TITLE / APPROVAL PAGE

Computer Simulation of the Telephone System in the Northern States of Nigeria

BY

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DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my own research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

Uzoanya N. Okparanta.

Date: July 20. 1982

DEDICATION

Dedicated to the sweet memory of my late father,

Ndubuisi N. Okparanta,

who fell asleep in death when this programme was still in progress, and to my beloved mother,

Victoria M. Okparanta.

ABSTRACT

The telephone system in Nigeria has for many years been a subject of attack from many quarters. The poor performance of the system has defied all attempts aimed at improving the situation. This study seeks to identify the cause or causes of the poor performance of the telephone system in the Northern States of the country. The exchanges in use in the system as well as the system itself are simulated on the computer. This work is based on the results of the simulations viz - a - viz what obtains in the real system. Recommendations aimed at improving the system performance are also discussed.

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CHAPTER ONE

INTRODUCTION

1.1 PREAMBLE

Communication, in one form or another, is indispensable to the survival of the human society. Humans communicate with one another using their five senses. The conditions and maximum distance over which communication is possible are limited by natural laws and the construction of the human body. That communication which overcomes unnatural conditions or distances is known as telecommunication.(1) A telecommunicated message must be transmitted for at least part of the distance between the communicating parties in a form different from its natural form. Electric transmission is the most flexible and widely used form and the only one to be considered here.

Telecommunication is used today to describe all electrical signalling methods employed for the communication of intelligence over some distance. The major forms of telecommunications include telephony, sound broadcasting, facsimile, telegraphy and data transmission.(2). Telephone is, as at now, the most important form of telecommunication in Nigeria.

Electric transmission was first used for the sending of written messages by telegraph and was later applied to messages spoken on the telephone. Since public services require destinations of the messages to be variable from the sending points, a form of switching must be employed.

Public telegraph services developed a kind of switching, now called MESSAGE SWITCHING, while telephone services have a different kind called CIRCUIT SWITCHING.(1) Only the latter is considered here. Circuit switching is carried out using sets of switches arranged in stages. This arrangement is called an EXCHANGE SYSTEM (or, simply, an Exchange).

1.2 BRIEF HISTORY OF TELEPHONY

The object of telephony is to make sounds, and, above all, spoken words audible over long distances. At an early stage people tried to use different types of speaking tubes. In 1667, Robert Hook discovered a method of transmitting sounds across fairly long distances by a membrane at each end of a wire.(3) A basis for practically applicable telephony was, however, not found until the progress in the field of electromagnetism made this possible in the 19th century. On February 14, 1876, an American, Alexander Graham Bell, applied for the patency for an electromagnetic telephone. The application was granted and Bell's telephone proved to be very successful.

The first telephone exchange ever was commissioned in New Haven, Connecticut, U.S.A., in 1878.(3) It included a switchboard and 21 subscriber lines.

The early telephone networks were, of course, not as reliable as their present counterparts. Long distance communication was hampered by one-way lines and weak batteries. But the situation gradually improved as progress was made in the field of electrical engineering. Initially,

the exchanges were manually operated but automatic telephone exchanges were later designed. The first automatic exchange was commissioned, once again, in U.S.A. in 1892.(3)

The first exchange was installed in Nigeria in 1908. It was a manual exchange with the magneto system. This was followed by the Central Battery Signalling Systems (CBS), which was introduced in 1929.(2). This was the last of the manual exchanges.

The first automatic exchange was introduced in Nigeria in 1950. It was installed in Port Harcourt on experimental basis. Due to its satisfactory performance, another one was installed in Lagos two years later. During the 1952 - 1962 Development Plan period, some of the manual exchanges were replaced by the step-by-step automatic exchanges. In 1968, the crossbar (automatic) exchange was introduced.(2)

1.3 TELEPHONE SYSTEM IN NIGERIA

There are four different types of exchanges: manual, step-by-step (or strowger), crossbar and electronic. The last three are automatic exchanges. The exchanges in use in Nigeria are of either the step-by-step or crossbar type, the old manual exchanges though having been phased out of the large cities, are still used in the rural towns. The electronic exchange is yet to be introduced. The exchanges are interconnected either using cables or by microwave links to form the telephone network.

For telecommunication purposes, the country is divided into four zones. Each of these zones has a central telephone

exchange usually referred to as a "HOMING" exchange. A homing exchange actually is a transit exchange and carries traffic from one exchange to the other within the same zone and from one zone to another. The homing exchanges are situated in Ibadan, Kaduna, Enugu and Benin. The exchanges are interconnected by microwave links except for the Lagos-Ibadan - Kaduna route which has both microwave and cable links. A very comprehensive description of the telephone system in Nigeria is contained in the reference.(2)

As has already been observed, telephony is the most important form of communication in Nigeria. In spite of this, however, its performance is far below expectations. It is easier for a camel to pass through the eye of a needle than to make a call from Zaria to Kano, for instance. In spite of all the money which successive governments of the country have spent towards the improvement of the system, it has remained as defiant as ever. In fact, the situation is so bad that many Nigerians have long ceased to hope that telephones in Nigeria will ever work - not in their lifetime for sure! What's more, the damage which the poor state of the system has done and is doing to the economic development of the country cannot be over-emphasized. This is indeed a most disheartening state of affairs.

Of course, there is nothing inherent in or peculiar to Nigeria that should make it anathema for telephones to work in the country. Hence the questions arise: What then is responsible for the perennial poor performance of the telephone system in Nigeria? Is it a problem of inadequate

or insufficient equipment, or both? Is it that of bad management?

This study attempts to look into some of these questions in the preceeding paragraph, with particular emphasis on the telephone system in the Northern States. To do this, a computer simulation of each of the types of exchanges in use has been performed by the author. The exchanges in Zaria and Kaduna have been used as models. The simulations have been designed to approach as closely as possible what obtains in practice in the exchanges. The performance of each exchange as obtained from the simulation is then compared with that of the real exchange. Further investigations were carried out on the real exchange systems to determine the causes of any observed differences. The telephone network in the Northern States has also been simulated. The expected performance of the system is compared with the real performance. Further investigations were also carried out on the real network to determine the causes of any observed differences. Recommendations, based on the results of these investigations, on how to improve on the performance of each of the exchange systems and that of the network as a whole are contained in this work.

1.4 WHY SIMULATION?

The advantages of simulation approach to system study are enormous. However, a few will be mentioned here, Simulation eliminates the usually huge cost of buying an equipment (a telephone exchange, for example) the performance

of which in the network in which it is to be used is unknown. It eliminates the need for building prototypes which in most cases may be very expensive. Simulation also allows the researcher to observe the performance of the system as certain parameters are varied without actually having to spend money and energy physically building the system. The importance and usefulness of such flexibility enjoyed in system study through simulation cannot be over-emphasized. Such enormous advantages as are mentioned above due to the simulation approach to system study far outweigh any disadvantages due to computer time and consequent cost.

It is for the above reasons that a simulation rather than an analytical approach has been chosen for this study.

1.5 THEORY OF SYSTEM SIMULATION

The technique of simulation consists of following the changes in a model of a system.(4) The systems simulated in this work are discrete systems, as the changes therein are predominantly discontinuous.

There are two general points of view which may be taken of the way in which discrete events are identified: (4)

1. In one point of view, referred to as PARTICLE-ORIENTED or MATERIAL-BASED, attention is focussed on the entities in the system, and the simulation is regarded as the task of following the changes that occur as the entities move from activity to activity. In that case, the times at which system changes occur are treated as attributes of the entities.

2. In the other point of view, referred to as EVENT-ORIENTED or MACHINE-BASED, attention is focussed on the activities as they are applied to different entities. In that case, the times at which system changes occur are treated as characteristics of the activities.

In this work, the event-oriented view is taken. However, in general, the point of view taken does not affect the execution of a simulation. The execution remains the same. Records must be kept of all the activities in progress and the entities involved, and they must be periodically changed to reflect the sequence of events within the system. To do so, records must be kept of EVENT-TIMES and calculations must compute future event times as the simulation proceeds.

The passage of time is recorded by a number referred to as CLOCK-TIME. It is usually set to zero at the beginning of a simulation and subsequently indicates how many units of simulated time have passed since the beginning of the simulation. There are two basic methods for updating clock time: (4)

1. The clock is advanced to the time at which the next event is due to occur. This is referred to as event-oriented.
2. The clock is advanced by small (usually uniform) intervals of time and it is determined at each interval whether an event is due to occur at that time. This is referred to as INTERVAL-ORIENTED.

Continuous system simulation is usually carried out by using the interval-oriented method while discrete system simulation normally uses the event-oriented method, which is the method consequently used here.

An important aspect of discrete system simulation is the generation of exogenous arrivals. It is possible that an exact sequence of arrivals has been specified for the simulation. The sequence may, for example, be the results of some observations on the system. Further, when there is no interaction between the exogenous arrivals and the endogenous events of the system, it is permissible to create a sequence of arrivals in preparation for the simulation.(4) Usually, however, the simulation proceeds by creating new arrivals as they are needed.

The exogenous arrival of an entity is defined as an event and the arrival time of the next entity is recorded as one of the event times. When the clock time reaches this event time, the event of entering the entity into the system is executed and the arrival time of the following entity is immediately calculated from the inter-arrival time distribution. The term BOOTSTRAPPING is often used to describe this process of making one entity create its successor.(4) The method requires keeping only the arrival time of the next entity. It is, therefore, the preferred method of generating arrivals for computer simulation programs and is the method used in this study.

The arriving entity usually needs to have some attribute values generated, in which case, attention must be paid to the time at which the values are generated. They could be generated at the time the arrival time is calculated, or they could be generated when the entity actually arrives. If there is no interaction between the attributes and the events occurring within the system, the generation may be done at either time. If, however, the attribute values depend upon the state of the system, it must be remembered that, at the time of generating the arrival time, the actual arrival is still an event in the future. The generation of the attribute values must then be deferred until the arrival event is executed. In this study, the details of the new arrival, other than its arrival time, are generated at the time the arrival takes place because the conditions existing in the system determine the possible origins for the call. On the other hand, there is no interaction between the distribution of call length and the state of the system, so the call length is generated at the time the arrival is decided. However, a call cannot come from a line that is already busy, so the choice of origin must be left until the call arrives. To select the origin when the arrival time is decided carries the risk that some other call will have made the proposed origin busy before the call arrives.

In this study, it has been assumed that any arrival can come, with equal probability, from any line not currently busy and that it is equally likely to go to any line other than itself irrespective of whether it is busy or not. For

this reason, a uniform random number generator is used to generate the origins and destinations of calls. The call arrival time and call length can be shown to be exponential and follow the Poisson distribution.(4) An exponential random number generator is, therefore, used for their generation.

There are three main tasks to be performed in preparing a complete program for a simulation: (4)

1. The first task is to generate a model and initialize it. From the description of the system, a set of numbers must be created to represent the state of the system. The set of numbers will be called the SYSTEM IMAGE, since its purpose is to reflect the state of the system at all times. The activities of the system must be represented as routines that are to carry out the changes to the system image.

2. The second task is to program the procedure that executes the cycle of actions involved in carrying out the simulation. This procedure is referred to as the SIMULATION ALGORITHM. While the routines representing the system activities are specific to the system being simulated, the simulation algorithm need not be.

3. The third task is the generation of an output report. The statistics gathered during the simulation will usually be specified by the report generator.

The simulations done in this study involve all the tasks listed above.

Carrying out the simulation algorithm involves repeated execution of the following five steps:

1. FIND the next potential event.
2. SELECT an activity.
3. TEST if the event can be executed.
4. CHANGE the system image.
5. GATHER statistics.

The simulation programs used in this study involve, generally all of the above steps. Specifically, they contain routines which perform the following functions:

1. Program initialization.
2. Finding the next potential event.
3. Connecting a call.
4. Disconnecting a call.
5. Gathering statistics.
6. Computing final statistics and printing out results.

Though the simulations have been programmed for the CYBER 72 computer, the concepts are machine independent.

1.6 CONCLUSION

It is hoped that the results of this research and the consequent recommendations by the author, if implemented, will go a long way in drastically improving on the performance of telephone systems in the Northern States in particular, and in the whole country in general.

CHAPTER TWO

LITERATURE REVIEW

The approach hitherto employed in the study of telephone switching systems has been largely mathematical. In 1955, C.Y. Lee proposed a method of analysis using a simplified model of the system.(5) This proposal included ways of finding the characteristics of a network such as blocking probability, retrial and connection time distributions. In Lee's analysis, the model is represented by a PROBABILITY LINEAR - GRAPH which is used as a probability model to calculate all characteristics of interest of the switching network. A (two-terminal) probability linear-graph, G, is defined as a finite, oriented, connected, cycle-free linear-graph with at least two nodes such that

1. there exists a pair of nodes called respectively an ORIGINATING and TERMINATING node, of G; this assignment being determined initially,

2. with each link of G is associated a random variable, $X_t^{(i)}$, the index, i, running over all links of G such that $X_t^{(i)}$ are mutually independent and have stationary probability distributions

$$f_{t_1}, f_{t_2}, \ldots, {}_{t_n}^{(i)}(\delta_1, \delta_2, \ldots, \delta_n) = P_r(X_{t_j}^{(i)} = \delta_j, j=1,2,\ldots,$$

$$\delta_j = 0 \text{ or } 1, \quad j = 1, 2, \ldots, n$$

The assumption that the link random variables, $X^{(i)}$, are independent is the principal weakness of Lee's model and will cause the results to depart from reality in varying degrees -

depending on the particular network. In general, the model will tend to overestimate blocking. The dependence that exists between the different links in a network stage and between the links in adjacent stages is incompletely understood, but nonetheless, real. Attempts to take account of inter-link dependence by judicious modification of link occupancy values have been only moderately successful in calculations. Moreover, as a computational tool, the utility of the graph model decreases with increasing complexity of the graph's geometrical structure.(6) Applied to more complicated structures, such as meshed graphs, the method of Lee will be very unwieldy and in most cases not applicable.(7) Hence Lee's model may not be useful in the study of realistic and, consequently, complex networks.

The speaking paths of modern telephone arrangements often consist of several selector stages in series, which are controlled by a centralized device in conditional selection. Idle links between the stages will only be selected if they can be used in a path connecting the inlet to an idle outlet. Thus, we often have the case where a certain inlet in stage 1 is to be connected with a certain outlet in stage S, i.e. with a certain outgoing line. The traffic loss due to nonavailability of an idle path between the two points is called POINT-TO-POINT LOSS or in short POINT LOSS.(7) In 1971, Karl Kummerle proposed two methods of calculating point-to-point loss in link systems.(7) In the first method, referred to as "multiplication and

summation of probabilities " formulas are derived for the calculations of point loss. When no occupation exists in a system, only a certain number of paths will be suited to switch a call from the inlet being marked to the outlet being marked. The entirety of these paths which are suited is called the graph of the system considered. In the first method, multiplication and summation of probabilities, the assumption of probabilities for x lines to be occupied in a section of the graph are known for each section. Besides this, the probability distribution for the whole outgoing group shall be known. The second method is known as the method of "average availability". In this method, formulas are derived for calculating the point loss in three- and four-stage link systems with series-parallel linking patterns. The comparison of the numerical results with the results of a full-scale simulation shows that the first method yields accurate results for three-stage systems when a weighting function is introduced. The results obtained with the average availability method were also sufficiently close to reality for three- and four-stage link systems.(7) The greatest advantage derived from using these methods is their simplicity. Their major weakness lies, however, in their non-reliability in the analysis of more complex systems.

The difficulty which will be encountered in the use of any of the methods discussed in the preceeding paragraphs has been noted. In an attempt to surmount this difficulty, a simulation program, code-named NEASIM, was jointly developed

in 1964 by R.F. Grantges and N.R. Sinowitz.(6) This simulation program differs from conventional simulators in that it simulates a mathematical model rather than a traffic-handling system. The major advantage of the simulator is that it allows for the incorporation of more a priori information about the actual behaviour of switching networks than is included in Lee's model, leading to a more accurate estimate of blocking probability. However, the characteristic feature of this simulation method is that not the whole link system and the real traffic are simulated, but the graph with independent Bernoulli distributions on each section is used upon which the calculation method is based. This means that with NEASIM, not the whole link system is simulated, but the calculation method of Lee is used. Therefore, the results of simulation with NEASIM naturally correspond to the numerical results of Lee and the significance of such results of simulation cannot be expected to be greater than the accuracy of the calculation method of Lee.

From the foregoing, it is clear that the most reliable - though very difficult - approach to the study of switching systems is the full-scale simulation of the system. This approach has been employed in this work. The simulation approach can be further justified by considering the fact that no systematic approach exists which completely accounts for the gross complexity encountered in large-scale congestion systems.(6) Although the engineer does not have a comprehensive theory, he does have a valuable tool in computer simulation.(6)

Simulation of telephone traffic flow has a long history in the Bell system.(6) As early as 1907, a rudimentary simulation was undertaken to improve switchboard performance. Artificial traffic was generated by a card-drawing technique, and the simulation was used to verify a semi-mathematical analysis of the loads which could be handled by a team of operators meeting an average delay criterion. In the ensuing years, simulation techniques have been aids in the study of complex traffic problems, such as the effect of limited sources on graded multiple capacities, the efficiency of random slipped multiples, the capacities of various alternate routing plans and the distribution of delays under various trunking plans. The traffic load capacity of the No.1 crossbar network was largely determined by the load-loss relationships in the link and junctor patterns obtained from elaborate simulation begun in 1936. This was the first time that the capacity of a largely complete system had come under study by simulation methods. A 10,000-line No.5 crossbar office was simulated in 1948 by a specially designed machine which co-ordinated the efforts of tone operators, providing significant data for the traffic engineering of this system.(6)

In more recent years, the high-speed electronic digital computer has proved an effective tool in large-scale traffic simulations. For this class of simulations, special computer programs are written which usually contain

1. a logical description of the system under consideration,

2. a procedure for generating and offering traffic to the system, and

3. a method for extracting and recording the desired system characteristics.(6)

Each of the simulation programs used in this work contains all the facilities enumerated above. The simulation programs have been designed for the analysis of the telephone system in the Northern States of Nigeria.

CHAPTER THREE

THE MANUAL (IDEAL) TELEPHONE EXCHANGE

3.1 INTRODUCTION

This chapter describes the program used for the simulation of the Manual Telephone Exchange.(4) The exchange has a number of telephones connected to it by lines. The switchboard (the exchange) has a number of links which can be used to connect any two lines, subject to the condition that only one connection at a time can be made to each line. It is initially assumed that the system is a lost call system, that is, any call that cannot be connected at the time it arrives is immediately abandoned. A call may be lost because the called party is engaged, in which case, the call is said to be a busy call; or it may be lost because no link is available, in which case, it is said to be a blocked call. (Later the program is modified to take care of any blocked call so that a blocked call is not necessarily a lost call). The object of the simulation is to process a given number of calls and determine what proportion are successfully completed, blocked, or found to be busy calls. This program is code-named 'TELSIM 1'.

Modified versions of TELSIM 1 are used to observe the performance of the exchange as the number of lines and maximum number of links are varied. TELSIM 1 is further modified to take into account the blocked calls. In this case, the system is no longer a lost-call system. All blocked calls are sent to a waiting list and connected, if possible, as soon as a link is free in the order of "first in first out" (FIFO).

The Zaria exchange parameters, where applicable, have been used as a model in all the simulations discussed in this thesis. The Zaria exchange, though having a maximum capacity of 2,000 lines, has been equipped for 1,700. This figure, unless otherwise indicated, has been used in all the simulations considered in this thesis.

The system image of each program is a set of tables and numbers that record the state of the system. Such tables and numbers are clearly defined in each program. All other variables not explicitly defined and appearing in any of the programs are self explicit.

A brief description of the simulation program of the manual (ideal) exchange (TELSIM 1) including the various routines responsible for the execution of the program now follows.

3.2 BRIEF DESCRIPTION OF THE PROGRAM

The flow chart showing how the simulation program is organized is shown in Fig.C.1(a) of Appendix C . When the program is started, the model is initialized for the particular run to be made. The input information includes the number of lines, the maximum number of links, the mean inter-arrival time, the mean call length and the maximum number of processed calls making a run. This information is supplied in the program proper and can be set to different values as desired. An initialization routine then sets various numbers to their correct initial values; for example, it zeroes the clock time and the counters. The first arrival time is

generated and the program enters the main routine concerned with executing each cycle of events. This initial entry point is also the point from which to recycle when all changes have been executed for one event.

Suppose the next call finishes at T_F and the next arrival is at T_A. The program first decides whether the next activity is to disconnect a call or to attempt to connect a call. The test of the condition $T_F \leq T_A$ makes this choice. With the test defined this way, a coincidence of a disconnect and a new arrival results in the disconnect being serviced first. Whichever activity is decided upon, the program updates the clock. When two events are coincidental, the program executes them successively and the clock remains unchanged until all events at that time have been executed. In the case of disconnecting a call, the activity is unconditional and the program immediately carries out the necessary action. Since a call has just finished, the time the next call finishes, T_F, is updated. The program collects statistics and returns for another cycle. In the case of a new call arriving, the call is generated and the program checks to see whether enough calls have been processed to finish the simulation run. If not, the attributes of the call are created at that time and the next arrival time is generated. Tests are then made to see if the call will be connected or lost either because no link is available or the called line is busy. When a call is connected, the program adjusts the records by entering the new call in the list of calls in progress. When a call is

lost the appropriate statistics are gathered. The program then resumes for one more cycle.

When enough calls have been processed to finish the simulation run, the simulation stops, the results are printed, and the program terminates.

The simulation program can be divided into major sections, each section carrying out a particular function, viz:-

1. Program initialization
2. Finding the next potential event
3. Connecting a call
4. Disconnecting a call
5. Gathering statistics
6. Computing final statistics and printing out results.

The flow charts showing how these routines implement their various functions are shown in Appendix C .

3.3 SIMULATION RESULTS AND ANALYSIS

The manual exchange is the simplest type of exchange and closely approximates the ideal exchange. Table 3.1 shows the results obtained from the simulation of the manual exchange. The simulation run covers a period of three hours, during which time 1,000 calls enter the system.

Table 3.1: Simulation Results for the Manual Exchange

No. of Lines	1700
No. of Links	10
Mean Call Interval	12 seconds
Mean Call Length	120 seconds
No. of Calls	1000
Clock Time	11076
Duration of Run	3 hours
Calls Completed	759
Busy Calls	5
Blocked Calls	226
No. of Active Calls	10

The graphs of Fig. 3.1 (a - k) show the behaviour of the system as certain parameters are varied while others are kept constant. (a) shows that for maximum number of links provided in the exchange greater than 20, the number of blocked calls is essentially zero. 20 is thus the critical value for the maximum number of links for this exchange. The completed - calls curve is roughly a mirror image of the blocked calls curve. This is to be expected, as the number of calls entering the system is fixed (at 1,000) for each run, the numbers of busy and active calls being relatively small. The exponential nature of the curves is also of interest. It

reflects the exponential distribution of arrival times of calls. The busy-calls curves of (d) and (e) are also roughly exponential. The graphs of Fig. 3.1 (b) and (c) show the behaviour of blocked and completed calls as the number of lines (NLINES) provided at the exchange is varied, for values of maximum number of links (NLNKS) of 20 and 10 respectively. As can be seen from the graphs, the average number of completed calls for NLNKS = 20 is greater than that for NLNKS = 10. On the other hand, the average number of blocked calls for NLNKS = 20 is less than that for NLNKS = 10. These observations, of course, are to be expected.

The graphs of Fig. 3.1 (f) and (g) show that the relationship between the blocked/completed calls with the number of calls entering the system is linear. In (f), the slope of the completed - calls curve is $^{200}/_{200} = 1$ while that of the blocked-calls is zero. In (g), the completed-calls curve has a slope of $^{145}/_{200} = 0.73$, which is less than 1 while the blocked-calls curve has a slope of $^{130}/_{600} = 0.22$, which is greater than zero. These results show that the average number of completed calls for NLNKS = 20 is greater than that for NLNKS = 10, while the average number of blocked calls is less for NLNKS = 20 than that for NLNKS = 10. This agrees with earlier observations. Fig. 3.1 (h) and (k) show that the relationship between the number of busy calls and number of calls entering the system is linear, the average number of busy calls being greater for NLNKS = 20 than for NLNKS = 10.

The system represented in Fig. 3.1 (j) is not a lost-call system, as in the cases hitherto considered. In this system, blocked calls are sent to a waiting list and connected as soon as a free link is available, in the order of "first-in-first-out" (FIFO). It will be observed that for the maximum number of links provided equal to or greater than 20, the number of blocked calls is zero. This agrees with the earlier observation on the simple lost-call system (Fig. 3.1 (a)). The graph of Fig. 3.1 (k) shows that the mean-waiting time for the blocked calls which were later connected is zero for values of NLNKS equal to or greater than 20. This agrees with the fact that for maximum number of links greater than 20, the number of blocked calls is essentially zero.

The graphs of Fig. 3.1 (l) and (m) represent modified systems where the numbers of calls entering the system are 500 and 2,000 respectively. The general similarity in shape between these graphs and those of Fig. 3.1 (b - c) show that the shapes of the graphs obtained for different varied parameters of the system are not dependent on the number of calls entering the system.

As has already been pointed out, the manual exchange has been almost completely replaced by the automatic exchanges in the telephone network in the Northern States. For this reason, there are no available statistics of the performances of the few manual exchanges still in use. However, this much is known about these exchanges: the most common problems encountered in their use are those associated with the human factor and those of damaged cables. The latter problem is

more fully discussed in the next chapter where its impact on the performance of the step-by-step exchange is considered.

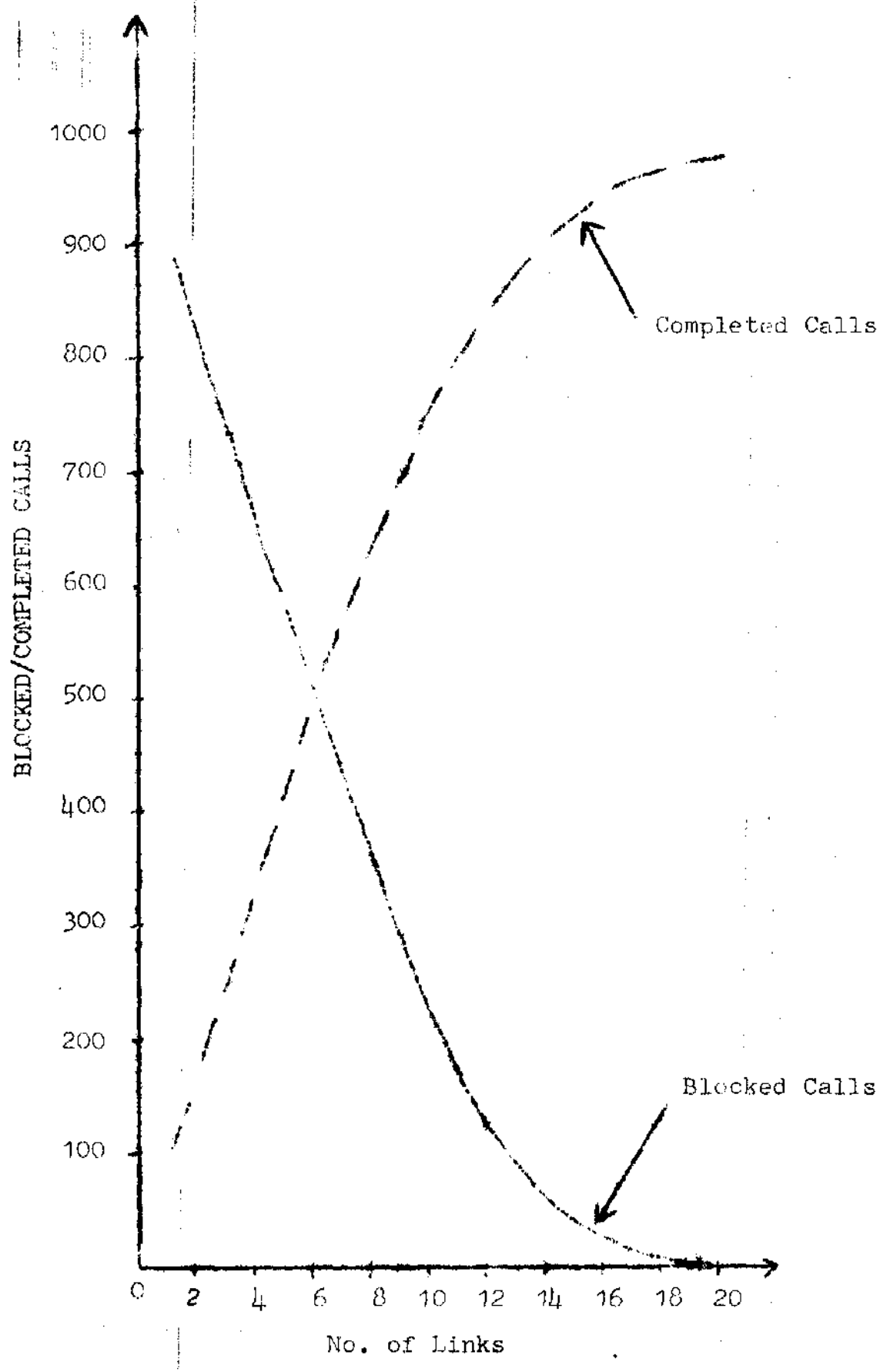


Fig. 3.1(a) Blocked/Completed Calls versus No. of Links

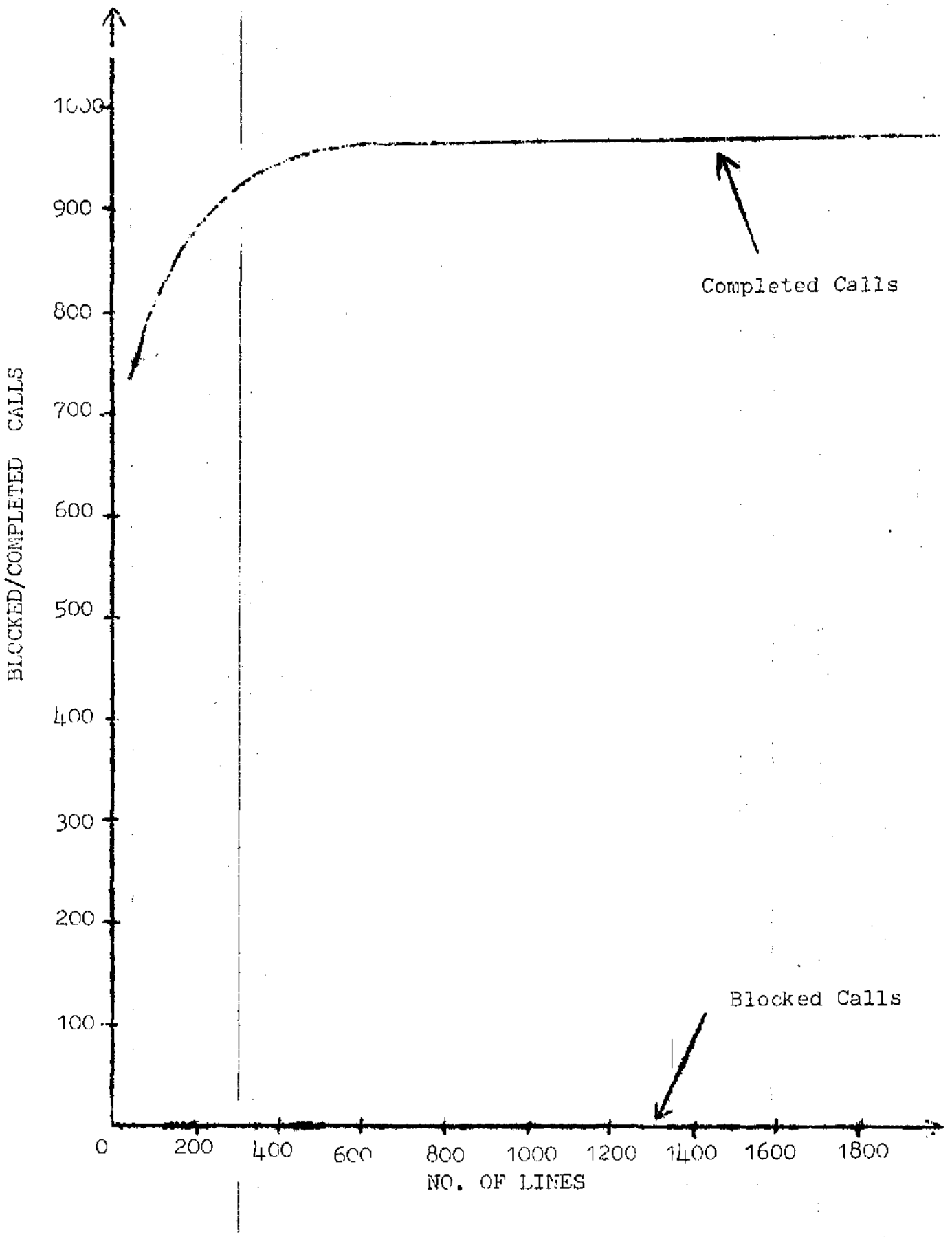


Fig. 3.1(b) Blocked/Completed Calls versus No. of Lines
(No. of Links = 20)

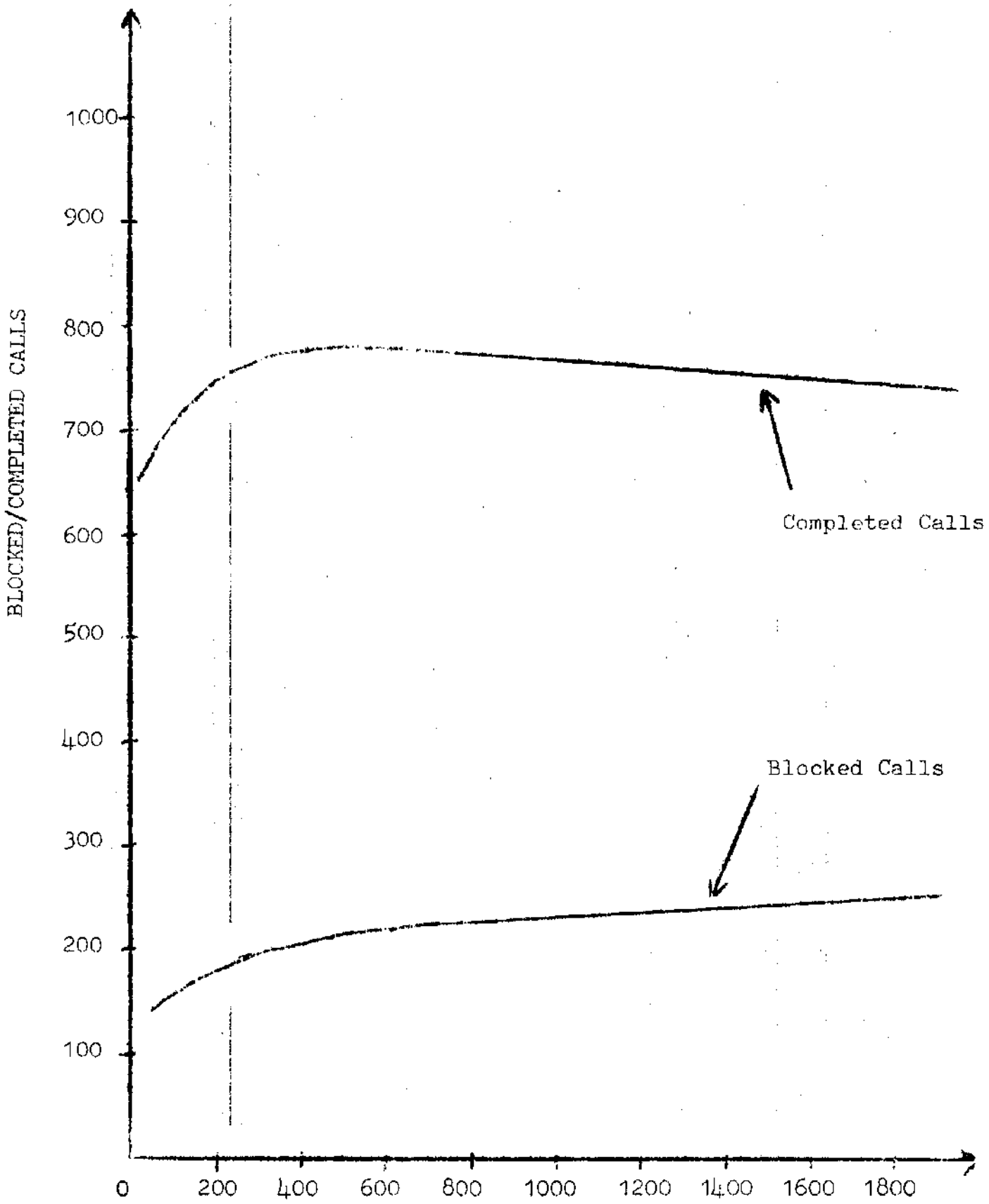


Fig. 3.1(c) Blocked/Completed Calls versus No. of Lines
(No. of Links = 10)

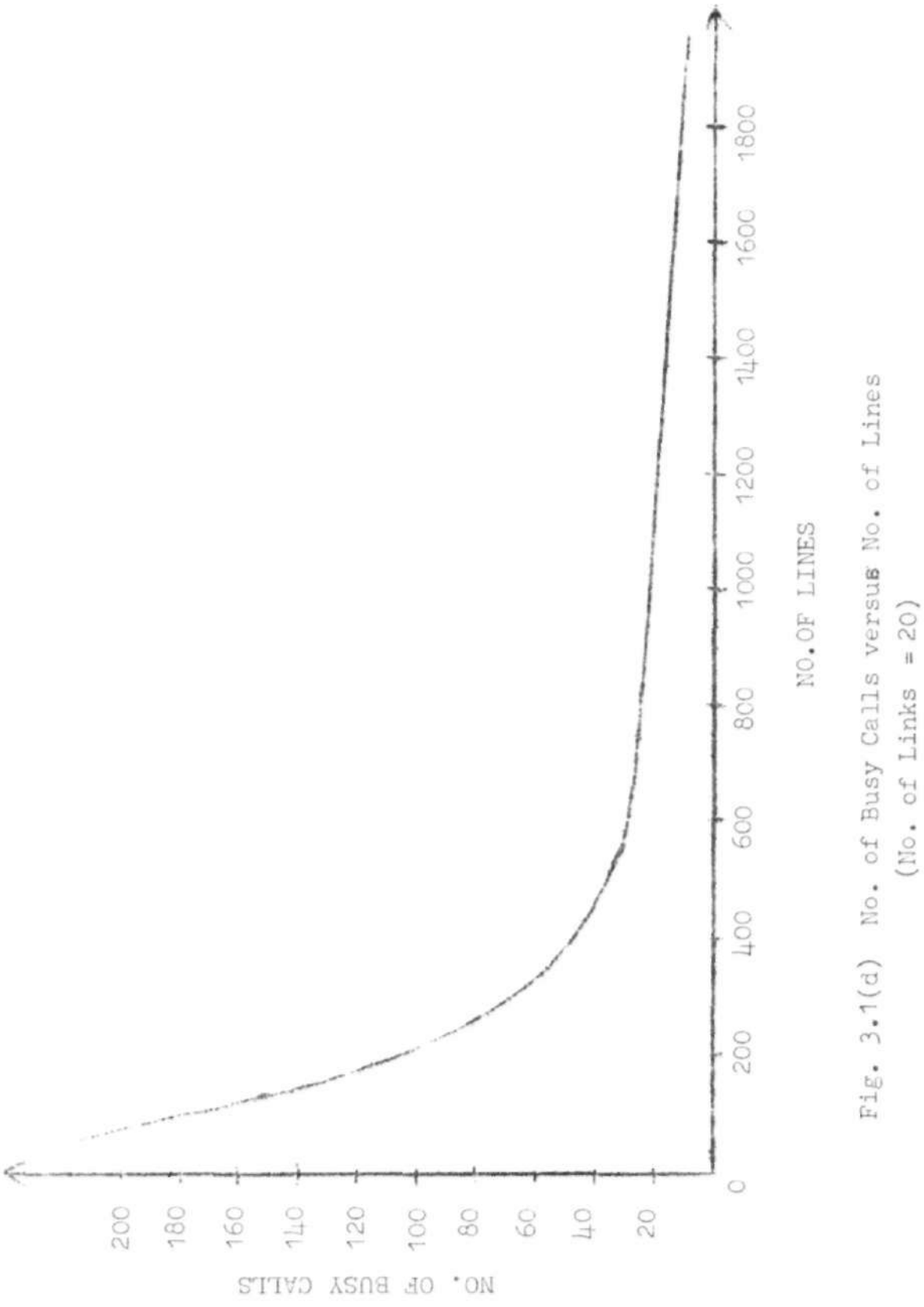


Fig. 3.1(d) No. of Busy Calls versus No. of Lines
(No. of Links = 20)

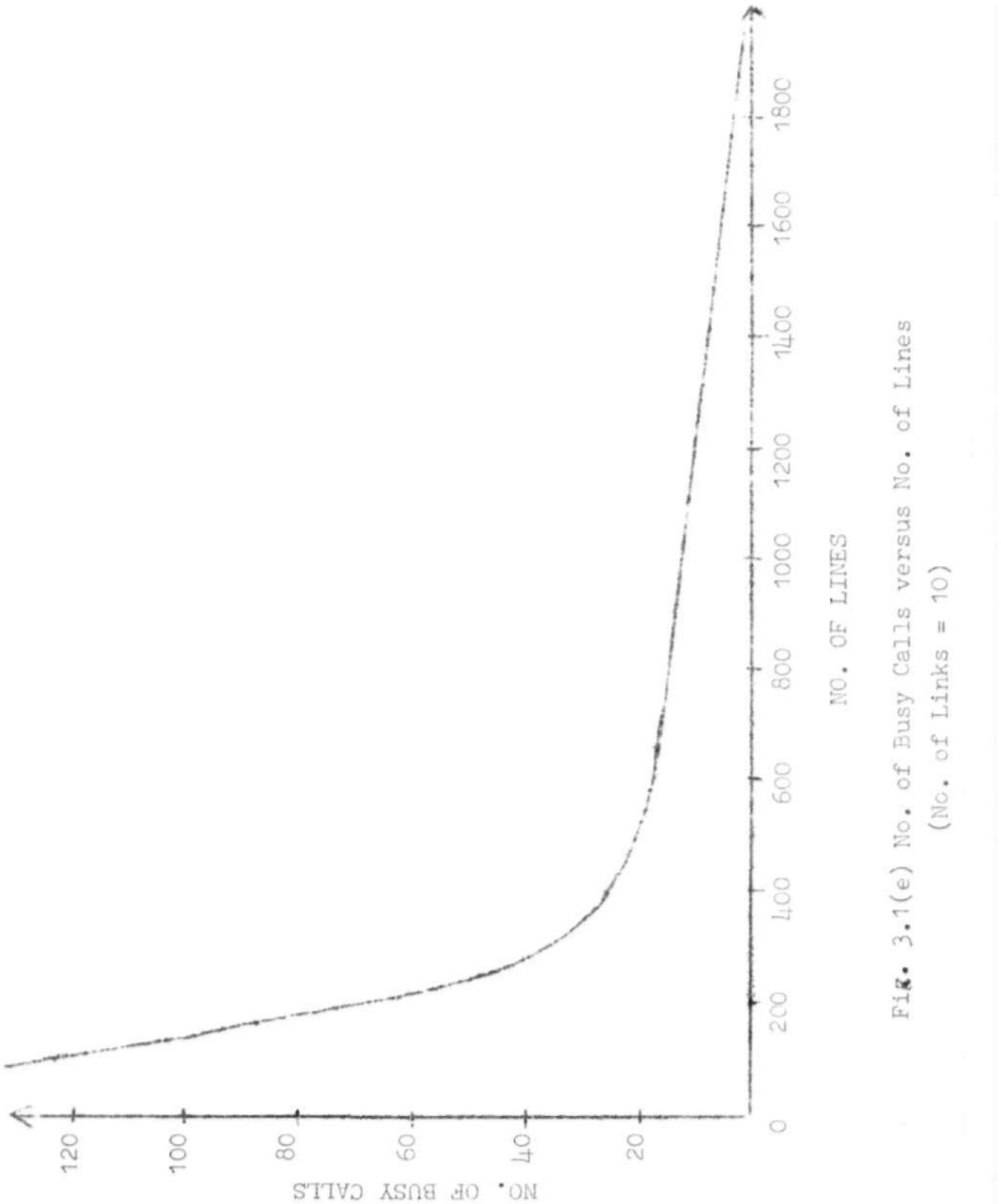


Fig. 3.1(e) No. of Busy Calls versus No. of Lines
(No. of Links = 10)

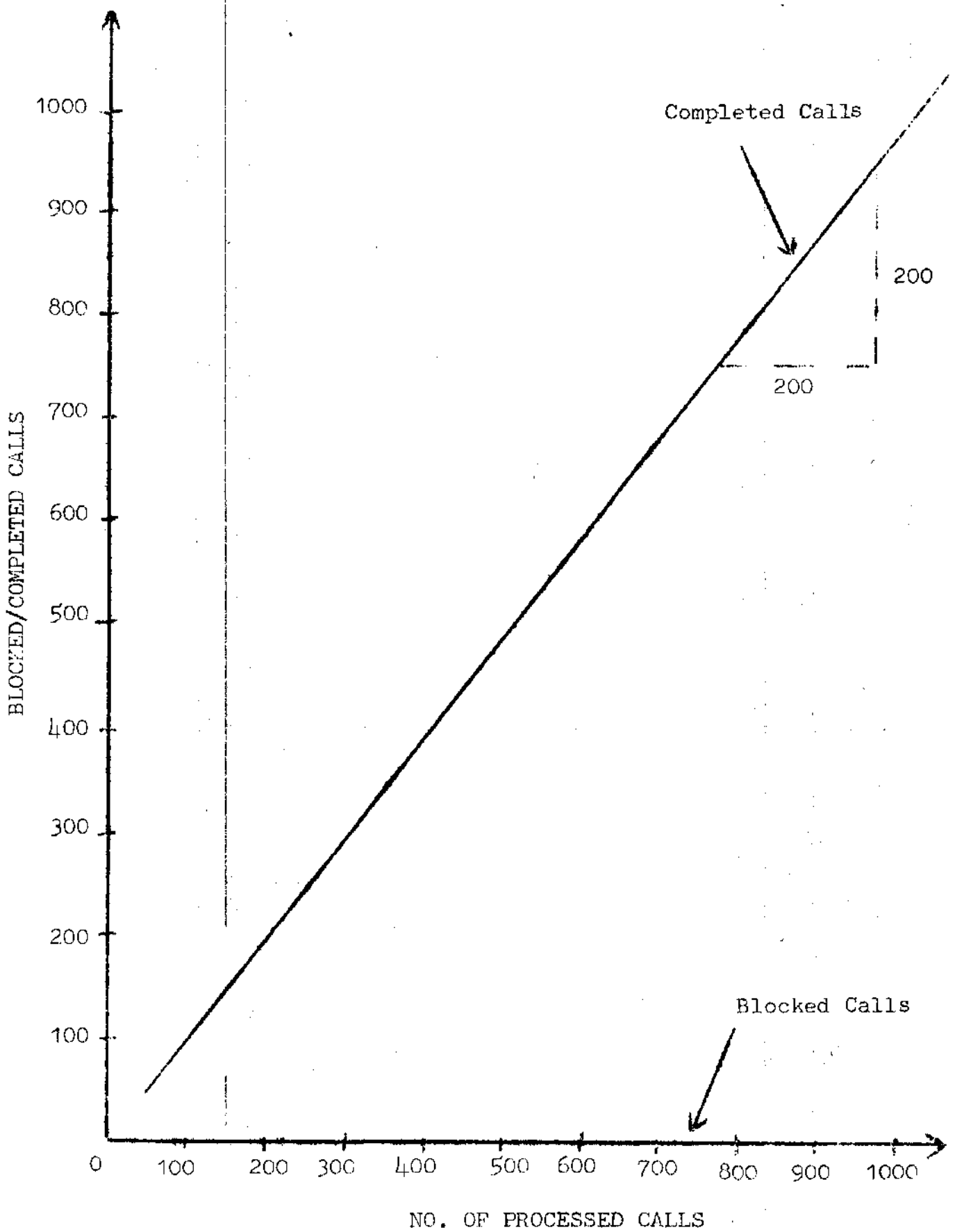


Fig. 3.1(f) Blocked/Completed Calls versus No. of Processed Cal

(No. of Links = 20)

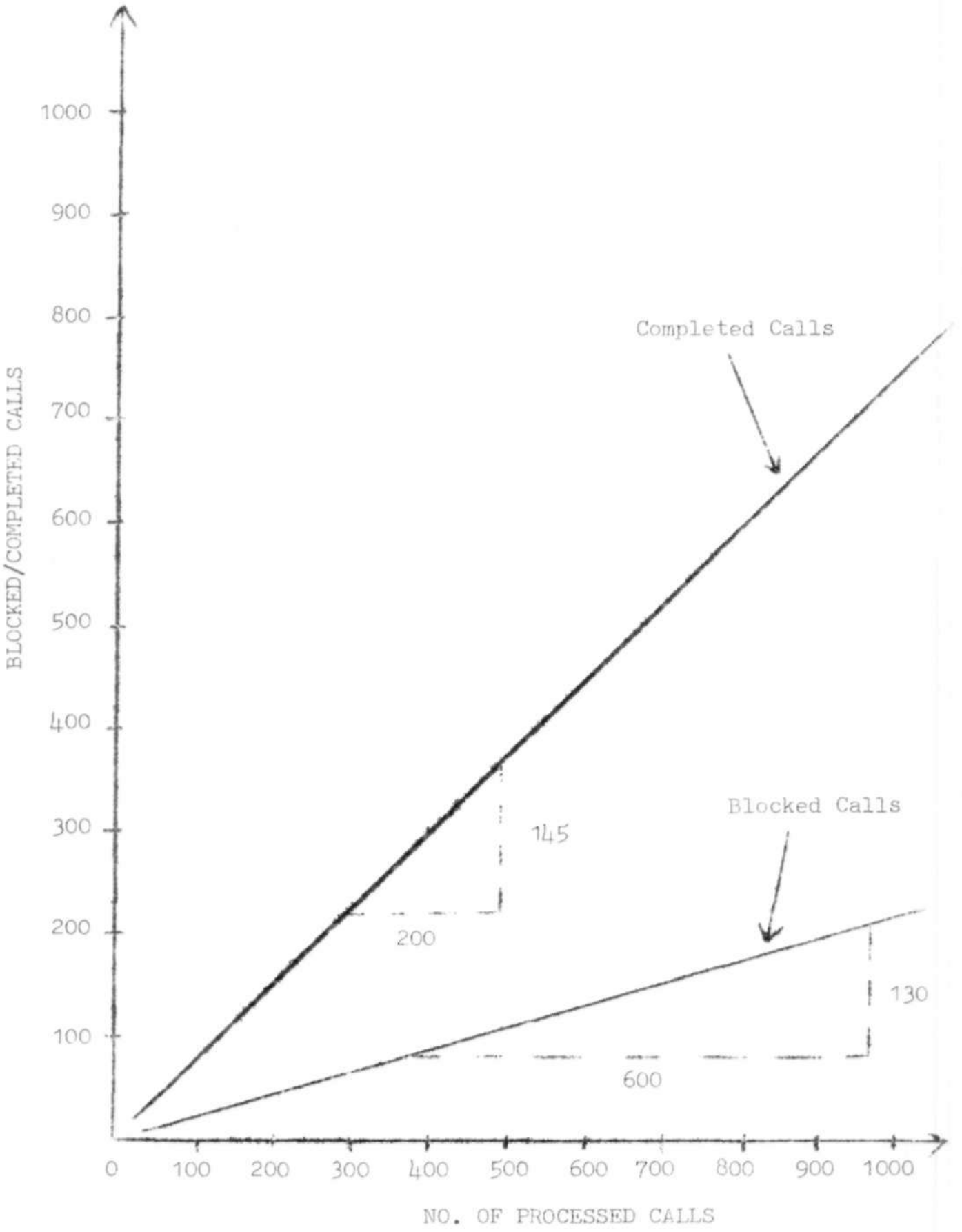


Fig. 3.1(g) Blocked/Completed Calls versus No. of Processed Calls
(No. of Links = 10)

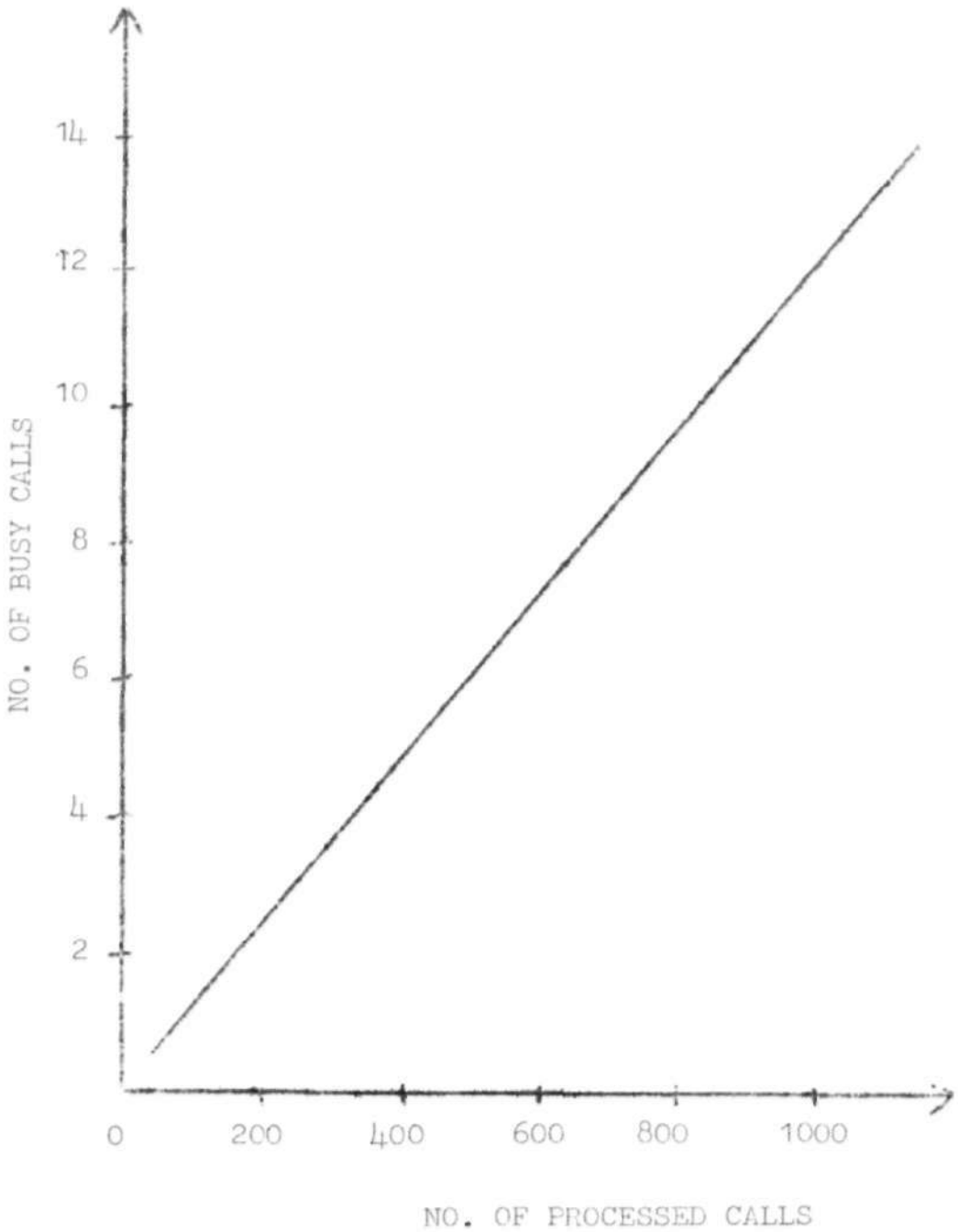


Fig. 3.1(h) No. of Busy Calls versus No. of Processed Calls
(No. of Links = 20)

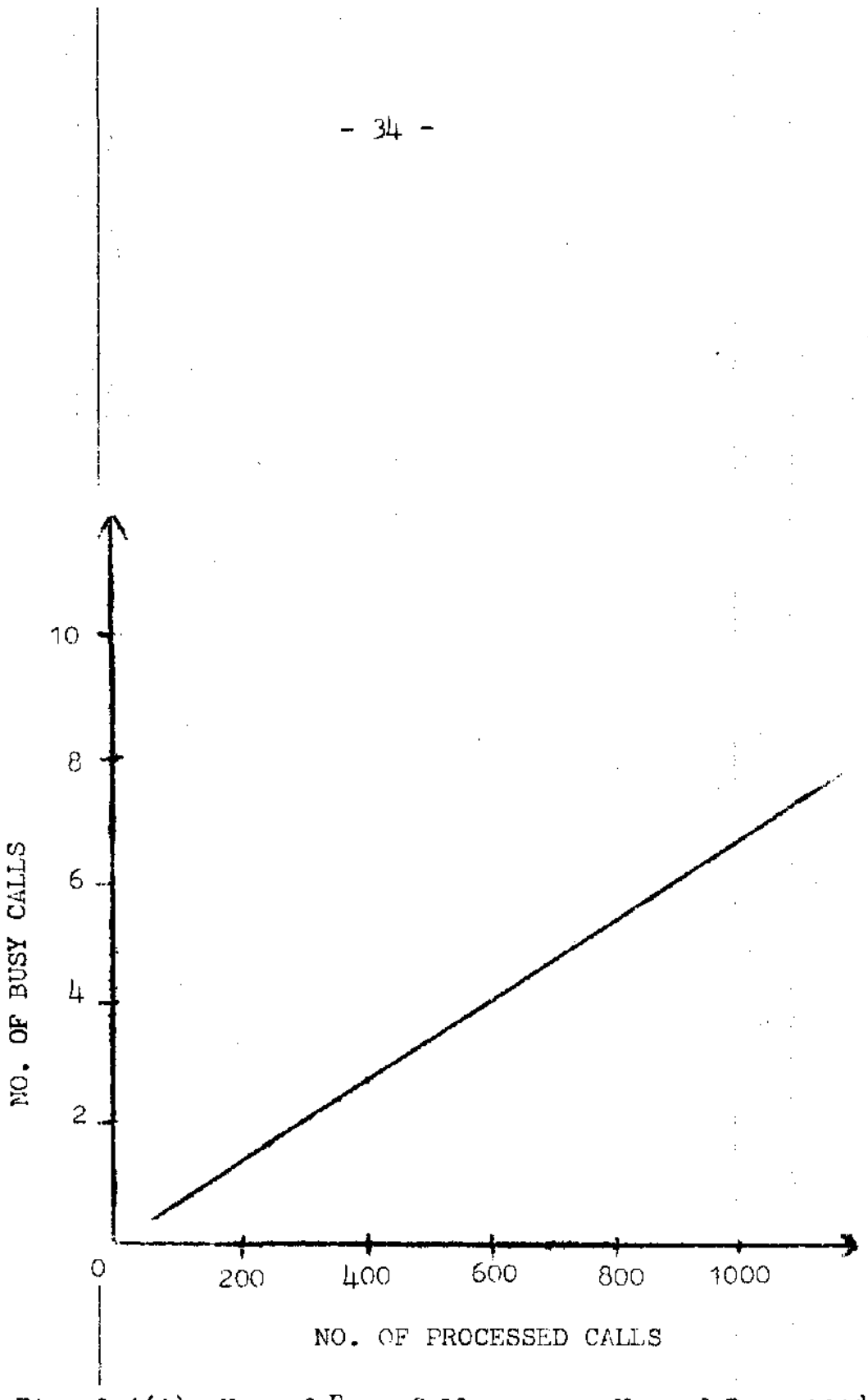


Fig. 3.1(i) No. of Busy Calls versus No. of Processed Calls
(No. of Links = 10)

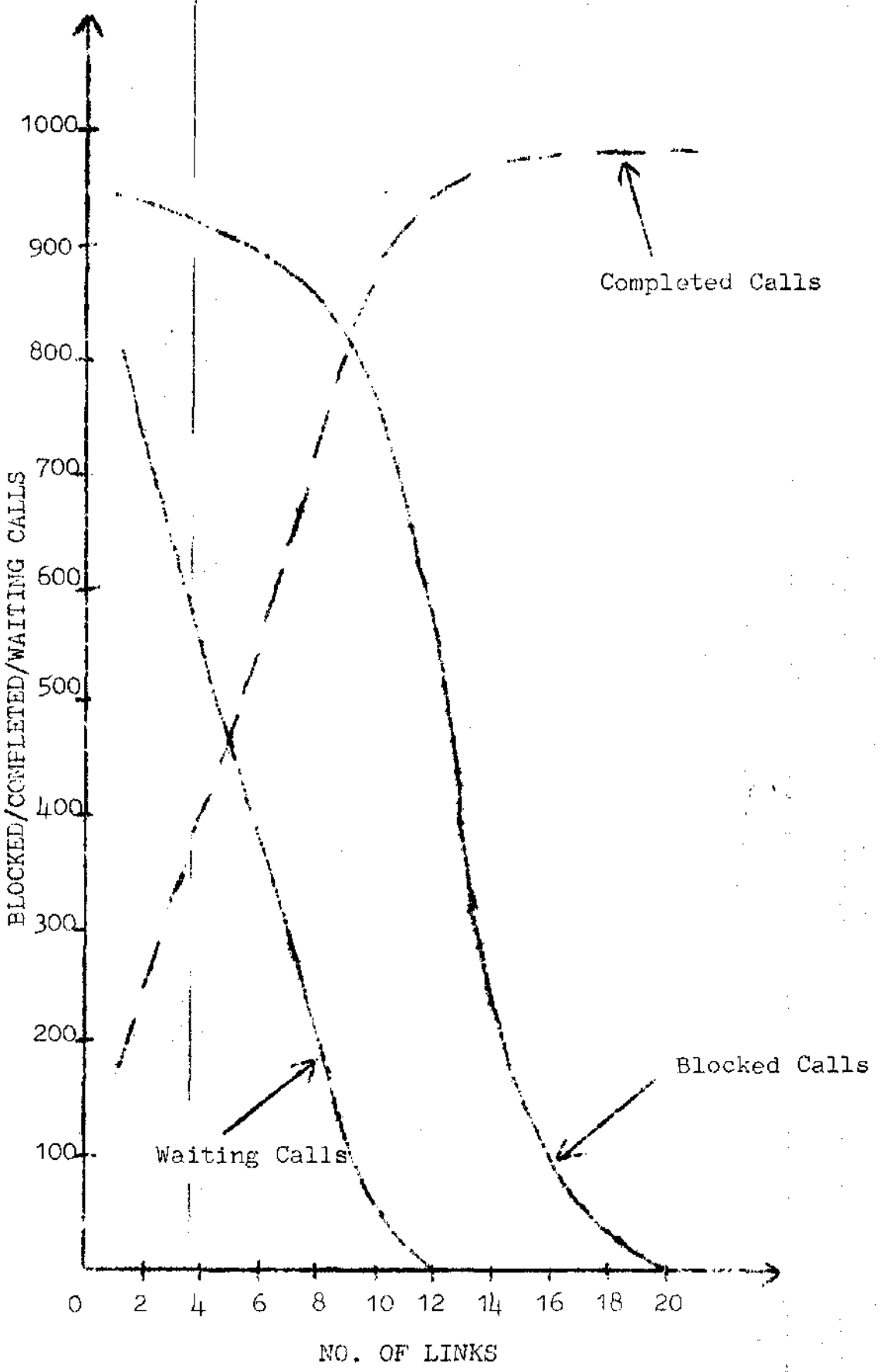


Fig. 3.1(j) Blocked/Completed/Waiting Calls versus No. of Links

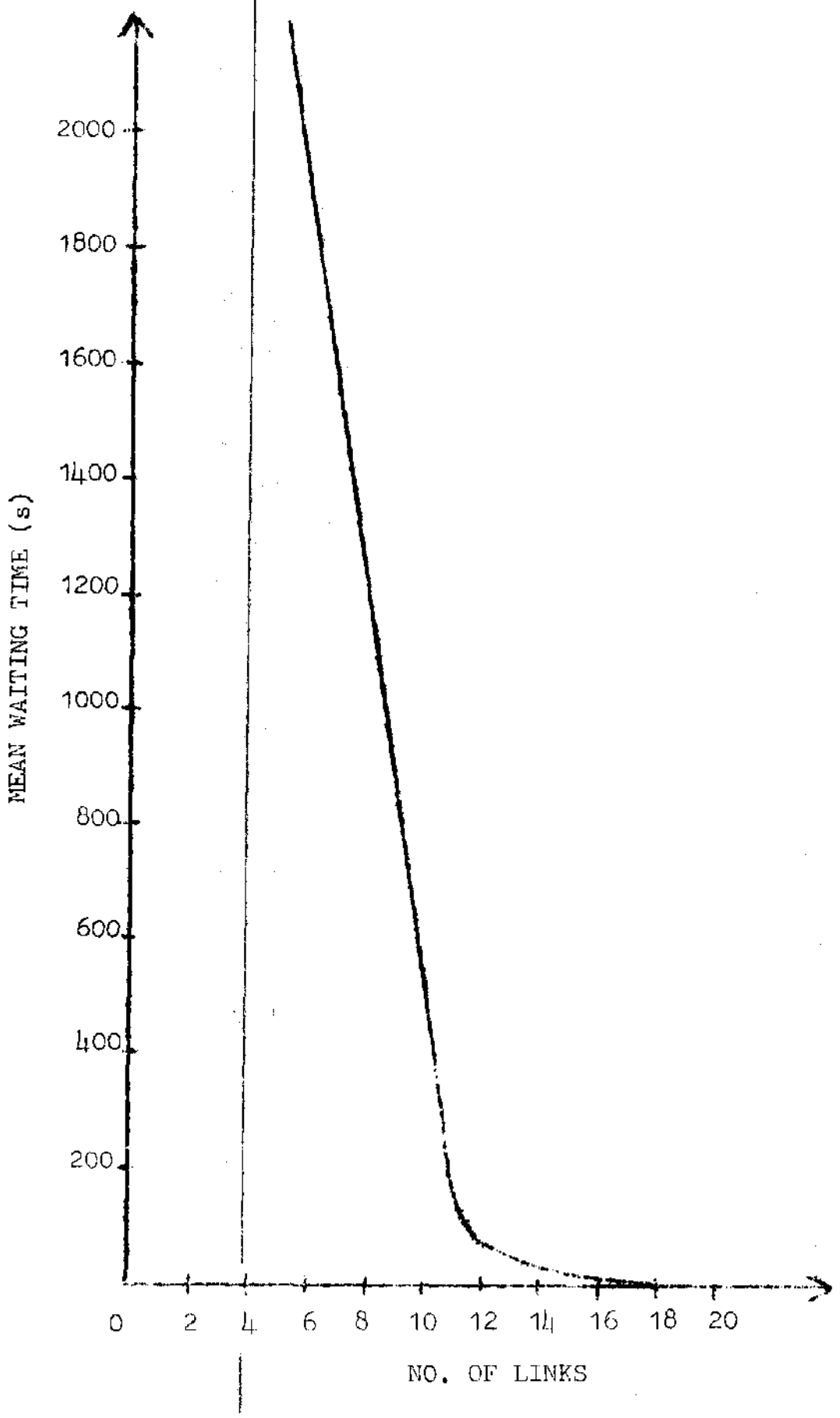


Fig.3.1(k) Mean Waiting Time versus No. of Links

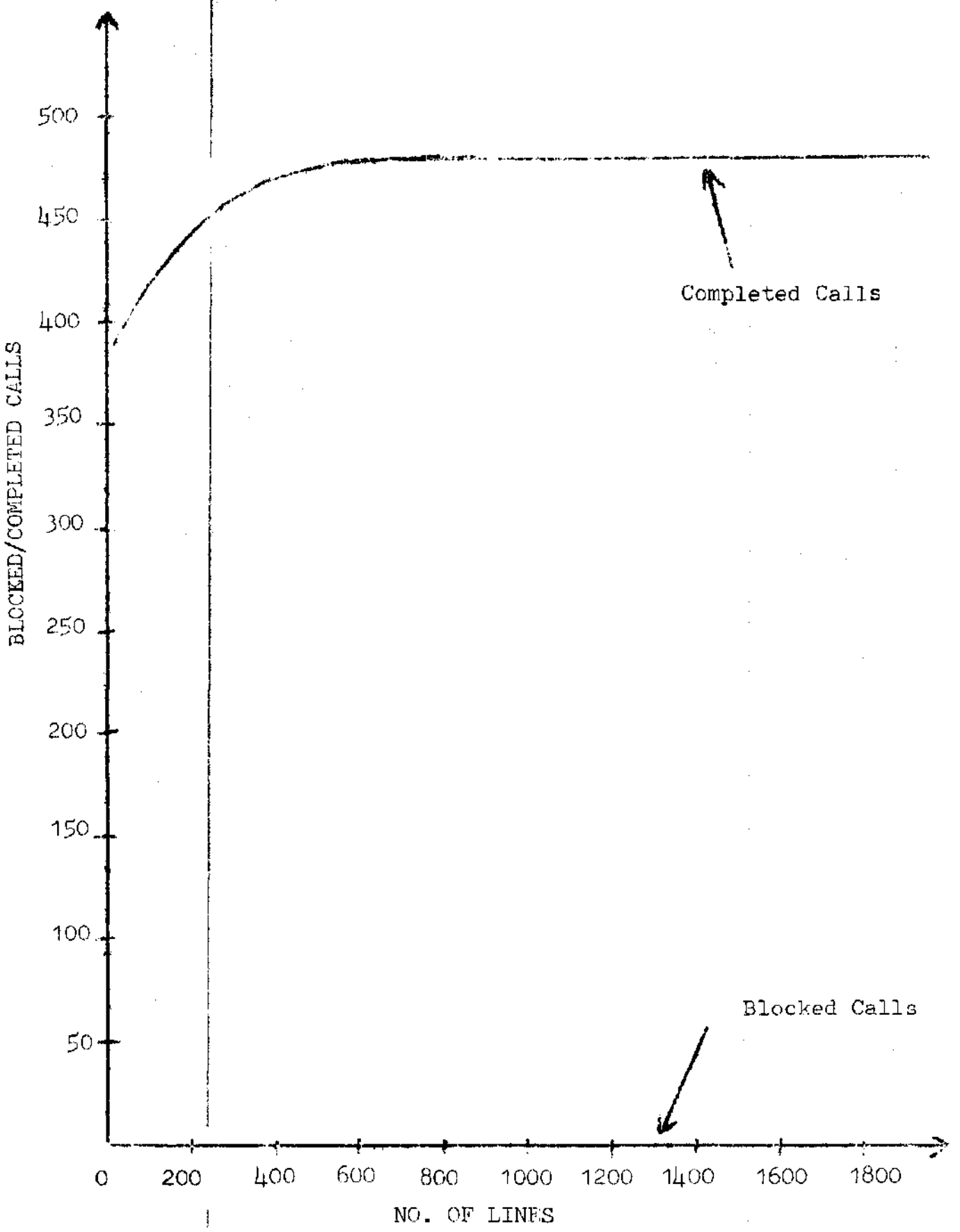
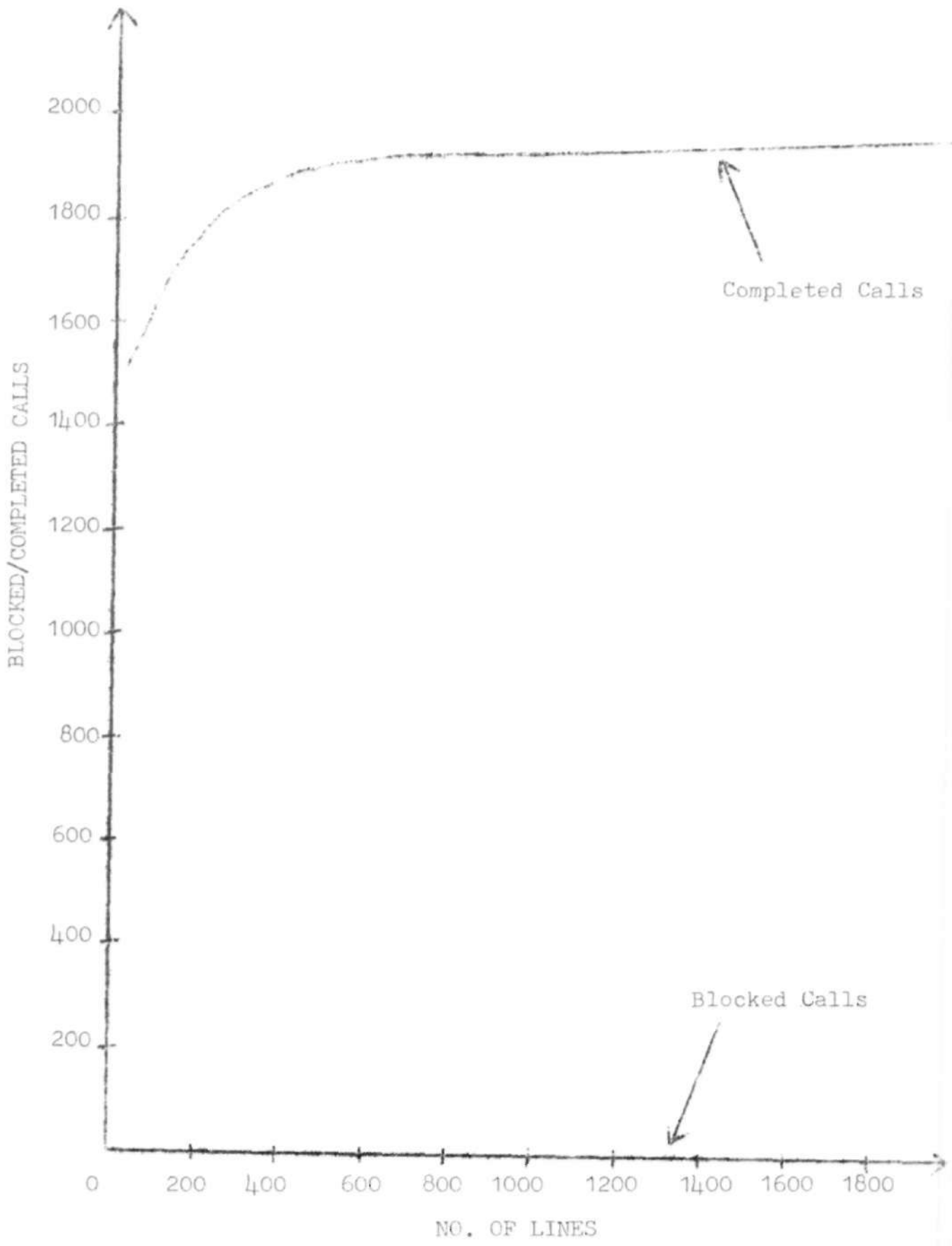


Fig. 3.1(1) Blocked/Completed Calls versus No. of Lines
(No. of Processed Calls = 500)



Fi.g 3.1(m) Blocked/Completed Calls versus No. of Lines
(No. of Processed Calls = 2000)

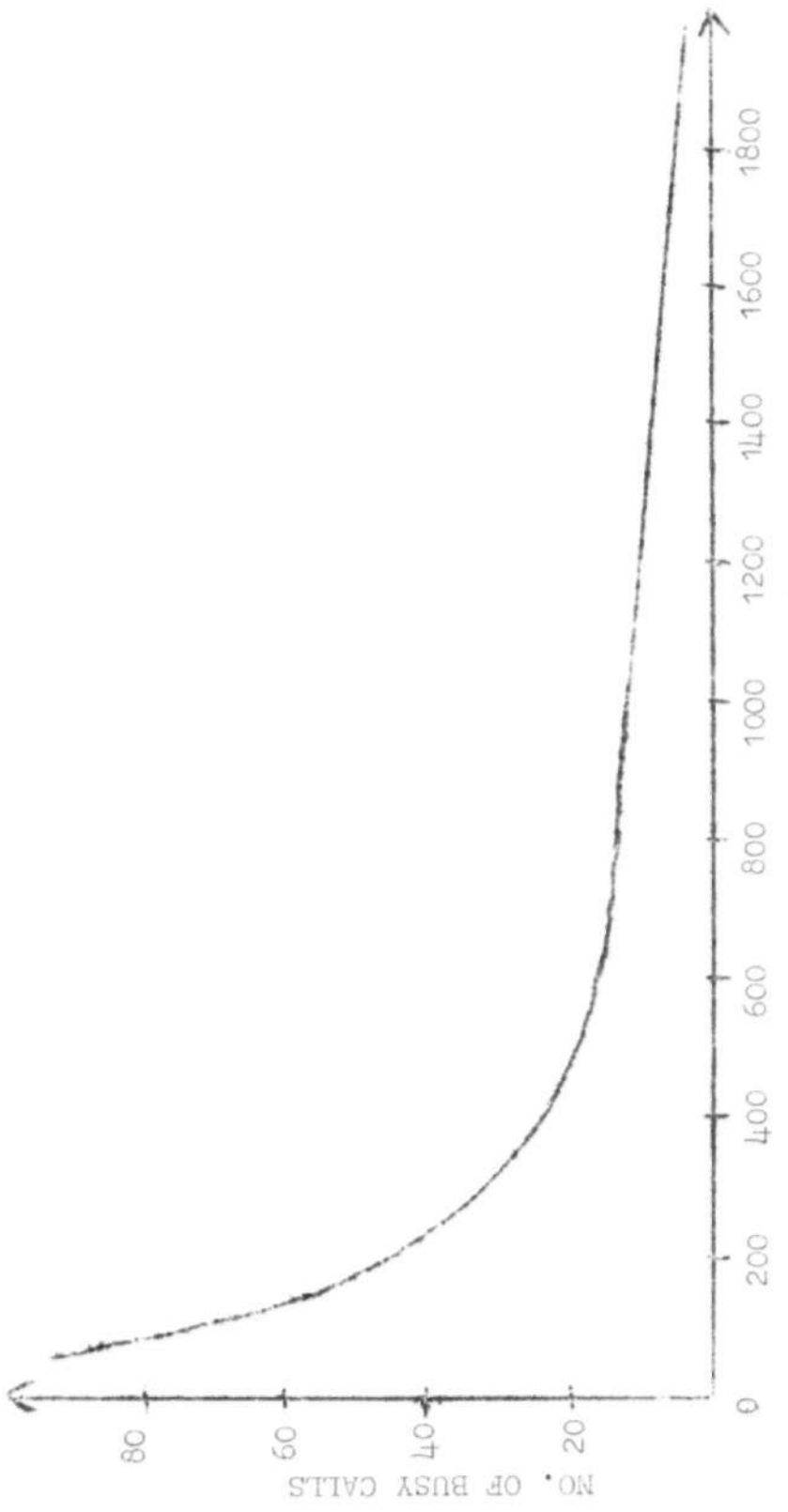


Fig. 3.1(n) No. of Busy Calls versus No. of Lines
(No. of Processed Calls = 50

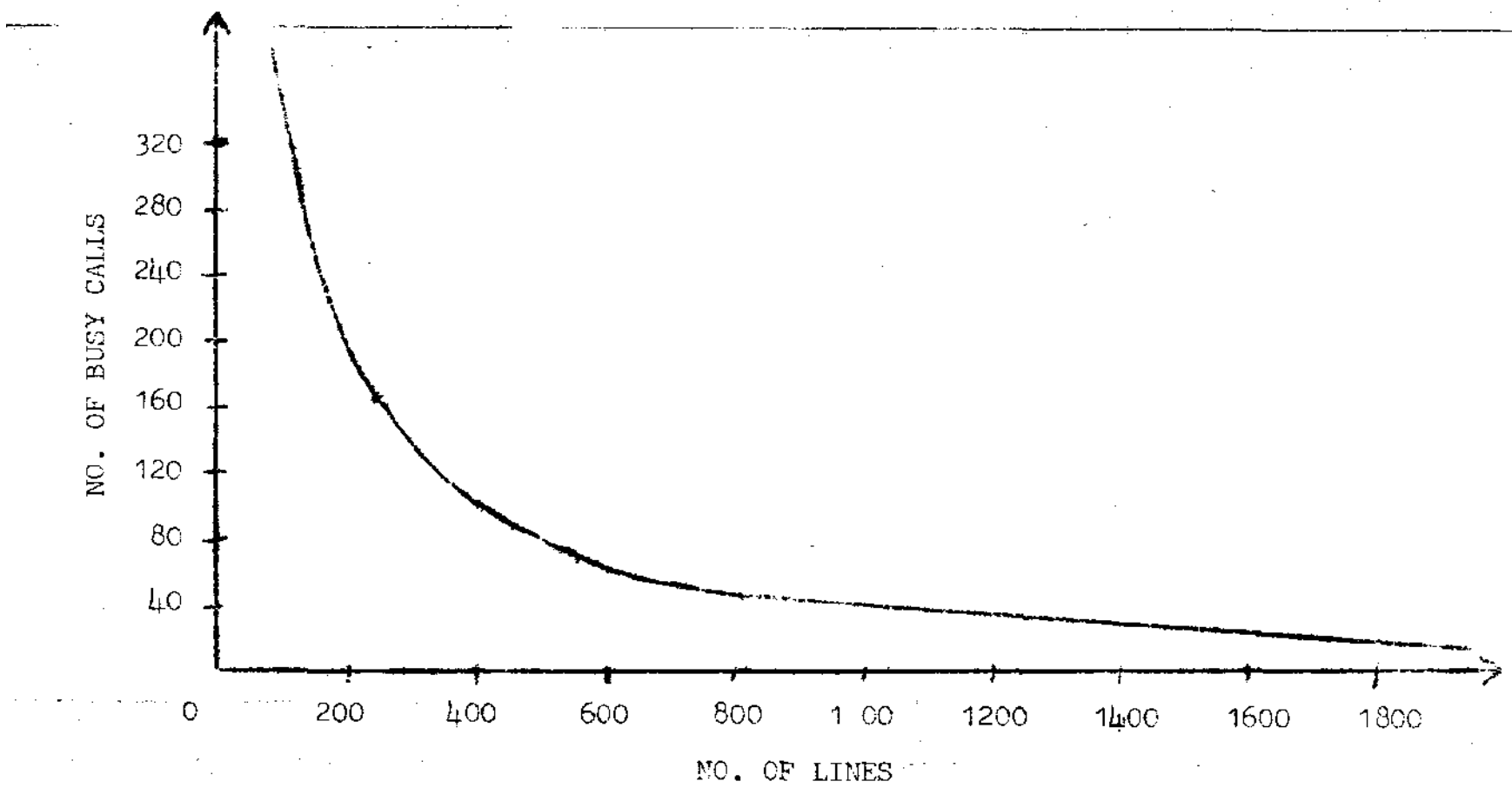


Fig. 3.1(p) No. of Busy Calls versus No. of Lines
(No. of Processed Calls = 2000)

CHAPTER FOUR

THE STEP-BY-STEP (STROWGER) EXCHANGE

4.1 INTRODUCTION

What is now generally known as the 'step-by-step exchange' was developed from a two-motion switch invented in 1891 by a funeral undertaker in Kansas City, United States of America, named Almond Stowger.(3)

The Strowger switch has a cylinder-shaped contact field comprising ten arcs of ten contact sets each, the arcs being mounted in parallel to form what are called levels. The fixed contacts considered as a unit of one switch are termed a bank of contacts. The bank contacts of many switches are multipled and connected to message circuits to which the wipers of each switch thus have access. The moving contacts are known as brushes or wipers. A set of wiper contacts is mounted on a shaft co-axial with the contact arcs and driven first axially to raise the wipers level by level to reach a selected one of the levels, and then rotationally, contact set by contact set to rest finally on a selected one of the sets.

Step-by-step axial and rotational movement is produced by individual ratchet motors pulsed with current once for each step.

The program used for the simulation of the step-by-step exchange is described in this chapter. The old Zaria step-by-step exchange, which is no longer in use, is used as

a model. The program is designed to simulate, as closely as possible, the conditions existing in the exchange as at the time it went into disuse.

The description of the simulation program is preceded by a brief description of the mode of operation of a step-by-step exchange.

4.2 FUNCTIONAL DESCRIPTION

The step-by-step exchange is made up of a number of strowger switches connected in stages. Each exchange line, the subscriber line, is terminated on a pre-selector switch known as the uniselector. Each uniselector has only one row of fixed contacts arranged in an arc. These contacts are connected to selectors forming the next stage. The fixed contacts of all uniselectors are commoned together so that all subscribers have access to each of the available selectors in the next stage. Each uniselector switch has from ten to about twenty-five contact sets depending on design and need. Usually, one bank position is sacrificed to a home position to which the wipers are returned after use so that operation starts from the same point.

The next stage of selectors is usually made up of ten two-motion switches. The wipers of each of these selectors are connected to one contact set of the preceeding stage. These selectors are usually referred to as GROUP SELECTORS. These group selectors may be followed by another set of group selectors or FINAL SELECTORS depending on the number of stages in the exchange. When there is more than one stage of group

selection; the switches in each stage are designated 1st Group Selectors, 2nd Group Selectors, and so on. In the group selector, the switch is stepped axially on the receipt of a pulse, the number of steps made corresponding to the number of pulses received. When the axial movement is completed, the shaft automatically rotates, making the wipers rotate over the bank of contacts of the selected level to choose a free selector in the next stage. This automatic rotary movement is sometimes referred to as non-numerical selection to distinguish it from the process of numerical selection which is controlled by the dial.(8) Rotary movement of the group selector takes place between consecutive digits from the calling subscriber's dial. The rotary movement of a final selector is controlled by the calling subscriber.

4.3 GENERALIZED OPERATION

4.3.1 Making A Call: Digit Selection - Pulse Transmission With A Dial

When the calling subscriber lifts his handset, the cradle switch closes a d.c. circuit from the local exchange across the subscriber line to the telephone instrument. A line loop is said to be closed. A dial tone is sent to the subscriber's telephone to indicate that the digit receiver is prepared to receive the digits. The subscriber can now start dialling.

There are two ways in which the digit information can be transmitted to the local exchange. In the first type, the telephone set is provided with a key set which generates voice frequencies. Each key gives a combination of two frequencies

which are recognised by the exchange. This is sometimes referred to as MULTIFREQUENCY (MF) dialling. In the second type, usually referred to as ROTARY dialling, a number of short interruptions in the line loop are generated by the dial of the telephone set. This is the type currently in use in Nigeria, and is the one considered in this thesis. When a digit is dialled, a number of pulses forming a pulse train are generated as shown in Fig. 4.1.(3)

The decimal digit signals are generated by a mechanical dial mechanism wound up an amount , according to the digit to be sent, by a finger inserted into one of ten holes in a dial plate rotated to a stop and let go. The dial restores under the control of a spring and governor to operate contacts in the loop and which break the loop a number of times equal to the value of the digit to be sent, ten breaks being used for the digit zero. The uniformly rotating spindle of the dial plate carries cams which operate the dial contacts in the loop.

Thus, the sending comprises loop breaks which are pulses of time durations and frequency dependent on the accuracy of the dial governor. The nominal frequency is ten pulses per second and the durations of the breaks, sixty to seventy percent of the pulse period.(1)

At the receiving point, the only timing requirements are means to determine when the duration of a loop break exceeds some predetermined value and when the duration of a loop closure exceeds some value which does not have to be the same

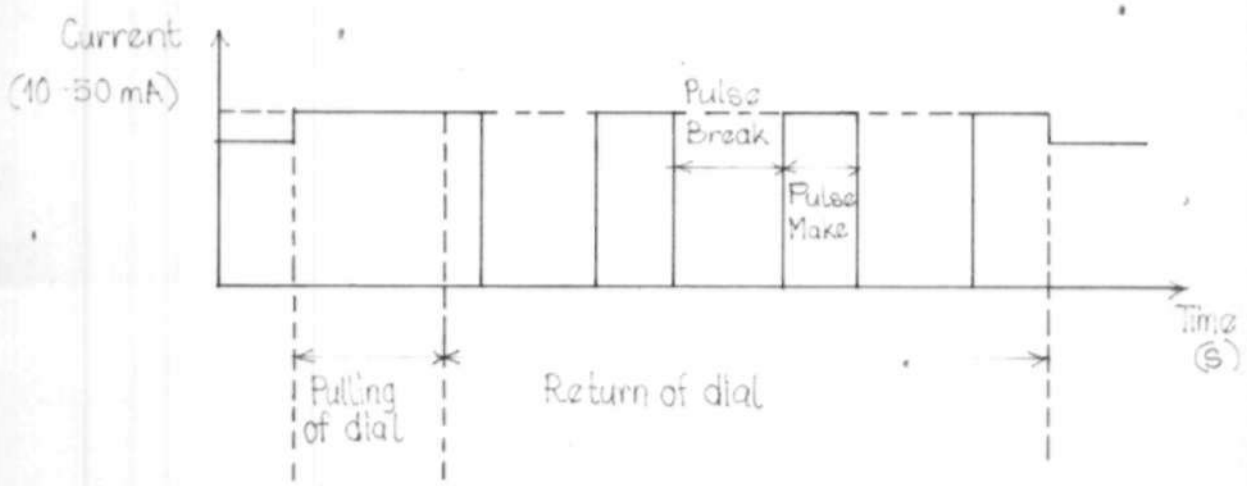


Fig. 4.1. Pulse Coded Digit Sending

as that of a loop break. Following the detection of a loop signal to initiate a new call, loop breaks are counted and timed. When the duration of a break exceeds a predetermined value, the call has been cleared. The make signals following breaks are also timed: One which exceeds some other predetermined time signifies the completion of a digit up to that point. Any further breaks belong to the next digit or are the clear signal.

4.3.2. Path-Search and Connection

The designation, "step-by-step", refers to every dial pulse causing the wipers of a selector to take one step, being one level or contact in a level, towards the final destination of a call being set up. (1)

When the calling subscriber lifts his handset, the cradle switch closes and completes a d.c. loop to the exchange. This loop is used to prepare the exchange for the receipt of pulses from the dial. The completion of the loop operates a line relay and the uniselector automatically rotates and hunts for a free outlet in the 1st Group. If and when a free outlet is found, a dial tone is sent across the line to the caller. This is a proceed-to-send-address data message.(1) If there is no free outlet, an engaged tone is sent to the caller.

On receipt of a dial tone, the caller proceeds to dial the required called subscriber address. As each digit is dialled, a pulse-train corresponding to the digit is generated as already described in the preceeding subsection. If, for

example, the digit "5" is dialled, during the return of the dial from the finger stop, a train of 5 break pulses is transmitted to the 1st Group selector of the exchange. The first pulse received is used to cut off the dial tone. The wiper assembly of the group selector moves axially to the level corresponding to the number of pulses in the pulse-train received. In the given example, the wipers will move to the 5th level. On getting to the appropriate level, the wipers then hunt automatically in a rotary manner, during the inter-digital pause to find a free path to the next set of selectors which may be group selectors or final selectors. If they fail to find a free path, that is, if they fail to find a free selector, an engaged tone is sent to the calling subscriber. If the level to which the wipers of the group selector moved is not in use and leads to nowhere, the dialling must be in error and circuits sending number unobtainable, n.u., tone back to the caller will be found on the contacts.

The next digit dialled operates one of the selectors of the 2nd Group, if there is one, in the same way as described above. The last two digits in a directory number are used to operate the final selectors. In the final selector, the rotary motion is control ed by the last digit dialled. The final selector completes the connection to the called subscriber. If the connection to the called subscriber can be made, a ring signal is sent to the telephone set of the subscriber, which starts the bell ringing. Simultaneously, a ringing tone is sent to the calling subscriber. If the connection cannot be made because the called line is busy or faulty, then a

busy or not obtainable tone, as appriopriate, is sent back to the caller.

To make the operation described above clearer, a 10,000 - line exchange is now considered. (See Fig. 4.2).(8) When the calling subscriber lifts his receiver, the uniselector automatically rotates to seize a free 1st Group selector in the common group. The 1st digit dialled steps the group selector to the required level and during the inter-digit pause, the 1st Group selector automatically hunts over the chosen level to seize a free 2nd Group selector. The 2nd Group selector responds to the second digit and at the end of the second impulse train, hunts over the level to find a free Final Selector. The 3rd digit from the caller's dial steps the final selector axially while the 4th and last digit directs the rotary motion of the final selector to route the call to the required line.

When a connection is established, a transmission bridge is provided to both parties for the energization of their respective transmitters. After dialling, and during the conversational time, the loop from the calling subscriber's telephone is utilized to provide a holding condition for the call until the callerreplaces his receiver. At the end of the conversation, the replacement of the caller's handset reopens the calling loop at the cradle switch contacts and the disconnection of the loop is utilized as a clearing signal to release the train of automatic switches in the exchange.

The old Zaria four-digit step-by-step exchange while in use, operated exactly like the 10,000-line exchange described above.

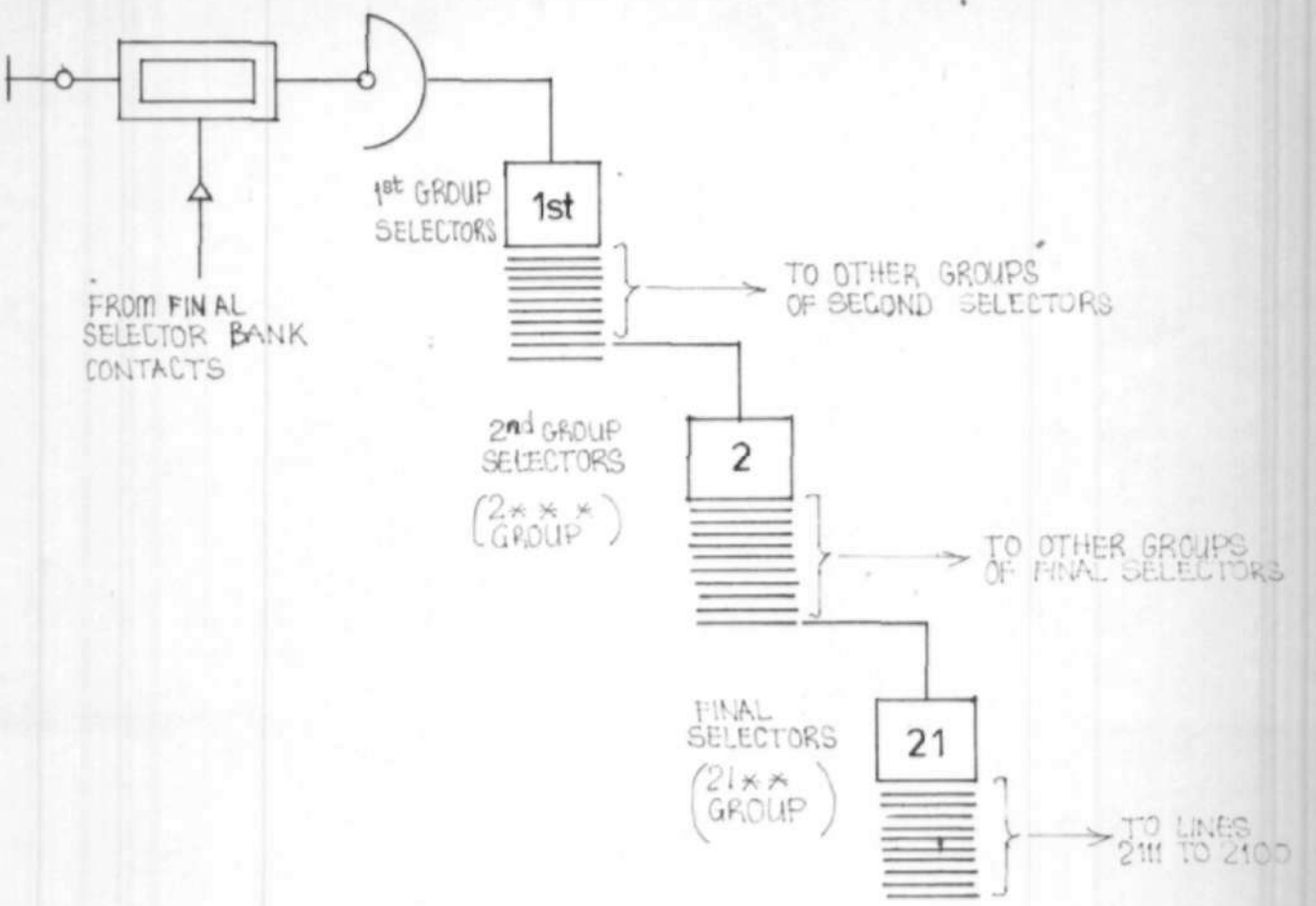


Fig 4.2. Elementary Trunking Diagram for a 4-digit Exchange with Subscribers' Uniselectors.

4.4 NUMBERING SCHEME RESTRICTIONS

Theoretically, a 2-digit numbering scheme should provide accommodation for 100 subscriber lines, a 3-digit scheme for 1000 lines and a 4-digit scheme for 10,000 lines. In practice, however, this theoretical multiple capacity is not obtained owing to the reservation of certain selector levels.

Experience has shown that it is inadvisable to use level 1 of first selectors on account of the danger of mis-routing resulting from false initial pulses.(8) In all automatic systems, a false pulse is liable to be transmitted by a subscriber fumbling the cradle switch when removing the receiver. If level 1 were included in the numbering scheme, and a subscriber proceed to dial a number after inadvertently transmitting a false pulse, a wrong number would be obtained. Moreover, tapping earth or short-circuit faults on subscribers' lines tend to step the first selector to level 1 and the use of this level would therefore incur the risk of false calls during storm conditions. For these reasons, it is the normal practice to treat level 1 of the first selector in a switching train as a spare level with its contacts connected to n.u. tone.

Level 0 is usually allocated for obtaining access to the operator, while level 9 is connected to a special group of second selectors to provide access to various miscellaneous services such as inquiries, speaking clock, police, fire-station and so on. In addition to the reservation of levels 1, 9 and 0, the numbering scheme of any particular exchange may be further restricted by the use of selector levels for outgoing junction

routes. As a result of these restrictions, the maximum capacity of a 4-digit exchange is 7,000 lines and the capacity is correspondingly smaller if there are outgoing junction routes from selector levels.(8)

The old Zaria exchange had a nominal capaity of 2,000 lines. However, only 1,700 lines were made available as subscribers' lines.

4.5 BRIEF DESCRIPTION OF THE SIMULATION PROGRAM

In so far as the general organizational structure is concerned, the simulation program for the step-by-step exchange is very similar to that for the manual exchange already described. However, differences occur in the execution routines as the automatic nature of the step-by-step exchange and its mode of operation have to be taken into account. The flow chart showing how the program is organized is shown in Fig.C.2(a)of Appendix C . The exchange is a lost call system, and is code-named SIMTEX 1 .

As in the case of the manual exchange, when the program is started, the model is utilized for the particular run to be made. The input information this time includes the number of lines, the mean inter-arrival time, the mean call length and the maximum number of processed calls making a run. The uniselectors and various group selectors are then set to their appropriate values. An initialization routine then sets various numbers to their correct initial values. The first arrival time is generated and the program enters the main routine concerned with executing each cycle of events. As in the simulation program for the manual exchange, this initial entry point is

also the point from which to recycle when all changes have been executed for one event.

Suppose the next call finishes at T_F and the next arrival is at T_A. The program first decides whether the next activity is to disconnect a call or to attempt to connect a call. The test of the condition $T_F \leq T_A$ makes this choice. With the test defined this way, a coincidence of a disconnect and a new arrival results in the disconnect being serviced first. Whichever activity is decided upon, the program updates the clock. When two events are coincidental, the program executes them successively and the clock remains unchanged until all events at that time have been executed. In the case of disconnecting a call, the activity is unconditional and the program immediately carries out the necessary action. Since a call has just finished, the time the next call finishes, T_F, is updated. The program collects statistics and returns for another cycle. In the case of a new call arriving, the call is generated and the program checks to see whether enough calls have been processed to finish the simulation run. If not, the attributes of the call are created at that time and the next arrival time is generated. Tests are then made to see if the call will be connected or lost either because one or more of the required groups of selectors is full or the called line is busy. When a call is connected, the program adjusts the records by entering the new call in the list of calls in progress. When a call is lost, the appropriate statistics are gathered. The program has been designed to show at what point exactly along the connection path it has been blocked, that is, whether at the

1st Group, 2nd Group or Final selectors. The program then resumes for one more cycle.

When enough calls have been processed to finish the simulation run, the simulation stops, the results are printed, and the program terminates.

As in the case of the simulation program for the manual exchange, the simulation program for the step-by-step exchange can be divided into major sections, each section carrying out a particular operation, viz:-

1. Program Initialization
2. Finding the Next Potential Event
3. Connecting a Call
4. Disconnecting a Call
5. Gathering Statistics
6. Computing Final Statistics and Printing out Results.

The flow charts showing how these sections implement their various functions are contained in Appendix C .

4.6 SIMULATION RESULTS AND ANALYSIS

Table 4.1 shows the selector-distribution in the exchange, while Table 4.2 contains the simulation results for the exchange.

Table 4.1: Selector Distribution in the Step-by-Step Exchange

SELECTORS	NUMBER
1st Group Selectors	181
2nd Group Selectors (Level 2)	119
2nd Group Selectors (Level 3)	79
FINAL SELECTORS:	
GROUP	NUMBER
21	13
22	19
23	19
24	13
25	19
26	13
27	13
28	19
29	0
20	75
31	13
32	19
33	13
34	13
35	13
36	13
37	13
38	0
39	0
30	13

Table 4.2: Simulation Results for the Step-by-Step Exchange

No. of Lines	1700
Mean Call Interval	12 seconds
Mean Call Length	120 seconds
Call Time	11325
Duration of Run	3 hours
No. of Calls	1000
Calls Completed	984
Busy Calls	5
Blocked Calls at 1st Group Selectors	0
Blocked Calls at 2nd Group Selectors	0
Blocked Calls at Final Selectors	0
Total Number of Blocked Calls	0
Number of Active Calls	11

It will be observed from Table 4.2 that there is no blocked call recorded for this exchange. The graphs of Fig. 4.3(a - d) show the behaviour of the system as certain parameters are varied while others are kept constant. The very close similarities between these graphs and the corresponding ones obtained for the manual exchange are striking. (See Fig. 3.1 (b - i)).

There is only one step-by-step exchange in use in the telephone network under consideration; most of the exchanges being of the crossbar type. In fact, a crossbar exchange intended to replace the step-by-step exchange has been approved for Kano. For this reason, a much more comprehensive study and analysis of an exchange equipment has been reserved for the crossbar exchange and is contained in the next chapter. Nevertheless, a comparison between the performance of the real step-by-step exchange along with its associated external plant and what its performance should be in the light of the simulation results is expedient and is made in the following discussion. An attempt is also made to account for any observed differences. The objective is to identify the factors adversely affecting the performance of the system and make recommendations on how the performance of the system can be improved.

As was earlier observed from the simulation results for the step-by-step exchange (Table 4.2), there is no blocked call recorded for this exchange. This reflects a very good performance on the part of the exchange equipment. The exchange equipment can, therefore, be said to be well-equipped to carry the required traffic. Insufficient equipment cannot, therefore, be said to be a problem of the Zaria telephone system. The system, according to simulation results, should perform very well.

A fairly comprehensive survey of the Zaria telephone system has been carried out.(10) The results of the survey in so far as the faults encountered in the system are concerned are summarized in Table 4.3. The statistics cover a period of one month.

Table 4.3: Statistics of Faults in the Zaria Step-by-Step Telephone System

Type of Fault	No. of Times Fault Occurs
Subscriber Instrument (Dials, cords, etc.)	10
PMBX Extensions	10
Overhead Block Terminals (BTs) and Ready Access Terminals (RATs)	170
Aerial Cable-Joints	70
Underground Cable-Joints	24
Overhead Damage: P & T Working Party	5
Overhead Damage: Others	1
Right When Tested (RWT)	72
Fault Not Found (FNF)	1
Long Duration Faults	1,602
Others	1

4.6.1 Observations and Comments

1. The Table does not contain any exchange fault i.e. none of the faults can be attributed to the exchange itself. All the recorded faults are external to the switching equipment.

2. RWT faults are those which clear themselves before any action can be taken on them. Since such faults are necessarily of very short duration, they will not be

considered in this analysis as they do not contribute appreciably to the performance of the system.

3. The high figure (1,602) recorded as long duration faults are those which take days, weeks or even months to clear. Such faults include damaged cable, knocked-down pole, etc., the replacement for which is not immediately available, or for which some construction work has to be done before the fault can be rectified. Hence, the same long duration fault may be recorded each day as a new fault. The figure 1,602 is, therefore, roughly cumulative and does not indicate 1,602 SEPARATE long duration faults; it rather shows the total number of long duration faults encountered for the whole period under consideration. It is safe to assume that the number of separate long duration faults for the month (of 28 days) is the mean of 1,602 as calculated from

$$\text{Average no. of long duration faults} = \frac{1602}{28}$$

$$= 57$$

The figure, 57, represents the average number of uncleared faults for the month considered. In other words, at the end of the period, there were roughly 57 uncleared faults.

4. Faults due to damage to overhead cables will be assumed, for the purpose of this analysis, to have been included in the long duration faults, as such damages usually take quite some time to rectify.

5. Faults due to subscriber instruments and PMBX extensions will be grouped, in this analysis, into the same class of faults: Subscriber-line Related Faults, as they are all subscriber - line related. All cable - joint faults will also be grouped together as Cable Faults.

On the basis of the preceding observations and comments, Table 4.3 has been modified to give Table 4.4.

Table 4.4: Summary of the fault statistics of the Zaria Telephone System

TYPE OF FAULT	No. of Time Fault Occurs	Ratio of No. of Times Fault Occurs to Total No. of Times (%)
Subscriber-line-related faults	20	5.85
Overhead BTs and RATs	170	49.70
Cable Faults	94	27.49
Uncleared Faults	57	16.67
Others	1	0.29

As has been observed, the recorded faults are mainly
ernal ones. None of the recorded faults is that of the
tching equipment itself. This not to be taken to mean that
ault at all occurred in the exchange equipment itself
the period under consideration. Of course, exchange
nt faults must have occurred during the period. However,
lts were minor and did not need to be reported. They

were the short-duration faults such as burnt-fuses, stuck switches, etc. Such faults have negligible impact on the overall performance of the system. It can, therefore, be safely concluded that it was mainly external plant faults that were adversely contributory to the performance of the Zaria telephone system at the time the survey was done.

Table 4.4 shows that faults due to Block Terminal (BTs) and Ready Access Terminals (RATs) have a rather high frequency of occurrence, (or fault-rate). This should be a cause for concern. The occurrence of cable faults is also disturbingly high, accounting for almost 30% of all recorded faults. However, the most serious of all, and ones that should be of utmost concern, are the uncleared faults. Even though they constitute less than 17% of the recorded faults, their impact on th of the system under consideration must not equipmer They consist of long duration faults which, such fau er on, include damaged cables, knocked-down during ight take several days, weeks or even ne seriousness of the impact of such faults y appreciated if one considers the fact involve an upward of fifty subscriber-lines, consequently put out of service. Indeed, long on faults can be said to be the most important and ous of all the faults encountered in the system under eview. It can even be hazarded that the performance of the system is a direct function of the number and frequency of the long duration faults occurring therein.

It is perhaps worthy of note at this point that the performance of the Zaria telephone system is not significantly affected by public power supply failures. Apart from the standby electricity generating plant provided, a set of batteries capable of continuous power supply to the exchange for ten hours is also available. Incidentally, this set of batteries has hardly ever been on load for any appreciable length of time as the standby generator is invariably switched on whenever there is a failure in the public power supply, albeit with some delay on a few occasions.

It has been established in this analysis that the major factor affecting the performance of the Zaria telephone system is the high number of long duration faults occurring therein. This conclusion has been arrived at on the basis of the survey conducted on the system.(10) It is necessary to emphasize that this survey was carried out in 1980 and since that time things have changed in respect of the system. The analysis based on this survey has been made mainly to illustrate the types of problems encountered with a step-by-step exchange and how these problems affect the performance of the system. Thus, it is pertinent to point out that the high rate of cable faults recorded for the system (Table 4.4) was actually due to the fact that most of the cables and cable-joint units in use at the time the statistics were gathered (1980) were very old and in need of replacement. Replacement, where necessary, has since been completed. From the author's private interviews with the technicians and technologists at the Zaria exchange, it was gathered that the situation has

improved markedly, relative to what it was a couple of years ago.

To verify this, the author initiated a total of 150 telephone calls at different periods of the day. Of the 100 random calls initiated during the peak period of the day (9.00 - 11.00 am) 68 were successful, 6 were engaged while there was no reply from 26 of the called subscribers. 25 of the 'no-reply' lines were found to belong to residential subscribers. Furthermore, 50 lines belonging to residential subscribers were chosen at random and calls initiated to the various subscribers. This was done between 9.00 and 10.00 pm. 44 of these calls were successful while there was no reply from 6 subscribers. While the subscribers whom the author conversed with on the phone complained bitterly about their seemingly perpetual inability to make any call outside Zaria town, they were very satisfied and pleased with the performance of the system in so far as making local calls was concerned. The results of this test confirm that the Zaria telephone system can now rightly be said to perform satisfactorily.

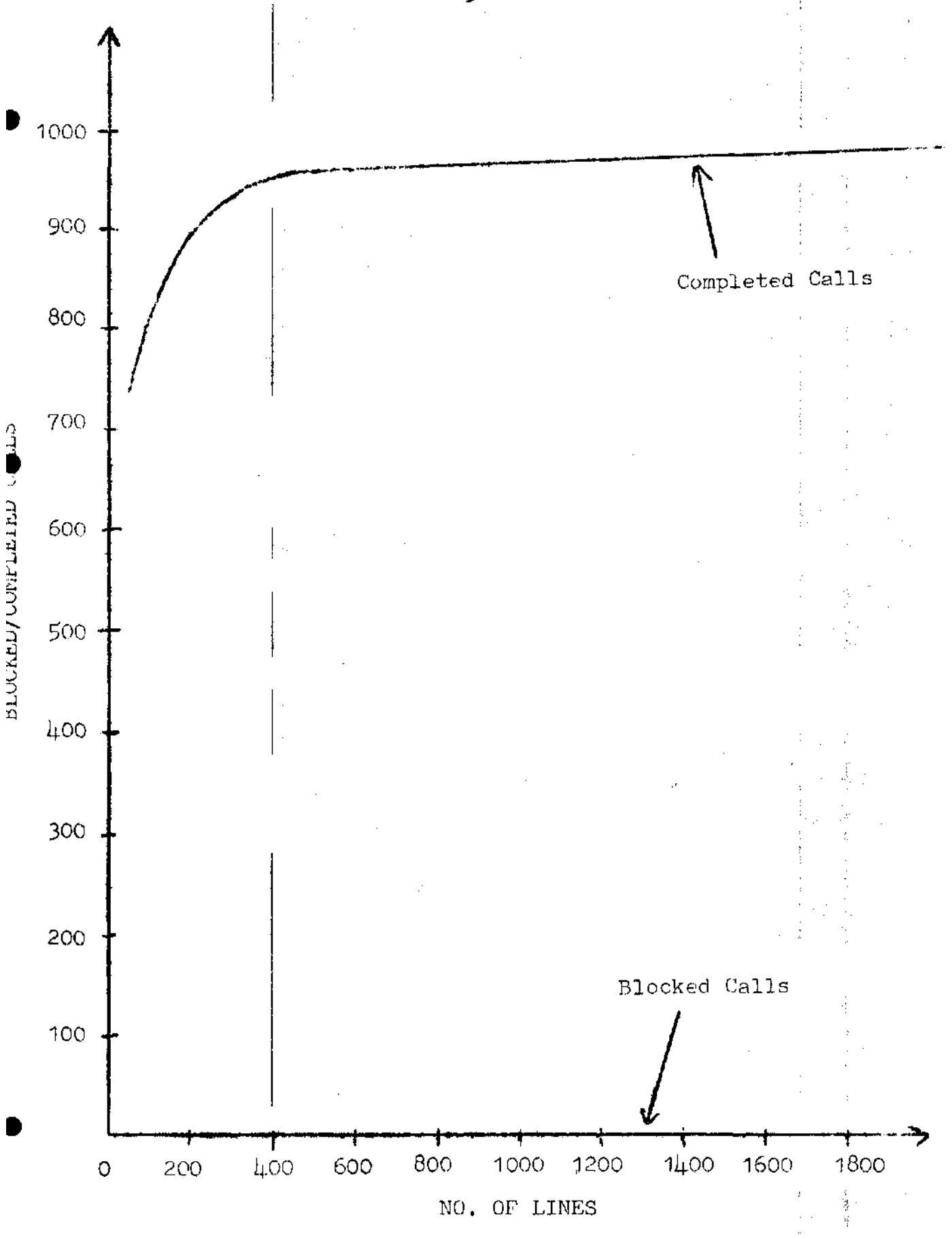


Fig. 4.3(a) Blocked/Completed Calls versus No. of Lines

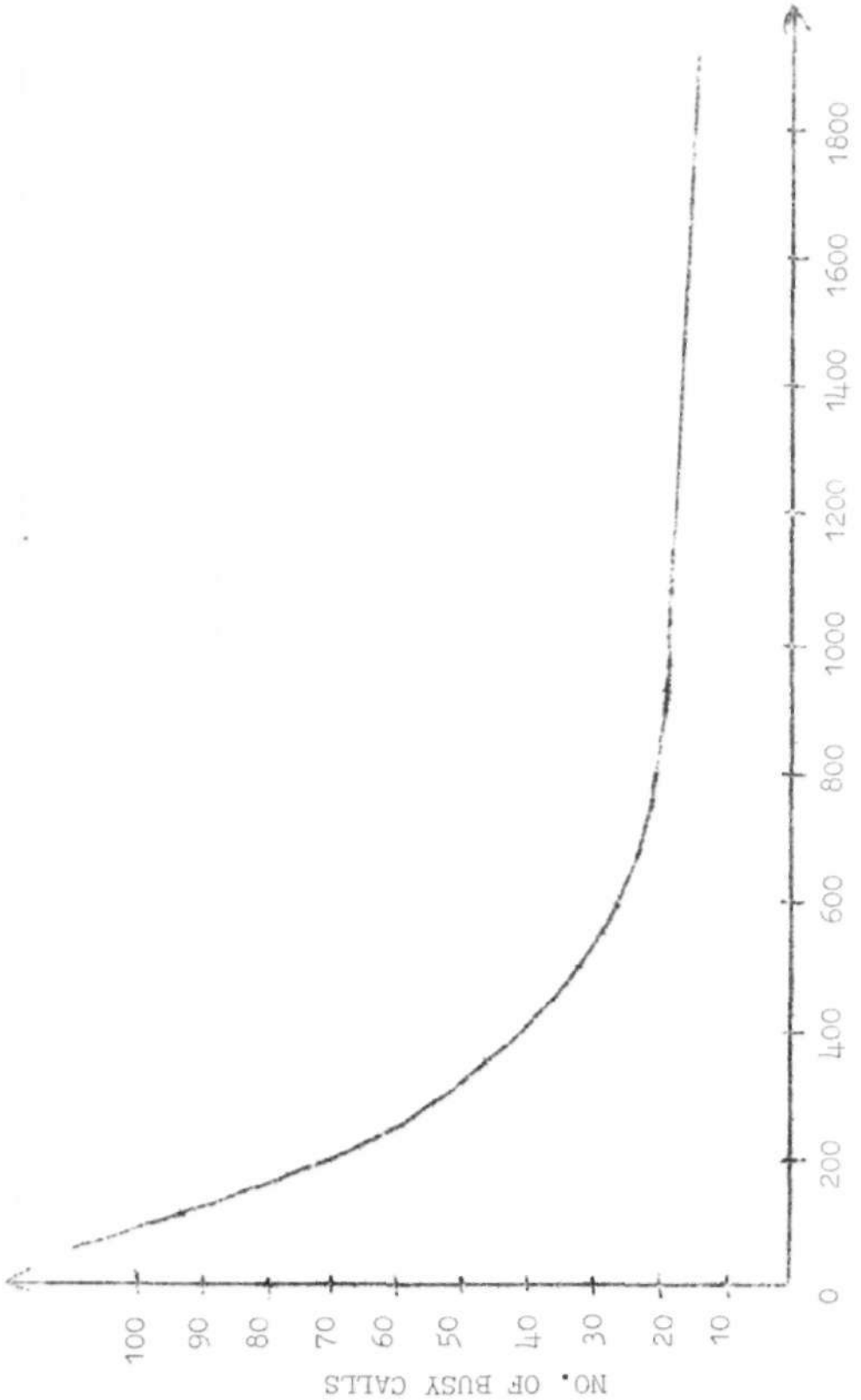


Fig. 4.3(b) No. of Busy Calls versus No. of Lines

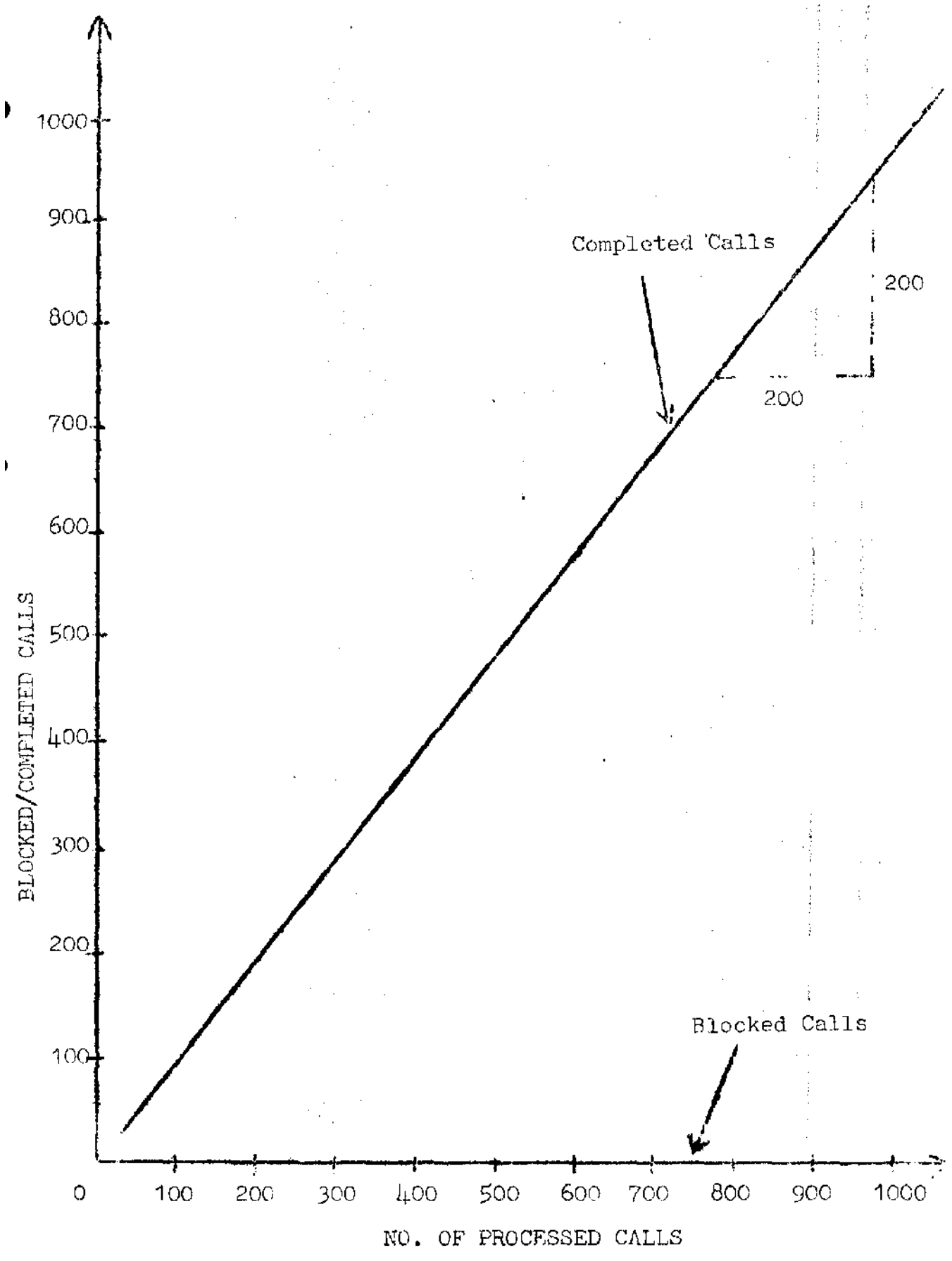


Fig. 4.3(c) Blocked/Completed Calls versus No. of Processed Calls

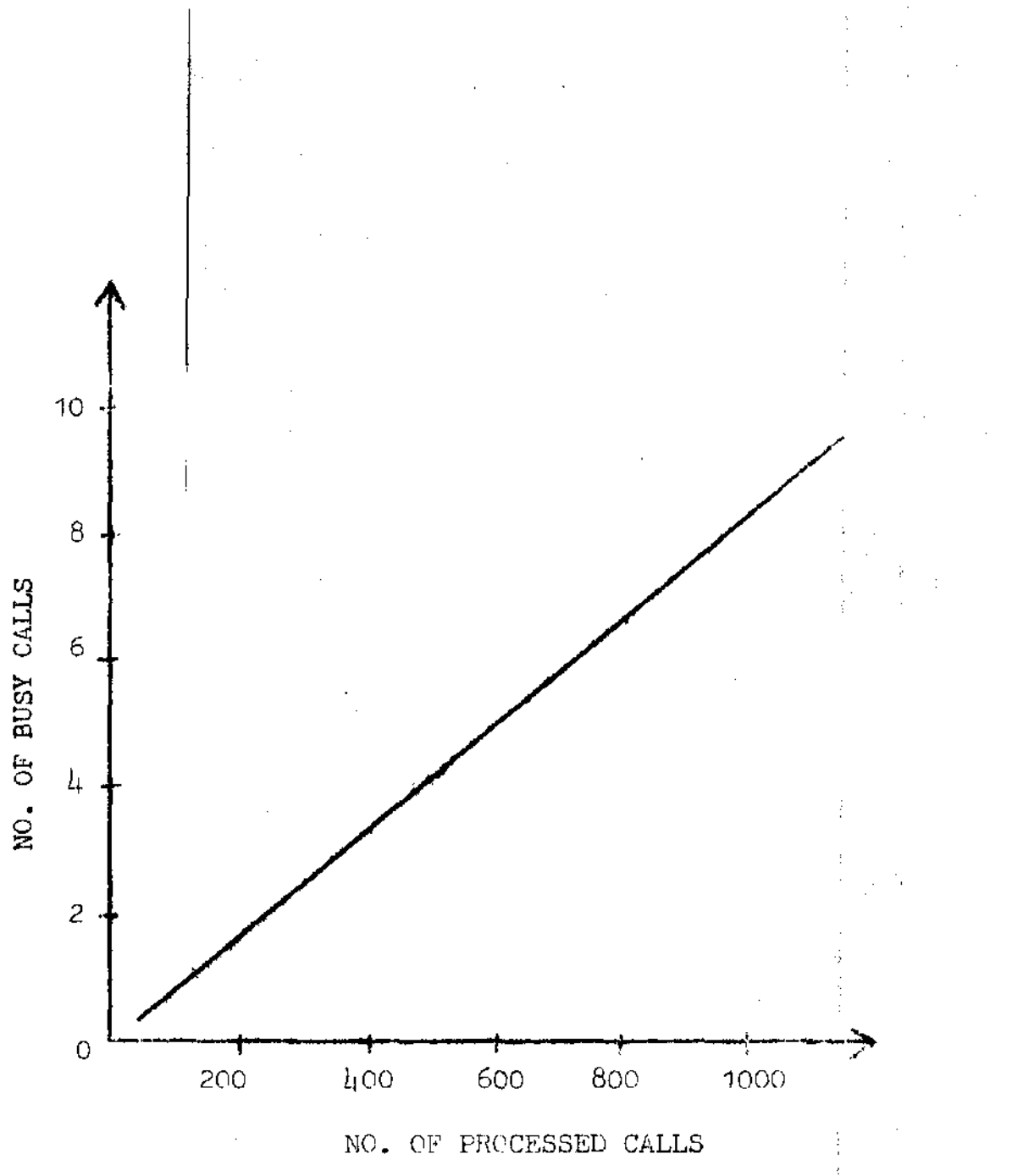


Fig. 4.3(d) No. of Busy Calls versus No. of Processed Calls

CHAPTER FIVE

THE CROSSBAR EXCHANGE

5.1 INTRODUCTION

The basic element in any crossbar system is the crossbar switch, which also gives the system its name. Talking connections through switching frames are made by crossbar switches.

Crossbar switches are co-ordinate relay contact switches with a select magnet, DM, per row and a bridge magnet, DM, per column of contacts as shown in Fig.5.1. (1) Any one set of contacts is closed by operating first the appropriate select magnet, which moves an armature to select a row of contact sets, and then the bridge magnet which has an armature common to all the sets in a column but closes the contacts of only those sets for which a select magnet has been operated prior to the movement of the bridge magnet. The bridge magnet having operated the select magnet or magnets may be released for the operation of other sets of contacts.

When a bridge magnet is not operated, all the contacts of its column of contacts are open and none is affected by the movement of any select magnet. When a bridge is operated, the contacts in the column which are closed and those which are open stay closed and open respectively no matter how the select magnet may subsequently move. Only the operation first of a select magnet and then of a bridge magnet is able to change the conditions of contacts

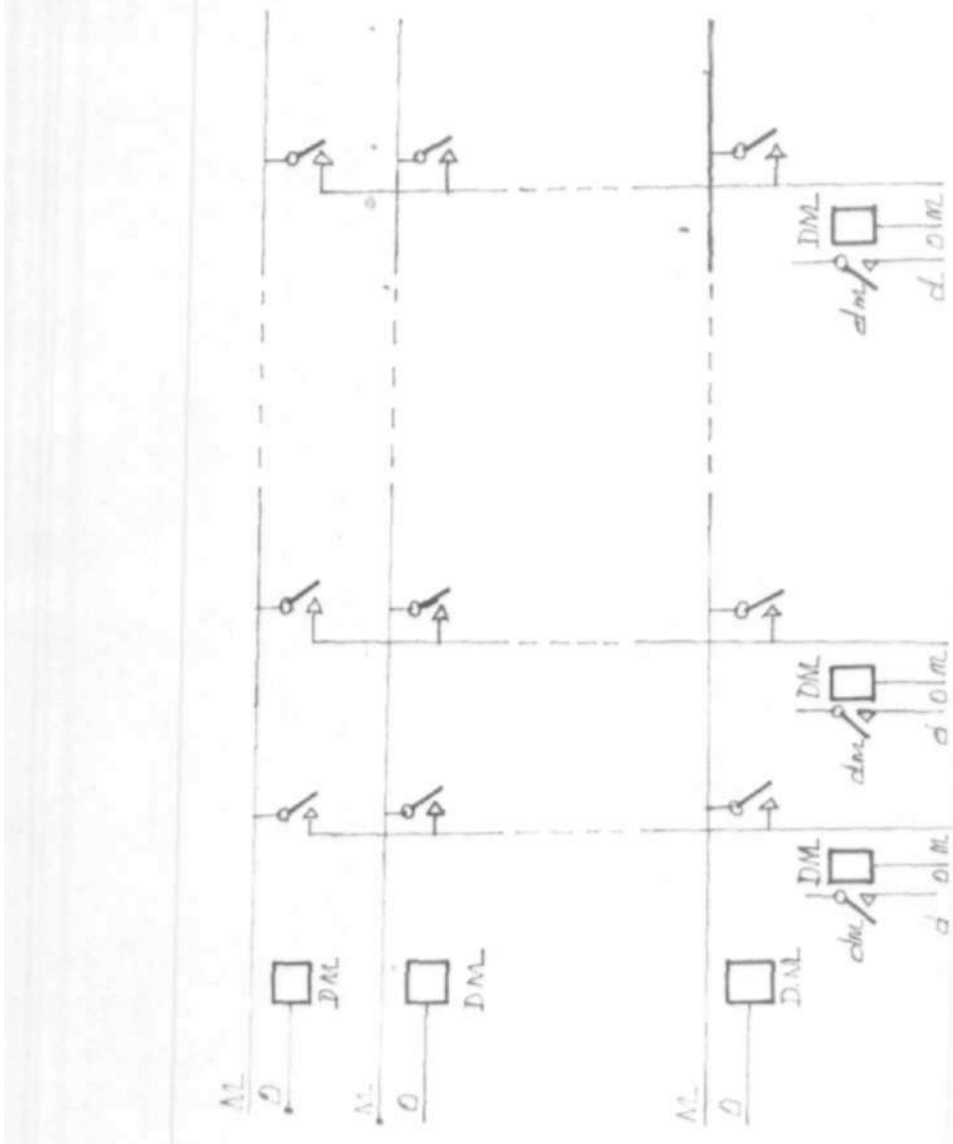


FIG 5.1. CROSS BAR SWITCH.

by closing those at the co-ordinate point of the horizontal select and vertical bridge magnets.

If more than one ... select magnet is operated, the bridge magnet will close contacts corresponding to each, and thereby sets of contacts in the same column may be operated simultaneously or one set at a time.

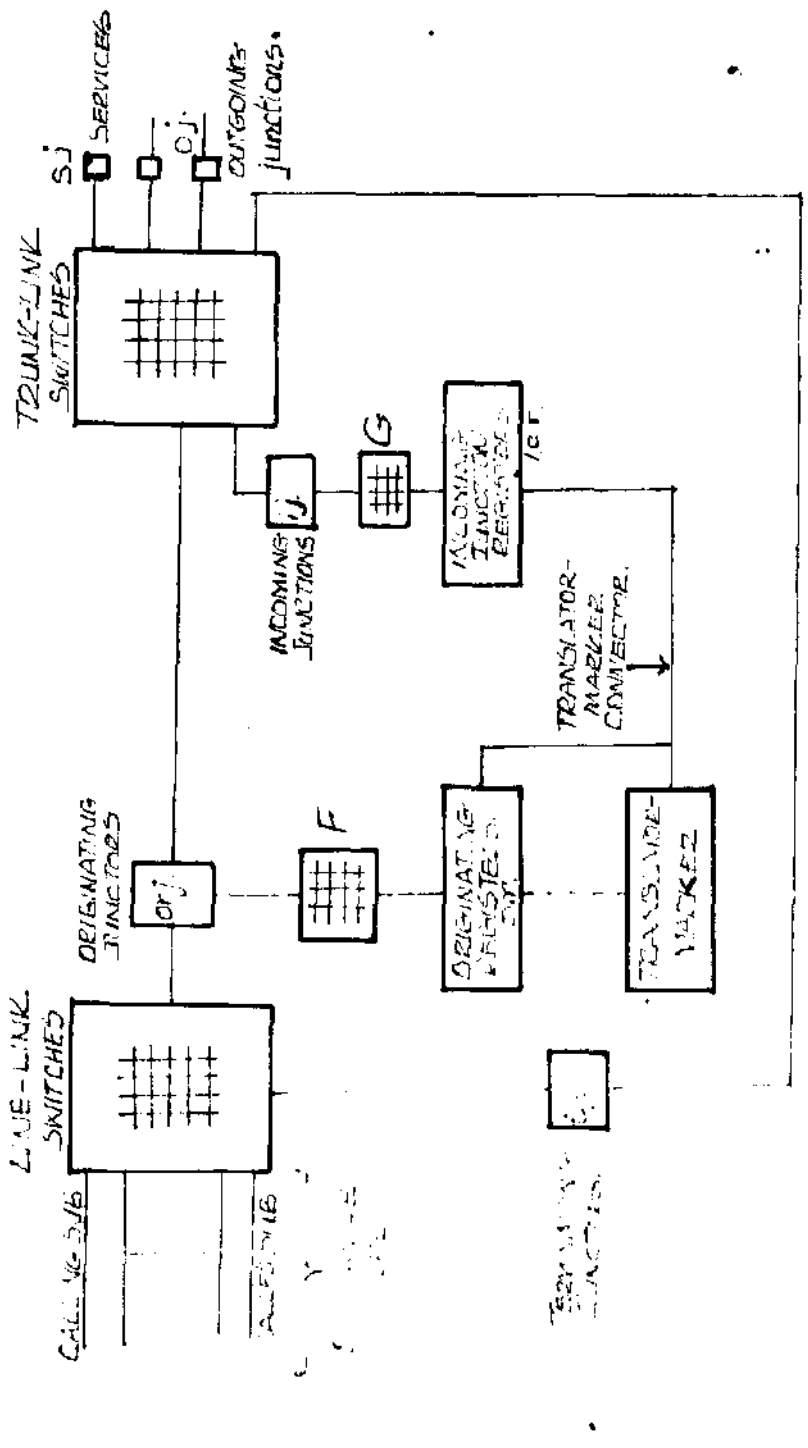
In some switches, the bridge magnet coil currents do not have to be maintained to keep the armatures operated, this being achieved by mechanical or remanent magnetism latching. Latched armatures are released by the momentary operation of a magnet which, according to the design, may be the select or the bridge magnet.(1)

Compared with individual relay operation, crossbar switches require fewer but larger and more powerful magnets, the operation being slower in consequence and the energy required to operate them greater. The releasing speed is comparable.

This chapter discusses the operating principles of a crossbar exchange in general and, in particular, the NE-5 Crossbar Exchange which has been used as a model in the simulation exercise. This is followed by the description of the simulation program of the crossbar exchange.

5.2 GENERALIZED OPERATION

There are several ways in which crossbar switches are connected together to form exchanges of various sizes. One



CROSSBAR EXCHANGE TRUNKING.

way is shown in Fig. 5.2. (1). This uses switching stages of three kinds. One kind concentrates the exchange line traffic to originating, or.j., and to terminating, t.j., circuit processors called junctors. Another kind interconnects or.j. and incoming junction junctors, i.j., with outgoing junction, o.j., service junctor, s.j., and terminating junctors, t.j.. The third connects or.j.'s and i.j.'s with originating registers, o.r., and incoming registers, i.r., respectively. Fig. 5.2 is typical of trunking used in practice. The switch sizes and numbers are, however, symbolic and large exchanges need to use much more switches in series than those shown in the figure.

A call originating from an exchange line is connected through its own set of switches to an originating junctor suited to its class of service. (The lines designated calling subscriber and called subscriber lines respectively are mainly for illustration as any of the exchange lines can be either a calling line or a called line at any given time). It is then passed through a set of switches to an originating register which receives, stores and processes the subscriber-dialled directory number digits which define the connection wanted.

A calling signal on an incoming junction actuates the incoming junctor to connect via the switch, G, to a junction register, i.c.r., which receives digits from a register connected to the other end of the junction.

When sufficient digits to define a connection through the exchange switches have been received, the register, o.r., or

i.c.r., actuates a translator-marker-connector switch to gain connection to a translator-marker. The digits stored by the register are then transferred to the translator-marker and at the same time, the register sends a datum through the F or G switch which is connecting it to a junctor to the junctor to instruct it to mark the point from which selection is to start.

If a connection can be made, there being free trunks and switches able to do so, the connection is made by path search and connection processors associated with the crossbar switches, not individually as in step-by-step systems, but in groups. The connection is made via the trunk-link switches to a service junctor, s.j., or to an outgoing junctor, o.j., and junction or to a terminating junctor suited to the class of service of the called station. If no effective connection can be made, the register connects busy or not-attainable, n.u., tone, as appropriate, back to the caller.

For calls terminating in the exchange on an exchange or service line or tone circuit, the register is immediately released. For calls outgoing on junctions, the register sends a calling signal over the junction to prepare the distant end to receive the call by the finding and connection of an incoming junction register, i.c.r. The distant register when connected, sends a proceed-to-send-the-address datum which, when received by the calling register, causes that register to transmit to the called register the information which it needs to advance or to complete the connection.

When all data have been sent, the calling register releases.

A connection, when completed through the exchange and released from the register which established it, contains only the circuit processors, i.e., the junctors, necessary to the supervision and control of the call until its release, together with the crossbar switches which make the connection by bridge magnets operated and held.

On established calls, the junctors receive, relay and process signals and data and exercise all control, applying ringing, tones and metering pulses and finally releasing the connections.

5.3 THE NE - 5 CROSSBAR EXCHANGE

5.3.1. General Description

The NE - 5 Crossbar Exchange is a product of Northern Electric Company Limited, Montreal, Canada, hence its name. The exchange has been equipped for a maximum of 1,900 lines.

The crossbar switch used in this exchange consists of ten horizontal paths and twenty vertical paths. Other models using a switch with ten vertical paths are also in use. Any horizontal path can be connected to any vertical path by means of magnets, as already described in Section 5.1. The points of connection are known as cross - points. The switch with 10 vertical paths has 100 cross-points and is called a 100 - point switch; the one with 20 vertical paths has 200 cross-points and is called a 200-point switch.(9)

There are five selecting bars mounted horizontally across the face of each switch. Each selecting bar has flexible

selecting fingers attached to it, one finger for each vertical path, and the bars can be rotated slightly to cause the select fingers to go either up or down.

Ten or twenty vertical units are mounted on the switch (in our model, 20) and each unit forms one vertical path. Each unit operates under the control of a hold magnet and has ten groups of contacts (one for each horizontal path) associated with it. Each group of contacts may consist of three to six pairs of contact springs. A switch is classified according to the number of crosspoints and pairs of springs, for example, a 200-point, 3-wire crossbar switch, as in our model.(9)

The normal position of the selecting fingers is horizontal, lying between two groups of contacts. When a select magnet operates, the selecting bar is rotated and one of the two horizontal paths available to this bar is chosen. The selecting fingers now lie in front of a group of contacts. The hold magnet of the vertical path to be connected to this horizontal path then operates its holding bar which, using the selecting finger as a wedge, causes the group of contacts beside the selecting finger to operate, thus connecting the horizontal and vertical paths. Both the select and hold magnets must be operated in order to close a crosspoint. The other groups of contacts on this vertical unit do not operate since there is no selecting finger between them and the holding bar.

After the operation of the hold magnet, the select magnet releases, returning the horizontal bar and all of the selecting fingers back to normal, except those actively held by operated hold magnets. The finger used to establish the

connection, being flexible, remains wedged against the contacts by the holding bar, and in this way keeps the contacts operated. When the hold magnet releases, the connection is released and the selecting finger returns to normal. Since the selecting finger tends to oscillate upon being released, damping cones are provided on the hold magnet armature to act in conjunction with the damping springs to minimize these oscillations.(8)

All connections in the message path to the crossbar exchange subscribers are established through two kinds of switching frames: Line-link frames and Trunk-link Frames. The subscriber-lines are connected to the switches on the line-link frames while the various trunks and register circuits are connected to the switches on the trunk-link frames. These frames interconnect over junctors that are attached to junctor switches which appear on the line-link and trunk-link frames. These switching operations are controlled by control equipment which includes markers and associated connectors.

Brief functional descriptions of the equipment elements now follow.

5.3.2. Line-Link Frames

The crossbar switches on the line-link frame are divided functionally into line switches and junctor switches. Subscriber lines are connected to the line switches, and junctors to the junctor switches. Line-links, which are merely connecting wires, are provided for interconnecting the line switches and junctor switches. Hence the name line-link frame. Fig. 5.3 is a simplified diagram of a line-link frame.

The basic line-link frame is available in two sizes: 190 lines and 290 lines. The 290-line frame most commonly used is a two-bay framework with each bay mounting ten 200-point crossbar switches. One and one-half switches on each level are used as line switches. Each vertical on a line switch is used for a customer line, except one which is used for no-test access to the remaining 29. The half-switches not used as line switches are used as junctor switches, thus providing ten verticals for terminating the junctors on each level. In the case of the 190-line frame, separate switches of ten verticals each are provided as junctor switches. The model exchange being considered has 190-line line-link frames. The line relays, one for each customer line, are mounted at the top of the line-link frame.

Line links appear on the horizontals of the switches, ten line links on each switch. These ten line links are distributed among the ten junctor switches, one line link to one horizontal on each of the ten junctor switches. This system of line links permits each line on a line-link frame to reach any one of the 100 junctors serving that frame. Fig. 5.4 shows how each line switch has access to all the junctor switches.

As already noted, each line-link frame has 100 junctor-terminations which are used to connect to all the trunk-link frames making up the exchange. Since each trunk-link frame has 200 junctor terminals for connecting to all line-link frames, the ratio of line-link frames to trunk-link frames in an exchange is generally 2 : 1. There are no half-frames.

(In an exchange with 13 line-link frames, there are usually 7 trunk-link frames). However, conditions peculiar to a particular exchange may cause some variations in this ratio. In the model being considered, there are ten line-link frames and, correspondingly, five trunk-link frames.

The 100 junctors from each line-link frame are divided into approximately equal groups with one group from each line-link frame going to each trunk-link frame. The number of junctors in a group depends on the number of trunk-link frames making up the exchange and is determined by dividing the 100 junctors by the number of trunk-link frames. However, there is a limiting factor: for efficient service, no group can contain less than ten junctors. In our model, each group contains 20 junctors.

When there are ten or fewer trunk-link frames, each junctor group has ten or more junctors. For example, in an exchange with 8 trunk-link frames and 16 line-link frames each junctor group contains either 12 or 13 junctors. Fig. 5.5 illustrates the junctor distribution for 2 trunk-link frames and 4 line-link frames. However, in an exchange with 11 to 20 trunk-link frames, each junctor is multiplied to two trunk-link frames in order to have at least 10 junctors per group. Fig. 5.5 illustrates the junctor distribution for 20 trunk-link frames and 40 line-link frames.

5.3.3. Trunk-Link Frames

The trunk-link frame is made up of trunk switches, junctor switches and various miscellaneous circuits. Trunks

and originating registers are connected to the trunk switches. The junctors from the line-link frame are connected to the junctor switches. The trunk and junctor switches are interconnected by trunk links which are similar to the line links. The trunk links connect the junctor switch verticals to the trunk switch verticals; line links connect horizontal to horizontal. The diagram of a trunk-link frame is shown in Fig.5.7.

The system of trunk links that permits any outlet or trunk on a trunk link frame to be connected to any one of 200 junctors serving that frame is similar in principle to that used on line-link frames. The number of trunk links, which is 200, is the same as the number of junctors. The trunk links run vertical to vertical, the junctors being connected to the horizontals of the junctor switches and the trunks to the horizontals of the trunk switches. In order to terminate 20 junctors, on the horizontals of one 200-point switch, it is necessary to split the horizontal multiple into a left-hand and a right-hand half-switches. The two half-switches thus formed are treated separately and the numbering of the verticals in each half is similar, but they are identified as left and right. Although the trunk switches are not physically split, the numbering of verticals is also on a left and right basis. Fig. 5.8 shows the distribution of the trunk links.

The ten trunk switches on the trunk-link frame furnish locations for 160 trunks, each switch having locations for 16 trunks on eight of its levels (horizontals). Fig. 5.9 illustrates how this is accomplished. Each of the ten trunk switches is so arranged that each one of levels 2 to 9 terminates

on two three-wire trunks. One trunk on each levels is connected to one set of three wires of the horizontal multiple and designated Appearance A, and the other trunk to a second set of three wires and designated Appearance B. The levels 0 and 1 are directing levels. The eight appearances on each switch that are selected by horizontal 0 are called A appearances and those selected by horizontal 1 are called B appearances.(9)

5.3.4. Channels

A channel is a combination of a line-link, a junctor, and a trunk-link that can be formed, by crosspoint closures, into a chain that interconnects a line and a trunk. The ten or more junctors in a group connecting a line-link frame with a trunk-link frame are distributed over the ten junctor switches of both the line-link and trunk-link frames. There are ten line links serving each particular subscriber line on the line-link frame, and these are also distributed over the ten junctor switches. There are twenty channels available for a connection These channels are illustrated in Fig. 5.10. An idle channel is selected by testing the twenty channels at the same time.

5.3.5. Markers

The markers are the most active of the larger pieces of common control equipment in the exchange. They are used in the completion of every call. Different exchanges have various numbers of markers depending on the size of the exchange and the traffic. The model has four markers. There are two types of markers in use: Dial Tone and Completing Markers.(9)

The dial tone marker is used exclusively for dial tone jobs while the completing marker is used for all other jobs. In the model under consideration, there are two dial tone markers but only one is in use at any given time while the other acts as a standby; there are two completing markers and they are both always simultaneously in use at any given time. The dial tone and completing markers are independent of each other. The completing marker normally completes each of its various functions in less than one second. A small number of markers can, therefore, serve a large exchange.

5.3.6. Originating Registers

Originating registers furnish dial tone to subscribers and record the digits that are dialled or keyed. After dialling or keying is completed, the called number is transferred from the register to a completing marker. These registers also make party test on a two-party line to determine whether a tip or ring party is making the call. Originating registers appear on trunk-link frames, and one is connected to the subscribers' line by the dial tone marker when the subscriber lifts the receiver off the hook.

5.3.7. Trunks

As has already been noted, trunks have their switch frame appearances on trunk-link frames and carry calls from one exchange to another and from subscriber to subscriber connected to the same exchange. Various types of trunks are provided to serve the various types of traffic in an exchange. The following is a list of some of the principal categories of trunks:(9)

1. Intra-office Trunks: These handle traffic between customers served by the same marker group. Each trunk requires two trunk-link frame locations: an A appearance for the calling customer, and a B appearance for the called customer. These trunks are usually divided into three groups: message rate, flat rate and coin.

2. Outgoing Inter-local Trunks: These are used to transmit calls outgoing from the exchange to a connecting exchange. The types of outgoing trunks used depend on the traffic in an individual exchange. Usually, there is one group of trunks for flat rate and message rate traffic and another for coin traffic.

3. Incoming Inter-local Trunks: These carry the traffic incoming to the exchange. There are two general types of these trunks namely, nontandem and tandem. The nontandem - type trunks carry only the calls completing to subscribers connected to the exchange. The tandem - type trunks carry calls completing to subscribers connected to the exchange and also calls which are switched through when the exchange functions as a tandem switching-point or a "homing" exchange.

4. Common Overflow Trunks: These are provided as a final route when all permanent signal holding or noncoin combination tone trunks are busy. This trunk returns a line busy signal to the calling party.

5.4 METHOD OF OPERATION

5.4.1. Definitions

A call between subscribers served by the same exchange is referred to as an intra-office call. The speech path in the

exchange consists of two channels established between the subscriber lines through an intra-office trunk as shown in Fig. 5.11.

A subscriber who makes an outgoing call to another office is connected through a channel to an outgoing trunk as shown in Fig. 5.12. An incoming call to the exchange is connected to the called subscriber by means of a channel between the incoming trunk and the called customer as shown in Fig. 5.13. Each of these calls is known as an inter-office call.

5.4.2. Establishing Dial Connection

When a subscriber lifts his handset, a line relay is operated which causes the line-link frame to inform the line-link marker connector that a dial tone marker is required. The line-link marker connector selects an idle dial tone marker. It then transmits to this marker the location of the calling line. The only time the line-link marker connector seizes a marker is when a dialling connection is to be established. (See Fig. 5.14, connection 1).

In order to establish a dial connection between the calling subscriber line and an idle originating register, the marker must determine:

(a) The class of service, and equipment location of the calling line i.e. the line-link frame number and the location of the line on that frame.

(b) Whether an idle register is available, and the number of the trunk-link frame on which it appears.

(c) That a channel between the line and the register can be obtained.

The calling line class of service and equipment location is stored in the originating register by the marker for subsequent use on marker intra-office or outgoing trunk jobs.

While the marker is obtaining the equipment location of the calling line from the number group via the number group connector, it is also selecting an originating register. Originating registers are distributed as equally as possible over all the trunk-link frames, and an idle register is selected in the same manner as an office trunk. The marker is notified, by means of test leads from each trunk-link frame, which frames have at least one idle register and are not being held busy by other markers. It selects an idle frame having one or more idle registers, and connects to that frame through a trunk-link connector. The marker then selects an idle register on that frame.

After the marker has selected a trunk-link frame, it goes back to the line-link frame via the line-link connector which carries both the leads for locating the position of the calling line on the line-link frame and the other leads, which the line-link marker connector does not have, for completing connections to the frame. (Fig. 5.14, connection 3).

Identification of the class of service of the calling line is passed to the marker from the line-link connector. The marker transmits the equipment location and class of service of the calling line to the originating register, where this information is stored.

The marker must now select an idle channel between the customer line and the originating register, where a channel consists of a line-link, junctor and trunk-link. When the marker finds an idle channel, it operates the select and hold magnets required to close through the channel. The marker then indicates to the originating register the identity of the line-link used in the channel and the register stores this information for later use.

Before the marker transfers control of the channel to the originating register, it checks the connection for continuity (connection 4). The marker then releases its associated connectors and itself, and leaves in the register, the calling line equipment location. It also registers the number of the line-link used in the dialling line. The register now furnishes dial tone to the subscriber and is ready to receive the digits which are dialled.

The dialled digits are registered in the originating register. As soon as dialling is completed, the originating register seizes a marker and transmits the registration to it.

It normally takes less than half a second to establish the dial connection and return dial tone to the calling subscriber.

The preceding description of how a dial connection is established applies to both intra-office and inter-office calls. The rest of this section which describes the method of operation of the NE - 5 Crossbar Exchange will concentrate on intra-office calls. Further treatment of inter-office calls will be made later. (See Chapter 6).

As has already been described, after the called number is dialled, the originating register engages a marker through an originating register marker connector. The register then transmits the line equipment location of the calling line and the digits of the called number to the marker. The marker translates the office code and determines that the called number is assigned to the same marker group as the calling line, and the call is consequently an intra-office call.

The marker then proceeds to perform an intra-office trunk job which consists of two parts: the establishment of a terminating connection and that of an originating connection. The terminating connection is set up between the called line and the B appearance of the intra-office trunk; the originating connection is set up between the calling line and the A appearance of the intra-office trunk.

5.4.3. Establishing Terminating Connection

The terminating connection is established first so that if the called line is busy, the marker can immediately connect the calling line to a tone trunk, and thus save holding time on equipment. Before the terminating connection can be set up, the marker has to obtain the equipment location of the called number, and the setting of the ringing selection switch. This information is obtained from the number group via the number group connector.

While the marker is obtaining this information from the number group, it is also selecting an intra-office trunk on an idle trunk-link frame. (Fig. 5.15 connection 2). Through

the line-link connector, the marker gains access to the line-link frame on which the called customer line is located. (Connection 4). If it is not busy, the terminating connection is set up between the B appearance of the intra-office trunk on the trunk-link frame and the called line (connection 5).

If there is no idle channel available, the marker recycles by releasing the intra-office trunk it was holding and selecting another one (usually on another frame). If there is no idle channel on this recycle, the marker reroutes the call to tone trunk.

5.4.4. Establishing Originating Connection

After the terminating connection is established, the marker proceeds to set up an originating connection between the calling line-link frame and the A appearance of the intra-office trunk on the trunk-link frame over an idle channel (connection 7). The marker seizes the line-link frame of the calling subscriber as shown in connection 6. Before it releases the dial connection, the marker determines whether there is an idle channel between the calling subscriber and the A appearance of the intra-office trunk. If there is an idle channel, the dial connection is released immediately, enabling the marker to use the dial connection line link as part of the originating connection, if necessary. However, if there is no idle channel available, the marker recycles as described in the preceding sub-section (5.4.3). In case no idle channel is found on the recycle, overflow tone is returned from the originating register through the dial connection.

After the marker has set up the ringing selection switch in the terminating connection in accordance with the information obtained from the number group, it releases itself and the originating register from the intra-office connection. The dial connection is disengaged and the subscribers are interconnected. The trunk now controls the ringing and supervision of the call. The ringing is tripped when the called party answers and the ringing selection switch releases. When the call is finished, the originating and terminating connections are broken and the intra-office trunk is released.

5.4.5. Timed - Release Feature

A timed-release feature is provided in order to prevent the calling party from holding the called line out of service indefinitely by failing to hang up the receiver. In this case, the timed-release feature automatically disconnects the calling line 13 to 35 seconds after the called customer hangs up. If the calling customer disconnects first and the called customer fails to disconnect, the timed-release feature disconnects the called party after 13 to 35 seconds.

5.5. BRIEF DESCRIPTION OF THE SIMULATION PROGRAM

The general organisational structure of this program is similar to those of the manual and step-by-step exchanges already described. As should be expected, differences occur in the different routines responsible for the execution of the program. These differences are very much pronounced, as the crossbar exchange, in both its physical structure and mode of operation, is very revolutionary compared to either the manual

or the step-by-step exchange. The flowchart of the simulation program is shown in Fig.C. 3(a) of Appendix C. The exchange is a lost call system, and is code-named SIMTEX 2 . The program has been designed to follow as closely as possible, what really obtains in practice in the physical exchange.

When the program is started, the model is initialized for the particular run to be made. The input information includes the number of subscriber lines, the mean inter-arrival time of calls, mean call length, the maximum number of processed calls making a run, the maximum number of line-link frames, the maximum number of lines per line-link frame,the maximum number of line-links per frame, the maximum number of trunk-link frames, the maximum number of trunk-links per frame, the maximum number of junctors per group and the maximum number of trunks per frame (A and B appearances). An initialization routine then sets various numbers to their correct initial values. The first arrival time is generated and the program enters the main routine concerned with executing each cycle of events. As with the previous simulation programs, this initial entry point is also the point from which to recycle when all changes have been executed for one event.

Suppose the next call finishes at T_F and the next arrival is at T_A. The program first decides whether the next activity is to disconnect a call or to attempt to connect a call. The test of the condition, $T_F \leqslant T_A$, makes this choice. As with the previous simulation programs, with the test defined this way, a coincidence of a disconnect and a new arrival results in the disconnect being serviced first. Whichever activity is

decided upon, the program updates the clock. When two events are coincidental, the program executes them successively and the clock remains unchanged, until all the events at that time have been executed. In the case of disconnecting a call, the activity is unconditional and the program immediately carries out the necessary action. Since a call has just finished, the time the next call finishes, T_F, is updated. The program collects statistics and returns for another cycle.

In the case of a new call arriving, the call is generated and the program checks to see whether enough calls have been processed to finish the simulation run. If not, the equipment location of the calling line is obtained and stored. A test is then made to see if a dial connection can be established. This depends on whether a free channel can be found between the calling line and an idle register, as described in Section 5.4.2, where a channel consists of a line-link, junctor and trunk-link. If there is no idle channel, the program collects statistics and returns to generate a new arrival. If there is an idle channel, the program establishes the dial tone connection.

The program then generates the destination, that is, the called subscriber's address, obtains the equipment location of the called line and stores this information. The call length and the next arrival time are generated. A check is then made whether the terminating connection can be established. A test is first made to see if the destination is free. If it is not free, the program collects statistics and returns for another cycle. If the destination is free, the program proceeds to

select an idle trunk on a trunk-link frame and checks whether an idle channel can be found between the called line and the trunk. If there is no available idle channel, the program releases the trunk and recycles, selecting an idle trunk on another idle frame. If there is no idle channel on this recycle, the selected idle trunk, if any, is released. The program now collects statistics and returns for another cycle (that is, finding the next potential event). If an idle channel is found, the terminating connection is established and the program proceeds to try to establish the originating connection.

The program checks whether an idle channel can be found between the trunk used for the terminating connection and the calling subscriber. If no idle channel is found, the program recycles as described above. If no idle channel is found on this recycle, the program collects statistics and returns for another cycle (that is, finding the next potential event). If an idle channel is found, the originating connection is made. The program then adjusts the records by entering the new call in the list of calls in progress.

When a call is lost, the appropriate statistics are gathered. The program has been designed to show at what point exactly, in the process of connecting a call, that the call has been blocked. The program then resumes for one more cycle.

When enough calls have been processed to finish the simulation run, the simulation stops, the results are printed, and the program terminates.

As in the case of the simulation programs for the manual and step-by-step exchanges, the simulation program for the crossbar exchange can be divided into major sections on the basis of what operation is carried out by each section, viz:-

1. Program Initialization
2. Finding the Next Potential Event
3. Connecting a Call
4. Disconnecting a Call
5. Gathering Statistics
6. Computing Final Statistics and Printing out Results.

The flow charts showing how these sections implement their various functions are contained in Appendix C .

5.6 SIMULATION RESULTS AND ANALYSIS

Table 5.1 contains the simulation results for the crossbar exchange. It will be observed that there is no blocked call recorded for this exchange.

The graphs of Fig. 5.16 to Fig. 5.20 show the behaviour of the crossbar exchange as various parameters are varied. In Fig. 5.16(a), it can be seen that for values of the mean call interval (NARR) greater than 4s, the number of blocked calls is zero. The simulation results for NARR = 4s are contained in Table 5.2. The rate of arrival of calls (or call-rate) is obtained by dividing the number of calls entering the system in a given period by the length of that period. Hence from

Table 5.1: Simulation Results for the Crossbar Exchange

No. of Lines	1700	
Mean Call Interval	12	seconds
Mean Call Length	120	seconds
Clock Time	11062	
Duration of Run	3	hours
Number of Calls	1000	
Calls Completed	980	
Busy Calls	11	
Blocked Calls (No Dial Tone Channel)	0	
Blocked Calls (No Terminating Channel)	0	
Blocked Calls (No Originating Channel)	0	
Blocked Calls (No Free Trunk)	0	
Total Number of Blocked Calls	0	
Number of Active Calls	9	

Table 5.2, the call-rate at a mean call interval of 4 seconds is given by:

$$\text{Call - rate} = \frac{1000}{3470} \text{ Calls/second}$$

$$= 0.288 \text{ calls/second}$$

$$\simeq 0.3 \text{ calls/second.}$$

Hence, for this system to perform satisfactorily, not more than 3 calls must enter the system in a space of 10 seconds, on the average.

Table 5.2: Simulation Results for the Crossbar Exchange (Mean Call Interval = 4s)

Mean Call Interval	4
Clock Time	3470
Number of Calls	1000
Calls Completed	925
Busy Calls	35
Blocked Calls (No Dial Tone Channel)	0
Blocked Calls (No Terminating Channel)	0
Blocked Calls (No Originating Channel)	0
Blocked Calls (No Free Trunk)	0
Total Number of Blocked Calls	0
Number of Active Calls	40

The blocked/completed calls curves of Fig. 5.16(a) are roughly mirror images of each other and are exponential. It will be recalled that similar observations were made for the curves of Fig. 3.1(a) (Manual Exchange). It will be observed in Fig. 5.16(a) that the number of blocked calls increases exponentially for values of mean call interval less than 4 seconds.

The graphs of Fig. 5.16 (c - f) show the behaviour of blocked/completed calls with the number of lines in the exchange for mean call intervals of 1, 2, 4 and 12 seconds, respectively. The number of blocked calls decreases as the mean call interval increases. Also, the graphs show that the number of completed calls increases as the mean call interval increases. These observations agree with the curves of Fig. 5.16 (a) already discussed. As the mean call interval increases, the call-rate decreases and there is a corresponding decrease in the demand on the exchange equipment - all other conditions, such as number of processed calls and mean call length, being held constant.

The variations in the number of blocked/completed calls with mean call interval as the number of lines is varied are clearly brought out in Fig. 5.17. The graphs of Fig. 5.16 (c - f) show that the numbers of blocked and completed calls increase and decrease, respectively, exponentially with number of lines (NLINES) until a critical value is reached beyond which the curves level out (or saturate). For NARR = 2, beyond the critical point (NLINES $\simeq$ 500), the blocked-calls curve increases slightly while the completed-calls curve decreases correspondingly. It is very interesting to observe the striking similarities between the graphs of Fig. 5.16 (c - j) with the corresponding curves obtained for the manual and step-by-step exchanges. (Fig. 3.1 (b - e) and Fig. 4.3 (a) and (b)).

Fig. 5.18 (a - d) shows the behaviour of blocked/completed calls as the number of processed calls (NRUN) is varied for mean call intervals of 1, 2, 4 and 12 seconds respectively. The variation of blocked/completed calls with NRUN is linear.

For NARR equal to 1, 2, 4 and 12 s , the slopes of the blocked-calls curve are respectively 0.61, 0.24, 0.0 and 0.0. The decreasing values of slope agree with the earlier observation that the number of blocked calls decreases with mean call interval. On the other hand, the number of completed calls increases with mean call interval, as can be seen from the increasing slopes of the completed-calls curves. Fig. 5.19 and Fig. 5.20 respectively show clearly the changing slopes of the blocked-calls and completed-calls curves.

Again, the similarities between the curves of Fig. 5.18 and those of Fig. 3.1 (f - i) (Manual Exchange) and Fig. 4.3 (c and d) (Step-by-Step Exchange) are most striking.

The following discussion seeks to compare the performance of the real crossbar exchange with what its performance should be in the light of the simulation results shown above. An attempt is also made to account for any observed differences. At the time of writing, the relevant statistics for the Zaria crossbar exchange were not available due to technical reasons: the exchange, though already in use, was yet to be commissioned. For this reason, the statistics on the Sokoto crossbar exchange have been used in the analysis.

Table 5.3 shows the statistics of faults in the Sokoto (local) telephone system. The statistics cover a period of one month. It will be observed from the table that the bulk of the faults are cable faults, overhead or underground. The high number of such faults (100 + 35 = 135) is really alarming, especially considering the fact that these faults are mostly long duration faults, which may take days, weeks or even month

Table 5.3: Statistics of faults in the Sokoto Telephone Exchange

TYPE OF FAULT	NO.OF FAULTS
Brought forward from previous month	123
No. of faults in the exchange equipment	0
No. of faults at exchange MDF	17
No. of Cable Faults (underground and overhead)	100
No. of faults on overhead loop	35
No. of faults on subscriber installation	0
No. of faults on junction circuits	0
No. of faults on subscriber telephone instruments	2
No. of faults on PBX Equipment	3
No. of faults on PABX Equipment	0
Total No. of faults in the reporting month	157
No. of faults cleared in the month	123

to rectify. Moreover even one damaged cable may involve upward of fifty subscriber-lines which may be consequently put out of service, as observed in Section 4.6.1. Again, it can be hazarded that the performance of the system is a direct function of the number and frequency of the long duration faults occurring therein. It can also be observed from Table 5.3 that of the 153 faults recorded, 123 were cleared. This represents about 72% of all the recorded faults. This shows an encouragingly high level of maintenance of the system. Hence it can be said that though there is still plenty of room for improvement, a low level of maintenance cannot be said to be a factor adversely affecting the performance of the system. It will also be noted from the table that no fault was recorded for the switching equipment itself for the period under consideration. This agrees with the observation earlier made in the discussion of the step-by-step exchange. (Section 4.6.1).

Table A.6 of Appendix A shows the statistics of calls for the Sokoto crossbar exchange. The statistics cover a period of one month. The average number of local calls entering the system per day for the month was 11,568 (25327 - 13759). If these calls are assumed to enter the system over an effective day of 10 hours, then the call-arrival rate is about 0.32 calls/second or 3.2 calls in 10 seconds, which is slightly higher than the maximum permissible call-arrival rate for the exchange (3 calls in 10 seconds, as shown above). Hence slight overloading (or flooding) of the switching equipment may occur especially during the peak traffic period of the day (9.00 - 11.00 am). To avoid this, the number of intra-office

(local) trunks provided in the exchange should be increased from the current 10 trunks per frame to about 12.

It has already been pointed out that the relevant performance statistics for the Zaria crossbar exchange were not available at the time of writing. This situation was also true of the exchanges in Bauchi, Kaduna, Kano, Jos and Yola. The exchanges are all of the crossbar type and from personal conversations with the technicians and technologists attached to the various exchanges, their performance is very similar to that of the Sokoto exchange and is satisfactory.

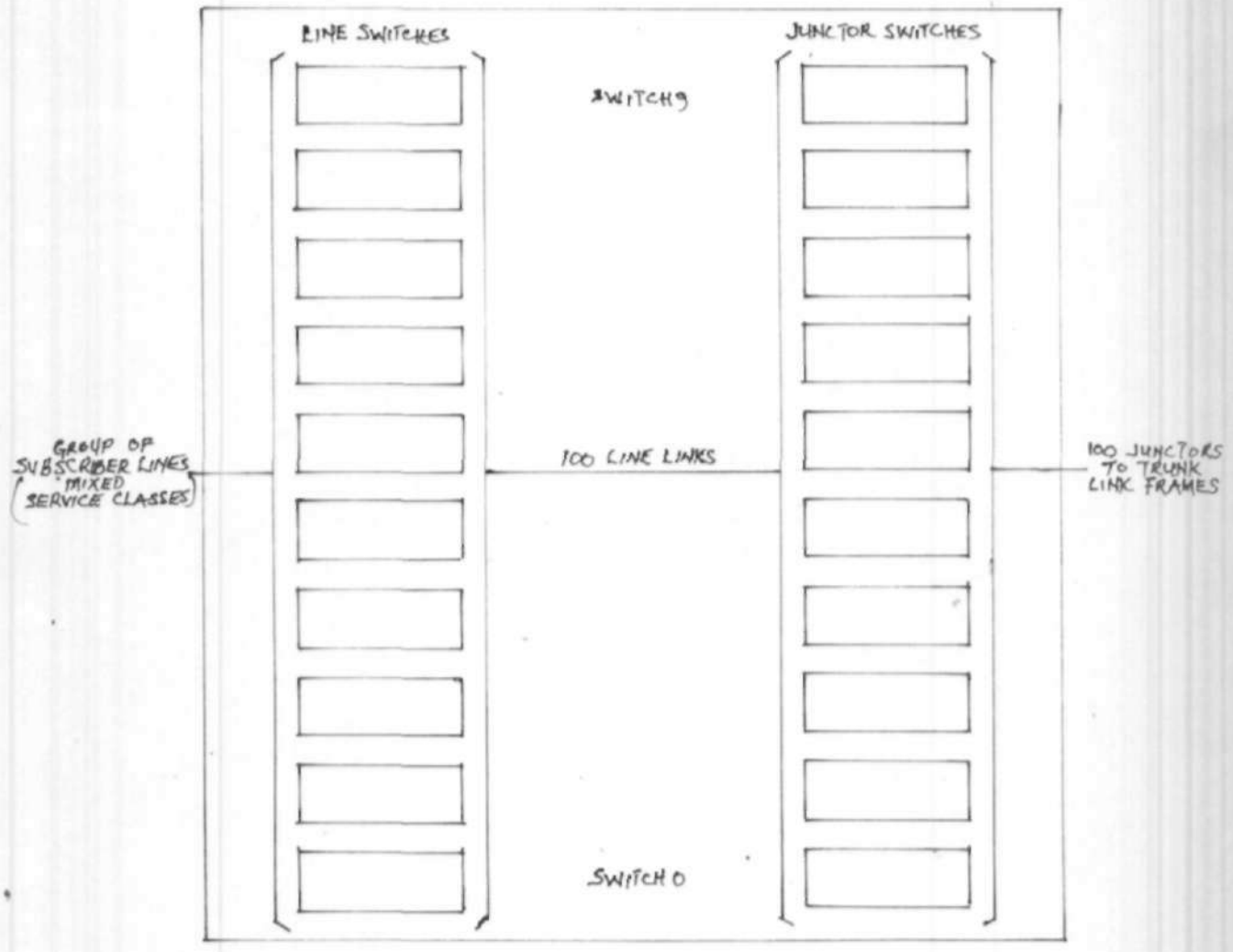


Fig. 53 - Line Link Frame

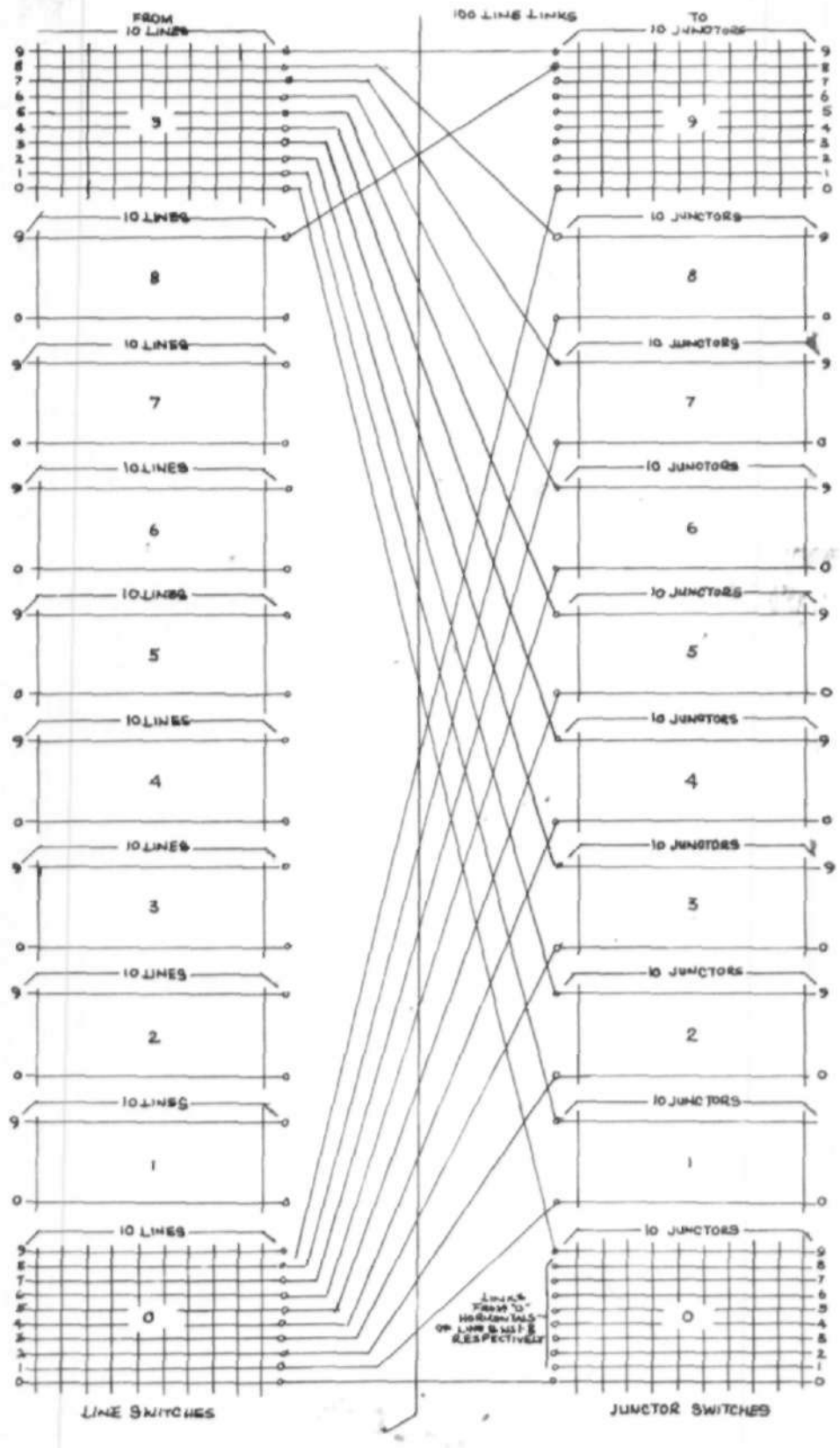


Fig. 5-4 - Line Link Distribution

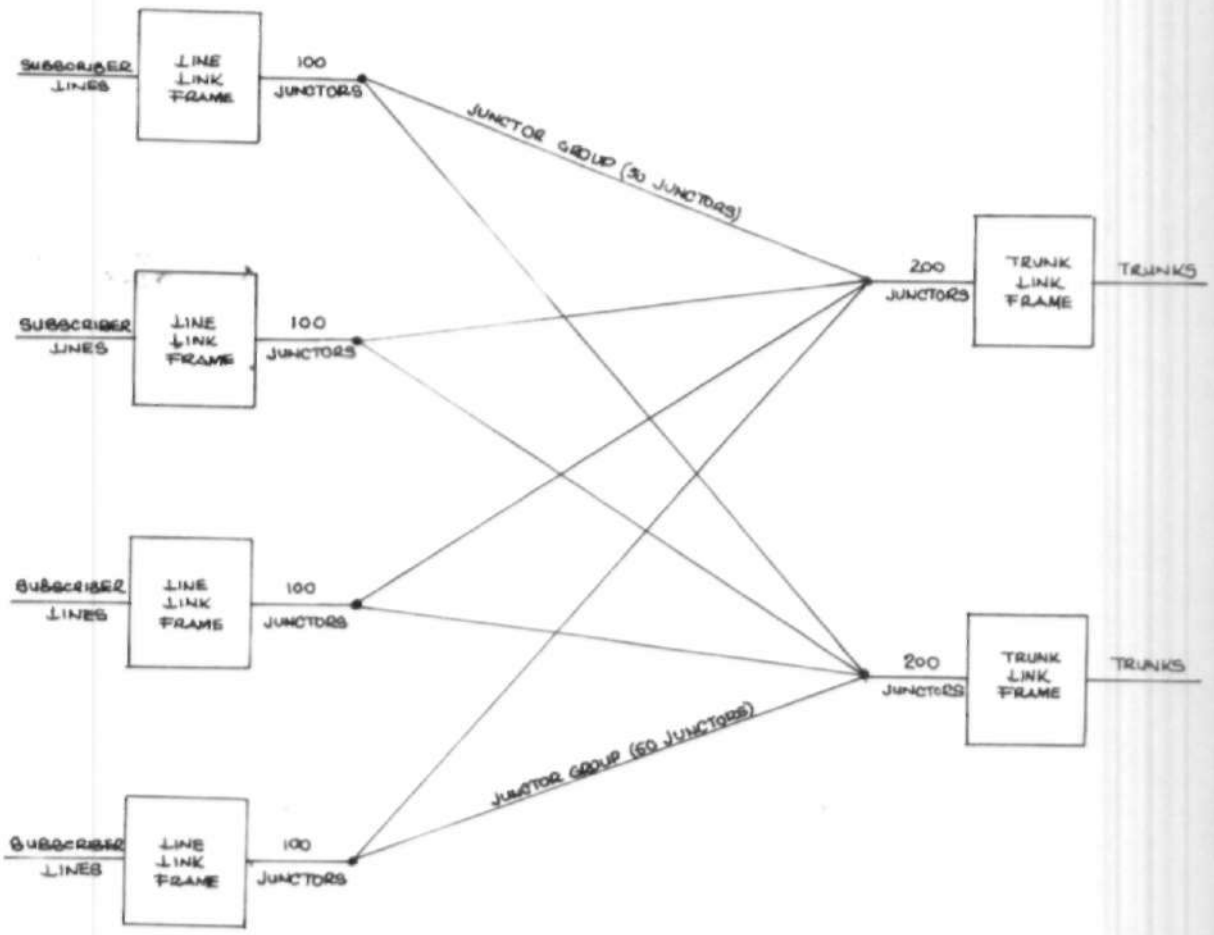


Fig.5.5–Junctor Distribution (Four Line Link and 2 Trunk Link Frames)

281283

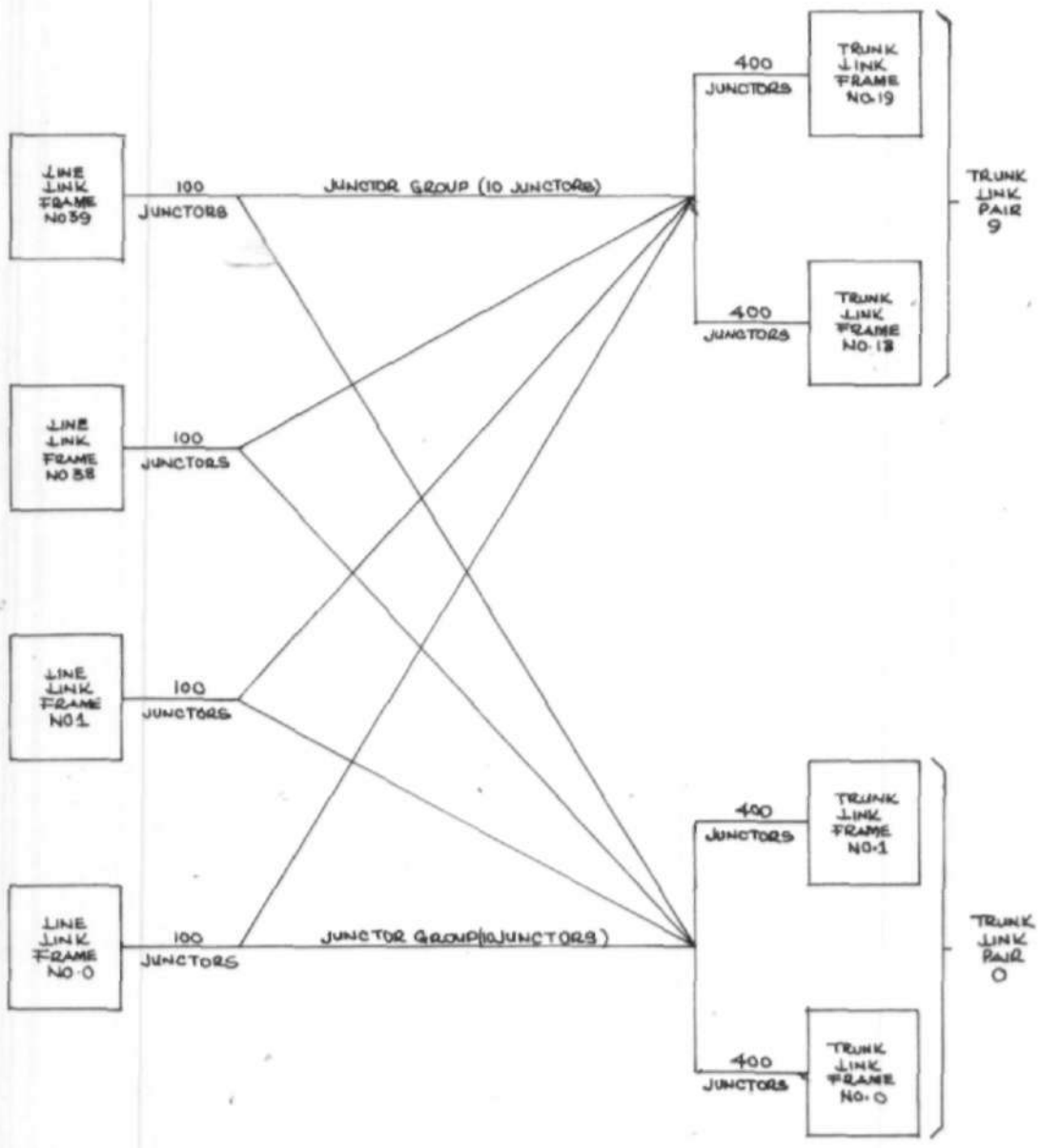


Fig. 5.6 - Pairing of Trunk Link Frames (40 Line Link and 20 Trunk Link Frames)

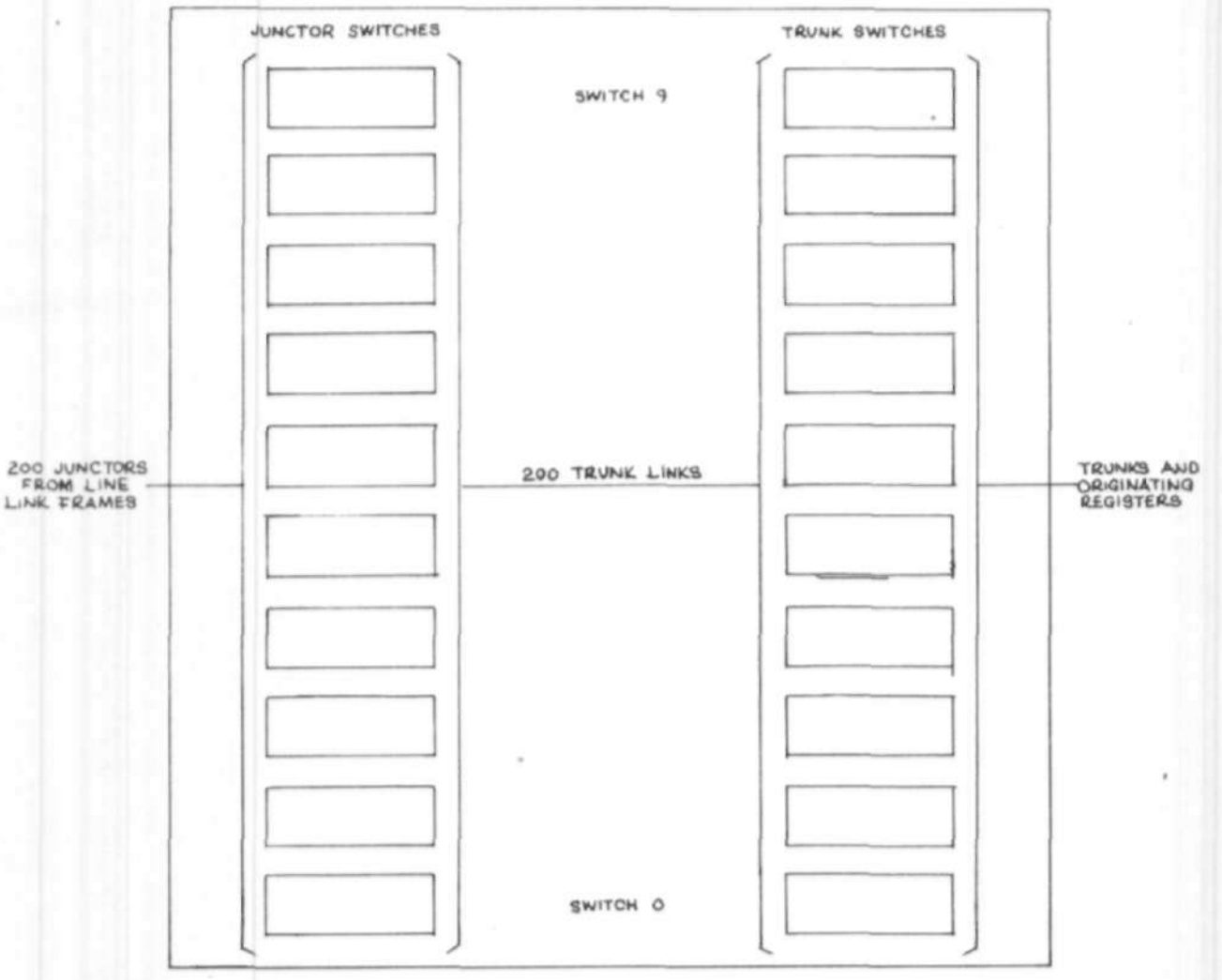


Fig 5.7 – Trunk Link Frame

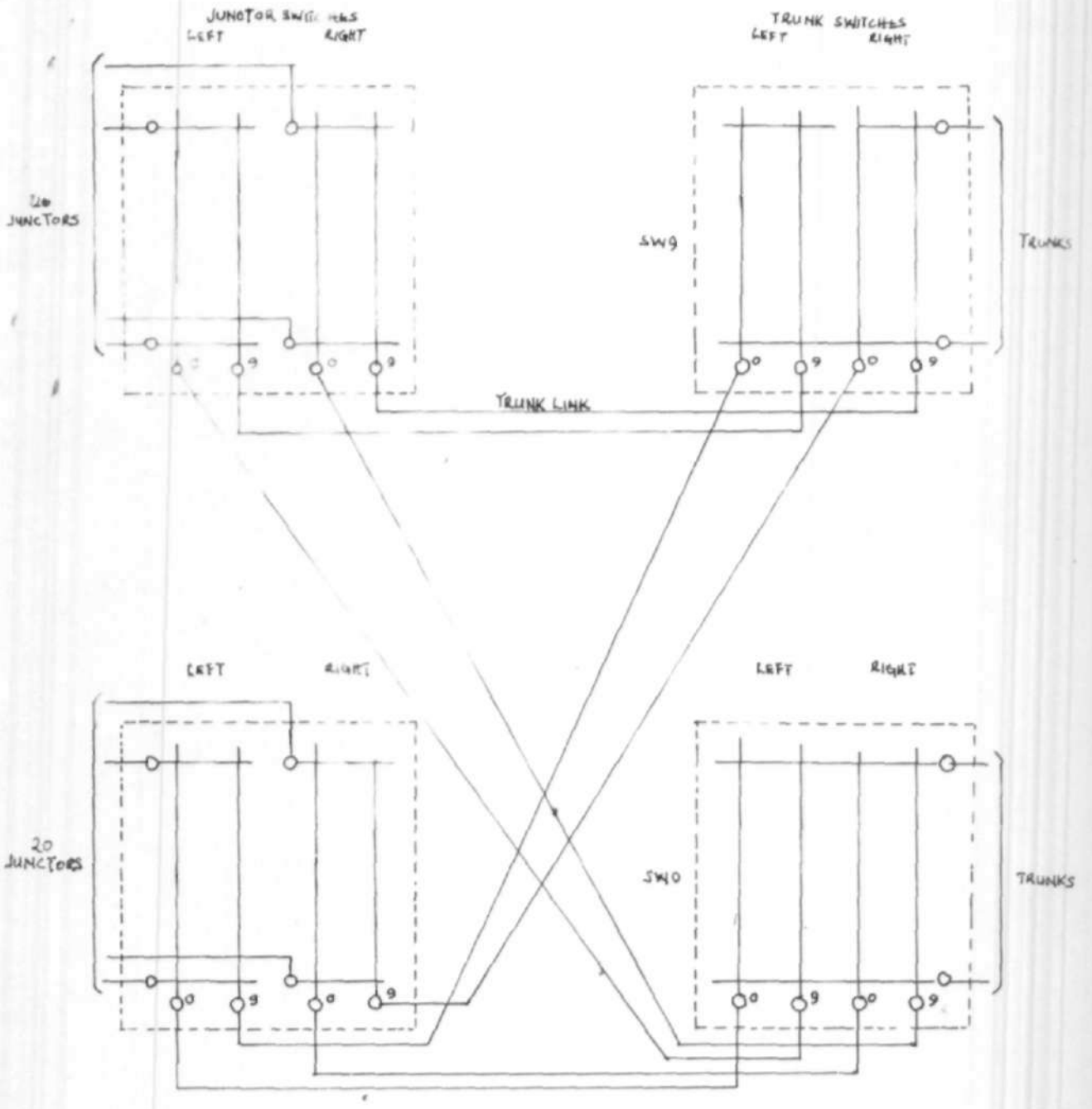


Fig. 5.8-Trunk Link Distribution

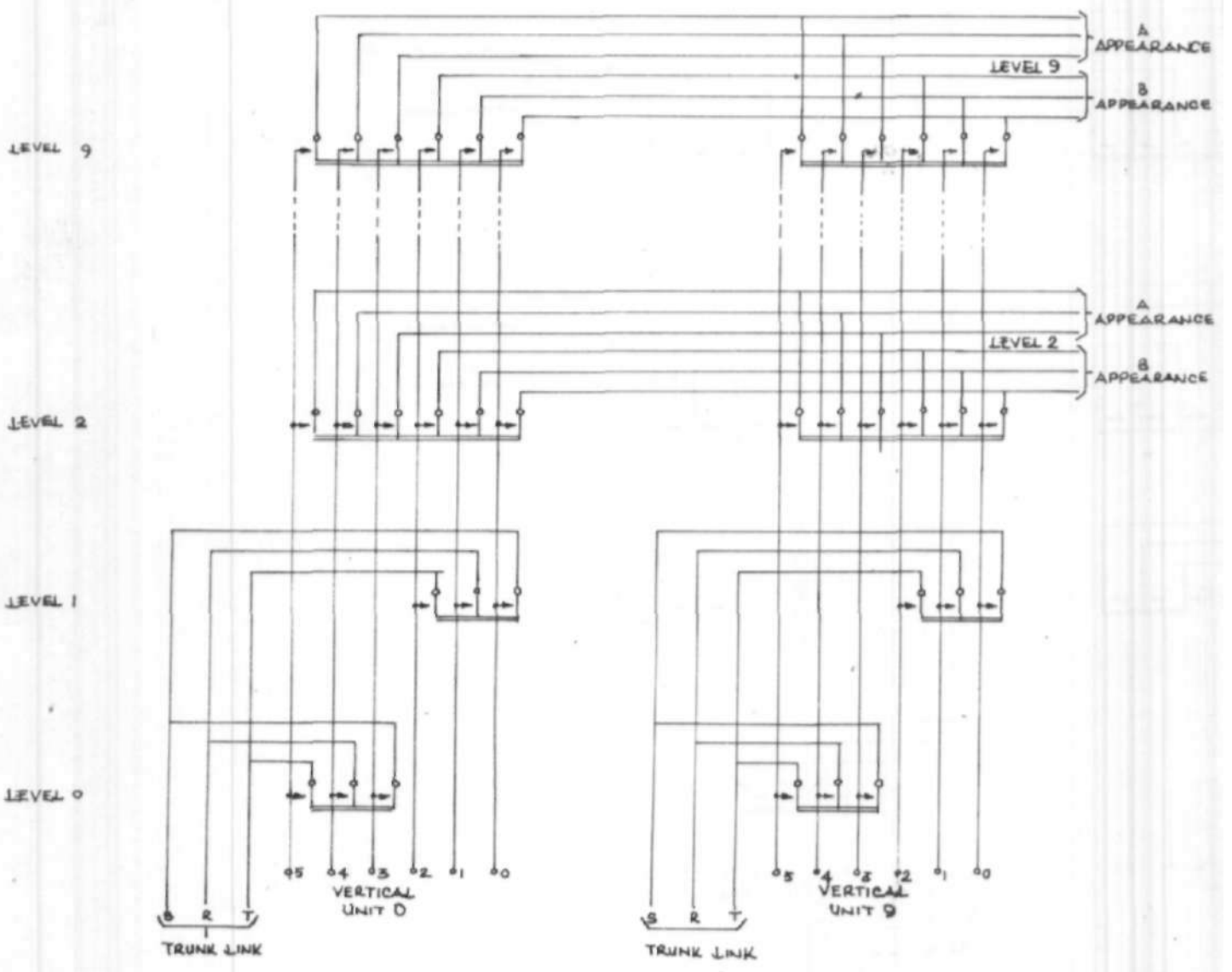
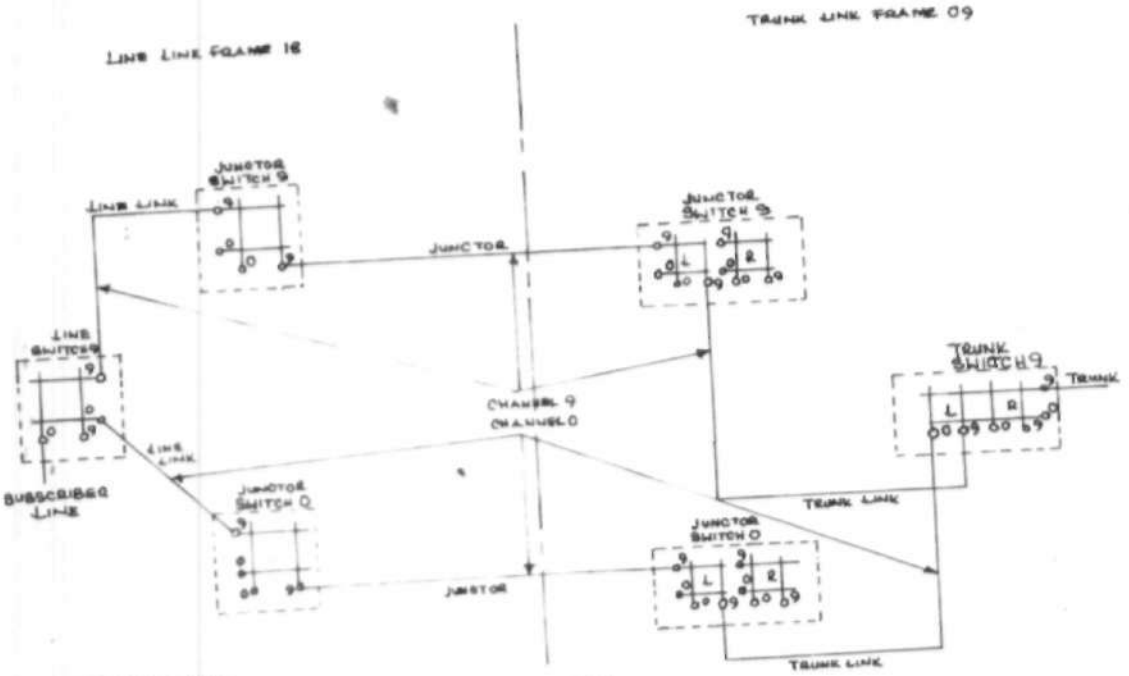


Fig. 5·9 – Switch Arranged for 16 Trunk Appearances on Trunk Link Frame



NOTE
THE CHANNEL NUMBER ALWAYS CORRESPONDS TO THE LINE SWITCH HORIZONTAL NUMBER OF THE LINE LINK, THE TRUNK SWITCH VERTICAL NUMBER OF THE TRUNK LINK, AND THE JUNCTOR SWITCH NUMBER. ALL OTHER ELEMENTS ARE NUMBERED INDEPENDENTLY OF CHANNEL NUMBER CONSIDERATIONS

FIG. 10(1)
CHANNELS FOR 20 LINE LINK - 10 TRUNK LINK FRAMES

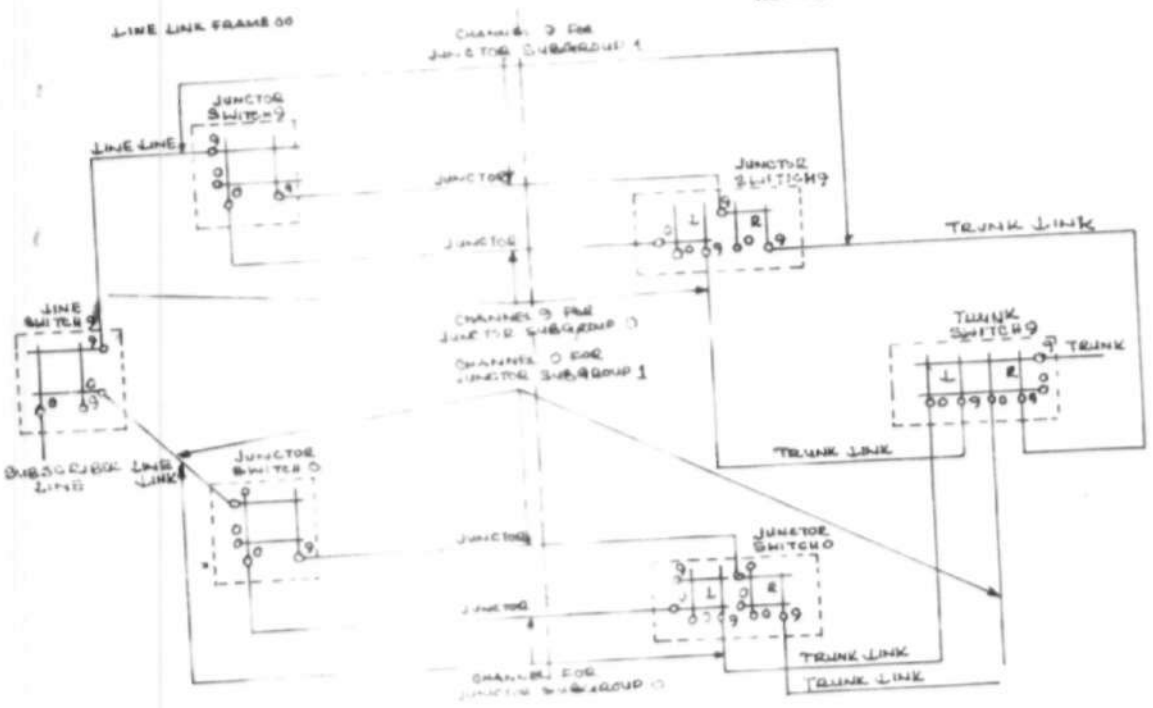


Fig. 10(2) Channel Distribution - Line Link to Trunk Link Frames

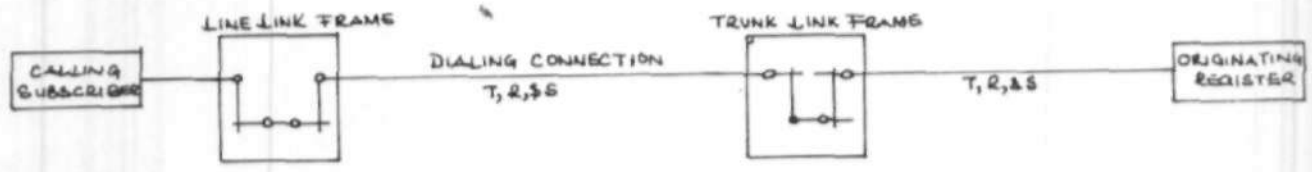


Fig 5-10 - Dialing Connection

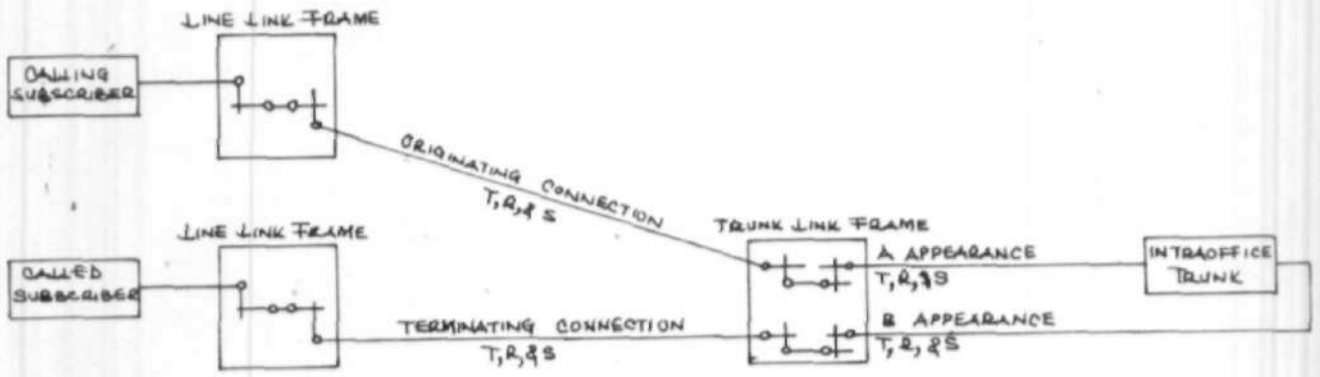


Fig. 5-11 – Intraoffice Trunk Connection

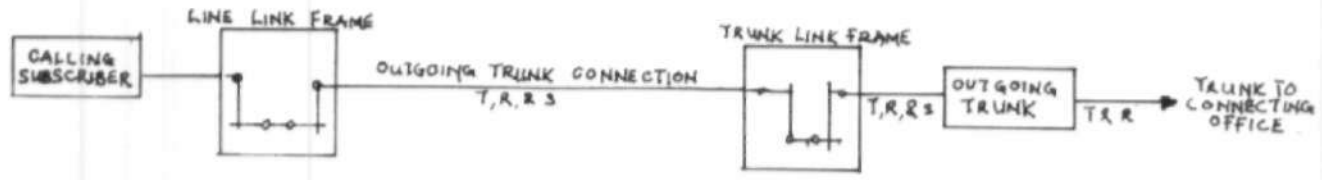


Fig. 5.12- Outgoing Trunk Connection

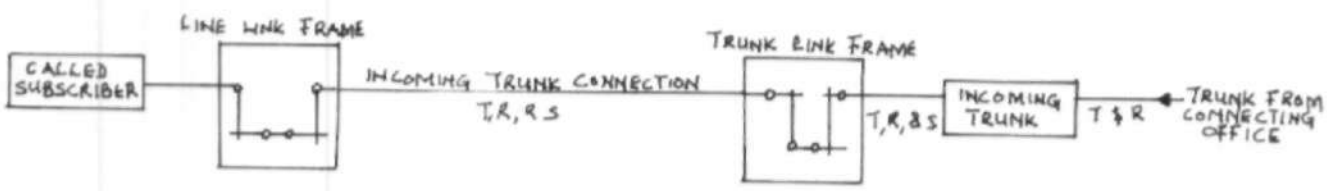


Fig. 5.13- Incoming Trunk Connection

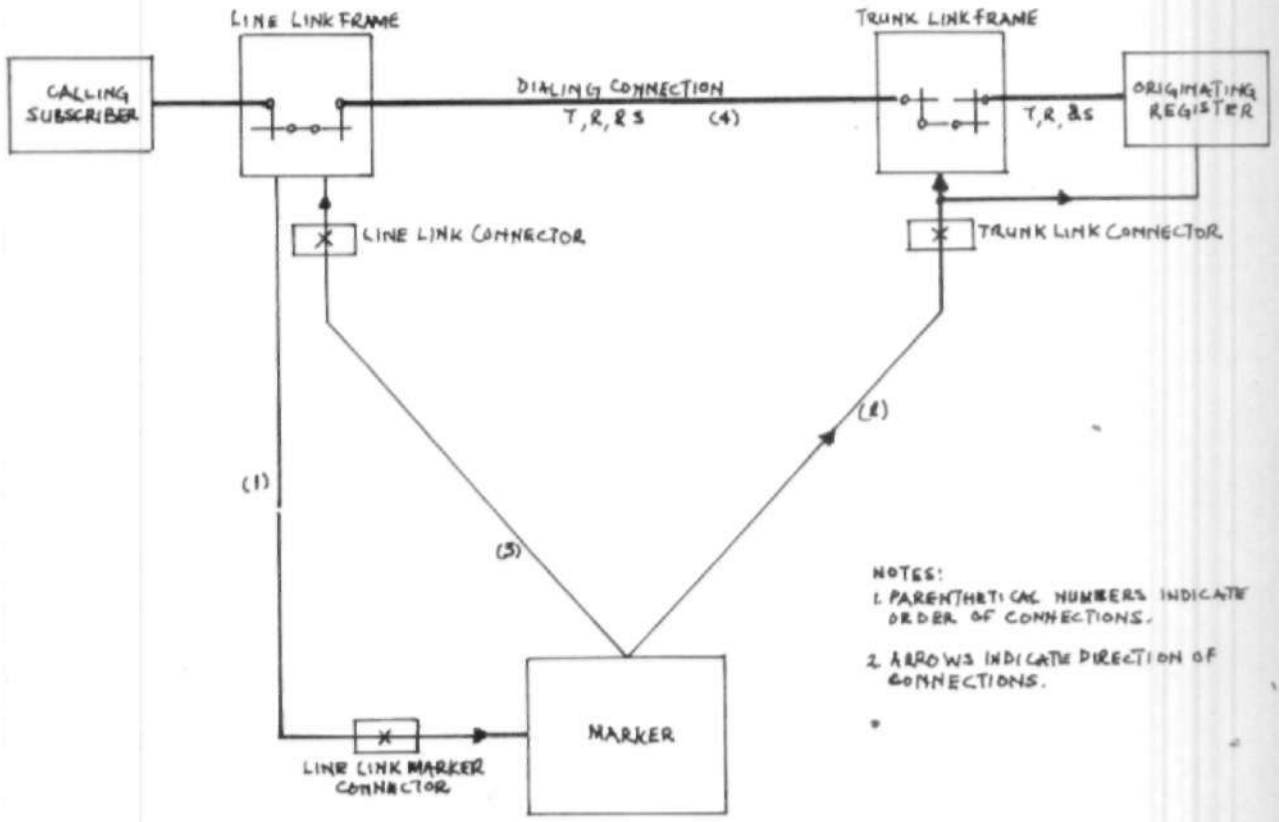
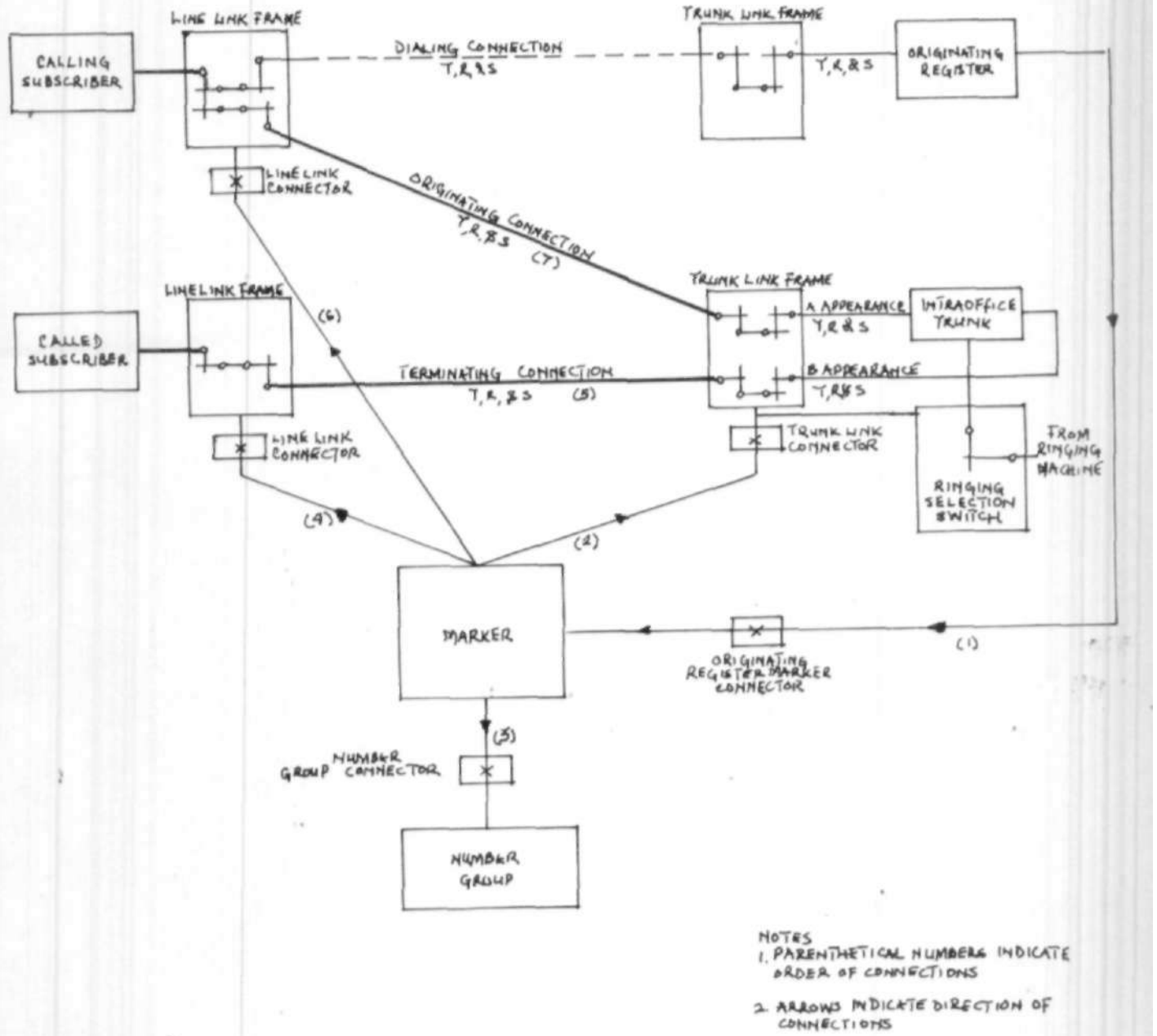


Fig. 5.14 - Establishing Dialing Connection



NOTES
1. PARENTHETICAL NUMBERS INDICATE ORDER OF CONNECTIONS
2. ARROWS INDICATE DIRECTION OF CONNECTIONS

Fig. 5-19-Establishing Intraoffice Trunk Connection.

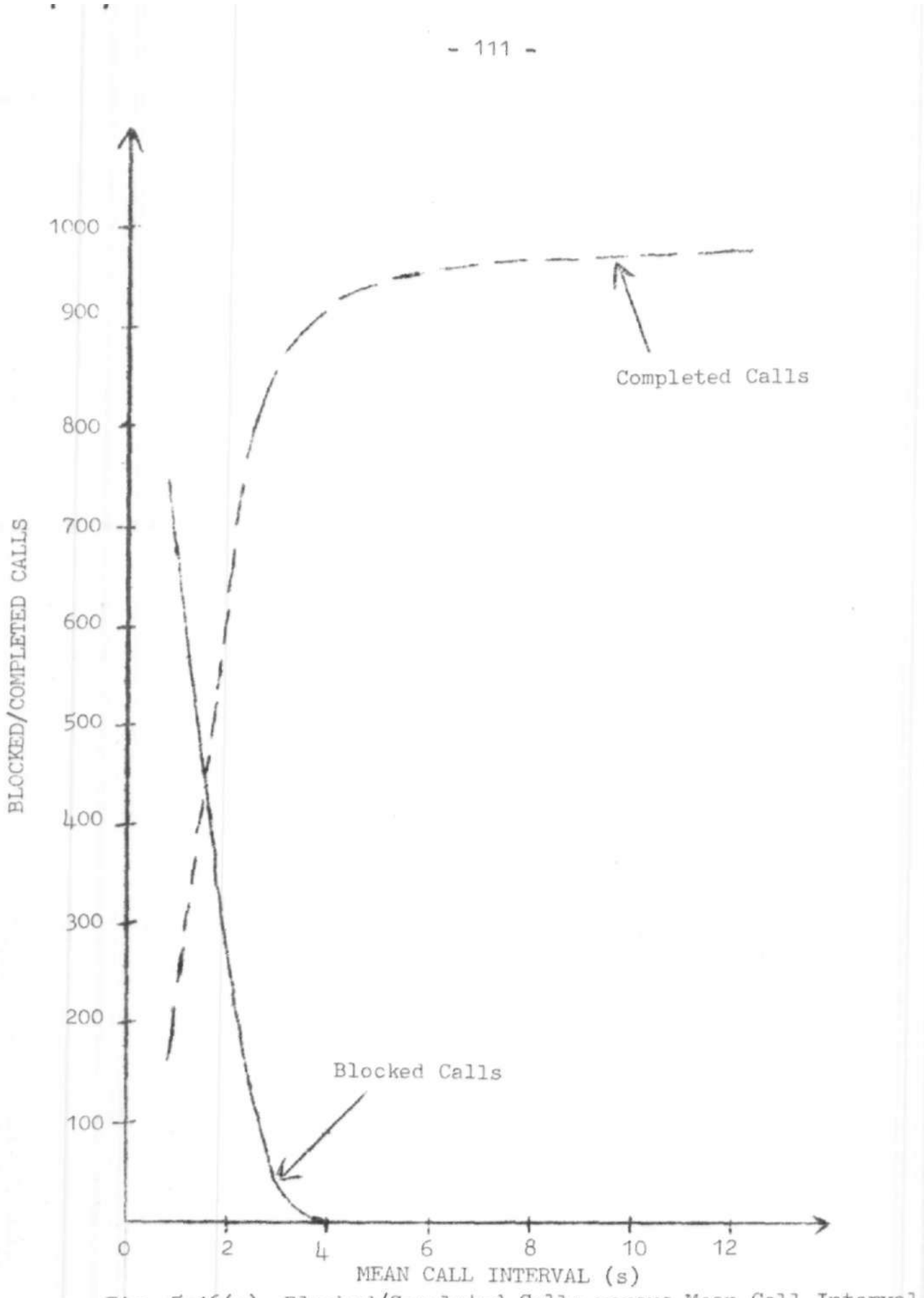


Fig. 5.16(a) Blocked/Completed Calls versus Mean Call Interval

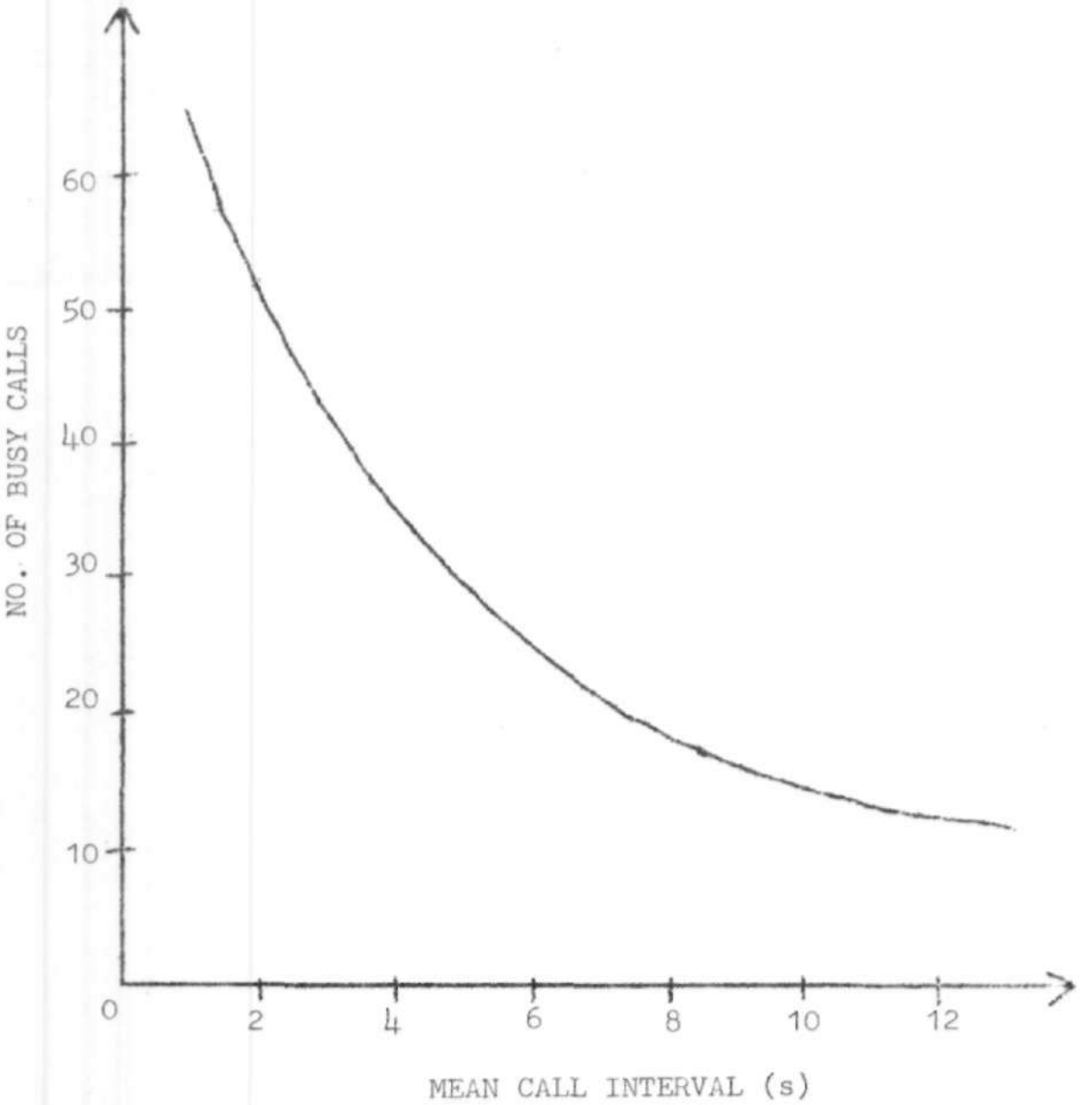


Fig. 5.16(b) No. of Busy Calls versus Mean Call Interval

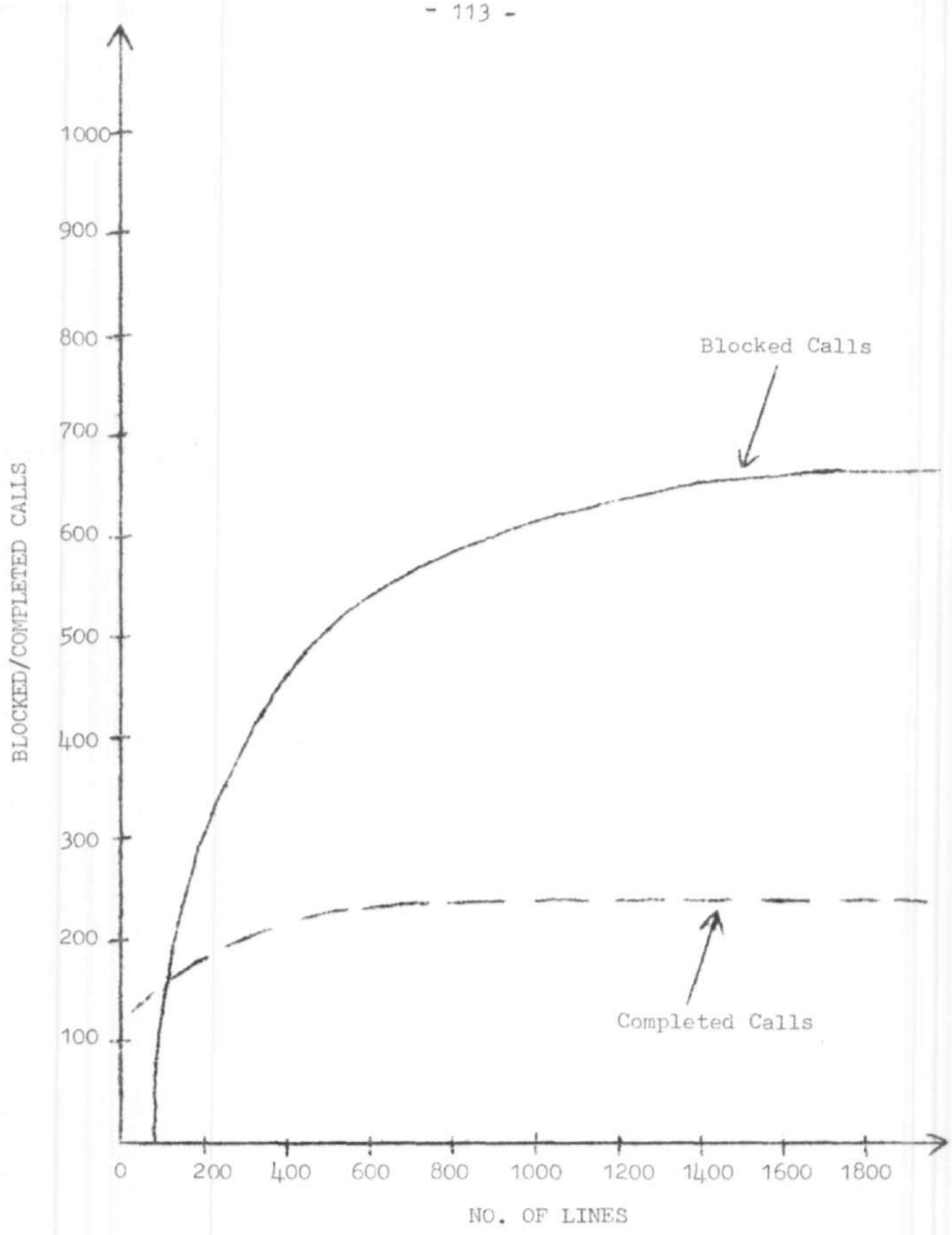


Fig. 5.16(c) Blocked/Completed Calls versus No. of Lines
(Mean Call Interval = 1 s)

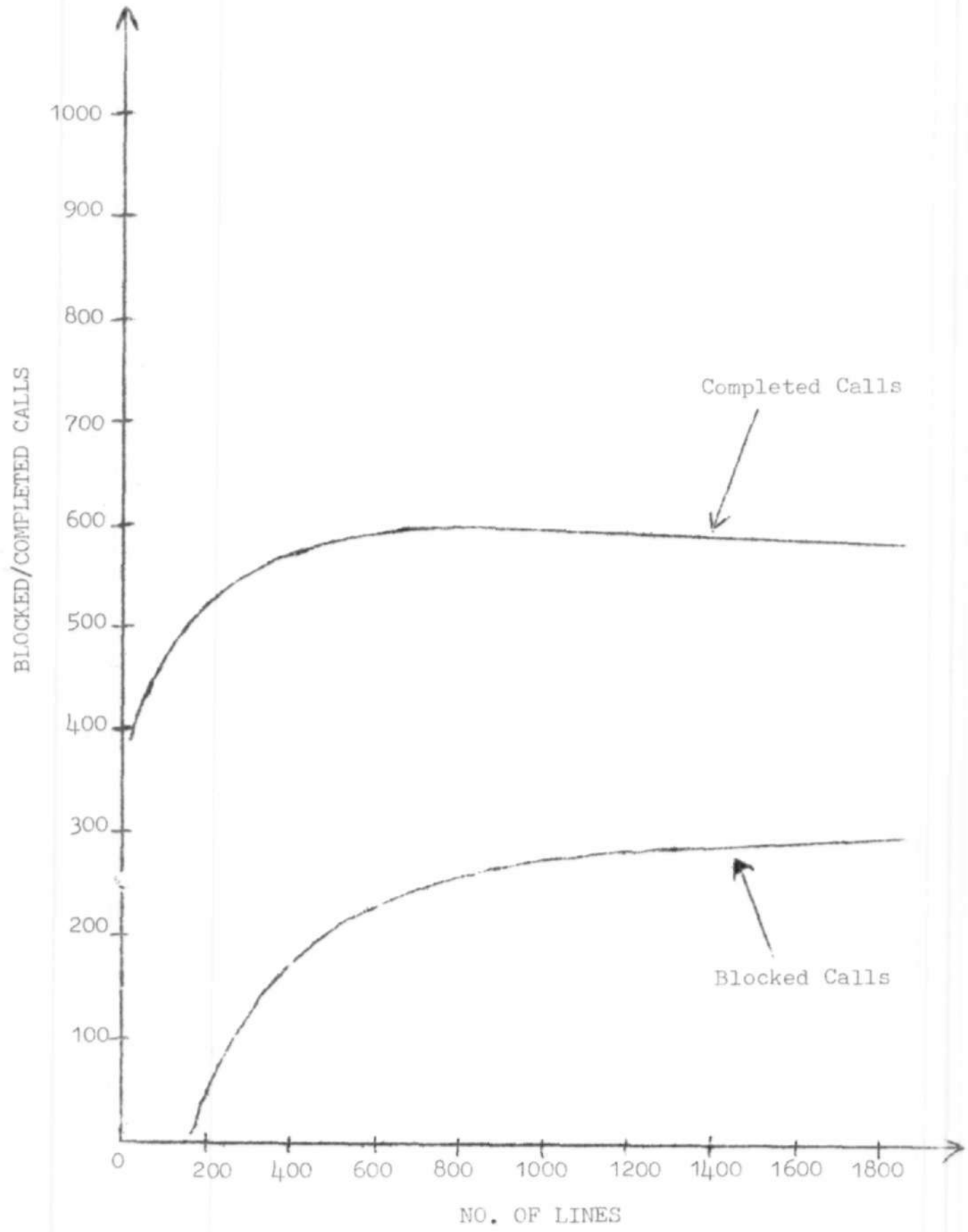


Fig. 5.16(d) Blocked/Completed Calls versus No. of Lines
(Mean Call Interval = 2 s)

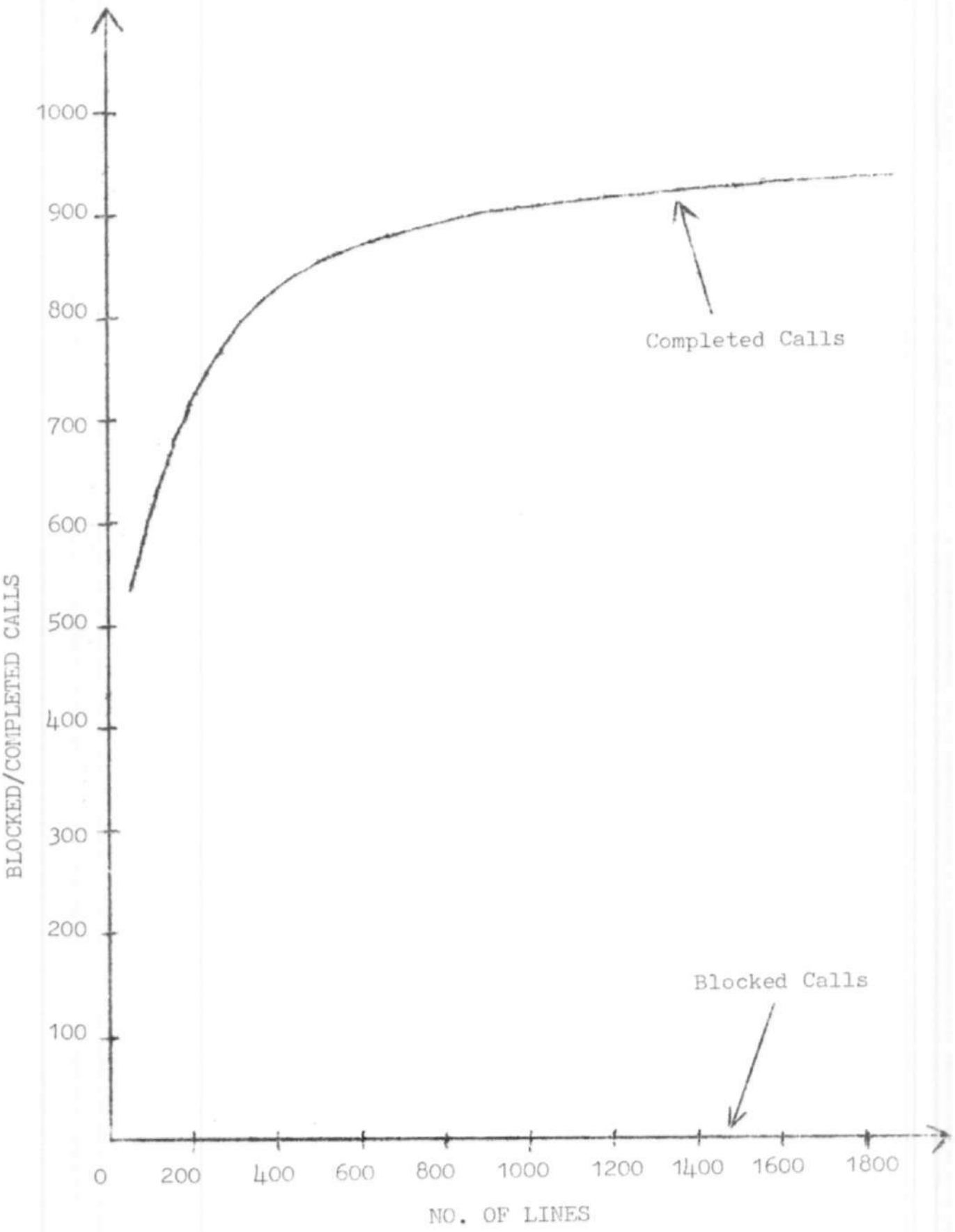


Fig. 5.16(e) Blocked/Completed Calls versus No. of Lines
(Mean Call Interval = 4 s)

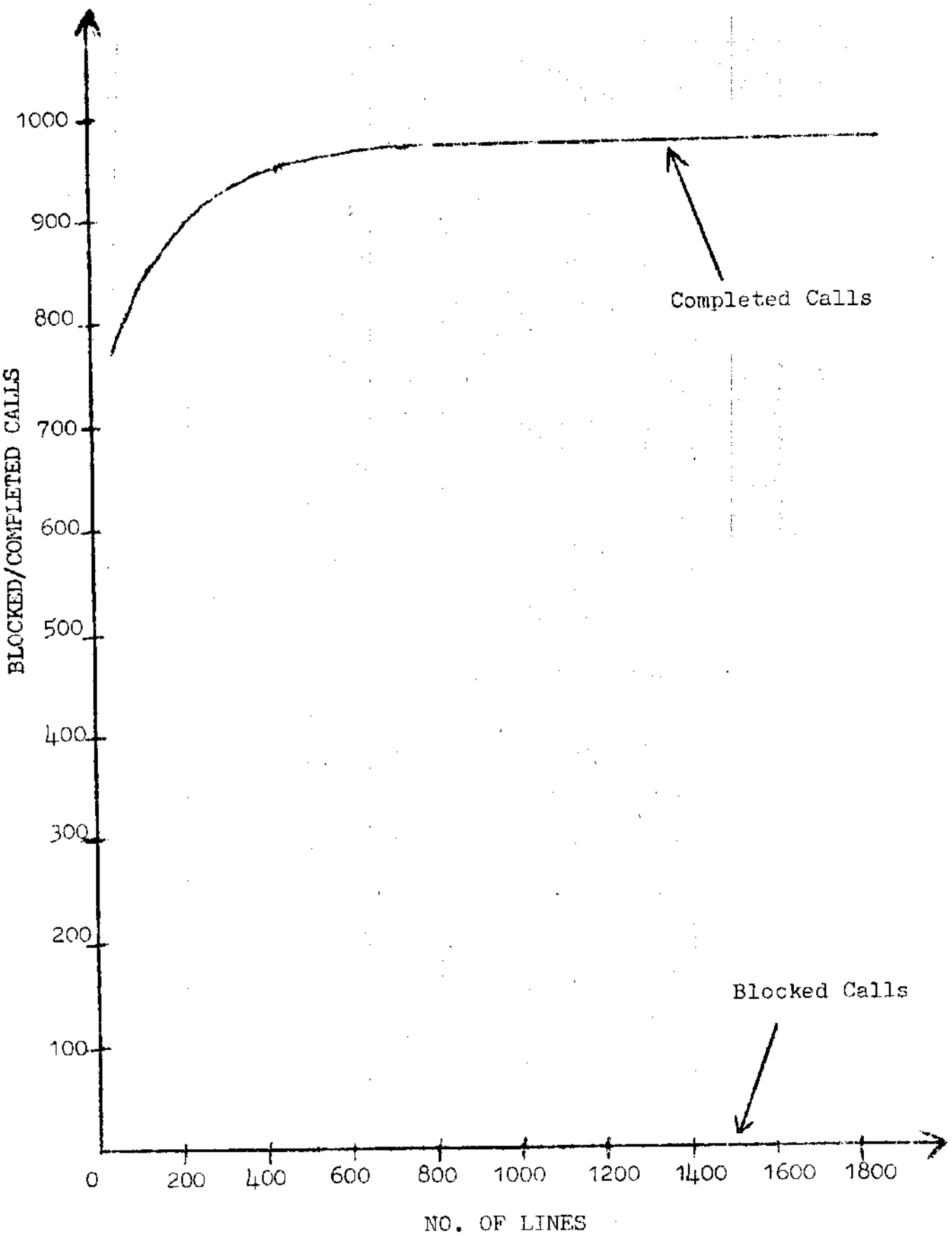


Fig. 5.16(f) Blocked/Completed Calls versus No. of Lines
(Mean Call Interval = 12 s)

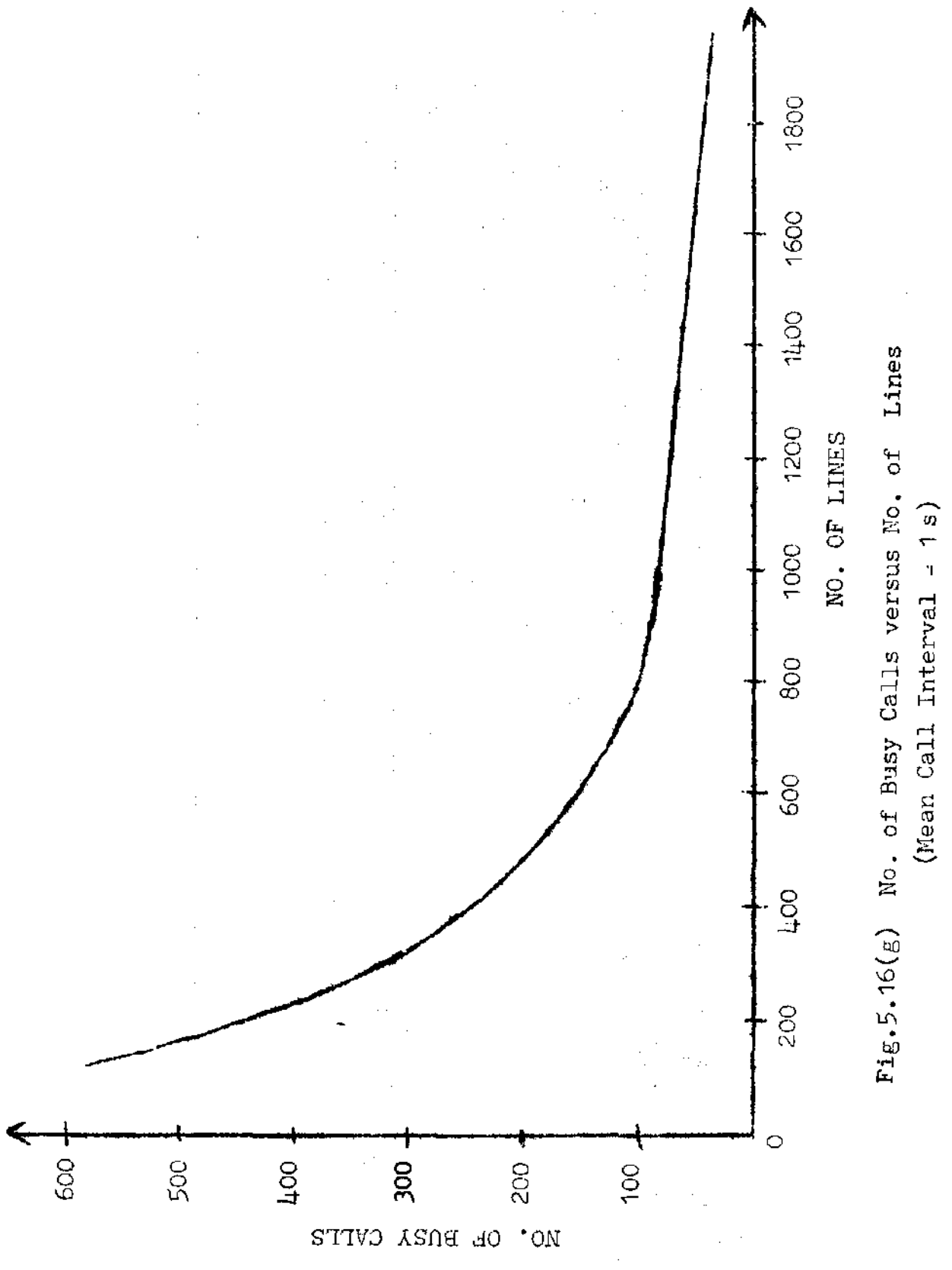


Fig.5.16(g) No. of Busy Calls versus No. of Lines
(Mean Call Interval - 1 s)

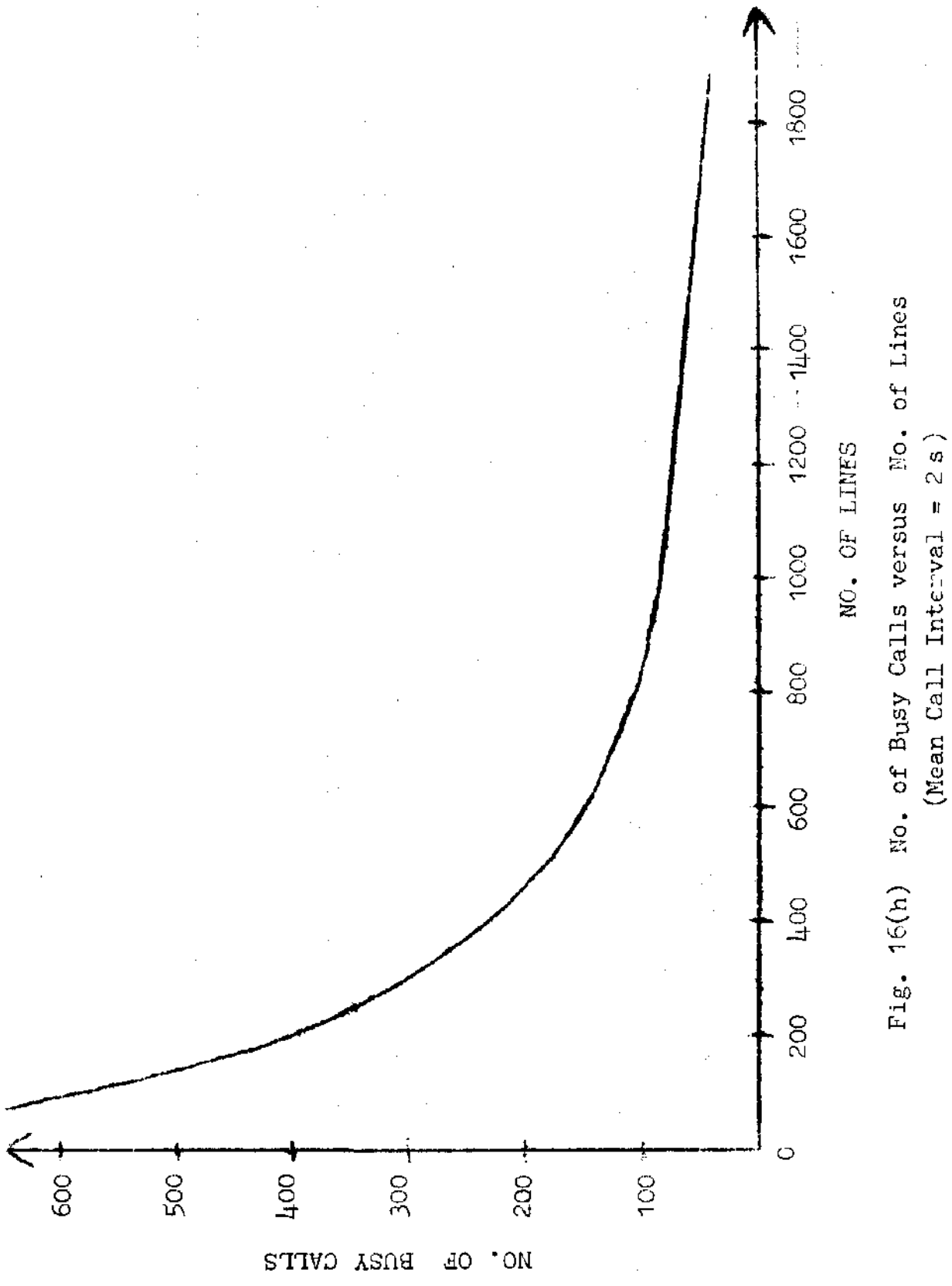


Fig. 16(h) No. of Busy Calls versus No. of Lines
(Mean Call Interval = 2 s)

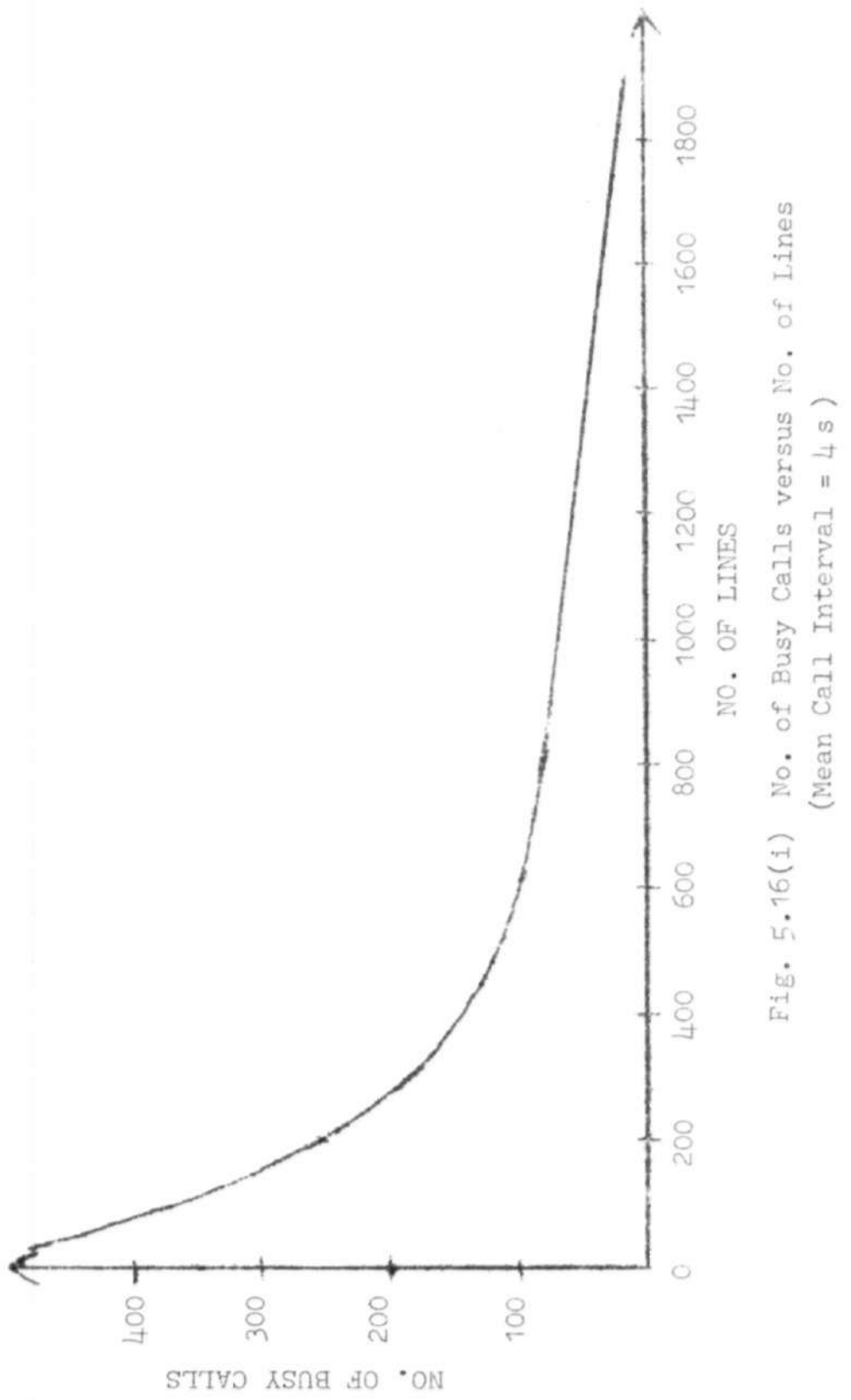


Fig. 5.16(i) No. of Busy Calls versus No. of Lines
(Mean Call Interval = 4 s)

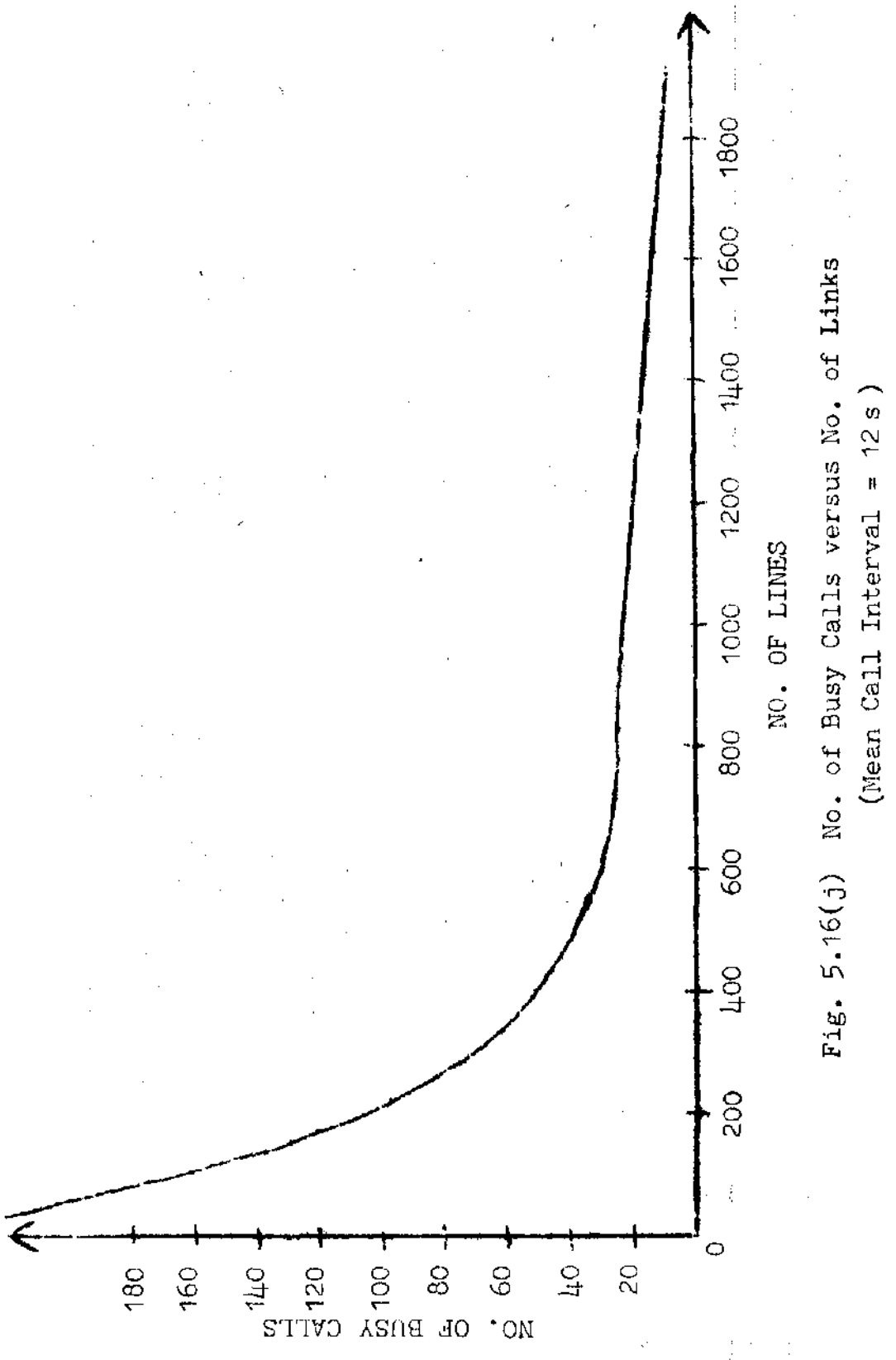


Fig. 5.16(j) No. of Busy Calls versus No. of Links
(Mean Call Interval = 12 s)

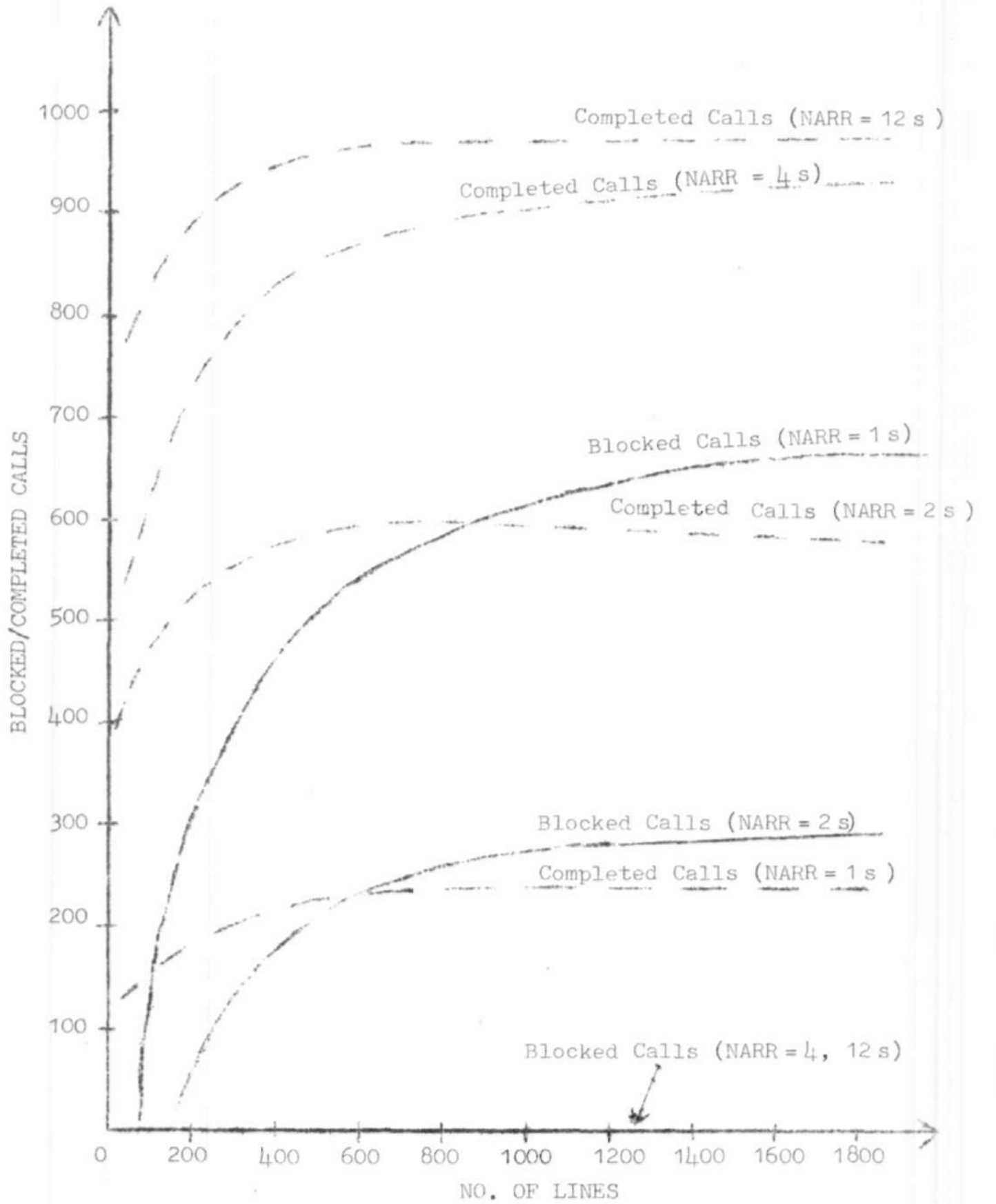


Fig. 5.17 Behaviour of Blocked/Completed Calls with variations in number of lines for different mean call intervals (NARR).

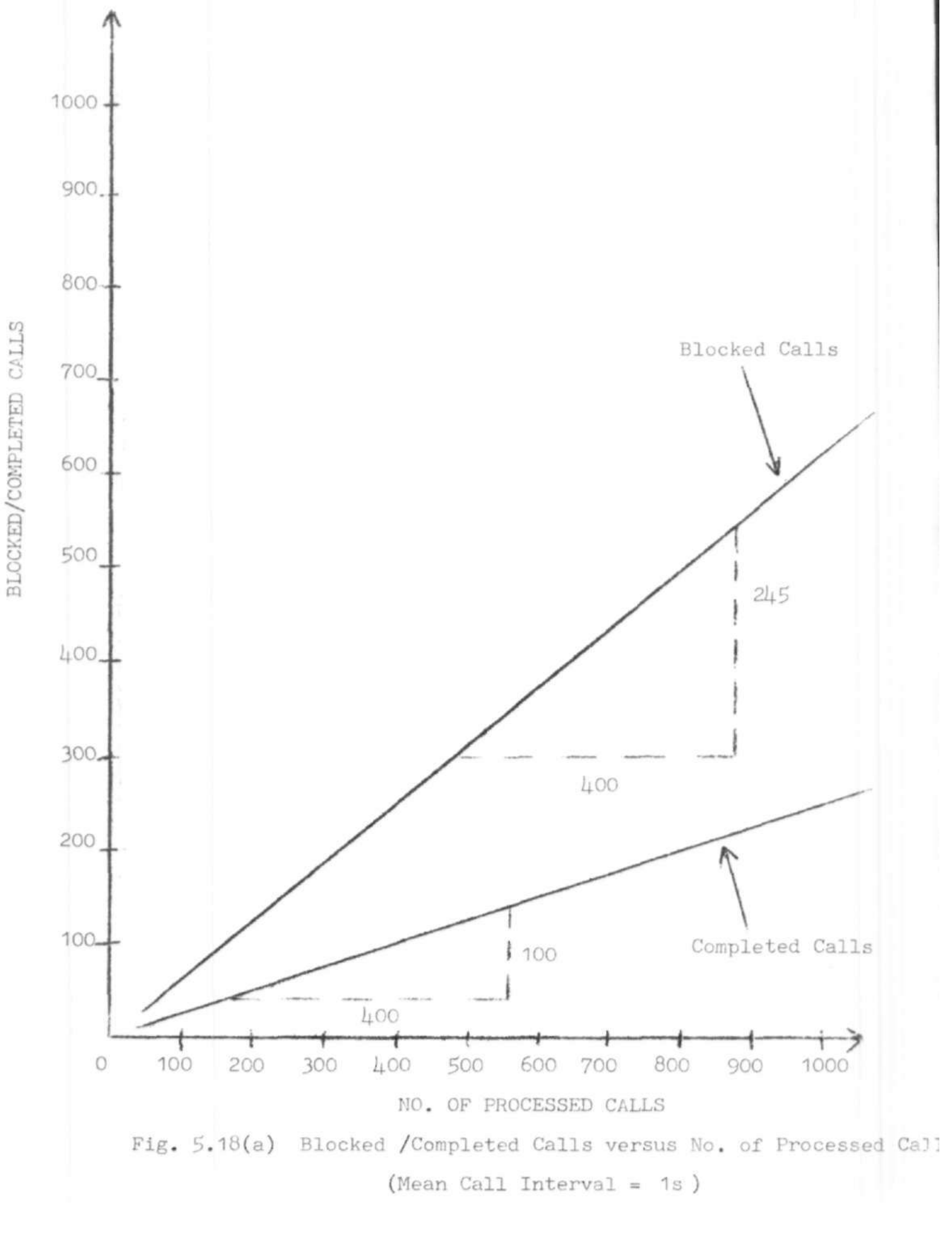


Fig. 5.18(a) Blocked /Completed Calls versus No. of Processed Call

(Mean Call Interval = 1s)

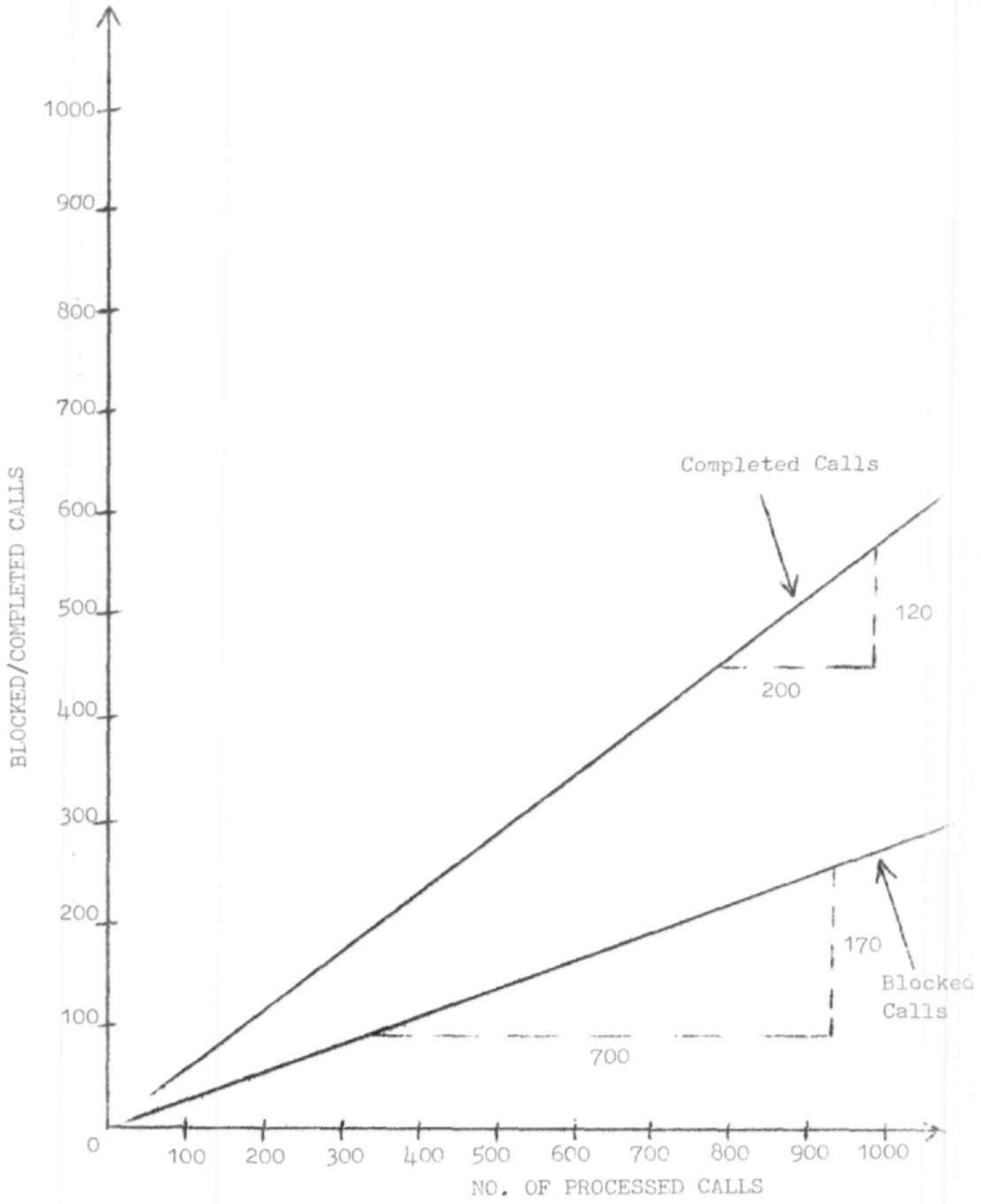


Fig. 5.18(b) Blocked/Completed Calls versus No. of Processed Calls
(Mean Call Interval = 2 s)

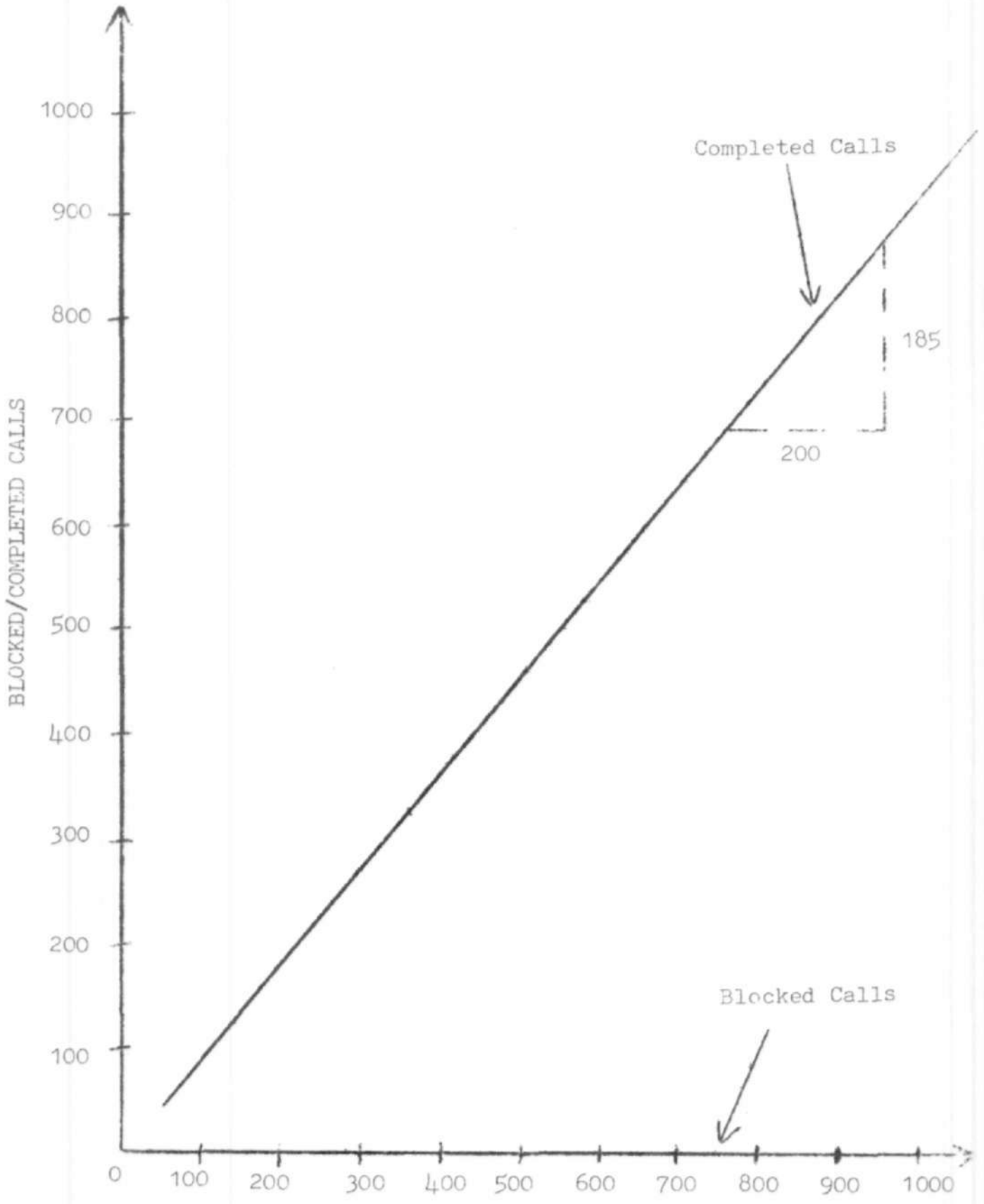


Fig. 5.18(c) Blocked/Completed Calls versus No. of Processed Calls
(Mean Call Interval = 4 s)

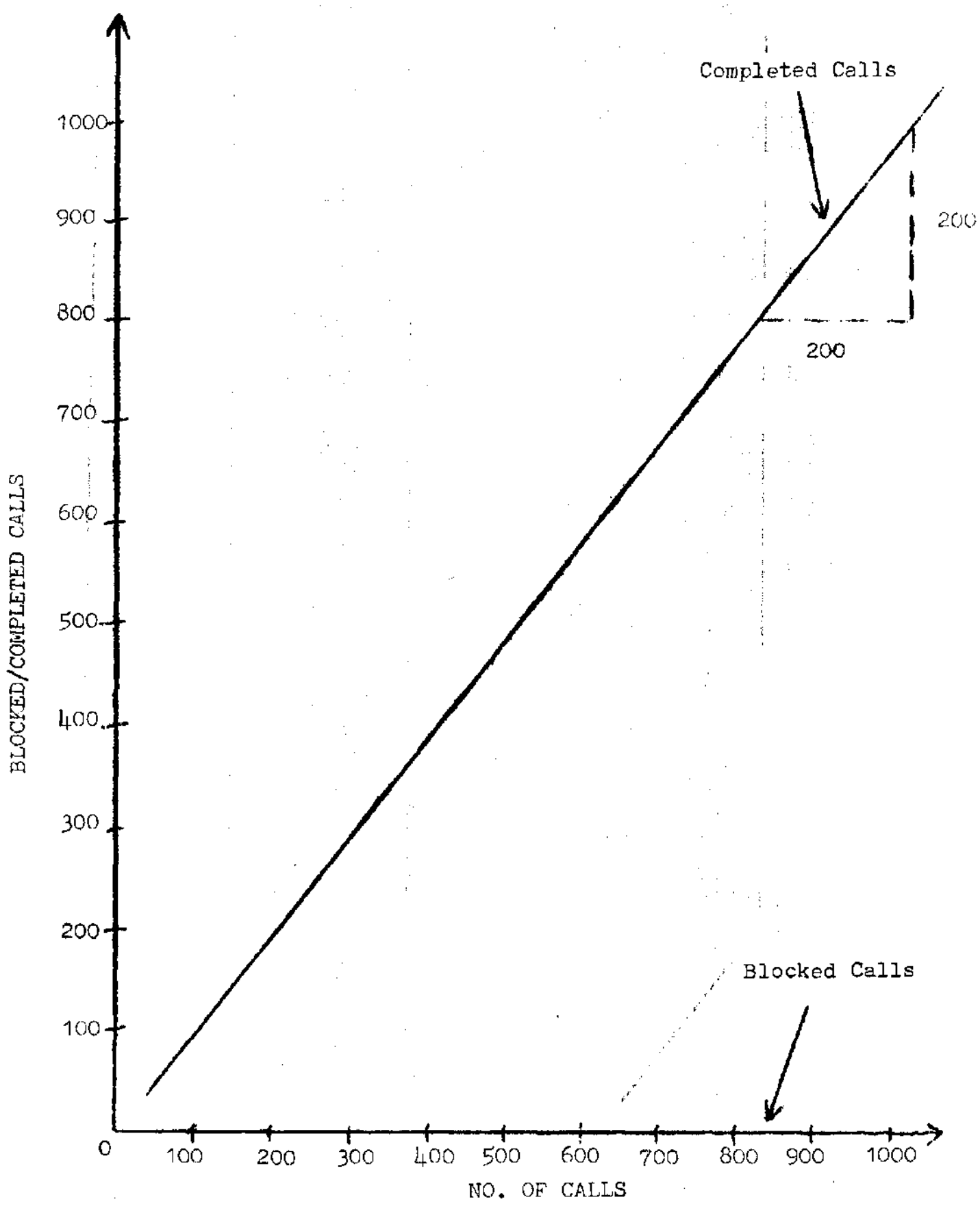


Fig. 5.18(d) Blocked/Completed Calls versus No. of Processed Calls
(Mean Call Interval = 12 s)

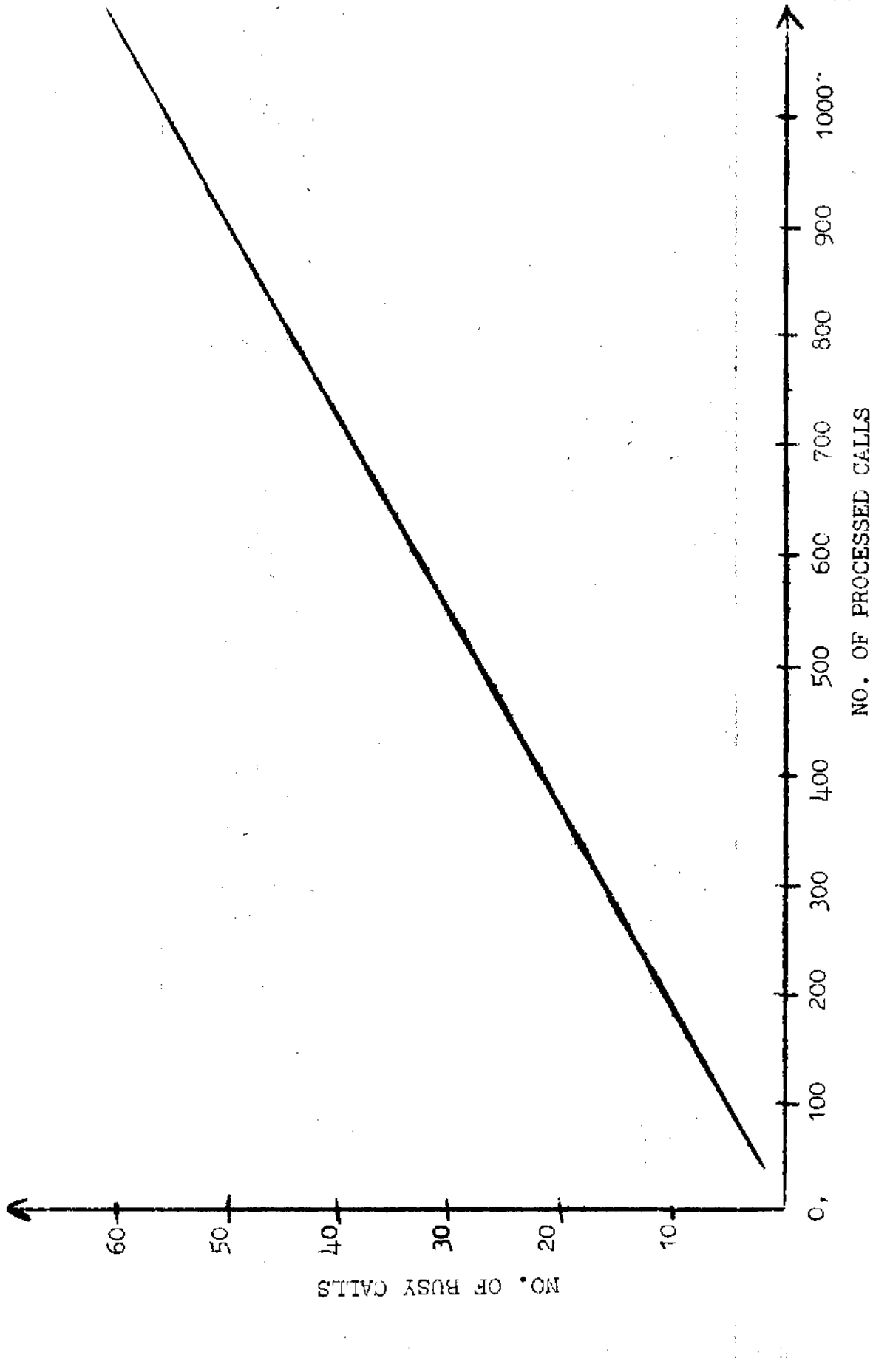


Fig. 5.18(e) No. of Busy Calls Versus No. of Processed Calls
(Mean Call Interval : 1s)

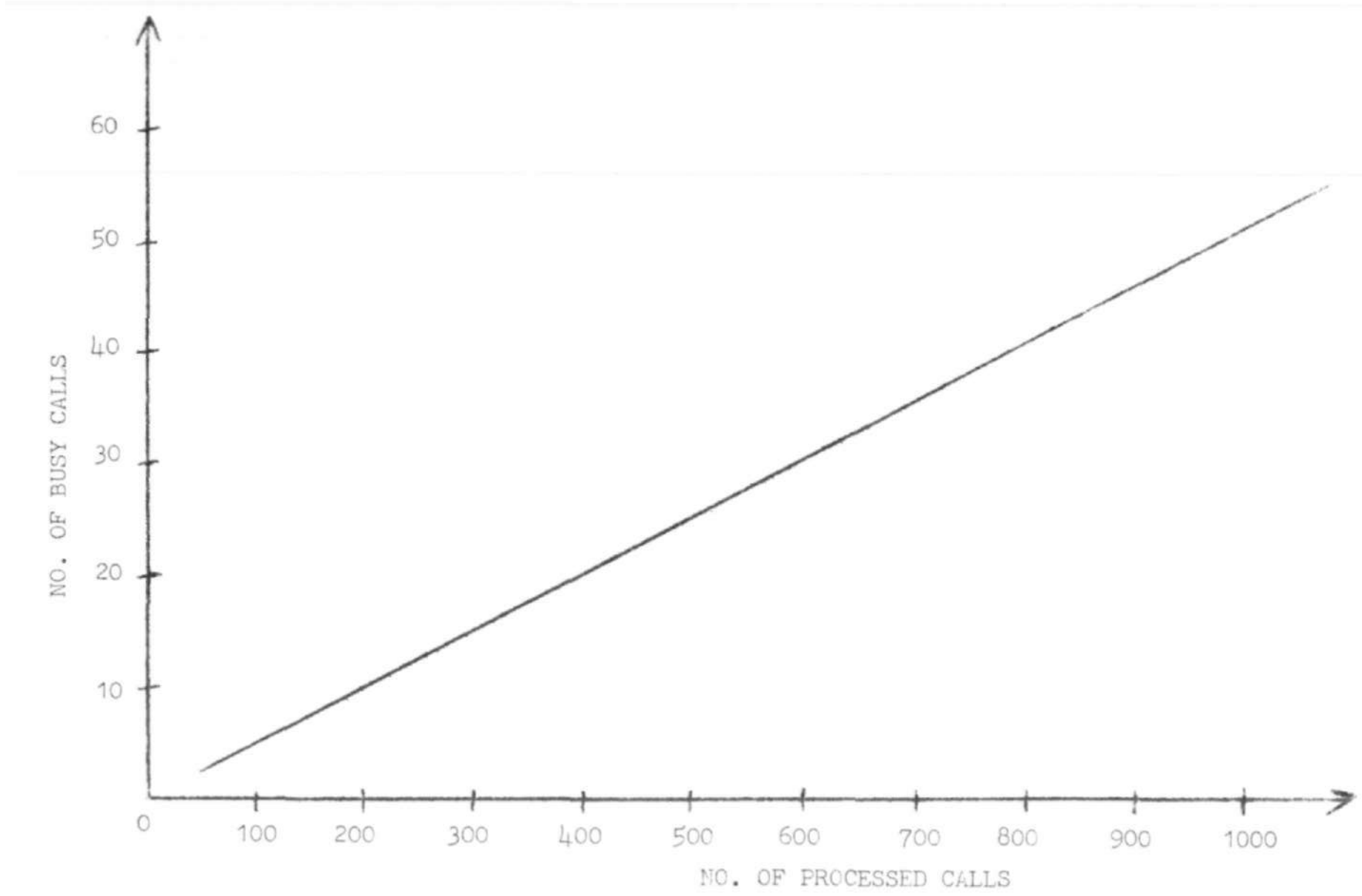


Fig. 5.18(f) No. of Busy Calls versus No. of Processed Calls
(Mean Call Interval = 2 s)

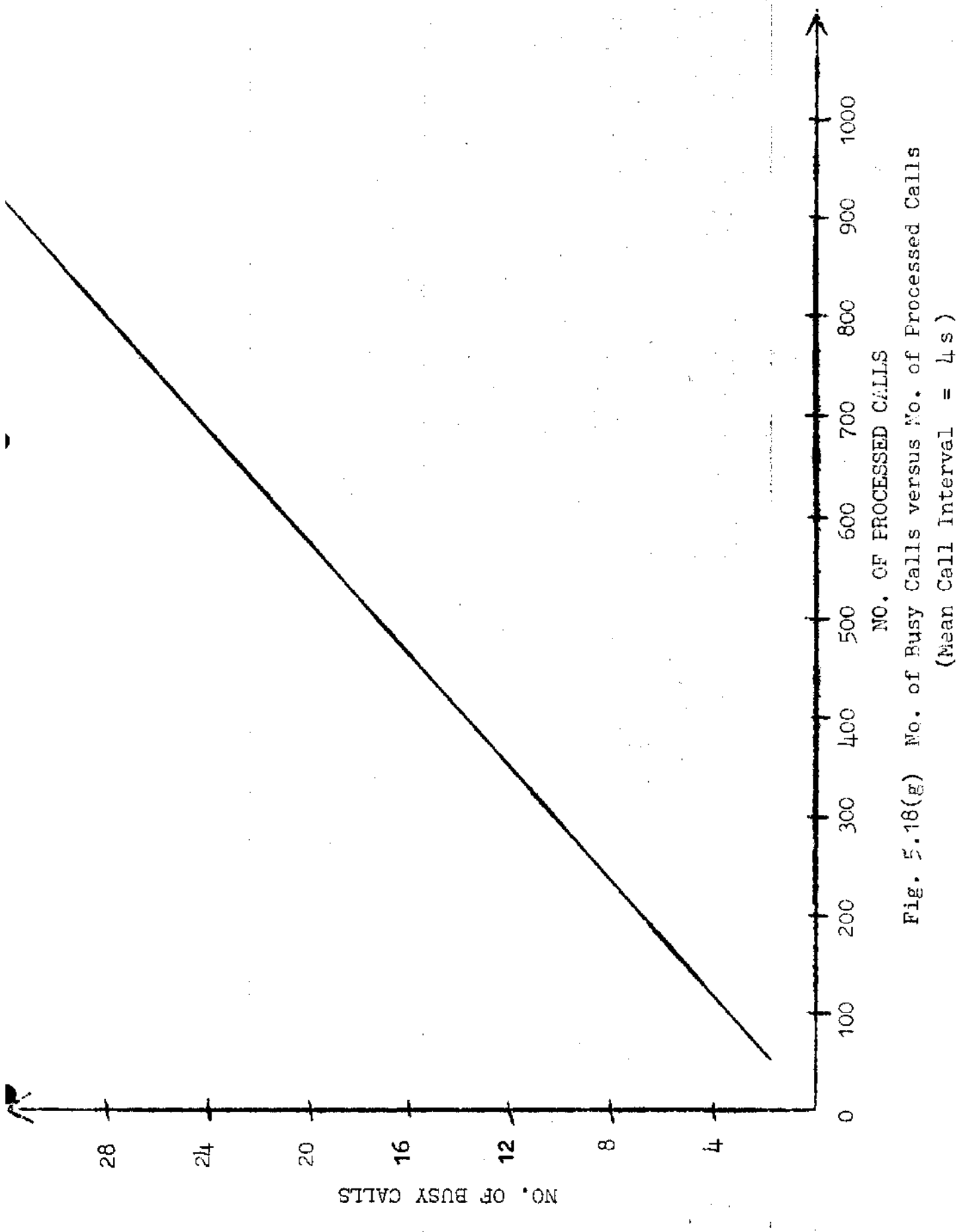


Fig. 5.18(g) No. of Busy Calls versus No. of Processed Calls
(Mean Call Interval = 4 s)

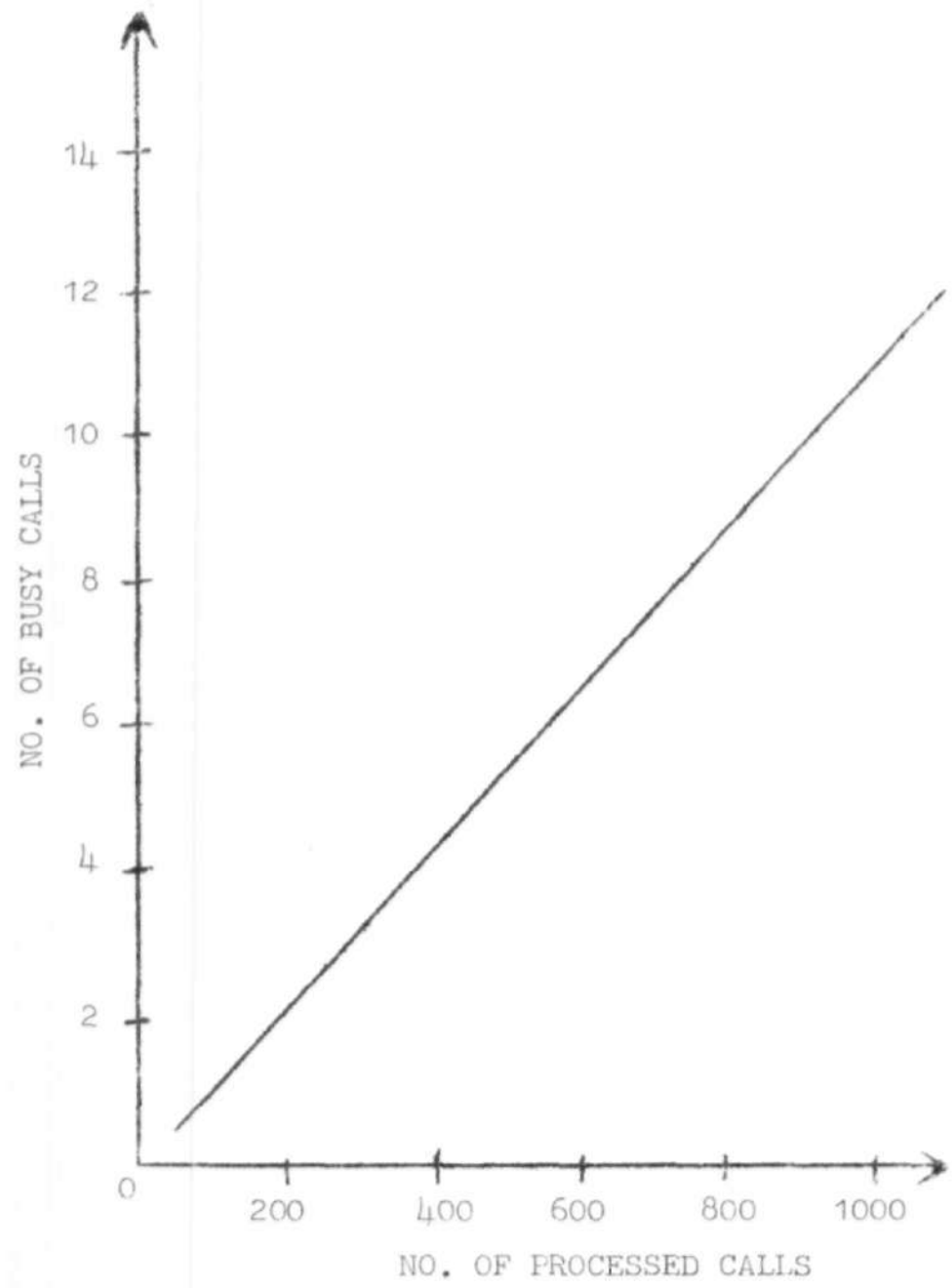


Fig. 5.18(h) No. of Busy Calls versus No. of Processed Calls
(Mean Call Interval = 12 s)

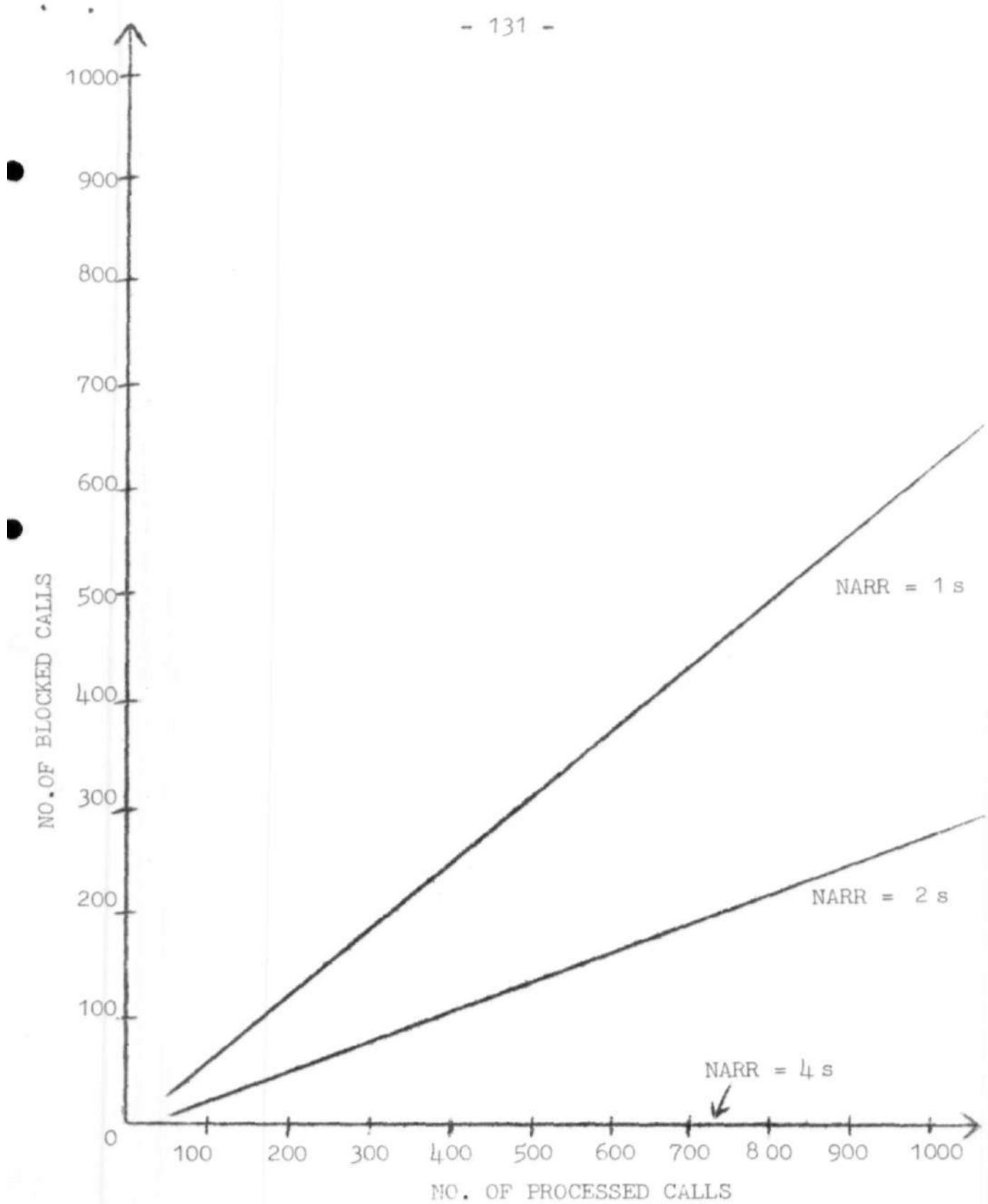


Fig.5.19 Blocked Calls versus Processed Calls for different values of Mean Call Interval (NARR)

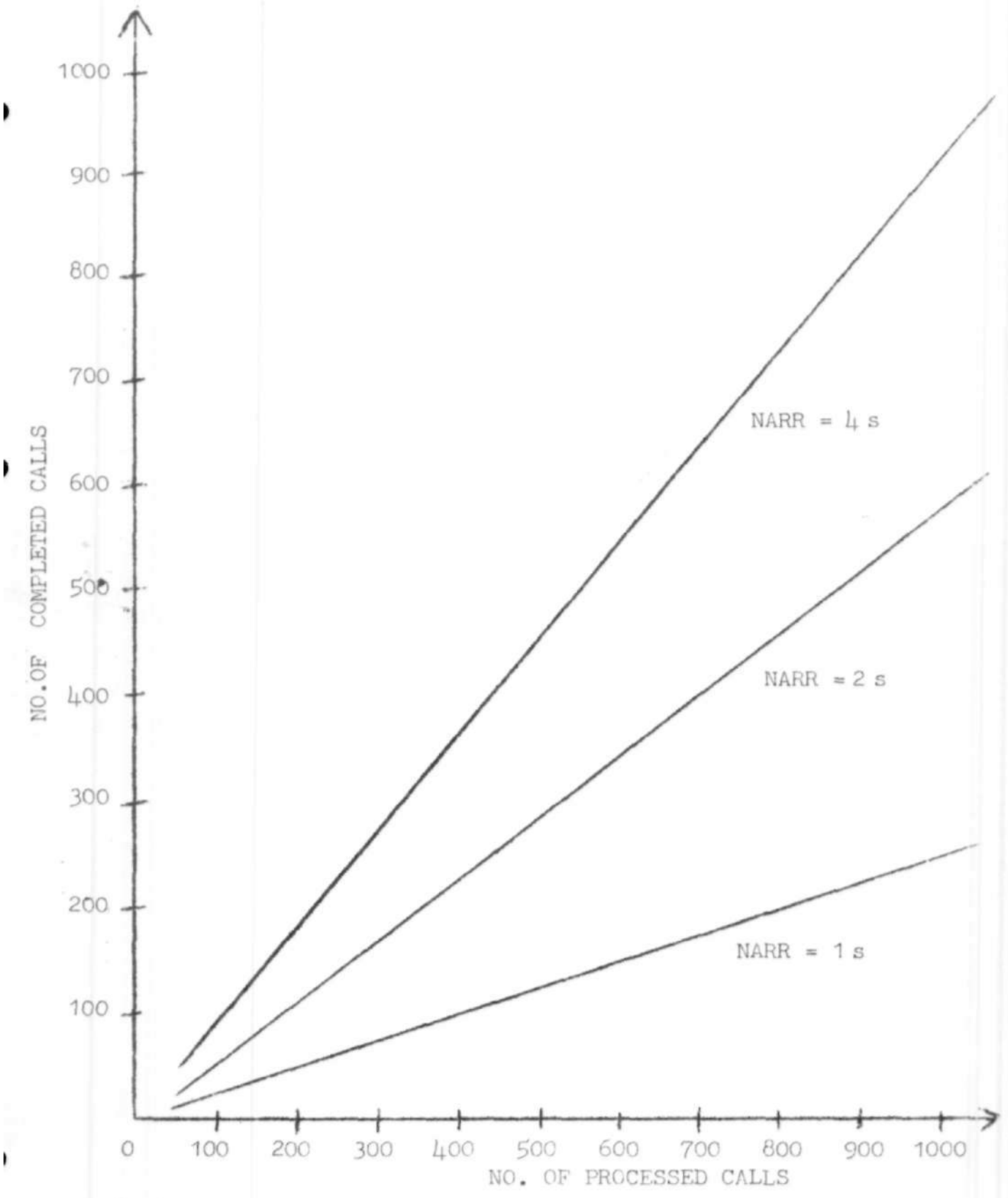


Fig. 5.20 Completed Calls versus Processed Calls for different values of Mean Call Interval (NARR)

CHAPTER SIX

NETWORK SIMULATION: SIMULATION OF TRUNK CALLS

6.1 INTRODUCTION

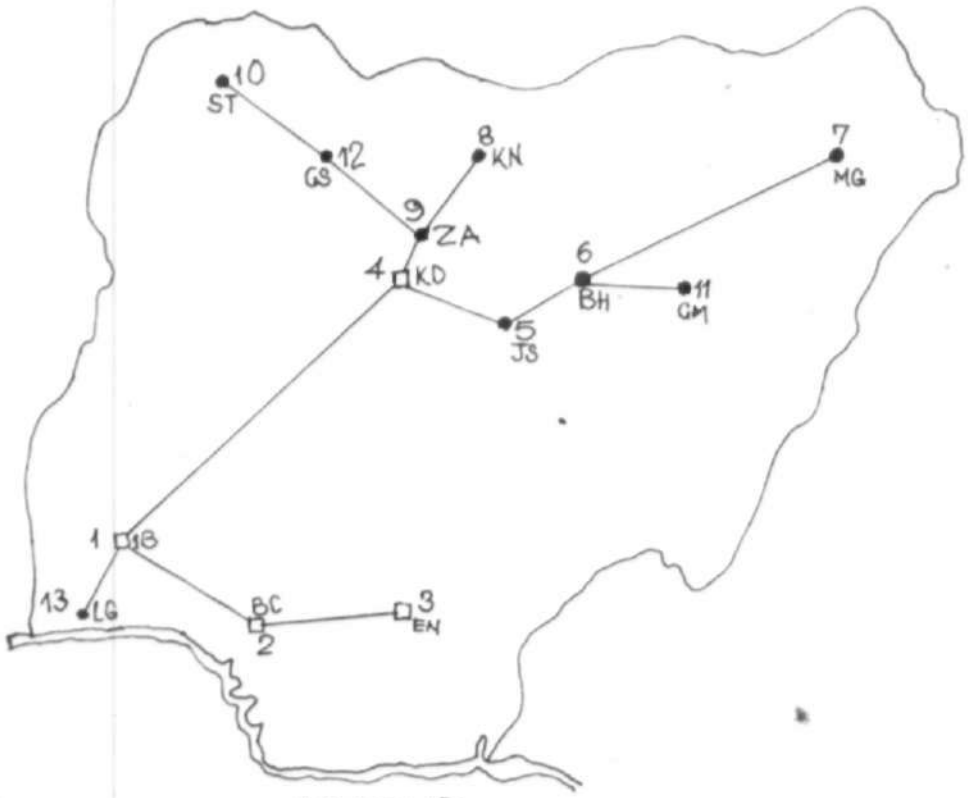
It may have been observed that the simulation programs discussed so far deal with calls between subscribers connected to the same exchange. Such calls are sometimes referred to as intra-office calls, as has already been mentioned (Section 5.4.1).

This chapter describes the program used for the simulation of calls between subscribers connected to different exchanges in different cities.

In the present telephone network in Nigeria, all calls originating from any city in the northern part of the country and going to another northern city must pass through the Kaduna exchange. Such calls are called TANDEM calls. All calls originating from any northern city and going to any city in the southern part of the country must also pass through the Kaduna exchange. The Kaduna exchange is thus known as the "HOMING" exchange for all northern exchanges. In this study, only TANDEM calls will be considered. Fig. 6.1 shows the telephone network in the Northern States.

At the "homing", Kaduna exchange, each city has been allocated a number of incoming and outgoing trunks (or channels) where the number of incoming or outgoing trunks for a given city may not be the same.

The simulation program has been designed to work with either a step-by-step or crossbar exchange, or both. A call may originate from a step-by-step exchange and terminate on a



LEGEND

□ — HOMING CENTRES
• — PRIMARY CENTRES
— — ROUTES

LG — LAGOS
IB — IBADAN
BC — BENIN CITY
EN — ENUGU
KD — KADUNA
JS — JOS
BH — BAUCHI
GM — GOMBE
MG — MAIDUGURI
ZA — ZARIA
KN — KANO
GS — GUSAU
ST — SOKOTO

Fig 6.1 The Telephone Network in the Northern States of Nigeria

crossbar exchange, or vice versa. A call may also originate from and terminate on the same type of exchange, step-by-step or crossbar. The simulation program has been designed to meet each of these conditions. The originating exchange type is fixed by the value placed in the location called KORGX in the program. Its value is 1 if the originating exchange is step-by-step and 2 if it is crossbar. The terminating exchange type is fixed by the value placed in the location called KTERMX in the program. Its value is 1 for a step-by-step exchange and 2 if exchange is crossbar.

The values of the allocated incoming and outgoing trunks in the transit exchange in so far as the originating and terminating exchanges involved in the simulation are concerned, are respectively the variables MTRKAB and MTRKBB in the program. The appropriate values for KORGX, KTERMX, MTRKAB and MTRKBB are set before the simulation run commences. The simulation program is code-named SIMTEX 3.

SIMTEX 3 is then modified so that the performance of the system is observed as various parameters such as the number of trunks at the homing exchange and the number of lines in the terminating exchange are separately varied.

A brief description of the modes of operation of the step-by-step and crossbar exchanges in the making of trunk calls follows.

6.2 MAKING TRUNK CALLS: BRIEF DESCRIPTION

6.2.1 Establishing Outgoing Trunk Connection

(a) Step-by-step Exchange

A separate set of selectors is provided in the step-by-step

exchange for the making of outgoing, trunk calls. These selectors are referred to as outgoing Trunks. In the old Zaria Exchange, 75 outgoing trunks were provided. The exchange recognizes from the dialled code number that the desired call is a trunk call. As soon as the code has been dialled, the calling line is routed, via its uniselector, to an outgoing trunk, if there is an idle one. If there is none, an engaged tone is returned to the calling subscriber. As soon as an idle trunk has been selected, a proceed-to-send-address tone is returned to the caller who now dials the required subscriber number. The dialled digits are received by the distant exchange.

(b) Crossbar Exchange:

When the subscriber has dialled the called number, the equipment location and class of service of the calling subscriber and the number of line-link frame used in the dial connection are obtained and stored as described in Chapter 5. The called number is also stored. (See Fig. 6.2. connection 1).

From the called number, the marker learns that the call is a trunk call and, therefore, requires an outgoing trunk job and also what type of pulsing the destination exchange requires (multifrequency dial, revertive, or panel call indicator). By means of the outgoing sender connector, the marker gains access to an outgoing sender that sends the type of pulses which the connecting (terminating) exchange receives. (connection 2).

When the outgoing sender connector is engaged, the marker, by means of the trunk-link connector, gains access to an idle trunk-link frame and an outgoing trunk on that frame (connection 3). The sender is now connected to the marker through the outgoing

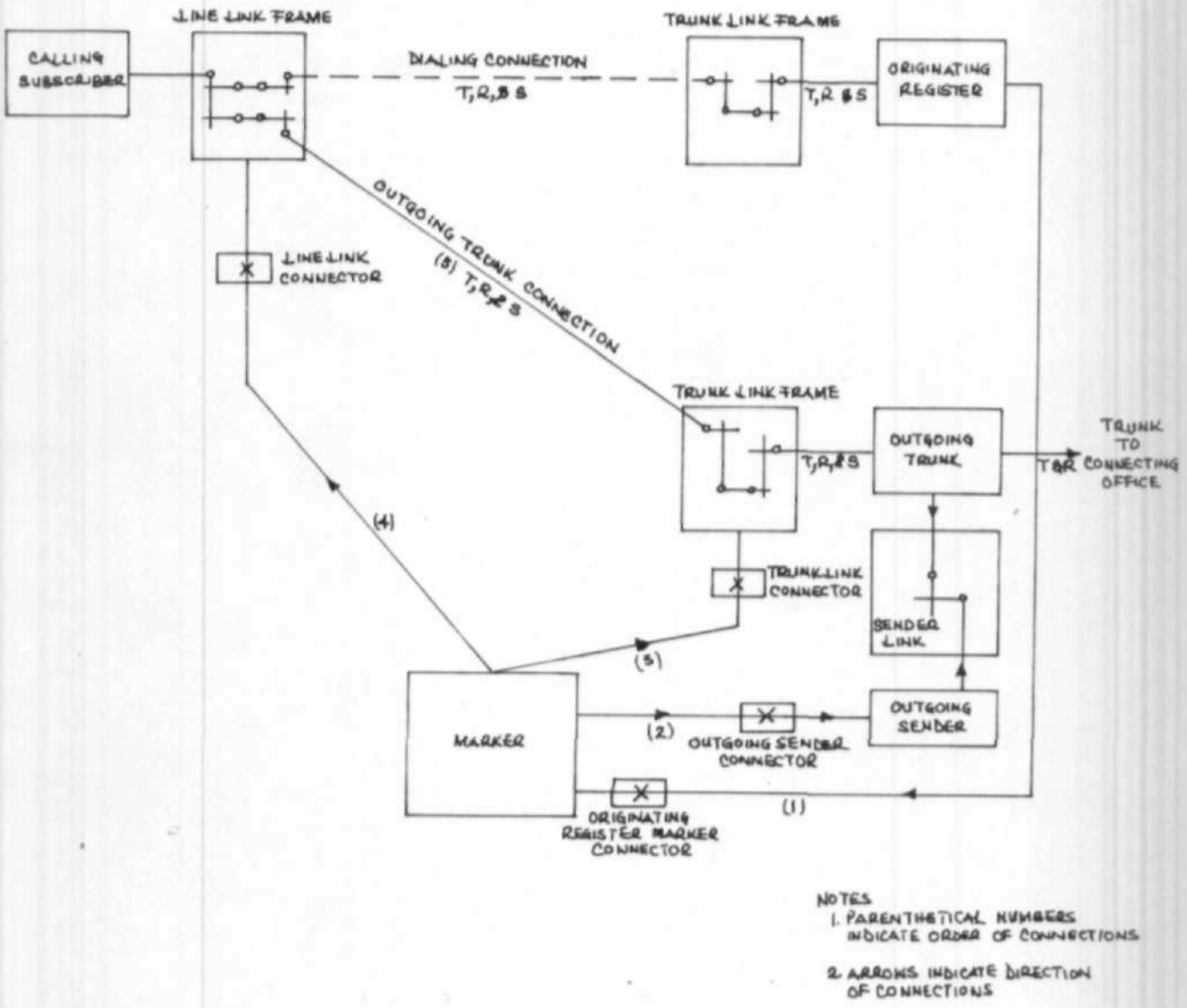


Fig. 6-2 — Establishing Outgoing Trunk Connection

sender connector, and receives the called number from the marker. The marker also sets up a connection between the outgoin sender through the sender link.

As soon as the trunk-link frame is seized, the marker connects to the line-link frame of the calling subscriber (connection 4) and establishes a channel between the subscriber and the ougoing trunk (connection 5). The dial connection is released if the marker finds an idle channel. The line-link used in the dial connection may be re-used in the outgoing connection in the same manner as for the intra-office call described in Chapter 5. If there is no idle channel available, the marker recycles the call by releasing the outgoing trunk it was holding and selects another one. If there is no idle channel on this recycle, the marker reroutes the call to a tone trunk on a trunk-link frame. The ougoing sender then makes trunk test. If the test fails, overflow tone is returned to the calling subscriber from the trunk. As in an intra-office call, the marker releases upon completion of its functions. The sender transmits the called number to the connecting exchange, then disconnects itself and the sender link. The outgoing trunk maintains supervision of the call.

6.2.2. Establishing Incoming Trunk Connection

(a) Step-by-step Exchange

In the step-by-step exchange, a separate set of two-motion switches is the first stage of selectors encountered in the process of establishing an incoming connection. These switches are known as incoming trunks. These trunks are activated by

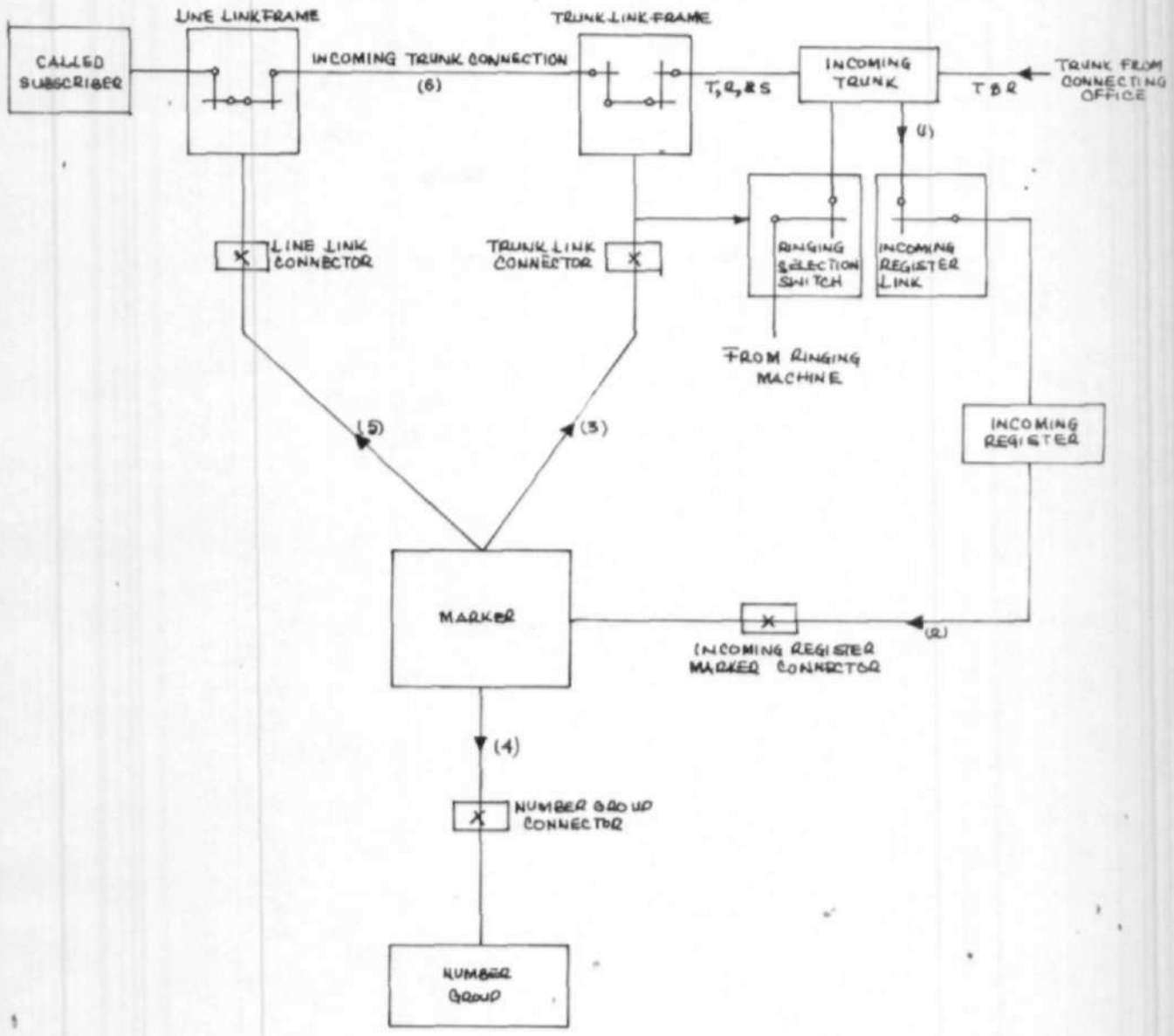
the incoming pulses dialled by the calling subscriber at the distant exchange. A free incoming trunk, if it exists,is pulsed axially to a level corresponding to the first digit of the called subscriber's number as dialled by the calling subscriber. During the inter-digital pause, the wipers hunt and seize a second group selector, if it exists, as described in Chapter 2. If there is no free second group selector, an engaged tone is returned to the calling subscriber.

The second group selector responds to the second digit and at the end of the second impulse train, hunts over the level to find a free selector in the group of final selectors. The call is then routed to the required called line, if a free final selector exists. If no selector exists, an engaged tone is sent back to the calling subscriber.

(b) Crossbar Exchange:

As soon as the incoming trunk is activated by a call originating in a connecting exchange, it seizes an incoming register through an incoming register link. (See fig. 6.3, connection 1). Separate groups of incoming registers are provided for each type of pulsing that the office is equipped to receive (multifrequency, dial or revertive pulsing).

After the trunk is seized in the called exchange, the incoming register is connected to the incoming trunk and receives the numericals of the called number. The register records the number of the trunk-link frame on which the incoming trunk appears in order that the marker will later be able to reach the incoming trunk. After the digits of the called number have been registered, the register gains access to a marker



NOTES:
1. PARENTHETICAL NUMBERS INDICATE ORDER OF CONNECTIONS
2. ARROWS INDICATE DIRECTION OF CONNECTIONS

Fig. 6.3 - Establishing Incoming Trunk Connection

(connection 2) and transmits the called digits and the trunk-link frame number to it.

The marker first seizes the trunk-link frame (connection 3) then selects the proper number group frame from which it obtains the equipment location of the called line. The marker then seizes the proper line-link frame and performs the line-busy test on the called line (connection 5).

If the called line is idle, the marker sets up a channel between the trunk and the called line (connection 6). Utilizing the ringing code information it has obtained from the number group, the marker sets the ringing selection switch. If the marker cannot find an idle channel, it sets the ringing selection switch to return a reorder signal and releases itself from the connection.

As soon as the marker has completed the above functions, it disconnects the incoming register, the register link and itself from the connection. The trunk now controls the ringing and further supervision of the call. The ringing selection switch vertical releases when the called party answers or the call is abandoned.

If the called line is busy, the marker sets up a busy signal on the ringing selection switch. The marker then releases the incoming register, the register link, and itself from the connection.

6.3 BRIEF DESCRIPTION OF THE SIMULATION PROGRAM

As with the previous programs, this program starts with the initialization routine in preparation for the run to be made. The input information includes the number of subscriber lines, the mean inter-arrival time of calls, mean call length and the maximum number of processed calls making a run. In this simulation, the mean inter-arrival time and the mean call length have been increased to 30 and 150 seconds respectively, as the calls are now trunk calls.(1) Also included in the input information are the maximum number of line-link frames in an exchange, the maximum number of lines per line-link frame, the maximum number of trunk-link frames in an exchange, the maximum number of trunk-links per frame, the maximum number of junctors per group and the maximum numbers of intra-office and inter-office trunks per frame (A and B appearances), in the case of a crossbar exchange, and, for the step-by-step exchange, the maximum numbers of outgoing trunks and incoming trunks and the maximum numbers of 2nd Group and Final Selectors. The homing or transit exchange is a crossbar exchange, hence the trunks allocated to each town at the exchange are A and B appearance trunks. The A appearances are the incoming trunks to the transit exchange while the B appearances are the outgoing trunks from the transit exchange. The program sets the values of the A and B appearances and an initialization routine then sets various numbers to their correct initial values. The program then sets for the appropriate types or type of originating and terminating exchanges. The first arrival time is generated and the program enters the main routine concerned with executing

each cycle of events. As with the previous simulation programs, this initial entry point is also the point from which to recycle when all changes have been executed for one event.

Suppose the next call finishes at T_F and the next arrival is at T_A. The program first decides whether the next activity is to disconnect a call or to attempt to connect a call. The test of the condition, $T_F \leq T_A$, makes this choice. As with the previous simulation programs, with the test defined this way, a coincidence of a disconnect and a new arrival results in the disconnect being serviced first. Whichever activity is decided upon, the program updates the clock. When two events are coincidental, the program executes them successively and the clock remains unchanged until all the events at that time have been executed. In the case of disconnecting a call, the activity is unconditional and the program immediately carries out the necessary action. Since a call has just finished, the time the next call finishes, T_F, is updated. The program collects statistics and returns for another cycle.

In the case of a new call arriving, the call is generated and the program checks to see whether enough calls have been processed to finish the simulation run. If not, the destination and the attributes of the call are generated. A check is made to determine whether the originating exchange is a step-by-step or a crossbar exchange. Using the outcome of this test, the program proceeds to the appropriate routine for the purpose of establishing an outgoing connection. If the exchange is step-by-step, this involves testing for a free outgoing trunk. If there is one, the call is routed out of the exchange to the transit

exchange. If there is no free outgoing trunk, the program collects statistics and returns for another cycle. If the exchange is a crossbar exchange, establishing an outgoing connection involves obtaining and storing the equipment location of the calling line. A test is then made to see if a dial connection can be established. This depends on whether a free channel can be found between the calling line and an idle register, as described in Chapter 5. If no idle channel can be found, the program collects statistics and returns to select a new origin. If there is an idle channel, the program establishes the dial tone connection. The program then proceeds to check whether the outgoing connection can be made. An idle trunk is selected on a trunk-link frame and a test is made to see if an idle channel can be found between the seized outgoing trunk and the calling line. If there is no available idle channel, the program releases the trunk and recycles, selecting an idle outgoing trunk on another trunk-link frame. If there is no idle channel on this recycle, the selected idle trunk, if any, is released. The program now collects statistics and returns for another cycle (that is, finding the next potential event). If an idle channel is found, the program proceeds to connect the outgoing call.

The program then proceeds to test if the call can be connected through the transit exchange. This involves testing for the presence of an idle outgoing trunk and an idle incoming trunk (B and A appearances, respectively). If there is no free one of either of the two types of trunks, the program collects statistics and returns for another cycle. If there are free

trunks of both types, the call is connected through the transit exchange and the program proceeds to route call through the appropriate terminating exchange and to establish incoming connection.

If the terminating exchange is a step-by-step exchange, the program tests to see if the call will be connected or lost either because one or more of the required groups of selectors is full or the called line is busy. In the case of a lost call, that is, the call cannot be connected, the program gathers appropriate statistics and returns for another cycle. When a call is successful, the program proceeds to connect the call. If the terminating exchange is a crossbar exchange, the program tries to establish the incoming connection by testing for and selecting an idle trunk, if there is one. If there is no idle incoming trunk, the program collects statistics and returns for another cycle. Having selected an idle trunk, the program proceeds to obtain and store the equipment location of the called line. A test is then made to see if the destination is free. If it is busy, the program collects statistics and returns for another cycle. If the destination is free, the program checks whether an idle channel can be found between the incoming trunk and the called line. If there is an idle channel, the call is connected. The program then adjusts the records by entering the new call in the list of calls in progress.

When a call is lost, the appropriate statistics are gathered. The program has been designed to show at what point exactly and in which exchange that the call has been blocked. The program then resumes for one more cycle.

When enough calls have been processed to finish the simulation run, the simulation stops, the results are printed and the program terminates.

As with the previous simulation programs, this program can be divided into major sections on the basis of what operation is carried out by the section, viz:-

1. Program Initialization
2. Finding the Next Potential Event
3. Establishing an Outgoing Call
4. Routing the Trunk Call through the Transit Exchange
5. Establishing an Incoming Connection
6. Disconnecting a Call
7. Gathering Statistics
8. Computing Final Statistics and Printing Out Results.

It is perhaps, necessary, at this point, to emphasize that this program assumes that the intervening media between the originating and transit exchanges and between the terminating and transit exchanges are ideal. It also assumes that any repeater equipment along the route is in perfect working condition. It follows from these assumptions that a call may fail only at any of the originating, transit or terminating exchanges.

The complete flow chart for this program is contained in Fig. C.4 of Appendix C. The flow charts showing how the various sections implement their functions are similar to the corresponding flow charts for SIMTEX 1 and SIMTEX 2 .

6.4 SIMULATION RESULTS AND ANALYSIS

In this section, an attempt will be made to evaluate the performance of the telephone network on the basis of the results of the simulation.

The simulation results are shown in Table 6.1. Table 6.1(a) contains the results for the run for which both the originating and terminating exchanges are of the crossbar type. (b) contains the results for the second run for which the originating exchange is crossbar while the terminating exchange is a step-by-step exchange.

Table 6.1: Simulation Results for Trunk Calls

(a) Originating and Terminating Exchanges: Crossbar

(b) Originating Exchange: Crossbar

Terminating Exchange: Step-by-Step

(a)

No. of Trunks at Transit Exchange:		
A Appearance	12	
B Appearance	60	
No of Lines	1700	
Mean Call Interval	30	seconds
Mean Call Length	150	seconds
Clock Time	28008	
Duration of Run	7	hours
Number of Calls	1000	
Calls Completed	982	
Busy Calls	7	

Table 6.1 (a) Contd.

Blocked Calls (No Dial Tone Channel)	0
Blocked Calls (No Outgoing Trunk)	0
Blocked Calls (No Originating Channel)	0
Blocked Calls (No Transit Trunk):	
A Appearance	7
B Appearance	0
Blocked Calls (No Incoming Trunk)	0
Blocked Calls (No Terminating Channel)	0
Blocked Calls at Originating Exchange	0
Blocked Calls at Transit Exchange	7
Blocked Calls at Terminating Exchange	0
Total Number of Blocked Calls	7
Number of Active Calls	4

(b)

No. of Trunks at Transit Exchange:	
A Appearance	12
B Appearance	60
Calls Completed	984
Busy Calls	4
Blocked Calls (No Dial Tone Channel)	0
Blocked Calls (No Outgoing Trunk)	0
Blocked Calls (No Originating Channel)	0
Blocked Calls (No Transit Trunk):	
A Appearance	5
B Appearance	0
Blocked Calls (No Incoming Trunk)	0
Blocked Calls at 2nd Group Selectors	0
Blocked Calls at Final Selectors	3
Blocked Calls at Originating Exchange	0
Blocked Calls at Transit Exchange	5
Blocked Calls at Terminating Exchange	3
Total Number of Blocked Calls	8
Number of Active Calls	4

It will be observed from (a) that for the run concerned, there are no blocked calls resulting from the nonavailability of either idle trunks or idle channels, or both, in either the originating or terminating exchange. The few blocked calls (7 in all) are stopped at the transit exchange. Thus, out of 1,000 calls entering the system, only 7 are blocked, giving a grade-of-service of 0.007. Table 6.1(b) shows that for the second run, 5 and 3 calls, respectively, are blocked at the transit and terminating exchanges. This gives an overall grade-of-service of 0.008. These observed grades-of-service are very acceptable.(8)

The graphs of Fig. 6.4 (a - g) show the variations of blocked/completed calls with A Appearance trunks for different values of B Appearance trunks. In (a), with B Appearance equal to 2, the blocked-calls and completed-calls curves are both parallel to the abscissa, the former being above the latter, indicating that there are more blocked than completed calls in this case. In (b) to (g), the situation has changed. Both curves are now roughly exponential. The numbers of blocked and completed calls increase and decrease, respectively, exponentially with A Appearance until a critical value is reached beyond which the curves level out. The saturation region in this case for completed calls is above that for blocked calls, indicating that there are more completed than blocked calls. The curves of Fig. 6.4 show that when each of A and B Appearances has a value greater than 10, the number of blocked calls closely approaches zero. In particular, (g) shows that for B Appearance sufficiently greater than 10 (15 in this example) the number of blocked calls approaches zero for A Appearance

greater than 12. It is clear from the foregoing that the number of blocked calls is not significant so long as the number of either set of trunks is not less than 12.

The striking similarity between the blocked-calls curve of Fig. 6.4(g) and that of Fig. 3.1(a) is noteworthy. This similarity is, however, to be expected as the A Appearance trunks, in so far as the trunk calls are concerned, perform exactly the same function as the links of the manual exchange.

There are three factors which may adversely affect the performance of the telephone network in the Norther States of Nigeria, viz:-

1. Insufficient equipment
2. Poor maintenance of existing equipment and
3. Radio transmission failure.

In the following, the impact of each of these factors on the performance of the system is examined.

6.4.1. Insufficient Equipment

This may imply inadequate provision of switches, trunks or channels in any of the exchanges making up the network. It has been established (Section 4.6) that insufficient equipment may not be a problem of the step-by-step exchange, while it may present only a minor problem with the crossbar exchange (Section 5.6). The simulation results of Table 6.1 also confirm that insufficient equipment may not be a factor adversely affecting the performance of the network.

It has also been observed that the number of blocked calls in the system is not significant so long as the number of either set of trunks (incoming and outgoing) allocated to any given town at the transit exchange is not less than 12.

The trunk distribution for Tandem Calls in the Kaduna Transit Exchange is shown in Table 6.2. Except for two towns, Yola and Suleija, each of the other towns has more than the critical value of 12 trunks allocated to it. (It is perhaps, necessary to state here that the allocation for Suleija is very temporary. The projected figures are 15 outgoing and 12 incoming, which, from the foregoing, should serve well).

Table 6.2 : Trunk Distribution in Kaduna Transit Exchange

TOWN	OUTGOING TRUNKS	INCOMING TRUNKS
BAUCHI	12	12
MAIDUGURI	12	12
YOLA	6	12
MINNA	12	12
JOS	60	97
SOKOTO	14	14
ZARIA	29	51
SULEIJA	4	6
KANO	127	217

In the following sub-section, it will be determined whether or not the relatively low trunk allocations to Yola and Suleija should have an adverse effect on the performance of the system under review.

6.4.2. Poor Maintenance of Existing Equipment

Much as there is room for improvement on the general level of maintenance of equipment, there are two reasons why it cannot be rightly said that the situation is so bad as to adversely affect the performance of the system. Firstly, most of the exchanges in the network are of the crossbar type, for which, in general, long duration faults seldom occur. Faults, when they occur, are usually minor ones, such as a blown fuse or a stuck switch. As soon as any of these faults occurs, an alarm is activated and steps are immediately taken to rectify the fault. Secondly, while it is true that the step-by-step exchange generally has a higher fault rate than the crossbar exchange, the number of step-by-step exchanges in the system (actually, only one, in Kano) is so small that its impact on the overall performance of the system may not be very significant.

Table 6.3 shows the average percentage trunk utilization in the transit exchange. The figures are those for one month and readings were taken once in 36 seconds for one hour during the peak traffic period (9.00 - 11.00 am) on every Monday of the month. The average utilization has been obtained as follows:

$$\text{Average utilization} = \frac{\text{No. of times trunk found to be engaged}}{\text{No. of working trunks} \times 100} \times \frac{100}{1}$$

$$= \frac{\text{No. of times trunk found to be engaged}}{\text{No. of working trunks}} \%$$

It will be observed from the table that the highest figure is obtained for Yola, which is allocated 6 outgoing trunks 2 of which were out of order when readings were taken. The average

Table 6.3: Average Trunk Utilization at the Transit Exchange

TOWN	NUMBER OF TRUNKS PROVIDED	NUMBER OF FAULTY TRUNKS	NUMBER OF TIMES TRUNKS FOUND TO BE ENGAGED	AVERAGE UTILIZATION OF TRUNKS (%)
BAUCHI	12	2	631	63.10
MAIDUGURI	12	3	369	41.00
SOKOTO	14	3	334	30.36
MINNA	12	1	225	20.45
JOS	60	35	741	29.64
ZARIA	29	8	490	16.90
YOLA	6	2	257	64.25
MAKURDI	16	11	209	41.80
KADUNA "A"	8	3	204	40.80
KADUNA "B" - AREA	14	7	233	33.29

utilization of the remaining 4 trunks is 64.25%, showing that only 64.25% of the 4 trunks were used most of the time. In other words, 3 instead of the 6 trunks allocated to Yola could have served equally well. Average utilization is also the ratio of actual traffic carried by the working trunks to the maximum traffic they can carry. Thus, for Yola, for instance, 64.25% of the maximum traffic that can be handled is actually carried by the working trunks. Hence, the trunks allocated to Yola can be said to be fairly under-utilized.

It may, therefore, be concluded, on the basis of the foregoing analysis, that the existence of faulty trunks, though undersirable, has not adversely affected the performance of the system and so the performance of the system has not been adversely

affected by the level of maintenance. However, it should be noted that from the way in which the measurements for the trunk utilization are made, the possibility of the existence of blocked calls has not been eliminated. That is, a call may arrive to find all the trunks allocated to its destined town to be engaged. This automatically becomes a blocked call. Such blocked calls have not been taken into account in the measurements. Moreover, the callers may not try again. Such callers may be called "frustrated callers". However, given a number of trunks sufficiently close to the threshold, such frustrated calls will be very small and the conclusions earlier reached may be assumed to be correct for all practical purposes.

Furthermore, it must be emphasized that the situation in which the number of allocated trunks is practically equal to the threshold (Table 6.3) does not make for good performance of the system. Fig. 6.4(g) shows that for number of trunks less than the threshold, the number of blocked calls increases exponentially. To avoid such a high number of blocked calls, due to the breakdown of one or two trunks, the number of trunks allocated to each of the towns should be well over the threshold of 12.

6.4.3. Radio Transmission Failure

It has been pointed out (section 6.3) that the simulation program for trunk calls assumes that the intervening media between the originating and transit exchanges and between the terminating and transit exchanges are ideal. It also assumes that any repeater equipment along the route is in perfect working condition. It follows from these assumptions that a call may

fail only at any of the originating, transit or terminating exchanges. In practice neither of these assumptions holds and the impact of this on the performance of the real system is discussed in the following paragraphs.

Table 6.4 gives a picture of the performance of the radio equipment at the Kaduna Transit Exchange. The statistics cover a period of one month. There were 200 recorded channel failures on the Kaduna - Zaria route during the period (of 31 days) considered -- an average of 7 failures per day. Furthermore, at the times readings were taken, all the channels together were found to be off for 8 days. These figures are certainly disturbingly high. The low values of the corresponding figures for Bauchi should, howevever, be noted. They indicate that the Kaduna - Bauchi channels behave much better than those for Kaduna - Zaria. The figures for Kaduna - Zaria are typical of those for the other towns such as Sokoto, Kano and Gusau.

Table 6.4: Performance Characteristics of the Kaduna Transit Exchange

TOWN	No. of Trunks	O.K.	T	N	P	S	OFF (DAYS)
LAGOS (Coaxial)	15	212	49	65	-	34	7
LAGOS (Microwave)	18	184	-	-	33	20	18
BAUCHI	12	222	20	22	19	3	8
ZARIA	29	332	200	2	52	27	8

LEGEND:-

O.K. - Trunk alright
T - No transmission
N - No clear back
P - Permanent earth on E wire
S - No signalling
OFF - Carrier-room off (No carrier)

It can, therefore, be rightly said that radio transmission failure has indeed had a highly adverse effect on the performance of the telephone network under review.

The rather high failure rate of radio channels observed in the preceding paragraph prompted the author to carry out further investigation to determine the causes of such an undesirable situation. Table A.1 (Appendix A) contains the daily radio fault analysis as recorded in the Zaria carrier-room for one particular month. Table.6.5 is a summary of this table.

Table 6.5: Statistics of Radio Faults as Recorded in Zaria

Causes of Fault	No. of Faults	Percentage of Total No. of Faults
Public power supply (NEPA) failure	24	52.1
Radio equipment fault in Zaria	3	6.5
Radio equipment fault in Kaduna, Kano and Gusau	11	23.9
Unknown	7	15.2
False alarm	1	2.1

It will be observed from Table 6.5 that there were 46 recorded radio faults for the month considered. About 30.4 (6.5 + 23.9) per cent of the 46 recorded faults were due to radio equipment problem. While this figure is relatively high, its significance in the overall performance of the system is minimal. This is so because most of the radio equipment faults were minor ones such as blown or burnt fuse, etc. (See Table A.1)

Such faults take only a couple of minutes to rectify.

On the other hand, Table 6.5 shows that public power supply (NEPA) failure accounts for over 50% of the total recorded faults. This is a significantly high figure. Indeed, on the basis of this figure, it can be safely concluded that the highly frequent and usually long-lasting public power supply failure is a major cause of the high rate of Radio Transmission failure observed earlier on and the consequent adverse effect it has on the performance of the telephone network under review.

The daily radio fault analysis for Kano, Bauchi, Jos and Sokoto are shown in Table A.2 to Table A.5 of Appendix A for comparison. The incidence of power failure at the repeater stations resulting from the breakdown of the electricity generating plants at the various locations will be observed from the tables. As a breakdown of the plant could be a long duration problem taking days, weeks or even months to rectify, its near disastrous impact on the performance of the system is obvious.

It has thus been established from the foregoing analysis that the major factor adversely affecting the performance of the telephone network in the Northern States of Nigeria is power supply failure. This power supply failure may be that of the public power supply system (NEPA) or may result from the breakdown of any of the electricity generating plants at the repeater stations, or both.

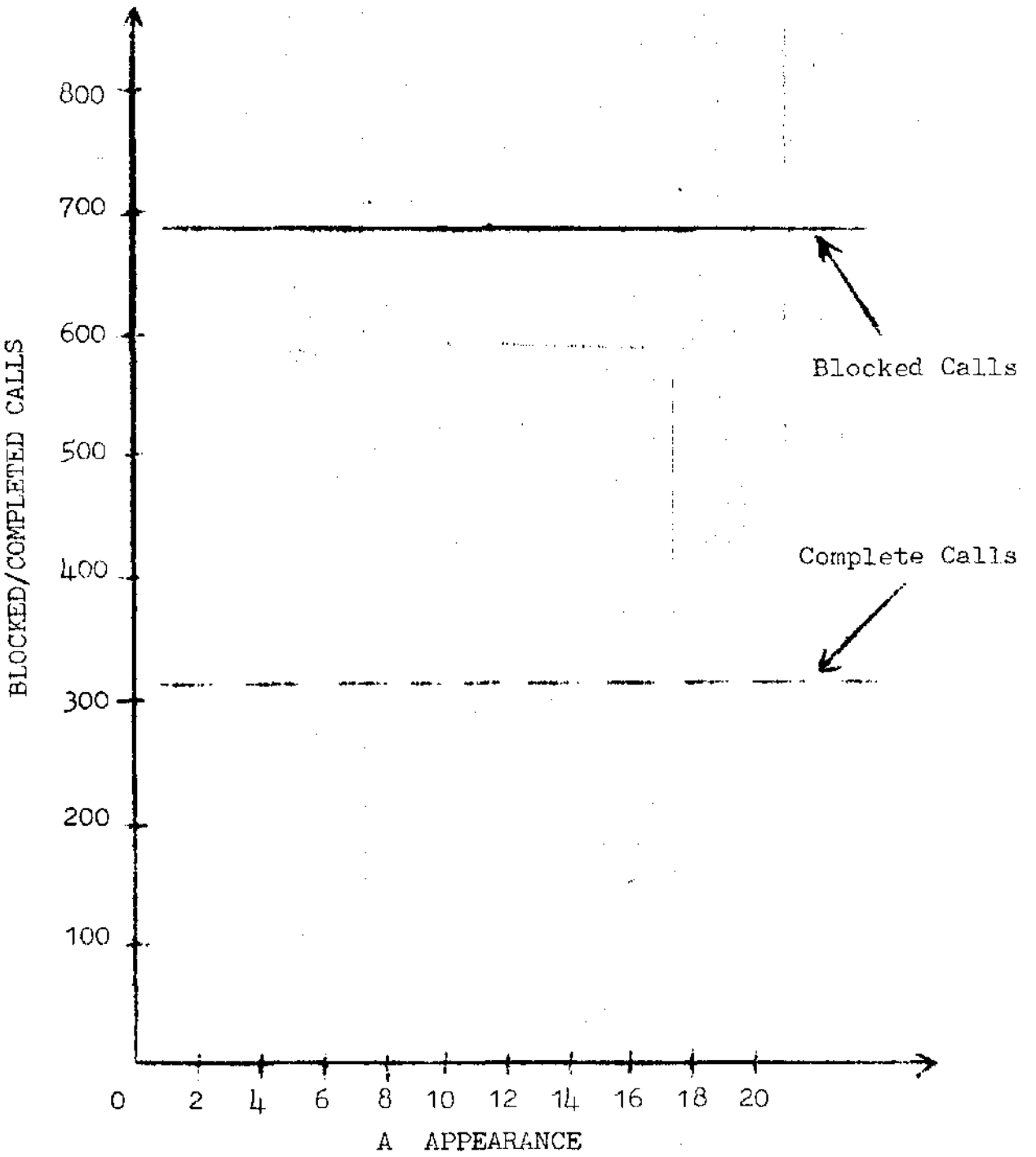


Fig. 6.4(a) Completed/Blocked Calls versus A Appearance

(B Appearance = 2)

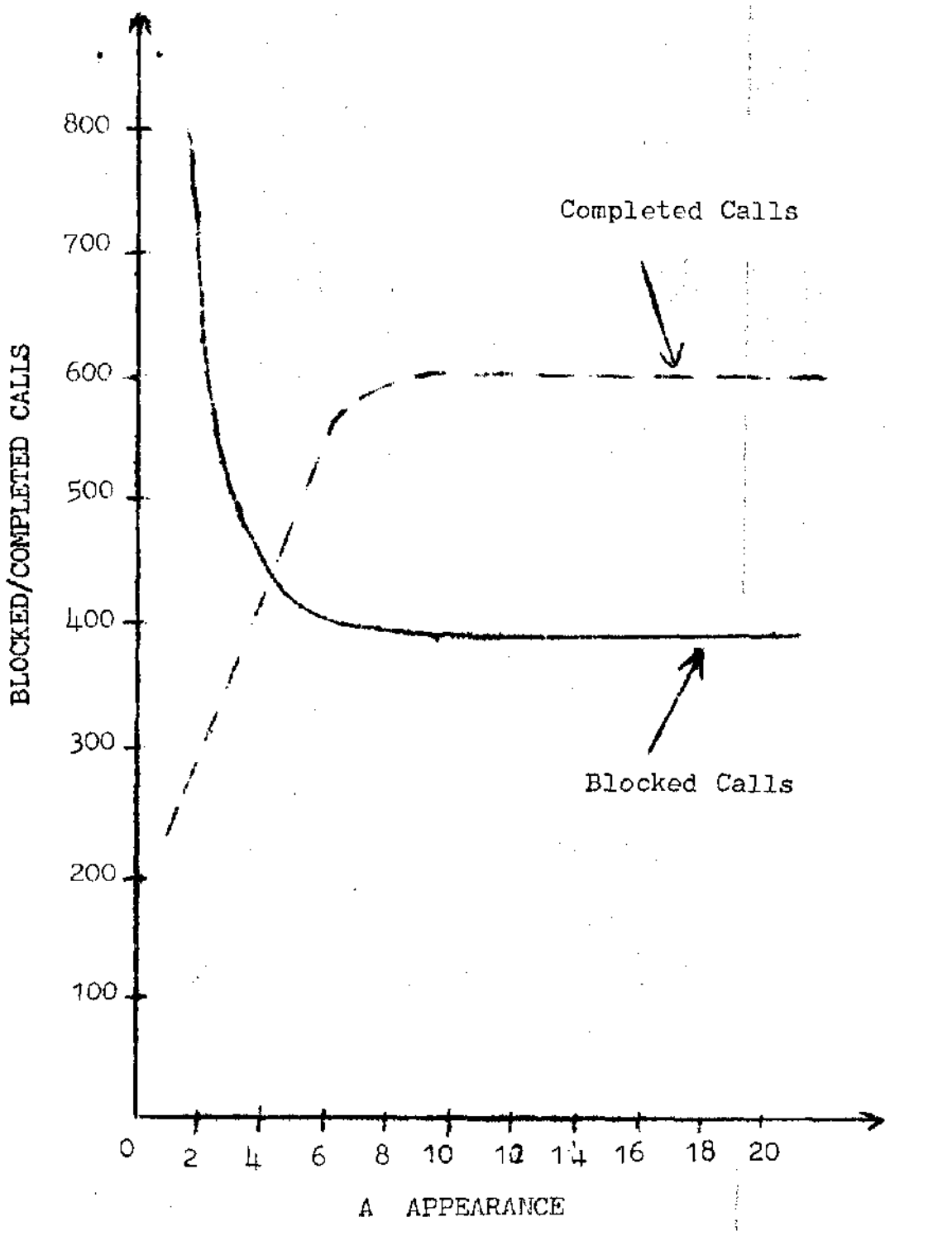


Fig. 6.4(b) Completed/Blocked Calls versus A Appearance

(B Appearance = 4)

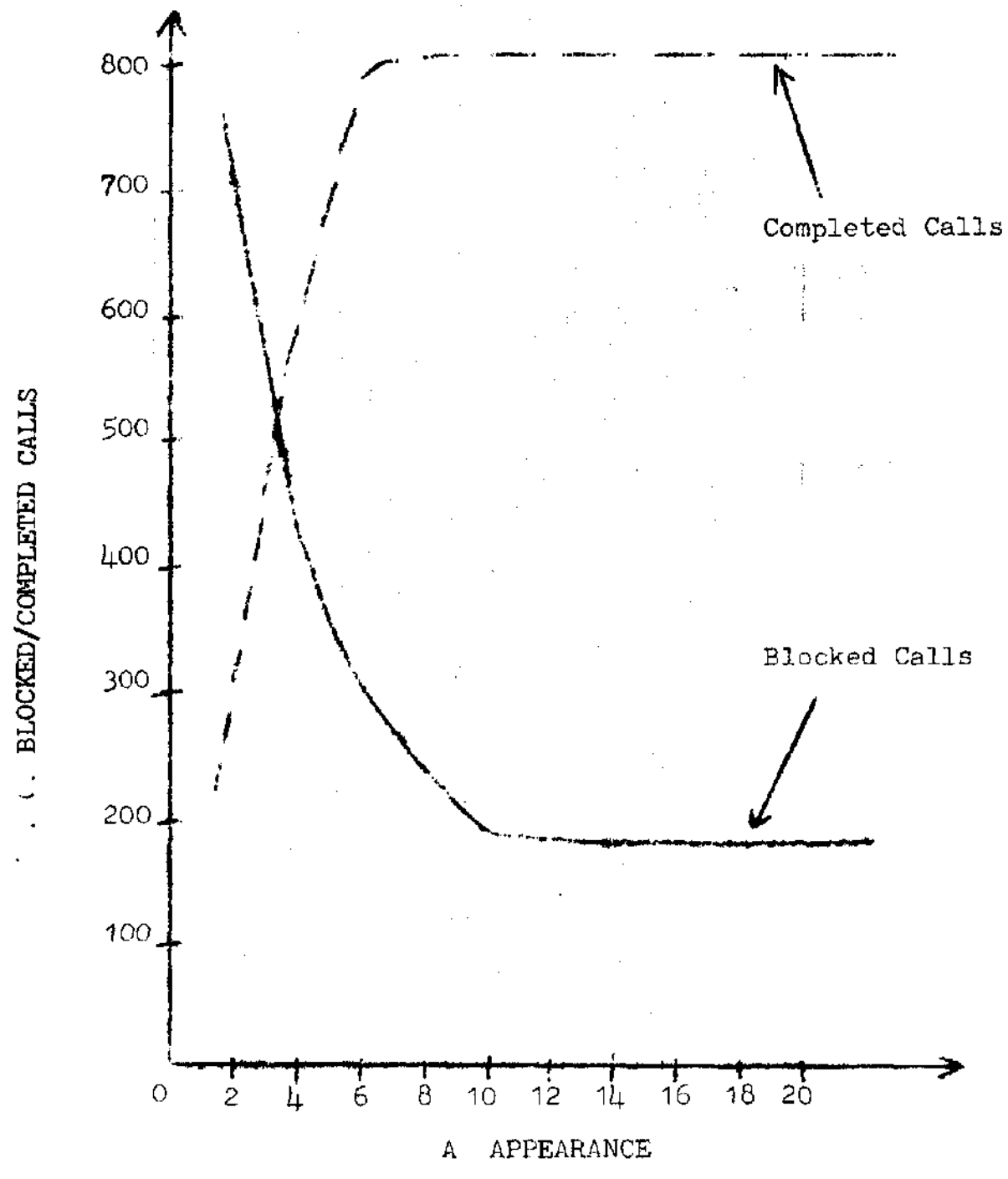


Fig. 6.4(c) Blocked/Completed Calls versus A Appearance

(B Appearance = 6)

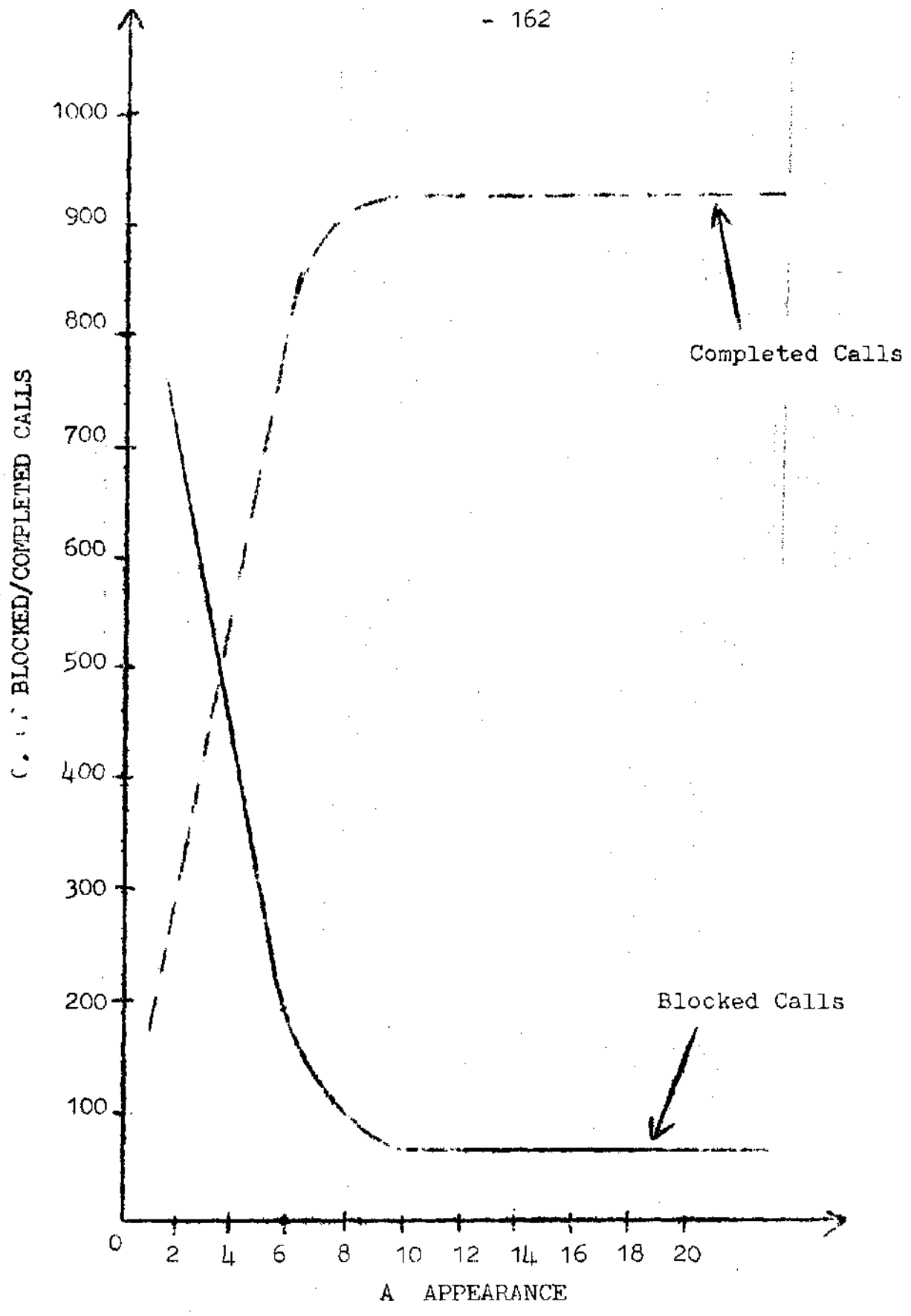


Fig. 6.4(d) Blocked/Completed Calls versus A Appearance
(B Appearance = 8)

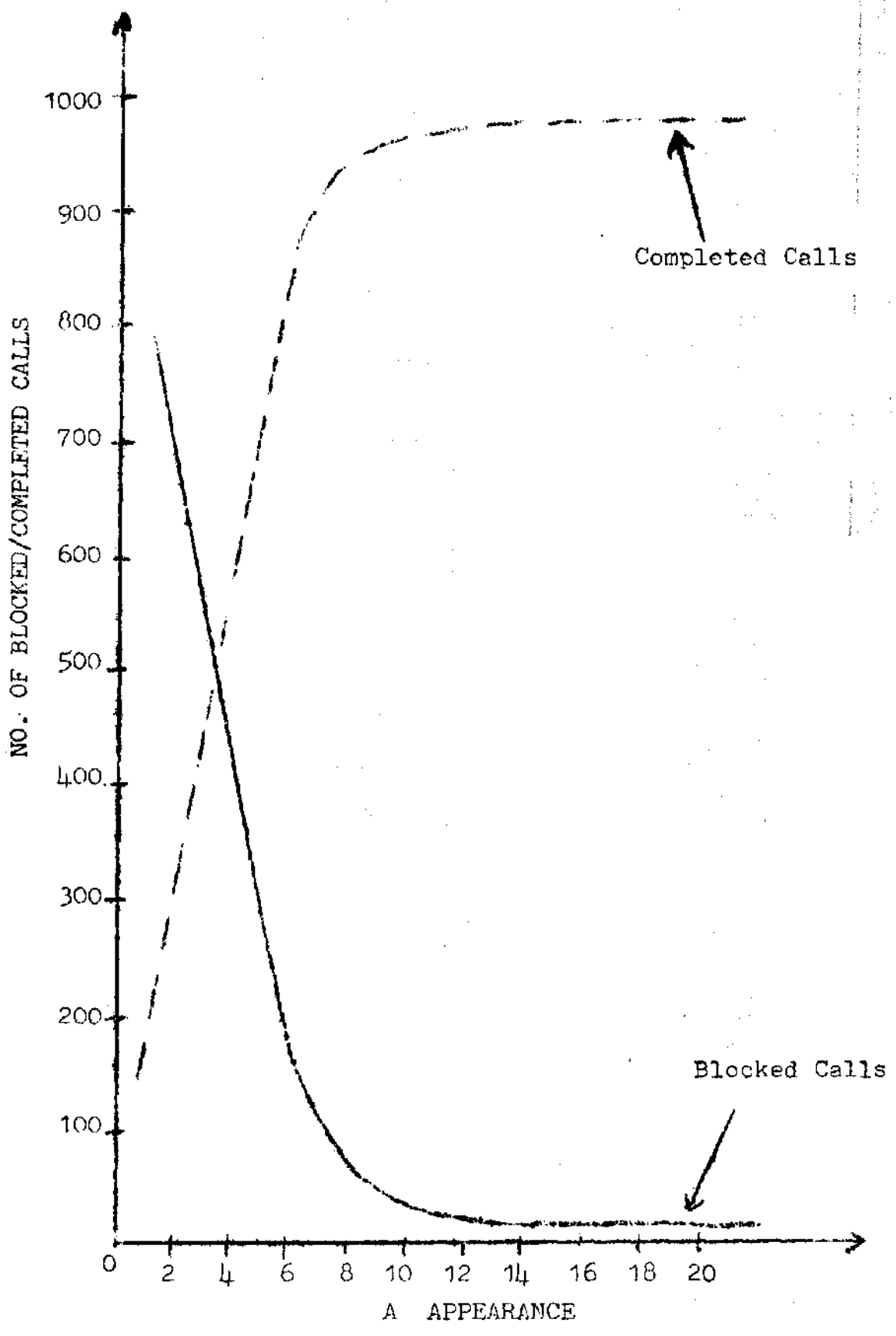


Fig. 6.4(e) Blocked/Completed Calls versus A Appearance
(B Appearance = 10)

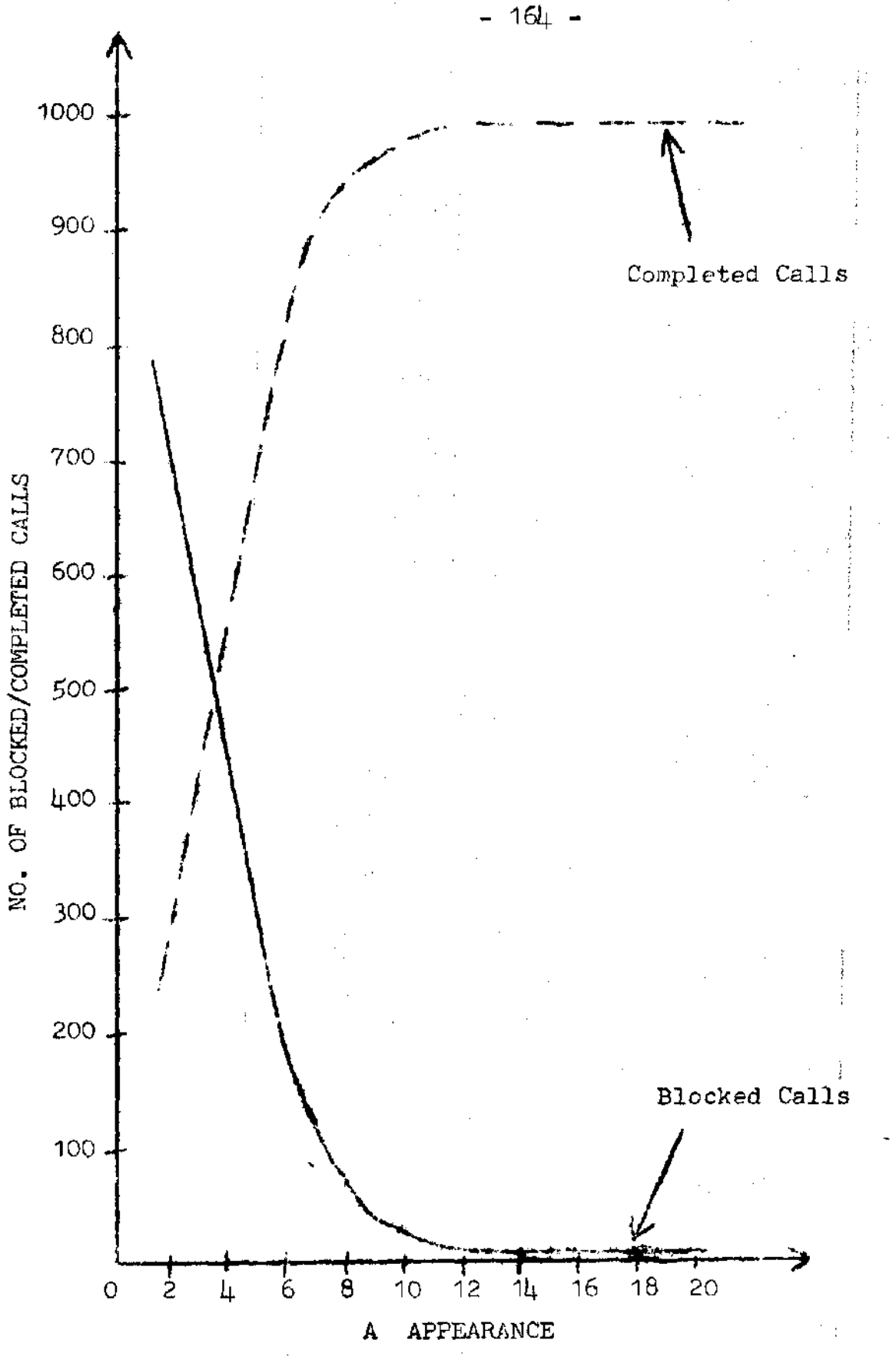


Fig. 6.4(f) Blocked/Completed Calls versus A Appearance

(B Appearance = 12)

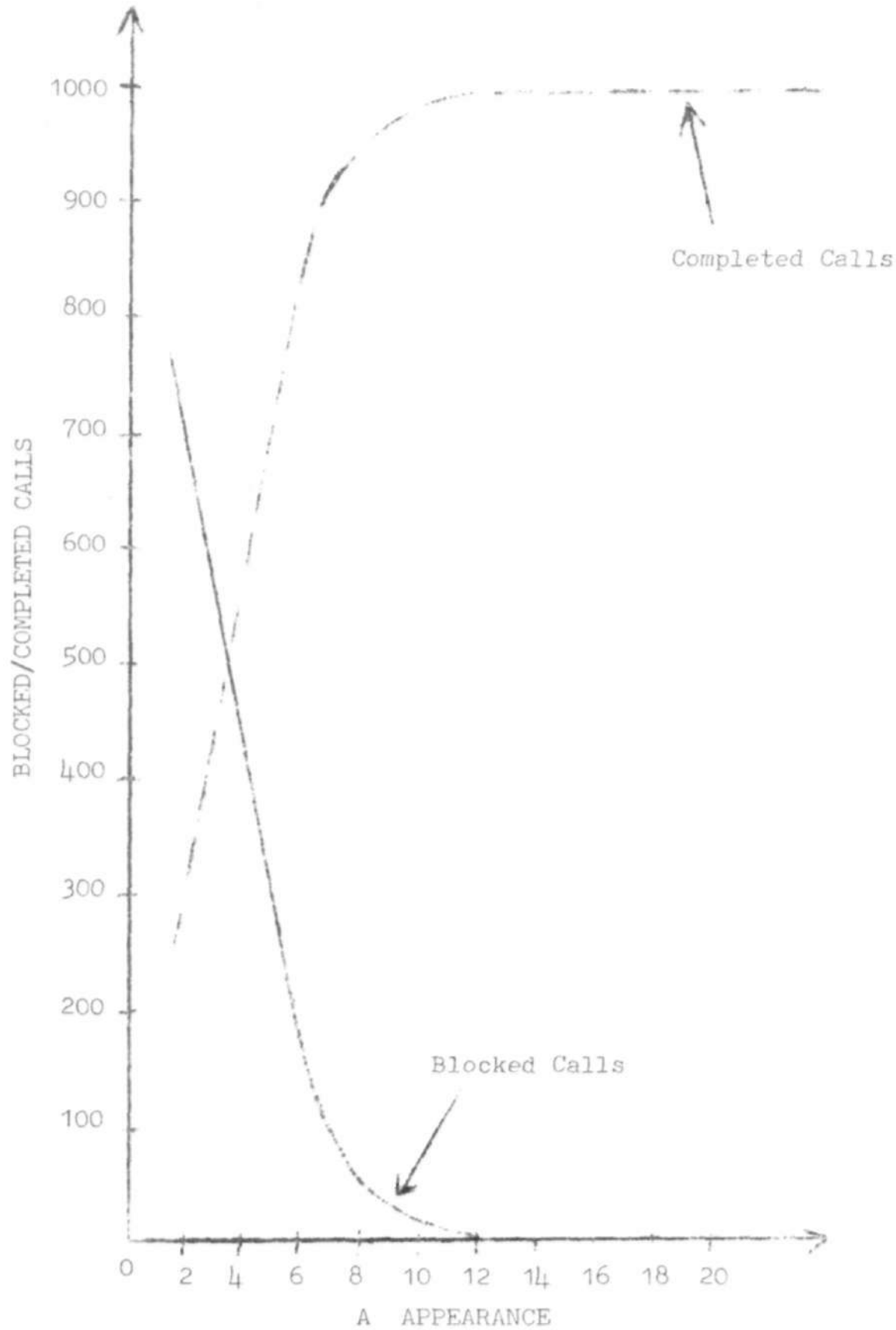


Fig.6.4(g) Blocked/Completed Calls versus A Appearance

(B Appearance = 15)

CHAPTER SEVEN

OBSERVATIONS AND RECOMMENDATIONS

7.1. INTRODUCTION

The observations and recommendations in this chapter fall into two categories. The first applies to the local telephone system. The second category deals with the network system as a whole.

7.2 THE LOCAL TELEPHONE SYSTEM

In this section, attention will be focussed on the exchange switching equipment as well as the external plant.

7.2.1. The Switching Equipment

It has been noted (Section 6.4.1) that insufficient equipment may not be one of the factors adversely affecting the performance of the telephone system under consideration. Now, it was shown in Section 5.6 that for the exchange to work satisfactorily, the mean call interval should not be less than 4 seconds. As at now, this condition is satisfied in the Zaria exchange as well as in most of the other exchanges in the network, and the performance of the exchanges is very satisfactory as has already been observed. However, the exponential increase in the number of blocked calls for mean call intervals less than 4 seconds (Fig. 5.16 (a)) shows that the situation may not remain this way for much longer. As the level of awareness and sophistication of potential telephone subscribers rises, the demand for telephone services will definitely increase and the mean call interval will eventually go much below the threshold of 4 seconds. A 10,000 - line telephone exchange has been approved for each of the major towns in

the Northern States. It is necessary to make adequate provision in each of the exchanges, in terms of equipment, to cope with the envisaged increase in traffic by the time the exchanges are commissioned - and even beyond - in order to avoid the possible problem of overloading. Table 7.1 contains the simulation results of the local exchange for mean call interval equal to 2 seconds. This represents a call-arrival rate of about 0.67 calls per second or 7 calls in 10 seconds. (This is equivalent to a traffic of 80 erlangs , calculated from the relation

$$A = y \times s \quad \text{(erlangs)}$$

where

A is the traffic

y is the number of calls during a given period, and

s is the mean holding time for one call.

The simulation results for mean call intervals of 1 and 3 seconds are shown in Appendix B.

It can be seen from Table 7.1 that all of the blocked calls are stopped at the trunks. This means that the number of local trunks (MTRKA and MTRKB) provided in the exchange cannot cope with the traffic. Hence, to avoid the problem of overloading, which may adversely affect the performance of the exchange, the number of trunks has to be increased. Fig. 7.1(a) shows the variation of blocked/completed calls with the number of trunks for a mean call interval of 2 seconds. For MTRKA and (MTRKB) equal to or greater than 20, the number of blocked calls is virtually zero. Hence for the exchange to carry the required traffic satisfactorily, the number of trunks provided must not be less than 20. It will be recalled

Table 7.1: Simulation Results for the Crossbar Exchange
(Mean Call Interval = 2 s)

No. of Trunks per frame:		
A Appearance	10	
B Appearance	10	
No. of Lines	1700	
Mean Call Interval	2	seconds
Mean Call Length	120	
Clock Time	1500	
Duration of Run	0	hours
Number of Calls	1000	
Calls Completed	620	
Busy Calls	49	
Blocked Calls (No Dial Tone Channel)	0	
Blocked Calls (No Terminating Channel)	0	
Blocked Calls (No Originating Channel)	0	
Blocked Calls (No Free Trunk)	286	
Total Number of Blocked Calls	286	
Number of Active Calls	45	

that MTRKA (and MTRKB) is the number of trunks per trunk-link frame. (See Section 5.3.2). Hence, for the exchange to work satisfactorily, a minimum of 20 intra-office, or local, trunks per trunk-link frame should be provided. This means there should be a total of 100 intra-office trunks, at the least, in the exchange, as there are five trunk-link frames in the simulated

exchange.

Fig. 7.1(b) illustrates the situation for a mean call interval of 1 second. For this case the minimum number of trunks that should be provided for the exchange to work satisfactorily is 38, that is, 38 intra-office or local trunks should be provided per trunk-link frame for the exchange performance to be satisfactory.

It is perhaps pertinent to point out at this point that the statistics of calls for the exchanges located in Kano, Jos and Bauchi were not available at the time of writing, as the various meters supposed to record such statistics were either not installed in the equipment or had brokendown. (The statistics of calls for the Zaria exchange were also not available but for a different reason, a technical one: the exchange had not been officially commissioned). It is, therefore, reasonable to recommend that the various meters be installed or reactivated, as the case may be, since the statistics obtained therefrom are invaluable for the regular and accurate evaluation of the performance of the switching equipment especially with regard to the problem of overloading.

7.2.2. The External Plant and General

Very exhaustive and practical suggestions on how the performance of the system can be improved are contained in the reference .(10) It is good, however, to highlight those considered from experience obtained and observations made during this investigation to be the most important, and also make observations as follows:

1. Attack by termites and water moisture was partly responsible for the damage to underground cables observed earlier on. (Section 4.6). This problem seems to be peculiar to tropical climates. The author suggests that appropriate establishments be encouraged to conduct research into this problem with a view to identifying the causes and ways of eliminating them.

2. Table 4.4 shows that there is room for improvement in the level of maintenance of the local telephone system. It seems that there is some shortage of trained technical staff to cope with the relatively high fault-rate observed for the system. As noted in reference (10), this is a general - and perennial - problem of the Post and Telecommunications (P & T) Department. This problem should be tackled on a national basis. It seems the shortage of staff can be traced to the inability of the P & T Department to retain trained technical staff. This may be due to the much better conditions of service existing in rival establishments. The department should, as a matter of urgency, explore ways of solving this problem once and for all . It may be necessary to remove the department from the Federal Civil Service structure.

3. The existing training schools for technicians and technologists located in Lagos, Kaduna, Enugu and Bauchi have proved inadequate to cope with the demand for this cadre of staff in the various exchanges. More training schools should be established. Furthermore, special courses in Telephone Systems with particular emphasis on switching systems should be introduced in the Polytechnics, Colleges of Technology and Universities. This will make it possible for graduates of such

institutions to relate directly to the telephone switching system without having to undergo any further and usually lengthy course on the system as is now the case. This will not only enhance the general efficiency of staff thereby significantly raising the level of maintenance, but will also reduce the operating costs and raise the revenue of the P & T Department.

7.3 THE NETWORK SYSTEM

It was established in the last chapter that the major factor adversely affecting the performance of the telephone network in the Northern States is inadequate power supply. Neither the public power supply system (NEPA) nor the electricity generating plants of the P & T Department have been able to cope with the situation. On this basis, the following suggestions are expedient:

1. Each carrier-room location should be supplied with a standby electricity generating plant.

2. Each standby plant should be equipped with the automatic-mains-failure facility. This will greatly reduce, if not completely eliminate, the down-time of the radio transmission. It will also eliminate the need to station an operator at each location for the sole purpose of switching on the plant whenever there is a cut in the public power supply. This will have the added advantage of reducing the operating costs of the system.

3. At locations where we already have standby plants, such generators must be well maintained and in good working condition at all times. Where the plant requires manual operation, an operator must be stationed at the location at all times to switch it on whenever it is necessary to do s

4. There are two generating plants at each repeater location in the system. The plants are arranged to work alternately, the operating time each way not exceeding 24 hours continuous operation. The switchover is designed to be automatic. In some cases, as can be seen from Appendix A, the switchover does not take place. This does not augour well for the plants. It is hereby suggested that all necessary steps be taken to ensure that the switchover at each repeater location takes place automatically.

5. It is very sad indeed to observe that some generating plants at the repeater stations sometimes go off due to lack of either diesel oil or lubricating oil, or both. This is most undesirable and should never be allowed to occur under any circumstances. The adverse impact of such phenomenon on the performance of the system cannot be over-emphasized. It it is, therefore, suggested that more regular inspection trips be made to the various locations by appropriate personnel.

6. Though radio equipment faults may not, as at now, adversely affect the performance of the system, the high fault-rate recorded indicates that all is not well with the equipment in the various carrier-rooms. (Table 6.5). The author feels that most of the radio equipment, due to either age or usage, or both, is in need of replacement either wholly or in part. It is suggested that a thorough inspection of the equipment in each of the carrier-rooms be undertaken by a combined team of engineers and technicians with a view to rectifying the situation.

7. All carrier-rooms should be effectively air-conditioned and dust-proof. As at now, this is not the case in most of the carrier-rooms. Such a state of affairs is not designed to enhance the efficiency of the radio equipment in the carrier-rooms.

8. It is necessary to emphasize that the situation whereby all trunk calls have to pass through only one exchange, the Kaduna Homing Exchange, as is currently the case with the system under review, is definitely not designed to ensure an efficient system and is most undesirable. At least one more homing exchange should be provided and strategically located so that if for any reason whatever a call cannot go through one homing exchange, it is automatically rerouted through another one. This will certainly greatly improve the performance of the system.

Though the above suggestions appear fairly expensive to implement, it is reasonable to assume that they will, if implemented, prove to be relatively cheap and cost-saving in the long run. What is more, they will go a long way in improving the image of the P&T Department which, as at now, is certainly nothing to write home about.

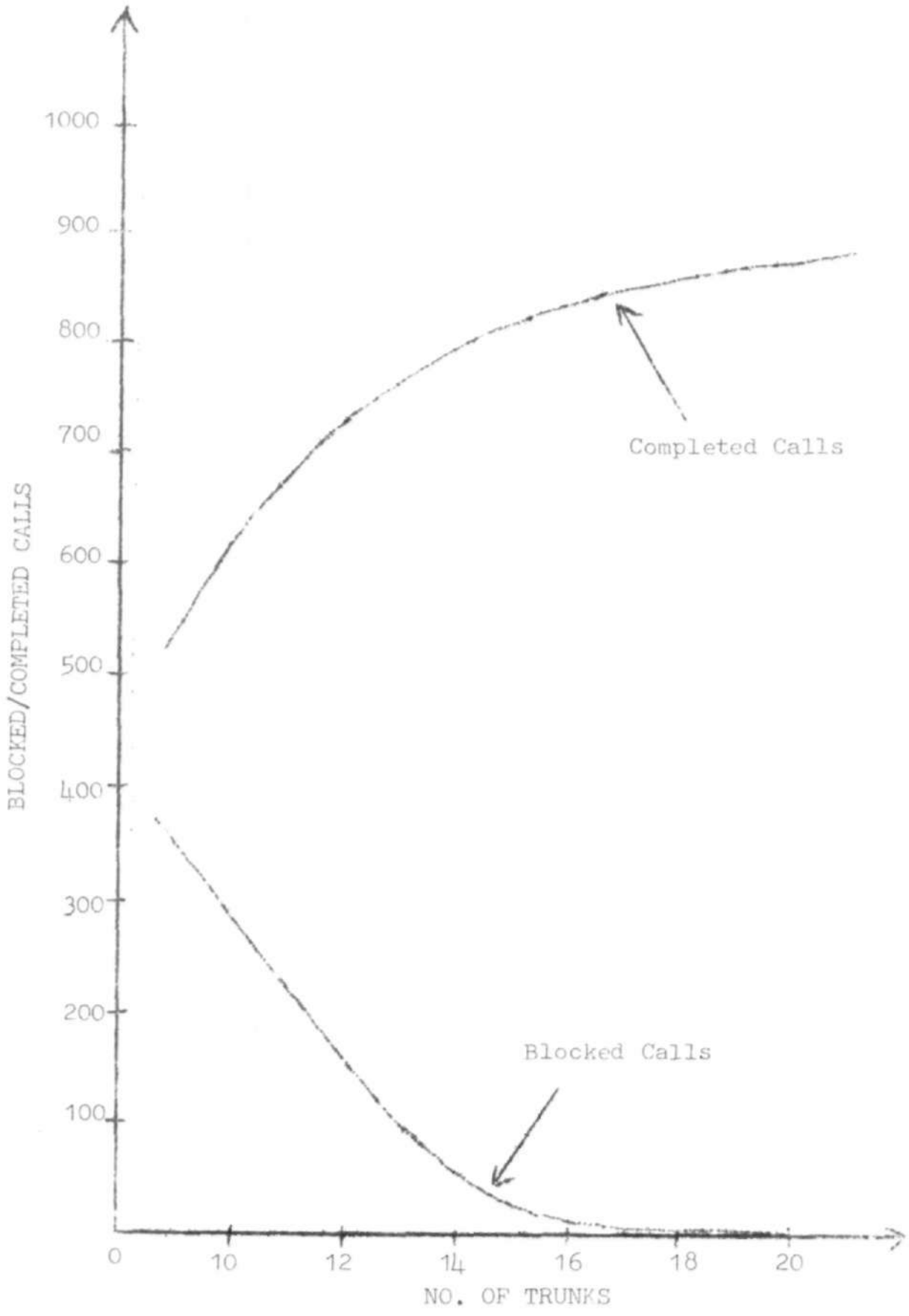


Fig. 7.1(a) Blocked/Completed Calls versus No. of Trunks for the Crossbar Exchange

(Mean Call Interval = 2 s)

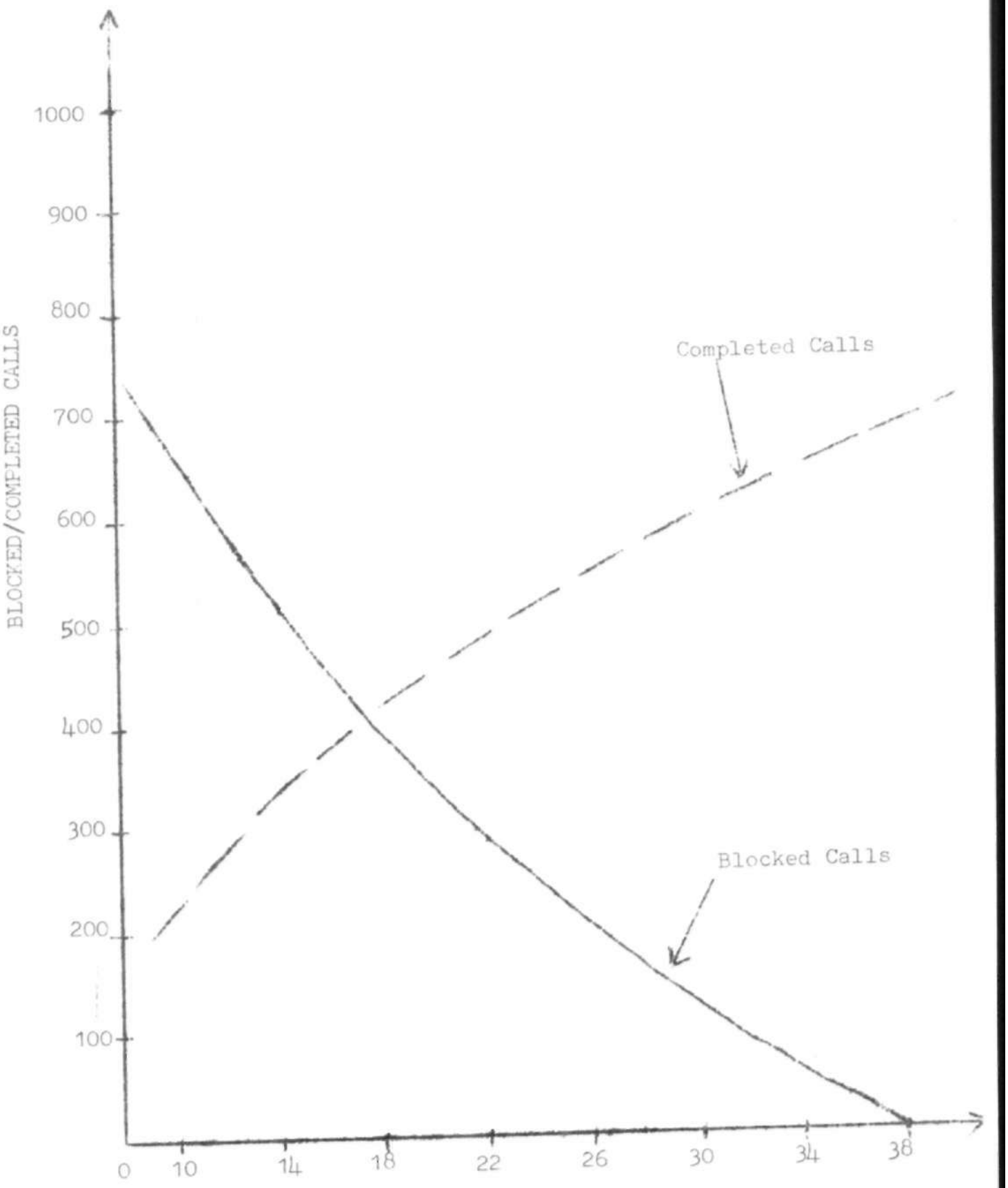


Fig. 7.1(b) Blocked/Completed Calls versus No. of Trunks for the Crossbar Exchange

(Mean Call Interval = 1 s)

CHAPTER EIGHT

SUMMARY AND CONCLUSION

This work had set out to identify the problems militating against the satisfactory performance of the telephone system in the Northern States of Nigeria. The approach has involved full-scale computer simulation of the exchanges used in the system and that of the network itself, and analysis of the simulation results. The conclusions drawn from the analyses were then related to the real local system and the network as a whole.

The analysis of the exchanges shows that the exchanges should perform satisfactorily. This conclusion has been shown to agree with what obtains in practice. The issue of overloading of the switching equipment, though not a problem now, has also been considered. Using the results of simulation and the analysis thereof, ways of averting the possible occurrence of such a situation have been advanced. These include increasing the number of trunks provided in the equipment as appropriate. The local telephone system as a whole has also been thoroughly analysed. It was observed that though the system has been found to work satisfactorily, the level of maintenance is relatively low. It was noted that the most important factor responsible for this is shortage of trained technical manpower. Suggestions have been made on how the situation can be rectified. These include the establishment of more training schools and the introduction of the study of telephone switching systems into the electrical engineering

curricula of the various Polytechnics, Colleges of Technology and Universities. This will have the effect of drastically reducing, if not completely eliminating, the need for graduates of such institutions to undergo extensive training on switching systems at the expense of the P & T Department thereby making substantial saving in operating costs.

The analysis of the results of the simulation of the network and that of the rather extensive data gathered on the system have identified inadequate power supply as the major cause of the present unsatisfactory performance of the system. For this reason, it has been suggested that all standby electricity generating plants at the various carrier-room locations, and all generating plants located at the various repeater stations should be kept in good operating condition at all times; and as a matter of policy, only plants with the automatic-mains-failure facility, in the case of the standby plants, should henceforth be purchased. The replacement of radio equipment either wholly or in part, as appropriate, has also been suggested. It has also been emphasized that contrary to what obtains in most of the rooms at present, each carrier-room should be effectively air-conditioned and dust-proof. Finally, it was emphasized that the present situation whereby all trunk calls have to pass through only one central or homing exchange is most undesirable and it has accordingly been suggested that at least one more homing exchange be provided and strategically placed so that calls which for any reason fail to go through a particular exchange could be automatically rerouted through another. This certainly will enhance the performance of the system.

It is perhaps pertinent to observe, that computer simulation is a most invaluable tool in the study of systems. It is, therefore, sad to note that the simulation approach has never been taken by our telephone system planners in the study and planning of the systems. The simulations done in this investigation, along with their results, and the analyses of the results have given a clear insight into the performance characteristics of a telephone exchange system and the telephone network system as a whole. Indeed, this study has been a most enlightening and satisfying one. The telephone system has been studied with a thoroughness and intensity never before done in this country. It is felt that if the results and recommendations in this work are utilized in any future planning of telephone network in this country, then many of the problems now afflicting the present system may be averted.

In the construction of a telephone network, the percentage costs of long distance transmission, switching, local loops and terminals are as follows:- (2)

Long distance	20
Switching	40
Local Loops	20
Terminals	20

It will be noted that switching alone accounts for 40% of the total cost. It is precisely for this reason that the simulations in this work have concentrated on the switching equipment at the exclusion of the other aspects of the network. However, further work could be carried out on this study as discussed in the following:-

1. The simulation of the local telephone system has assumed an ideal path as well as its associated equipment between the subscriber set and the switching equipment. This, of course, is not the case in practice. It has been observed in this work that problems do arise along the path. The relevant simulation program for the local exchange may be modified to incorporate such problems.

2. In the simulation program for trunk calls, it has been assumed that the transmission path along with its associated equipment is ideal. However, as it has been observed in this work, radio transmission failure does occur in practice. This failure may be due to atmospheric conditions, equipment breakdown along the route (such as at the repeater stations) or power supply failure, or any combination of these. The simulation program could be modified to include these factors.

3. With regard to the earlier recommendation that the number of homing exchanges be increased, the objective should be to obtain the optimum number of such exchanges for the system. This is an optimization problem on which further work could be done. In approaching this problem, the simulation program for trunk calls may be modified accordingly.

4. A simulation program for the telephone network in the country as a whole may be developed from the programs in this work as well as modifications thereof as suggested above. The simulation results may be analysed in the same way as in this work, the objective being to identify the factors adversely affecting the performance of the telephone system in the country and suggest ways of improving the performance thereof.

APPENDIX A

Table A.1: Daily Radio Fault Analysis as recorded in Zaria

Date	Fault	Cause
2	1) KN - ZA standby channel off 2) KD-ZA channels I & II Pilot off Input level from NR-15 O.K.	1) NEPA failure in Kano 2) NEPA failure at Kaduna
3	1) GS-ZA channel I traffic off. Input from NWR-1 O.K. 2) KD-ZA channel I pilot off. Input from NR-15 O.K.	1) NEPA failure at Gusau 2) Unknown
5	Zaria Carrier equipment down	NEPA failure
6	GS-ZA channel II pilot off. Input from NWR-1 O.K.	Equipment fault at Gusau
7	1) Kaduna channels I & II pilots off. Input from NR-15 O.K. 2) ZA carrier-room off.	1) NEPA failure at Kaduna 2) NEPA failure at Zaria
8	Pilot failure at Receiver amplifier on channel translating equipment	Blown fuse on AFC rack in Kaduna
9	KD-ZA channel I pilot off. Input from NR-15 O.K.	Power supply (E.H.T.) fault at Kaduna
10	1) KD-ZA channel I pilot off. Input from NR-15 O.K. 2) KD-ZA channels I & II pilots off. Input from BR-15 O.K.	1) Fault at Kaduna 2) NEPA failure at Kaduna
11	KD-ZA channels I & II pilots off. Input from NR-15 O.K.	NEPA failure at Kaduna

Table A.1 Contd

Date	Fault	Cause
12	1) KD-ZA channel I pilot off. Input from NR -15 O.K.	1) Unknown
	2) Zaria Carrier off.	2) NEPA failure
13	1) ZA-KD traffic off.	1) Blown fuse in Zaria
	2) Zaria Carrier-room off.	2) NEPA failure
	3) KD-ZA channels I & II pilots off	3) NEPA failure at Kaduna
14	1) KD-ZA channels I & II pilots off. Input from NR-15 O.K.	1) NEPA failure at Kaduna
	2) Zaria Carrier-room off.	2) Faulty Power supply unit (Burnt relay).
	3) KD-ZA channel I off. Input from NR-15 O.K.	3) Unknown
	4) KD-ZA channels I & II pilots off. Input from NR-15 O.K.	4) NEPA failure at Kaduna
15	1) KD-ZA channels I & II pilots off. Input from NR - 15 O.K.	1) NEPA failure at Kaduna
	2) Zaria Carrier-room off	2) NEPA failure in Zaria.
17	KN-ZA channel I pilot off. Input from NR-16 o.k.	Fault in Kano Carrier-room
18	KD-ZA channel I Pilot off. Input from NR-15 O.K.	Unknown
19	KN-ZA channel I pilot off. Input from NR-16 O.K.	Fault in Kano Carrier-room
20	KN-ZA channel I pilot off. Input from NR-16 O.K.	NEPA failure in Kano

Table A.1 Contd

Date	Fault	Cause
21	1) KN-ZA channel I pilot off. Input from NR-16 O.K.	1) Unknown
	2) KD-ZA channel II pilot off. Input from NR - 15 O.K.	2) Unknown
	3) Zaria Carrier-room off	3) NEPA failure
22	KN-ZA channel I pilot off	Fault in Kano Carrier-room
25	1) KD-ZA channels I & II pilots off. Input from NR-15 O.K.	1) NEPA failure at Kaduna.
	2) KD-ZA channel I pilot off. Input from NR-15 O.K.	2) Faulty Power supply equipment at Kaduna
	3) Zaria Carrier-room off	3) NEPA failure
26	1) KD-ZA channels I & II pilots off. Input from NR-15 O.K.	1) NEPA failure at Kaduna.
	2) Zaria Carrier-room off.	2) NEPA failure
27	1) KD-ZA channel I pilot off. Input from NR-15 O.K.	1) Fault in Kaduna Carrier-room
	2) GS-ZA channel I pilot off. Input from NR - 1 O.K.	2) NEPA failure at Gusau.
	3) Zaria Carrier-room off.	3) NEPA failure
28	1) KD-ZA channel I pilot off. Input from NR-15 O.K.	1) Fault in Kaduna Carrier-room.
	2) KN-ZA channel I pilot off. Input from NR-16 O.K.	2) Unknown
29	1) KD-ZA channel I pilot off Input from NR-15 O.K.	1) Faulty power supply unit in Kaduna
	2) Zaria Carrier-room off.	2) NEPA failure
30	1) Zaria Carrier-room off.	1) Blown fuse.
	2) GS-ZA channel I alarm showing	2) False alarm

Table A.2 Daily Radio Fault Analysis as recorded in Kano

Date	Fault Fault	Cause
1	KN-KD Route off	Power unit fault at KD C/R
3	KN-KD off	Fault Not Found (F.N.F.)
7	KN-KD off	NEPA failure in KN C/R
8	KN-KD off	Power unit failure (blown fuse) in KD C/R
11	KN-KD off	F.N.F.
12	KN-KD off	F.N.F.
14	KN-KD off	NEPA failure in KN C/R
15	KN-KD off	NEPA failure in KN C/R
16	KN-KD off	Tx fault at NR 17
19	KN-KD off	NEPA low voltage at KN C/R
21	KN-KD No clear back	Rx Oscillator at NR 17 faulty
25	KN-KD off	Power failure at NR 17
27	1) KN-KD off 2) KN-KD unsteady	1) F.N.F. 2) F.N.F.

Table A.3: Daily Radio Fault Analysis as recorded in Sokoto

DATE	FAULT	CAUSE
3	Pilot failure	Kaduna Carrier-room
4	1) High noise overriding signal 2) Pilot failure	1) Unknown 2) NWR 1 down
5	Pilot failure	Kaduna C/R
6	T_x 1 at NWR 7 down (Transmission not affected).	Burnt fuse
7 8 9 10	Pilot failure " " " " " "	Power problem at NWR 5
11	T_x failure at NWR 7	Unknown
12	Pilot failure	KD-ZA end
13	Pilot failure	KD C/R
14	1) Pilot failure 2) NEPA failure (transmission not affected as generator is automatic but exchange affected as batteries are not connected)	1) KD C/R
15	Pilot failure	KD C/R
16	Pilot failure	KD C/R
17	1) Pilot failure 2) High Noise	KD C/R Unknown
18 19	High noise (transmission hampered) High noise continues	NR 15
20	1) High Noise 2) Pilot failure	NR 15

Table A.3 Contd

DATE	FAULT	COURSE
21 22	Pilot failure Pilot failure	Generator break-down at NWR 6
25	1) Pilot failure 2) High noise over-ride	1) Unknown 2) Unknown
26	Dial problem	Operator equipment fault
27	Dial problem	" "
28	1) Dial problem 2) Pilot failure	1) " " 2) KD C/R
29	Pilot failure	KD C/R
30	Pilot failure	ZA C/R
31	Dial problem	Operator equipment fault

Table A.4: Daily Radio Fault Analysis as recorded in Jos

DATE	FAULT	CAUSE
2	JS-KD Route off	NEPA failure in KD C/R
3	JS-MR " "	NEPA failure in JOS C/R
4	JS-LG " "	Unknown
5	1) JS-LG Route off	1) Blown power fuses at NR4
	2) JS-LG off	2) Generator failure at NR 4
6.	1) JS-KD off	1) Generator maintenance at NCR 2
	2) JS-LG (High noise)	2) Unknown
7	JS-LG (High noise)	Unknown
8	JS-KD/LG off	Motor overload trip at NR 4
9	JS-LG off	High engine temperature at NR 4
11	JS-MR-off	NEPA failure in MR
12	1) JS-LG off	1) Radio equipment (Set B) fault
	2) JS-MR off	2) Standby generator motor overload trip in MR
13	1) JS-MR off	1) NEPA failure in JS
	2) JS-KD	2) Blown fuses in the power supply unit in KD C/R
14	1) JS-KD off	1) Tx 1 in JS C/R faulty
	2) JS-KD off	2) NEPA failure in JS
15	1) JS-LG off	1) Power cut due to leaking C/R building
	2) JS-MR off	2) Engine shutdown

Table A.4 Contd

DATE	FAULT	CAUSES
15	3) JS-LG off	3) Power failure at NR 12
16	JS-MR off	Low NEPA voltage in MR
17	JS-LG off	Power fault at NR 12
18	JS-MR off	Low NEPA voltage in MR
21	1) JS-LG off	1) Power maintenance at NR 11
	2) JS-MR off	2) Power maintenance at RE 3
22	JS/KD/LG off	Power maintenance at NER 4
24	1) JS-BH off	1) Tx channel I off
	2) JS/KD/LG off	2) Low NEPA voltage in KD
	3) JS-LG off	3) Power failure at NR 14
26	1) JS-MR off	1) NEPA failure at MR C/R
	2) JS-KD-LG off	2) Low oil level at NER 3
	3) JS-MR off	3) Standby Generator cannot start.
	4) JS-MR	4) Power failure at NR 8
	5) JS-MR off	5) NEPA failure in MR C/R
28	1) JS-MR off	1) NEPA failure in MR C/R
	2) JS-LG off	2) Power failure at NR 7
29	JS - MR off	NEPA failure in MR C/R
30	JS - MR off	Motor overload trip at MR C/R
31	1) JS-KD-LG off	1) Power failure at NER 4
	2) JS-MR off	2) Motor overload trip at MR C/R

Table A.5: Daily Radio Fault Analysis as recorded in Bauchi

DATE	FAULT	CAUSE
1	BH-GM off	Power failure at ENR 3
3	1) BH-GM off	1) Power failure at ENR 3
	2) BH-PM off	2) Power generator down due to lack of oil at NER 11
4	BH-GM off	NEPA failure in BH
5	1) BH-MR off	1) Generator maintenance at NER 15
	2) BH-JS off	2) Blown fuses in T_x in BH C/R
7	BH-MR off	NEPA failure at MR C/R
8	BH-KD off	Blown fuse in KD C/R
12	BH-KD off	" " " "
21	BH-KD off	Power maintenance at NER 15
22	BH-PM off	Power supply failure (Broken fuel pipe)
27	BH-PM off	Tx fault at NER 11
30	BH-PM off	Tx fault at NER 9
31	BH-KD off	Power fault at NER 4

Table A.6: Statistics of Calls in the Sokoto Exchange

DATE	DT	DTFM	OG	OGFM	IC	ICFM	LB	NU
1	29063	0	18792	38	5580	7	1282	732
2	28059	0	16798	6	4989	36	1223	753
3	46819	0	24891	0	8513	6	2098	1207
4	24739	0	14181	10	3889	13	964	587
5	21152	0	12237	0	2719	0	615	642
6	15213	0	8067	0	1684	0	335	422
7	10593	0	4078	0	1342	0	232	346
8	22450	0	11143	0	4462	0	955	719
9	24321	0	11501	0	4808	0	883	704
10	12143	0	6230	0	2482	0	438	682
11	30304	0	17330	0	5335	0	1281	811
12	30096	0	18398	3	5123	0	1147	819
13	19345	0	10536	0	2726	0	457	504
14	11289	0	5417	0	1875	0	67	359
15	18426	0	8479	0	3754	2	979	485
16	39144	1	23848	3	7945	18	1987	1000
17	-	-	-	-	-	-	-	-
18	31953	0	18430	10	5901	0	1335	1373
19	25519	0	14977	0	4685	0	1128	661
20	17372	0	10337	0	3145	0	495	574
21	8306	0	3937	0	1322	0	260	286
22	33082	0	19675	3	6517	6	1740	848
23	52668	3	32069	5	10305	7	2680	1238

Table A.6: (Contd)

DATE	DT	DTFM	OG	OGFM	IC	ICFM	LB	NU
24	13008	0	8059	0	2368	6	426	254
25	31401	3	18704	1	5881	0	1433	772
26	43803	0	20275	0	6004	0	1260	1103
27	17840	0	6696	0	1562	0	156	382
28	25734	0	6391	0	1782	0	239	300
29	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-
TOTAL	683842	7	371494	79	116698	101	26095	18563
AVERAGE	25327	0.26	13759	2.93	4322	3.74	966.5	687.5

LEGEND:-

DT - No. of Dial Tone signals recorded (i.e. total no of calls entering the system).

DTFM - No. of Times Dial Tone Channel cannot be found

OG - No. of Outgoing Calls

OG - No. of Unsuccessful Outgoing Calls

IC - No. of Incoming Calls

ICFM - No. of Unsuccessful Incoming Calls

LB - No. of Busy Calls

NU - No. of Unobtainable Calls (Number Unobtainable)

APPENDIX B

Table B.1: Simulation Results for the Crossbar Exchange
(Mean Call Interval = 1 s)

No. of Lines	1700
Mean Call Interval	1 second
Mean Call Length	120 seconds
Clock Time	571
Duration of Run	0 hour
Number of Calls	1000
Calls Completed	233
Busy Calls	54
Blocked Calls (No Dial Tone Channel)	0
Blocked Calls (No Terminating Channel)	0
Blocked Calls (No originating Channel)	0
Blocked Calls (No Free Trunk)	663
Total Number of Blocked Calls	663
Number of Active Calls	50

Table B.2 Simulation Results for the Crossbar Exchange
(Mean Call Interval = 3 s)

Mean Call Interval	3 seconds
Clock Time	2518
Duration of Run	0 hour
Number of Calls	1000
Calls Completed	867
Busy Calls	53
Blocked Calls (No Dial Tone Channel)	0
Blocked Calls (No Terminating Channel)	0
Blocked Calls (No Originating Channel)	0
Blocked Calls (No Free Trunk)	42
Total Number of Blocked Calls	42
Number of Active Calls	38

REFERENCES

1. Flowers, T.H.(1976), Introduction to Exchange Systems. John Wiley & Sons, London.

2. Bajoga, B.G. (1975), "Telecommunication Development in Nigeria", Report, Department of Electrical Engineering, Ahmadu Bello University, Zaria, Nigeria.

3. Cavalli-Bjorkman, A. (1973), "Telecommunication Systems. L.M. Ericsson Telephone Company and Esselte Studium AB, Stockholm, Sweden.

4. Gordon, G. (1969), System Simulation. Prentice-Hall, Inc., New York.

5. Lee, C.Y. (1955), "Analysis of Switching Networks", Bell System Technical Journal, Vol. 34, pp.1287 - 1315.

6. Grantges, R.F. and Sinowitz, N.R. (1964), "NEASIM: A General Purpose Computer Simulation Program for Load-Loss Analysis of Multistage Central Office Switching Networks", Bell System Technical Journal, Vol. 43, pp. 965 - 1003.

7. Kummerle, K. (1971), "Point-to-Point Loss in Link Systems: Model and Calculation Methods", IEEE Transactions on Communication Technology, Vol. COM - 19, No. 3, pp. 261 - 267.

8. Atkinson, J. (1958), Telephony, Volume II. Sir Isaac Pitman & Sons Ltd., London.

9. "NE - 5 Crossbar Exchange", Operational Manual, Northern Electric Company Ltd., Montreal, Canada.

10. Egwu, O.H. (1980), "Survey of the Telephone System in Zaria", Final Year Project, Department of Electrical Engineering, Ahmadu Bello University, Zaria, Nigeria.

APPENDIX C

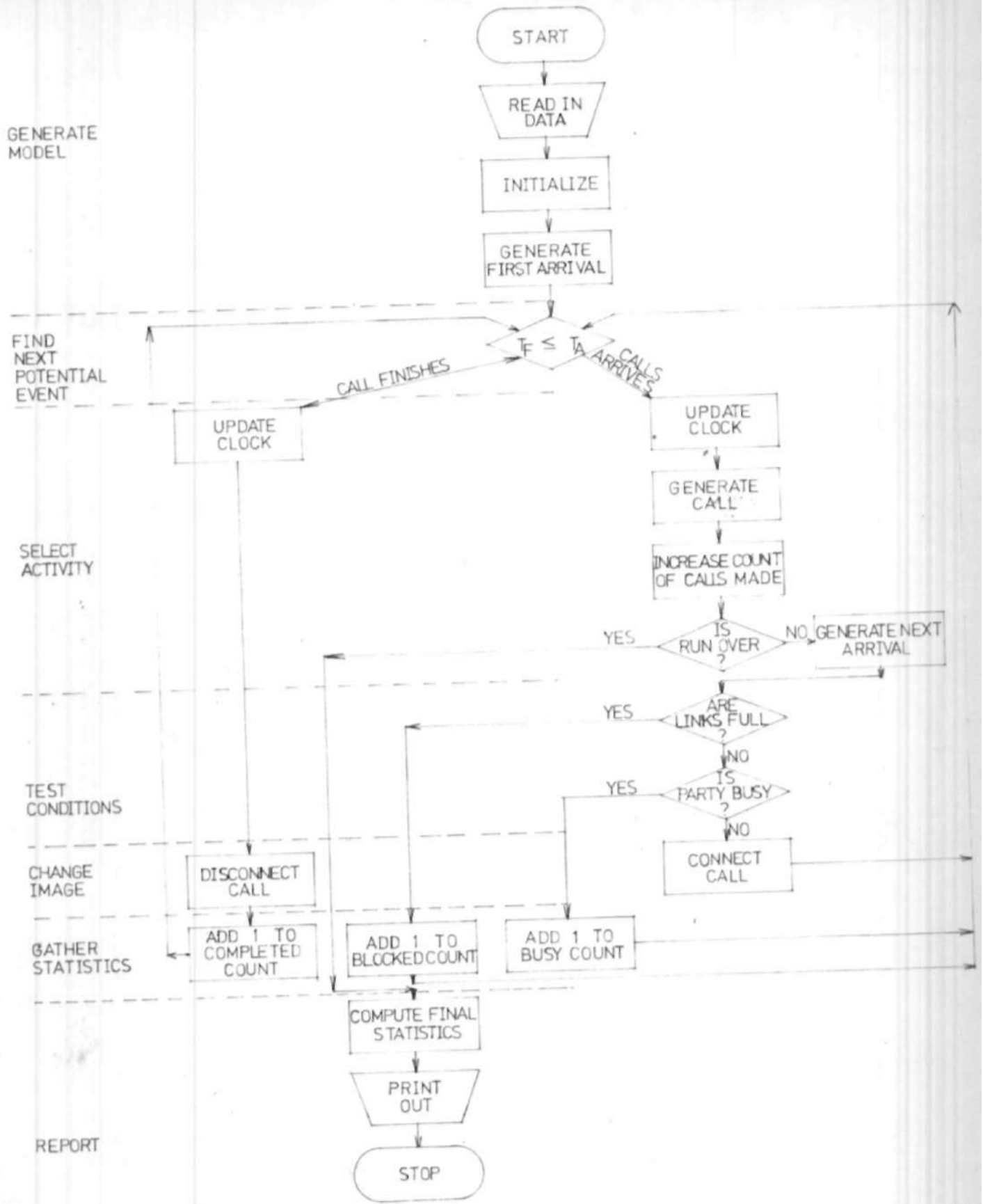


Fig.C.1 TELSIM 1: FLOW CHART

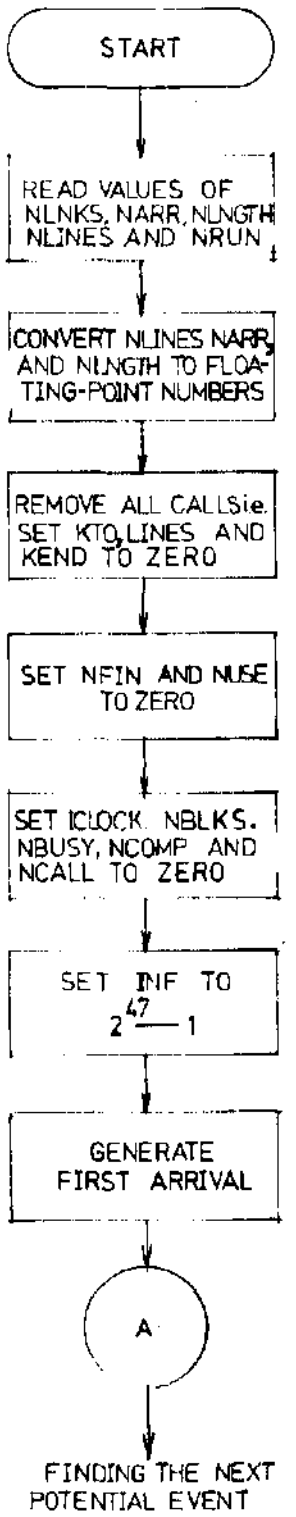


Fig.C.1(b) PROGRAM INITIALIZATION

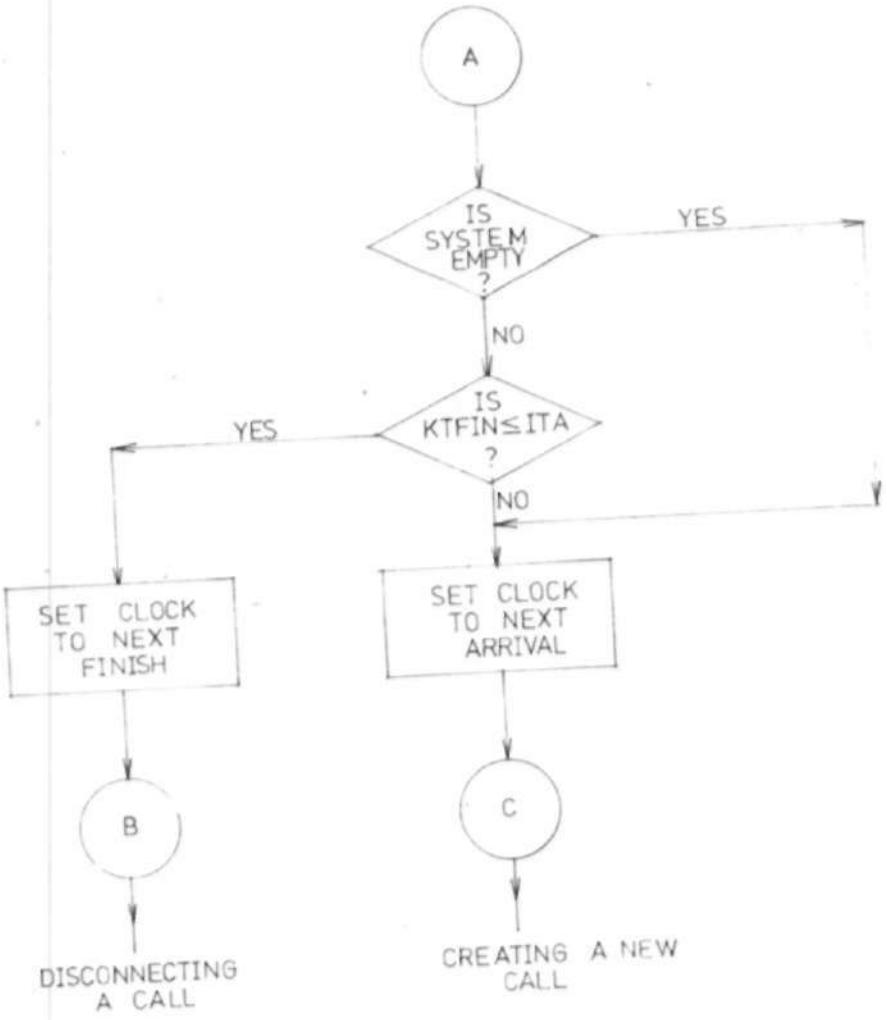


Fig.C.1(c) FINDING THE NEXT POTENTIAL EVENT

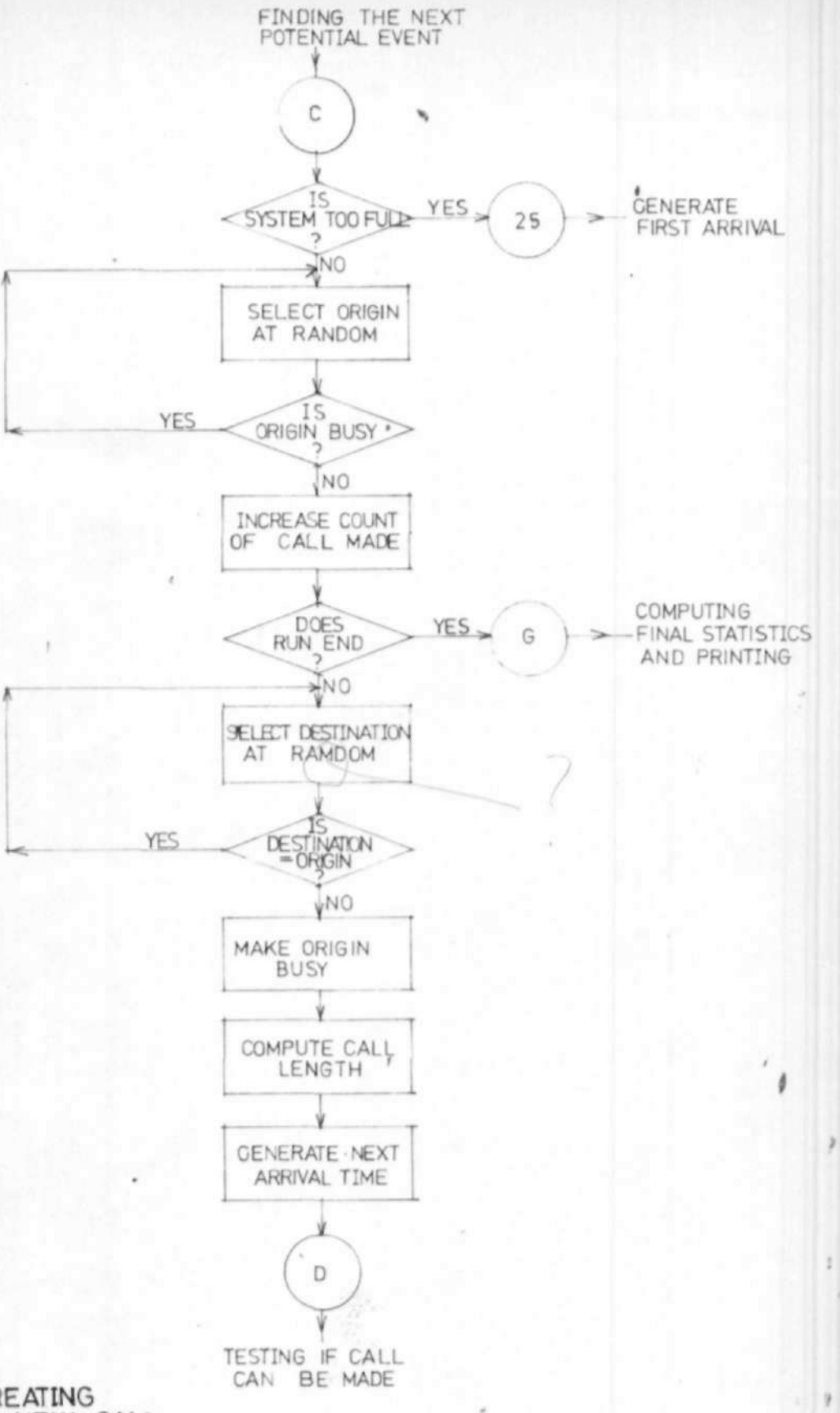


Fig.C.1(d) CREATING A NEW CALL

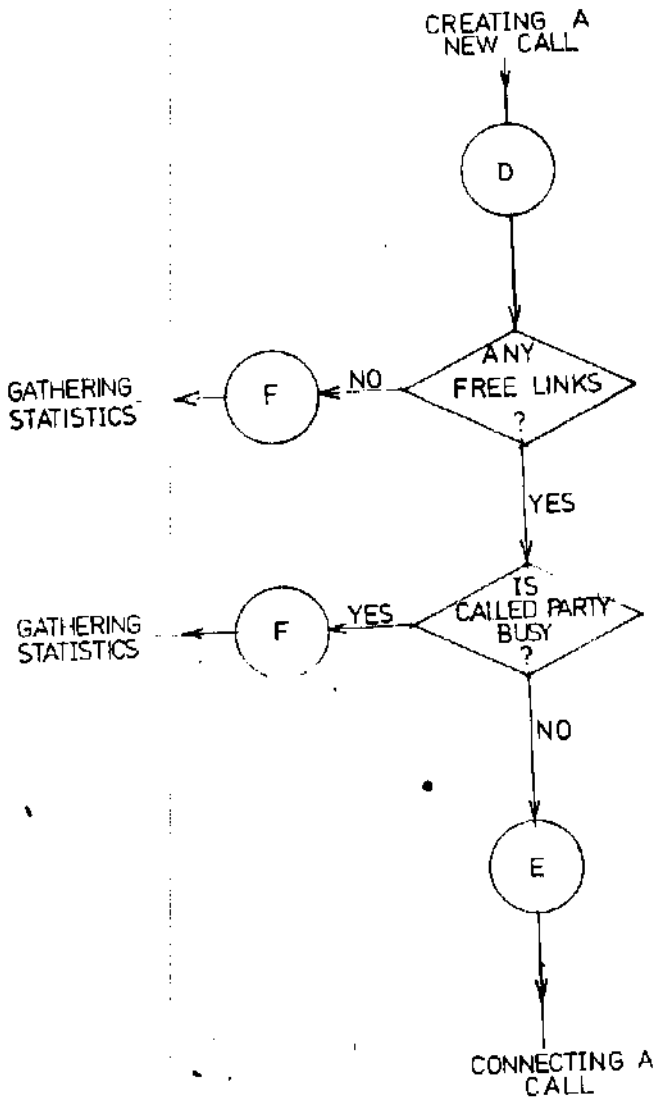


Fig.C.1(e) TESTING IF A CALL CAN BE CONNECTED

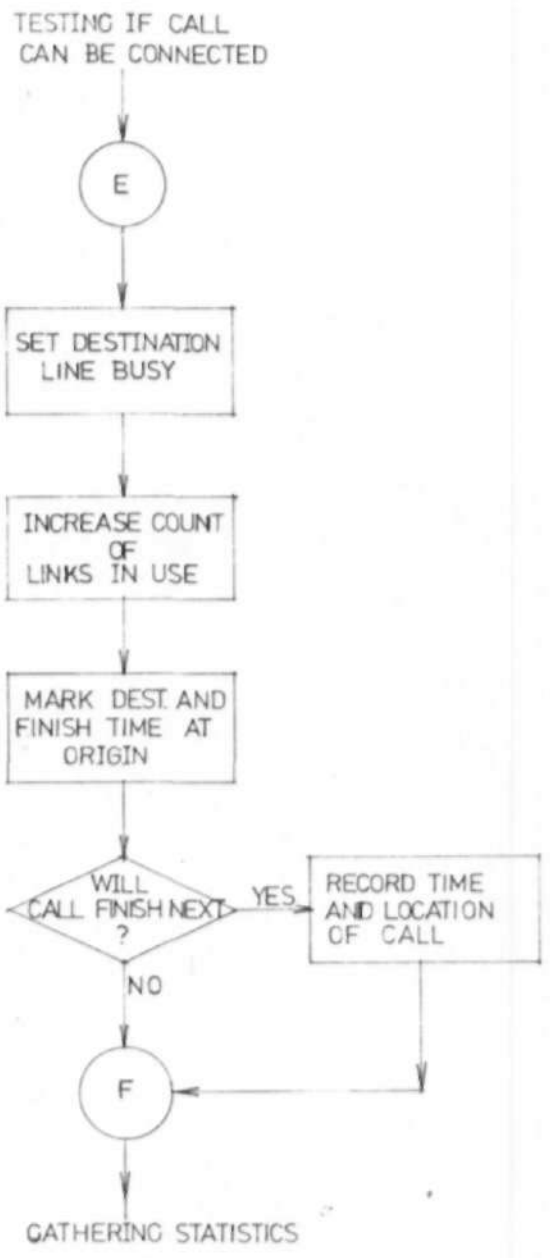


Fig.C.1(f) CONNECTING A CALL

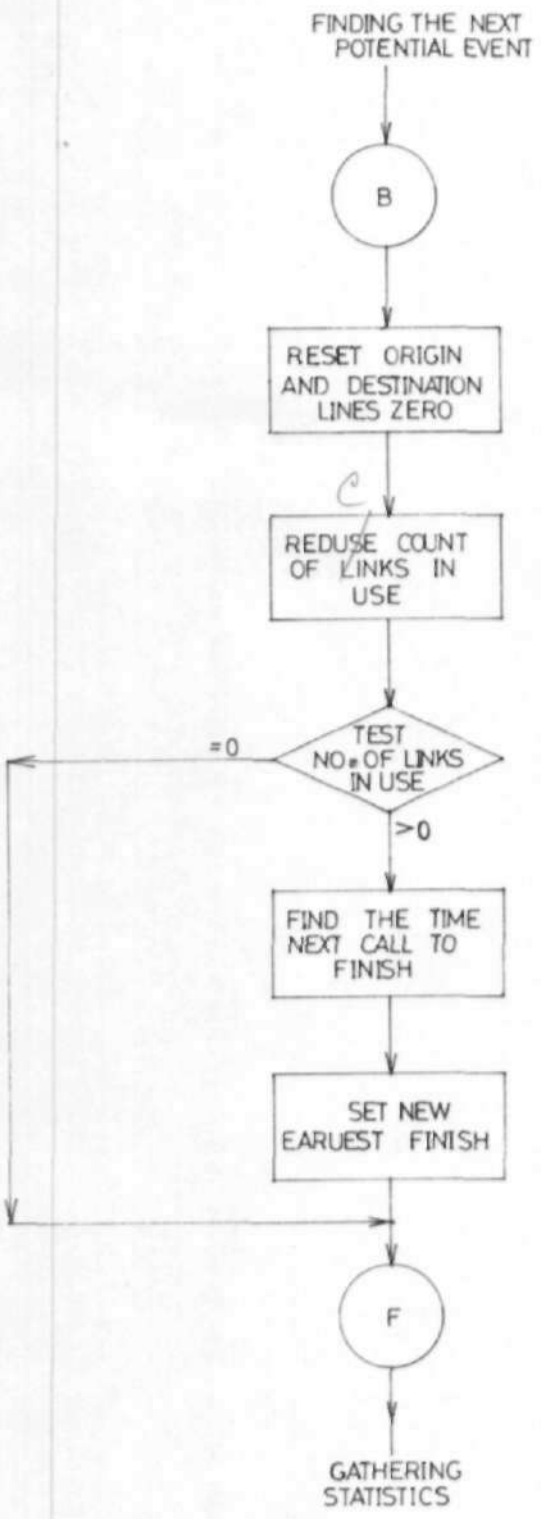


Fig C.1(9) DISCONNECTING A CALL

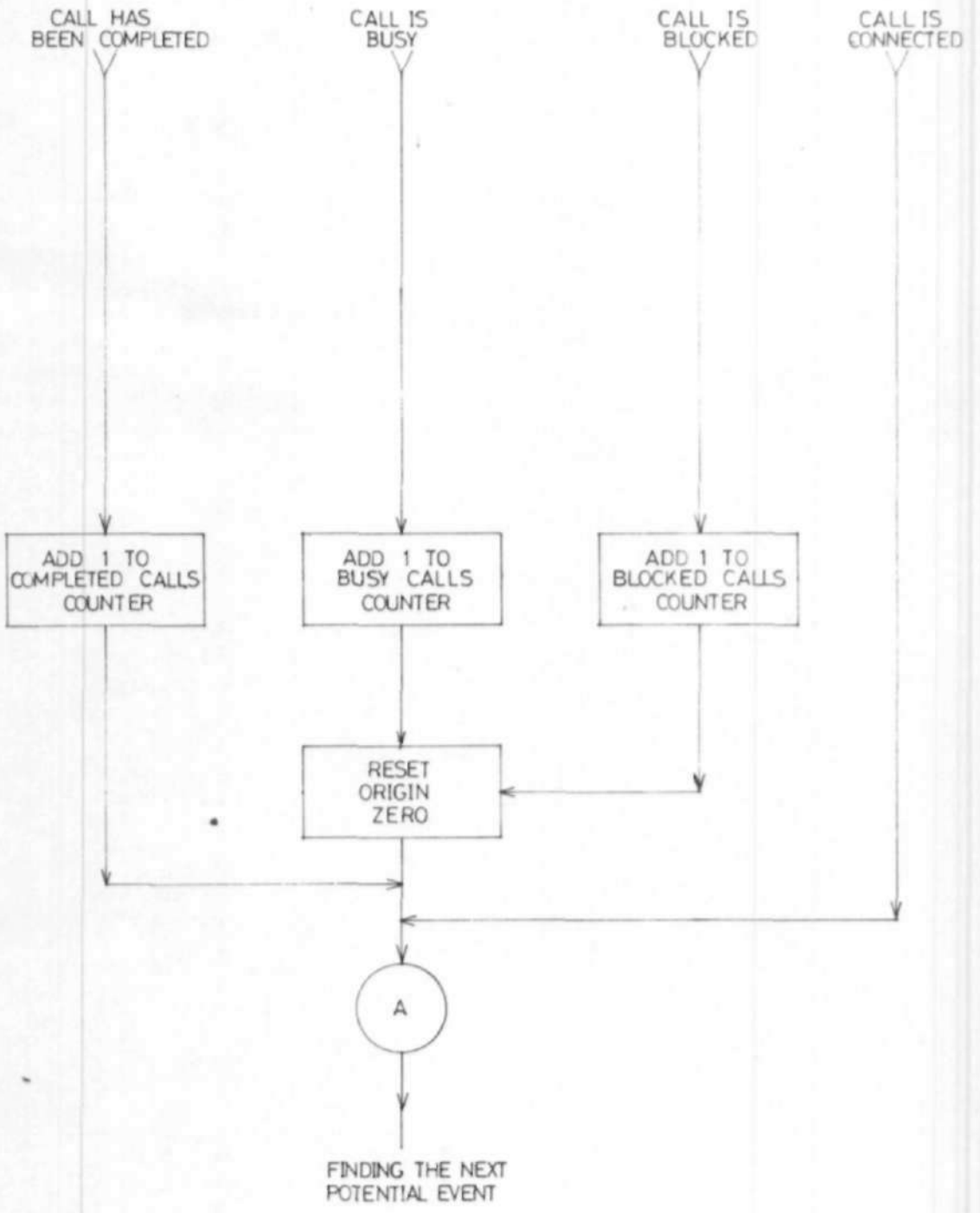


Fig.C.1(h) GATHERING STATISTICS

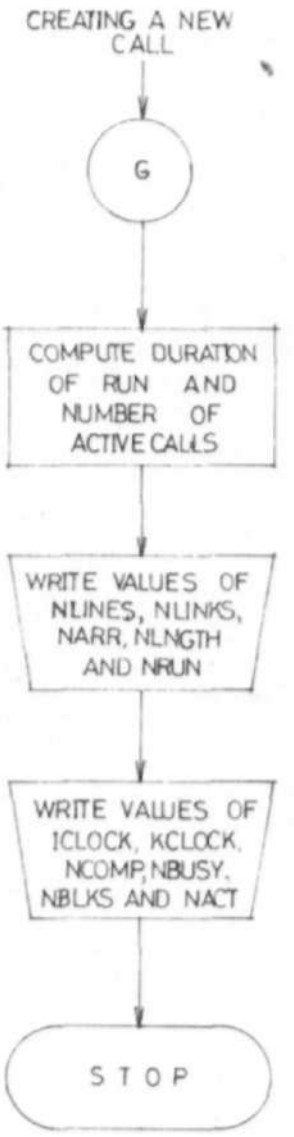


Fig.C.1(i) COMPUTING FINAL STATISTICS AND PRINTING OUT RESULTS

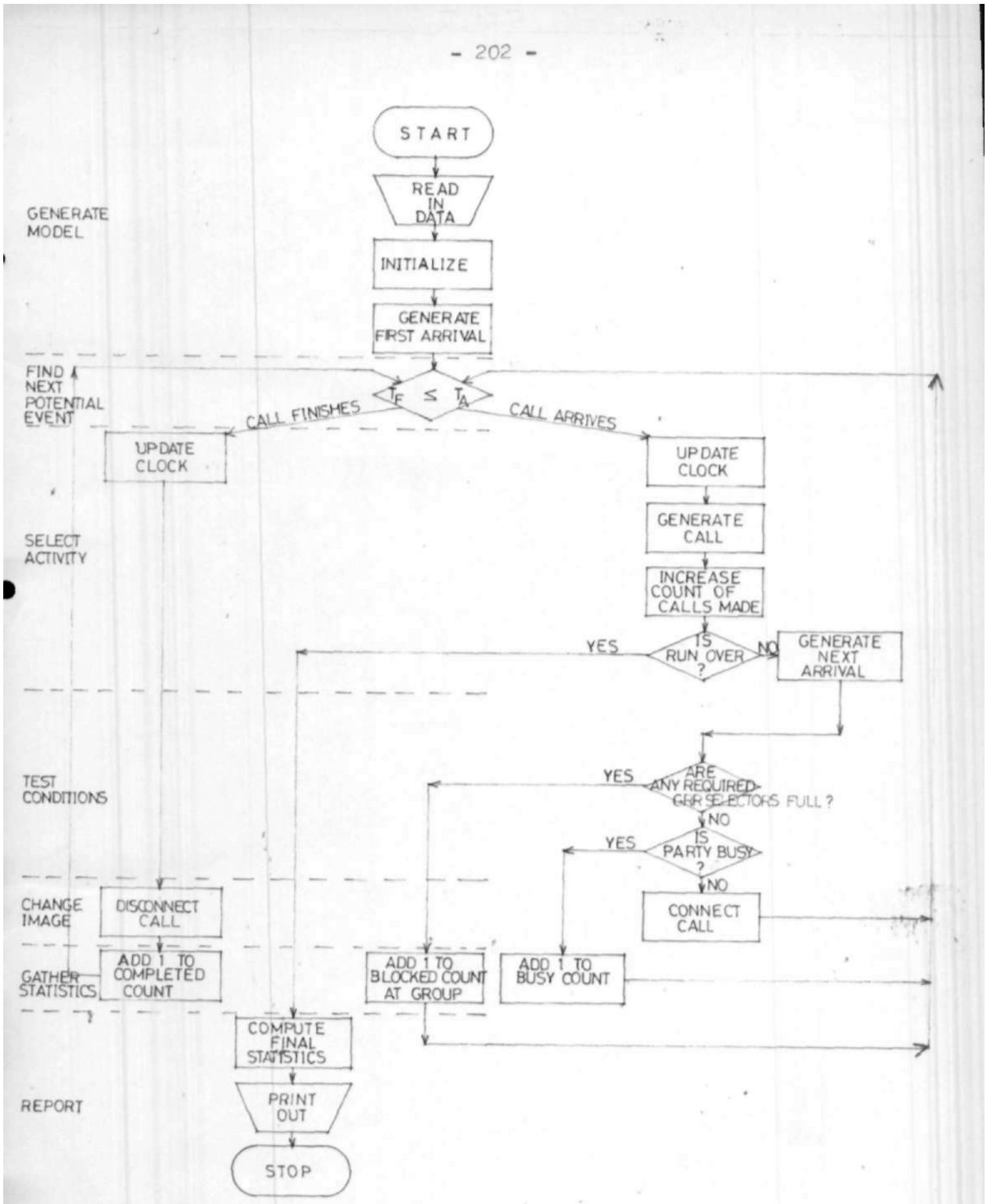


Fig.C.2(a) SIMTEX 1: FLOW CHART.

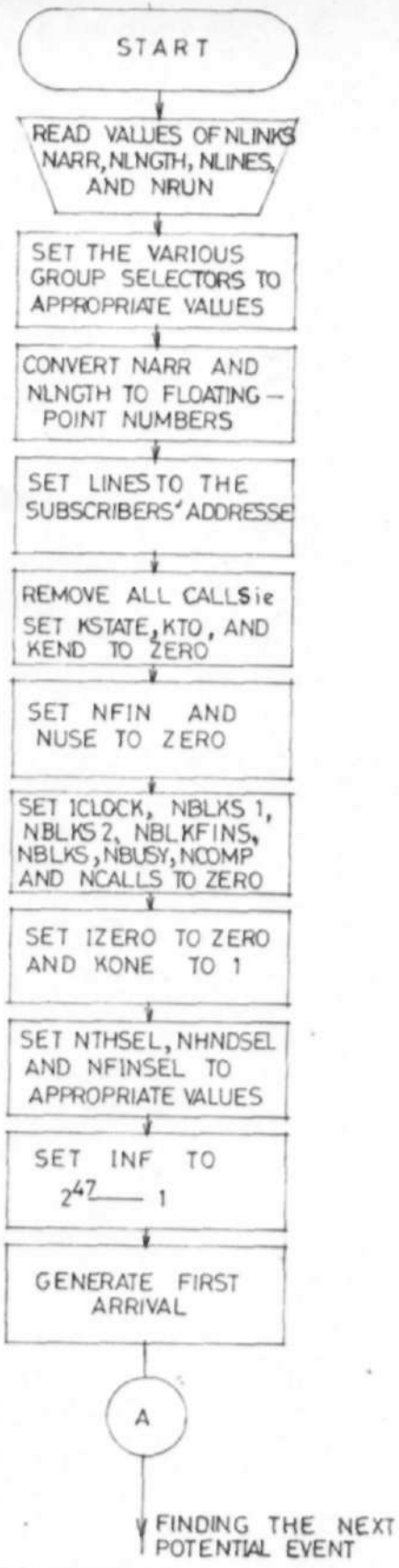


Fig C.2(b) PROGRAM INITIALIZATION

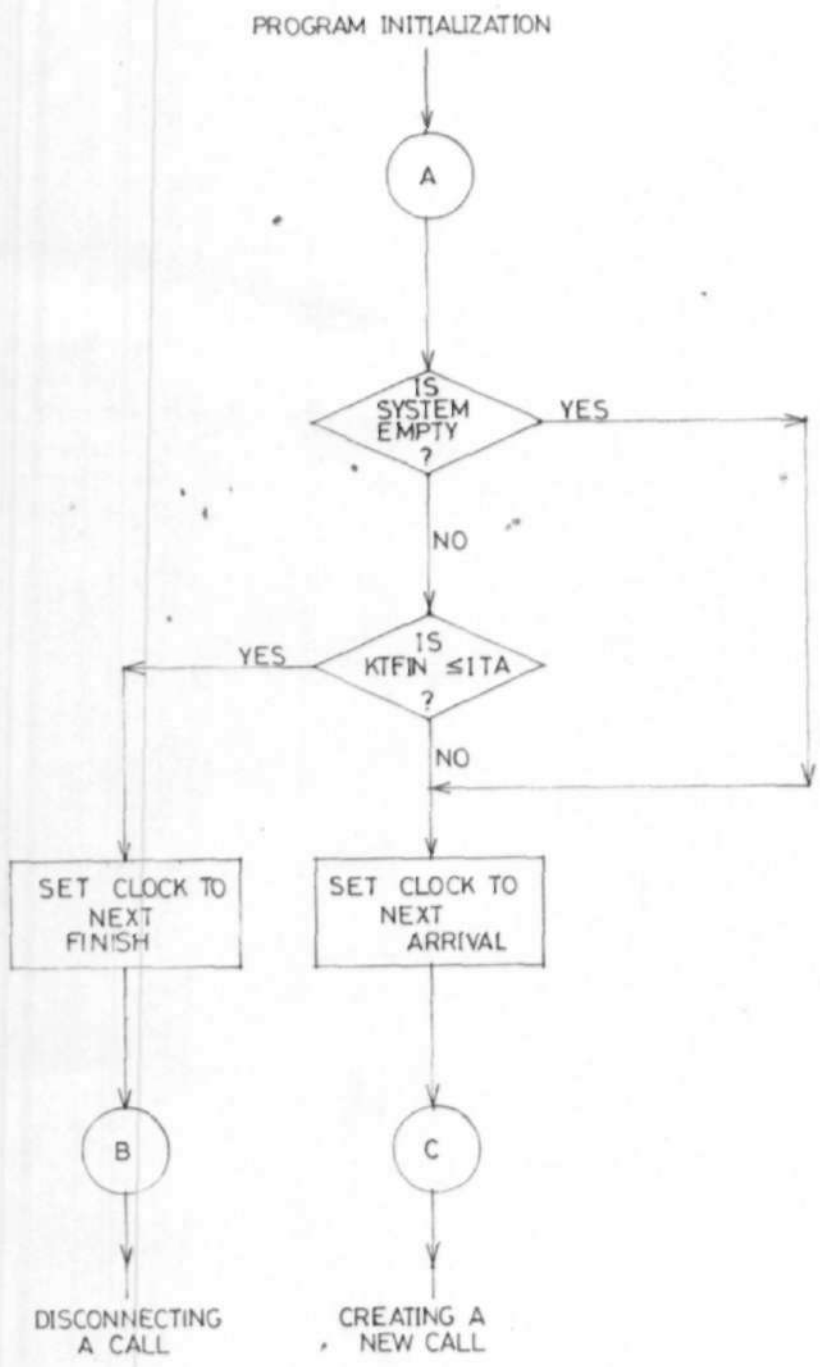


Fig.C.2(c) FINDING THE NEXT POTENTIAL EVENT

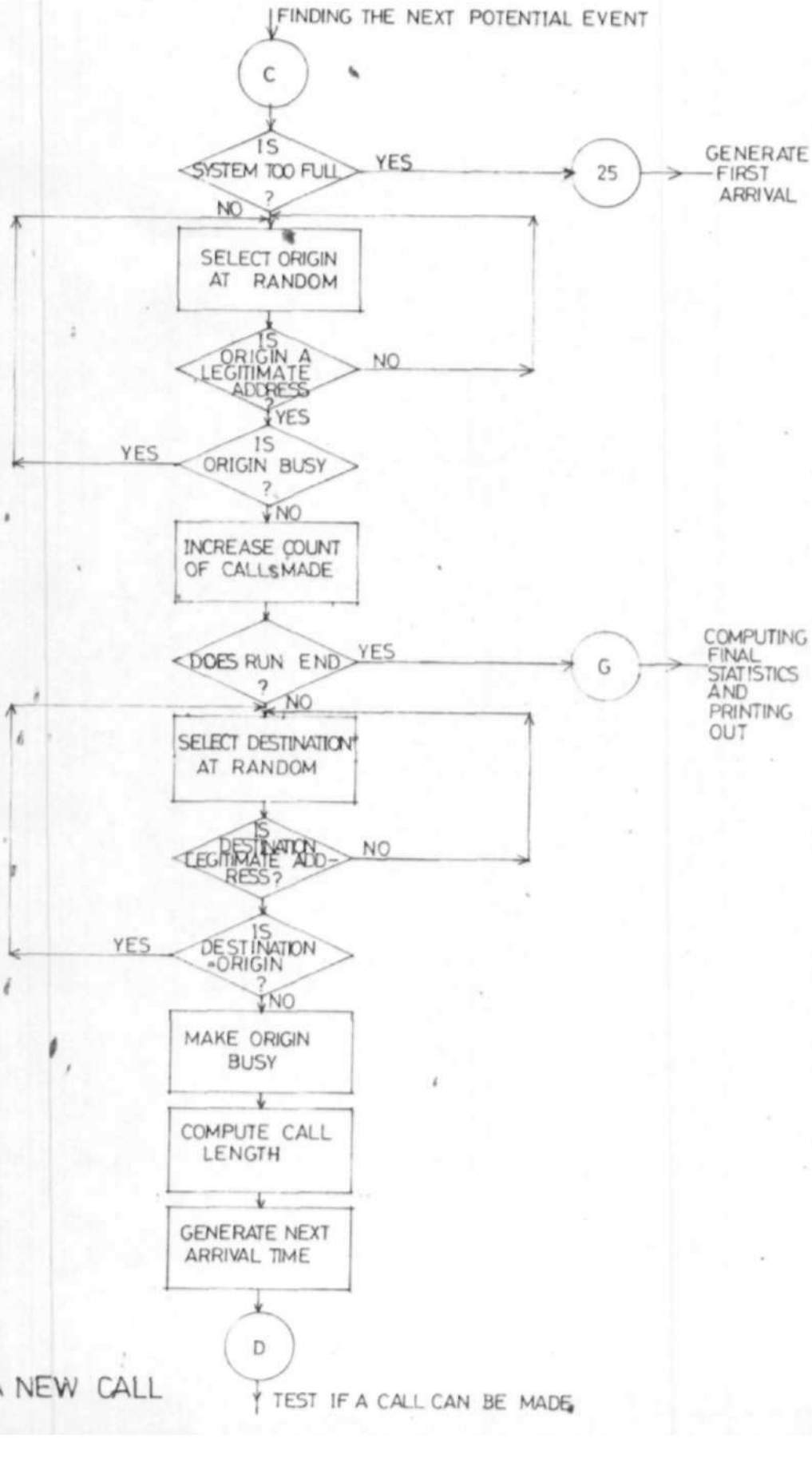


Fig.C.2(a) CREATING A NEW CALL

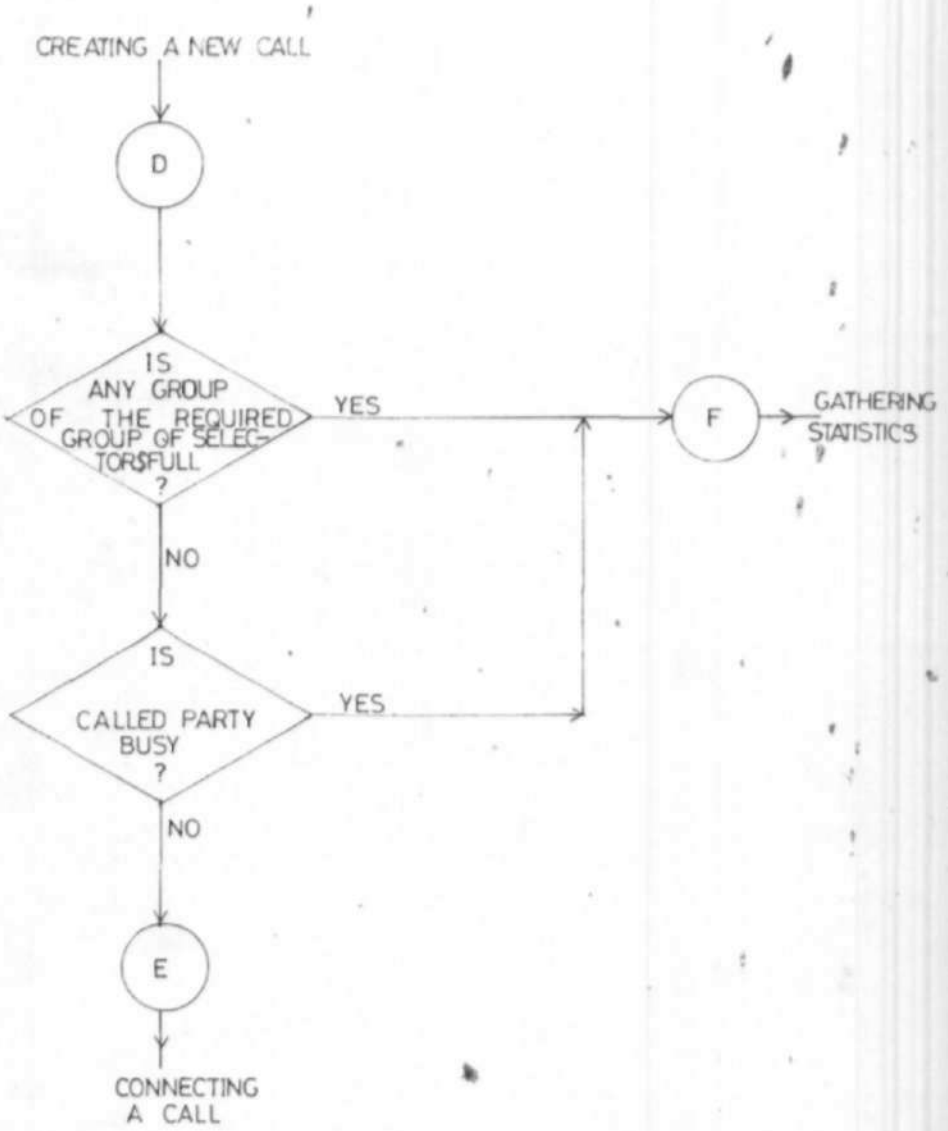


Fig.C.2(e) TESTING IF A CALL BE CONNECTED

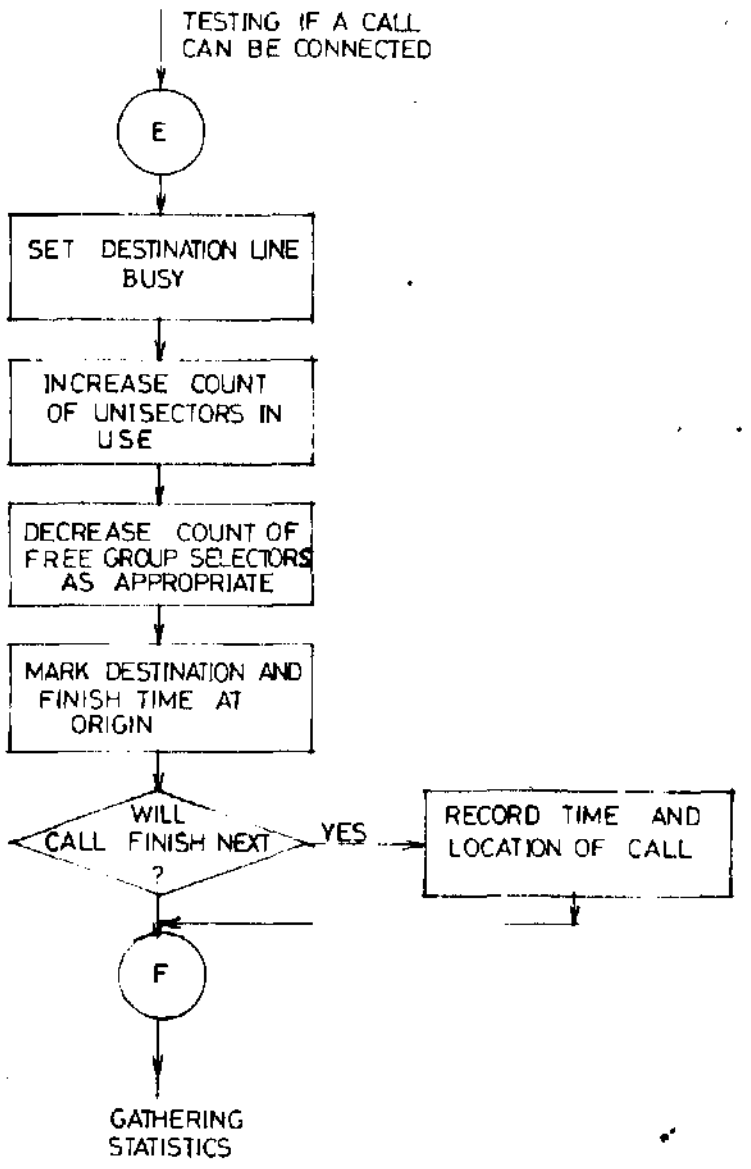


Fig C.2(f) CONNECTING A CALL

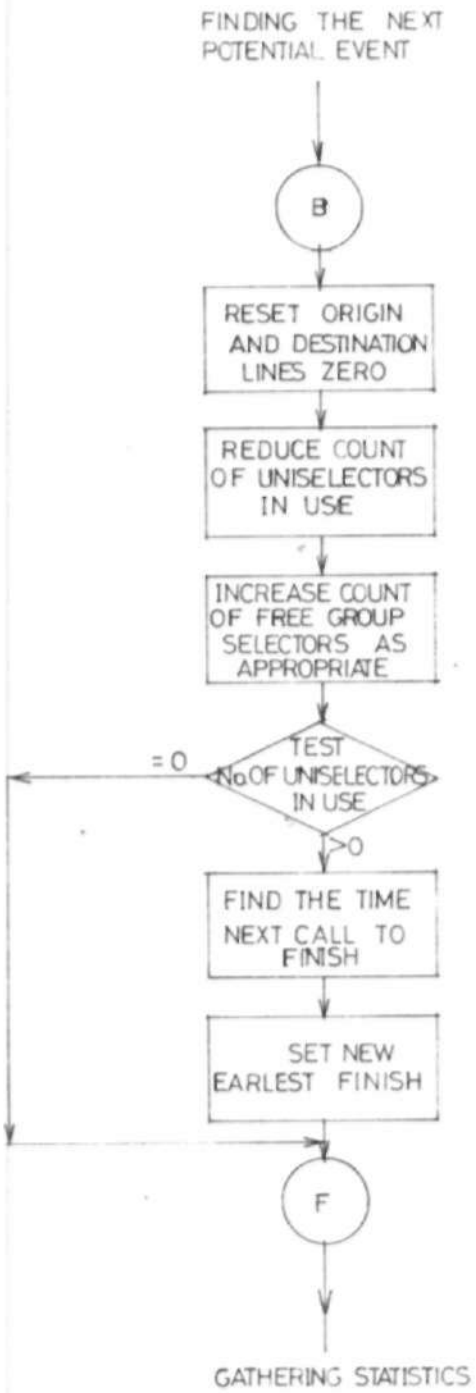


Fig.C.2(g) DISCONNECTING A CALL

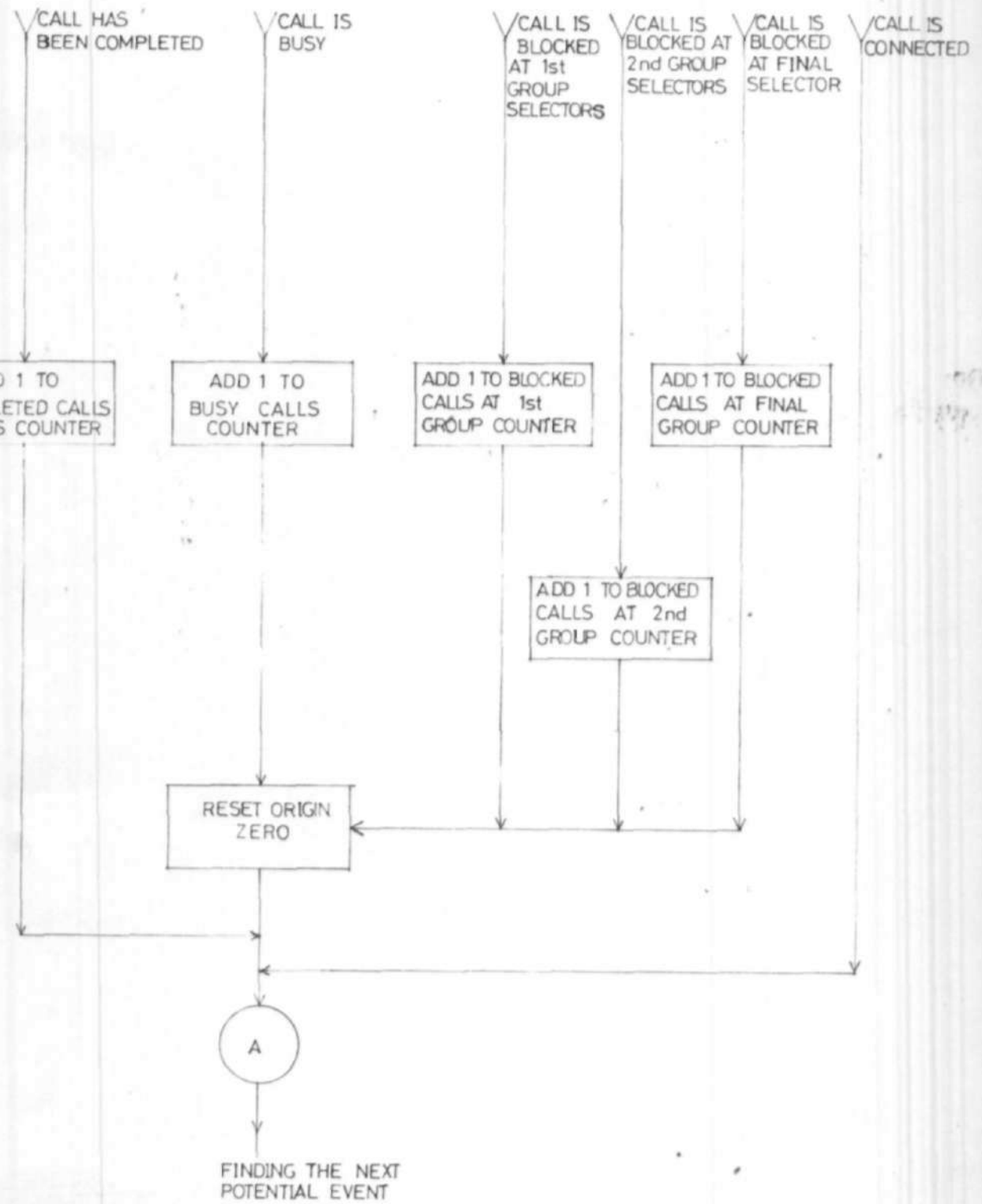


Fig.C.2(h) GATHERING STATISTICS

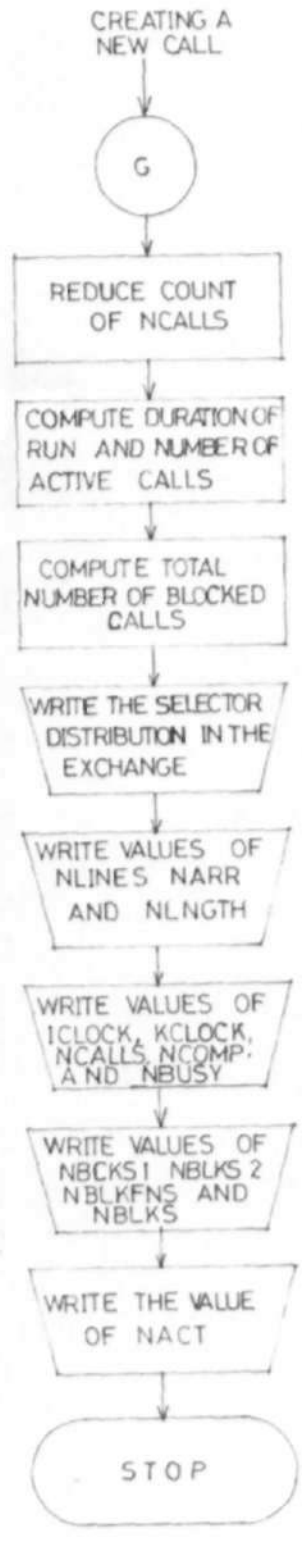
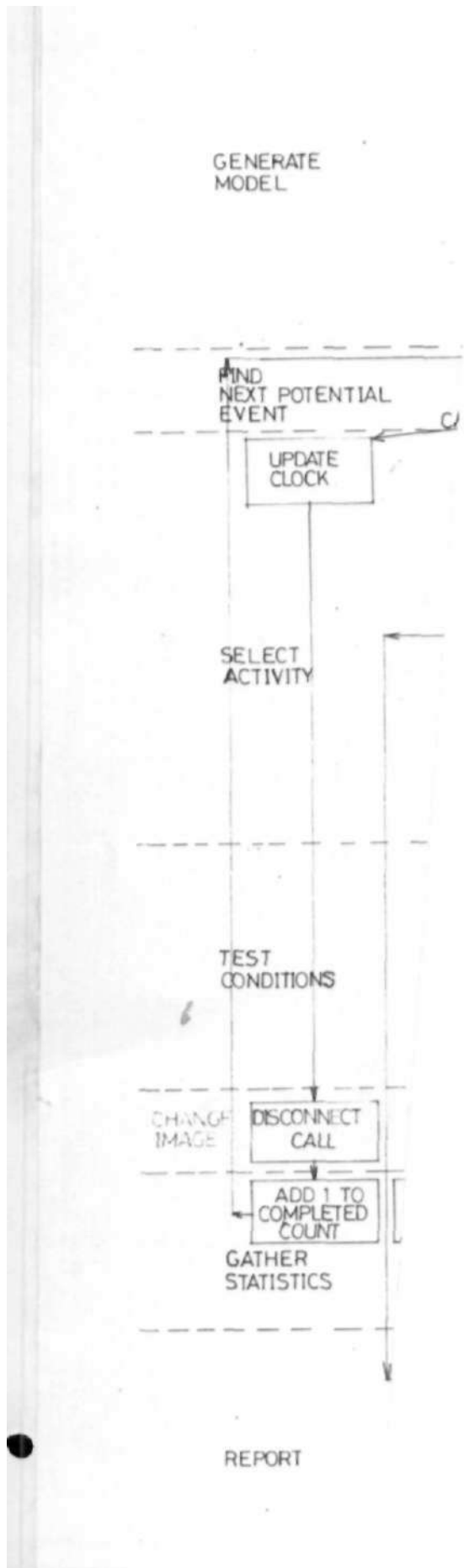


Fig.C.2(i) COMPUTING FINIAL STATISTICS AND PRINTING OUT RESULTS


GENERATE
MODEL
FIND
NEXT POTENTIAL
EVENT
UPDATE
CLOCK
SELECT
ACTIVITY
TEST
CONDITIONS
CHANGE
IMAGE
DISCONNECT
CALL
ADD 1 TO
COMPLETED
COUNT
GATHER
STATISTICS
REPORT

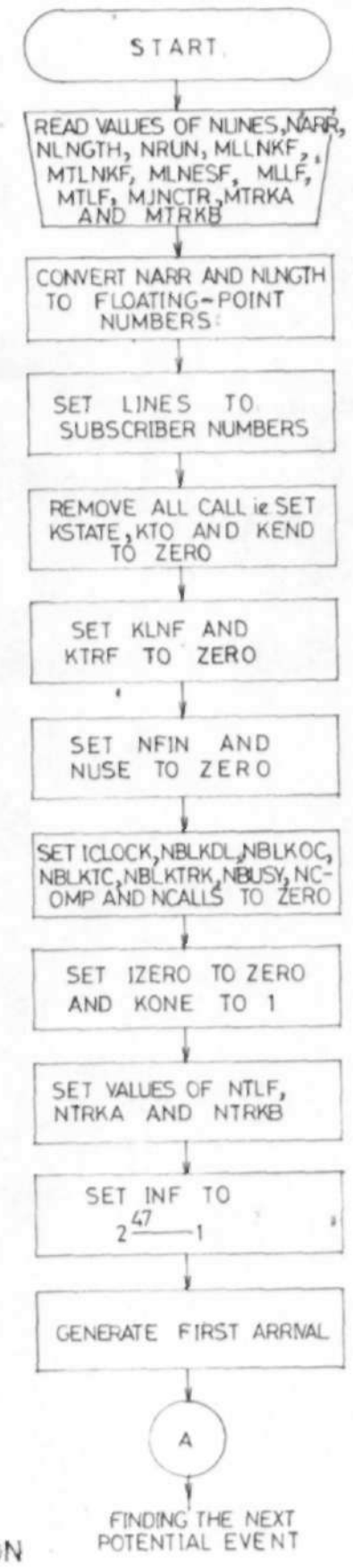


Fig.C 36 PROGRAM INITIALIZATION

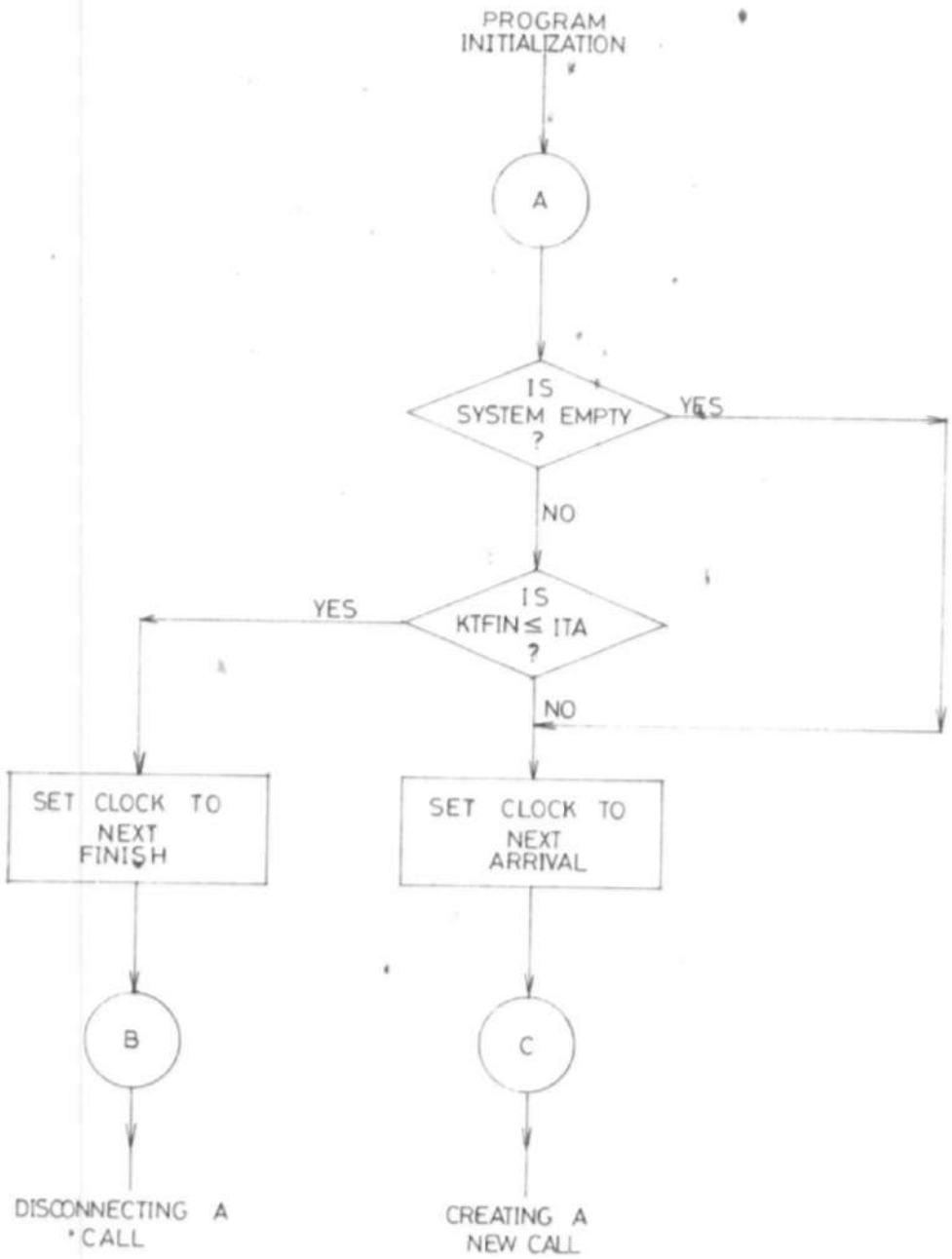


Fig.C 3(c) FINDING THE NEXT POTENTIAL EVENT.

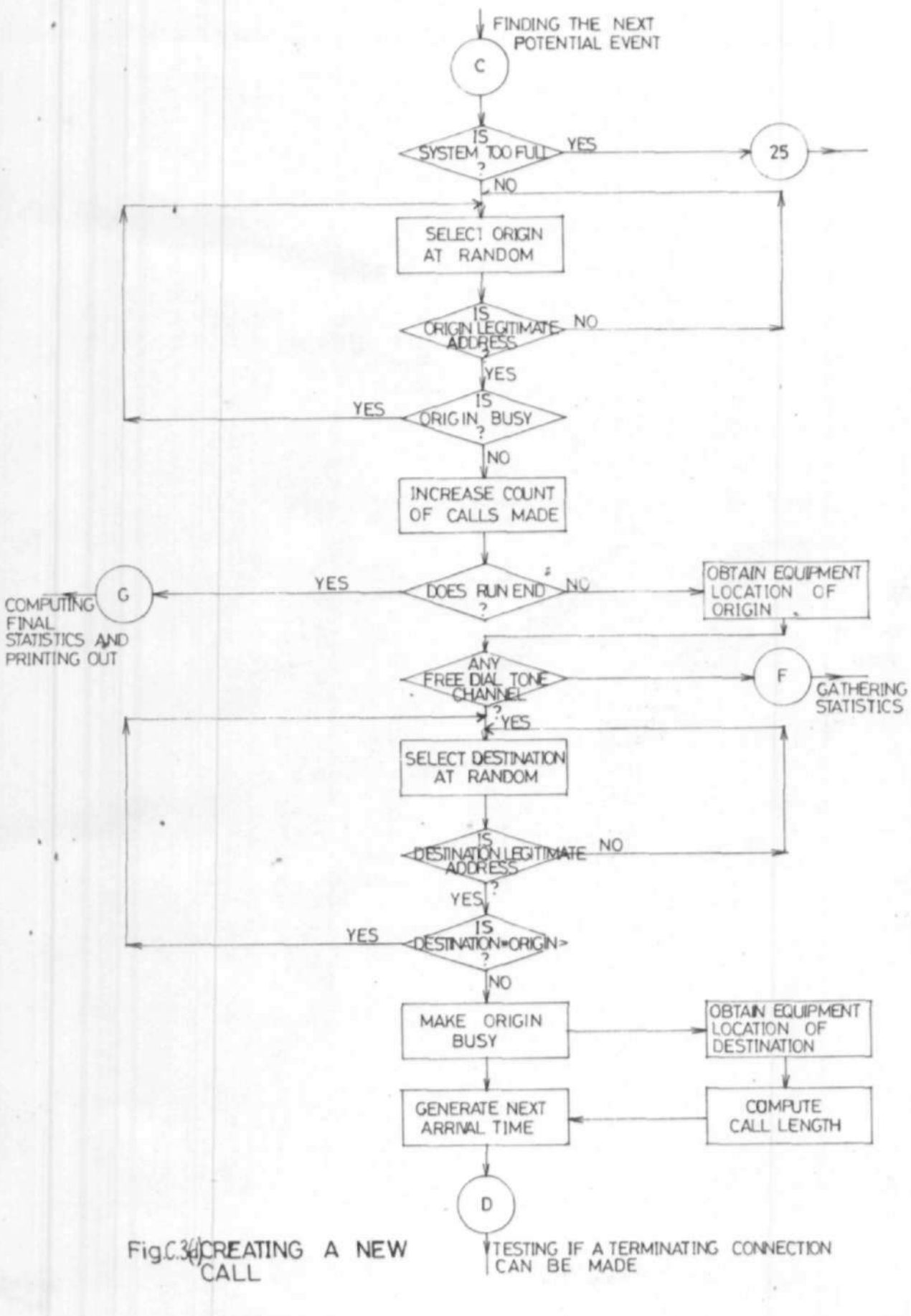


Fig.C.3(j) CREATING A NEW CALL

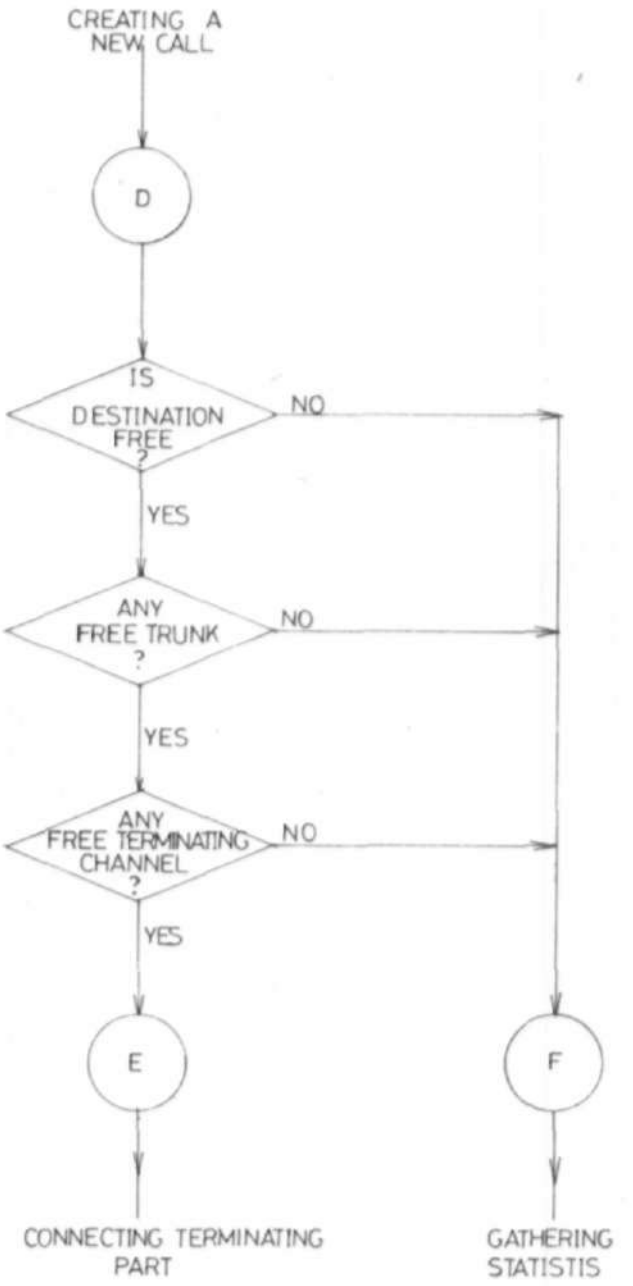


Fig.C.3(e) TESTING IF A TERMINATING CONNECTION CAN BE MADE.

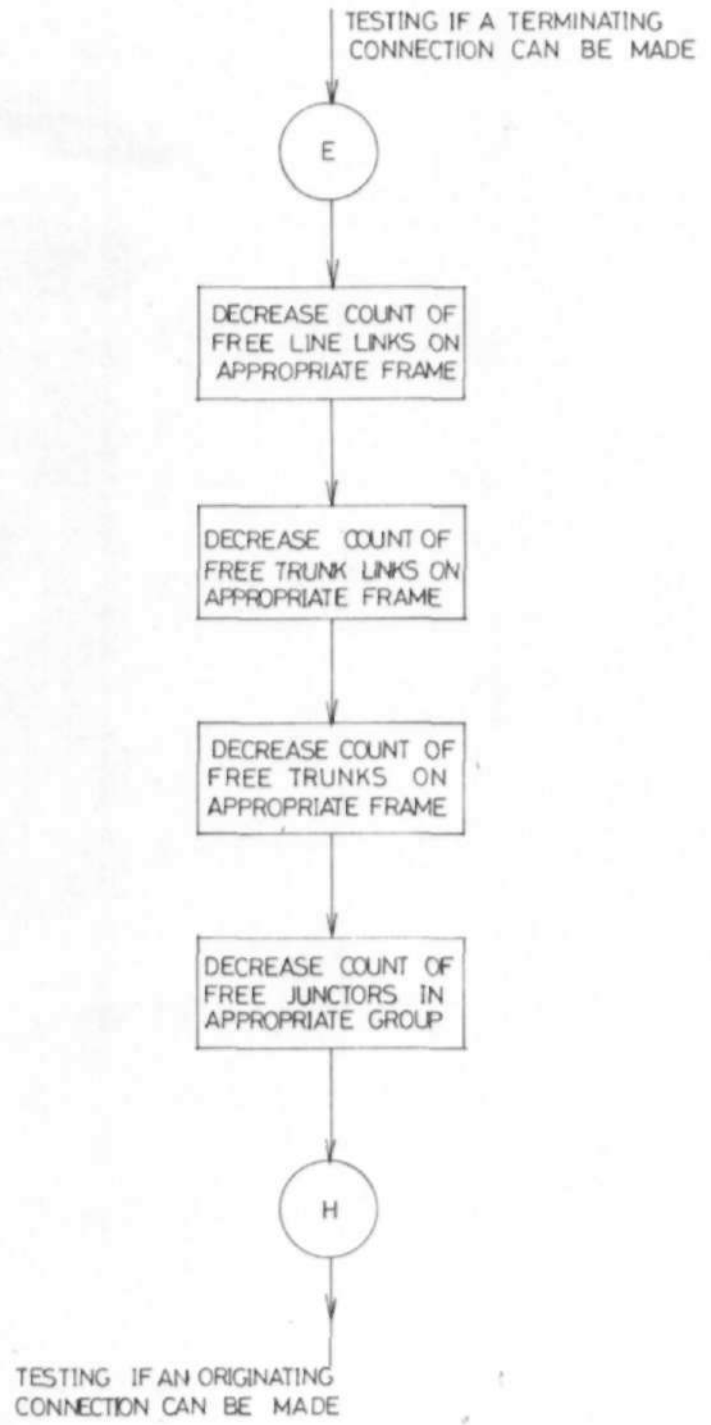


Fig.C.36 CONNECTING TERMINATING PART.

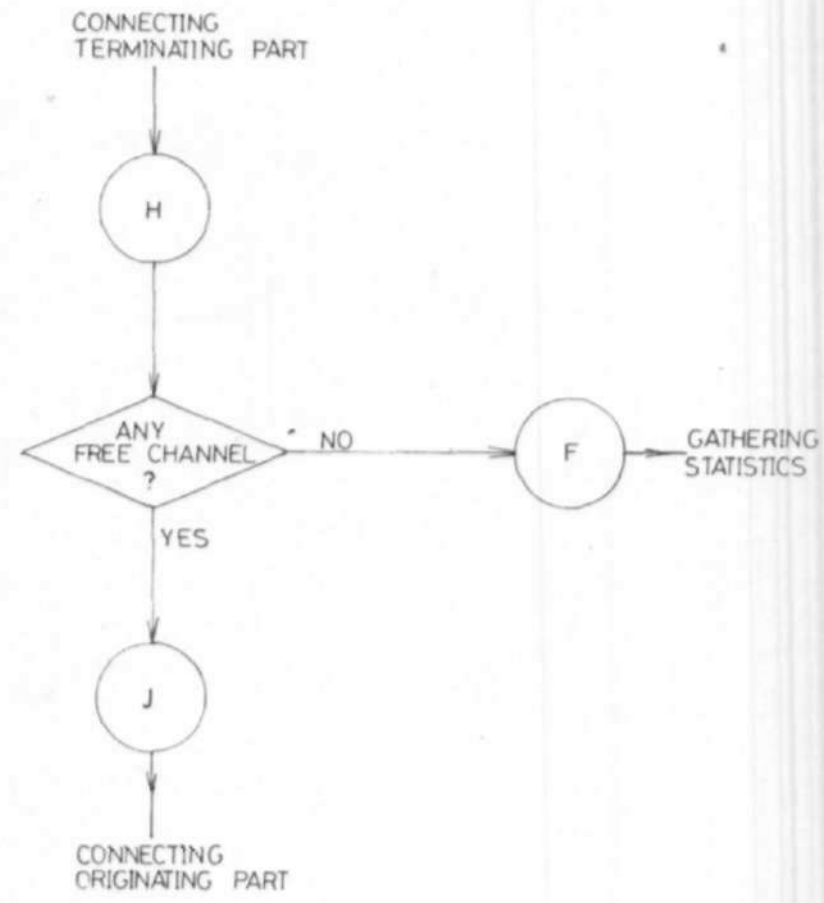


Fig.C.36 TESTING IF AN ORIGINATING CONNECTION CAN BE MADE

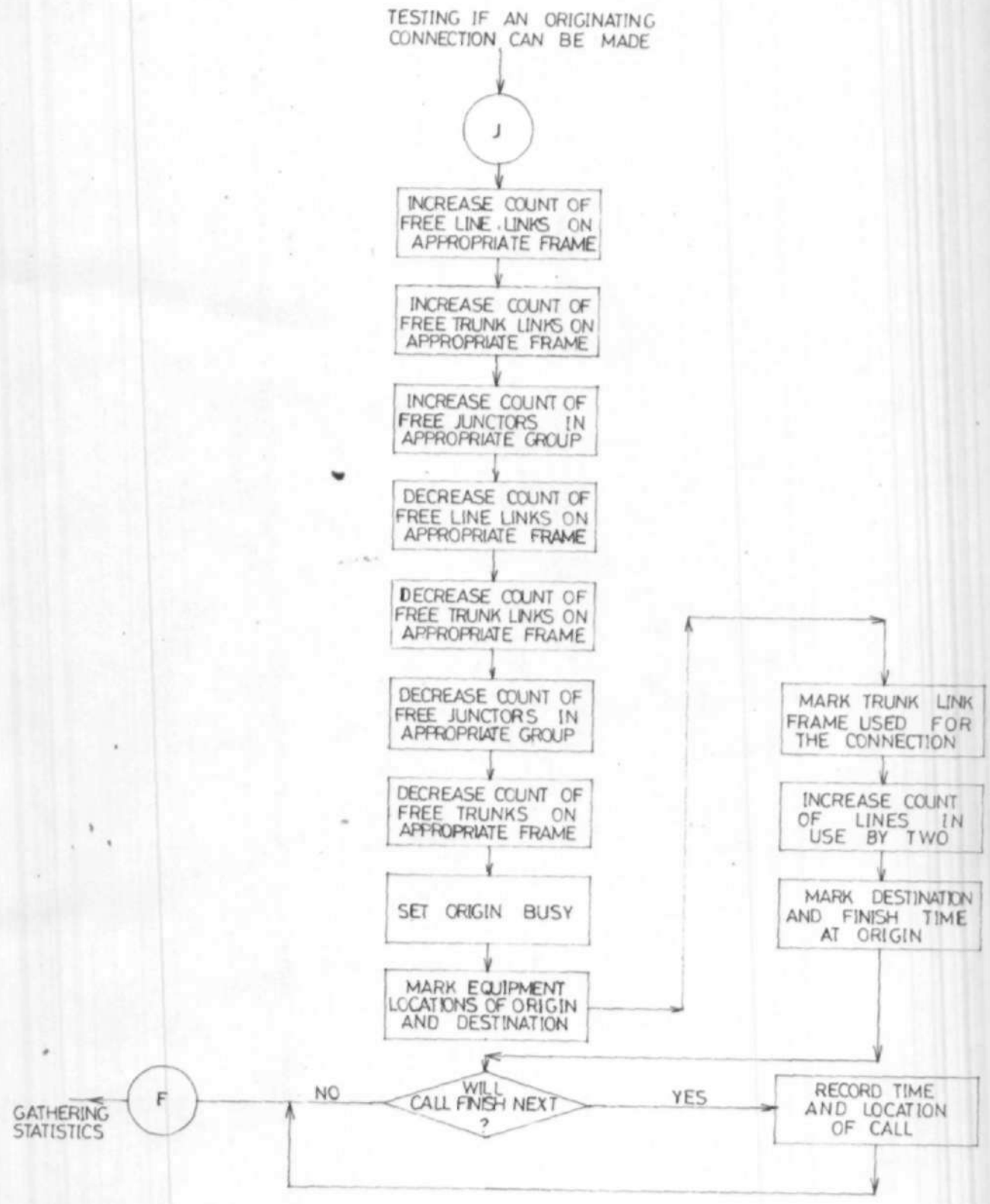


Fig.C.3(h) CONNECTING ORIGINATING PART.

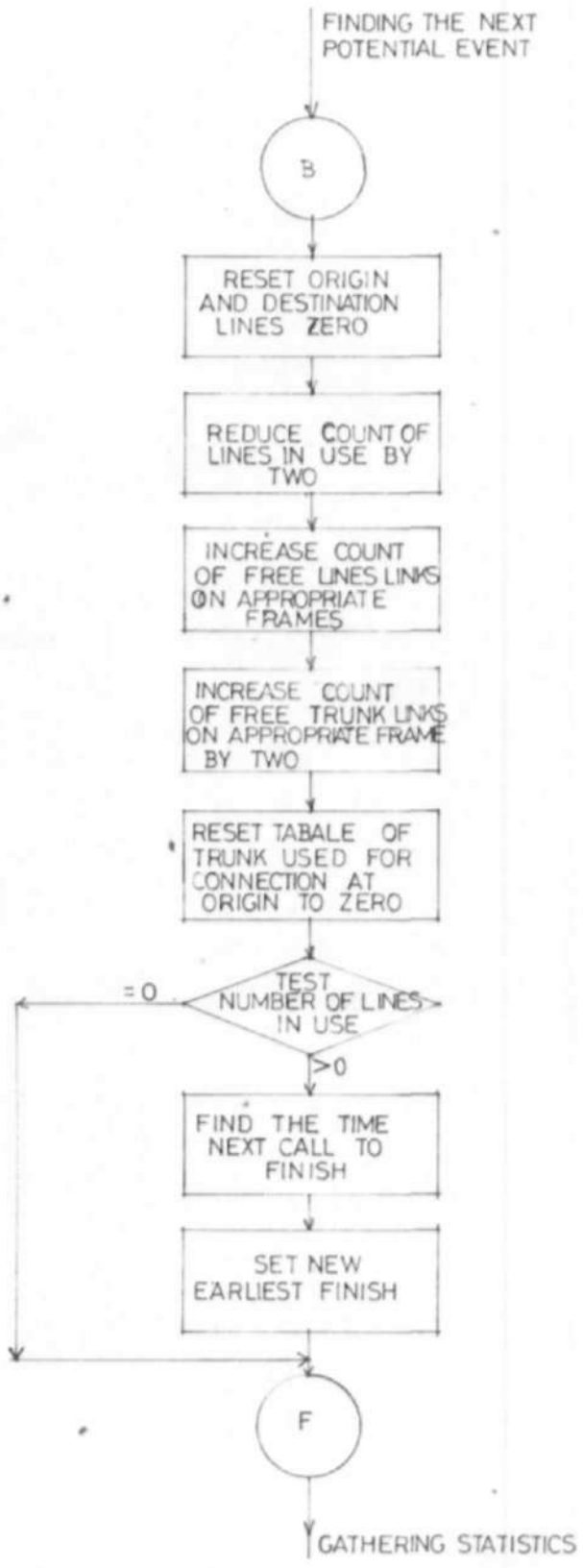


Fig C.3(i) DISCONNECTING A CALL

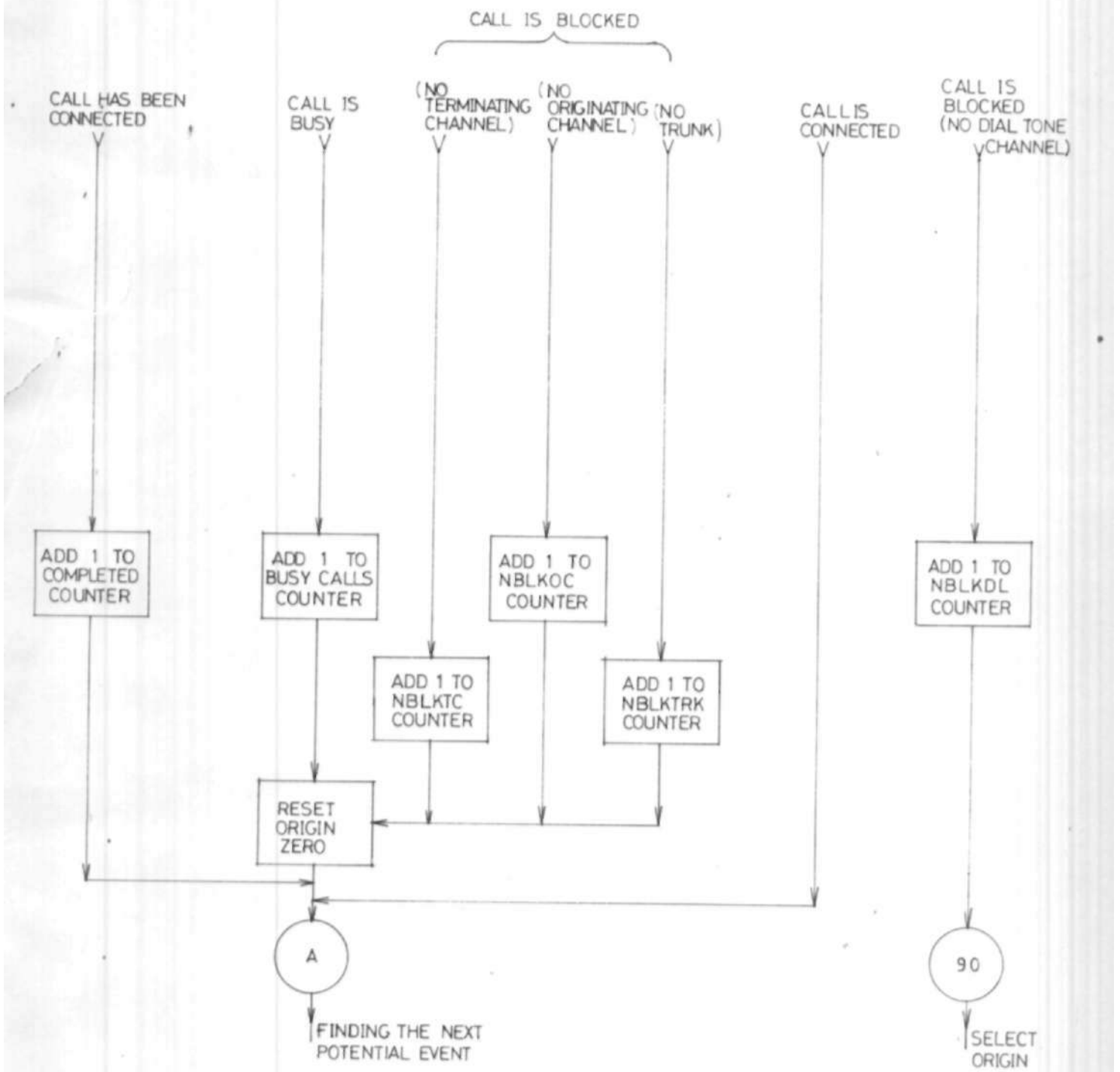


Fig.C.3() GATHERING STATISTICS.

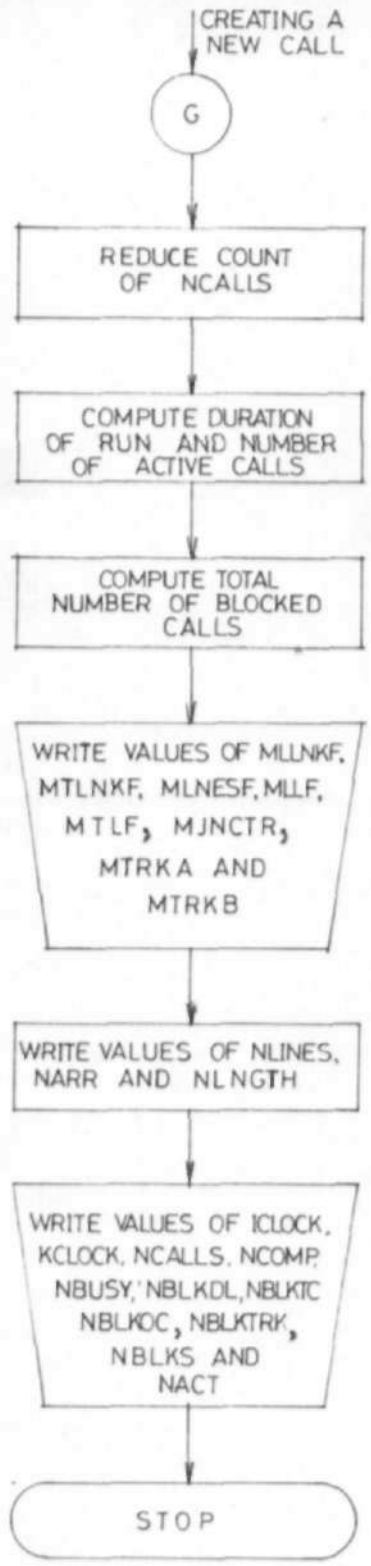


Fig.C 3(k) COMPUTING FINAL STATISTICS AND PRINTING OUT RESULTS.