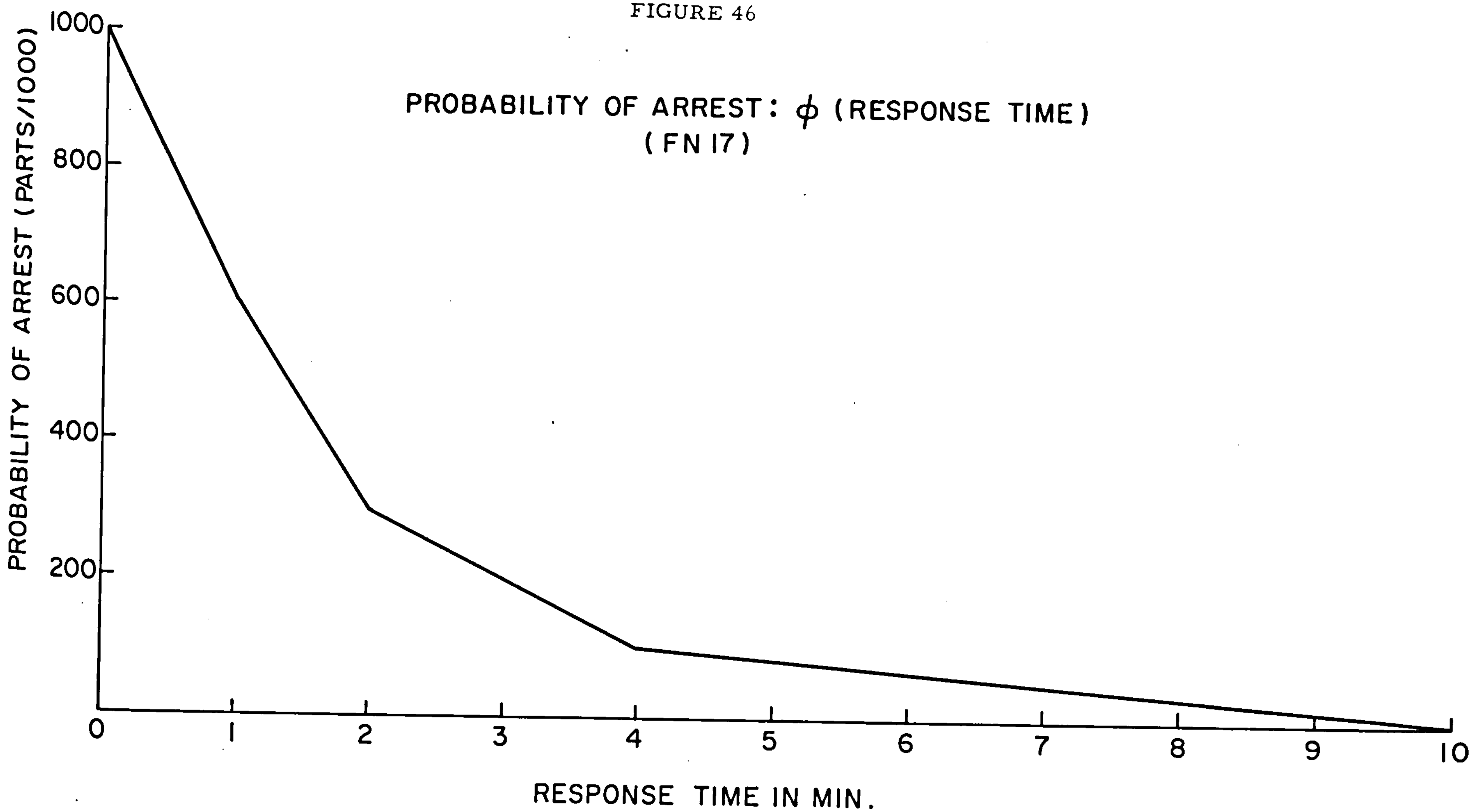


FIGURE 46

PROBABILITY OF ARREST: ϕ (RESPONSE TIME)
(FN 17)



OUTPUT

TABLES

TABLE 3 - This table gives the distribution of time to reach dispatcher queue.

TABLE 4-9 - These tables give the distributions of time until dispatch for low priority emergency calls for Manhattan Divisions 1 - 6.

TABLES 10-15 - These tables give the distributions of time until dispatch for high priority emergency calls for Manhattan Divisions 1 - 6.

TABLES 16-21 - These tables give the distributions of time until the scene reached (response time) for low priority emergency calls for Manhattan Divisions 1 - 6.

TABLES 22-27 - These tables give the distributions of time until scene reached (response time) for high priority emergency calls for Manhattan Divisions 1 - 6.

TABLES 28-33 - These tables give the distributions of time until disposition completed (time spent in system) for low priority emergency calls for Manhattan Division 1 - 6.

TABLES 34-39- These tables give the distributions of time until disposition completed (time spent in system) for high priority emergency calls for Manhattan Divisions 1 - 6.

TABLE 40 - This table gives the distribution of time until dispatch for all Manhattan emergency calls. It is a summary of TABLES 4-15.

TABLE 41 - This table gives the distribution of time until scene reached for all Manhattan emergency calls. It is a summary of TABLES 16-27.

TABLE 42 - This table gives the distribution of time until disposition completed for all Manhattan emergency calls. It is a summary of TABLES 28-39.

MATRIX SAVE VALUES	DESCRIPTION
CRTYP	Number of emergency requests by request type and division. Columns represent request type. Rows represent division. Column 9 is a total by request type. Row 9 is a total by division.
CARCR	Number of cars in use for each division at various times throughout the run. Colums represent divisions. Rows are sampled values.
CARAV	Similar to CARCR except average number of cars in use.
SCTCR	Similar to CARCR except number of scooters in use at various times throughout the run.
SCRAV	Similar to CARAV except average number of scooters in use.

Detailed Logic Description

Calls are generated at a specified mean inter-arrival time using FUNCTION 20, the exponential distribution. Next FUNCTION 3 is assigned to PARAMETER 9. This indicates whether the call is a Manhattan emergency call (1-6), a non-emergency or non-Manhattan emergency call (7,8). Since only Manhattan emergency calls are considered in this version, types 7,8 are terminated. Next the request type is assigned to PARAMETER 2 in the following manner:

1. The function number for the proper function, depending on division, is assigned to PARAMETER 1 by the INDEX Block.
2. PARAMETER 2 is assigned a value designating re-request type (1-8), randomly selected for the function whose number is given in PARAMETER 1.

Next the state of being inside/outside is assigned to the call. Since a zero in PARAMETER 3 indicates inside, only those calls which are to be considered as being outside incidents must be tagged with a 1. FUNCTION 10 is interrogated for the probability that the particular request type is inside and that fraction of the calls is transferred to BYPOT. The remainder is assigned a 1 in PARAMETER 3. In similar manner, the state of being in progress/past is assigned. In this case, FUNCTION 11 is interrogated for the probability that the particular request type is in progress.

The model then simulates the time spent at the turret boards. The ADVANCE block labeled TRRT randomly selects a time from FUNCTION 1 (Distribution of Time Spent at the Turret Boards). Priorities for dispatching are assigned by the routine labeled ASPRI. The true priorities are assigned to PARAMETER 6 of the call; this is used throughout the model to determine the order of transactions on USER CHAINS. The higher the parameter value, the lower the priority. Request types 1-3, if they are crimes in progress, are assigned a 1 in PARAMETER 6. All others are assigned a 2 in PARAMETER 6. A value of 3 is assigned later in the model to indicate that disposition is complete and the field resource is attempting to reach the dispatcher for report-back. The high priority calls also have their GPSS PRIORITIES set to 1. This is used only for tabulation purposes.

At the block labeled CONVR the call spends time to represent the conveyor belt carrying the slips with the recorded information about the call to the master dispatcher.

The particular request type and division is then entered to the MATRIX SAVEVALUE CRTYP. A test is made to see if the call is from Manhattan North or South and the appropriate master dispatcher number is assigned to PARAMETER 5 at the blocks labeled MSDSO or MSDNO. The calls queue for the appropriate master dispatcher, and, if the master dispatcher is busy, they are linked to the USER CHAIN whose number and name is identical to that of the FACILITY representing the master dispatcher. The calls are linked on the basis of PARAMETER 6 which contains an indication of the call priority. The high priority calls are handled first. When the master dispatcher is free, the call is unlinked and seizes the master dispatcher. He spends time to determine the precinct and sector of the call and is then released. The next call waiting is unlinked and sent to the master dispatcher and TABLE 3 is tabulated for the call.

Next the type of resource to be dispatched is assigned to the call. This is done by interrogating FUNCTION 16 and assigning the values (0 for cars, 1 for scooters) to PARAMETER 7. The STORAGE number of the particular group of resources to be assigned is placed in PARAMETER 8. This is done in the following manner:

1. FUNCTION 16 value (0 or 1) is multipled by the constant 6 and placed in PARAMETER 8.
2. The constant 8 is added to PARAMETER 8.
3. PARAMETER 9, which contains the Division Number, is added to PARAMETER 8.

A field resource can now be assigned by the dispatcher. The call joins a queue identical in name and number to the dispatcher and is linked to a USER CHAIN if the dispatcher is busy. The linking is done on the PARAMETER 6 value so that high priority calls get access to the dispatcher before low priority calls. Report-back calls are last on the chain since they are assigned a PARAMETER 6 value of 3 prior to report-back. When the call is unlinked (or if it was never linked because the dispatcher was free), it is sent to CKBAK. At CKBAK, PARAMETER 6 is interrogated for a value of 3 to determine if this is a report-back call and, if so, the call is sent to SZDS2 in the report-back routine. Calls to be dispatched are not diverted and continue on to the remainder of the dispatching routine.

The linking and unlinking of both calls to be dispatched and report-back calls using the same dispatcher is further complicated by the use of multiple resources (cars, scooters). Since field resources of any given type (cars, scooters) in any division should never be all in use under normal operating conditions, the model assumes that this is the case. A test is made upon calls to be dispatched to determine if the resources they desire are all in use. If all are in use, the call is sent to a routine ERROR where the run is terminated. Otherwise the call seizes the dispatcher indicated in PARAMETER 9 and departs the queue. A *unit of field* resource indicated in PARAMETER 8 is taken. The ADVANCE block represents the time to locate and dispatch a field unit (radio reach time). It is assumed that these times are exponentially distributed where the mean is a function of the utilization of the field resource required. FUNCTION 12 gives this relationship. The call then releases the dispatcher and unlinks the next call waiting for the dispatcher from the USER CHAIN. At this point "Time Until Dispatch" is tabulated. This is done twice. Once by division and priority and once for an "all call" tabulation. A MACRO labeled TABL is used since similar tabulations are made throughout the model. The field resource traveling to the scene of the request is next simulated. The proper travel time FUNCTION number (12 or 13) is assigned to PARAMETER 1 by the INDEX block. It is assumed that travel times are exponentially distributed with the mean a function of field resource utilization. These relationships are given by FUNCTION 12 for cars and FUNCTION 13 for scooters. The ADVANCE block utilizes the mean selected from the proper FUNCTION and the exponential distribution.

At this point the arrest determination is made. Arrests are generated only for crimes in progress. The probability of an arrest is assumed to be a function of response time and this relationship is given by FUNCTION 17. This fraction of calls is randomly assigned a 1 in PARAMETER 10 indicating that an arrest has been made.

The time required to handle the request by the field unit (disposition) is assumed to be exponentially distributed with the mean a function of request type and whether or not an arrest is made. FUNCTION 18 gives this relationship. The ADVANCE block labeled DISPO simulates the disposition using the mean selected from FUNCTION 18 and the exponential distribution (FUNCTION 20). Time Until Disposition is then tabulated using the MACRO TABL.

After disposition, reporting back by the field resource is simulated. The call is assigned a PARAMETER 6 value of 3 to indicate that it is now a report-back call. It joins a QUEUE and is LINKED to the USER CHAIN if the dispatcher is occupied. The ordering of the CHAIN is on the value of PARAMETER 6 so that report-back calls have access to the dispatcher only when there are no calls waiting to be dispatched. When the call is unlinked, it is sent to CKBAK as are all calls unlinked from the Dispatcher User Chain. Report-back calls are sent to SZDS2 from there. Calls that do not get linked (find the dispatcher free) go on to SZDS2 also.

At SZDS2 the call SEIZEs the dispatcher and DEPARTs the queue. Time is spent in reporting back to the dispatcher (ADVANCE block). The dispatcher and the unit of field resource are RELEASED. The next call waiting for the dispatcher is UNLINKED and sent to CKBAK. The "Time Until Disposition Completed" is tabulated using the MACRO TABL and the transaction is terminated.

TIMER is a routine which generates a transaction every ten minutes. This transaction is used for timing and also for storing the number of cars and scooters currently in use and average usage of cars and scooters in the appropriate SAVEVALUES.

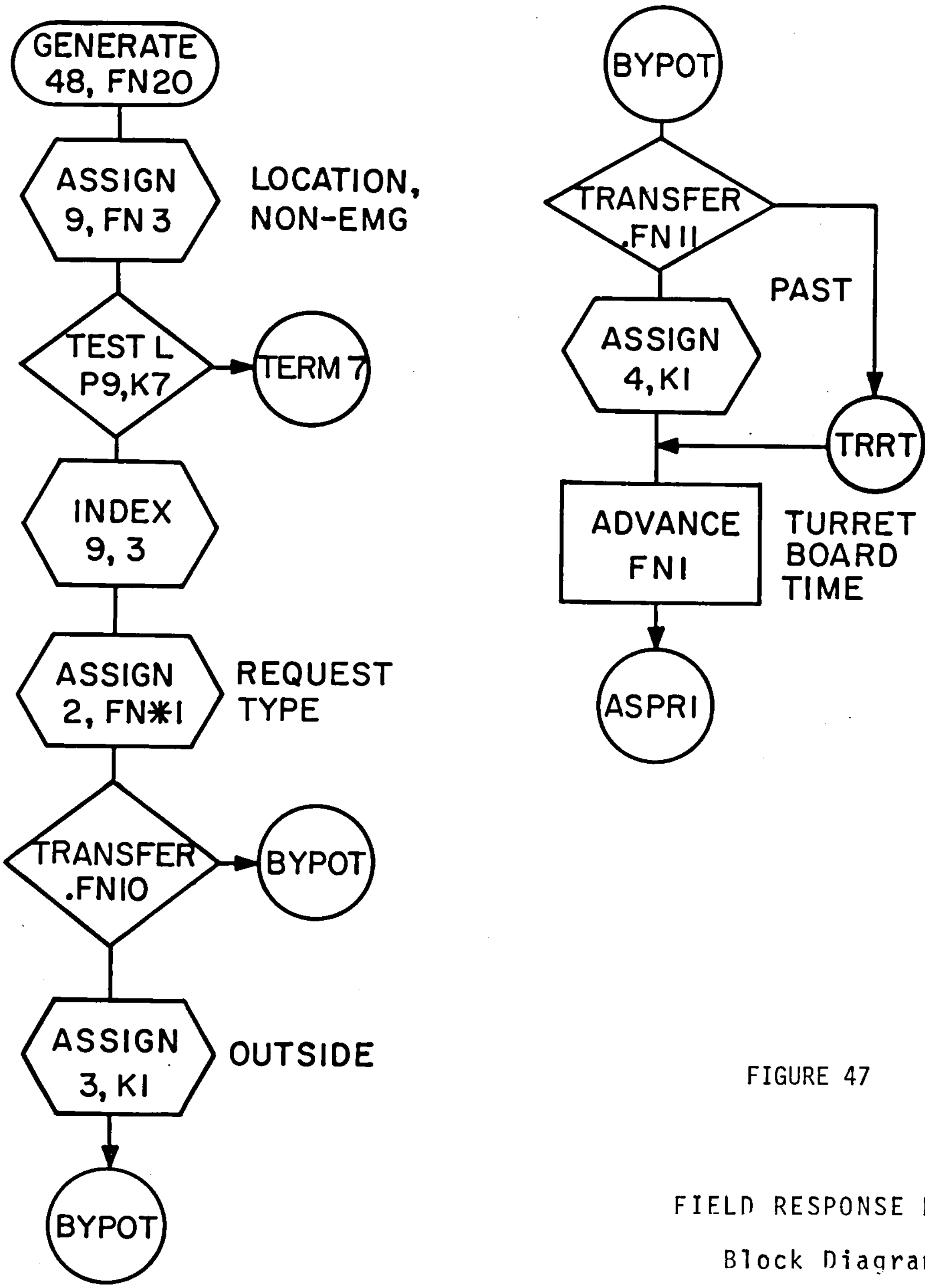
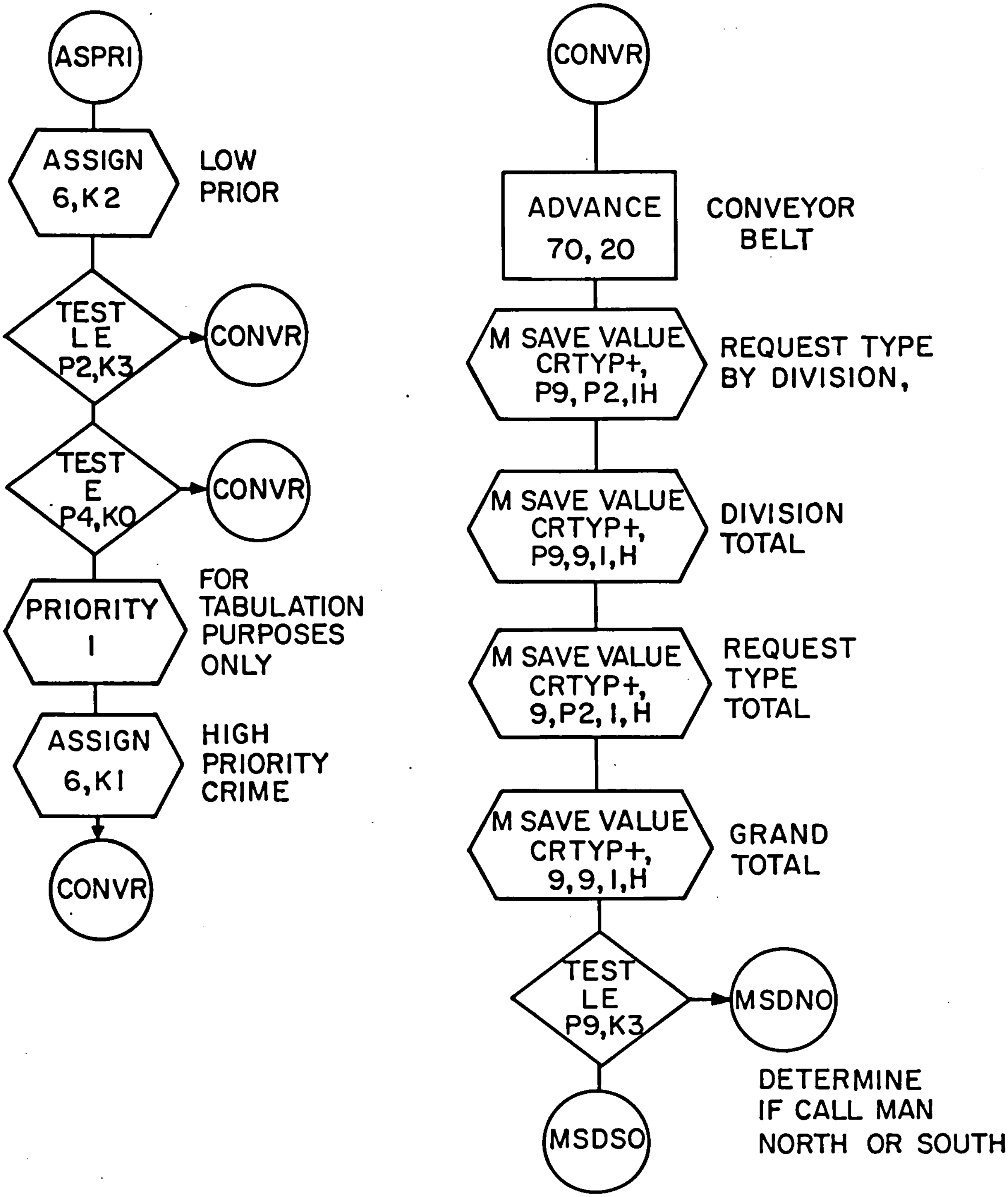


FIGURE 47

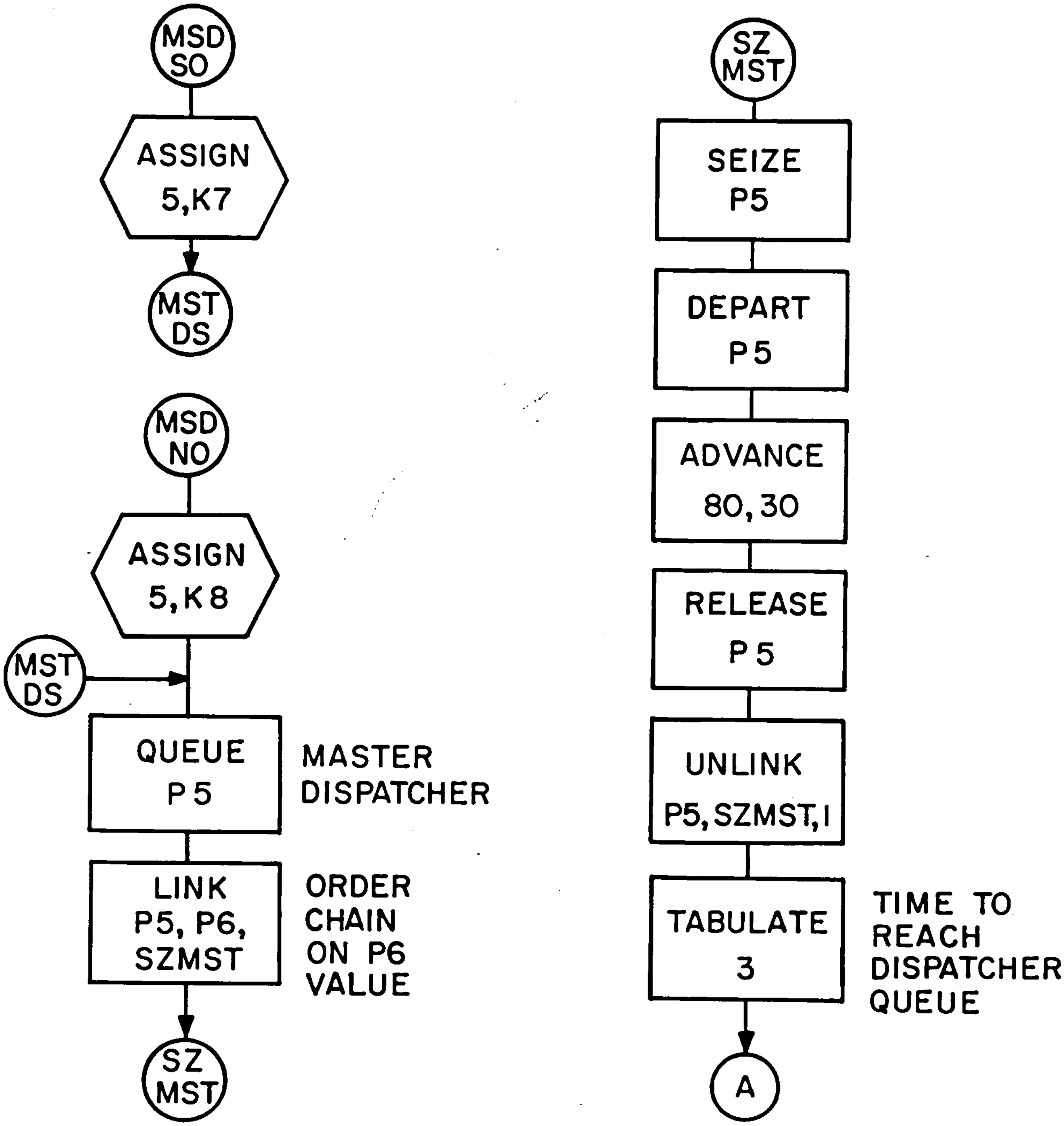
FIELD RESPONSE MODEL

Block Diagram 1



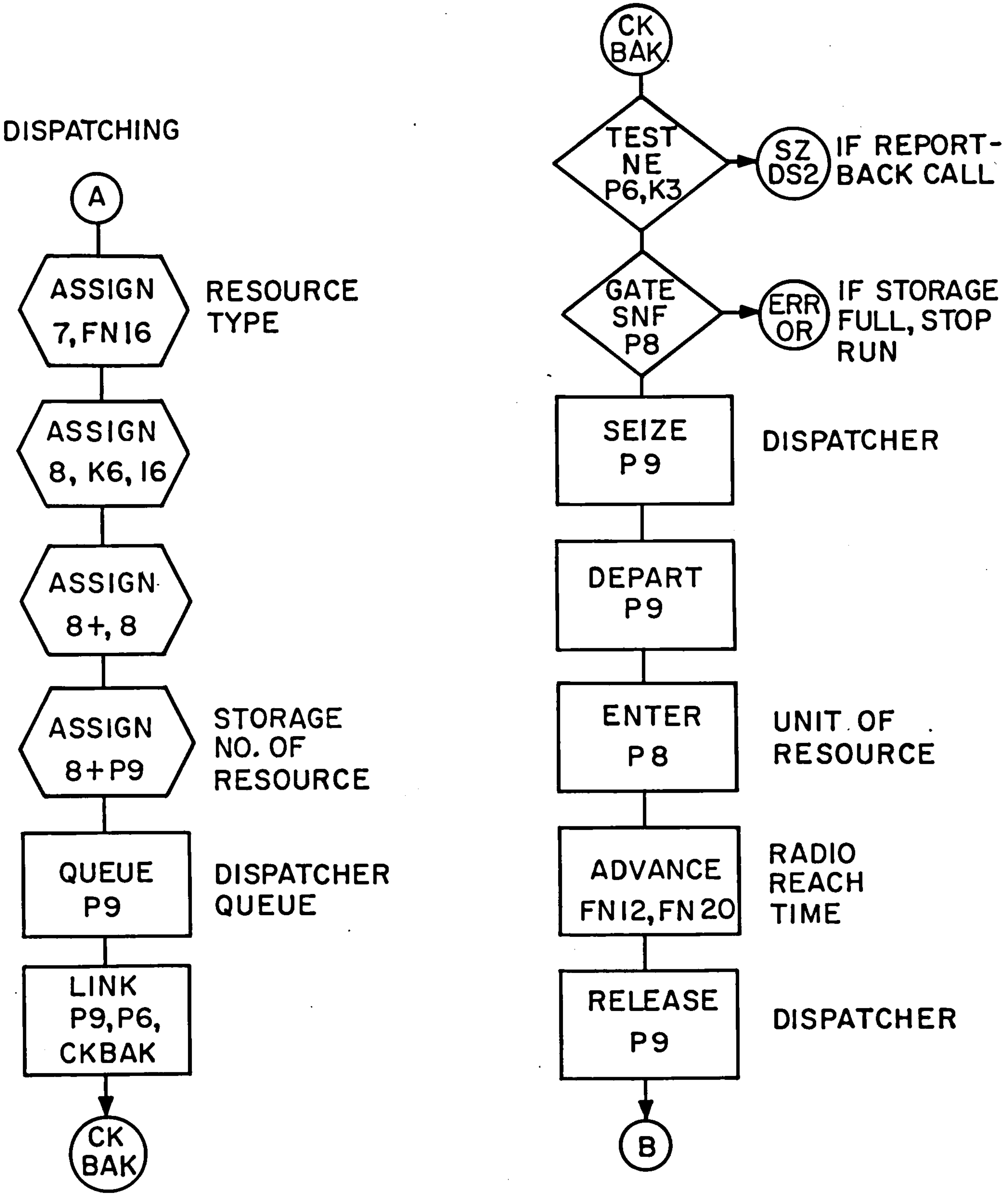
FIELD RESPONSE MODEL

Block Diagram 2



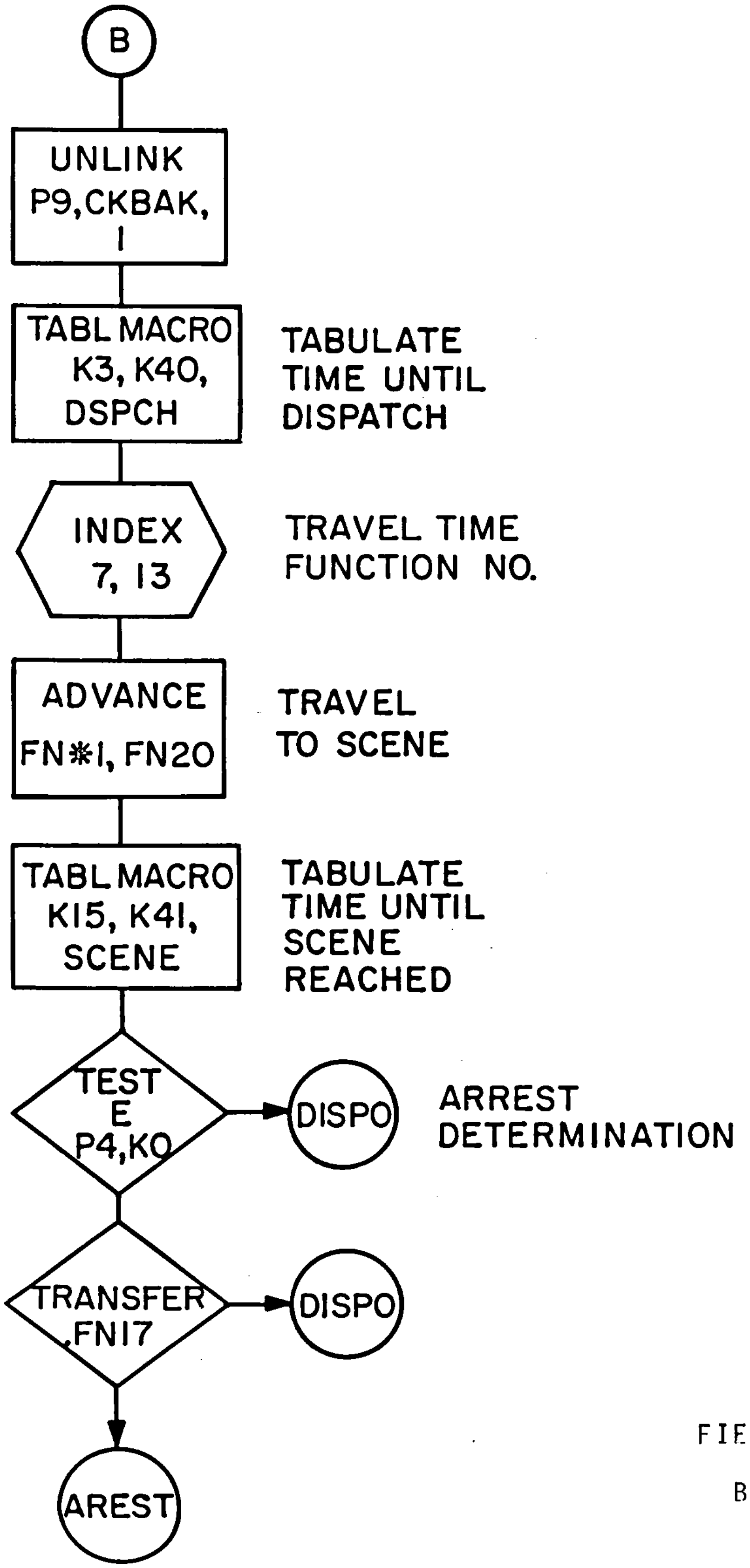
FIELD RESPONSE MODEL

Block Diagram 3



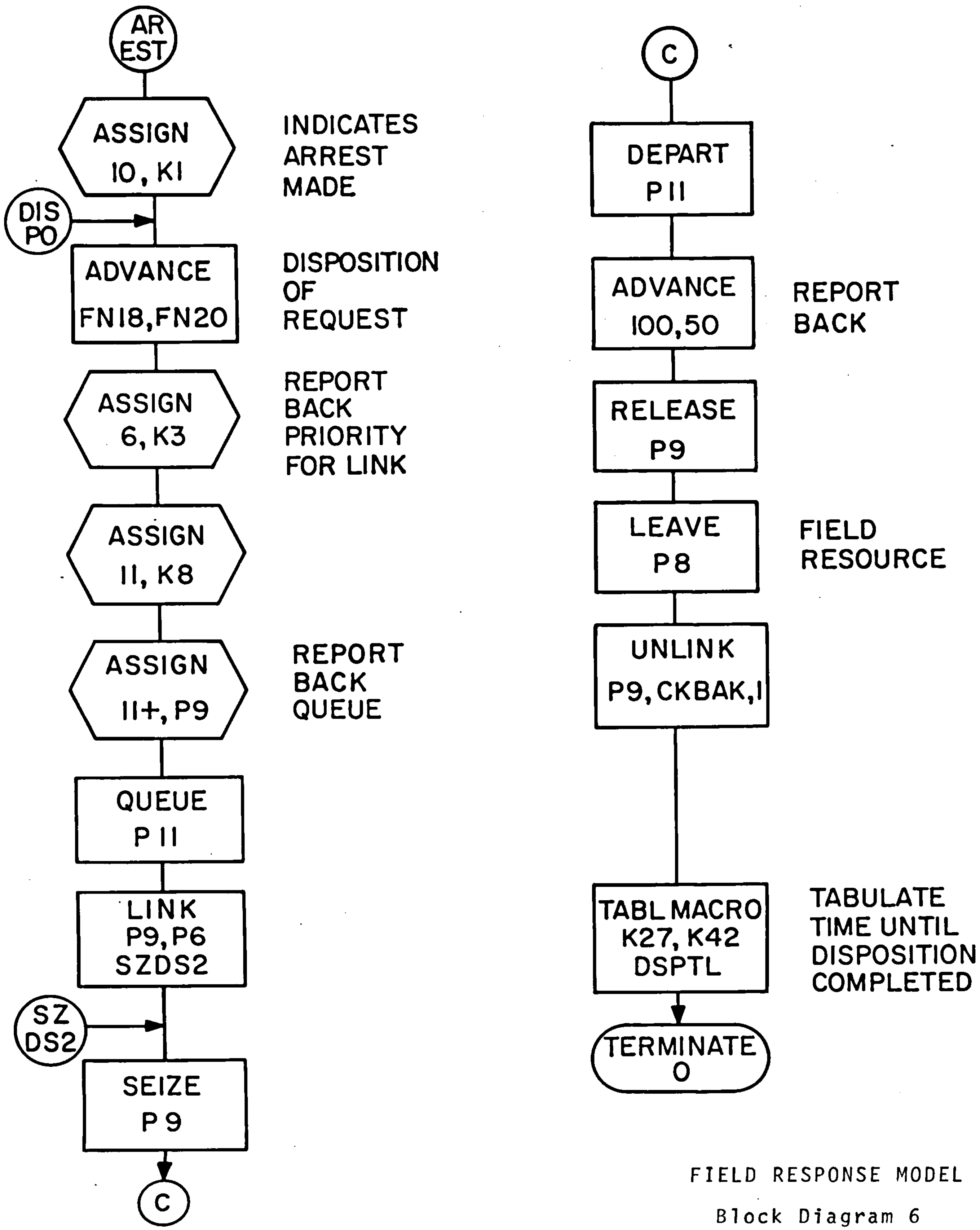
FIELD RESPONSE MODEL

Block Diagram 4



FIELD RESPONSE MODEL

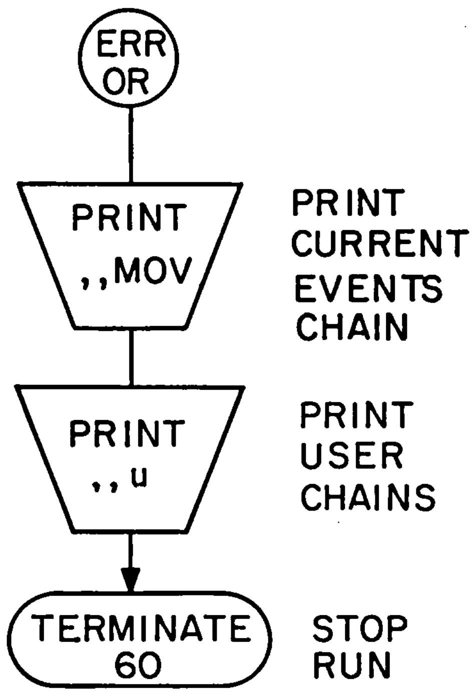
Block Diagram 5



FIELD RESPONSE MODEL

Block Diagram 6

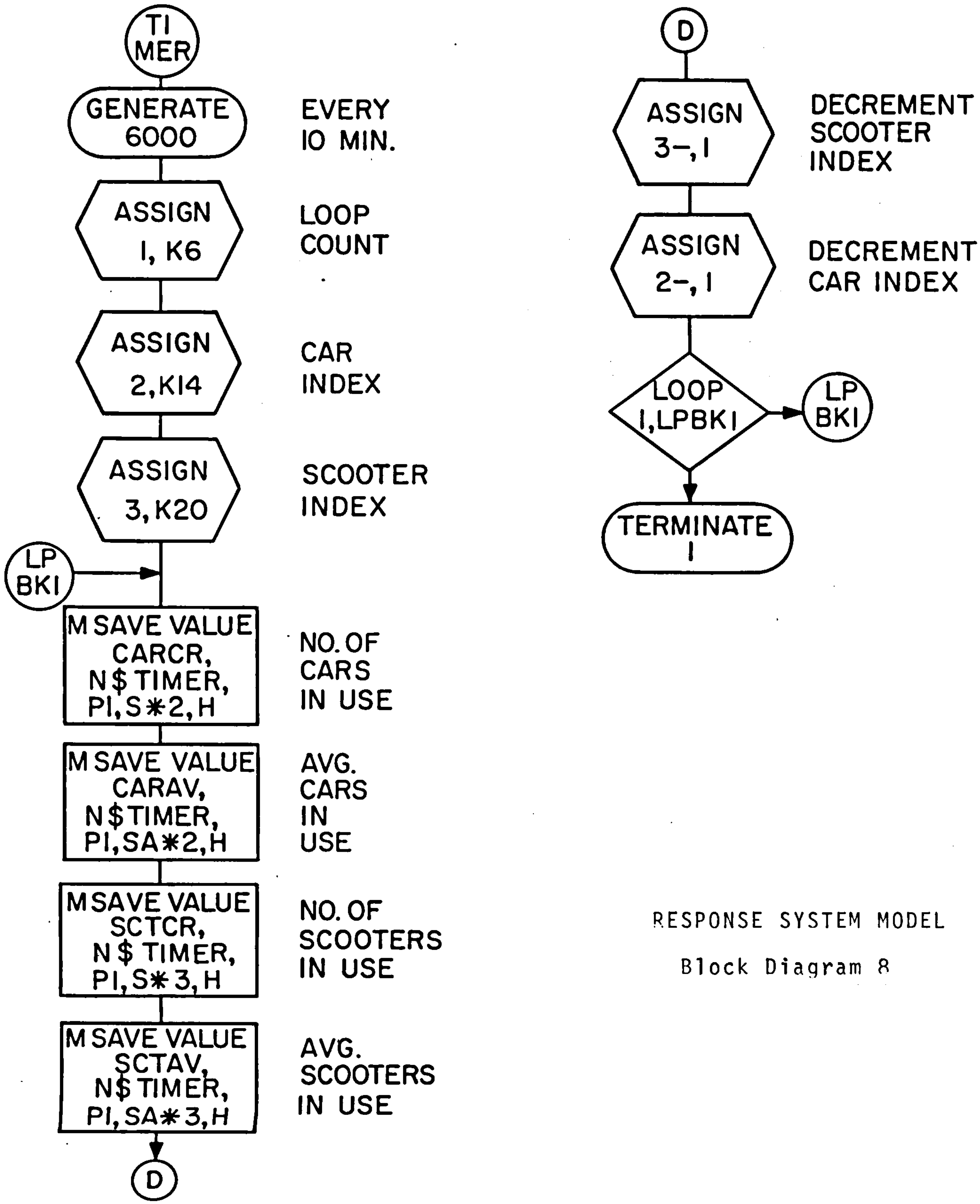
STOP RUN
IF RESOURCES FULL



FIELD RESPONSE MODEL

Block Diagram 7

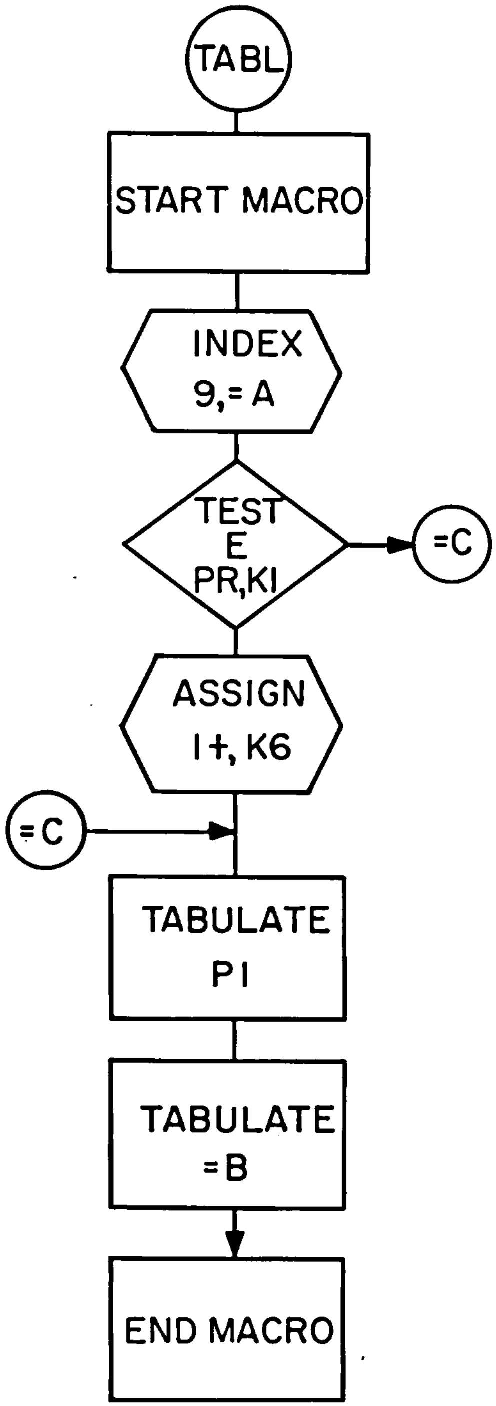
TIMING & TABULATING ROUTINE



RESPONSE SYSTEM MODEL

Block Diagram 8

MACRO USED
FOR TABULATING



RESPONSE SYSTEM MODEL

Block Diagram 9

```
BLOCK                                                                                          CARD
NUMBER  *LOC    OPERATION  A,B,C,D,E,F,G            COMMENTS                                   NUMBER
        *
        *
        *          N.Y.C. POLICE DEPT. - RESPONSE SYSTEM SIMULATION
        *
        *       ALL BOROUGH CALLS SIMULATED
        *       ONLY MANHATTAN EMG CALLS DISPATCHING AND MANHATTAN
        *                  FIELD RESOURCES SIMULATED
        *
        *                  TIME UNIT - TENTH OF A SECOND %1/10 SEC<
        *
        *
         TABL   STARTMACRO
                INDEX      9,#A
                TEST E     PR,K1,#C
                ASSIGN     1+,K6
         #C     TABULATE   P1
                TABULATE   #B
                ENDMACRO
        *
                SIMULATE
        *
        *  FUNCTION 1  DEFINES               DISTRIBUTION OF TIME SPENT BY EMG
        *                                    CALL IN THE TURRETS OBTAINED FROM
        *                                    MODEL 2 (IA TIME=4.8 SEC)
        *
         1      FUNCTION   RN1,C4            TIME SPENT IN TURRET BOARDS
        0,100/.15,400/.7,840/1.0,1800
        *
        *  FUNCTION 3 DEFINES                1-6:  DIVISION NO (MAN EMG)
        *                                    7:    NON MAN EMG AND NON-EMG
        *
         3      FUNCTION   RN1,D7
        .033,1/.073,2/.109,3/.146,4/.178,5/.212,6/1.0,7
        *
        *  FUNCTIONS 4-9 ARE PROB OF TYPE OF REQUEST FOR POLICE ASSISTANCE
        *                 (CRIME TYPE FOR DIV 1-6)
        *
        *       1  MURDER,RAPE
        *       2 - FELON ASSAULT, ROBBERY   3 - BURG, GD LARCENY
        *       4 - GD LCY MTR VEHIC         5 - AMBULENCE REQUEST
        *       6 - MISDEMEANOR              7 - OFFENSE
        *       8 NON CRIME REQUEST
        *
        *
         4      FUNCTION   RN1,D8            DIVISION 1
        .001,1/.020,2/.134,3/.149,4/.349,5/.531,6/.600,7/1.0,8
        *
         5      FUNCTION   RN1,D8            DIVISION 2
        .001,1/.031,2/.208,3/.224,4/.424,5/.565,6/.6,7/1.0,8
        *
         6      FUNCTION   RN1,D8            DIVISION 3
        .001,1/.021,2/.164,3/.176,4/.376,5/.526,6/.6,7/1.0,8
        *
         7      FUNCTION   RN1,D8            DIVISION 4
```

```
.001,1/.03,2/.167,3/.181,4/.381,5/.53/,6/.6,7/1.0,8
*
 8     FUNCTION    RN1,D8               DIVISION 5
.002,1/.046,2/.165,3/.178,4/.378,5/.581,6/.6,7/1.0,8
*
 9     FUNCTION    RN1,D8               DIVISION 6
.003,1/.085,2/.196,3/.206,4/.406,5/.57,6/.6,7/1.0,8
*
*
*  FUNCTION 10 DEFINES                        PROB OF CRIME BEING INSIDE
*                                             VS CRIME TYPE %PARTS/1000<
*
 10    FUNCTION    P2,L8
1,600/2,420/3,750/4,50/5,700/6,500/7,500/8,500
*
*
*   FUNCTION 11 DEFINES                       PROB OF CRIME IN PROGRESS
*                                             VS CRIME TYPE %PARTS/1000<
*                                             TYPES 5,8 MUST EQ ZERO
*
 11    FUNCTION    P2,L8
1     100   2     100    3     100    4       100    5     0     6     100
7     100   8     0
*
*  FUNCTION 12 DEFINES                        MEAN RADIO REACH TIME
*                                             VS RESOURCE UTILIZATION
*                                             %PARTS/1000<
*
 12    FUNCTION    SR*8,C4
0,100/500,250/800,450/1000,600
*
*  FUNCTION 13 DEFINES                        MEAN CAR TRAVEL TIME TO REACH
*                                             SCENE VS CAR UTILIZATION
*                                             %PARTS/1000<
*
 13    FUNCTION    SR*8,C4
0,300/500,1200/800,2400/1000,4800
*
*  FUNCTION 14 DEFINES                        MEAN SCOOTER TRAVEL TIME
*                                             TO REACH SCENE VS SCOOTER
*                                             UTILIZATION %PARTS/1000<
*
 14    FUNCTION    SR*8,C4
0,300/500,1200/800,2400/1000,4800
*
*
*  FUNCTION 16 DEFINES                        RESOURCES ASSIGNED BY CRIME
*                                             TYPE-
*                                             0,CAR     1,SCOOTER
*
 16    FUNCTION    P2,L8
1      0     2     0     3     0      4       0      5     1     6     0
7      0     8     0
*
*  FUNCTION 1/ DEFINES                        PROB OF ARREST VS
*                                             RESPONSE TIME %PARTS/1000<
*
```

```
 17     FUNCTION    M1,C6
0,1000/600,600/1200,300/1800,200/2400,100/6000,0
*
*
*  FUNCTION 18 DEFINES                          MEAN DISPOSITION TIME BY
*                                               CRIME TYPE, ARREST/NON ARREST
*                                               ABSCISSA - TENS DIGIT,1 IF
*                                               ARREST, 0 NON ARREST
*                                               UNITS CRIME TYPE
*
 18     FUNCTION    V6,L18
01      38400 02    27600 03    21000 04    20400 05    28200 06    20400
07      15000 08    17400 09    00    10    00    11    21900012    102000
13      97800 14    19980015    00    16    14220017    90600 18    18000
*
 20     FUNCTION    RN1,C24                     EXPONENTIAL DISTRIBUTION
0       0     .1    .104  .2    .222  .3    .355  .4    .509  .5    .69
.6      .915  .7    1.2   .75   1.38  .8    1.6   .84   1.83  .88   2.12
.9      2.3   .92   2.52  .94   2.81  .95   2.99  .96   3.2   .97   3.5
.98     3.9   .99   4.6   .995  5.3   .998  6.2   .999  7     .9998 8
*
*
*
*                    VARIABLES
*
 6      VARIABLE    P10*K10&P2        FN18 LOOK-UP
*
*
*
*                        MATRICES
*
 CRTYP MATRIX       H,9,9             NO OF CRIMES BY DIV & TYPE
 CARCR MATRIX       H,60,6            #CARS IN USE-CURRENT (EVERY 10 MIN)
 CARAV MATRIX       H,60,6            #CARS IN USE-AVERAGE (EVERY 10 MIN)
 SCTCR MATRIX       H,60,6        #SCOOTERS IN USE-CURRENT (EVERY 10 MIN)
 SCTAV MATRIX       H,60,6        #SCOOTERS IN USE-AVERAGE (EVERY 10 MIN)
*
*
*
*  PARAMETER        DESCRIPTION OF USE
*
*     1             UTILITY - USED FOR INDEXING TABLE NOS, ETC
*     2             CRIME TYPE
*     3             INSIDE 0, OUTSIDE 1
*     4             IN PROGRESS 0, PAST 1
*     5             MASTER DISPATCHER FACILITY NO  7-SO  8-NO
*     6             USED FOR LINKING  3-REPORT BACK, 1-HIGH PR, 2-LOW PR
*     7             RESOURCE ASSIGNED  0-CAR  1-SCOOTER
*     8             STORAGE NO OF RESOURCE    9-14  CARS,   15-20  SCOOTERS
*     9             1-6: DIV NO (MAN EMG)  7: NON MAN EMG & NON-EMG
*    10             1-ARREST MADE      0-NO ARREST
*    11             QUEUE NO FOR REPORT BACK
*    12             NOT USED
*
*
*  FACILITY,QUEUE AND USER CHAINS DESCRIPTION
*
```

```
* DSPH1            MAN DIV 1 DISPATCHER %F1 & Q1& C1)
* DSPH2            MAN DIV 2 DISPATCHER %F2 & Q2 & C2)
* DSPH3            MAN DIV 3 DISPATCHER %F3 & Q3 & C3)
* DSPH4            MAN DIV 4 DISPATCHER %F4 & Q4 & C4)
* DSPH5            MAN DIV 5 DISPATCHER %F5 & Q5 & C5)
* DSPH6            MAN DIV 6 DISPATCHER %F6 & Q6 & C6)
* MSDSO            MAN SO MASTER DISPATCHER %F7 & Q7 & C7)
* MSDNO            MAN NO MASTER DISPATCHER %F8 & Q8 & C8)
*
 DSPH1 EQU         1,F,Q,C
 DSPH2 EQU         2,F,Q,C
 DSPH3 EQU         3,F,Q,C
 DSPH4 EQU         4,F,Q,C
 DSPH5 EQU         5,F,Q,C
 DSPH6 EQU         6,F,Q,C
 DSPSO EQU         7,F,Q,C
 DSPNO EQU         8,F,Q,C
*
 RPBK1 EQU         9,Q
 RPBK2 EQU         10,Q
 RPBK3 EQU         11,Q
 RPBK4 EQU         12,Q
 RPBK5 EQU         13,Q
 RPBK6 EQU         14,Q
*
*
*  STORAGE DESCRIPTION
*
 CAR1  EQU         9,S
 CAR2  EQU         10,S
 CAR3  EQU         11,S
 CAR4  EQU         12,S
 CAR5  EQU         13,S
 CAR6  EQU         14,S
*
 SCTR1 EQU         15,S
 SCTR2 EQU         16,S
 SCTR3 EQU         17,S
 SCTR4 EQU         18,S
 SCTR5 EQU         19,S
 SCTR6 EQU         20,S
*
*
*
 CAR1  STORAGE     50                  MAN DIV 1 CARS %S9<
 CAR2  STORAGE     50                  MAN DIV 2 CARS %S10<
 CAR3  STORAGE     50                  MAN DIV 3 CARS %S11<
 CAR4  STORAGE     50                  MAN DIV 4 CARS %S12<
 CAR5  STORAGE     50                  MAN DIV 5 CARS %S13<
 CAR6  STORAGE     50                  MAN DIV 6 CARS %S14<
*
 SCTR1 STORAGE     20                        MAN DIV 1 SCOOTERS  (S15)
 SCTR2 STORAGE     20                        MAN DIV 2 SCOOTERS  (S16)
 SCTR3 STORAGE     20                        MAN DIV 3 SCOOTERS  (S17)
 SCTR4 STORAGE     20                        MAN DIV 4 SCOOTERS  (S18)
 SCTR5 STORAGE     20                        MAN DIV 5 SCOOTERS  (S19)
 SCTR6 STORAGE     20                        MAN DIV 6 SCOOTERS  (S20)
```

```
*
*
*
*
*
 3      TABLE      M1,0,150,50            TIME TO REACH DISPATCHER QUE
*
*
 4      TABLE      M1,0,300,50        TIME UNTIL DISPATCH-DIV 1 LOW PRIOR
 5      TABLE      M1,0,300,50        TIME UNTIL DISPATCH-DIV 2 LOW PRIOR
 6      TABLE      M1,0,300,50        TIME UNTIL DISPATCH-DIV 3 LOW PRIOR
 7      TABLE      M1,0,300,50        TIME UNTIL DISPATCH-DIV 4 LOW PRIOR
 8      TABLE      M1,0,300,50        TIME UNTIL DISPATCH-DIV 5 LOW PRIOR
 9      TABLE      M1,0,300,50        TIME UNTIL DISPATCH-DIV 6 LOW PRIOR
*
10      TABLE      M1,0,150,50        TIME UNTIL DISPATCH-DIV 1 HIGH PRIOR
11      TABLE      M1,0,150,50        TIME UNTIL DISPATCH-DIV 2 HIGH PRIOR
12      TABLE      M1,0,150,50        TIME UNTIL DISPATCH-DIV 3 HIGH PRIOR
13      TABLE      M1,0,150,50        TIME UNTIL DISPATCH-DIV 4 HIGH PRIOR
14      TABLE      M1,0,150,50        TIME UNTIL DISPATCH-DIV 5 HIGH PRIOR
15      TABLE      M1,0,150,50        TIME UNTIL DISPATCH-DIV 6 HIGH PRIOR
*
*
16      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 1 LOW PRIOR
17      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 2 LOW PRIOR
18      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 3 LOW PRIOR
19      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 4 LOW PRIOR
20      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 5 LOW PRIOR
21      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 6 LOW PRIOR
*
22      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 1 HIGH PRIOR
23      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 2 HIGH PRIOR
24      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 3 HIGH PRIOR
25      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 4 HIGH PRIOR
26      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 5 HIGH PRIOR
27      TABLE      M1,0,300,50        TIME TO REACH SCENE DIV 6 HIGH PRIOR
*
*
28      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 1 LOW PRI
29      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 2 LOW PRI
30      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 3 LOW PRI
31      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 4 LOW PRI
32      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 5 LOW PRI
33      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 6 LOW PRI
*
34      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 1 HIGH PRI
35      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 2 HIGH PRI
36      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 3 HIGH PRI
37      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 4 HIGH PRI
38      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 5 HIGH PRI
39      TABLE      M1,3000,6000,50    TIME DISPO COMPLETE DIV 6 HIGH PRI
*
*
40      TABLE      M1,0,300,50        TIME TO DISPATCH-ALL MAN CALLS
41      TABLE      M1,0,300,50        TIME TO REACH SCENE -ALL MAN CALLS
42      TABLE      M1,3000,6000,50    TIME TO DISPO COMPLETE-ALL MAN
*
```

```
         *
         *
         *
1         GEN    GENERATE    48,FN20               CALL COMES IN (IA TIME=4.8 SEC)
2                ASSIGN      9,FN3
3                TEST L      P9,K7,TERM7                 IF NOT MAN EMG SKIP DETAILS
         *
4                INDEX       9,3                         FUNCTION NO FOR CRIME TYPE
         *                                               DEPENDING ON DIV - P1 USED
         *                                               AS TEMP STORAGE
         *                                               DIV PLUS 3 GIVES PROPER
         *                                               FUNCTION NO
         *
         *
5                ASSIGN      2,FN*1                      CRIME TYPE IN P2
6                TRANSFER    .FN10,,BYPOT                PROB OF INSIDE %PARTS/1000<
7                ASSIGN      3,K1                        1 IN P3 MEANS OUTSIDE
8         BYPOT  TRANSFER    .FN11,,TRRT                 PROB OF IN PROGRESS%PTS/1000<
9                ASSIGN      4,K1                        1 IN P4 MEANS PAST
         *
10        TRRT   ADVANCE     FN1                   TIME SPENT IN TURRET
         *
         *
         *  ASSIGN PRIORITIES FOR DISPATCHING
         *
11               ASSIGN      6,K2                        MARK ALL AS LOW PRI FOR LINK
12               TEST LE     P2,K3,CONVR                 HIGH PRIORITY CRIME
13               TEST E      P4,K0,CONVR                 IN PROGRESS
14               PRIORITY    1                           ASSIGN PRIORITY
15               ASSIGN      6,K1                        MARK AS HIGH PRI FOR LINK
         *
         *  CONVEYER BELT CARRIES CALLS TO MASTER DISPATCHERS
         *
16        CONVR  ADVANCE     70,20                       CONVEYER BELT
         *
         *  STORING NO. OF CRIMES BY TYPE AND DIVISION
         *
17               MSAVEVALUE  CRTYP+,P9,P2,1,H
18               MSAVEVALUE  CRTYP+,9,P2,1,H   COLUMN TOTAL FOR EACH CRIME TYPE
19               MSAVEVALUE  CRTYP+,P9,9,1,H   ROW TOTAL FOR EACH DIVISION
20               MSAVEVALUE  CRTYP+,9,9,1,H    TOTAL NO OF CRIMES
         *
         *  MASTER DISPATCHERS
         *
21               TEST LE     P9,K3,MSDNO                 ASSIGN MASTER DISPATCHER NO
22        MSDSO  ASSIGN      5,K7                        MAN SO MSTR DISPATCHER
23               TRANSFER    ,MSTDS
24        MSDNO  ASSIGN      5,K8                        MAN NO MSTR DISPATCHER
25        MSTDS  QUEUE       P5                          MASTER DISPATCHER
26               LINK        P5,P6,SZMST                 ORDER CHAIN ON P6 VALUE
27        SZMST  SEIZE       P5
28               DEPART      P5
29               ADVANCE     80,30                       FIND PRECINCT, SECTOR
30               RELEASE     P5
31               UNLINK      P5,SZMST,1                  NEXT SLIP TO MSTR DISPATCHER
32               TABULATE    3                           TIME TO REACH DISPATCHER
         *
```

```
        *  CALL HANDLING BY DISPATCHERS                                                340
        *                                                                              341
 33            ASSIGN    7,FN16                    RESOURCE TYPE                       342
 34            ASSIGN    8,K6,16                   STORAGE NO OF RESOURCE BY DIV-      343
 35            ASSIGN    8+,8                                                          344
 36            ASSIGN    8+,P9                     9-14 CARS    15-20 SCOOTERS         345
 37            QUEUE     P9                        JOIN DISPATCHER QUEUE               346
 38            LINK      P9,P6,CKBAK               LINK IF DISPATCHER BUSY             347
 39      CKBAK TEST NE   P6,K3,SZDS2               REPORT BACK CALL (P6=3) IS          348
        *                                          SENT TO SZDS2                       349
 40            GATE SNF  P8,ERROR         IF STORAGE FULL, TERMINATE                   350
        *                                                                              351
        *  NOTE:   FOLLOWING ENTER AND SEIZE BLOCKS MUST BE TOGETHER IN ORDER          352
        *          THAT PRECEDING GATE BLOCK DOES PROPER CHECKING.                     353
        *                                                                              354
 41            SEIZE     P9                        DISPATCHER                          355
 42            DEPART    P9                                                            356
 43            ENTER     P8                        TAKE A UNIT OF RESOURCE             357
 44            ADVANCE   FN12,FN20                 MEAN RADIO REACH TIME AND           358
 45            RELEASE   P9                        DISPATCHER                          359
        *                                                                              360
 46            UNLINK    P9,CKBAK,1                UNLINK NEXT, CHECK RPT BK           361
        *                                                                              362
        *  TABULATE TIME UNTIL DISPATCH BY DIVISION, PRIORITY                          363
        *                                                                              364
         TABL  MACRO     K3,K40,DSPCH     TIME UNTIL CAR FOUND                         365
 47            INDEX     9,K3                                                          365
 48            TEST E    PR,K1,DSPCH                                                   365
 49            ASSIGN    1+,K6                                                         365
 50      DSPCH TABULATE  P1                                                            365
 51            TABULATE  K40                                                           365
        *                                                                              366
        *  FIELD RESPONSE                                                              367
        *                                                                              368
 52            INDEX     7,13                      TRAVEL TIME FUNCTION NO IN P1       369
 53            ADVANCE   FN*1,FN20                 MEAN TRAVEL TIME, EXPON DIST        370
        *   TABULATE TIME UNTIL SCENE REACHED                                          371
        *                                                                              372
         TABL  MACRO     K15,K41,SCENE    TIME UNTIL SCENE REACHED                     373
 54            INDEX     9,K15                                                         373
 55            TEST E    PR,K1,SCENE                                                   373
 56            ASSIGN    1+,K6                                                         373
 57      SCENE TABULATE  P1                                                            373
 58            TABULATE  K41                                                           373
        *                                                                              374
        *  ARRESTS ARE GENERATED ONLY FOR CRIMES IN PROGRESS                           375
        *                                                                              376
 59            TEST E    P4,K0,DISPO                                                   377
 60            TRANSFER  .FN17,DISPO,AREST          FN17#PROB OF ARST%PARTS/1000<      378
 61      AREST ASSIGN    10,K1                     1 IN P10 INDICATES ARREST           379
 62      DISPO ADVANCE   FN18,FN20                 MEAN DISPOSTN TIME, EXPON DIST      380
        *                                                                              381
        *  REPORT BACK                                                                 382
        *                                                                              383
 63            ASSIGN    6,K3                      TAG REPORT BACK CALLS               384
 64            ASSIGN    11,K8            THESE TWO BLOCKS PUT KPBK QUEUE NO           385
 65            ASSIGN    11+,P9           IN P11                                       386
```

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        *
66            QUEUE       P11
67            LINK        P9,P6,SZDS2
        *
        *
68      SZDS2 SEIZE       P9                      DISPATCHER
69            DEPART      P11
70            ADVANCE     100,50                  REPORT BACK
71            RELEASE     P9
72            LEAVE       P8                      RESOURCE NOW FREE
        *
73            UNLINK      P9,CKBAK,1              UNLINK NEXT, CHECK RPT BK
        *
        *
        *   TABULATE DISPOSITION TIME
        *
        TABL  MACRO       K27,K42,DSPTL
74            INDEX       9,K27
75            TEST E      PR,K1,DSPTL
76            ASSIGN      1+,K6
77      DSPTL TABULATE    P1
78            TABULATE    K42
        *
        *
79      TERM7 TERMINATE   0                 REGULAR TERMINATION OF ALL CALLS
        *
        *
80      ERROR PRINT       ,,MOV             CURRENT EVENTS CHAIN PRINTED
81            PRINT       ,,U               USER CHAINS PRINTED
82            TERMINATE   60                ABNORMAL TERMINATION
        *
        *
        *
83      TIMER GENERATE    6000              EVERY 10 MIN
84            ASSIGN      1,K6              USED FOR LOOPING
85            ASSIGN      2,K14             USED TO INDEX CAR STORAGE
86            ASSIGN      3,K20             USED TO INDEX SCOOTER STORAGE
87      LPBK1 MSAVEVALUE  CARCR,N$TIMER,P1,S*2,H         #CARS IN USE-CURRENT
88            MSAVEVALUE  CARAV,N$TIMER,P1,SA*2,H        #CARS IN USE-AVERAGE
89            MSAVEVALUE  SCTCR,N$TIMER,P1,S*3,H         SCOOTERS IN USE-CURRENT
90            MSAVEVALUE  SCTAV,N$TIMER,P1,SA*3,H        SCOOTERS IN USE-AVERAGE
91            ASSIGN      3-,1              REDUCE P3 BY 1
92            ASSIGN      2-,1              REDUCE P2 BY 1
93            LOOP        1,LPBK1           TAKE CARE OF ALL STORAGES
94            TERMINATE   1
        *
        *
        *
              START       18,NP             INITIAL (3 HOURS)
        *
              RESET
              INITIAL    MH$CRTYP(1-9,1-9),0
              START       60                RUN OF 10 HOURS
        *
        *
        *
        *************************************************************************
```

USER CHAIN	TOTAL ENTRIES	AVERAGE TIME/TRANS	CURRENT CONTENTS	AVERAGE CONTENTS	MAXIMUM CONTENTS
DSPH1	82	132.804		.030	3
DSPH2	127	163.779		.057	4
DSPH3	136	209.558		.079	4
DSPH4	133	192.451		.071	3
DSPH5	65	159.661		.028	3
DSPH6	114	175.482		.055	4
DSPSO	122	44.163		.014	2
DSPNO	156	50.929		.022	3

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.	PREEMPTING TRANS. NO.
DSPH1	.167	485	124.061		
DSPH2	.218	575	136.660		
DSPH3	.241	552	157.554		
DSPH4	.243	585	149.695		
DSPH5	.163	450	130.893	70	
DSPH6	.215	556	139.291		
DSPSO	.177	798	80.045		
DSPNO	.176	800	79.562	119	

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
DSPH1	2	.014	240	200	83.3	22.104	132.625		
DSPH2	3	.025	284	222	78.1	32.454	148.661		
DSPH3	3	.037	274	207	75.5	48.729	199.283		
DSPH4	3	.031	294	230	78.2	38.904	178.718		
DSPH5	2	.010	227	198	87.2	17.083	133.724		
DSPH6	2	.025	278	218	78.4	32.593	151.016		
DSPSO	2	.014	798	676	84.7	6.751	44.163		
DSPNO	3	.022	800	644	80.4	9.931	50.929		
RPBK1	3	.015	244	203	83.1	22.889	136.219		
RPBK2	4	.032	291	226	77.6	39.804	178.199		
RPBK3	2	.042	278	210	75.5	54.489	222.764		
RPBK4	3	.039	291	222	76.2	48.652	205.188		
RPBK5	3	.018	223	187	83.8	29.147	180.555		
RPBK6	3	.030	278	224	80.5	39.366	202.666		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

STORAGE	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	ENTRIES	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
CAR1	50	10.755	.215	200	19359.046	8	20
CAR2	50	13.348	.266	248	19377.140	10	22
CAR3	50	12.265	.245	231	19115.363	12	27
CAR4	50	13.471	.269	252	19245.167	14	24
CAR5	50	10.669	.213	194	19799.167	12	19
CAR6	50	13.815	.276	241	20637.382	16	24
SCTR1	20	4.290	.214	52	29701.804		9
SCTR2	20	5.146	.257	55	33685.105	2	12
SCTR3	20	5.308	.265	62	30825.238	3	12
SCTR4	20	4.473	.223	58	27769.550	5	9
SCTR5	20	4.146	.207	45	33170.597	4	10
SCTR6	20	4.660	.233	59	28439.980	6	11

TABLE 3

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1597	941.451	432.000	1503499.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-2.179
150	0	.00	.0	100.0	.159	-1.832
300	35	2.19	2.1	97.8	.318	-1.484
450	127	7.95	10.1	89.8	.477	-1.137
600	178	11.14	21.2	78.7	.637	-.790
750	279	17.47	38.7	61.2	.796	-.443
900	284	17.78	56.5	43.4	.955	-.095
1050	219	13.71	70.2	29.7	1.115	.251
1200	88	5.51	75.7	24.2	1.274	.598
1350	70	4.38	80.1	19.8	1.433	.945
1500	76	4.75	84.9	15.0	1.593	1.292
1650	63	3.94	88.8	11.1	1.752	1.640
1800	83	5.19	94.0	5.9	1.911	1.987
1950	87	5.44	99.4	.5	2.071	2.334
2100	7	.43	99.9	.0	2.230	2.681
2250	1	.06	100.0	.0	2.389	3.029

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 4

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
237	1139.147	495.000	269978.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-2.301
300	0	.00	.0	100.0	.263	-1.695
600	29	12.23	12.2	87.7	.526	-1.089
900	62	26.16	38.3	61.6	.790	-.483
1200	63	26.58	64.9	35.0	1.053	.122
1500	28	11.81	76.7	23.2	1.316	.728
1800	17	7.17	83.9	16.0	1.580	1.335
2100	31	13.08	97.0	2.9	1.843	1.941
2400	4	1.68	98.7	1.2	2.106	2.547
2700	3	1.26	100.0	.0	2.370	3.153

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 10

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
4	1779.750	286.000	7119.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-6.222
150	0	.00	.0	100.0	.084	-5.698
300	0	.00	.0	100.0	.168	-5.173
450	0	.00	.0	100.0	.252	-4.649
600	0	.00	.0	100.0	.337	-4.125
750	0	.00	.0	100.0	.421	-3.600
900	0	.00	.0	100.0	.505	-3.076
1050	0	.00	.0	100.0	.589	-2.551
1200	0	.00	.0	100.0	.674	-2.027
1350	0	.00	.0	100.0	.758	-1.502
1500	1	25.00	25.0	75.0	.842	-.978
1650	1	25.00	50.0	50.0	.927	-.453
1800	0	.00	50.0	50.0	1.011	.070
1950	0	.00	50.0	50.0	1.095	.595
2100	2	50.00	100.0	.0	1.179	1.119

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 16

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
237	1802.210	794.000	427124.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-2.269
300	0	.00	.0	100.0	.166	-1.891
600	5	2.10	2.1	97.8	.332	-1.514
900	18	7.59	9.7	90.2	.499	-1.136
1200	40	16.87	26.5	73.4	.665	-.758
1500	31	13.08	39.6	60.3	.832	-.380
1800	37	15.61	55.2	44.7	.998	-.002
2100	22	9.28	64.5	35.4	1.165	.375
2400	36	15.18	79.7	20.2	1.331	.752
2700	14	5.90	85.6	14.3	1.498	1.130
3000	12	5.06	90.7	9.2	1.664	1.508
3300	14	5.90	96.6	3.3	1.831	1.886
3600	2	.84	97.4	2.5	1.997	2.264
3900	3	1.26	98.7	1.2	2.164	2.642
4200	1	.42	99.1	.8	2.330	3.019
4500	1	.42	99.5	.4	2.496	3.397
4800	1	.42	100.0	.0	2.663	3.775

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 22

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
4	2048.500	484.000	8194.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-4.232
300	0	.00	.0	100.0	.146	-3.612
600	0	.00	.0	100.0	.292	-2.992
900	0	.00	.0	100.0	.439	-2.372
1200	0	.00	.0	100.0	.585	-1.753
1500	0	.00	.0	100.0	.732	-1.133
1800	2	50.00	50.0	50.0	.878	-.513
2100	0	.00	50.0	50.0	1.025	.106
2400	1	25.00	75.0	25.0	1.171	.726
2700	1	25.00	100.0	.0	1.318	1.346

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 28

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
240	23471.648	23248.000	5633196.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
3000	14	5.83	5.8	94.1	.127	-.880
9000	54	22.49	28.3	71.6	.383	-.622
15000	47	19.58	47.9	52.0	.639	-.364
21000	29	12.08	59.9	40.0	.894	-.106
27000	29	12.08	72.0	27.9	1.150	.151
33000	11	4.58	76.6	23.3	1.405	.409
39000	16	6.66	83.3	16.6	1.661	.667
45000	4	1.66	84.9	15.0	1.917	.926
51000	8	3.33	88.3	11.6	2.172	1.184
57000	7	2.91	91.2	8.7	2.428	1.442
63000	3	1.24	92.4	7.5	2.684	1.700
69000	5	2.08	94.5	5.4	2.939	1.958
75000	2	.83	95.4	4.5	3.195	2.216
81000	2	.83	96.2	3.7	3.450	2.474
87000	2	.83	97.0	2.9	3.706	2.732
93000	2	.83	97.9	2.0	3.962	2.990
99000	2	.83	98.7	1.2	4.217	3.248
105000	0	.00	98.7	1.2	4.473	3.506
111000	0	.00	98.7	1.2	4.729	3.764
117000	0	.00	98.7	1.2	4.984	4.023
123000	2	.83	99.5	.4	5.240	4.281
129000	0	.00	99.5	.4	5.495	4.539
135000	0	.00	99.5	.4	5.751	4.797
141000	1	.41	100.0	.0	6.007	5.055

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 34

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
4	14282.750	12752.000	57131.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
3000	0	.00	.0	100.0	.210	-.884
9000	2	50.00	50.0	50.0	.630	-.414
15000	1	25.00	75.0	25.0	1.050	.056
21000	0	.00	75.0	25.0	1.470	.526
27000	0	.00	75.0	25.0	1.890	.997
33000	0	.00	75.0	25.0	2.310	1.467
39000	1	25.00	100.0	.0	2.730	1.938

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 40

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1597	1155.324	477.000	1845054.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-2.422
300	5	.31	.3	99.6	.259	-1.793
600	145	9.07	9.3	90.6	.519	-1.164
900	410	25.67	35.0	64.9	.779	-.535
1200	422	26.42	61.4	38.5	1.038	.093
1500	235	14.71	76.2	23.7	1.298	.722
1800	165	10.33	86.5	13.4	1.558	1.351
2100	162	10.14	96.6	3.3	1.817	1.980
2400	38	2.37	99.0	.9	2.077	2.609
2700	14	.87	99.9	.0	2.337	3.238
3000	1	.06	100.0	.0	2.596	3.867

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 41

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1597	1965.989	960.000	3139685.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-2.047
300	0	.00	.0	100.0	.152	-1.735
600	22	1.37	1.3	98.6	.305	-1.422
900	107	6.70	8.0	91.9	.457	-1.110
1200	203	12.71	20.7	79.2	.610	-.797
1500	238	14.90	35.6	64.3	.762	-.485
1800	238	14.90	50.5	49.4	.915	-.172
2100	213	13.33	63.9	36.0	1.068	.139
2400	168	10.51	74.4	25.5	1.220	.452
2700	123	7.70	82.1	17.8	1.373	.764
3000	83	5.19	87.3	12.6	1.525	1.077
3300	67	4.19	91.5	8.4	1.678	1.389
3600	34	2.12	93.6	6.3	1.831	1.702
3900	24	1.50	95.1	4.8	1.983	2.014
4200	22	1.37	96.5	3.4	2.136	2.327
4500	18	1.12	97.6	2.3	2.288	2.639
4800	10	.62	98.3	1.6	2.441	2.952
5100	10	.62	98.9	1.0	2.594	3.264
5400	4	.25	99.1	.8	2.746	3.577
5700	5	.31	99.4	.5	2.899	3.889
6000	1	.06	99.5	.4	3.051	4.202
6300	2	.12	99.6	.3	3.204	4.514
6600	1	.06	99.7	.2	3.357	4.827
6900	3	.18	99.9	.0	3.509	5.139
7200	0	.00	99.9	.0	3.662	5.452
7500	1	.06	100.0	.0	3.814	5.764

REMAINING FREQUENCIES ARE ALL ZERO

TABLE 42

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1605	23860.343	24176.000	38295856.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
3000	87	5.42	5.4	94.5	.125	-.862
9000	370	23.05	28.4	71.5	.377	-.614
15000	301	18.75	47.2	52.7	.628	-.366
21000	223	13.89	61.1	38.8	.880	-.118
27000	135	8.41	69.5	30.4	1.131	.129
33000	121	7.53	77.0	22.9	1.383	.378
39000	69	4.29	81.3	18.6	1.634	.626
45000	71	4.42	85.7	14.2	1.885	.874
51000	56	3.48	89.2	10.7	2.137	1.122
57000	42	2.61	91.9	8.0	2.388	1.370
63000	24	1.49	93.3	6.6	2.640	1.618
69000	21	1.30	94.7	5.2	2.891	1.867
75000	13	.80	95.5	4.4	3.143	2.115
81000	17	1.05	96.5	3.4	3.394	2.363
87000	7	.43	97.0	2.9	3.646	2.611
93000	11	.68	97.6	2.3	3.897	2.859
99000	6	.37	98.0	1.9	4.149	3.108
105000	5	.31	98.3	1.6	4.400	3.356
111000	7	.43	98.8	1.1	4.652	3.604
117000	1	.06	98.8	1.1	4.903	3.852
123000	3	.18	99.0	.9	5.154	4.100
129000	5	.31	99.3	.6	5.406	4.348
135000	3	.18	99.5	.4	5.657	4.597
141000	2	.12	99.6	.3	5.909	4.845
147000	1	.06	99.7	.2	6.160	5.093
153000	0	.00	99.7	.2	6.412	5.341
159000	0	.00	99.7	.2	6.663	5.589
165000	0	.00	99.7	.2	6.915	5.838
171000	0	.00	99.7	.2	7.166	6.086
177000	2	.12	99.8	.1	7.418	6.334
183000	0	.00	99.8	.1	7.669	6.582
189000	0	.00	99.8	.1	7.921	6.830
195000	0	.00	99.8	.1	8.172	7.078
201000	0	.00	99.8	.1	8.424	7.327
207000	0	.00	99.8	.1	8.675	7.575
213000	0	.00	99.8	.1	8.926	7.823
219000	1	.06	99.9	.0	9.178	8.071
225000	0	.00	99.9	.0	9.429	8.319
231000	1	.06	100.0	.0	9.681	8.567

REMAINING FREQUENCIES ARE ALL ZERO

MATRIX HALFWORD SAVEVALUECRTYP

ROW	COL. 1	2	3	4	5	6	7	8	9
1	0	4	36	3	49	45	15	88	240
2	0	5	48	4	47	34	11	135	284
3	0	5	35	5	59	48	17	105	274
4	0	8	43	4	56	44	16	123	294
5	0	10	39	2	43	36	4	93	227
6	0	38	29	4	52	47	8	101	279
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	70	230	22	306	254	71	645	1598

MATRIX HALFWORD SAVEVALUECARCR

ROW	COL. 1	2	3	4	5	6
1	6	13	15	11	13	12
2	8	20	15	13	10	20
3	7	10	15	13	13	18
4	5	14	17	15	15	19
5	7	16	17	13	14	21
6	7	14	19	14	10	20
7	5	11	20	16	10	16
8	3	8	19	18	12	18
9	3	15	19	21	9	16
10	5	15	27	22	9	14
11	6	14	23	21	9	16
12	9	14	19	15	11	19
13	9	16	16	16	11	19
14	11	17	16	20	14	23
15	13	18	15	20	11	22
16	11	13	17	18	9	22
17	12	12	15	13	11	19
18	7	12	16	15	15	16
19	5	12	15	14	14	13
20	9	14	12	12	18	17
21	9	10	13	10	12	12
22	10	9	11	9	11	13
23	10	16	13	8	10	10
24	11	14	14	12	9	5
25	11	12	10	13	7	8
26	9	17	6	13	11	9
27	10	12	9	13	8	11
28	8	15	11	10	9	10
29	9	16	9	9	8	7
30	9	9	11	10	8	7
31	11	9	11	14	9	11
32	15	9	8	17	10	15
33	12	14	9	12	9	14
34	15	12	10	18	10	10
35	12	10	11	15	9	16
36	14	9	12	13	12	13
37	14	13	13	13	9	9
38	16	14	10	13	10	7
39	15	20	10	10	13	11
40	12	20	7	7	9	12
41	14	19	11	5	9	14
42	13	14	9	12	11	10
43	13	15	11	13	12	7
44	12	14	11	16	10	6
45	14	15	9	16	11	9
46	14	15	5	14	12	7
47	14	16	7	12	12	13
48	15	13	5	14	11	12
49	13	15	6	13	9	11
50	14	12	10	11	9	17
51	15	11	12	9	7	18
52	14	14	9	12	10	15
53	16	13	12	10	8	19
54	19	12	14	12	11	15
55	15	15	10	11	10	12
56	13	19	7	15	17	15
57	9	13	7	12	13	15

APPENDIX C

COMPUTER PROGRAM - PRELIMINARY MODEL

The following refers to the program printout at the end of this Appendix. Familiarity with the GPSS/360 language is assumed.

Definitions

Storage	Description
TURUL (5)	Turret Board Operators

Facilities	Description
MANOR (1)	Manhattan North Dispatcher
AMBL (6)	Ambulance Dispatcher

Queues	Description
MANOR (1)	Calls to be dispatched waiting for the Manhattan North Dispatcher
NDISP (3)	Report-back calls waiting for the Manhattan North Dispatcher
TURUAL (5)	Calls waiting to be answered by Turret Board Operators
AMBL (6)	Calls to be dispatched waiting for the Ambulance Dispatcher
ADISP (7)	Report-back calls waiting for the Ambulance Dispatcher

Tables	Description
TURIL (8)	Distribution of Turret Operator Utilization
CADIP (9)	Distribution of Time until dispatch
CADIS (10)	Distribution of Time until disposition complete

Function	Description
1	Cumulative Exponential Distribution
2	Distribution of Report-back Times
3	Distribution of Manhattan North radio reach times

4	Distribution of Ambulance Dispatcher radio reach times
5	Distribution of disposition times for patrol cars
6	Distribution of disposition times for ambulances
7	Distribution of time for ambulance to converse and fill out form for emergency calls excluding ambulance requests
8	Distribution of time to converse and fill out form for ambulance calls
9	Distribution of time to notify precinct and perform clerical operations after call answered
10	Distribution of time to converse and supply information for non-emergency

Detailed Logic Description

Calls are generated, at the block labeled BEGIN, according to the exponential distribution and a specified mean inter-arrival time. A TRANSFER block tests whether the turret operators are all busy and if so sends the call to BUSY. Otherwise it is answered by a turret operator. A fraction of the calls are sent to TERM by the TRANSFER block, these are considered non-emergency calls. The remainder (emergency calls) are assigned a PARAMETER 1 value randomly selected from FUNCTION 9 which represents the time to notify the precinct and perform the necessary clerical operations after the completing of the conversation.

A fraction of these calls are sent to AMBUL; these represent emergency calls which require an ambulance. The remainder (emergency calls not requesting an ambulance) spend time at the turret boards to represent telephone conversation and the filling out of the form. This time is randomly selected from FUNCTION 7. A duplicate transaction is created by a SPLIT block and sent to DISPL. This represents the slip going to the dispatcher. At FILE, the call transaction spends time to represent the turret operator notifying the precinct and performing clerical operations. This time was assigned to PARAMETER 1. The turret operator is then released and the transaction is terminated.

The routine labelled BUSY handles calls which found the turret operators busy. They join a QUEUE; a PRIORITY block is used to allow other transactions in the system to release a turret operator if it is time for them to do so. A GATE block prevents the transaction which found the turret operators busy from attempting to leave the QUEUE until a turret operator is free. At that time the call leaves the QUEUE and is sent to ANSR. At ANSR, the calls go through the same sequence of steps as other calls which did not find the turret operators all busy.

The routine AMBUL handles the fraction of calls designated as ambulance requests. Time is spent to represent conversation and the filling out of the form. This time is randomly selected from FUNCTION 8. A duplicate transaction is sent to DISPL for car dispatching and another duplicate is sent to DISAM for ambulance dispatching. The transaction is then sent to FILE.

The fraction of calls that were designated non-emergency calls were sent to TERM. PARAMETER 1 is assigned the time to converse and supply information to non-emergency calls. This time is selected from FUNCTION 10. The call is then sent to FILE. Since PARAMETER 1 contains the above time, the routine FILE represents non-emergency call conversation in addition to precinct notification and clerical operations for emergency calls.

At DISPL a fraction of the transactions are sent to NORTH. The remainder, representing cars to be dispatched for Manhattan South, are terminated. At NORTH, a time to reach patrol car (radio reach time) is assigned to PARAMETER 1. This value is randomly selected from FUNCTION 3. The dispatcher queue number (1) is assigned to PARAMETER 2, and the report-back queue number (3) is assigned to PARAMETER 3. A value representing time to dispose of case is assigned to PARAMETER 4. This value is randomly selected from FUNCTION 5. Turret operator utilization is sampled and an entry made in TABLE 8. The transaction is then sent to TUBE.

The transaction representing ambulances to be dispatched were sent to DISAM. Here, a value representing time to reach an ambulance (radio reach time for ambulances) is assigned to PARAMETER 1. The value is randomly selected from FUNCTION 4. The dispatcher and queue number (6) is assigned to PARAMETER 2, the report-back queue number (7) is assigned to PARAMETER 3. A value representing disposition time is randomly selected from FUNCTION 6 and assigned to PARAMETER 4. The transactions then go to TUBE.

All calls to be dispatched proceed to TUBE. They join in the appropriate QUEUE indicated in PARAMETER 2. They are LINKed to a User Chain having the same number as the dispatcher, if the dispatcher is busy. When he is free, the call is sent to AAA where it DEPARTs the queue and is handled by the dispatcher indicated in PARAMETER 2. They are delayed to represent radio reach time. The time that this requires is obtained from PARAMETER 1. The dispatcher is then released and the next call waiting for the dispatcher is unlinked. Time Until Dispatch (Table 9) is TABULATEd. The call is delayed to represent disposition of the case. The time is obtained from PARAMETER 4.

The call is ready for report-back at this point and joins the report-back queue indicated in PARAMETER 3. It is LINKED to the Dispatcher User Chain indicated in PARAMETER 2 if the dispatcher is busy. When the dispatcher is free, the call DEPARTs the queue and the dispatcher handles the call. The time spent in reporting-back is randomly selected from FUNCTION 2. The dispatcher is then released and the next call waiting is UNLINKed. Time Until Disposition Complete (TABLE 10) is tabulated and the call is TERMINATED.

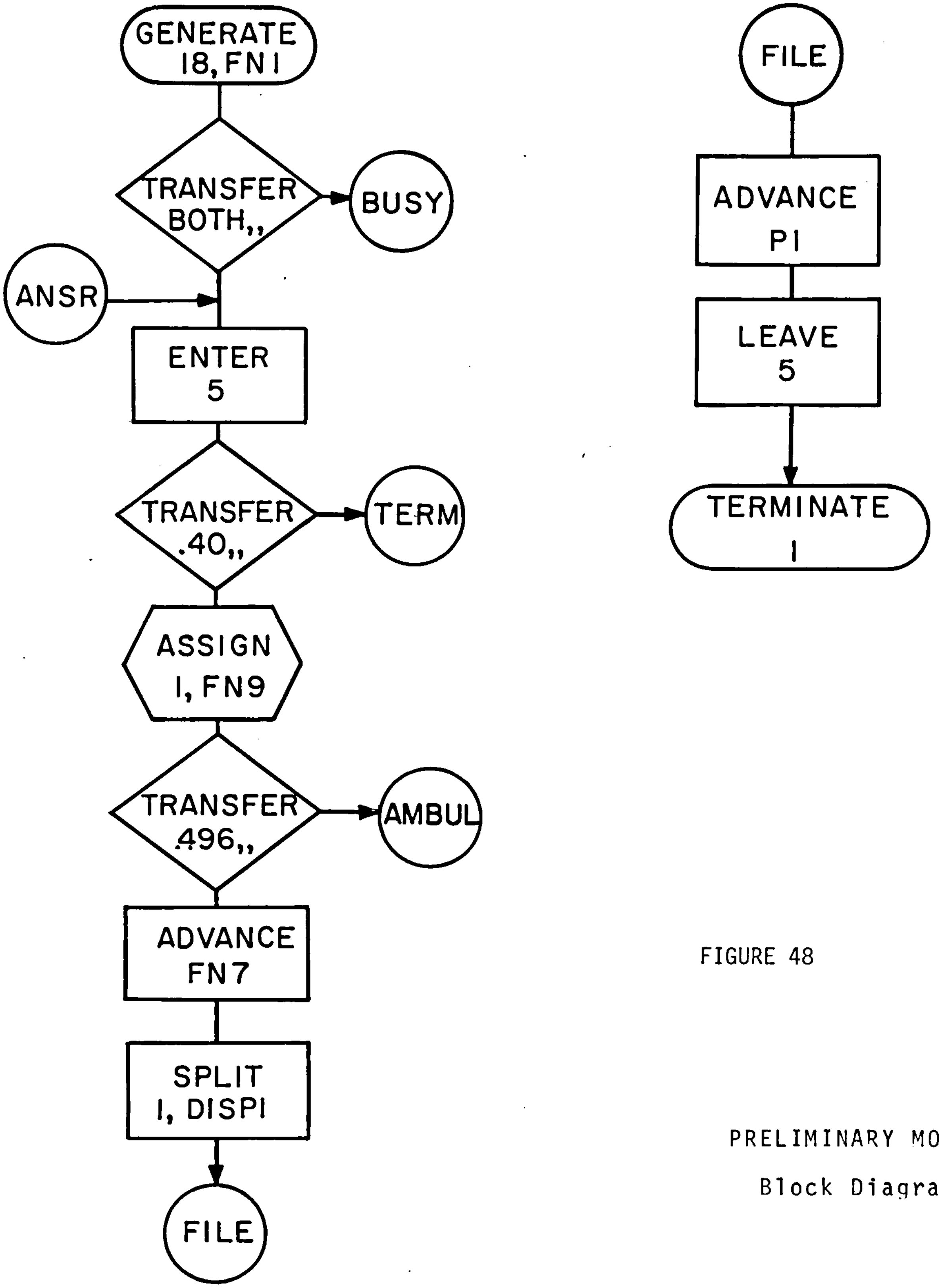
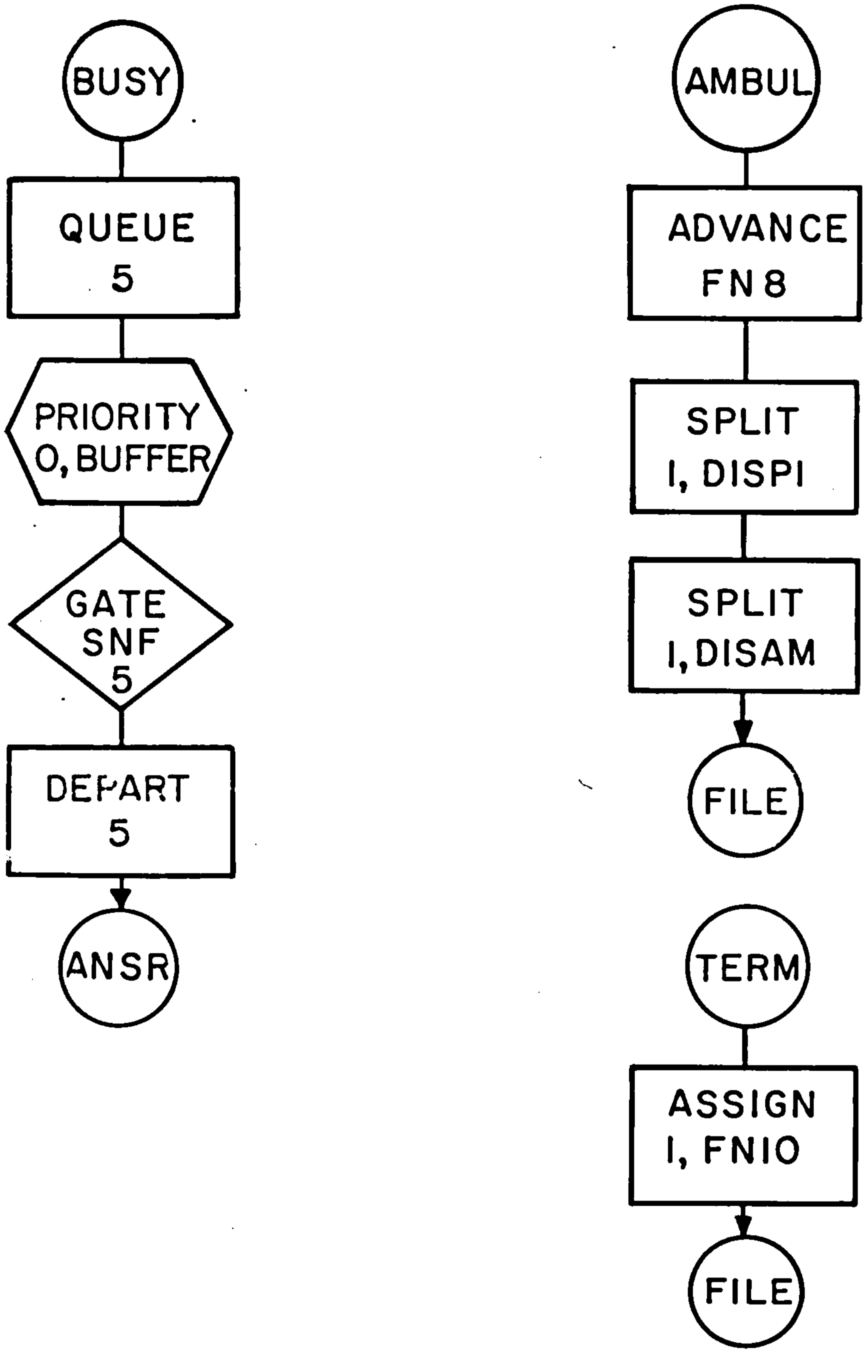


FIGURE 48

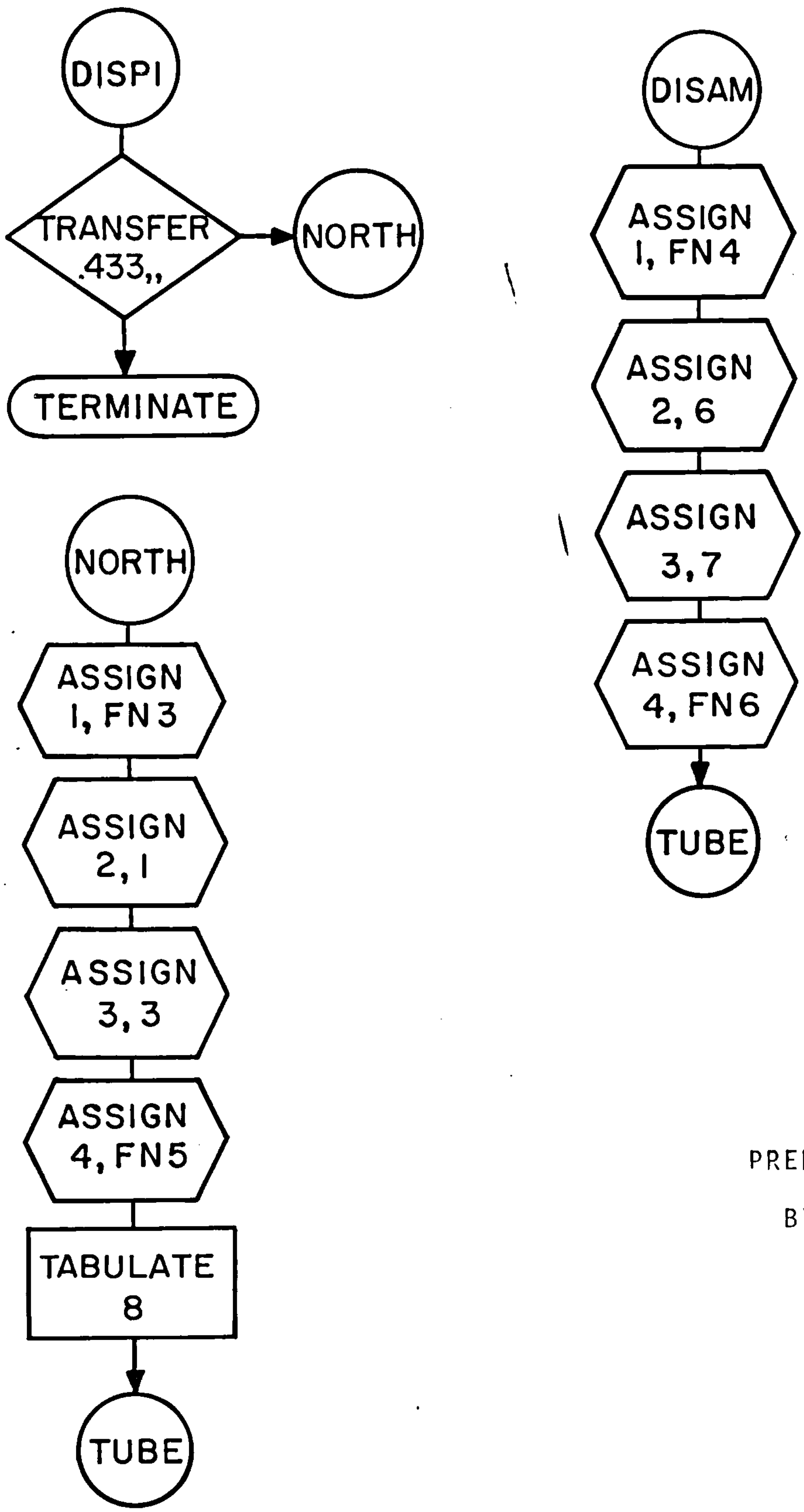
PRELIMINARY MODEL

Block Diagram 1



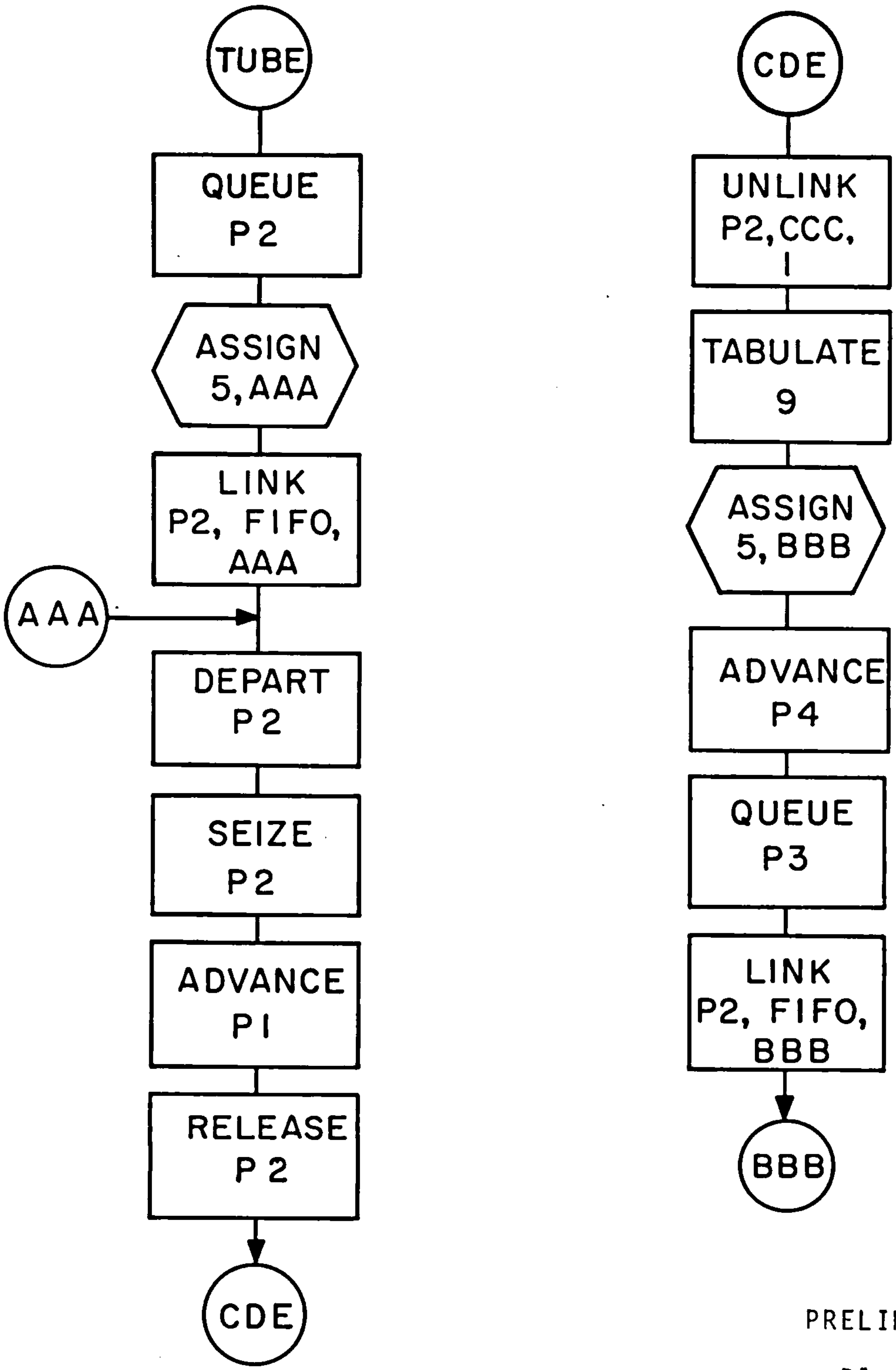
PRELIMINARY MODEL

Block Diagram 2



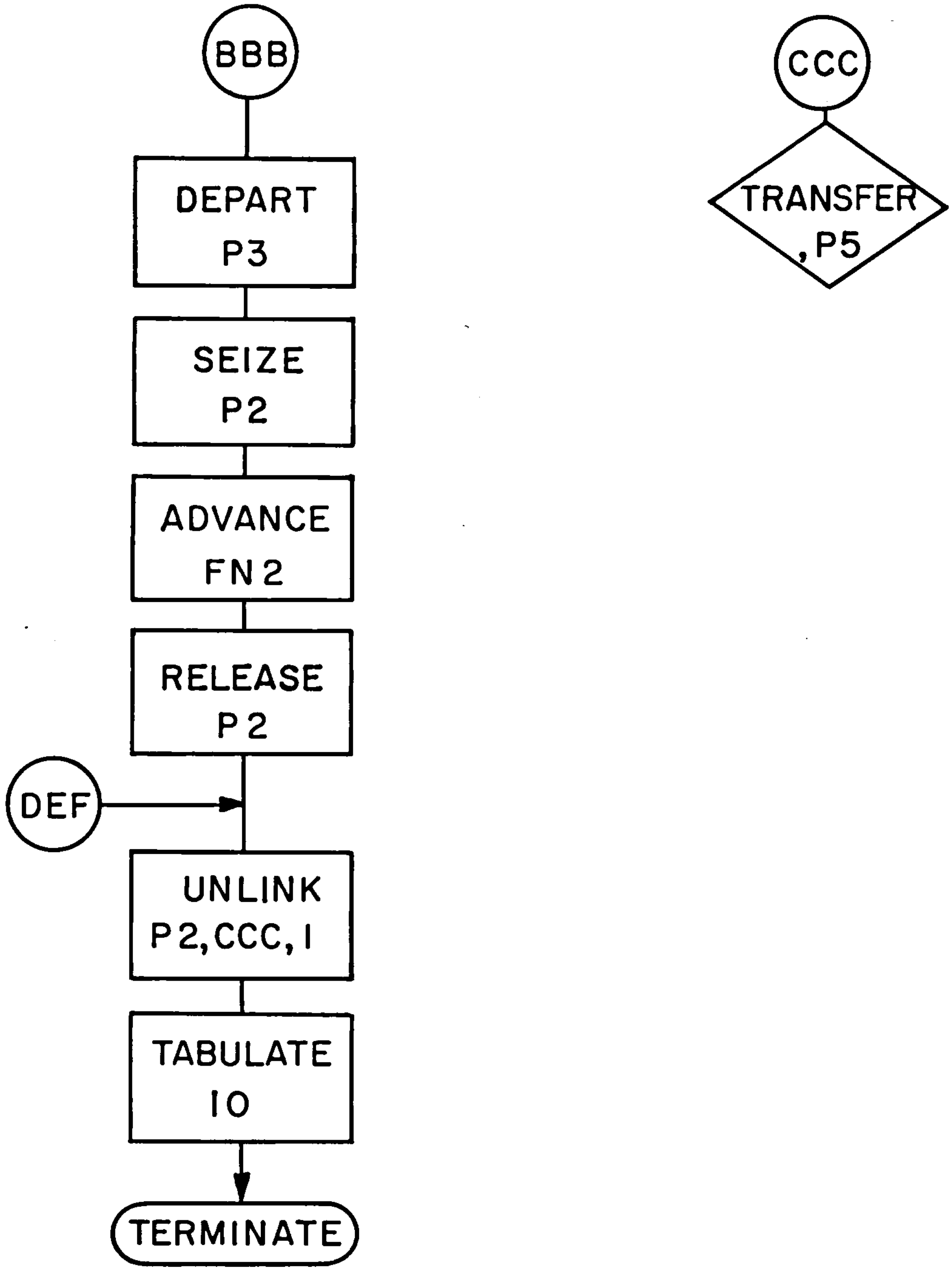
PRELIMINARY MODEL

Block Diagram 3



PRELIMINARY MODEL

Block Diagram 4



PRELIMINARY MODEL

Block Diagram 5

```
BLOCK
NUMBER  *LOC   OPERATION  A,B,C,D,E,F,G              COMMENTS
        *      SIMULATE
        *
               1 FUNCTION  RN1,C24     EXPONENTIAL DISTRIBUTION
        0      0     .1    .104  .2    .222  .3    .355  .4    .509  .5    .69
        .6     .915  .7    1.2   .75   1.38  .8    1.6   .84   1.83  .88   2.12
        .9     2.3   .92   2.52  .94   2.81  .95   2.99  .96   3.2   .97   3.5
        .98    3.9   .99   4.6   .995  5.3   .998  6.2   .999  7     .9997 8
        *
               2 FUNCTION  RN1,C4      DISPOSITION OF CASE
        0      3     .6    9     .95   15    1     25
        *
               3 FUNCTION  RN1,C4      RADIO DISPATCHER
        .01    7.5   .85   34.3  .99   43.5  1     120
        *
               4 FUNCTION  RN1,C5      AMBULANCE DISPATCHER
        0      12    .066  21    .866  48    .99   63    1     120
        *
               5 FUNCTION  RN1,C4      RADIO REPLY
        .08    150   .88   2250  .98   3450  1     5000
        *
               6 FUNCTION  RN1,C4      AMBULANCE REPLY
        .01    150   .88   4350  .96   6750  1     7100
        *
               7 FUNCTION  RN1,C18   RADIO RUN
        .0256 42     .0768 57    .1548 62    .206  67    .2316 72    .2828 77
        .3608 82     .4633 87    .5145 92    .6170 97    .7195 102   .7451 107
        .8731 112    .8987 117   .9243 122   .9499 127   .9755 177   1.0   192
               8 FUNCTION  RN1,C19
        .025   37    .050  42    .075  47    .150  57    .175  62    .225  67
        .250   72    .275  77    .325  82    .375  87    .475  92    .550  97
        .600   102   .700  107   .850  112   .925  117   .950  132   .975  152
        1.0    172
               9 FUNCTION  RN1,C9
        .125   12    .250  17    .350  22    .475  27    .650  32    .825  37
        .900   42    .950  47    1.0   52
              10 FUNCTION  RN1,C22
        .025   12    .075  17    .100  22    .150  27    .175  37    .200  42
        .275   47    .325  52    .375  57    .400  72    .475  77    .525  82
        .625   92    .675  97    .725  102   .800  107   .850  112   .900  117
        .925   132   .950  172   .975  177   1.0   234
        *
         AMBL   EQU        6,F,G
         TURUL  EQU        5,S,Q
         MANOR  EQU        1,F,Q
         RDISP  EQU        3,Q
         ADISP  EQU        7,Q
         TURIT  EQU        8,T
         CADIP  EQU        9,T
         CADIS  EQU        10,T
1        BEGIN  GENERATE   18,FN1
2               TRANSFER   BOTH,,BUSY
3         ANSR  ENTER      5
4               TRANSFER   .40,,TERM
5               ASSIGN     1,F,0
6        ABC    TRANSFER   .496,,AMFUL
```

```
 7    BCD   ADVANCE    FN7
 8          SPLIT      1,DISP1
 9    FILE  ADVANCE    P1            NOTIFY PRECINCT,FILE FORM
10          LEAVE      5
11          TERMINATE  1
      *
12    BUSY  QUEUE      5
13          PRIORITY   0,BUFFER
14          GATE SNF   5
15          DEPART     5
16          TRANSFER   ,ANSR
      *
17    AMBUL ADVANCE    FN8
18          SPLIT      1,DISP1
19          SPLIT      1,DISAM
20          TRANSFER   ,FILE
      *
21    TERM  ASSIGN     1,FN10        TIME TO TERMINATE CONVERSATION
22          TRANSFER   ,FILE
      *
23    DISP1 TRANSFER   .433,,NORTH
24          TERMINATE
      *
25    NORTH ASSIGN     1,FN3         TIME TO REACH PATROL CAR
26          ASSIGN     2,1           DISPATCHER QUEUE NUMBER
27          ASSIGN     3,3           DISPOSITION QUEUE
28          ASSIGN     4,FN5         TIME TO DISPOSE OF CASE
29          TABULATE   8
30          TRANSFER   ,TUBE
      *
31    DISAM ASSIGN     1,FN4         TIME TO REACH AMBULANCE
32          ASSIGN     2,6           DISPATCHER AND QUEUE NUMBER
33          ASSIGN     3,7           DISPOSITION QUEUE
34          ASSIGN     4,FN6         DISPOSITION TIME
35    TUBE  QUEUE      P2            IF DISPATCHER BUSY
36          ASSIGN     5,AAA
37          LINK       P2,FIFO,AAA
38    AAA   DEPART     P2
39          SEIZE      P2
40          ADVANCE    P1            CALL PATROL CAR %AMBULANCE<
41          RELEASE    P2
42    CDE   UNLINK     P2,CCC,1
43          TABULATE   9
44          ASSIGN     5,BBB
45          ADVANCE    P4            WAIT WHILE CASE BEING DISPOSED
46          QUEUE      P3            IF DISPATCHER BUSY
47          LINK       P2,FIFO,BBB
48    BBB   DEPART     P3
49          SEIZE      P2
50          ADVANCE    FN2           RECORD DISPOSITION ,FILE
51          RELEASE    P2
52    DEF   UNLINK     P2,CCC,1
53          TABULATE   10
54          TERMINATE
      *
55    CCC   TRANSFER   ,P5
      *
```

```
    5 STORAGE    12          SWITCHBOARD CAPACITY
*
    8 TABLE      S5,0,1,40   SWITCHBOARD USAGE
    9 TABLE      M1,20,20,50
   10 TABLE      M1,300,300,50  TOTAL TIME
*
      START      50,NP
      RESET
      START      3000
      REPORT
      OUTPUT
      EJECT
 FAC  TITLE      1,THE FOLLOWING STATISTICS REFER TO FACILITY 1. THE  #
MANHATTEN NORTH DISPATCHER
      SPACE      3
      SPACE      3
      TEXT       NORTH RADIO MAN UTILIZATION IS#F1,2/2RXX.X#%,AND     *
AVERAGE DISPATCH TIME IS#F1,4/XX.X#SECONDS
      SPACE      3
      SPACE      3
 FAC  TITLE      6,THE FOLLOWING STATISTICS REFER TO FACILITY 6,THE   #
AMBULANCE DISPATCHER
      SPACE      3
      SPACE      3
      TEXT       AMBULANCE DISPATCHER UTILIZATION IS#F6,2/2RXX.X#%,   *
AND AVERAGE DISPATCH TIME IS#F6,4/XX.X#SECONDS
      SPACE      3
      SPACE      3
 STO  TITLE      5,THE FOLLOWING STATISTICS REFER TO STORAGE 5. THE   #
TWELVE TURRET SWITCHBOARD
      SPACE      3
      SPACE      3
      TEXT       COMBINED AVERAGE UTILIZATION OF THE 12 TURRETS IS    #
#S5,4/2RXX.X#%, AND AVERAGE CALL HANDLING TIME IS#S5,6/XXX#SECONDS
      SPACE      3
      SPACE      3
 QUE  TITLE      1, THE FOLLOWING STATISTICS REFER TO CASES AWAITING  #
THE NORTH DISPATCHER
      SPACE      3
      SPACE      3
 QUE  TITLE      3,THE FOLLOWING STATISTICS REFER TO DISPOSITION      #
REPORTS AWAITING THE NORTH DISPATCHER
      SPACE      3
      SPACE      3
 QUE  TITLE      5,THE FOLLOWING STATISTICS REFER TO CALLS AWAITING   #
SWITCHBOARD HANDLING
      SPACE      3
      SPACE      3
 QUE  TITLE      6,THE FOLLOWING STATISTICS REFER TO CASES AWAITING   #
THE AMBULANCE DISPATCHER
      SPACE      3
      SPACE      3
 QUE  TITLE      7,THE FOLLOWING STATISTICS REFER TO DISPOSITION      #
REPORTS AWAITING THE AMBULANCE DISPATCHER
      EJECT
*     FAC  NUMBER  AVG TIME/TRANS  QUE NUMBER  AVG QUE CAPACITY
 10   FORMAT     1/F1,F4,Q1,Q3
```

```
10    FORMAT     6/F1,F4,Q1,Q3
      SPACE      3
      SPACE      3
TAB   TITLE      8,TABLE 8 BELOW IS TURRET OPERATOR UTILIZATION AT     #
SWITCHBOARD%MAX. 12 OPERATORS<
      EJECT
      GRAPH      TP,8
      ORIGIN     48,10
      X          ,3,5,0,,13
      Y          0,2,14,3
40    STATEMENT  11,27,TURRET OPERATOR UTILIZATION
3     STATEMENT  20,1,P
3     STATEMENT  21,1,E
3     STATEMENT  22,1,R
3     STATEMENT  23,1,C
3     STATEMENT  24,1,E
3     STATEMENT  25,1,N
3     STATEMENT  26,1,T
3     STATEMENT  29,1,U
3     STATEMENT  30,1,T
3     STATEMENT  31,1,I
3     STATEMENT  32,1,L
3     STATEMENT  33,1,I
3     STATEMENT  34,1,Z
3     STATEMENT  35,1,A
3     STATEMENT  36,1,T
3     STATEMENT  37,1,I
3     STATEMENT  38,1,O
3     STATEMENT  39,1,N
50    STATEMENT  53,19,NUMBER OF OPERATORS
      ENDGRAPH
      EJECT
TAB   TITLE      9,TABLE 9 TIME BETWEEN CALL AND DISPATCH%SECONDS<
      SPACE      3
TAB   TITLE      10, TABLE 10 ,TIME BETWEEN CALL AND DISPOSITION      #
REPORT
      EJECT
      GRAPH      TP,9
      ORIGIN     48,10
      X          ,1,5,20,,16
      Y          0,2,14,3
30    STATEMENT  10,32,FREQUENCY OF CALL DISPATCH TIMES
3     STATEMENT  12,1,R
3     STATEMENT  13,1,E
3     STATEMENT  14,1,L
3     STATEMENT  15,1,A
3     STATEMENT  16,1,T
3     STATEMENT  17,1,I
3     STATEMENT  18,1,V
3     STATEMENT  19,1,E
3     STATEMENT  21,1,P
3     STATEMENT  22,1,E
3     STATEMENT  23,1,R
3     STATEMENT  24,1,C
3     STATEMENT  25,1,E
3     STATEMENT  26,1,N
3     STATEMENT  27,1,T
```

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3     STATEMENT  29,1,O
3     STATEMENT  30,1,F
3     STATEMENT  32,1,C
3     STATEMENT  33,1,A
3     STATEMENT  34,1,L
3     STATEMENT  35,1,L
3     STATEMENT  36,1,S
50    STATEMENT  52,30,TIME BETWEEN CALL AND DISPATCH
      ENDGRAPH
      EJECT
      GRAPH      TR,6
      ORIGIN     58,10
      X          ,,4,0,,13
      Y          0,5,20,2
30    STATEMENT  8,38,CUMULATIVE TURRET OPERATOR UTILIZATION
3     STATEMENT  16,1,C
3     STATEMENT  17,1,U
3     STATEMENT  18,1,M
3     STATEMENT  19,1,U
3     STATEMENT  20,1,L
3     STATEMENT  21,1,A
3     STATEMENT  22,1,T
3     STATEMENT  23,1,I
3     STATEMENT  24,1,V
3     STATEMENT  25,1,E
3     STATEMENT  27,1,R
3     STATEMENT  28,1,E
3     STATEMENT  29,1,M
3     STATEMENT  30,1,A
3     STATEMENT  31,1,I
3     STATEMENT  32,1,N
3     STATEMENT  33,1,D
3     STATEMENT  34,1,E
3     STATEMENT  35,1,R
50    STATEMENT  52,33,NUMBER OF ACTIVE TURRET OPERATORS
      ENDGRAPH
      EJECT
      GRAPH      TD,9
      ORIGIN     48,10
      X          ,,3,20,,22
      Y          0,5,20,2
40    STATEMENT  8,25,CUMULATIVE DISPATCH TIMES
3     STATEMENT  16,1,C
3     STATEMENT  17,1,U
3     STATEMENT  18,1,M
3     STATEMENT  19,1,U
3     STATEMENT  20,1,L
3     STATEMENT  21,1,A
3     STATEMENT  22,1,T
3     STATEMENT  23,1,I
3     STATEMENT  24,1,V
3     STATEMENT  25,1,E
3     STATEMENT  27,1,P
3     STATEMENT  28,1,E
3     STATEMENT  29,1,R
3     STATEMENT  30,1,C
3     STATEMENT  31,1,E
```

```
3      STATEMENT  32,1,N
3      STATEMENT  33,1,T
3      STATEMENT  34,1,A
3      STATEMENT  35,1,G
3      STATEMENT  36,1,E
50     STATEMENT  52,30,TIME BETWEEN CALL AND DISPATCH
       ENDGRAPH
       EJECT
       GRAPH      TP,10
       ORIGIN     52,5
       X          ,1,4,300,,19
       Y          0,1,15,3
       ENDGRAPH
       END
```

FACILITY	AVERAGE UTILIZATION	NUMBER ENTRIES	AVERAGE TIME/TRAN	SEIZING TRANS. NO.	PREEMPTING TRANS. NO.
MANOR	.432	1437	16.015		
AMBL	.679	1622	22.271	85	

STORAGE	CAPACITY	AVERAGE CONTENTS	AVERAGE UTILIZATION	ENTRIES	AVERAGE TIME/TRAN	CURRENT CONTENTS	MAXIMUM CONTENTS
TURUL	12	5.638	.469	3006	99.774	6	12

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES	ZERO ENTRIES	PERCENT ZEROS	AVERAGE TIME/TRANS	$AVERAGE TIME/TRANS	TABLE NUMBER	CURRENT CONTENTS
MANOR	6	.170	722	410	56.7	12.544	29.028		
NDISP	5	.152	714	407	57.0	11.331	26.355		
TURUL	3	.004	19		.0	12.842	12.842		
AMBL	6	.585	822	251	30.5	37.896	54.555		
ADISP	8	.587	800	271	33.8	39.087	59.111		

$AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES

USER CHAIN	TOTAL ENTRIES	AVERAGE TIME/TRANS	CURRENT CONTENTS	AVERAGE CONTENTS	MAXIMUM CONTENTS
1	636	26.962		.322	9
6	1109	56.285		1.173	11

TABLE TURIL

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
722	6.749	2.175	4873.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
0	0	.00	.0	100.0	-.000	-3.102
1	0	.00	.0	100.0	.148	-2.642
2	9	1.24	1.2	98.7	.296	-2.182
3	37	5.12	6.3	93.6	.444	-1.723
4	77	10.66	17.0	82.9	.592	-1.263
5	92	12.74	29.7	70.2	.740	-.803
6	113	15.65	45.4	54.5	.888	-.344
7	138	19.11	64.5	35.4	1.037	.115
8	97	13.43	77.9	22.0	1.185	.574
9	79	10.94	88.9	11.0	1.333	1.034
10	46	6.37	95.2	4.7	1.481	1.494
11	23	3.18	98.4	1.5	1.629	1.953
12	11	1.52	100.0	.0	1.777	2.413

REMAINING FREQUENCIES ARE ALL ZERO

TABLE CADIP

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1545	143.984	50.250	222456.000	NON-WEIGHTED

UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
20	0	.00	.0	100.0	.138	-2.467
40	0	.00	.0	100.0	.277	-2.069
60	15	.97	.9	99.0	.416	-1.671
80	89	5.76	6.7	93.2	.555	-1.273
100	166	10.74	17.4	82.5	.694	-.875
120	258	16.69	34.1	65.8	.833	-.477
140	328	21.22	55.4	44.5	.972	-.079
160	238	15.40	70.8	29.1	1.111	.318
180	163	10.55	81.3	18.6	1.250	.716
200	91	5.88	87.2	12.7	1.389	1.114
220	69	4.46	91.7	8.2	1.527	1.512
240	53	3.43	95.1	4.8	1.666	1.910
260	23	1.48	96.6	3.3	1.805	2.308
280	18	1.16	97.7	2.2	1.944	2.706
300	17	1.10	98.8	1.1	2.083	3.104
320	8	.51	99.4	.5	2.222	3.502
340	4	.25	99.6	.3	2.361	3.900
360	3	.19	99.8	.1	2.500	4.298
380	2	.12	100.0	.0	2.639	4.696

REMAINING FREQUENCIES ARE ALL ZERO

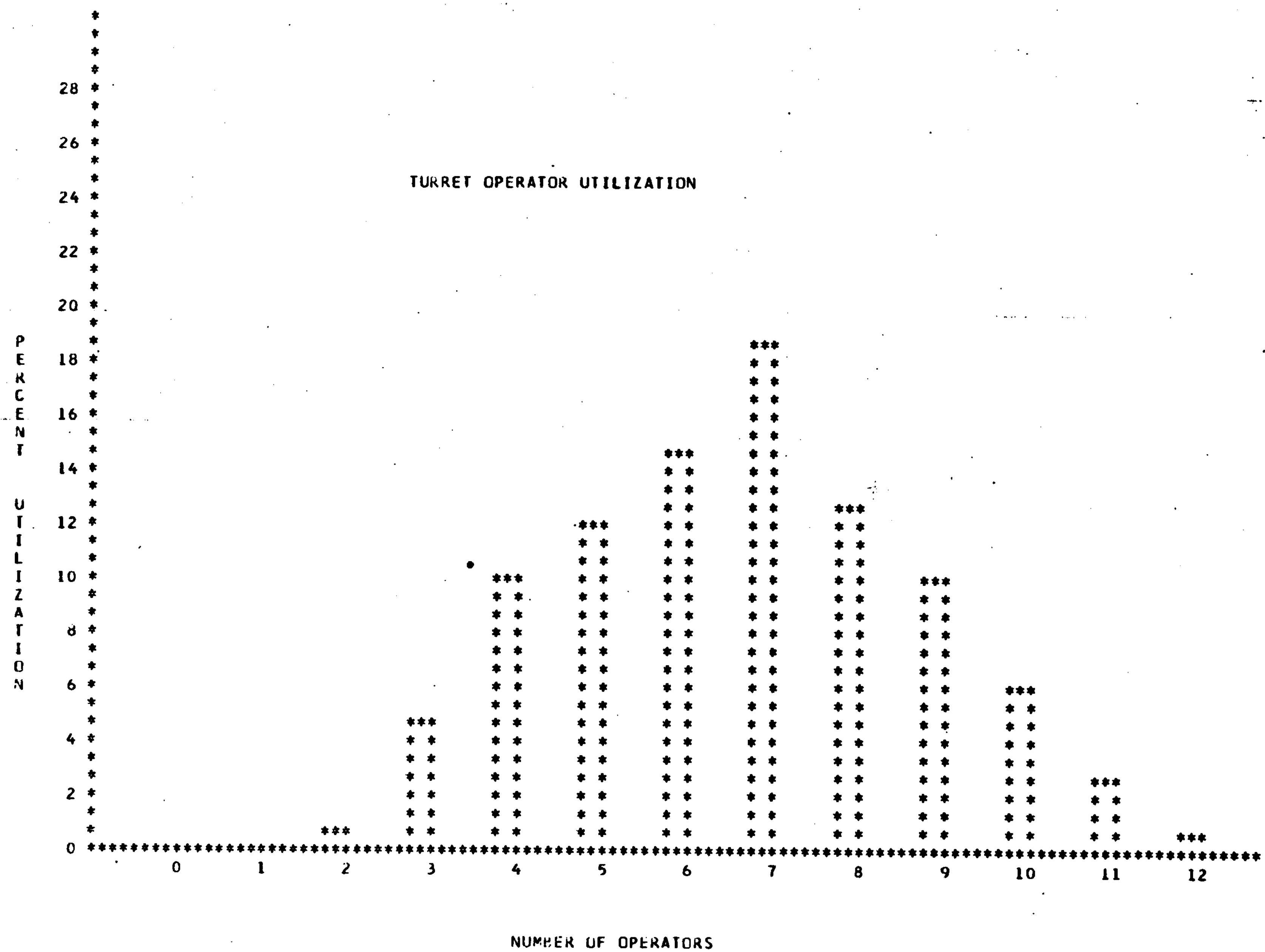
TABLE CADIS

ENTRIES IN TABLE	MEAN ARGUMENT	STANDARD DEVIATION	SUM OF ARGUMENTS	
1513	2154.158	1518.000	3259242.000	NON-WEIGHTED

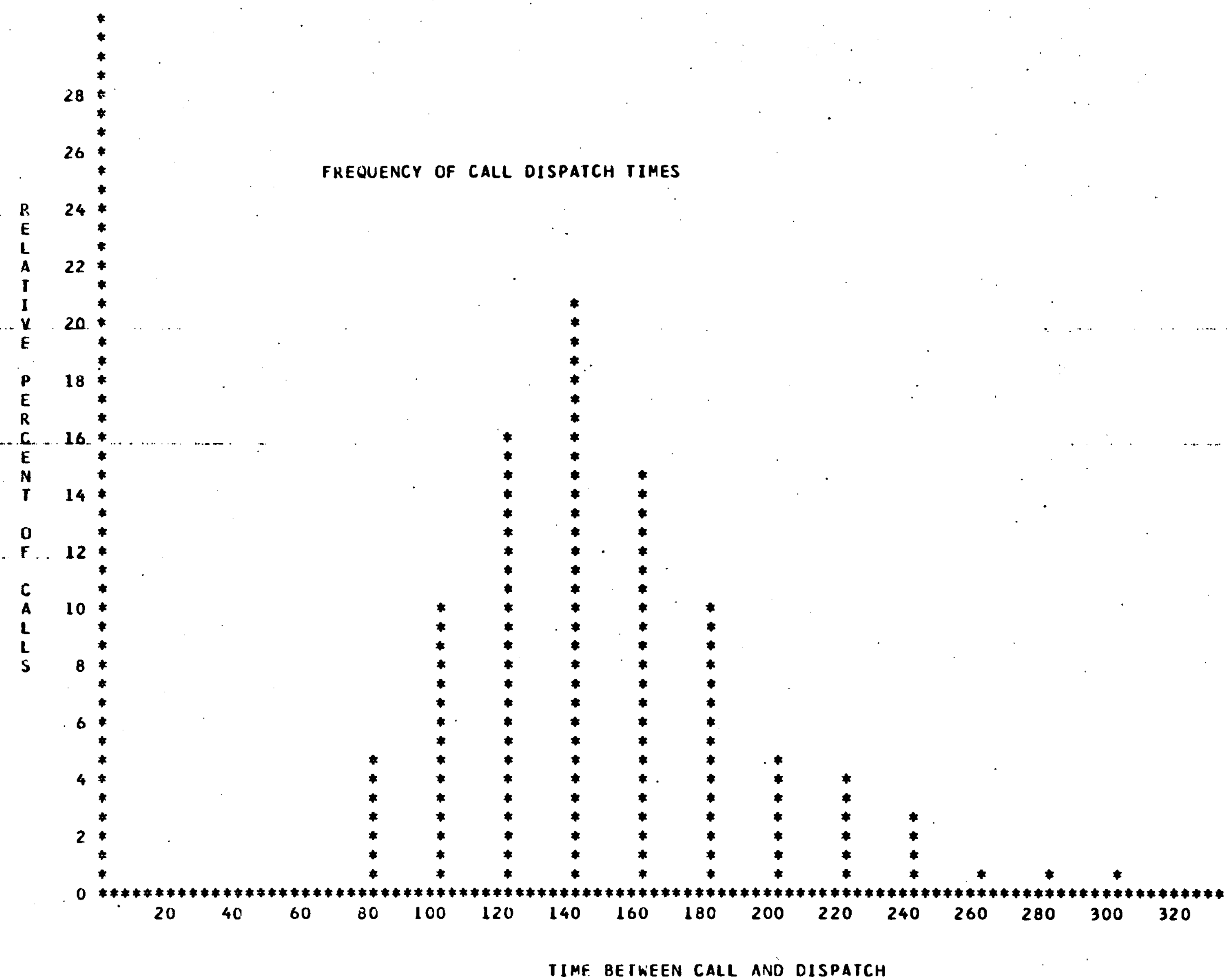
UPPER LIMIT	OBSERVED FREQUENCY	PER CENT OF TOTAL	CUMULATIVE PERCENTAGE	CUMULATIVE REMAINDER	MULTIPLE OF MEAN	DEVIATION FROM MEAN
300	55	3.63	3.6	96.3	.139	-1.221
600	143	9.45	13.0	86.9	.278	-1.023
900	157	10.37	23.4	76.5	.417	-.826
1200	120	7.93	31.3	68.6	.557	-.628
1500	144	9.51	40.9	59.0	.696	-.430
1800	123	8.12	49.0	50.9	.835	-.233
2100	127	8.39	57.4	42.5	.974	-.035
2400	129	8.52	65.9	34.0	1.114	.161
2700	58	3.83	69.7	30.2	1.253	.359
3000	57	3.76	73.5	26.4	1.392	.557
3300	78	5.15	78.7	21.2	1.531	.754
3600	56	3.70	82.4	17.5	1.671	.952
3900	60	3.96	86.3	13.6	1.810	1.150
4200	45	2.97	89.3	10.6	1.949	1.347
4500	52	3.43	92.7	7.2	2.088	1.545
4800	22	1.45	94.2	5.7	2.228	1.742
5100	9	.59	94.8	5.1	2.367	1.940
5400	13	.85	95.7	4.2	2.506	2.138
5700	17	1.12	96.8	3.1	2.646	2.335
6000	9	.59	97.4	2.5	2.785	2.533
6300	7	.46	97.8	2.1	2.924	2.731
6600	5	.33	98.2	1.7	3.063	2.928
6900	4	.26	98.4	1.5	3.203	3.126
7200	17	1.12	99.6	.3	3.342	3.324
7500	6	.39	100.0	.0	3.481	3.521

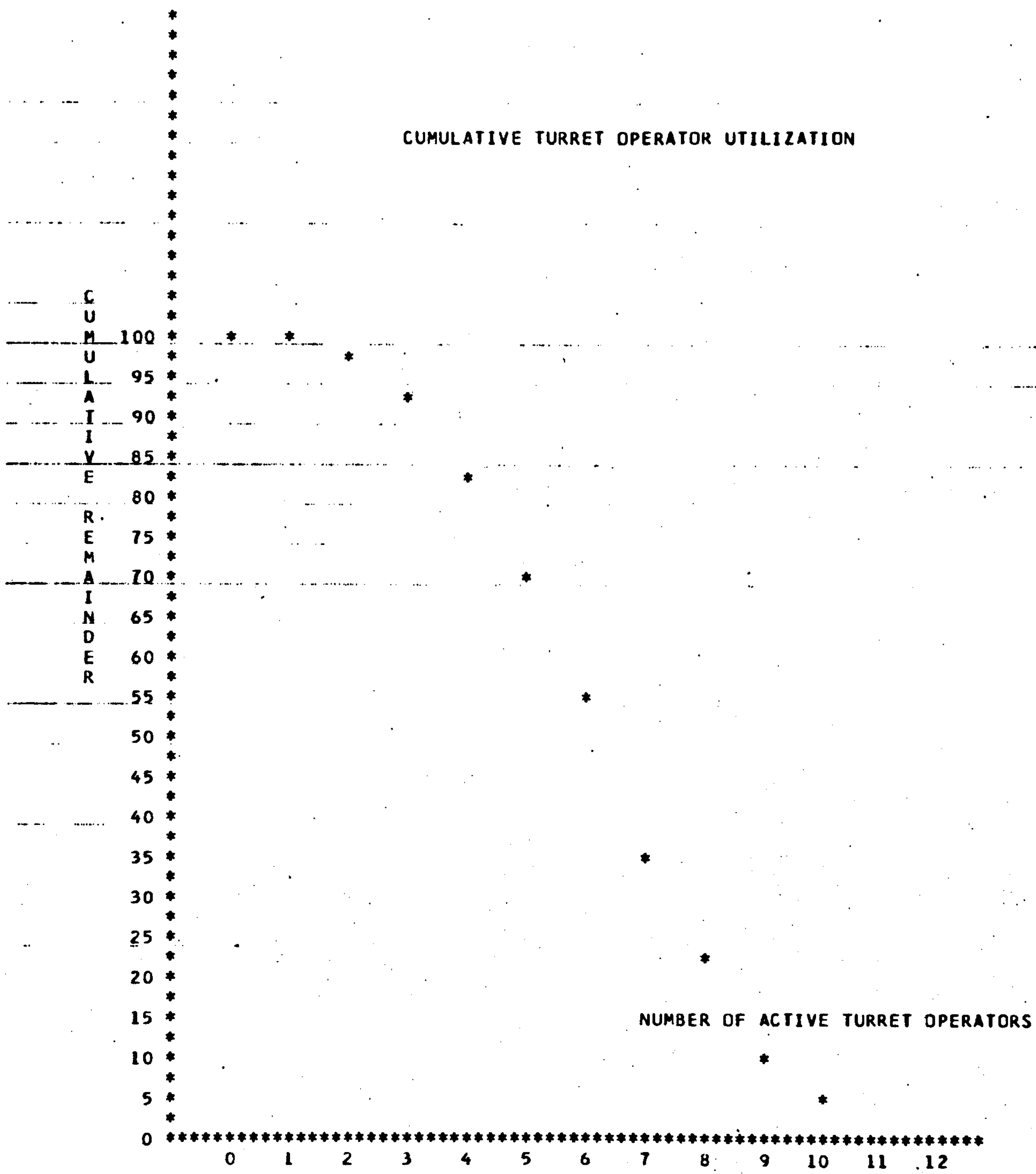
REMAINING FREQUENCIES ARE ALL ZERO

TURRET OPERATOR UTILIZATION



FREQUENCY OF CALL DISPATCH TIMES




CUMULATIVE TURRET OPERATOR UTILIZATION
CUMULATIVE REMAINDER
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12
NUMBER OF ACTIVE TURRET OPERATORS