NATIONAL BUREAU OF STANDARDS REPORT

10 488

A COMPUTER MODEL FOR SIMULATING THE RESPONSE ACTIVITIES OF A FIRE DEPARTMENT

Prepared for

The Fire Research Program
National Bureau of Standards

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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ABSTRACT

This paper discusses a computer model for simulating the response activities of a fire department. It presents the model from the viewpoint of a user who may wish to run the model "as is" or change it to resemble more closely the fire department of a particular city. The paper assumes some knowledge of SIMSCRIPT, the language in which the program is written.

Keywords: fire department, simulation, SIMSCRIPT.

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I. INTRODUCTION

In conjunction with project PHOENIX it was desired to simulate the response activities of the fire departments of various cities. In order to accomplish this aim, a computer program or model, FIDOS2, was developed. The language in which the program is written is SIMSCRIPT. This paper will discuss the model from the viewpoint of a user who may wish to use the model "as is" or perhaps modify it to model more closely the fire department of a particular city. Some knowledge of SIMSCRIPT will facilitate the reading, particularly in Sections IV and V. References [2 and 3] are major documentations of the SIMSCRIPT language. A reader familiar with simulation in general can probably read and understand the rest of the paper.

In a very general sense, the model may be described as follows: a case enters the system, i.e., the fire department receives a call for service. The assignment portion of the model acts as the dispatcher by determining which resources will serve the case. The selected resources then travel to the case and remain at the scene of the case for a specified length of time. At the end of this specified time, the resources leave the scene and return to their stations. When the last resource leaves the scene of the case, the case is terminated.

Unlike the RAND simulation model for the Fire Department of New York City [1], FIDOS2 is quite simple and is not designed to model any particular fire department. As the model now stands, it is best suited to model fire departments in relatively small cities. FIDOS2 does not now include provisions for such things as the queuing of cases at the dispatcher, delayed responses resulting when a case occurs in an area whose resources are already busy, interruption of service to "low priority" cases when an urgent case occurs, or "moving up" resources into other stations in areas where most of the resources are out on call. These provisions, although obviously important in modeling some fire departments, have not been of major concern in the applications of the model thus far. The inclusion of such provisions in the model would over-complicate the systems simulated to date. It should be noted, however, that the modular structure of FIDOS2 was developed to minimize the difficulty associated with adding such provisions to adapt the model to a particular fire department.

The purpose of the simulation model is to estimate measures of the ability of the fire department to respond "quickly" when needed under various system configurations. The output of the model gives measures of response time, utilization, and availability which can be used to indicate to what extent proposed changes in the system would improve the overall service.

The basic system parameters which can be varied via input are:

1. The number and locations of fire stations.
2. The amount and location of equipment (only engines and trucks are now considered).
3. The average speeds at which vehicles travel in emergency and non-emergency situations.

4. The starting delay, i.e. the time between the notification of a resource that its services are needed and the resulting departure of the resource from its station.

By revising one subroutine in the code, it is possible to change the dispatching or assignment policy used. The policy which is presently coded will be discussed in Section II (under the description of subroutine RESAP).

Two important terms should be clarified at this time. First, throughout the remainder of this paper the word resource will be used frequently. As the model is coded, a resource can be either a single piece of equipment, i.e. an engine or a truck, or else a company, i.e. an engine company or a truck company, where the individual pieces of equipment comprising the company act as a single unit with respect to response time and time spent at the scene of a case. Either interpretation can be applied (so long as it is applied consistently) in defining the situation to be simulated and in interpreting the outputs of the model.

The second point concerns the use of the term alarm. An alarm is a request for one or more resources. All resources associated with an alarm are dispatched at the same time and remain at the scene of the case for the same length of time. If they come from different locations they will (in general) arrive at the scene at different times and will therefore leave the scene at different times. Thus a case requiring three engine resources and two truck resources, all of which are requested at the same time and will stay on scene the same length of time, could be input either with one alarm requesting three engines and two trucks, or with five alarms each requesting one resource of the given type.

The cases to be served by the fire department being simulated are input to the model via the Exogenous Events Tape. The format of the tape is discussed in Section V. The data on this tape are derived from reports logged by the fire department being simulated. A pre-processor program must generally be written to extract the data from the reports and put them in the appropriate format. One very important conclusion drawn from this study thus far is the need for standardized reporting forms. Since the data and format of the report forms vary among fire departments, a detailed discussion of a general preprocessor is meaningless. Until such time as standardized reporting forms are used, each fire department to be simulated requires a different preprocessor. The help of the fire department will be useful in deriving the required data from the reported data. The following list gives the case attributes required as input to the model.

1. The day and time the case occurs.
2. An identification number for the case, such as its log number.
3. The number of alarms for the case.
4. The location of the case, in (x, y) coordinates.
5. A number indicating the type of case, e.g. public service, accidental alarm, fire, etc.

6. The time of occurrence, the on scene time (service time excluding travel time to and from the case), the number of engine resources, and the number of truck resources, for every alarm of the case.

It should be noted that the Exogenous Events Tape could be reduced. It is possible to have an endogenous event corresponding to the occurrence of a case where the time between such events is sampled from a distribution, e.g. negative exponential. The log number for the I-th incoming case could be I, and the remaining case and alarm attributes could be gotten by sampling distributions derived from historical data. This arrangement has the advantage of allowing the user to vary the case scenario so as to answer questions such as " "How does the system perform if the number of false alarms decreases, for example after a community relations program has been initiated?" or "What is the effect on availability and response time if the number of serious cases (cases requiring many resources) increases by ten percent?" Using three months' data (approximately 900 cases) from the fire department records for the city of Alexandria, Virginia, it has been shown in [4] that the times between case occurrences do follow a negative exponential distribution. If it is desired to simulate other than historical cases, it will be necessary to develop probability distributions for the case attributes based on historical records and to verify the distributions hypothesized for the city being simulated. These distributions could then be included in the model, thereby reducing the Exogenous Events Tape so that it contains only the events which start and stop the simulation.

Implicit in the model are several major assumptions concerning the locations of resources and cases, and the network over which resources travel to and from cases. First, it is assumed that a grid has (conceptually) been placed over the city being simulated. As the model is now coded, the cells of the grid are assumed to be square. (This restriction was imposed because of the particular grids used in coding the case locations of the cities thus far simulated. The data were collected prior to the development of FIDOS2.) For the cities simulated thus far, all cases occurring within a cell were pre-coded as occurring at the center of the cell. The station locations specified via the Initial Deck must be defined relative to the same grid.

Second, a "metropolitan metric" is used when determining the distance d between two points (x_1, y_1) and (x_2, y_2). Thus d is calculated as

$$d = |x_1 - x_2| + |y_1 - y_2|.$$

It is assumed that the speed of travel is the same in both the x and y directions so that travel time is simply d/speed, where the speed depends on the type of case being served. Only two speeds are now used in the model. The slower, non-emergency speed is used for cases of type 1 (public service), and also when returning to the station from all cases.

Finally, mention should be made of the paths over which resources travel to and from cases. In general, there are numerous routes of distance d, as calculated previously, between (x_1, y_1) and (x_2, y_2). However, the model assumes that routes are parallel to the coordinate axes and that the entire distance in one direction is traveled prior to travelling any distance in the other direction. There is a probability of 0.5 associated with traveling first in the x-direction.

II. EVENTS AND SUBROUTINES

The simulation model involves three exogenous events, eight endogenous events, and five subroutines.

Exogenous Event START occurs when the simulation begins. It initializes several variables, and creates and causes an event NUDAY to end the first day, an event NUCRU to end the first shift, and an event AVAIL to occur a half hour after the simulation begins.

Endogenous Event AVAIL occurs every hour on the half hour. It counts the number of idle engine resources. A resource is termed "idle" if it is neither enroute to a case nor on the scene of a case. The counts obtained by this event are used to form the availability distribution for each shift. Each AVAIL also causes another event AVAIL to occur an hour later.

Endogenous Event NUCRU occurs at the end of every shift. (The number of shifts per day and the time that each shift ends are specified via the initialization deck.) It accumulates the utilization of the individual resources by shift, and causes another event NUCRU to occur at the end of the next shift.

Endogenous Event NUDAY occurs every day at 2400 hours. It accumulates utilization of the individual resources by day of the week and causes another event NUDAY to occur 24 hours later.

Exogenous Event ALERT occurs whenever a case occurs. It is the input routine for the case attributes. It creates and causes an event ALARM to occur at the specified time for each alarm associated with the case. It also prints the input attributes of the case.

Endogenous Event ALARM occurs when one or more resources are requested to respond to the scene of a case. It calls subroutines ARR and RESAP to determine which specific resources will serve the alarm, and subroutine SERVE which assigns the resources to the alarm.

Subroutine ARR determines the time to respond to the scene of a case for every idle resource. If the company is idle at its station (as opposed to idle returning from a case), a fixed delay time specified via the initialization deck is added to the travel time. The locations of resources enroute back to their stations are determined via calls to subroutine WHERE. The resources are filed into a set RSET ranked on response time, i.e. the resource which can arrive soonest is the first member of the set.

Subroutine WHERE determines the location of a moving resource. The calculations are based on the speed at which the resource is traveling, the coordinates of the origin of the resource, the coordinates of the destination of the resource, the time at which the resource departed, and a random number indicating whether the resource first travels in the x direction or the y direction.

Subroutine RESAP is concerned with the resource assignment policy. The policy now used in the model selects those resources of each type which are idle and can arrive on the scene the quickest. The number of resources of each type is an attribute of the ALARM supplied on input. The engine resources to be assigned are filed into the set ESET (ALARM) and the truck resources are filed into the set TSET (ALARM). If fewer than the requested number of resources are available, a message is printed indicating that an incomplete response is being made. The number of such incomplete responses is output at the end of the run.

Subroutine SERVE actually assigns the resources to the alarm. It sets up various bookkeeping parameters and cancels any event, e.g. HOME, which may have been scheduled for the resource prior to the present assignment. It changes the status of the resource to "busy going to a case." Usually it creates and causes an event ARVSN to occur when the resource arrives at the scene of the case. If, however, the on scene time as input for the alarm is negative, it creates an event SNDBK to occur after the resource has traveled half the distance to the scene of the case. The motivation for this provision arose from examination of recorded data from several fire departments. In some instances the time of departure and the time back "on the air" logged in by the individual companies indicated that the company never actually arrived at the scene of the case. This could reasonably occur if another resource arrived at the scene and reported back to the dispatcher that less than the requested amount of equipment was needed. The excess resources would then be sent back to their stations.

Endogenous Event SNDBK occurs when a resource is told to return to the station before reaching the scene of a case. It determines the location of the resource via calls to subroutine WHERE, and creates and causes an event FINSH to occur immediately, thereby relieving the resource of its assignment.

Endogenous Event ARVSN occurs when a resource arrives at the scene of a case. The status of the resource is changed to "busy at the scene" and the location of the resource is changed to the location of the case. Various statistics on response time for the case and the resource are collected. ARVSN creates and casues an event FINSH to occur at the end of the on scene time specified for the alarm on input.

Endogenous Event FINSH occurs when a resource finishes serving a case. The status of the resource is changed to "idle returning." Case utilization statistics are collected here. FINSH creates and causes an event HOME to occur when the resource arrives back at the station. If all resources assigned to a case have completed their service, subroutine TERM is called to terminate the case.

Subroutine TERM occurs when a case is terminated. Various statistics for measuring the service of the case (in terms of time only) are collected. TERM prints out the case number, and the date and time of termination.

Endogenous Event HOME occurs when a resource arrives at its assigned station. The location of the resource is changed to the location of the station. The status of the resource is changed to "idle at the station." Resource utilization statistics are collected here.

Exogenous Event ENDSIM occurs when the simulation is to end. It averages various data, converts data to appropriate units, and outputs the statistics summarizing the simulation. A description of the output is given in Section VI.

III. DEFINITIONS OF MAJOR VARIABLES

The following list will define all entities, attributes, event notices, and major variables appearing in the Definition Deck. Any other variables used in the simulation are local variables used in at most one subroutine or event and are of no real concern to the average user. Attributes will be listed beneath the appropriate entity. In the case of temporary entities and event notices, a diagram of the storage layout will follow the definitions.

A. The Temporary Entity CASE

CASE - a call to the fire department for service.

ASET(CASE) - the set of all ALARM's associated with the CASE.

AVRES(CASE) - the average response time for the CASE. The average is taken over all resources responding to the case.

CNRES(CASE) - the total number of resources arriving on the scene of the CASE.

FASET(CASE) - the first ALARM in ASET (CASE).

FIRST(CASE) - the first resource to arrive on the scene of the CASE.

NCOMP(CASE) - the number of resources that have completed their service to the CASE.

NECO(CASE) - the number of engine resources needed for the CASE.

NOALM(CASE) - the number of ALARMS for the CASE.

NOCAS(CASE) - the user-supplied identification number, e.g. log number, for the CASE.

NTCO(CASE) - the number of truck resources needed for the CASE.

OCCUR(CASE) - time the CASE occurs.

TOTME(CASE) - the total number of resource-days used by the CASE.

TWAIT(CASE) - the time between OCCUR(CASE) and the arrival of the first resource on the scene.

TYPE(CASE) - the number indicating the kind of CASE.

XC(CASE) - the x-coordinate of the CASE location.

YC(CASE) - the y-coordinate of the CASE location.

<table>
<tr><th>Record</th><th>Word</th><th colspan="4">Storage Layout for Attributes of CASE</th></tr>
<tr><td>0</td><td>1</td><td colspan="2">FASET</td><td colspan="2"></td></tr>
<tr><td></td><td>2</td><td colspan="2">NOCAS</td><td colspan="2"></td></tr>
<tr><td></td><td>3</td><td colspan="4">OCCUR</td></tr>
<tr><td></td><td>4</td><td>NECO</td><td>NTCO</td><td>TYPE</td><td>FIRST</td></tr>
<tr><td></td><td>5</td><td colspan="2">XC</td><td colspan="2">YC</td></tr>
<tr><td></td><td>6</td><td colspan="4">TWAIT</td></tr>
<tr><td></td><td>7</td><td colspan="2">TOTME</td><td colspan="2">AVRES</td></tr>
<tr><td></td><td>8</td><td colspan="2">NOALM</td><td>NCOMP</td><td>CNRES</td></tr>
</table>

B. The Temporary Entity ALARM

ALARM - a request for resources to be sent to serve a CASE. This also acts as an event notice occurring at the time of request.

CAS(ALARM) - the SIMSCRIPT identification number assigned to the CASE with which the ALARM is associated.

ESET(ALARM) - the set of engine resources which will serve the ALARM.

FESET(ALARM) - the first engine resource in ESET (ALARM).

FIRST(ALARM) - the first of the resources (requested by ALARM) to arrive on scene.

FTSET(ALARM) - the first truck resource in TSET (ALARM).

NECO(ALARM) - the number of engine resources needed for the ALARM.

NTCO(ALARM) - the number of truck resources needed for the ALARM.

NUMBR(ALARM) - the sequential number of the ALARM with respect to the case, i.e. the first ALARM is the one which chronologically occurs first.

OCCUR(ALARM) - the time difference between the case occurrence and the alarm occurrence, on input. It is immediately changed to the time of occurrence of the alarm.

OST(ALARM) - the length of time which all resources associated with the ALARM must remain on the scene of the case. If OST < 0, the resources are sent back to their home stations after traveling half the distance toward the scene.

SASET(ALARM) - the successor of ALARM in ASET (CAS(ALARM)).

TSET(ALARM) - the set of truck resources which will serve the ALARM.

TWAIT(ALARM) - the time between OCCUR (ALARM) and the arrival on scene of the first resource associated with ALARM.

Record	Word	Storage Layout for Attributes of ALARM			
0	1	Reserved by SIMSCRIPT			
	2	Timing routines			
	3	OCCUR			
	4	NECO	NTCO	NUMBER	FIRST
	5	CAS		SASET	
	6	TWAIT			
	7	FESET		FTSET	
	8	OST			

C. The Temporary Entity RUN

RUN - temporary entity created when a resource is out of the station.

DEP(RUN) - the time at which the resource associated with the RUN left its last location.

IDEV(RUN) - SIMSCRIPT-assigned identification number for the next endogenous event scheduled for the resource associated with the RUN.

IDIR(RUN) - a flag to indicate the path the resource follows. If IDIR = 0, the entire x-distance is traveled first. If IDIR = 1, the y-distance is traveled first.

NEXT(RUN) - A code number to determine which type of endogenous event is next to occur for the RUN. ARVSN = 1; FINSH = 2; HOME = 3; SNDBK = 4.

TOUT(RUN) - the time at which the resource associated with the RUN left its station.

XDEST(RUN) - the x-coordinate of the location toward which the resource is moving. If XDEST = 0 and YDEST = 0, the resource is on scene.

YDEST(RUN) - the y-coordinate of the location toward which the resource is moving.

Record	Word	Storage Layout for Attributes of RUN		
	1	DEP		
	2	XDEST		YDEST
	3	TOUT		
	4	NEXT	IDIR	IDEV

D. Event Notices AVAIL, NUCRU, NUDAY

The purpose of these three events is explained in Section II. They have no attributes and the only storage needed are the two words required for the SIMSCRIPT timing routines.

E. Event Notices ARVSN, SNDBK, FINISH, and HOME

The purpose of these four events is explained in Section II. Each requires four words of storage, two of which are used by the SIMSCRIPT timing routines. The fourth word is blank. The third word is occupied by two attributes which have the same names for each of the four events.

RESNO - the number of the resource for which the event is scheduled.

ALMNO - the SIMSCRIPT identification number of the alarm associated with the event.

F. The Permanent Entity RES

RES - a resource.

CMXRS(RES) - the identification number of the case for which RES's largest response time (during the simulated period) occurred.

CRES(RES) - the response time of RES for the case it is currently serving.

DAILY(RES, WDAY) - the average utilization of RES on the day of the week WDAY.

DUTIL(RES) - the utilization of RES on a single day. This is used in the process of determining DAILY.

IB(RES) - a flag to indicate the status of the RES:1 = idle at the station; 2 = idle returning to the station; 3 = busy going to a case; 4 = busy on the scene of a case.

IRUN(RES) - the SIMSCRIPT-assigned identification number of the RUN associated with RES. If RES is in the station, IRUN(RES) = 0.

MXRES(RES) - the maximum time it took for RES to respond when called.

NALAM(RES) - the number of ALARMS for which RES actually arrived at the scene.

NMXRS(RES) - the number of the ALARM for which RES had its maximum response time.

PRSET(RES) - the predecessor of RES in RSET.

RALAM(RES) - the SIMSCRIPT identification number for the ALARM being served by RES.

RUTIL(RES) - the total number of hours that RES is out of the station.

RWAIT(RES) - the total response time for RES.

SESET(RES) - the successor of RES in ESET.

SRSET(RES) - the successor of RES in RSET.

STN(RES) - the station to which RES is assigned.

STSET(RES) - the successor of RES in TSET.

SUTIL(RES, SHIFT) - the total time RES is out of the station during shift SHIFT.

TARR(RES) - the time it would take for RES to arrive at the scene of a case. Resources are put into RSET ranked by this attribute.

TUTIL(RES) - the total time RES is out of the station in the current shift. This is used in calculating SUTIL.

TYP(RES) - a coded number indicating the type of RES. 1 = engine; 2 = truck.

XR(RES) - the x-coordinate of the location of RES.

YR(RES) - the y-coordinate of the location of RES.

G. <u>The Permanent Entity KINDS</u>

KINDS - a type of case which can occur

AVTME(KINDS) - the average number of resource-hours required to serve cases of type KINDS.

AVTWT(KINDS) - the average first response time for cases of type KINDS.

CKIND(KINDS) - the number of cases of type KINDS which occurred.

ELAPS(KINDS) - the average total duration of cases of type KINDS. (Duration is defined as the time difference between the original notification of the fire department about the case and the departure of the last resource from the scene of the case.)

IDTYP(KINDS) - a six-character name to be used on output to identify the type KINDS.

H. The Permanent Entity STATN

STATN - a fire station

XS(STATN) - the x-coordinate of the location of STATN.

YS(STATN) - the y-coordinate of the location of STATN.

I. The Permanent Entity SHIFT

SHIFT - a period of time during the day.

FREQ2(FREE, SHIFT) - the number of times during SHIFT that FREE engine resources were observed to be idle.

SUTIL(RES, SHIFT) - described under RES.

TME(SHIFT) - the hour of the day at which SHIFT ends.

TSHFT(SHIFT) - the total amount of simulated time occurring during SHIFT.

J. The Permanent Entity WDAY

WDAY - a day of the week.

DAILY(RES, WDAY) - described under RES.

CDAYS(WDAY) - the total number of days WDAY simulated.

K. The Permanent Entity CITY

CITY - the name of the city whose fire department is being simulated. NCITY is the number of computer words required to store the name of the city. (One computer word equals six alphanumeric characters.)

NAME(CITY) - the actual characters used in the name of the city. For example, for the city Alexandria, Va., NCITY = 3 and NAME(1) = "ALEXAN", NAME(2) = "DRIA, Δ", and NAME(3) = "VA.ΔΔΔ", where Δ indicates "blank."

L. <u>The Permanent Entity REST</u>

REST - a resource type.

TYPER(REST) - a six-character name for REST to be used on output, e.g. "ENG CO".

M. <u>The Permanent Entity CATEG</u>

CATEG - a cell in the frequency distribution for response time of the last arriving resource.

CLIM(CATEG) - the right hand end point of the interval defining cell CATEG.

FREQ1(FREE, CATEG) - the number of times (for cases using FREE engine resources) that the response time for the FREE-th arriving engine resource fell into cell CATEG.

N. <u>The Permanent Entity FREE</u>

FREE - a number of possible idle engine resources. Since as few as 0 and as many as NOENG engine resources could be idle, NFREE = NOENG + 1.

FREQ1(FREE, CATEG) - defined under CATEG.

FREQ2(FREE, SHIFT) - defined under SHIFT.

O. <u>General System Variables</u>

AVAVR - an average "average response time," i.e. the average response time per case is summed and divided by the number of cases.

CASES - the number of cases that were completed.

CINC - the width of the cells of the frequency distribution of the response time of the last arriving engine resource.

CMXTW - the user-supplied identification number of the case having the maximum first response time.

DEBUG - a flag to print or surpress intermediate output for use in debugging the model. 1 = print debug output; 0 = no debug output.

DELAY - the length of time it takes for a resource idle at the station to prepare to leave the station.

FRSET - the first resource in RSET.

IDAY - the index of the day of the week on which the simulation begins; 1 = Monday; 2 = Tuesday, etc.

INSUF - the number of times that there were not enough idle resources to satisfy the needs of an ALARM.

LRSET - the last resource in RSET.

MXTWT - the maximum first response time over all cases in the simulation.

NOENG - the number of engine resources.

PSHFT - the index of the present shift.

RMXTW - the resource associated with the maximum first response time in the simulation.

SP1 - the speed at which resources travel in emergency situation. The units are "grid segments per day."

SP2 - the speed at which resources travel in non-emergency situations. The unit are "grid segments per day".

TLAST - the time at which the last previous shift ended and the present shift began.

IV. INITIALIZATION DECK

The data deck consists of the system specifications card, followed by the initial conditions deck, a blank card, and the exogenous events deck.

A. System Specifications Card

The contents and format of the system specifications card are as follow:

Columns	Contents
1	The number "1".
6	If non-blank, the initial conditions deck will be printed.
7-12	Maximum array number (as shown in the definition deck) as a right-justified integer. The present value is 64.
13-36	Parameters which set the number of minutes per hour, hours per day, root to be used by the random number generator, and unit for reading the initial conditions deck. If left blank, the values will be 60, 24, 1, and 5.
37-42	Right-justified integer giving the logical unit from which to read the exogenous event deck. If left blank, it is assumed to be 5, the card reader.
43-48	The logical unit for report generator output. There are no report generators used in FIDOS2.
49-54	Right-justified integer giving the number of lines per printed page. The maximum value is 59. If blank, it is set to 55.

B. Initial Conditions Deck

The initial conditions deck serves to assign initial values to every array specified in the definition deck. The format of the initialization cards is very rigid. The reader is referred to Chapter 14 of [2]. Throughout the following table it shall be understood that all numbers are right-justified integers in the indicated columns. The term "format" appearing as the content of columns 50-66 on some cards refers to the format in which the following data cards are to be read. The particular format used is left to the discretion of the user, although an example is provided to show the type of format e.g., I, U, H, etc., which is needed. All format are left-justified in the field. The comment field, columns 67-80, may contain any comment the user desires. In the following example, the name of the variable is the comment unless the card refers to more than one variable such as on card 3.

Initialization Card	Columns	Content
1	4	The number "1."
	12	The letter "R."
	50-66	Number of resources in the run.
	67-80	Comment, e.g. "NRES."
2	4	The number "2."
	10	The number "1."
	12	The letter "R."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "4."

Initialization Card	Columns	Contents
	50-66	Format, e.g. "10(I2)."
	67-80	Comment, e.g. "IB."

Data cards giving the initial status of each resource must follow card 2. See the explanation of IB in Section III.

3	4	The number "3."
	8	The number "4."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	67-80	Comment
4	4	The number "5."
	10	The number "1."
	12	The letter "R."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "4."
	50-66	Format, e.g. "10(I2)."
	67-80	Comment, e.g. "TYP."

Data cards giving the type of each resource follow card 4. See page 18 for the explanation of TYP.

Initialization Card	Columns	Content
5	4	The number "6."
	10	The number "1."
	12	The letter "R."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	50-66	Format, e.g. "10(U3.2)."
	67-80	Comment, e.g. "XR."

Data cards giving the x-coordinate of the initial location of each resource follow card 5.

6	4	The number "7."
	10	The number "1."
	12	The letter "R."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	50-66	Format, e.g. "10(U3.2)."
	67-80	Comment, e.g. "YR."

Data cards giving the y-coordinate of the initial location of each resource follow card 6.

7	4	The number "8."
	7- 8	The number "13."
	10	The number "1."
	13	The letter "Z."

Initialization Card	Columns	Content
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	67-80	Comment
8	3- 4	The number "14."
	10	The number "1."
	12	The letter "R."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "4."
	50-66	Format, e.g. "10(I2)."
	67-80	Comment, e.g. "STN."

Data cards following card 8 give the number of the station to which each resource is initially assigned.

9	3- 4	The number "15."
	12	The letter "R."
	50-66	The speed at which resources travel in emergency situations, a floating point number in "grid segments per day".
	67-80	Comment, e.g. "SP1."
10	3- 4	The number "16."
	12	The letter "R."
	50-66	The speed in "grid segments per day" at which resources travel in non-emergency situations; a floating point number.

Initialization Card	Columns	Content
	67-80	Comment, e.g. "SP2."
11	3- 4	The number "17."
	7- 8	The number "19."
	13	The letter "Z."
	67-80	Comment.
12	3- 4	The number "20."
	7- 8	The number "22."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of resources in the run
	22	The number "1."
	34	The number "2."
	67-80	Comment.
13	3- 4	The number "23."
	12	The letter "R."
	50-66	The number of kinds of cases, left-justified.
	67-80	Comment, e.g. NKINDS.
14	3- 4	The number "24."
	13	The letter "Z."
	67-70	Comment, e.g. "CASES."

Initialization Card	Columns	Content
15	3- 4	The number "25."
	7- 8	The number "26."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of kinds of cases.
	21-22	The number "23."
	67-80	Comment.
16	3- 4	The number "27."
	13	The letter "Z."
	67-80	Comment, e.g. "AVAVR."
17	3- 4	The number "28."
	12	The letter "R."
	50-66	The number of stations; a left-justified integer.
	67-80	Comment, e.g. "NSTATN."
18	3- 4	The number "29."
	10	The number "1."
	12	The letter "R."
	15-18	The number of stations in the run.
	21-22	The number "28."
	34	The number "2."
	50-66	Format, e.g. "6(U3.2)."
	67-80	Comment, e.g. "XS."

Initialization Card	Columns	Content
Data cards follow card 18 giving the x-coordinate of the location of each station.		
19	3- 4	The number "30."
	10	The number "1."
	12	The letter "R."
	15-18	The number of stations in the run.
	21-22	The number "28."
	34	The number "2."
	50-66	Format, e.g. "6(U3.2)."
	67-80	Comment, e.g. "YS."
Data cards follow card 19 giving the y-coordinate of the location of each station.		
20	3- 4	The number "31."
	12	The letter "R."
	50-66	Left-justified integer number of shifts in each day.)
	67-80	Comment, e.g. "NSHIFT."
21	3- 4	The number "32."
	10	The number "2."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	23-26	Number of shifts per day.

Initialization Card	Columns	Content
	29-30	The number "31."
	34	The number "2."
	67-80	Comment, e.g. "SUTIL."
22	3- 4	The number "33."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	67-80	Comment, e.g. "DUTIL."
23	3- 4	The number "34."
	12	The letter "R."
	50	The number "7." (The number of days per week.)
	67-80	Comment, e.g. "NWDAY."
24	3- 4	The number "35."
	10	The number "2."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	26	The number "7." (Days per week.)
	29-30	The number "34."
	67-80	Comment, e.g. "DAILY."

Initialization Card	Columns	Content
25	3- 4	The number "36."
	12	The letter "R."
	50-66	The shift number when the run begins, usually "1," left-justified.
	67-80	Comment, e.g. "PSHFT."
26	3- 4	The number "37."
	13	The letter "Z."
	67-80	Comment, e.g. "TLAST."
27	3- 4	The number "38."
	12	The letter "R."
	50	The number of the weekday on which the run begins, Monday = 1, Tuesday = 2, etc. Left-justified.
	67-80	Comment, e.g. "IDAY."
28	3- 4	The number "39."
	10	The number "1."
	12	The letter "R."
	15-18	Number of shifts per day.
	21-22	The number "31."
	34	The number "2."
	50-66	Format, e.g. 3(H3.2).
	67-80	Comment, e.g. "TME."

Initialization Card	Columns	Content

Data cards follow card 28 giving the ending times of each shift in the day.

29	3- 4	The number "40."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	67-80	Comment, e.g. "TUTIL."
30	3- 4	The number "41."
	12	The letter "R."
	50-66	Number of words required to store the name of the city being simulated.
	67-80	Comment, e.g. "NCITY"
31	3- 4	The number "42."
	10	The number "1."
	12	The letter "R."
	15-18	The number of words need to store the name of the city.
	21-22	The number "41."
	50-66	Format, e.g. "3(A6)."
	67-80	Comment, e.g. "NAME."

A data card giving the name of the city whose fire department is being simulated follows card 31.

Initialization Card	Columns	Content
32	3- 4	The number "43."
	10	The number "1."
	13	The letter "Z."
	15-18	The number of kinds of cases.
	21-22	The number "23."
	67-80	Comment, e.g. "ELAPS."
33	3- 4	The number "44."
	10	The number "1."
	13	The letter "Z."
	15-18	The number of kinds of cases.
	21-22	The number "23."
	34	The number "2."
	67-80	Comment, e.g. "CKIND."
34	3- 4	The number "45."
	12	The letter "R."
	50-66	The number of resource types; a left-justified integer.
	67-80	Comment, e.g. "NREST."
35	3- 4	The number "46."
	10	The number "1."
	12	The letter "R."
	15-18	The number of resource types.
	21-22	The number "45."

Initialization Card	Columns	Content
	50-66	Format, e.g. "2(A6)."
	67-80	Comment, e.g. "Typer."

Data cards following card 35 give a six-character name for each resource type, e.g. "ENG CO."

36	3- 4	The number "47."
	7- 8	The number "48."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	67-80	Comment
37	3- 4	The number "49."
	7- 8	The number "50."
	13	The letter "Z."
	67-80	Comment
38	3- 4	The number "51."
	12	The letter "R."
	50-66	Number of engine resources in the run; left-justified integer.
	67-80	Comment, e.g. "NOENG."
39	3- 4	The number "52."
	10	The number "1."
	13	The letter "Z."

Initialization Card	Columns	Content
	18	The number "7" (days per week).
	21-22	The number "34."
	67-80	Comment, e.g. "CDAYS."
40	3- 4	The number "53."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of shifts per day.
	21-22	The number "31."
	67-80	Comment, e.g. "TSHIFT."
41	3- 4	The number "54."
	10	The number "1."
	12	The letter "R."
	15-18	Number of kinds of cases.
	21-22	The number "23."
	50-66	Format, e.g. "7(A6)".
	67-80	Comment, e.g. "IDTYP."

Data cards follow card 41 giving a six character name for each kind of case.

42	3- 4	The number "55."
	12	The letter "R."
	50-66	Indicator for debugging type output. 0 = no debug output; 1 = print all debug output.
	67-80	Comment, e.g. "DEBUG."

Initialization Card	Columns	Content
43	3- 4	The number "56."
	12	The letter "R."
	50-66	Number of cells in the frequency distribution of response times for the last arriving engine resource.
	67-80	Comment, e.g. "NCATEG."
44	3- 4	The number "57."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of cells in the frequency distribution of response times for the last arriving engine resource.
	21-22	The number "56."
	67-80	Comment, e.g. "CLIM."
45	3- 4	The number "58."
	12	The letter "R."
	50-66	The number of possible idle engine resources, i.e. one more than the number of engine resources in the run; left-justified.
	67-80	Comment, e.g. NFREE
46	3- 4	The number "59."
	13	The letter "Z."
	67-80	Comment, e.g. "INSUF."

Initialization Card	Columns	Content
47	3- 4	The number "60."
	12	The letter "R."
	50-66	The cell width in minutes of the frequency distribution on response time of the last arriving engine resource; a left-justified floating point number.
	67-80	Comment, e.g. "CINC."
48	3- 4	The number "61."
	10	The number "2."
	13	The letter "Z."
	15-18	Number of possibly free engine resources.
	21-22	The number "58."
	23-26	Number of cells in frequency distribution of response times for last arriving engine resource.
	29-30	The number "56."
	30	The number "2."
	67-80	Comment, e.g. "FREQ1."
49	3- 4	The number "62."
	10	The number "2."
	13	The letter "Z."
	15-18	Number of possibly free engine resources.
	21-22	The number "58."
	23-26	Number of shifts in the day.

Initialization Card	Columns	Content
	29-30	The number "31."
	34	The number "2."
	67-80	Comment, e.g. "FREQ2."
50	3- 4	The number "63."
	12	The letter "R."
	50-66	The delay time for resources idle in the station; left-justified floating point number in units of days.
	67-80	Comment, e.g. "DELAY."
51	3- 4	The number "64."
	10	The number "1."
	13	The letter "Z."
	15-18	Number of resources in the run.
	22	The number "1."
	34	The number "2."
	67-80	Comment, e.g. "CRES."

V. EXOGENOUS EVENTS TAPE

The Exogenous Events Tape drives the simulation by starting the simulation, causing cases to occur, and stopping the simulation at the end of the run. The Exogenous Event Tape can be either a deck of computer cards or a magnetic tape containing card image records. For most runs, the number of cases is so large that the use of cards is impractical. In the following description, all numbers are right-justified integers unless otherwise specified. Cases must be in chronological order.

Card Number	Columns	Variable Name	Format and Content
1	3	---	The number "1"
	4-7	---	I4; the day the simulation begins (Usually "0".)
	8-10	---	I3; the hour the simulation begins (Usually "0".)
	11-12	---	I2; the minute the simulation begins (Usually "0".)
2	3	---	The number "2".
	4-7	*	I4; the day the case is to occur.
	8-10	*	I3; the hour the case is to occur.
	11-12	*	I2; the minute the case is to occur.
	16-20	NOCAS(CASE)	I5; the identification number of the case.
	21-25	NALAM(CASE)	I5; the number of alarms for the case.
	26-30	XC(CASE)	D4.0; the x-coordinate of the case location.
	31-35	YC(CASE)	D4.0; the y-coordinate of the case location.
	36-40	TYPE(CASE)	I5; the index of the type of case.

(Note: The variables marked by "*" are stored in OCCUR(CASE).)

Card Number	Columns	Variable Name	Format and Content
3	1-5	OCCUR(ALARM)	M5; the time difference (in minutes) between the occurrence of the case and the occurrence of the alarm.
	6-10	OST(ALARM)	M5; the on scene time (in minutes) for the alarm.
	11-13	NECO(ALARM)	I3; the number of engine resources requested for the alarm.
	14-15	NTCO(ALARM)	I2; the number of truck resources requested for the alarm.

The format shown for the first four fields of card 3 is repeated four more times on card 3, i.e. card 3 can contain data for as many as five alarms. If more than five alarms are needed for the case, additional cards like card 3 are needed. Thus, each case consists of one card like card 2 and one or more cards like card 3. The last card of the Exogenous Events Tape has the following format:

Card Number	Columns	Variable Name	Format and Content
Last	3	---	The number "3".
	4-7	---	I4; the day the simulation is to end.
	8-10	---	I3; the hour the simulation is to end.
	11-12	---	I2; the minute the simulation is to end.

VI. OUTPUT

The standard output from FIDOS2 consists of two main parts. The first part is simploy a record of case occurrences and terminations. It is useful in examining the characteristics of the individual cases and in giving an indication of the congestion of the system at a particular time.

When the exogenous event ALERT occurs, the phrase "Case Input" is printed followed on the same line by the SIMSCRIPT identification number of the case, the case parameters input on the first "card" for the case, and the time the cases occurs. On the following line or lines are the alarm number, time of occurrence, on scene time, number of engine resources, and number of truck resources for each alarm of the case. Each of these lines of output contains data for at most five alarms. When a case ends, i.e., when subroutine TERM is called, the routine prints the phrase "End of Case" followed by the SIMSCRIPT identification number of the case, the time the case ends, and the case number specified by the user on input. A sample of this type of output is given in Figure VI-1.

The basic output of the model consists of six pages of summary data. Examples of this output are shown in Figures VI-2 through VI-7. The first page (Figure VI-2) is a very general summary of the simulation. It identifies the city whose fire department is being simulated, NAME(I), for I = 1, 2, 3; the total number of days simulated, DPART(TIME), where TIME is the time at which exogenous event ENDSIM occurs; the total number of cases completed, CASES; the mean average response time per case, AVAVR; the total case utilization in resource-hours (utilization by type of case is summed over all types and stored in the local variable TOTAL for printing purposes); and the number of incomplete responses, INSUF.

```
CASE INPUT     42159 1630    3    2    6.    4.    5106.20.19
  1 106.20.190.00.08 1 0    2 106.20.190.00.23 1 0    3 106.20.190.00.06 1 0    4 106.20.190.00.08 0 1    5 106.20.190.00.23 0 1
                                                                 END OF CASE     42159106.20.52     1630
CASE INPUT     42159 1631    2    1    15.    9.    3107.04.04
  1 107.04.040.00.12 1 0    2 107.04.040.00.05 1 0    3 107.04.040.00.12 0 1
                                                                 END OF CASE     42159107.04.20     1631
CASE INPUT     42157 1632    1    0    14.    3.    1107.07.14
  1 107.07.140.00.14 1 0
                                                                 END OF CASE     42159107.07.36     1632
CASE INPUT     42159 1633    1    0    5.    2.    2107.07.41
  1 107.07.410.01.22 1 0
                                                                 END OF CASE     42159107.09.07     1633
CASE INPUT     42159 1634    1    0    18.    12.    2107.14.08
  1 107.14.080.00.16 1 0
                                                                 END OF CASE     42159107.14.29     1634
CASE INPUT     42207 1635    1    0    17.    9.    2107.15.10
  1 107.15.100.00.09 1 0
                                                                 END OF CASE     42207107.15.22     1635
CASE INPUT     42207 1636    1    0    4.    8.    2107.19.40
  1 107.19.400.00.11 1 0
                                                                 END OF CASE     42207107.19.55     1636
CASE INPUT     42215 1637    1    0    13.    10.    2107.23.38
  1 107.23.380.00.15 1 0
CASE INPUT     42191 1638    0    1    16.    6.    2107.23.55
  1 107.23.550.00.17 0 1
                                                                 END OF CASE     42215107.23.56     1637
                                                                 END OF CASE     42191108.00.15     1638
CASE INPUT     42191 1639    1    0    2.    5.    2108.00.48
  1 108.00.480.00.21 1 0
                                                                 END OF CASE     42191108.01.13     1639
CASE INPUT     42191 1640    1    0    18.    12.    2108.07.18
  1 108.07.180.00.15 1 0
                                                                 END OF CASE     42191108.07.36     1640
CASE INPUT     42215 1641    3    1    19.    6.    6108.12.25
  1 108.12.250.00.59 1 0    2 108.12.250.00.52 1 0    3 108.12.250.01.06 1 0    4 108.12.250.00.52 0 1
CASE INPUT     42343 1642    3    2    7.    8.    3108.13.08
  1 108.13.080.00.08 1 0    2 108.13.080.00.00 1 0    3 108.13.080.00.00 1 0    4 108.13.080.00.08 0 1    5 108.13.080.00.00 0 1
                                                                 END OF CASE     42343108.13.21     1642
                                                                 END OF CASE     42215108.13.37     1641
CASE INPUT     42215 1643    3    2    7.    7.    6108.13.50
  1 108.13.500.00.56 1 0    2 108.13.560.00.53 1 0    3 108.13.500.00.47 1 0    4 108.13.500.00.59 0 1    5 108.13.500.00.47 0 1
                                                                 END OF CASE     42215108.14.52     1643
CASE INPUT     42215 1644    3    2    19.    8.    6108.15.48
  1 108.15.480.00.25 1 0    2 108.15.480.01.09 1 0    3 108.15.480.00.47 1 0    4 108.15.480.00.47 0 1    5 108.15.480.00.09 0 1
CASE INPUT     42375 1645    1    0    19.    6.    2108.16.16
  1 108.16.160.00.18 1 0
                                                                 END OF CASE     42375108.16.59     1645
                                                                 END OF CASE     42215108.17.00     1644
CASE INPUT     42215 1646    1    0    18.    10.    3108.21.16
  1 108.21.160.00.04 1 0
                                                                 END OF CASE     42215108.21.22     1646
CASE INPUT     42215 1647    1    0    7.    8.    2108.22.17
  1 108.22.170.00.08 1 0
                                                                 END OF CASE     42215108.22.27     1647
CASE INPUT     42215 1648    1    0    6.    7.    2108.23.15
  1 108.23.150.00.32 1 0
                                                                 END OF CASE     42215108.23.49     1648
CASE INPUT     42215 1649    1    0    17.    2.    2109.01.34
```

Figure VI-1
Sample Output Showing Case Occurrences and Terminations

SIMULATION OF FIRE DEPARTMENT ACTIVITIES FOR THE CITY OF ALEXANDRIA, VA.

NUMBER OF DAYS SIMULATED	123
TOTAL NUMBER OF CASES SERVED	915
MEAN AVERAGE RESPONSE TIME (PER CASE)	3.06 MINUTES
TOTAL UTILIZATION	834.65 RESOURCE-HOURS
NUMBER OF INSUFFICIENT RESPONSES	1

Figure VI-2
Sample of General Summary Output

RESOURCE DATA

		STATION	TOTAL NO. OF ALARMS SERVED	TOTAL HOURS OUT OF STATION	AVG. RESPONSE TIME(MINUTES)	MAX. RESPONSE TIME(MINUTES)	CASE NO. OF MAX RESPONSE	ALARM NO. OF MAX RESPONSE
ENG CO	1	1	168	80.59	2.27	12.12	1695	3
ENG CO	2	2	199	111.50	3.63	12.87	1419	3
ENG CO	3	3	172	79.31	3.49	12.87	956	3
ENG CO	4	4	308	145.94	3.15	12.12	877	1
ENG CO	5	5	355	143.	2.81	16.66	996	3
ENG CO	6	6	146	77.41	3.84	13.63	1088	1
ENG CO	7	7	177	94.41	4.64	11.36	1600	1
TRK CO	1	5	198	81.47	2.97	12.87	1326	5
TRK CO	2	2	114	61.52	4.07	12.87	1419	5
TRK CO	3	3	79	39.30	4.36	15.91	1695	5
TRK CO	4	6	98	50.44	4.35	13.63	1601	1

Figure VI-3
Sample of Summary Output Indicating Resource
Work Load and Response Capability

BREAKDOWN OF RESOURCE UTILIZATION DATA

AVERAGE HOURS OUT OF STATION BY DAY OF WEEK

	MON	TUE	WED	THU	FRI	SAT	SUN
ENG CO 1	0.56	0.61	0.76	0.47	0.97	0.88	0.40
ENG CO 2	1.54	0.94	0.46	0.58	0.88	1.17	0.86
ENG CO 3	0.56	1.11	0.83	0.59	0.56	0.52	0.33
ENG CO 4	1.00	1.75	0.86	0.85	1.24	1.88	0.97
ENG CO 5	1.32	1.34	1.31	0.93	1.23	1.18	1.06
ENG CO 6	0.70	0.81	0.60	0.50	0.65	0.64	0.56
ENG CO 7	0.97	0.90	0.67	0.84	0.62	0.69	0.74
TRK CO 1	0.91	0.65	0.63	0.55	0.79	0.64	0.54
TRK CO 2	0.40	0.68	0.60	0.29	0.53	0.65	0.38
TRK CO 3	0.33	0.58	0.28	0.31	0.30	0.29	0.11
TRK CO 4	0.59	0.37	0.40	0.35	0.39	0.44	0.34

Figure VI-4
Sample of Summary Output Showing Breakdown of Resource Utilization by Day of the Week

SUMMARY OF FIRE SERVICE BY TYPE OF CASE

	TYPE	NO. CASES	AVERAGE TOTAL RESOURCE-HOURS REQUIRED	AVERAGE FIRST RESPONSE TIME (MINUTES)	AVERAGE DURATION (MINUTES)
1	PUB SV	50	0.6919	3.53	41.44
2	SPECL	348	0.4590	2.82	25.63
3	MALIC	241	0.4038	1.97	11.80
4	ACCID	19	2.3743	3.91	58.98
5	NONE	132	1.4216	2.56	36.48
6	FIRE	122	2.5361	2.47	58.04
7	MU.AID	3	0.2823	2.28	16.94

Figure VI-5
Sample of Output Summarizing
Fire Service by Type of Case

DISTRIBUTION OF RESPONSE TIMES FOR THE LAST ARRIVING ENGINE

RESPONSE TIME IN MINUTES	1 ENG. CASES FREQ	1 ENG. CASES REL FREQ	2 ENG. CASES FREQ	2 ENG. CASES REL FREQ	3 ENG. CASES FREQ	3 ENG. CASES REL FREQ	4 ENG. CASES FREQ	4 ENG. CASES REL FREQ	5 ENG. CASES FREQ	5 ENG. CASES REL FREQ
0. TO 0.5	3	0.0055	0	0.	0	0.	0	0.	0	0.
0.5 TO 1.0	3	0.0055	0	0.	0	0.	0	0.	0	0.
1.0 TO 1.5	8	0.0146	0	0.	0	0.	0	0.	0	0.
1.5 TO 2.0	215	0.3931	1	0.0143	0	0.	0	0.	0	0.
2.0 TO 2.5	116	0.2121	11	0.1571	43	0.1547	0	0.	0	0.
2.5 TO 3.0	0	0.	1	0.0143	0	0.	0	0.	0	0.
3.0 TO 3.5	73	0.1335	12	0.1714	69	0.2482	0	0.	0	0.
3.5 TO 4.0	73	0.1335	8	0.1143	31	0.1115	0	0.	0	0.
4.0 TO 4.5	9	0.0165	1	0.0143	3	0.0108	0	0.	0	0.
4.5 TO 5.0	18	0.0329	11	0.1571	16	0.0576	1	1.	0	0.
5.0 TO 5.5	12	0.0219	10	0.1429	11	0.0396	0	0.	0	0.
5.5 TO 6.0	0	0.	0	0.	0	0.	0	0.	0	0.
6.0 TO 6.5	5	0.0091	6	0.0857	10	0.0360	0	0.	0	0.
6.5 TO 7.0	3	0.0055	2	0.0286	9	0.0324	0	0.	0	0.
7.0 TO 7.5	0	0.	0	0.	0	0.	0	0.	0	0.
7.5 TO 8.0	2	0.0037	1	0.0143	7	0.0252	0	0.	0	0.
8.0 TO 8.5	1	0.0018	4	0.0571	9	0.0324	0	0.	0	0.
8.5 TO 9.0	0	0.	0	0.	1	0.0036	0	0.	0	0.
9.0 TO 9.5	0	0.	0	0.	17	0.0612	0	0.	0	0.
9.5 TO 10.0	1	0.0018	0	0.	11	0.0396	0	0.	0	0.
10.0 TO 10.5	0	0.	0	0.	0	0.	0	0.	0	0.
10.5 TO 11.0	1	0.0018	0	0.	1	0.0036	0	0.	0	0.
11.0 TO 11.5	2	0.0037	0	0.	10	0.0360	0	0.	0	0.
11.5 TO 12.0	0	0.	0	0.	1	0.0036	0	0.	0	0.
12.0 TO 12.5	1	0.0018	0	0.	12	0.0432	0	0.	0	0.
12.5 TO 13.0	0	0.	0	0.	9	0.0324	0	0.	0	0.
13.0 TO 13.5	0	0.	0	0.	0	0.	0	0.	0	0.
13.5 TO 14.0	1	0.0018	0	0.	0	0.	0	0.	0	0.
14.0 TO 14.5	0	0.	0	0.	1	0.0036	0	0.	0	0.
14.5 TO 15.0	0	0.	0	0.	0	0.	0	0.	0	0.
15.0 TO 15.5	0	0.	0	0.	0	0.	0	0.	0	0.
15.5 TO 16.0	0	0.	0	0.	0	0.	0	0.	0	0.
16.0 TO 16.5	0	0.	0	0.	2	0.0072	0	0.	0	0.
16.5 TO 17.0	0	0.	0	0.	1	0.0036	0	0.	0	0.
17.0 TO 17.5	0	0.	1	0.0143	0	0.	0	0.	0	0.
17.5 TO 18.0	0	0.	0	0.	0	0.	0	0.	0	0.
18.0 TO 18.5	0	0.	0	0.	0	0.	0	0.	0	0.
18.5 TO 19.0	0	0.	0	0.	0	0.	0	0.	0	0.
19.0 TO 19.5	0	0.	0	0.	0	0.	0	0.	0	0.
19.5 TO 20.0	0	0.	1	0.0143	4	0.0144	0	0.	0	0.
TOTALS	547		70		278		1		0	

Figure VI-6
Sample of Output Showing Distribution of Response Times
for the Last Arriving Engine

AVAILABILITY

NO. OF IDLE ENG. CO.	SHIFT 1		SHIFT 2		SHIFT 3	
	FREQ.	REL. FREQ.	FREQ.	REL. FREQ.	FREQ.	REL. FREQ.
0	0	0.	0	0.	0	0.
1	2	0.0020	0	0.	1	0.0010
2	3	0.0030	0	0.	1	0.0010
3	6	0.0061	5	0.0051	7	0.0071
4	13	0.0132	17	0.0173	41	0.0417
5	19	0.0193	20	0.0203	22	0.0224
6	50	0.0508	68	0.0691	95	0.0965
7	891	0.9055	874	0.8882	817	0.8303

Figure VI-7
Sample of Availability Output

The second page (Figure VI-3) gives an indication of the work load and the response capability of the individual resources. Each resource I is identified by type, TYPER(TYP(I)), number (the first NOENG resources are assumed to be of type 1, i.e., engines), and the number of the station to which it is assigned, STN(I). The data printed are the number of alarms for which resource I arrived on scene, NALAM(I); the total number of hours out of the station, RUTIL(I); the average response time in minutes, (1440)RWAIT(I)/NALAM(I); the maximum response time, MXRES(I); the case for which this maximum response occurred; CMXRS(I); and the number of the alarm associated with this case, NMXRS(I).

The third page (Figure VI-4) is a breakdown of the utilization of the individual resources by day of the week. Each resource I is identified by type, TYPER(TYP(I)), and number (again the first NOENG resource are assumed to be of type 1, engines). The table consists of the variables DAILY (I,J), i.e., the average number of hours that resource I was out of the station on the Jth day of the week where day 1 is Monday.

The fourth page (Figure VI-5) gives measures of the service provided for each type of case I. The types are identified by number, I, and name, IDTYP(I). The data are the number of cases of type I that were completed, CKIND(I); the average number of resource-hours required to serve cases of type I, AVTME(I); the average first response time in minutes, AVTWT(I); and the average total duration in minutes, ELAPS(I).

The fifth page (Figure VI-6) gives the distributions of response times for the last arriving engine resource for cases using 1, 2, ..., 5 engine resources. If there exist cases using more than five engine resources, exogenous event ENDSIM must be revised to print those distributions as another page or pages. The frequencies which form the distributions are accumulated in subroutine TERM. When a case ends, it is possible to determine N, the total number of engine resources that arrived on the scene, and R, the time difference between the occurrence of the case and the arrival of the last resource on the scene. Then J is determined such that $CLIM(J-1)<R\leq CLIM(J)$. The variable FREQ1(N,J) is then increased by one. Each time interval I is identified on output by CLIM(I-1) and CLIM(I). Then for values of K = 1 through 5 the frequencies FREQ1(K,I) are printed for I = 1 through NCATEG. Also printed are the relative frequencies, computed and stored for each K in variables REL(K) for printing purposes:

$$REL(K) = FREQ1(K,J) \Big/ \sum_{I=1}^{NCATEG} FREQ1(K,I).$$

The sixth page of summary output is concerned with availability. The variable FREQ2(N,J) are printed for each shift J. FREQ2(N,J) is the number of times during shift J that endogenous event AVAIL observed N-1 idle engine resources, N = 1 through NFREE. Also printed are the relative frequencies, again computed and stored for printing purposes in a local variable REL(J) for each value of J:

$$REL(J) = FREQ2(K,J) \Big/ \sum_{I=1}^{NFREE} FREQ2(I,J).$$

VII. OPERATING INSTRUCTIONS

The operating instructions explained herein will apply to runs made on the UNIVAC 1108 at NBS under the EXEC 2 operating system. The simulation model is stored on the FASTRAND drum under the file name FIDOS2. It will be assumed that the cases to be simulated are stored on magnetic tape. In this case, the first card of the initialization deck, the System Specifications Card, must have in column 42 the number of the logical unit on which the Exogenous Tape is to be mounted. This number must corespond to the letter shown on the ASG card assigning the tape. (A corresponds to 7, B to 8, etc.)

Two complete run decks will be discussed. The first will apply to the user who simply wants to run the model "as is". The second applies to the user who wishes to change one or more subroutines and events. The following symbols will be used:

@ = keypunch both a seven and an eight

Δ = blank.

A. <u>Run deck for running the model "as is".</u> (Refer to Figure VII-1.)

<u>Card 1:</u>

<u>D</u> is the priority of the run.

<u>RUN</u> indicates the RUN card.

<u>NAMEFG</u> is the six character user name.

<u>RUNID</u> is a five digit account number.

<u>MM</u> is the maximum run time in minutes.

<u>PP</u> is the maximum number of pages to be printed.

Card 2:

ASG indicates a tape assignment.

A specifies the letter of the tape drive.

XXXX is the reel number of the Exogenous Events Tape.

Card 3:

Keypunch exactly as shown. This calls in the Complex Utility Routines.

Card 4:

Keypunch exactly as shown. This brings the program FIDOS2 into the user storage.

Card 5:

Keypunch exactly as shown. This begins execution of the program.

Card 6:

The System Specifications Card is shown separately here only to show the correspondence between the tape drive A on Card 2 and the "7" in column 42 of this card.

Initialization Deck and Blank Card:

This was described in Section IV.

Last Card:

Keypunch exactly as shown. This indicates the end of the run.

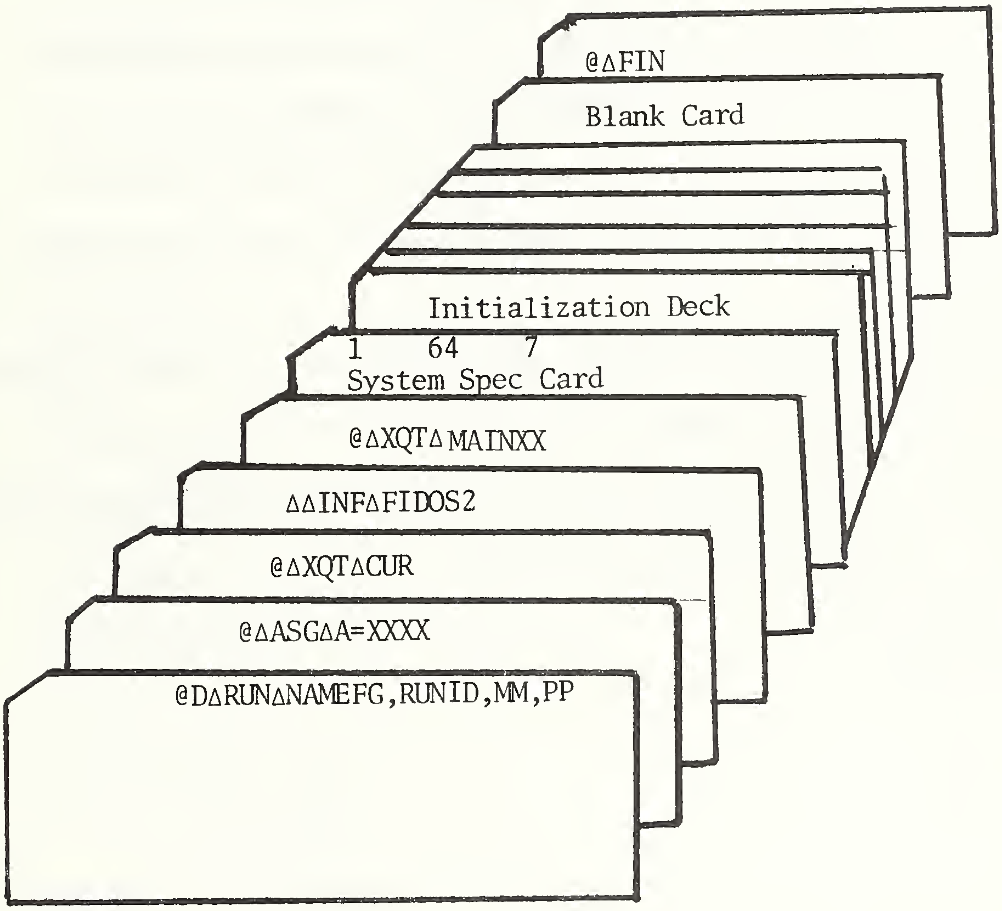

Figure VII-1

Sample Run Deck to Execute Program
"As Is"

B . To recompile a portion of the program.

It may at some time be desirable to change one or more events and subroutines of the model. This change requires a recompilation of the routines being changed. A sample run deck for recompiling subroutine RESAP, endogenous event HOME, and exogenous event ENDSIM, is shown in Figure VII-2. The new version of the entire program will exist on the second file of reel number YYYY mounted on unit B.

There are several major points to be noted in Figure VII-2.

1. There is no choice regarding the tape drive used by SIMSCRIPT to output the compiled version of the program; it must be unit B.

2. The Definition Deck must precede the routines to be recompiled.

3. A card with a "$" in column 1 must follow the last routine being recompiled.

4. Endogenous events are referred to on the DEL and ASM cards with the letter "X" preceding the name.

To execute the revised program from the tape, replace cards 3 and 4 shown in Figure VII-1 with the following four cards:

@ΔASGΔB = YYYY

@ΔXQTΔCUR

ΔΔPEFΔB

ΔΔINΔB

```
@D△RUN△NAMEFG,RUNID,MM,PP
@W△ASG△
@△XQT△CUR
△△INF△SIMSC6
@N△XQT△SIM
 Definition Deck
 New Version of Subroutine RESAP
 New Version of endogenous event HOME
 New Version of exogenous event ENDSIM


$
@△XQT△CUR
△△ERS
△△INF△FIDOS2
△△DEL△RESAP
△△DEL△XHOME
△△DEL△ENDSIM
△△IN△B
@N△ASM,*△RESAP, RESAP
@N△ASM,*△XHOME,XHOME
@N△ASM,*△ENDSIM,XHOME
@△XQT△CUR
△△OUT△B
△△TEF△B
△△TRI△B
@△FIN
```

Figure VII-2
Sample Run Deck for Recompilation

VIII. COMPUTATIONAL RESULTS AND FUTURE DEVELOPMENT

At the time of this writing the simulation model has only been applied to two cities, Alexandria, Virginia and Washington, D. C. For Washington only one run was made so that little if anything was learned regarding possible changes in the system. For Alexandria several runs were made testing different station locations, different numbers of stations, and different locations for equipment. The results of this study are reported in [4].

Figure VIII-1 shows the relevant details of the two base runs, and their running times. It should be noted that neither run time includes compilation and assembly which take approximately 2.5 minutes. Although the Washington run simulated approximately 3.2 times as many cases as the Alexandria run, the running time for Washington was approximately 6.4 times the running time for Alexandria. This is attributable mainly to the fact that in Washington there are 4.5 times as many resources as there are in Alexandria. Every time a case occurs all resources are examined as possible respondees, so that the resource assignment section of the model requires more time in the Washington run. Furthermore, although the average utilization per case is clearly greater in Alexandria (834.7/915 = .91 vs. 2023.6/2766 = .73 for Washington), many of the cases in Washington used more resources than the cases in Alexandria. In summary, the Washington simulation required more computations per case than did the Alexandria run.

The future use of the model may well require revisions in various portions of the code to more closely model a particular fire department. It is impossible to anticipate all the desired revisions and expansions of the model; however the following list includes those changes which seem most desirable at present.

1. Revise the distance-time calculations so that grids with rectangular cells can be considered.

2. Vary the speeds on links, possibly by section of the city and/or time of day.

	Alexandria	Washington
No. of days simulation	123	31
No. of cases simulated	915	2766
No. of engine resources (companies)	7	32
No. of truck resources (companies)	4	17
Total utilization (resource-hours)	834.7	2023.6
Running time (minutes)	1.34	8.45

Figure VIII-1
Comparison of Two Basic Runs

3. Provide for resources other than engines and trucks, e.g., ambulances and rescue squads. This change would probably require a provision for queuing cases.

4. Provide for a dynamic resource assignment policy. For example case location and/or time of day may be used probabilistically to determine "expected case type", which could dictate the response level. This would of course require some method for determing the effectiveness of the response, i.e., some penalty should be incurred if the response is not suited for the case.

Clearly there are numerous changes that may be made to model a particular fire department. The present version of the model was purposely developed to be a general model, not specifically tailored to match any single system. The modular form of the simulation should make any necessary changes fairly easy to incorporate.

References

1. Carter, G. and Ignall, E., "A Simulation Model of Fire Department Operations: Design and Preliminary Results," IEEE Transactions on Systems Science and Cybernetics, Vol. SSC-6, No. 4, October 1970, pp. 282-293.

2. Markowitz, H., Hausner, B., Karr, H., Simscript: A Simulation Programming Language, Prentice-Hall, Englewood Cliffs, N. J., 1963.

3. Simscript I.5, Consolidated Analysis Center, Inc., Santa Monica, California, 1967.

4. Nilsson, E., Saunders, P., Swartz, J., Weber, A., Application of Systems Analysis to the Alexandria Virginia Fire Department, NBS Report No. 10454, June 1971.

Appendix: Computer Listing of FIDOS2

```
COMPILED BY UNIVAC 1107/1108 SIMSCRIPT 1.5  DATED - MAR. 6, 1969  VERSION 2.11
THIS COMPILATION WAS DONE ON 17 AUG 71 AT 14:05:32

23456789012345678901234567890123456789012345678901234567890123456789012
1 CASE 8        T FASET 11/2 I  1RES    E          ASET1.
                T NOCAS 21/2 I  2IF     1 /4 I     RSETO  .TARR  L
                T OCCUP 3 /  F  3RUTIL  1 /2 F     ESET1.
                T NECO  41/4 I  4TARR   1 /2 F     TSET1.
                T NTCO  42/4 I  5TYP    1 /4 I
                T TYPE  43/4 I  6XP     1 /2 F
                T FIRST 44/4 I  7YR     1 /2 F
                T XC    51/2 F  8SFSET  1 /2 I
                T YC    52/2 F  9SMSET  1 /2 I
                T TWAIT 6 /  F 10RALAM  1 /2 I
                T TOTME 71/2 F 11IRUN   1 /2 I
                T AVRES 72/2 F
                T NOALM 81/2 I
                T NCOMP 83/4 I 12RWAIT  1 /2 F
                T CURES 84/4 I 13NALAM  1 /2 I
N ALARM8        N NUMBR 43/4 I 14STN    1 /4 I
                N CAS   51/2 I 15SP1    0      F.
                N SASET 52/2 I 16SP2    0      F.
                N FESET 71/2 I 17MXTWT  0      F
                N FTSET 72/2 I 18CMXTW  0      I
                N OST   81/2.F 19RMXTW  0      I
T RUN    4      T DEP   1 /  F 20MXRES  1 /2 F
                T XDEST 21/2 F 21CMXRS  1 /2 I
                T YDEST 22/2 F 22NMXRS  1 /2 I
                T TOUT  3    F 23KINDS  E
                T NEXT  41/4 I 24CASES  0      I
                T IDIR  42/4 I
                T IDEV  42/2 I 25AVTME  1      F
                               26AVTWT  1      F
                               27AVAVR  0      F
                               28STATN  E
                               29XS     1 /2 F
                               30YS     1 /2 F
                               31SHIFT  E
                               32SUTIL  2 /2 F
                               33DUTIL  1 /2 F
                               34WDAY   E
                               35DAILY  2      F
                               36PSHFT  0 /    I
                               37TLAST  0 /    F
                               38IDAY   0 /    I.
                               39TME    1 /2 F
                               40TUTIL  1 /2 F
                               41CITY   E
                               42NAME   1      I.
                               43ELAPS  1      F
                               44CKIND  1 /2 I
                               45REST   E
                               46TYPER  1      I.
N NUCP02                       47PRSET  1 /2 I
N NUDAY2                       48SRSET  1 /2 I
                               49FRSET  0      I
                               50LRSET  0      I
                               51NOENG  0      I.
```

```
                                        52CDAYS I     I
                                        53TSHFT I     F
                                        54IDTYP I     I
                                        55DEBUG O     I
                                        56CATEG E
                                        57CLIM  I     F
                                        58FREE  E
                                        59INSUF O     I
                                        60CINC  O     F
                                        61FREQ1 2 /2  I
                                        62FREQ2 2 /2  I
                                        63DELAY O     F
                                        64CRES  I /2  F
N ARVSN4        N RESNO 31/2 I
                N ALMNO 32/2 I

N SNDBK4
N FINSH4
N HOME 4
N AVAIL2
```

```
EVENTS
3 EXOGENOUS
  START (1)
  ALERT (2)
  ENDSIM (3)
8 ENDOGENOUS
  ALARM
  SNDBK
  ARVSN
  FINSH
  HOME
  NUCRU
  NUDAY
  AVAIL
END
```

```
      EXOGENOUS EVENT START
C
C     EXOGENOUS EVENT START IS THE FIRST EVENT OF THE SIMULATION. IT
C     SETS UP THE CURRENT SHIFT AND DAY OF THE WEEK.
C
   10 CREATE NUCRU
      CAUSE NUCRU AT THE(PSHFT)
      LET TLAST = TIME
      CREATE NUDAY
      CAUSE NUDAY AT TIME + 1.0
      LET CLIM(1) = CINC
      DO TO 10, FOR I=(2)(NCATEG)
      LET CLIM(I) = CLIM(I-1)+CINC
   10 LOOP
      CREATE AVAIL
      CAUSE AVAIL AT TIME + 1./48.
      RETURN
      END OF START
```

```
      ENDOGENOUS EVENT NUCRU
C
C     ENDOGENOUS EVENT NUCRU OCCURS WHEN THERE IS A CHANGE OF SHIFTS,
C     MAY BE USED TO ACCUMULATE UTILIZATION BY SHIFTS AND/OR TO CHANG
C     THE NUMBER OF MEN.
C
      DO TO 30, FOR EACH RES IRS
      IF IB(IRS) EQ 1, GO TO 20
      IF TOUT(IRUN(IRS)) GR TLAST, GO TO 10
      LET TUTIL(IRS) = TUTIL(IRS) + TIME - TLAST
      GO TO 20
   10 LET TUTIL(IRS) = TUTIL(IRS) + TIME-TOUT(IRUN(IRS))
   20 LET SUTIL(IRS,PSHFT) = SUTIL(IRS,PSHFT) + TUTIL(IRS)
      LET TUTIL(IRS) = 0.
   30 LOOP
      LET TSHFT(PSHFT) = TSHFT(PSHFT) + TIME-TLAST
      LET PSHFT = PSHFT + 1
      IF PSHFT GR NSHIFT, LET PSHFT = 1
      LET TLAST = TIME
      LET DD = DPART(TIME)
      IF DD+FLOAT(TME(PSHFT)) LS TIME, LET DD=DD+1.0
      CAUSE NUCRU AT DD + TME(PSHFT)
      LET DEBUG = 0
      RETURN
      END OF NUCRU
```

```
          ENDOGENOUS EVENT NUDAY
C
C         ENDOGENOUS EVENT NUDAY OCCURS AT THE SAART OF A NEW DAY. IT IS
C         ENDOGENOUS EVENT NUDAY OCCURS AT THE START OF A NEW DAY. IT IS
C         USED TO ACCUMULATE UTILIZATION BY DAY OF THE WEEK.
C
          LET ILAST = DPART(TIME)
          LET MIL = ILAST - (ILAST/7)*7
          IF MIL EQ 0, LET MIL = 7
          LET INDEX = MIL-1+IDAY
          IF INDEX GR 7, LET INDEX = INDEX - 7
          LET CDAYS(INDEX) = CDAYS(INDEX) + 1
          DO TO 30, FOR EACH RES IRS
          IF IB(IRS) EQ 1, GO TO 20
          IF TOUT(IRUN(IRS)) GR ILAST-1, GO TO 10
          LET DUTIL(IRS) = 1.0
          GO TO 20
       10 LET DUTIL(IRS) = DUTIL(IRS) + TIME-TOUT(IRUN(IRS))
       20 LET DAILY(IRS,INDEX) = DAILY(IRS,INDEX) + DUTIL(IRS)
          LET DUTIL(IRS) = 0.
       30 LOOP
          CAUSE NUDAY AT TIME + 1.0
          RETURN
          END OF NUDAY
```

```
      ENDOGENOUS EVENT AVAIL
      LET IC = 1
      DO TO 10, FOR I=(1)(NOENG)
      IF IH(I) LS 3, LET IC = IC+1
   10 LOOP
      LET FREQZ(IC,PSHFT) = FREQZ(IC,PSHFT) + 1
      CAUSE AVAIL AT TIME + 1./24.
      RETURN
      END OF AVAIL
```

```
      EXOGENOUS EVENT ENDSIM
      DIMENSION ISUM(5),REL(5)
      WRITE ON TAPE 6, NAME(1),NAME(2),NAME(3)
      FORMAT (*1*,S22,*SIMULATION OF FIRE DEPARTMENT ACTIVITIES FOR THE
     *CITY OF *,3A6)
      LET TOTAL = 0.
      LET AVAVR = AVAVR*1440./FLOAT(CASES)
      LET CASES = 0
      DO TO 10, FOR I=(1)(NKINDS)
      IF CKIND(I) EQ 0, GO TO 10
      LET TOTAL = TOTAL + AVTME(I)
      LET CASES = CASES + CKIND(I)
      LET AVTWT(I) = AVTWT(I)*1440./FLOAT(CKIND(I))
      LET ELAPS(I) = ELAPS(I)*1440./FLOAT(CKIND(I))
      LET AVTME(I) = AVTME(I)*24./FLOAT(CKIND(I))
   10 LOOP
      LET TOTAL = TOTAL*24.
      WRITE ON TAPE 6, DPART(TIME),CASES,AVAVR,TOTAL,INSUF
      FORMAT (///////////////* NUMBER OF DAYS SIMULATED*,S18,I5//* TOTAL
     * NUMBER OF CASES SERVED*,S14,I5//* MEAN AVERAGE RESPONSE TIME (PER
     * CASE)*,S5,D2.2,* MINUTES*//* TOTAL UTILIZATION*,S19,D8.2,* RESOUR
     *CE-HOURS*//* NUMBER OF INSUFFICIENT RESPONSES*,S10,I5)
      WRITE ON TAPE 6
      FORMAT (*1*,S48,*RESOURCE DATA*///S22,*TOTAL NO. OF   TOTAL HOURS
     *     AVG. RESPONSE  MAX. RESPONSE  CASE NO. OF   ALARM NO. OF*/S12,
     **STATION  ALARMS SERVED  OUT OF STATION   TIME(MINUTES)  TIME(MINU
     *TES) MAX RESPONSE  MAX RESPONSE*/)
      DO TO 150, FOR EACH RES I
      LET TEMP = 0.
      LET J = I
      IF I GR NOENG, LET J=I-NOENG
      IF NALAM(I) LE 0, GO TO 100
      LET RUTIL(I) = RUTIL(I)*24.
      LET MXRES(I) = MXRES(I)*1440.
      LET TEMP = RWAIT(I)*1440./FLOAT(NALAM(I))
  100 WRITE ON TAPE 6, TYPER(TYP(I)),J,STN(I),NALAM(I),RUTIL(I),TEMP,
     *MXRES(I),CMXRS(I),NMXRS(I)
      FORMAT (* *,A6,I4,I5,I15,D12.2,D13.2,D12.2,2I12)
  150 LOOP
      WRITE ON TAPE 6
      FORMAT (*1*,S19,*BREAKDOWN OF RESOURCE UTILIZATION DATA*///S16,*AV
     *ERAGE HOURS OUT OF STATION BY DAY OF WEEK*/S17,*MON       TUE
     *WED       THU       FRI       SAT       SUN*)
      DO TO 190, FOR EACH WDAY J
      IF CDAYS(J) LE 0, GO TO 190
      DO TO 180, FOR EACH RES I
      LET DAILY(I,J) = DAILY(I,J)*24./FLOAT(CDAYS(J))
  180 LOOP
  190 LOOP
      DO TO 200, FOR EACH RES I
      LET J = I
      IF I GR NOENG, LET J = I-NOENG
      WRITE ON TAPE 6, TYPER(TYP(I)),J,DAILY(I,1),DAILY(I,2),
     *DAILY(I,3),DAILY(I,4),DAILY(I,5),DAILY(I,6),DAILY(I,7)
      FORMAT (* *,A6,I3,S2,7D6.2)
  200 LOOP
      DO TO 250, FOR EACH SHIFT J
```

```
        IF TSHFT(J) LE 0., GO TO 250
        DO TO 240, FOR EACH NES I
        LET SUTIL(I,J) = SUTIL(I,J)*24./TSHFT(J)
    240 LOOP
    250 LOOP
        WRITE ON TAPE 6
        FORMAT ('1',S14,'SUMMARY OF FIRE SERVICE BY TYPE OF CASE'//S23,'AV
       *ERAGE TOTAL AVERAGE FIRST  AVERAGE'/S4,'TYPE    NO. CASES  RESOURC
       *E-HOURS  RESPONSE TIME  DURATION'/S25,'REQUIRED        (MINUTES)
       * (MINUTES)'/)
        WRITE ON TAPE 6, I,IDTYP(I),CKIND(I),AVTME(I),AVTWT(I),ELAPS(I),
       * FOR EACH KINDS I
        FORMAT (I3,S1,A6,I8,D10.4,D1).2,D12.2)
        DO TO 310, FOR J=(1)(5)
        LET ISUM(J) = 0
        DO TO 300, FOR I=(1)(NCATEG)
        LET ISUM(J) = ISUM(J) + FREQ(J,I)
    300 LOOP
    310 LOOP
        WRITE ON TAPE 6
        FORMAT ('1',S19,'DISTRIBUTION OF RESPONSE TIMES FOR THE LAST ARRIV
       *ING ENGINE'///' RESPONSE TIME',S7,'1 ENG. CASES   2 ENG. CASES   3
       * ENG. CASES   4 ENG. CASES  5 ENG. CASES'/'   IN MINUTES',S7,
       *'FREQ REL FREQ  FREQ REL FREQ  FREQ REL FREQ  FREQ REL FREQ  FREQ
       *REL FREQ')
        LET C1 = 0.
        DO TO 360, FOR I=(1)(NCATEG)
        DO TO 355, FOR J=(1)(5)
        LET REL(J) = 0.
        IF ISUM(J) NE 0, LET REL(J) = FLOAT(FREQ(J,I))/FLOAT(ISUM(J))
    355 LOOP
        LET C2 = CLIM(I)
        WRITE ON TAPE 6, C1,C2,FREQ(1,I),REL(1),FREQ(2,I),REL(2),
       *FREQ(3,I),REL(3),FREQ(4,I),REL(4),FREQ(5,I),REL(5)
        FORMAT (D4.1,' TO',D3.1,S6,I4,S2,D1.4,S3,I4,S2,D1.4,S3,I4,S2,D1.4,
       *S3,I4,S2,D1.4,S3,I4,S2,D1.4,S3)
        LET C1 = C2
    360 LOOP
        WRITE ON TAPE 6, ISUM(1),ISUM(2),ISUM(3),ISUM(4),ISUM(5)
        FORMAT ('0',S3,'TOTALS',I14,4I15)
        DO TO 510, FOR I=(1)(3)
        LET ISUM(I) = 0
        DO TO 500, FOR J=(1)(NFREE)
        LET ISUM(I) = ISUM(I) + FREQ2(J,I)
    500 LOOP
    510 LOOP
        WRITE ON TAPE 6
        FORMAT ('1',S39,'AVAILABILITY'///' NO. OF IDLE',S13,'SHIFT 1',S13,
       *'SHIFT 2',S13,'SHIFT 3'/' ENG. CO.',S11,'FREQ.  REL. FREQ.   FREQ.
       *  REL. FREQ.   FREQ.  REL. FREQ.')
        DO TO 550, FOR I=(1)(NFREE)
        DO TO 520, FOR J=(1)(3)
        LET REL(J) = 0.
        IF ISUM(J) GR 0, LET REL(J) = FLOAT(FREQ2(I,J))/FLOAT(ISUM(J))
    520 LOOP
        LET K=I-1
        WRITE ON TAPE 6, K,FREQ2(I,1),REL(1),FREQ2(I,2),REL(2),FREQ2(I,3),
       *REL(3)

        FORMAT (I5,S15,I5,S3,D1.4,S6,I5,S3,D1.4,S6,I5,S3,D1.4)
    550 LOOP
        STOP
        END OF ENOSIM
```

```
         EXOGENOUS EVENT ALERT
         SAVE EVENT CARD
   C
   C     EXOGENOUS EVENT ALERT ACTS AS AN INPUT ROUTINE. IT OCCURS WHENEVER
   C     THE FIRE DEPARTMENT IS NOTIFIED THAT ITS SERVICES ARE NEEDED AT A
   C     PARTICULAR CASE.
   C
         CREATE CASE
         READ NOCAS(CASE),NOALM(CASE),XC(CASE),YC(CASE),TYPE(CASE)
         FORMAT (S3,2I5,2D4.0,I5)
         LET OCCUR(CASE) = TIME
         LET N=NOALM(CASE)
         LET FIRST(CASE) = 0
         WRITE ON TAPE 6, CASE,NOCAS(CASE),NOALM(CASE),XC(CASE),YC(CASE),
        *TYPE(CASE),OCCUR(CASE)
         FORMAT (* CASE INPUT*,I10,2I5,2D5.0,I5,M3.2.2)
         DO TO 40, FOR I=(1)(N)
         CREATE ALARM
         FILE ALARM IN ASET(CASE)
         LET CAS(ALARM) = CASE
         LET NUMBR(ALARM) = N-I+1
      40 LOOP
         READ OCCUR(I),OST(I),NECO(I),NTCO(I), FOR EACH I IN ASET(CASE)
         FORMAT 5(2M5.I3.I2)
         LET NECO(CASE) = 0
         LET NTCO(CASE) = 0
         DO TO 50, FOR EACH ALARM IN ASET(CASE)
         LET NECO(CASE) = NECO(CASE) + NECO(ALARM)
         LET NTCO(CASE) = NTCO(CASE) + NTCO(ALARM)
         LET OCCUR(ALARM) = TIME + OCCUR(ALARM)
         CAUSE ALARM AT OCCUR(ALARM)
      50 LOOP
         WRITE ON TAPE 6, NUMBR(ALARM),OCCUR(ALARM),OST(ALARM),NECO(ALARM),
        *NTCO(ALARM), FOR EACH ALARM IN ASET(CASE)
         FORMAT 5(I5,M4.2.2,M1.2.2,2I2)
         RETURN
         END OF ALERT
```

```
          ENDOGENOUS EVENT ALARM
C         ENDOGENOUS EVENT ALARM OCCURS WHENEVER IT IS DESIRED TO DISPATCH
C         MORE RESOURCES TO THE SCENE OF A CASE.
C
          LET CASE = CAS(ALARM)
          IF DEBUG EQ 1, WRITE ON TAPE 6, NOCAS(CAS(ALARM)),CAS(ALARM),
         *NUMBR(ALARM),TIME
          FORMAT (' INSIDE ALARM FOR CASE',I5,' ID',I10,' ALARM NO.',I5,' AT
         * TIME',M3.2.2)
          CALL ARR(ALARM)
          CALL RESAP(ALARM)
          IF ESET(ALARM) IS EMPTY, GO TO 20
          DO TO 10, FOR EACH IRS IN ESET(ALARM)
          CALL SERVE(ALARM,IRS)
       10 LOOP
       20 IF TSET(ALARM) IS EMPTY, RETURN
          DO TO 30, FOR EACH IRS IN TSET(ALARM)
          CALL SERVE(ALARM,IRS)
       30 LOOP
          RETURN
          END OF ALARM
```

```
          SUBROUTINE ARR(ALARM)
      C
      C   SUBROUTINE ARR DETERMINES THE TIME IT WOULD TAKE FOR EACH RESOURCE
      C   TO ARRIVE AT THE SCENE OF THE CASE. THE RESOURCES ARE PUT IN A
      C   RANKED SET RSET.
      C
       10 IF RSET IS EMPTY, GO TO 20
          REMOVE FIRST IRS FROM RSET
          GO TO 10
       20 LET CASE = CAS(ALARM)
          DO TO 90, FOR EACH RES IRS
          GO TO (70,50,90,90),IB(IRS)
       50 LET DIST = (TIME-DEP(IRUN(IRS)))*SP2
          IF IDIR(IRUN(IRS)) EQ 1, GO TO 60
          CALL WHERE(**XR(IRS),XDEST(IRUN(IRS)),**DIST)
          IF DIST EQ 0., GO TO 70
          CALL WHERE(**YR(IRS),YDEST(IRUN(IRS)),**DIST)
          GO TO 70
       60 CALL WHERE(**YR(IRS),YDEST(IRUN(IRS)),**DIST)
          IF DIST EQ 0., GO TO 70
          CALL WHERE(**XR(IRS),XDEST(IRUN(IRS)),**DIST)
       70 LET D = ABS(XC(CASE)+.5-XR(IRS)) + ABS(YC(CASE)+.5-YR(IRS))
       80 LET SPEED = SP1
          IF TYPE(CASE) LS 2, LET SPEED = SP2
          LET TARR(IRS) = D/SPEED
          IF IB(IRS) EQ 1, LET TARR(IRS) = TARR(IRS) + DELAY
          FILE IRS IN RSET
       90 LOOP
          IF RSET IS EMPTY, RETURN
          IF DEBUG EQ 0, RETURN
          DO TO 100, FOR EACH IRS IN RSET
          WRITE ON TAPE 6, IRS,TARR(IRS),XR(IRS),YR(IRS),IB(IRS)
          FORMAT (' RSET CONTAINS',I5,M5,2D4.0,I5)
      100 LOOP
          RETURN
          END OF ARR
```

```
      SUBROUTINE WHERE (RX,DX,DIST)
C
C     SUBROUTINE WHERE DETERMINES THE 'X' COORDINATE OF A RESOURCE
C     TRAVELING FROM XR TO XD WHICH HAS TRAVELED A TOTAL DISTANCE DIST.
C
      LET DELX = DX-RX
      LET ADELX = ABS(DELX)
      IF ADELX LE DIST, GO TO 10
      IF DELX LS 0., LET RX = RX-DIST
      IF DELX GR 0., LET RX = RX + DIST
      IF RX LS 0., LET RX = 0.
      LET DIST = 0.
      RETURN
   10 LET RX = DX
      LET DIST = DIST - ADELX
      RETURN
      END OF WHERE
```

```
          SUBROUTINE RESAP(ALARM)
    C
    C     SUBROUTINE RESAP CONCERNS THE RESOURCE ASSIGNMENT POLICY. IT
    C     SELECTS THE PARTICULAR RESOURCES WHICH WILL RESPOND TO THE ALARM.
    C
          LET CASE = CAS(ALARM)
          LET NEN = 0
          LET NTR = 0
       10 IF RSET IS EMPTY, GO TO 30
          REMOVE FIRST IRS FROM RSET
          IF IB(IRS) GR 2, GO TO 10
          IF TYP(IRS) EQ 2, GO TO 20
          IF NEN GE NECO(ALARM), GO TO 10
          FILE IRS IN ESET(ALARM)
          LET NEN = NEN + 1
          GO TO 10
       20 IF NTR GE NTCO(ALARM), GO TO 10
          FILE IRS IN TSET(ALARM)
          LET NTR = NTR + 1
          GO TO 10
       30 IF ESET(ALARM) IS EMPTY, GO TO 40
          IF DEBUG EQ 0, GO TO 40
          WRITE ON TAPE 6, IRS,TARR(IRS),IB(IRS),TYP(IRS), FOR EACH IRS IN
         *ESET(ALARM)
          FORMAT (' ESET CONTAINS',I5,M5,2I5)
       40 IF TSET(ALARM) IS EMPTY, GO TO 50
          IF DEBUG EQ 0, GO TO 50
          WRITE ON TAPE 6, IRS,TARR(IRS),IB(IRS),TYP(IRS), FOR EACH IRS IN
         *TSET(ALARM)
          FORMAT (' TSET CONTAINS',I5,M5,2I5)
       50 IF NEN + NTR EQ NECO(ALARM)+NTCO(ALARM), RETURN
          WRITE ON TAPE 6, NECO(CASE),NECO(ALARM),NEN
          FORMAT (3I10)
          LET NECO(CASE) = NECO(CASE) - NECO(ALARM) + NEN
          LET NTCO(CASE) = NTCO(CASE) - NTCO(ALARM) + NTR
          LET INSUF = INSUF + 1
          WRITE ON TAPE 6, TIME,NUMBR(ALARM),NOCAS(CAS(ALARM)),NECO(ALARM),
         *NTCO(ALARM),NEN,NTR
          FORMAT ('OAT TIME',M4.2.2,' ALARM NO.',I2,' OF CASE NO.',I6,' RECE
         *IVES AN INCOMPLETE RESPONSE.'/' THE ALARM CALLS FOR',I2,' ENGINE C
         *OMPANIES AND',I2,' TRUCK COMPANIES. ONLY',I2,' ENGINE COMPANIES AN
         *D',I2,' TRUCK COMPANIES ARE AVAILABLE.')
          RETURN
          END OF RESAP
```

```
      SUBROUTINE SERVE(ALARM,IRS)
C
C     SUBROUTINE SERVE IS CALLED WHEN A RESOURCE IS ASSIGNED TO SERVE A
C     PARTICULAR ALARM. IT SETS UP BOOKKEEPING DEVICES FOR DATA ON
C     RESOURCE UTILIZATION.
C
      LET CASE = CAS(ALARM)
      LET TEMP = TIME + TARR(IRS)
      IF DEBUG EQ 1, WRITE ON TAPE 6, IRS,CASE,TIME,TARR(IRS),TEMP
      FORMAT (' SERVE',2I10,3M3.2.2)
      GO TO (30,10,20,25),IR(IRS)
   10 CANCEL HOME CALLED IDEV(IRUN(IRS))
      DESTROY HOME CALLED IDEV(IRUN(IRS))
      GO TO 40
   20 CANCEL ARVSN CALLED IDEV(IRUN(IRS))
      DESTROY ARVSN CALLED IDEV(IRUN(IRS))
      GO TO 40
   25 CANCEL FINSH CALLED IDEV(IRUN(IRS))
      DESTROY FINSH CALLED IDEV(IRUN(IRS))
      GO TO 40
   30 CREATE RUN CALLED IRUN(IRS)
      LET TOUT(IRUN(IRS)) = TIME
   40 LET DEP(IRUN(IRS)) = TIME
      LET F = RANDM
      LET IDIR(IRUN(IRS)) = 0
      IF F GR .5, LET IDIR(IRUN(IRS)) = 1
      LET IR(IRS) = 3
      LET RALAM(IRS) = ALARM
      LET XDEST(IRUN(IRS)) = XC(CASE) + .5
      LET YDEST(IRUN(IRS)) = YC(CASE) + .5
      IF OST(ALARM) LS 0., GO TO 100
      CREATE ARVSN CALLED IDEV(IRUN(IRS))
      STORE IRS IN RESNO(IDEV(IRUN(IRS)))
      STORE ALARM IN ALMNO(IDEV(IRUN(IRS)))
      CAUSE ARVSN CALLED IDEV(IRUN(IRS)) AT TIME + TARR(IRS)
      LET NEXT(IRUN(IRS)) = 1
      RETURN
  100 LET TEMP = OST(ALARM) + TARR(IRS)
      IF TEMP LE 0., LET TEMP = TARR(IRS)/2.0
      CREATE SNORK CALLED IDEV(IRUN(IRS))
      STORE ALARM IN ALMNO(IDEV(IRUN(IRS)))
      STORE IRS IN RESNO(IDEV(IRUN(IRS)))
      CAUSE SNORK CALLED IDEV(IRUN(IRS)) AT TIME + TEMP
      LET NEXT(IRUN(IRS)) = 4
      RETURN
      END OF SERVE
```

```
          ENDOGENOUS EVENT SNDBK
          STORE ALMNO(SNDBK) IN ALARM
          STORE RESND(SNDBK) IN IRS
          IF DEBUG EQ 1, WRITE ON TAPE 6, IRS,NDCAS(CAS(ALARM)),
        , NUMBR(ALARM),TIME
          FORMAT (' INSIDE SNDBK',3I10,M3.2,2)
          DESTROY SNDBK CALLED IDEV(IRUN(IRS))
          LET SPEED = SP2
          IF TYPE(CAS(ALARM)) GE 2, LET SPEED = SP1
          LET DIST = (TIME-DEP(IRUN(IRS)))*SPEED
          IF IDIR(IRUN(IRS)) EQ 1, GO TO 20
          CALL WHERE(**XR(IRS),XDEST(IRUN(IRS)),**DIST)
          IF DIST EQ 0, GO TO 50
          CALL WHERE(**YR(IRS),YDEST(IRUN(IRS)),**DIST)
          GO TO 50
       20 CALL WHERE(**YR(IRS),YDEST(IRUN(IRS)),**DIST)
          IF DIST EQ 0, GO TO 50
          CALL WHERE(**XR(IRS),XDEST(IRUN(IRS)),**DIST)
       50 CREATE FINSH CALLED IDEV(IRUN(IRS))
          STORE ALARM IN ALMNO(IDEV(IRUN(IRS)))
          STORE IRS IN RESND(IDEV(IRUN(IRS)))
          CAUSE FINSH CALLED IDEV(IRUN(IRS)) AT TIME
          RETURN
          END OF SNDBK
```

```
          ENDOGFNOUS FVENT ARVSN
C
C         ENOOGENOUS EVENT ARVSN OCCURS WHEN A RESOURCE ARRIVES AT THE SCENE
C         OF A CASE.
C
          STORE RESNO)ARVSN) IN IRS
          STORF ALMNO)ARVSN) IN ALARM
          LET IR(IRS) = 4
          LET CASE = CAS(ALARM)
          IF DEBUG EQ 1, WRITE ON TAPE 6, IRS,CASE,TIME
          FORMAT (* ARVSN*,2I10,M3.2.2)
          LET XR)IRS) = XOEST(IRUN(IRS))
          LET YR(IRS) = YDEST(IRUN(IRS))
          LET XDEST(IRUN)IRS)) = 0.
          LET YDEST(IRUN)IRS)) = 0.
          IF FIRST(CASE) NE 0, GO TO 50
          LET FIRST(CASE) = IRS
          LFT TWAIT(CASE) = TIME-OCCUR(ALARM)
          IF TWAIT(CASE) LE MXTWT, GO TO 50
          LET MXTWT = TWAIT(CASE)
          LET CMXTW = NOCAS(CASE)
          LFT RMXTW = IRS
       50 IF FIRST(ALARM) NE 0, GO TO 60
          LFT FIRST)ALARM) = IRS
          LET TWAIT)ALARM) = TIME-OCCUR(ALARM)
       60 LFT TEMP = TIME-OCCUR)ALARM)
          LFT CRES))RS) = TEMP
          LFT RWAIT(IRS) = RWAIT)IRS) + TEMP
          LET AVRES(CASE) = AVRES(CASE) + TEMP
          LFT CNRES(CASE) = CNRES(CASE) + 1
          LFT NALAM()RS) = NALAM(IRS) + 1
          IF TEMP LE MXRES(IRS), GO TO 70
          LFT MXRES)IRS) = TEMP
          LET CMXRS)IRS) = NOCAS(CAS(ALARM))
          LET NMXRS(IRS) = NUMBR(ALARM)
       70 DESTROY ARVSN CALLEO IOEV)IRUN(IRS))
          LFT NEXT)IRUN(IRS)) = 2
          CREATE FINSH CALLEO IOEV(IRUN(IRS))
          STORE ALARM IN ALMNO(IOEV)IRUN(IRS)))
          STORE IRS IN RESNO(IOEV)IRUN(IRS)))
          CAUSE FINSH CALLEO IOEV(IRUN(IRS)) AT TIME + OST(ALARM)
          RETURN
          ENO OF ARVSN
```

```
        ENDOGENOUS EVENT FINSH
C
C       ENDOGENOUS EVENT FINSH OCCURS WHEN A RESOURCE FINISHES RENDERING
C       ASSISTANCE TO AN ALARM.
C
        STORE ALMNO(FINSH) IN ALARM
        STORE RESNO(FINSH) IN IRS
        LET CASE = CAS(ALARM)
        IF DEBUG EQ 1, WRITE ON TAPE 6, IRS,CASE,TIME
        FORMAT (' FINSH',2I10,M3.2.2)
        DESTROY FINSH CALLED IDEV(IRUN(IRS))
        LET DIST = ABS(XR(IRS)-XS(STN(IRS))) + ABS(YR(IRS)-YS(STN(IRS)))
        CREATE HOME CALLED IDEV(IRUN(IRS))
        STORE IRS IN RESNO(IDEV(IRUN(IRS)))
        CAUSE HOME CALLED IDEV(IRUN(IRS)) AT TIME + DIST/SP2
        LET XDEST(IRUN(IRS)) = XS(STN(IRS))
        LET YDEST(IRUN(IRS)) = YS(STN(IRS))
        LET IB(IRS) = 2
        LET DEP(IRUN(IRS)) = TIME
        LET NEXT(IRUN(IRS)) = 3
        LET NCOMP(CASE) = NCOMP(CASE) + 1
        LET TOTME(CASE) = TOTME(CASE)+TIME-OCCUR(ALARM)
        IF NCOMP(CASE) LS NECO(CASE)+NTCO(CASE), RETURN
        CALL TERM(CASE)
        RETURN
        END OF FINSH
```

```
        ENDOGENOUS EVENT HOME
C
C       ENDOGENOUS EVENT HOME OCCURS WHEN A RESOURCE ARRIVES AT ITS 'HOME'
C       FIRE STATION.
C
        STORE RESNO(HOME) IN IRS
        IF DEBUG EQ 1, WRITE ON TAPE 6, IRS,TIME
        FORMAT (' HOME',I10,H3.2,2)
        DESTROY HOME CALLED IOEV(IRUN(IRS))
        LET IB(IRS) = 1
        LET XR(IRS) = XS(STN(IRS))
        LET YR(IRS) = YS(STN(IRS))
        LET RUTIL(IRS) = RUTIL(IRS) + TIME-TOUT(IRUN(IRS))
        IF TOUT(IRUN(IRS)) GR TLAST, GO TO 10
        LET TUTIL(IRS) = TUTIL(IRS) + TIME - TLAST
        GO TO 20
     10 LET TUTIL(IRS) = TUTIL(IRS) + TIME -TOUT(IRUN(IRS))
     20 IF DPART(TIME) EQ DPART(TOUT(IRUN(IRS))), GO TO 30
        LET OUTIL(IRS) = OUTIL(IRS) + TIME - FLOAT(DPART(TIME))
        GO TO 40
     30 LET OUTIL(IRS) = OUTIL(IRS) + TIME - TOUT(IRUN(IRS))
     40 LET IRUN(IRS) = 0
        RETURN
        END OF HOME
```

```
      SUBROUTINE TERM(CASE)
C
C     SUBROUTINE TERM OCCURS WHEN A CASE IS TERMINATED.
C
      WRITE ON TAPE 6, CASE,TIME,NOCAS(CASE)
      FORMAT IS70,* END OF CASE*,I10,M3.2.2,I10)
      IF TYPE(CASE) LS 1, GO TO 40
      IF TYPE(CASE) GR NKINDS, GO TO 40
      LET ELAPS(TYPE(CASE)) = ELAPS(TYPE(CASE)) + TIME - OCCUR(CASE)
      LET CKIND(TYPE(CASE)) = CKIND(TYPE(CASE)) + 1
      LET AVTWT(TYPE(CASE)) = AVTWT(TYPE(CASE)) + TWAIT(CASE)
      LET AVTME(TYPE(CASE)) = AVTME(TYPE(CASE)) + TOTME(CASE)
   40 IF CNRES(CASE) GR 0, LET AVAVR = AVAVR + AVRES(CASE)/
     *FLOAT(CNRES(CASE))
      IF CNRES(CASE) GR 0, LET CASES = CASES + 1
      LET IC = 0
      LET TMAX = 0.
   50 IF ASET(CASE) IS EMPTY, GO TO 60
      REMOVE FIRST ALARM FROM ASET(CASE)
      IF NECO(ALARM) EQ 0, GO TO 55
   52 IF ESET(ALARM) IS EMPTY, GO TO 55
      REMOVE FIRST IRS FROM ESET(ALARM)
      IF CRES(IRS) LS 0., GO TO 52
      LET IC = IC+1
      LET SMAX = OCCUR(ALARM) - OCCUR(CASE) + CRES(IRS)
      IF SMAX GR TMAX,LET TMAX = SMAX
      GO TO 52
   55 DESTROY ALARM
      GO TO 50
   60 IF IC EQ 0, GO TO 70
      LET TMAX = TMAX*1440.
      DO TO 65, FOR I=(1)(NCATEG)
      IF TMAX GR CLIM(I), GO TO 65
      LET FREQ(IC,I) = FREQ(IC,I) + 1
      GO TO 70
   65 LOOP
      LET FREQ(IC,NCATEG) = FREQ(IC,NCATEG) + 1
   70 DESTROY CASE
      RETURN
      END OF TERM
```