ARAB REPUBLIC OF EGYPT

THE INSTITUTE OF NATIONAL PLANNING

Memo No. 1082

The Maritime Transportation Series

(c) A Simulation Model for the Commercial Fleet Operations

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Oct, 1975

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TABLE OF CONTENTS

ABSTRACT

A digital computer simulation model is built for the maritime transportation network that may contian transloading points of cargo. The model serves as a utility tool for testing certain designs, system configurations, or the implications of prespecified policies. A high degree of modularity, segmentation, and hence flexibility is achieved. The model was tested and validated on the ICL 1900. E computer and is presented here in considerable details.

CHAPTER 1

SIMULATION MODELS

Model building is usually associated with the following two objectives :[42,43]

1- To be able to predict performances before the system is built.

2- To have assurance that the system design selected is optimal in terms of the design criteria adopted.

Thus, model building is oftenly carried out to provide inferences about the real system through experiments conducted with the model.

Representation of the system by a physical model, either in the form of scale or an analogue model is usually time consuming and expensive, and there is no assurance that other designs, not considered, would not be superior.

An alternative to physical models is mathematical models, which often permit the application of analytical techniques for determining optimal design, but mathematical models usually have the following limitations :-

1- They usually have implicit assumptions, normally tailored to fit certain specified applications. For example, linear programming formulations for transportation models are based on the assumption that only a single type of commodity is being shipped ([illegible]). This would restrict the applicability of linear programming in a multi-commodity flow environment such as the maritime transportation sector ([illegible]).

2- When an attempt is made to modify the underlying assumptions to incorporate more relevant factors, the model usually gets too complicated to be solvable with the available algorithms. For example certain attempts have been carried out to develop reliable algorithms for the case of multi-commodity non-linear concave cost function networks ([illegible]). Usually conclusions arrived at through complicated mathematical procedures are hardly conceivable by top management.

3- Furthermore, mathematical models cannot be relied upon in the design of information-feedback scheduling and operations rules. For example, the scheduling procedure for a freighter transport fleet prepared several months ahead, must take into account cargo demands at various ports, ship capacities and speeds, uncertainties due to delays and port congestion. Many shipping lines that own a large fleet of vessels must reschedule daily as they receive more accurate information about uncertain events.

In addition to these limitations and upon dealing with complex systems, mathematical models may become very difficult and can alternatively be replaced by numerical techniques to determine the changes in the system resulting from events. This technique is digital computer simulation and is particularly valuable for studying systems in which model relationships are stochastic.

System simulation has proved to be a powerful tool in dealing with and analysing complex transportation networks. Through simulation, it is possible to establish a model for shipping operations which permits feedback of dynamic parameters affecting the optimum requirements of design for future replacement vessels. A performance criterion could be introduced which might include physical, operational, human as well as economic factors.

The technique is most suitable for the maritime transportation sector. The diversity of problems encountering the sector and the relatively wide variation of routing, scheduling and allocation decisions to be taken requires an equally flexible tool to cope with these many facets problems when attempting to determine the consequencies in any specific case whatever reasonable assumptions required are made to get a reasonable answer from whatever description of the problem is at hand. In other words, the assumptions and techniques for solving the problem can be tailored to each case. When, however, this task is to be referred to an electronic computer, these assumptions have to be made beforehand, and they have to be reasonable for a sufficiently wide range of problems to justify the effort of coding and computations [..]. Moreover, the format and description of the problem must be set forth beforehand, and again, must be flexible enough so that a reasonably large number of problems can be described and that every problem can be worked dozens of times.

In applying a simulation technique, an immage of the system is produced in the form of a set of numbers that represent the state of the system, and a complete program is written embodying the relationships controlling the changes of state in the system [..]. The general operations of a simulation program are roughly the generation of inputs, the determination of the next event and whether it can be executed, the changes in state which occur from an event, and the generation of output.

The general programming tasks corresponding to these operations are the generation of data, scanning of events, logical testing, update and creation of tables, and the computation of statistics and their organization in a report. In constructing the model and program, efficient use of memory space and simulation processing time are very important.

Simulation models have been successfully applied in the maritime as well as in other modes of transportation. Variables such as : proposed vessels, ship characteristics, fleet replacements, route structures, level of service, cargo offerings, and seasonal variations are included and evaluated in the models. As an example a maritime simulation model was developed to serve three interrelated tasks :

1- Study selected trade routes to define operational features that might be incorporated into new ship system designs.

2- Use generated inputs to develop a mathematical simulation model of merchant fleet operations.

3- Analyzing world-wide maritime and connecting inland transportation links.

A second example is furnished by a medium range freighter fleet simulation model. The model is a deterministic one and has been used principally as a device for scheduling rather than long-range planning. The model was used with little modifications to assist in the study of the effects on profit of forcing ships to delay in port for additional cargo offerings, and thus increase voyage utilization. It has also been employed in the investigation of the fleet position against proposed large scale competition in the concerned trade.

In 1969, the U.S. Department of Commerce built a simulation model to analyze the traversal of defined trade routes by diversily designed vessels (112). It was also used to appraise the effects of variations in speed on the profit margin.

In the following chapters, the simulation technique is applied in a novel development of a model for the Egyptian Fleet units operations. The model is rather a utility device intended to suit a wide variation of purposes.

CHAPTER 2

MODEL DESCRIPTION

2.1 - INTRODUCTION

In this chapter we shall be concerned with developing a model simulating the movement of cargo over a complex transportation network that may contain transloading points and in which several different types of transport ships may be used. As indicated in Chapter 3, the model is intended for rationalizing decisions concerning testing certain designs, system configurations, and the implications of prespecified policies. This entails decisions relating to growth, routing, fleet composition, ship capacity, ...etc. The attainment of the desired model flexibility is achieved by constructing a simulation model which is not oriented towards a specific corporate situation. For this reason the "format" of the description of the problem must be set in advance, and liable to accommodate a reasonably large number of problems that can be described and worked several times. Thus, the user will be able, under the necessary assumptions and good quality input data requirement, to undertake a series of experiments yielding quantifiable results amenable for statistical analysis and inferences.

2.2 - DESIRABLE FEATURES OF THE MODEL

Upon the development of a simulation model of this type, usually one is confronted with two factors, rather contradicting ; they are : the incorporation of much details to achieve the greatest possible deal of realism, and to keep the model fairly away from irrelevant complications. In the present model a compromise between the above two factors have been made in such a way that only those features of direct bearing on the problem are incorporated. Of the desired features, the two most important ones are: containerization and transshipment of cargo. The importance of these two features stem from the fact that the first is a possible development for the Egyptian fleet while the second has special significance to the integration of fleets of the Arab Confederation. Each of these two features is discussed in the following sections.

2.2.1 - Containerization

Containerization of commercial cargo is being now undertaken all-over the world on large scale and certainly it is timely for Egypt. A strong trend is now calling for the necessary measures to catch up with the new technique being hailed as the biggest thing in maritime affairs in the last 20 years [90,104]. Preliminary measures have already been taken at Alexandria port to deal with container ships.

The technique is developed to reduce the serious impediment to cargo handlings introduced by the heterogeneous nature of dry mixed cargo and increase their efficiency. The method acquires its greatest advantage from integrating several transportation modes including trucks and railroad cars. The actual discharge of the cargo takes place at the final destination of cargo. Containerization promises an increased rate of handling with consequent lower costs and a decreased turnaround time. Further, it significantly reduces the paper work which is, otherwise, required. Containers guard against pilferage and provide protection against damage and weather [90]. They are sufficiently sturdy to be used as temporary storage.

On the other hand there are several disadvantages which might handicap containerization advantages. Chief among these are costs of purchasing, maintenance, and returning the empties (when necessary). Other disadvantages are containers dead-weight and the inside lost cubic space due to imperfect fit. Special handling equipment may be required. Finally, present tarrifs and custom regulations pose special problems. However, efficient management, good scheduling and tight controls will be the deciding factors in the system.

Due to the fact that complete switching to container ships might not be feasible in Egypt at the early stages, provision has been made in the model for having some container holds among the ship holds. Entire container ships are, however, possible to be dealt with in the model.

Considering containerization, three major decisions have to be taken about :

1. The size of the container, relative to certain standards,
2. The number of the container inventory, and,
3. The allocation and scheduling scheme along the trade route.

In the developed model, no attempt has been made to impose a particular technique of scheduling and allocating containers to the system ports because such attempt will depend on the real conditions upon application and any assumption in this connection may impair the flexibility and generality of the model.

An input array INVCO(I) is provided to be read as system data giving the initial container inventory at port (I). Each time a container is filled or emptied, container inventory of the given port is updated. Container inventory is considered to be those empty containers ready for filling with cargo originating from this port. Transshipment containers whether loaded or discharged have nothing to do with container inventory. On the other hand any final destination container discharged from the current ship will increase the container inventory at this port. This is not done at once since discharged containers will need sometime to be emptied and ready for new shipments. Thus an assumption is made that discharged containers are accumulated during processing of a given ship and are piled up to the port's inventory at the end to be available for subsequent events. Container inventory at system ports is displayed on the monitor at specified simulation intervals in subroutine CARGO. No shipment of empty containers is considered by the model.

2.2.2 - Transshipment of Cargo

Shipment of cargo between the origin and destination ports may not occur in a single voyage. There may be one or more transshipment ports at which cargo is to be discharged for further shipments by other ships calling at such ports.

Accordingly, two types of transportation service could be distinguished; a single and a feeder line service (118).

In a single service cargo moves directly from origins to destinations, no transshipment of cargo through an intermediate port is involved.

A feeder line service usually exists if the network includes at least one transshipment port. This concept has its practical merits which enables wide latitude in planning and integrating transportation policies. The concept is best illustrated by the network configuration shown in Fig. (2.1). Such a network is characterized by a set of ports clustering to each other, due to geographical features into two main groups separated by a relatively wide distance. The application of a feeder line service to such a network might yield favourable results. Instead of operating the fleet units allover the whole network, it might be more economical if these units were operating within ports of each group with one or more ships running in a shuttle service between two transloading points in each group as shown in the figure. The main idea applies also for the integration of two fleets operating within the same groups. Moreover, the concept might be extended, with minor modifications, to study the integration of different modes of transportation such as an inland railway feeder network with a maritime network where

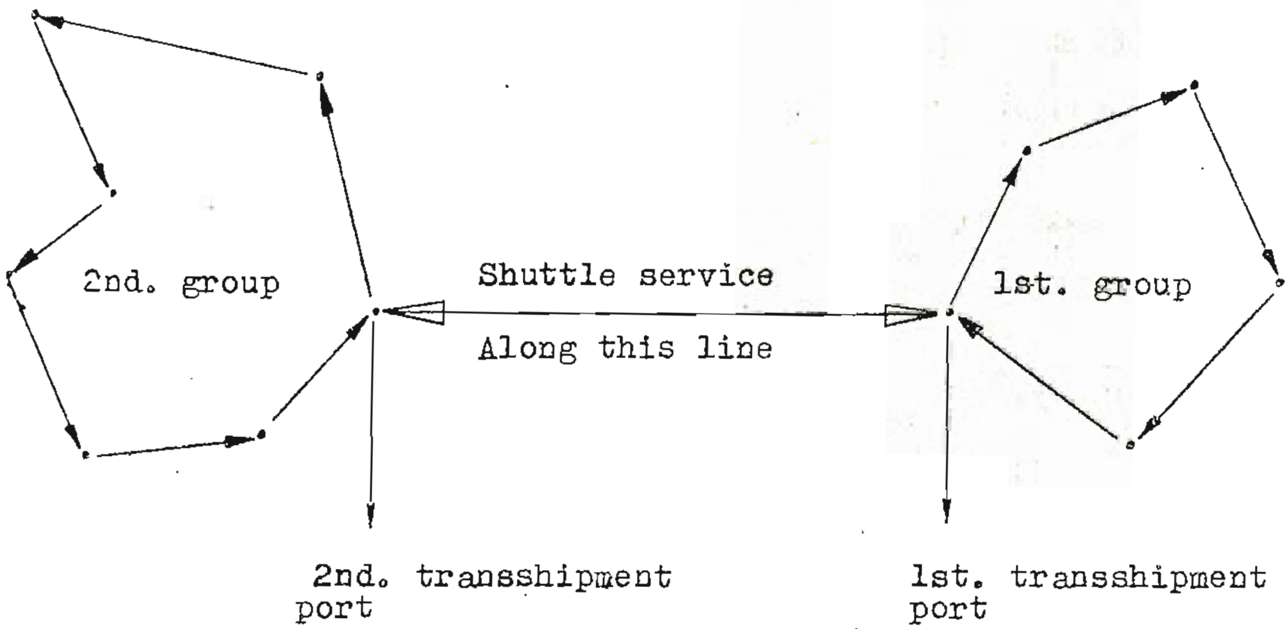


Figure 2-1 : Concept of a Feeder Network the exporting ports are considered as a transloading point of cargo.

The model developed in this study has the flexibility of optional capability of simulating both single and feeder line services.

2.3 - DESCRIPTION OF THE CONCEPTUAL SYSTEM OF THE MODEL

From the presentation given in previous chapters, the system simulated in the developed model is depicted as a maritime environment composed of a network of ports and a commercial fleet engaged in the movement of cargo among these ports. The fleet units might belong to one or more corporations. They run along predefined navigation routes that are specified according to conference, geographical or other considerations.

Ports are arbitrarily classified into NODES and SUPERNODES (118). Nodes are defined as origin and destination of cargo while supernodes, in addition to these characteristics have the further capability of accumulating cargo for further shipments. One or two supernodes might be available in the system.

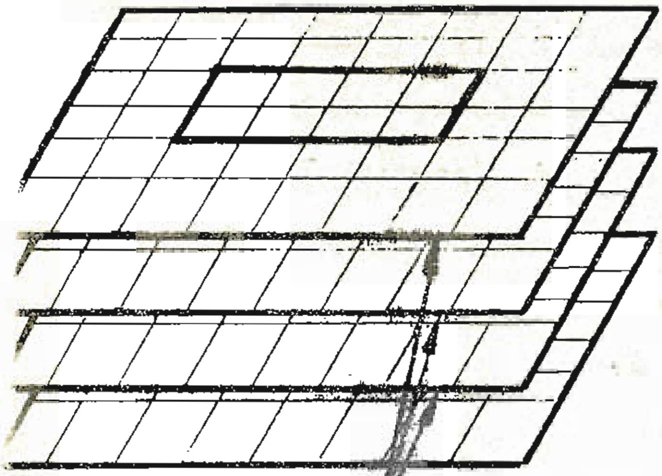
Ships, in turn, are classified into REGULAR and EXPRESS ships according to their itineraries (118). A regular ship calls on both nodes and supernodes while express ships call only on supernodes.

Cargo considered in the system is classified into three main categories : container, break bulk, and bulk (liquid or dry) cargo. Bulk cargo is of a continuous type that does not necessarily need packing such as crude oil and grains. This type of cargo is handled more easily, if not packed, due to the use of special machinery in both loading and unloading. Break bulk cargoes are those continuous cargoes that are packed in small packages such as cement sacks.

Cargo is stowed in the ships in internal holds. A hold is a rectangular parallelepiped that is divided into spaces of equal volume and weight capacities referred to as standard spaces. The holds carry only those cargo compatible to it. For a container hold, the number of standard spaces is equal to the container capacity of the hold. A bulk hold is considered to be of a single space. It should be noticed that these main groups might entail further subgroups. For example container spaces might include dry containers, fresh products in refregirated containers, or oil in special tank-like containers. Bulk cargo might be subdivided into liquid or grain ... and so forth.

A break bulk hold is depicted to have successive layers or decks. Spaces within each deck are divided into hatch and wing area spaces, (Fig. 2.2). Hatch area spaces

Isometric of a b.bulk Hold



Plan of the Bottom-most Deck

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

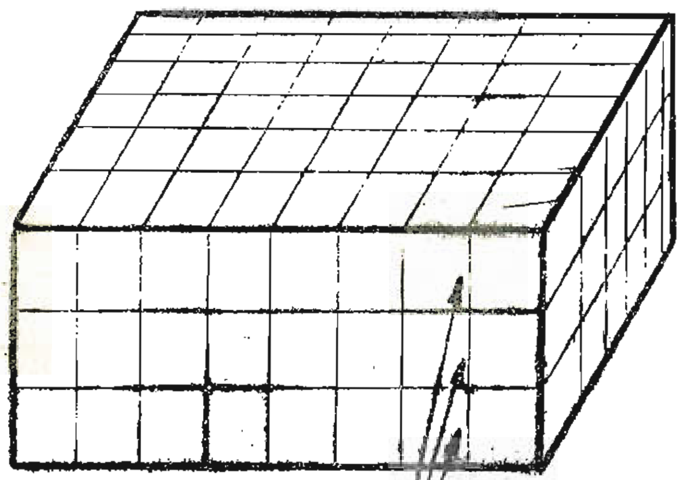
Successive Decks

Spaces within box are hatch **spaces**

within bo are wing spaces

Figure 2-2 : Layout of a Break Bulk Hold and Spaces Numbering System.

Isometric of a Container Hold



Plan of the Bottom-most Layer

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

Successive Layers

Figure 2-3 : Layout of a Container Hold and Spaces Numbering System.

are easily accessible to the cargo handling cranes. On the contrary, cargo in wing areas must be removed to the hatch of the same deck before being accessible to the cranes.

Containers are stowed in stacks or columns, break bulk in standard spaces. Each standard space contains only cargo of the same commodity type and attributes. Bulk cargo is stowed in a single space hold or tank. Bulk shipments are never mixed. If a liquid shipment partially fills a tank then all other bulk is excluded.

Each ship has an itinerary which is an ordered list of ports called arranged according to their visiting order. Between any two ports, the ship will sail at a certain nominal speed which is specified as a percentage of its maximum speed due to navigational or inland waterway considerations. Before calling on a port, the ship will undergo queing delay. On berth, a series of operations referred to as "port processing" will take place. This will include unloading, booking, and loading.

- PORT PROCESSING

Whenever a ship seizes a berth in a given port, cargo is offered for transportation according to Monte Carlo or other techniques as will be explained later. A consecutive cycle of operations will then commence which are referred to as port processing. These operations will be carried out on each hold and will include unloading, booking, and loading. Every aspect of these three aspects differs slightly according to the type of the hold under consideration.

1- Unloading :

This is the first aspect of port processing performed within a particular hold. Normally all standard spaces within the hold are scanned in pre-defined order. Attributes of cargo in nonempty spaces are checked for unloading conditions. Cargo might be discharged at a final or an intermediate destination. Transshipped containers unloaded in a particular port are accumulated on each other. Transshipped bulk as well as break bulk cargoes are grouped in several homogeneous groups with cargoes in each group having the same attributes. It might happen that the cargo to be unloaded from a certain space is being blocked by other spaces. Then the cargo in these later spaces are labelled overstowed cargo and have to be removed first before the space to be unloaded is accessible to the handling crane. Overstowage will increase both time and cost statistics.

2. Booking

The booking process can be viewed of as to be composed of three main stages, namely :

a- Scanning of cargo offered for booking at the port and the determination of the hold's share of such cargo according to certain rules. These rules ensure homogeneous distribution of cargo among all holds to avoid undue concentration in some holds, in which case problems of cargo stowage and balancing will arise. Such problems could be avoided through the above-mentioned scheme. Of course, hold's share of cargo offered is subject, to weight as well as volume constraints.

b- Rearrangement of overstowed spaces, encountered upon the unloading process of the hold spaces, in accordance with the rule, last-port first, in order to minimize overstowage time and cost that will be encountered in subsequent ports.

c- Booking of cargo offered according to the priority decision rules into the next empty space within the hold (spaces are scanned also in a prescribed order). The booking process is terminated at either one of the following three cases :

i- The hold is completely full, volumwise

ii- All cargo offered for booking in this hold is over.

iii- No container inventory is available for cargo originating at this port (i.e cargo other than transshipment cargo).

3. Loading

Once the booking process is completed, loading will then mean the transfer of cargo to their assigned spaces. Time and costs are incurred accordingly. It should be noted that loading overstowage might be encountered here also, inwhich case extra time and costs are incurred too.

In loading as well as unloading, the handling time is obtained by multiplication of tonnages by longshore-gang productivity rate for that type of cargo, a port parameter that is input to the model at the very beginning.

2.5 - OVERSTOWAGE & HOLD NUMBERING REQUIREMENTS

As previously mentioned, cargo within a hold are stowed in standard spaces. Containers are stowed in columns or stacks in their holds, in which case each container is considered to occupy a standard space.

Standard spaces within container and break bulk holds are assigned serial numbers such that each space in the hold has a unique identifying number. The numbering system used must be carefully chosen such that when a computer commences scanning of spaces from the lowest to the highest number, the spaces will retain the proper physical relationship to one another.

The appropriate physical relationship that is of prime importance in cargo arrangement, is the overstowage of cargo, that is which cargo is blocking access to other cargo. No overstowage is met with bulk cargo. With break bulk cargo, loading as well as unloading overstowage are possible, while with container holds only unloading overstowage is encountered.

In unloading a container hold, the computer starts its search from the bottom-most layer for cargo to be discharged in the current port and then proceeds with the above layer and so on. The search within each layer commences from the centermost space and moves outwards towards the bulk head as shown in fig.(.2). Whenever cargo within a certain space is to be discharged, the computer checks all the above containers in the same column or stack. All nonempty containers not destined to the current port as final or intermediate destination are considered as overstowed cargo and are labelled as such. The overstowed cargo must be removed before unloading the bottom container, thus increasing unloading time and cost.

The numbering system by which the above procedure is achieved in a container set-up is a modular numbering system. The number assigned to a standard space in a hold if added to a modulus will yield the code number of the container immediately above it. If the code number of the container in the second above layer and in the same column, is desired, the computer simply multiplies the modulus by two and adds it to the code number of the reference container. The modulus is equal to the number of spaces or containers in a single layer. This method is demonstrated in fig.(.3).

Likewise, in unloading a break bulk hold, the computer scans standard spaces within each deck (layer) successively, starting from the bottom-most deck. Within each deck, the scan of spaces commences with the centermost wing area space and proceeds towards the bulkheads until all the wing area spaces have been scanned. The scan then continues with the center-most hatch space, proceeding outwards towards the bulk head. If the first space sensed to be discharged in this port was a wing area space, then all nonempty hatch spaces of the same and subsequent decks not destined to the current port would be considered as overstowed spaces. If the first space sensed to be discharged happens to be a hatch area space, then all non-empty spaces in the subsequent decks will be considered as overstowed spaces.

From the aforementioned presentation, the unloading procedure and its numbering system applied for break bulk holds, is summarized in the following: The layers are called "decks". Each deck is composed of wing area and hatch area spaces (Fig. [illegible].2). The serial numbering of standard spaces in a hold is chosen such that it starts from the centermost wing area space and proceeds outwards towards the bulk heads. It is then continued with the centermost hatch area space of the same deck and proceeds outwards towards the bulk heads. This serial numbering commences from the first wing area space in the bottom-most deck, proceeds in accordance with the prespecified order, and terminates with the last hatch area space of the upper-most deck.

With break bulk holds, it is possible to encounter loading overstowage, while in container holds loading overstowage is not possible to take place. Loading overstowage in break bulk holds indicates that hatch area spaces are full with cargo blocking access to the first empty space in a bottom deck. This may happen in either one of two cases. The first case when a ship's hold has no cargo to be unloaded in the current port but meanwhile it has some empty spaces. In such case, the ship proceeds directly to the loading operation. The second case occurs wheneve the first empty space happens to be in a deck lower than the lowest deck whose hatch area spaces are considered as overstowed in the unloading operation. In computing loading overstowage statistics, the computer searchs in a prescribed "scanning discipline" for the first empty space. If this space is in a wing area, then the first layer whose hatch area spaces are considered as overstowed are those nonempty spaces of the same deck. If on the other hand, the first empty space is a hatch area space then the non-empty hatches of the next deck will be the beginning of overstowage spaces.

2.6 - PRIORITY DECISION RULES APPLIED FOR BOOKING

By considering the booking process at a certain port, three types of cargo may be offered : namely, originating, transshipment and rejected cargo. The originating cargo has the present port as an origin and is offered transportation service by the current ship. If a part of this cargo is left behind due to space limitations, then this part will be treated in subsequent events, at this port, as a rejected cargo. Transshipment cargo as specified before (.3) resides on berth waiting for further shipments to its final destination.

Having defined types of cargo waiting for shipment at a port, the applied priority decision rules for booking may be the following :

1. If the port is a supernode, priority is given to the transshiped cargo. At a node where no transshipped cargo exists, the rejected cargo is prior to the generated cargo.

2. For each of the above 3 cargo types, the "last-port-first" rule is applied i.e. cargo destined to further destinations are preferred to those destined to closer destinations. This rule evidently ensures a higher utilization factor, besides it will minimize stevedoring and cargo handling operations at the ports. To follow this rule, a booking list is prepared from the ship's itinerary after the elimination of ports' duplication on the list. It should be noted here that transshipped cargoes for all port on the booking list are booked first before any rejected and/or generated cargoes are considered. For every port on the list, booking for the rejected and generated cargoes is then considered.

3. For each transshipped and rejected type, the cargo having the longest waiting time is prefered.

4. In addition to the above rules, rejected and generated cargoes are booked item by item according to the prepared commodity list of that port. Obviously, the order in the commodity list follows what is called "commodity priority discipline".

2.7 - BOOKING DISCIPLINE OF STANDARD SPACES

Upon booking a space with a particular amount of cargo as well as upon the rearrangement of a cargo in spaces marked as overstowed during unloading, there will be a search for the next empty space to perform this operation. This search is performed in a prespecified discipline that will facilitate the cargo handling operations and resemble what is normally adopted in practice.

For a container hold, the search seeks for the centermost empty stack within the hold under consideration. If such a stack exists, then booking or rearrangement will take place in its spaces commencing from the lowest space and moving upwards. When the stack spaces are over, the next empty stack is searched for and so on. In case there is no empty stacks, then the search will be for the first empty space in the centermost stack. It should be pointed-out here that the numbering system adopted for spaces within container holds facilitates such scanning procedure.

For a break bulk hold the devised discipline will be such that the search for an empty space will start from the centermost wing area space of the bottom deck and proceeds outwards toward the bulk heads. When all wing area spaces are scanned, wing spaces of the deck immediately above will be scanned in the same manner. This will continue until all wing areas of the different decks are over. Scan then continues with the centermost hatch area space of the successive decks commencing from the bottom deck and proceeding upwards.

2.8 - PREPARATION OF THE BOOKING LIST

Each ship in the system is got an itinerary in the form of an array input to the model. The ship's itinerary is an ordered list of the numbers of the ports called according to the visiting order beginning with the home port and ending with the last port to be visited before returning to the home port.

There are two types of itineraries, which can be illustrated by the following two examples, (Fig.8.4):-

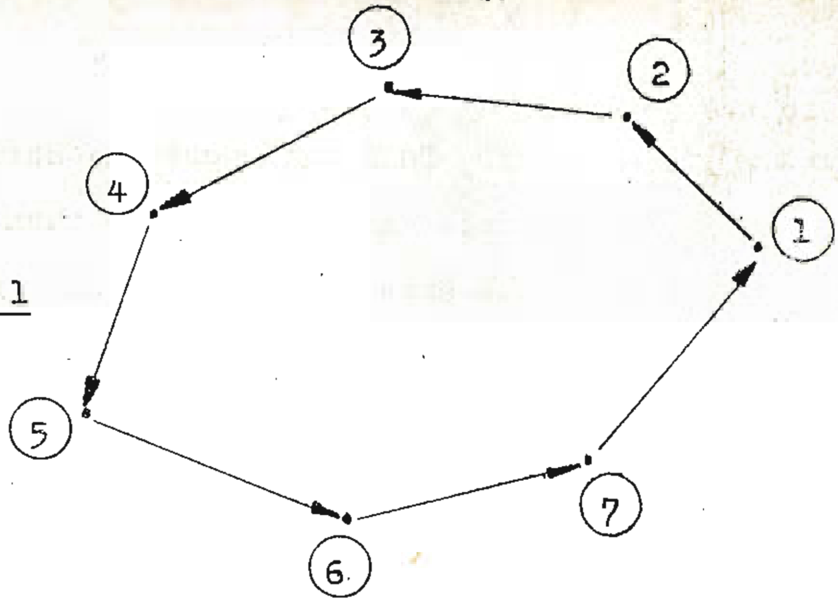
example 1 : 2 - 3 - 4 - 5 - 6 - 7 - 1

example 2 : 2 - 3 - 4 - 5 - 4 - 3 - 1

where port 2 is the home port.

In example (1), the itinerary is characterized by the fact that all ports in the list are different. The ship starts out from port 2, and visits each other port once before returning to its home port. The second type of itineraries is characterized by having at least one port in the list appearing twice. Thus in example 2, two ports (no. 3 & 4) are visited twice before the voyage is completed.

EXAMPLE 1



EXAMPLE 2

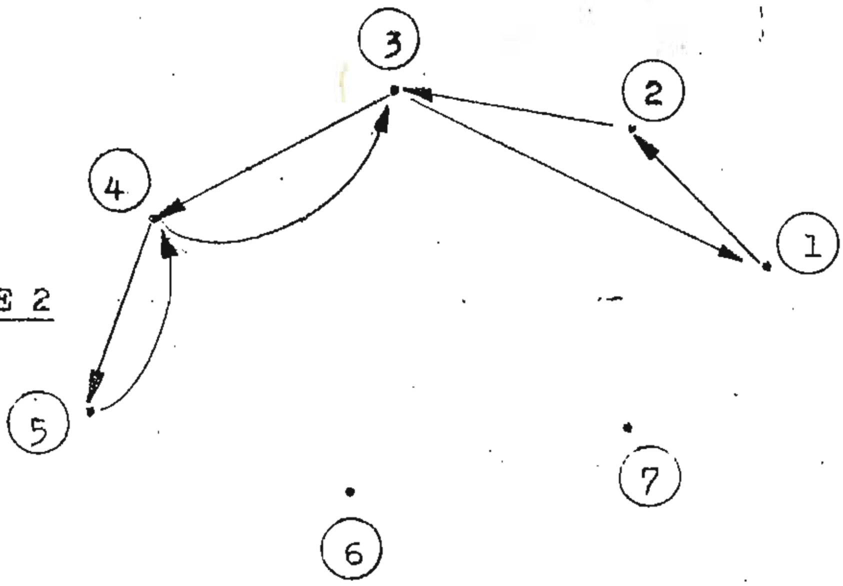


Figure 2-4 : Types of Itineraries

Cargo is booked at any port according to "the last-port-first" basis. Whenever a ship calls on a certain port, a booking list is prepared from the ships itinerary according to this priority rule i.e starting from the last port in the voyage, the home port, and proceeding backwards till the next port visited after the current port. As an illustration by example 1, if the current port is port 3, the booking list will be :

2 - 1 - 7 - 6 - 5 - 4

In the case of example 2 (and the current port is no. 3), the booking list is more difficult to prepare because of the duplication of ports. Thus by following the previous rule, the list would be :

2 - 1 - 3 - 4 - 5 - 4

indicating that port 4 is to be called on twice and the cargo at the present port (no. 3) destined for port 4 (the second one) may be booked but will not be discharged in the first time the ship calls on port 4. Such situation is corrected by eliminating duplication through removing the first item of every duplicated port. In our case the booking list becomes :

2 - 1 - 3 - 5 - 4

2.9 PARALLEL PROCESSING OF HOLDS

The estimation of cargo handling times of an individual hold is carried-out each time the hold is loaded or unloaded. Handled tonnage and longshoregang productivity rate at the port concerned is used for this purpose. The estimate takes into account any overstowage statistics. Thus eventually statistics for processing times of each hold will be available. The model allows for the possibility of processing more than one hold in parallel. The number of holds that could be worked in parallel is a port parameter depending on the equipments and cargo handling installations of the particular port. Cargo handling is performed by longshoregang hired by the ship's agency bureau at that port upon its arrival.

If the port's equipments are such that only one hold could be handled at a time, then the ship's processing time will be a straightforward summation of the respective times of its individual holds. On the other hand, the ship's processing time is much reduced when more than one hold are processed in parallel. The number of holds that could be worked simultaneously depends upon the number of cargo handling channels available for processing one ship at the respective port.
It is to be stated that the number of channels actually employed

(and consequently the number of gangs), may not necessarily equal the maximum number available at this port.

It is self-evident that both the port authorities and ship owners are interested in minimizing the ship's processing time. The decision of applying a new channel is not taken unless this extra channel will introduce an assured reduction in the total processing time. This is illustrated through the following example :

Given a 3 hold ship with individual processing times of 150, 110, 30 time units say hours respectively. If the assumption is made that no more than one channel could be applied in the same time to the same hold, then one channel will be engaged with the first hold for 150 hours. If the same channel is applied to the second hold, its engagement time, and consequently the ship processing time will be increased by 110 hours. For this reason, it is obvious that a second channel should be applied to the second hold. Meanwhile a 3rd. channel, when available, if applied to the third hold will not introduce any reduction in the ship processing time, on the contrary this will increase the number of employed longshoregangs and accordingly their cost. The second channel, with the same gang could be applied to the 2nd. and 3rd. holds in series. The channel will work in parallel with the first one and the ship processing time will be kept at 150 hours.

Related to the number of channels used is the number of hired stevedoring gangs. The number of channels actually used equals the number of gangs employed since no more than one gang could use the same channel simultaneously. Any increase in the number of gangs employed will introduce undue increase in their standby-cost, if applicable, during the interval between the commencement of their shift and the actual start of the ship processing. It is assumed in the model that the saving introduced by shortening the ship's processing time by using an extra channel is in general more than the standby-costs incurred by employing an extra gang for such channel. Accordingly, minimizing the processing time will assume top priority regardless its impact on standby-cost i.e even if the standby-cost were less than the cost of employing the extra gang.

2.10 - ALLOWANCES FOR DELAY, BREAK HOURS AND STANDBY-COST

The arrival of a ship at a port is referred to as an event. A new event time of a certain ship at a given port indicates her arrival outside the harbor before seizing a free berth. Until then, the ship will undergo queing delay. The total time spent at this port is the sum of both the queing delay and the total ship processing time.

Queing delay time is a stochastic variable that is to be generated by the computer using Monte Carlo methods [51]. The distribution assumed here is a uniform distribution, the variable value ranges between zero and twice the average queing time which is an input parameter for that port. However, other distributions could be used in the model with minor modifications.

On the other hand, the ship processing time, as obtained in the previous section, must be normalized to allow for any enlargement due to break hours between shifts of longshoremen gangs. The shift practice, in this model, is assumed to be of two shifts extending between 8 and 18 O'clock and between 20 and 6 O'clock with two breaks, 2 hours each. Differences due to local times at each port are ignored. The time ellapsed between the commencement of a shift and the actual arrival of a ship on berth is a standby-time for longshore gangs. The standby-cost must be allowed for by the model. At some ports such cost item might not be applicable. However, the model allows for its optional applicability at each port. Details of computations of break hours and standby-costs are given latter in the description of SUBROUTINE SUMMARY in the next chapter.

2.11 - TRANSPORTATION DEMAND

Demand is defined in the model as those tonnages of cargo at a given port seeking transportation service by the system ships, classified both on a commodity and destination basis. The model structure permits the movement of cargo between any two ports. Nevertheless, it allows more easily the study of the movement of foreign trade of a certain country via one or two national ports to other system ports and vice versa. This is a typical case of the Egyptian trade.

The subject of demand involves a great deal of details and relevant factors that have to be set to a comprehensive study before using the model. Factors such as, persistence of demand, seasonal variations, commodity classification, type and parameters of demand functions to be used ....etc are examples of the issues involved under this subject. The number of factors, could however be reduced to two major ones, namely the commodity items offered for transportation and their tonnages. The treatment of each of the two factors in the presented model is explained in the following, keeping in mind that the approaches used are chosen to give much flexibility to the model user.

In connection with the first factor, the model devices a certain entity referred to as the commodity list. Each port in the system maintains a certain set of commodities which are represented in such a list with their respective code numbers. Commodity items in this list are grouped into 3 main groups according to the following order :

- container commodities group.
- break bulk commodities group.
- bulk commodities group.

The three main groups as well as individual items within each of these groups are arranged according to their booking priority. Since it is a common practice in the maritime industry to specify freight rates on both volume and weight considerations, it is suggested to use stowage factors (i.e density) as an index for this arrangement. The maximum number of items in a commodity list of a given port is decided by the computer storage limitations and is specified for a given port by an input parameter for this port.

In connection with the second factor, the tonnages of each of the items on the commodity list of a given port are classified according to their destination. Cargo tonnage for each commodity-destination combination could be treated as either stochastic or deterministic. In the latter case it might be assumed as either fixed or variable with time while in the former case, a probability density function is used to generate the required tonnages by means of Monte Carlo technique.

Any distribution could be assumed. The model allows for inputting two parameters for the distribution of each commodity-destination combination. In the current representation, a uniform distribution is assumed. This should not hide the fact that any other distribution could be easily used.

The importance of carrying-out studies about the demand function is once more emphasized here since the assumptions underlying its shape and parameters will decide the degree of realism in the model and the quality of the decisions drawn from the results.

CHAPTER 3

DEVELOPMENT OF THE COMPUTER PROGRAM

3.1 - INTRODUCTION

In the course of developing a computer program for the system described, the inherent consideration has been to achieve a great deal of modularity (64). This objective is realized to a great extent by means of program segmentation into various subroutines and seeking modularity within individual subroutines too. This is believed a prerequisite to the important requirement of flexibility for generalised simulation models of this type. Use of subroutines helps in reducing the complexity of programs. As the program increases in size, the increase in its complexity is exponential rather than linear. Another advantage of using subroutines is the reduction in testing, debugging and maintenance time. Testing and debugging can be done as soon as each subroutine becomes ready and in the case of maintenance work, changes need to be made only to the subroutines involved (64).

The main concern in this chapter is to present a general discussion about the prerequisite elements of developing a computer program, while the specific details of the simulation model are the subject matter of chapter 10.

5.2 - PROGRAMMING LANGUAGE

One of the most controversial subjects in simulation modeling is to decide upon the programming language to be used. A wide variety of simulation languages are now available which are developed for the purpose of facilitating programming tasks. This is usually against some sacrifice with the running speed. A detailed account of simulation languages is available (11). The confusion as to the most appropriate language for a certain user is most likely resolved by the intensity with which simulation is being pursued (114). For occasional use, a simple language, which is easy to understand and learn, may be more valuable than one of the sophisticated languages which have many facilities, but by the nature of these facilities, become much more complicated to use and understand.

In this model, the language question has been decided according to the available machine at the Institute of National planning which is an IBM 1620 machine with limited storage and peripherals possibility for model of this type. However, the machine was intensively used for testing individual subroutines. For this reasons FORTRAN was chosen as a programming language for the model.

The program was later integrated, modified and tested on the Cairo University ICL 1905 E machine. The final form of the program is now in accordance with the 1900 series "Extended FORTRAN" manual (Edition 1, TP4269).

3.3 - LEGEND

Variables and symbols used in subsequent sections are given in Appendix (D), legend. It has a complete account of all variables, symbols used in the developed program. It gives description of these symbols used in the respective subroutines where they first appear. It gives also indication of other subroutines where these items may later be used or referred to. Subroutines are arranged in this appendix according to their logical calling order. This scheme will help in developing the common blocks of the program.

3.4 - TIME ADVANCE AND GENERAL FUNCTIONNING OF THE MODEL

As mentioned before, the arrival of a ship in a port is referred to as an "event". Each ship in the system has an initial event time, indicating the beginning of port activities at the first (home) port on the ship's itinerary. The initial event times of all the ships in the system are listed in an event array CRTM(I) where CRTM(I) is the next event time of ship I. The earliest event time is compared with the simulation clock time. If the event time is greater than the clock time, the clock continues to increment the time in one day intervals until the earliest event time is equal to or less than the clock time. When this occurs, the ship begins a series of port activities which include, queuing delay, cargo generation, derivation of booking list and port processing. This latter aspect is subdivided into unloading, booking and loading patterns. Whenever the port processing is over, any necessary modifications in cargo or ship status are made by updating two direct access disc files established at the outset of the simulation to keep track with cargo and ships throughout the system. An event summary is also derived and the time spent by ship at the port is worked out.

The ship is then assigned a new event time which is placed in the event array CRTM(I). The new event time is derived as the sum of the sailing time to the next port plus the time spent at port. The port time in turn is computed as the sum of the queuing delay and the port processing time. The port processing time is affected by shift practice of longshoregangs and their break hours.

The sailing time to the next port is computed by multiplying the ship's nominal speed into the interport distance which is input to the system. A provision is made for variations in the navigational speed between ports from the nominal speed due to inland water ways or other geographical constraints. This provision is satisfied by means of a speed reduction factor input to the system into which the nominal speed is multiplied to obtain the actual sailing speed to the next port.

When an event is completed, control will return to the event times array CRTM(I) in order to select the earliest event time and a new event takes place, and so on.

The simulation system contains a clock which in this model, ticks off successive days. Simulation time units could be altered to be days, hrs , ...etc. according to the particular use of the model. The clock ticks successive days starting from day one. Each day will cover a period of 24 hrs. All port processing operations and delays are computed in hour units and its fractions.

At equal time intervals to be specified by the user, the cargo build-up situation at the various ports of the system and their container inventory are displayed by the computer to help in studying any bottle necks or inventory management.

An event summary at the end of every event is displayed too. It is possible to output this summary on any appropriate peripheral such as paper or magnetic tape to be used later as an input to a post processor developing a managerial report to be designed at the user's discretion.

3.5 - SYSTEM IMMAGE

The main style adopted in developing this model follows an appropriate method suggested for digital simulation models [41]. The method depends on developing an immage of the system. It entails two steps. The first is the layout of the various subroutines and their calling order, and the second is the definition of the entities and attributes of the system in the form of a set of variables and arrays (Figures .1 to .11).

3.6 - SUBROUTINES LAY-OUT

The model is made up of a master executive program and a collection of 15 subroutines, the main function of each is indicated in the following :

1. MASTER : It is the executive main program. It initializes the system, chooses the ship and port for the next event, calls subroutine HARBOR to start port activities and processing. After processing it assigns a new event time to the ship and repeats the same procedure till the end of simulation.

2. HARBOR : It performs the operations preliminary to port processing, such as cargo generation, preparation of booking list, ...etc.

3. PROCESS : It offers ships'holds one after the other for port processing and calls the appropriate subroutines for this purpose.

4. CONULG : It unloads a container hold.
5. BBKULG : It unloads a break bulk hold
6. BLKULG : It unloads a bulk hold
7. CONBKG : It books a container hold
8. BBKBKG : It books a break bulk hold
9. BLBKLG : It books and loads a bulk hold
10. CONLDG : It loads a container hold
11. BBKLDG : It loads a break bulk hold
12. DFILE : It updates ships and ports data on disc files
13. TIME : It computes ship's processing time
14. SUMMARY : It computes port time and outputs summary
15. CARGO : It outputs cargo build-up situation at system ports.
16. R.N. GENERATOR : It provides a uniformly distributed random number. This is available in the software of the machine used.

Fig. (3.12) illustrates the general lay-out and calling order of the different subroutines. Subroutines description are given in more details in later sections.

3.7 - SYSTEM ENTITIES AND ATTRIBUTES

These are best exhibited by Figs. 9.1 to 9.11. Each entity together with its attributes are represented in a boldface box. Information regarding description, size and initialization subroutine are also given in these figures.

3.8 - INPUT, OUTPUT AND PERIPHERALS

The input to the model is classified into the following main categories of data and parameters. The word "parameters" is used here to identify those items which remain unaltered and fixed through a simulation run.

3.8.1 - System parameters :

Number and array of system ships.
Number and array of regular ships.
Number and array of express ships.
Number and array of system ports.
Number and array of supernodes.
Number and array of nodes.
Matrix of interports distances and speed reduction factor.
Duration of simulation run.
Duration between two successive calls of subroutine CARGO.
Date and number of current simulation run.
Initial container inventory at various system ports.
A set of switches to print-out or not print-out detailed information of unloading, loading, and booking patterns.

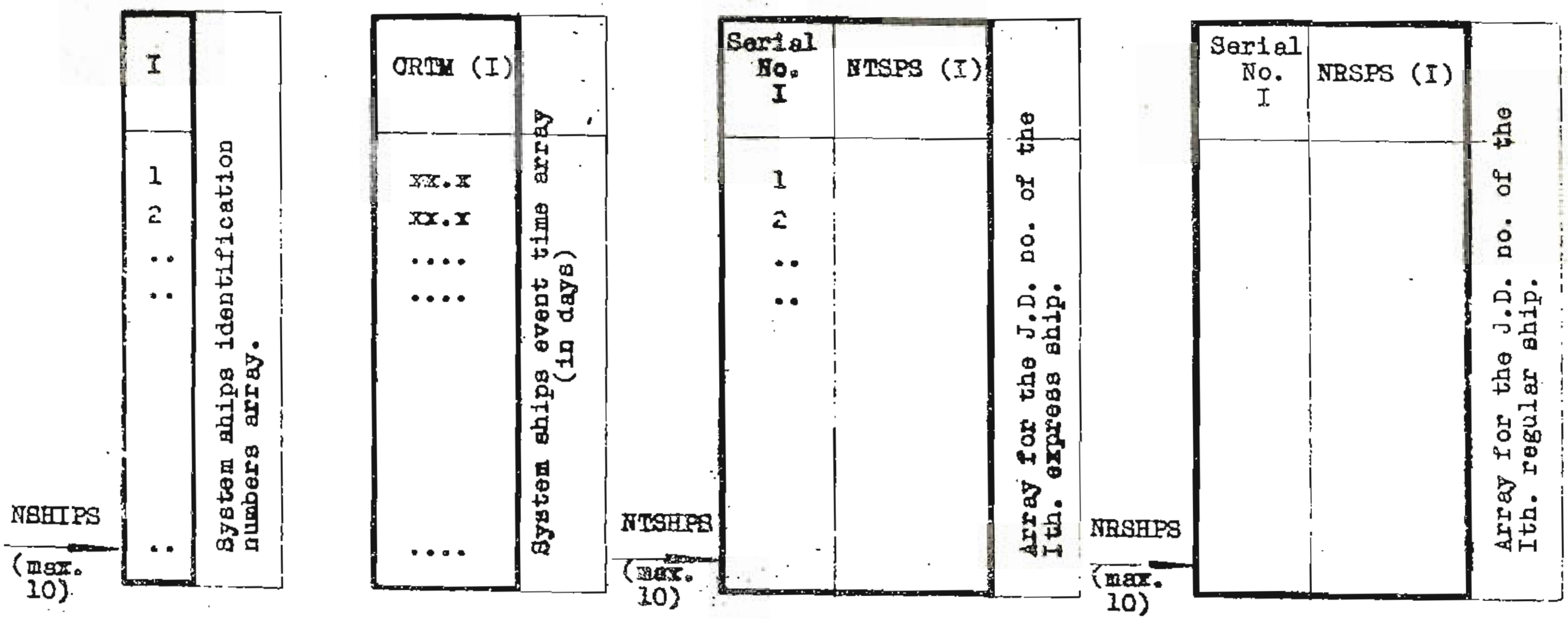


Figure 3-1 : System Entities that Remains throughout the Simulation.

Serial No. (I)	NRSP(I)
1	xx
2	xx
..	
..	..

Array for the J.D. no. of the Ith. node

NRP (13 max.) → last row

Serial No. (I)	NTSP(I)
1	xx
2	xx

I.D. no. of the Ith. S.node

NTP (2 max.) → last row

Figure 3-1 : System Entities that Remains throughout the simulation, cont'd.

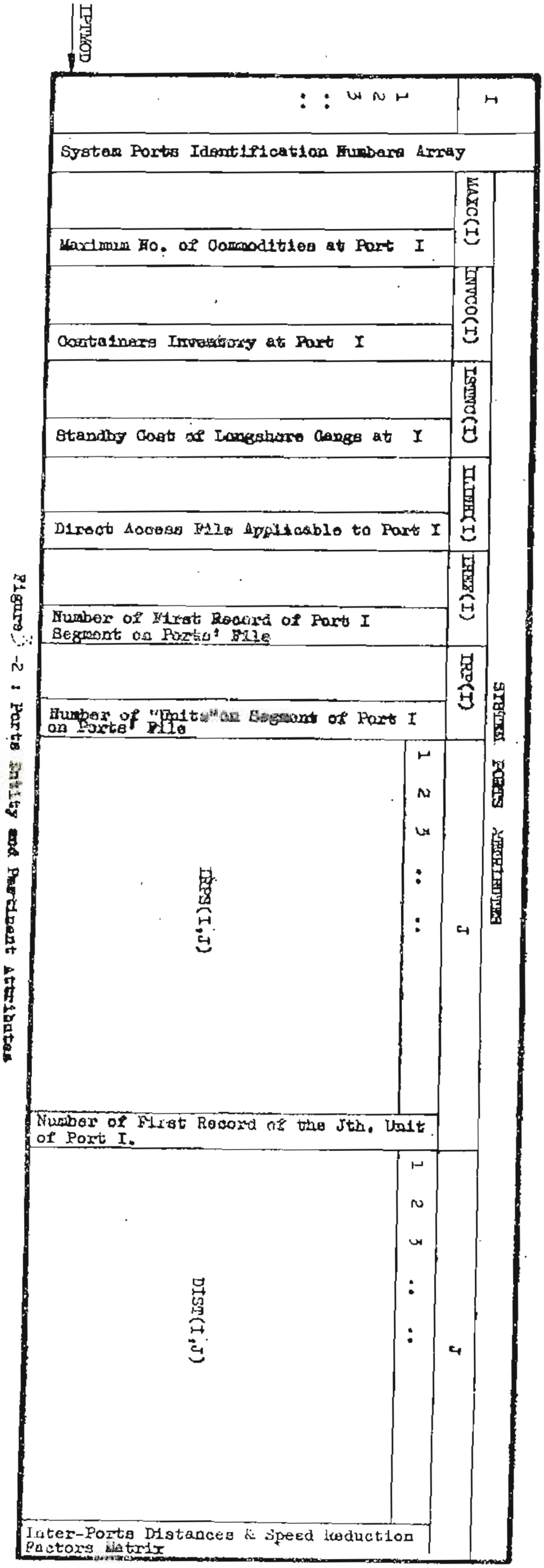


Figure 2-2 : Ports Entity and Pertinent Attributes

ITHOLD

I	1 2 : : :
Serial No. of Holds of current ship.	

Ship Holds Attributes

ITYPE (I)	Type of hold I, 1=cont., 2=b.bulk, 3=bulk
IHOLD (I)	No. of standard spaces of hold I
MODULO (I)	No. of standard spaces per deck or layer
IHMOD (I)	For b.bulk holds, the no. of hatch spaces per deck
ISW (I)	The no. of decks of hold (I)
CUBIC (I)	Bale cubic of hold I, cubic ft.
DWTH (I)	Deadweight capacity of hold (I)

IMAGE OF HOLDS OF SHIP UNDERGOING PROCESSING

NPTS (max. 15)

Ser. No. (I)	1 2 : :
IROUTE (I)	:

ITINERARY OF SHIP UNDERGOING PROCESSING

Figure 3-3 : Entities and Attributes Pertinent to the Ship Under Processing.

Comm. Code I	Commodity List of Current Port	Commodity List Attributes											
		ADEN (I)	Stowage factor of comm. I	Destination J: 1 2 3 .. IPTMOD (15 max)	Freight rate per long ton of comm. I, dest. J	Destination J: 1 2 3 .. IPTMOD (15 max)	1st. transsh. port of comm. I, dest. J	Destination J: 1 2 3 .. IPTMOD (15 max)	2nd. transsh. port of comm. I, dest. J	Destination J: 1 2 3 .. IPTMOD (15 max)	1st. param. of cargo tonn. distr.	Destination J: 1 2 3 .. IPTMOD (15 max)	2nd. param. of cargo tonn. distr.
				FRATE (I,J)		IPTA (I,J)		IPTB (I,J)		TCL (I,J)		TOGEN (I,J)	

Figure 3-4 : Commodity List Entity and its Attributes at the current port.

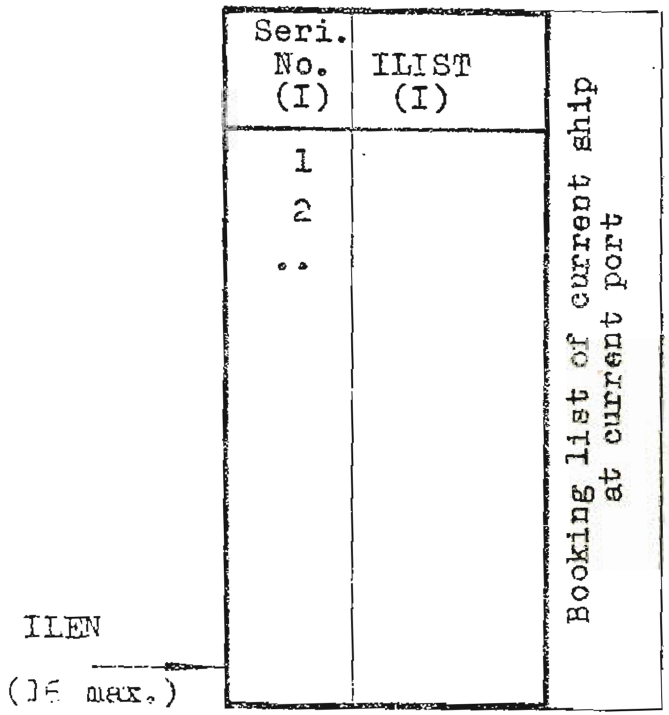
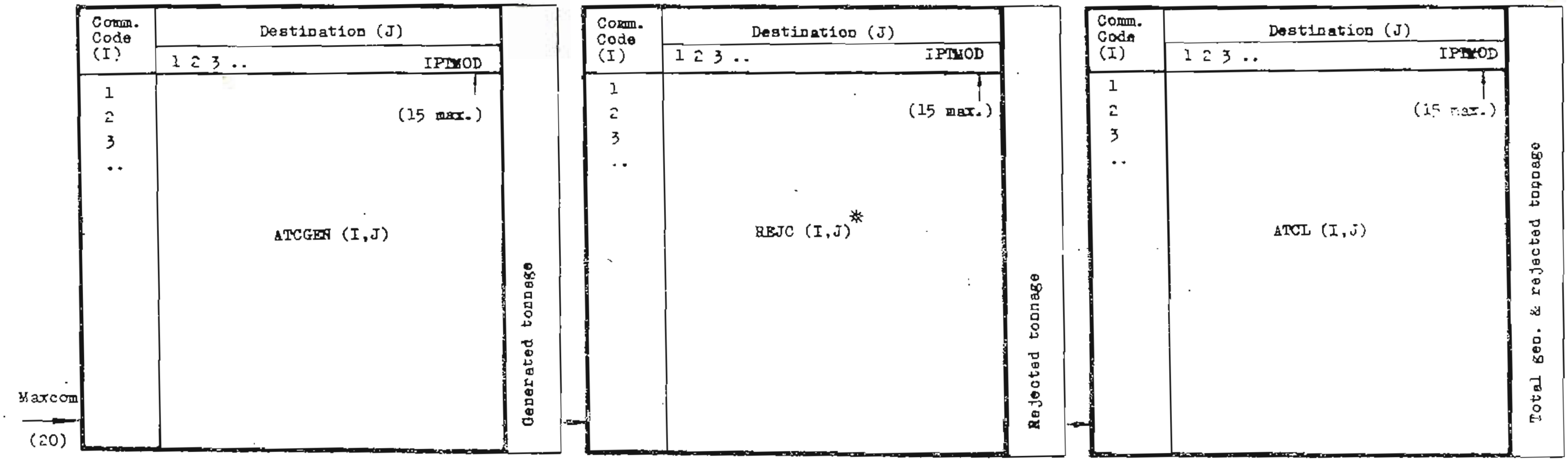


Figure -5 : Booking list Entity at the Current Port



* Read from ports' d.a. file

Figure 3-6 : Cargo Tables at the Current Port

THOLD (ID)

Hold Standard Spaces Attributes

(I)	Identification no. of hold standard spaces
VOL (I)	For cont. holds only; volume of empty portion of space (I)
DEN (I)	For bulk & b.bulk holds only; stowage (density) of contents of space (I)
ICOMM (I)	For bulk & b.bulk holds only; comm. code of contents of space (I)
STOW (I)	Tonnage of contents of space (I)
ORGT (I)	Origin time of contents of space (I)
IORG (I)	Origin port of contents of space (I)
IDESTA (I)	First intermediate dest. port of contents of space (I)
IDESTB (I)	Second intermediate dest. port of contents of space (I)
IDEST (I)	Final destination port of contents of space (I)
IOSTOF (I)	Switch indicating whether contents of (I) overstowed or not.

Figure 7-7 : System entity; standard spaces of Hold currently under processing and its attributes.

NCGP (max.250)

Transshipped Unloaded Containers Attributes

(I)	Serial no. of unloaded transshipped conts.
DVOL (I)	Volume of empty portion of the I th. transsh. unloaded cont.
DSTOW (I)	Tonnage of the Ith. transshipped unloaded cont.
DORGT (I)	Origin time of the Ith. transshipped unloaded cont.
MORG (I)	Origin port of the Ith. transshipped unloaded cont.
MDESTA (I)	First int. dest. port of the Ith. transshipped unloaded cont.
MDESTB (I)	Second int. dest. port of the Ith. transshipped unloaded cont.
MDEST (I)	Final dest. of the Ith. transshipped unloaded cont.

Figure 3-8 : system entity: unloaded transshipped containers and their attributes.

NBGP (50 max)

I	Serial No. of unloaded transshipped b.bulk groups
TDEN (I)	Stowage factor (density) of group I
KCOMM (I)	Comm. code no. of group 1
TSTOT (I)	Tonnage of group I
TORGT (I)	Origin time of group I
KORG (I)	Origin port of group I
KDESTA (I)	1st. interm. destination port of group I
KDESTB (I)	2nd. intermediate destination port of group I
KDEST (I)	Final destination port of group I

Attributes of Transshipped Unloaded B.Bulk Groups

Figure 7-9 : System Entity; Unloaded Transshipped B.Bulk Groups and their Attributes

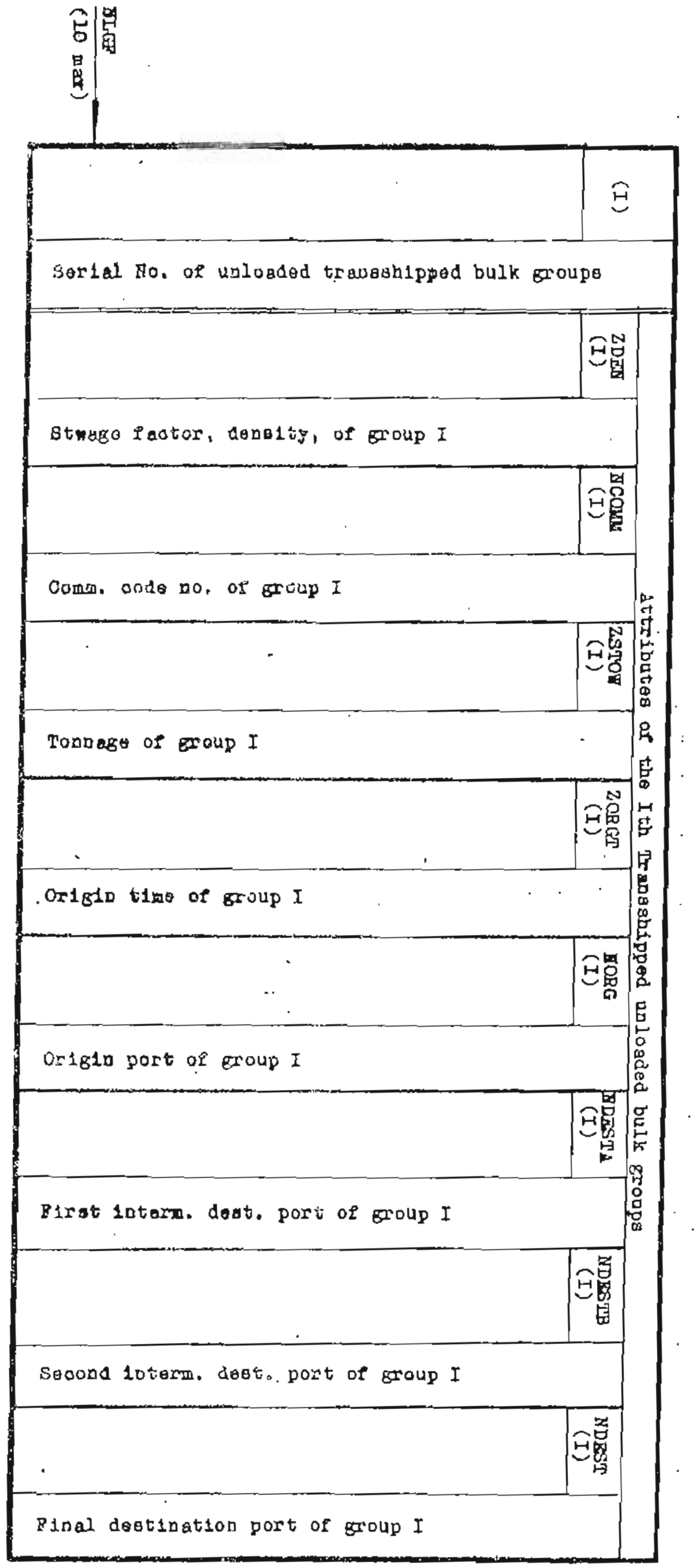


Figure 3-10 : System Entity : unloaded transshipped bulk groups and their attributes

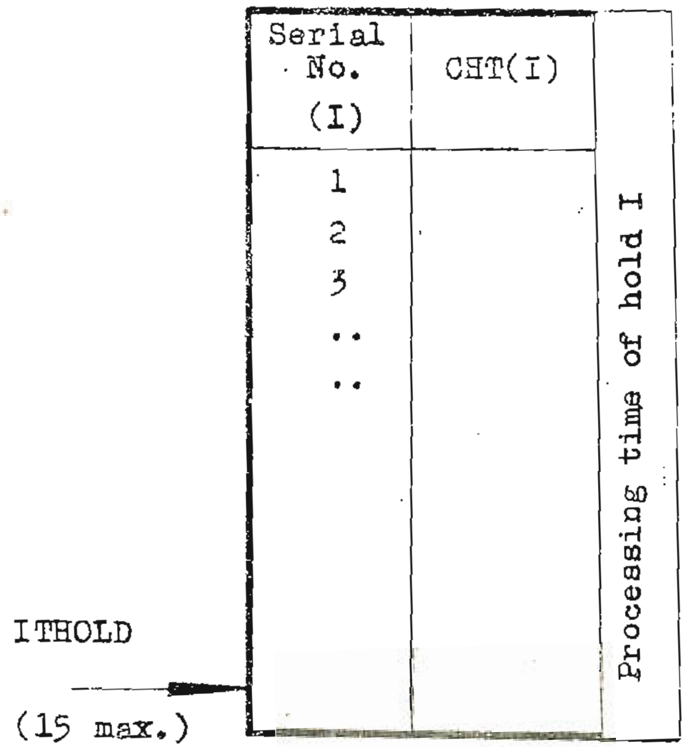


Figure 3-11 : System Entity ; Processing Time of the Holds of the Current Ship.

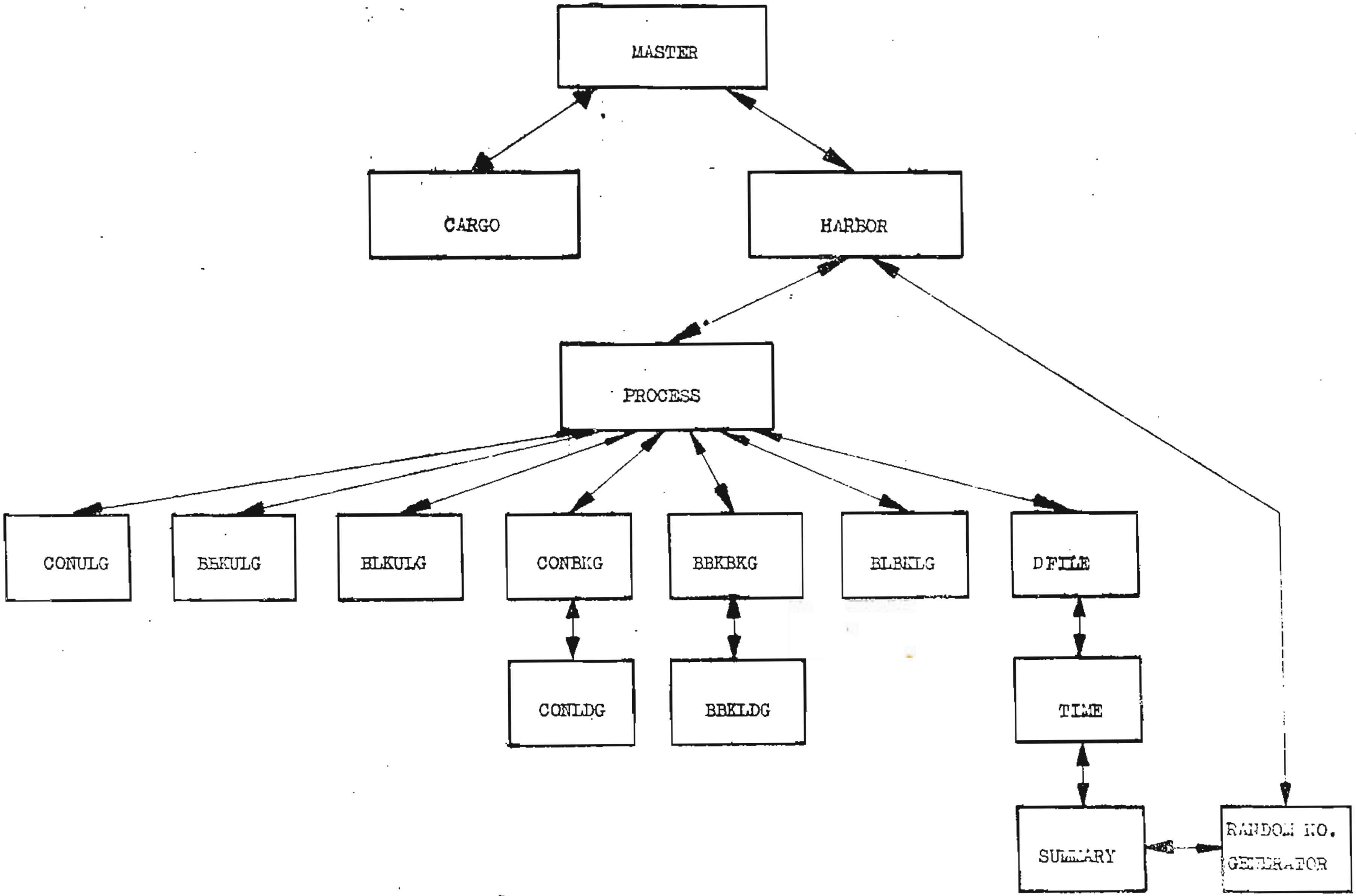


Figure 5-12 : Subroutines calling order

An input array for initial layout of port's disc file.
An array of switches indicating whether standby costs are applicable or not at the various ports of the system.

2.8.2 - Ships Parameters

For every ship in the system:

Ship's name.
Deadweight tonnage.
Speed.
Initial time of starting its journey at home port.
Number of holds.
Number of container holds.
Number of break bulk holds.
Number of bulk holds.

And for every hold with this particular ship:

Hold type.
Number of standard spaces.
Number of standard spaces per deck.
Number of hatch area spaces (for break bulk holds only).
Number of decks.
Hold deadweight capacity.
Hold cubic capacity.

2.8.3 - Ports Parameters

For every port in the system:

Port name.
Port number.
Maximum number of items on the commodity list

Number of holds that could be processed in parallel.
Average queuing time outside the port.
Longshoregang rate.
Longshoregang stevedoring rate for container cargo.
Longshoregang stevedoring rate for break bulk cargo.
Longshoregang stevedoring rate for bulk cargo.
Any wharfage or cost items at this port.
Number and code of all commodity items destined. from this port to every other port in the system.

And for every commodity-destination combination:
Freight rate per nautical mile.
First transloading port.
Second transloading port.
Parameters of tonnage frequency distribution curve.
Stowage factor array for all items on commodity list.
Termination points for the three main cargo classes on the commodity list.

3.8.4 - Ships Data

For every standard space within a ship's hold:
Tonnage of cargo contents.
Commodity code.
Stowage factor.
Origin port.
Destination port.
First transloading point.
Second transloading point.
Origin time.
Volume of empty portion (for container spaces only).

3.8.5 - Ports Data

For every cargo group on a given port and for each main cargo class within a group :

Tonnage of cargo contents.
Commodity code.
Origin port.
Destination port.
First transloading port.
Second transloading port.
Origin time.
Tonnage of rejected cargo within each group by commodity-destination.

3.8.6 - Peripherals

All previous data and parameters are held on 4 input/output peripherals as follows :

Channel 1 : A card reader for:
System parameters
Ships parameters
Ports parameters

Channel 2 : A magnetic tape for:
Ports parameters

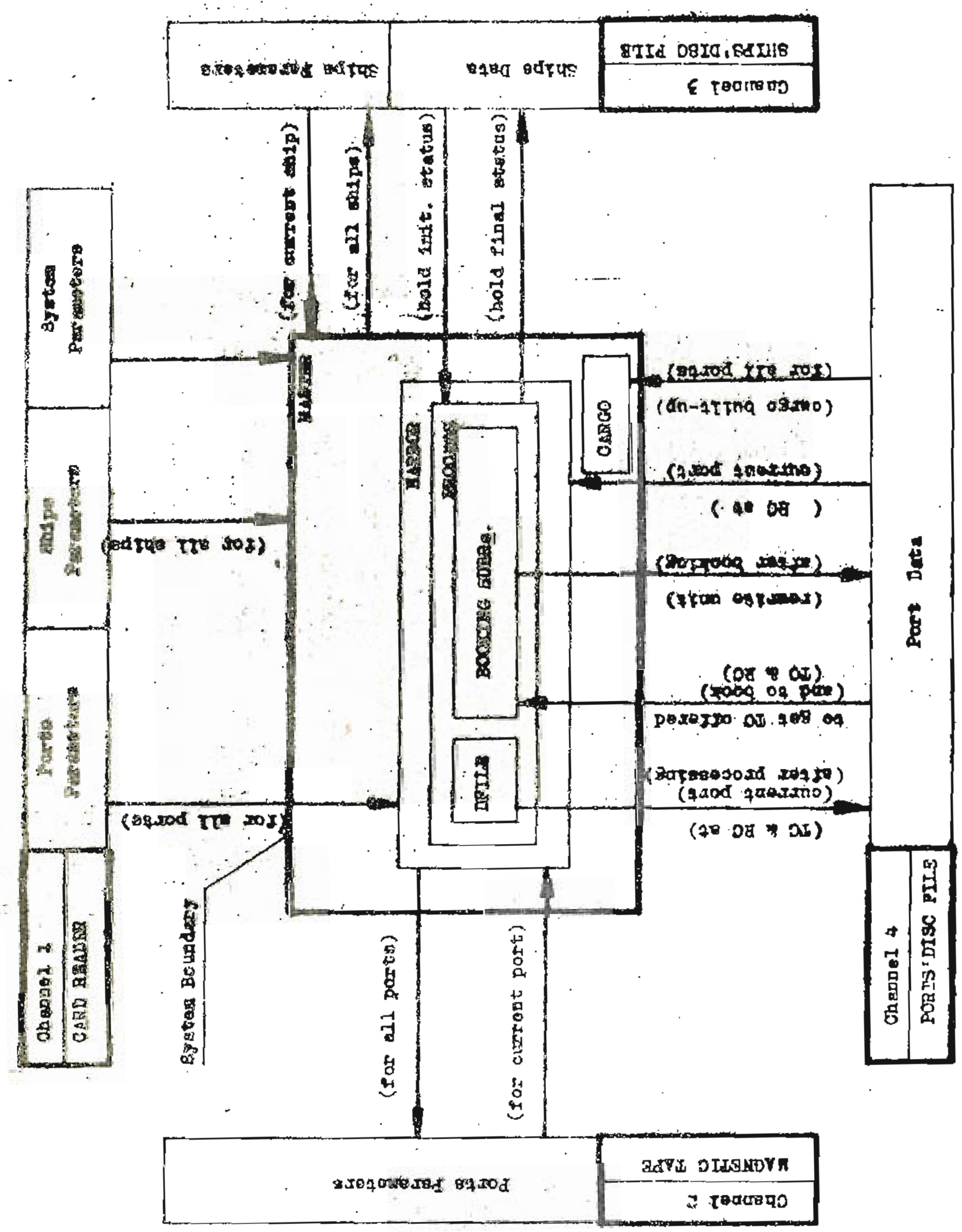
Channel 3 : Ships direct access disc file for:
Ships parameters
Ships data

Channel 4 : Ports direct access disc file for:
Ports data

3.8.7 - Input/Output Details

Fig. (3-13) is a schematic illustration of all input/output operations from the previous peripherals to/from the system. Excluded from this figure is the line printer whose output will be dealt with separately. The system boundary is represented by a heavy type box as shown in the figure with the different subroutines represented by smaller internal boxes. Only those subroutines involved in an input/output operation are shown. The convention is made in the figure that each subroutine is represented by a smaller box within that box of the calling subroutine. The four named peripherals are shown around the system with the type of data or parameters held on each channel indicated. Input/output operations are represented by means of arrows between the system and the peripheral used. Furthermore, the arrows extend beyond the system boundary to point-out the particular subroutine within which this input/output operation is carried-out.

In the MASTER program, the card deck contains three categories of input parameters : system, ships and ports parameters. System parameters are read into core where they remain throughout the simulation. Ship parameters for all ships in the system are input to be subsequently output on the ships disc file. When MASTER selects the ship with the earliest event time for the next simulation event, those parameters of this ship are



TC = transshipment cargo
RC = rejected cargo

Figure 3-13 : Schematic Representation of Input/Output Operations reinput into core from the ships file. Port parameters cards are read into subroutine HARBOR. A magnetic tape file for all ports parameters is established once in this subroutine. Current port's parameters are then read into core from this tape file.

Whenever a ship arrives at a certain port in subroutine HARBOR, all rejected cargo at this port from previous events at different times which reside as part of port data on the ports' file are input to core and accumulated in the REJC (I,J) & ATCL (I,J) tables. Subsequent dealing with rejected cargo during port processing is to be through these tables. Any necessary modifications in this cargo while booking is carried-out in the booking subroutines.

At the commencement of port processing, subroutine PROCESS offers the ships hold, one by one for such processing. The initial status of cargo tonnages and attributes in the different standard spaces of the hold under processing are read into core from the ship's file. Upon termination of a hold processing and in subroutine PROCESS also, the final status of hold spaces are output to the file.

As mentioned before, port data is made up of such data concerning tonnages and attributes of transshipped and rejected cargo at that port. The data is grouped into different units with each unit having those cargo rejected or unloaded at the same time. Units are designed and reside on the ports file in that way as will be explained in file organization.

In the booking subroutines, the units are referred to and read into core twice, the first time to compute the tonnage offered for the current ship and the second to book cargo in the hold vaccant spaces. Booking of any rejected cargo causes an immediate updating of involved units on the file. At the end of booking transshipped cargo the unit involved is rewritten with its final status on the port's file.

Port's file is referred to later after processing the whole ship to rearrange the different units of the segment of that file belonging to the current port. The file is referred to again in subroutine CARGO where cargo build-up at the various ports is read into core before being displayed on the line printer.

On the other side, model output is viewed as composed of two main categories. The first is a summary of every event which is output in subroutine SUMMARY on a tape, preferably paper, to be used as an input to a post processor to be designed at the user's discretion as a managerial report or as events resumé for any further statistical analysis or study. The other is a paper print out throughout the simulation that includes the following :

1. A notice at the arrival of a ship to a port including, name of ship and port, time of event, information and parameters of the port.
2. Each time cargo is generated, it is listed by tonnage and other relevant attributes.
3. Upon unloading cargo at its final destination, space number, origin, destination, transloading ports and transportation time are printed-out. Also printed-out are the total hold unloading time, unloading cost and number of overstowed spaces.
4. Upon booking a certain space, its number, origin, destination, transloading ports and origin time are pointed-out.
5. Upon loading a certain hold, a hold manifest giving attributes of all hold spaces is printed-out together with loading time and cost and the number of overstowed spaces.
6. After processing the last hold of a given type, the rejected portion of the generated cargo tonnage of that type is printed-out.
7. Upon the termination of processing all holds, the total handling times for each hold are printed, along with the portion of the cargo generated for the ship that has already been loaded aboard. This is classified into commodity, tonnage, and destination.
8. When the ship leaves a port, the event summary includes :

   - Total revenue by commodity
   - Tonnage utilization percentage to next port
   - Volume utilization percentage to next port
   - Total cargo handling time

- Queuing time for available berth
- Total overstowed containers
- Total overstowed break bulk tonnage
- Total cost of overstowage
- Total port time
- Total cargo handling cost
- Total earnings
- Opportunity loss of rejected cargo

9. At the user's option at equal time intervals specified by him, cargo build-up situation at the different ports is displayed showing for a supernode :
   - Tonnage of transshipped container cargo
   - Tonnage of transshipped break bulk cargo
   - Tonnage of transshipped bulk cargo
   - No. of containers
   - Tonnage of rejected cargo
   - Container inventory

   For a nodal port, transshipment cargo is excluded.

3.9 - DIRECT ACCESS FILES

The developed simulation program establishes and uses two direct access files created on a magnetic disk pack. The first one is assigned a channel no. 3 and is used to store data pertaining to all ships in the system including attributes of cargo borne in the standard spaces of the different holds of the individual ships. This file is referred to and updated whenever a ship undergoes processing at any port. The file will be referred to as the ships'd.a. file, (direct access file of all ships).

The second file is assigned channel no. 4. This one is used for filing data pertaining to the attributes of cargo built up at the different ports in the system. Cargo built up at a particular port are rejected cargo or rejected and/or transhipped cargo, depending on whether the port under consideration is a node or a supernode, respectively. Transshipment cargo, in turn are classified as : container, break bulk and bulk transshipment cargo. This latter file is referred to as the Ports' d.a. file (direct access file of all ports) and is referenced and updated at subsequent events at a given port.

Both files are organized in the indexed sequential method with unformatted type of records [62 & 64]. Ships' d.a. file is made up of 320 records while the Ports' d.a. file is composed of 1800 records. The associated variables for the two files are ID1 & ID2 respectively. Each file is divided into several segments with each segment belonging to an individual port or ship. In the following section an illustration is presented for the make up and lay-out of each file which are devised to suit the simulation purposes.

3.9.1 - Ships' d.a. File

The ships' d.a. file is made up of 320 records and 10 segments, one segment for each ship. All segments are of equal size fixed to 32 records per segment, Figures 9-14.

REMARKS :

- Each segment is assigned to one ship, segments are of equal sizes on the contrary of the ports' d.a. File.
- Since the segments are of equal sizes, no input array is used to identify the first record of each segment. This is computed by the program.
- Each segment is made up of one unit. A unit, in turn, is composed of 32 records.

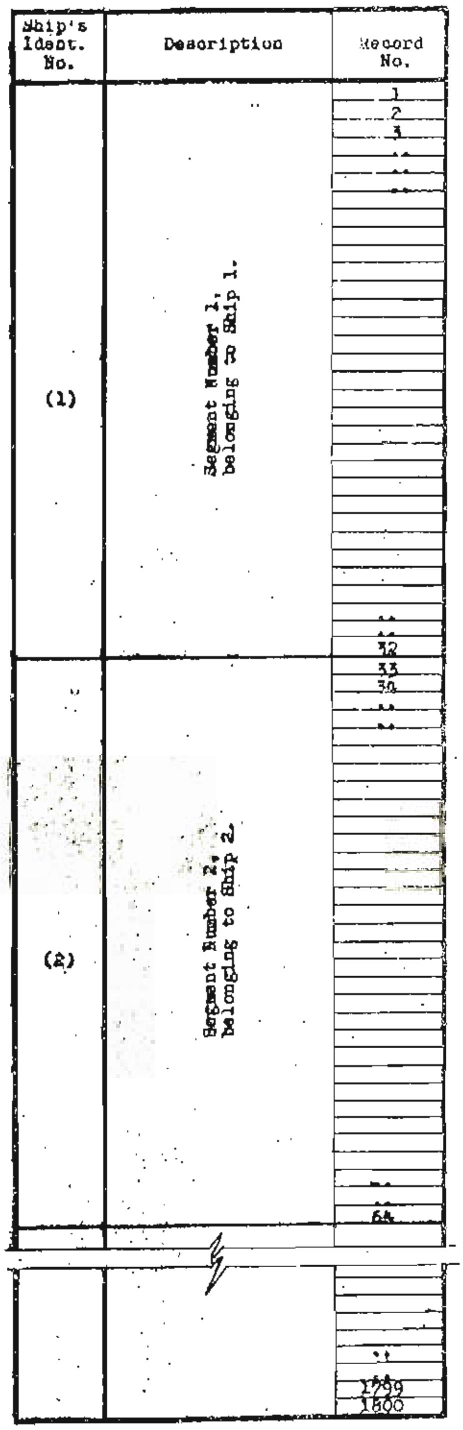


Figure 3-14 : Layout of the Ships' D.A. File

No data indicating the number of the first record of each segment is input since this can easily be developed by the computer. Because segments are created successively according to ships numbers, the number of the first record of a certain segment is given by

$$(IC - 1) * 32 + 1$$

where : IC is the ship's identification number.

The lay-out of records within each segment is given in fig. (3-15). The first record is devoted for the ship's name, identification number, parameters as well as the ship's itinerary, the second record for arrays describing the different holds of the ship. Subsequent records are used to store attributes of cargo in the standard spaces of the different holds. Two records are devoted for each hold (max. no. of holds = 10). It should be noted that the sequence of organizing data on a particular record corresponds to the sequence of elements in the output list of the associated WRITE statement. This sequence must be followed in any READ statement from the same record. Since the input and output of data on this file are made from and to internal storage respectively, no formatted records are used.

The ships' d.a. file is defined and created at MASTER where parameters and data of all ships in the simulation are written on the corresponding file records. When a particular

	Residing Variable(s) Symbol	Residing Variable(s) Description	Record No.
General specifications of the Ship	ISHIP(K) DWT SPEED CRITIM ISCODE ITHOLD NXPORT NUMCC NUMBB NUMLL NPTS IROUTE(K)	Ship's Name Ship's DWT Capacity Ship's Speed Ship's Initial Event Time Ship's Ident. No. Ship's No. of Holds Ship's Next Calling Port Ship's No. of Container Holds Ship's No. of b.bulk Holds Ship's No. of bulk Holds Ship's No. of Calling Ports Ship's Itinerary	33
	ITYPE(J) IHOLD(J) MODULO(J) IHMOD(J) ISW (J) CUBIC (J) DWTH (J)	Type of Hold (J) in the ship No. of spaces of Hold (J) " No. of spaces per deck " No. of Hatch spaces per deck No. of Decks of Hold (J) Cubic capacity of Hold (J) Tonnage capacity of Hold (J)	34
Attributes of cargo in Hold 1	VOL (M) STOW (M) IORG (M) IDEST(M) ICOMM(M)	Empty volume in space M Tonnage of cargo in space M Origin port of cargo " " Dest. " " " " " Comm. code " " " "	35
	IDESTA(M) IDESTB(M) DEN (M) ORGT (M)	First Transsh. port " " Second Transsh. port " " Stowage Factor " " " Origin Time " " "	36
Attributes of cargo in Hold 2	VOL (M) STOW (M) IORG (M) IDEST(M) ICOMM(M)	Empty volume in Space M Tonnage of cargo " " Origin Port " " " Dest. Port " " " Comm. Code " " "	37
	IDESTA(M) IDESTB(M) DEN (M) ORGT (M)	First Transsh. port " " Second Transsh. port " Stowage Factor " " " Origin Time " " "	38
... etc. till hold no. 10		..etc.	

Figure -35 : Details of One Unit on a Ship's D.A. File ship is choosen in MASTER to be processed in a new event, the first two records of that ship's segment of the ships' file are read into core. These are the records upon which ship's parameters and itinerary are written. The file is referenced again at PROCESS where the attributes of standard spaces within the hold under processing are read into core from the remaining records on the ship's segment on the file. This is done hold by hold since port processing cycle (unloading, booking and loading) is performed on each hold individually and successively. The necessary amendments and modifications in the attributes of standard spaces of the hold due to unloading, booking and loading operations are made on such attributes into core. Eventually at the loading subroutines, the updated attributes of the hold spaces are rewritten in the appropriate position on the file.

3.9.2 - Ports' d.a. File

Generally speaking all ports in the simulation syste are assigned to one file, referred to as the Ports' d.a. file or channel no. 4. The file is made up of 1800 records divided into several segments with one segment belonging to each port, fig. -15 The file is used in storing information regarding cargo built up a the different ports in the system. The type of cargo built up at certain port depends on whether such port is a node or a supernode At a node, cargo built up is composed of rejected cargo only.

REMARKS

- The model allows for one or more ports files. The array ILINK (I) gives the number of the file applicable to port I. The total number of records per file = 1800.
- Each port is assigned a segment on a ports' file. The segment is made-up of one or more "units".
- A unit on a supernode's segment = 11 records
- A unit on a node's segment = 2 records
- Units are numbered chronologically according to their creation time.
- The array IREF(I), I = 1, IPTMOD is an input to the program. It gives the no. of the first record on the segment belonging to port I.
- The array IRP(I) gives the actual no. of units established on the segment of port (I).

  e.g. IRP(1) = 3
  IRP(2) = 1
  IRP (3)= 2
- The matrix IRPS (I,J) gives the no. of the first record of the Jth. unit on the segment of port I.

  e.g. IRPS (3,2) = 18
  IRPS (1,3) = 3

Port No. (I)	IREF (I)	Description		Record No.
1	1	Segment 1 (a s.node) (3 units)	unit 1,seg.1	1, 2
			unit 3,seg.1	3, 4
			unit 2,seg.1	5, 6
2	7	Segment 2 (a s.node) (1 unit)	unit 1,seg.2	7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
3	18	Segment 3 (a s.node) (3 units)	unit 2,seg.3	18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28
			unit 1,seg.3	29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
			(not used area)	40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50
4	51		unit 1,seg.4	51, 52
5	53	..etc.	...	53, 54, ..
15		Segment 15 (a node)	...	..
			...	..
			...	..

Figure 3-16 : Layout of the Ports'D.A. File

At a supernode, in addition to rejected cargo, there may be transshipment cargo also waiting for subsequent shipment to its final destination. The transshipment cargo is further subdivided into container, b.bulk and bulk transshipment cargo. Therefore the size of a segment belonging to a super-node on this file is greater than the size of a node. On the other hand, cargo built up at a particular port may have different waiting times. Since the waiting time is taken into consideration in booking priorities, the cargo built up at each port are grouped into several "groups" having the same group originating time. A group is formed at the end of each event when a given ship finishes its processing at a given port. A group is composed of all transshipped cargo of homogeneous attributes unloaded from that ship or a homogeneous rejected cargo originating at this port and is offered for booking on board of this ship but are rejected due to inavailable space. In the case of a node, groups are composed of rejected cargo only. The group time is the event time of the current ship.

In order to accommodate for these considerations in designing the layout of the port's d.a. file, the port's segment on that file is divided into one or more "units". A "unit" is used to store information regarding cargo built up of all groups having the same time. Units within a certain segment are numbered serially in a chronological order with unit no.1 having cargo with waiting time longer than unit no.2, and so on. A unit in turn is made up of a certain number of records. For a supernode port, the unit will have 11 records. A node port unit will have 2 records. The maximum number of units available for a particular segment is left to the researcher and is specified by the input array IREF(I). IREF(I) gives the number of the first record of the segment belonging to port (I). The number of records within a certain segment will be multiples of 11 if the segment belongs to a supernode and multiples of 2 if the segment belongs to a node. The no. of records assigned to port (I) is given by

IREF (I+1) - IREF(I)

Meanwhile, two arrays specifying the lay-out of units within a certain segment are initialized in MASTER, namely IRP (I) & IRPS (I,J). The first array, IRP(I) gives the actual number of "units" created within the segment belonging to port I. A segment with, say 22 records, might have only one unit, and thus having IRP(I) = 1 with the remainder 11 records left blank for possible units to be created at subsequent time. The second array, IRPS(I,J) gives the no. of the first record of the first record of the Jth. unit within port's I segment.

Figs. (3.17 and 3.18) illustrate the internal layout of data within the records of a supernode's and a node's "unit" respectively. For a supernode's unit :

	Residing Variable: Symbol	Residing Variable: Description	Record No.
General specification of the Unit	SFT	Creation time of this unit	29
	NMBC	No. of transsh. b.bulk groups "	
	NMCO	No. of transsh. containers "	
	NML	No. of transsh. bulk groups "	
	NRJC	No. of rejected groups "	
	TNMBB	Total tonnage of b.bulk groups	
	TNMCO	Total tonnage of container "	
	TNML	Total tonnage of bulk "	
	TNRJC	Total tonnage of rejected "	
Attributes of Ith. transsh. b.bulk group	BSTOW(I)	Tonnage of group I	30
	BORGT(I)	Origin time " " "	
	JORG (I)	Origin port " " "	
	JDESTA(I)	First interm. port " " "	
	JDESTB(I)	Second interm. port " " "	
	JDEST (I)	Final destination " " "	
	BDEN (I)	Stowage factor " " "	
	JCOMM (I)	Commodity code " " "	
Attributes of Kth. transsh. container	CVOL (K)	Volume of empty portion of cont.K	31
	CSTOW(K)	Tonnage " " "	32
	CORGT(K)	Origin time " " "	33
	LORG (K)	Origin port " " "	34
	LDESTA(K)	First interm. port " " "	35
	LDESTB(K)	Second interm. port " " "	36
	LDEST(K)	Final destination " " "	37
Attributes of Lth. transsh. bulk group	YSTOW (L)	Tonnage of group L	38
	YORGT (L)	Origin time " "	
	NLORG (L)	Origin port " "	
	NLDESA(L)	First interm. port " "	
	NLDESB(L)	Second interm. port " "	
	NLDEST(L)	Final destination " "	
	YDEN (L)	Stowage factor " "	
	NLCOMM(L)	Commodity code " "	
Rej. carg.	REJO (J,N)	Tonnage of rejected groups, comm. J, destination N.	39

One Unit (rows 29–39) (Unit 1, Segment 3 of Figure 9-16)

Figure 3-17 : Details of a Unit Layout on the Ports' D.A. File (Port is a supernode)

	Residing Variable		Record No.
	Symbol	Description	
Unit 2	SFT NRJC TNRJC	Creation time of this unit No. of rejected groups " Tonnage of rejected groups	1795
	REJC (K,J)	Tonnages of rejected cargo of the same time, commodity K, destination J	1796
Unit 3	SFT NRJC TNRJC	Creation time of this unit No. of rejected groups Tonnage of rejected groups	1797
	REJC (K,J)	Tonnages of rejected cargo of the same time, commodity K, destination J	1798
Unit 1	SFT NRJC TNRJC	Creation time of this unit No. of rejected groups Tonnage of rejected groups	1799
	REJC (K,J)	Tonnages of rejected cargo of the same time, commodity K, destination J	1800

(Segment 15, Figure 9-16)

Figure -18 : Details of a Unit Layout on the Ports'D.A.File (Port is a node)

- The second record stores arrays for the attributes of transshipped b.bulk groups.
- Records 3, 4, ... & 9 are used to store the attributes of individual transshipped containers with one record devoted to one attribute. A maximum of 250 transshipped containers are allowed thus specifying the maximum record capacity of this file with 700 words.
- The 10th. record is used to store arrays for the attribute of transshipped bulk groups.
- The 11th. record is used to store arrays for the tonnages of rejected groups, REJC(I,J) of commodity I and destination J.
- The first record is used to store data of the unit as a whole such as the number of transshipped or rejected groups of each type and the group formation time SFT.

A "unit" of a node is made up of two records only :

- The second record is used to store an array for the tonnage of rejected groups REJC(I,J) of commodity I, destination J.
- The first record contains the number of such groups NRJC in addition to the rejection time SFT.

Units are created after port processing at the end of a particular event in subroutine "DFILE". For this purpose, three tables are initialized in storage in PROCESS. These tables are used as temporary storage for the different unloaded groups of transshipped cargo formed while port processing before being written on a separate unit on the port's d.a. file. The first table is for transshipped break bulk cargo. The second one is for the transshipped containers while the third is for transshipped bulk cargo. As cargo is unloaded from the different holds of the ship while port processing, its tonnage is accumulated to that tonnage of tha appropriate group within the proper table having the same attributes as the unloaded cargo. If one such attribute is different, a new group is formed.

At the conclusion of port processing and if there is cargo rejected or transshipped cargo unloaded, a unit has to be created. Data to be written on this unit will be output from core from the corresponding temporary storage table. In subroutine "DFILE" rearrangement of units and numbering of new units are carried out to utilize the space becoming available due to the existence of blank units. Blank units are created in the booking subroutines. This is explained in details in subroutine "DFILE", section 10.9.

TABLE 3-1 : Sizes of Arrays and Common Blocks

Array	No. of Variables		Size in Words			Segment
	Integer	Real	Integer	Real	Total	
DIMENSION	38	225	38	450	488	MASTER
B1	853	32	853	64	917	MASTER,HARBOR, PROCESS,CONULG, BBKULG,BLKULG, CONBKG,BBKBKG, BLBKLG,CONLDG, BBKLDG,DFILE, SUMMARY,CARGO
B2	473	913	473	1838	2311	HARBOR,PROCESS, CONULG,BBKULG, BLKULG,CONBKG, BBKBKG,BLBKLG, CONLDG,BBKLDG, DFILE,SUMMARY
B3	1810	1378	1810	2756	4566	PROCESS,CONULG, BBKULG,BLKULG, CONBKG,BBKBKG, BLBKLG,CONLDG, BBKLDG,DFILE, TIME,SUMMARY
B4	2	7	2	14	16	CONULG,BBKULG BLKULG,BBKBKG CONLDG,BBKLDG
B5	1	–	1	–	1	BBKULG,BBKBKG
B6	13	236	13	472	485	BLKULG,CONBKG, BBKBKG,BLBKLG, CONLDG,DFILE, CARGO
B7	–	3	–	6	6	BBKBKG,BLBKLG
B8	–	2	–	4	4	CONBKG,BLBKLG, BBLDG

Continued

Continuation of Table 10-1

Array	No. of Variables Integer	No. of Variables Real	Size in Words Integer	Size in Words Real	Size in Words Total	Segment
B9	1	1	1	2	3	TIME, SUMMARY
B10	1	1	1	2	3	MASTER, HARBOR, SUMMARY
B11	16	-	16	-	16	MASTER, HARBOR, PROCESS, SUMMARY, HEADING
B12	100	-	100	-	100	PROCESS, CONULG, BBKULG, BLKULG, CONBKG, BBKBKG BLBKLG, CONLDG BBKLDG, DFILE, SUMMARY
DIMENSION	10	5	10	10	20	TIME
DIMENSION	25	15	25	30	55	BLBKLG
DIMENSION	25	15	25	30	55	BBKBKG
DIMENSION	20	15	20	30	50	CONBKG
DIMENSION	3	450	3	900	903	HARBOR
					9999	

3.10 - SOURCE PROGRAM

The source program of the model is compiled on the ICL 1900E machine using the compiler "XFAT MK 4C". The core size of the program is 42432 words. Individual sizes of DIMENSION arrays and COMMON blocks together with their respective initiation segment are given in table (3-1). The maximum size of these arrays at any one time is 9383 words (compressing integer variables). The program can accommodate for the following items:

- 15 ports including 2 supernodes.
- 10 ships.
- 10 holds in each ship.
- 100 standard spaces or containers per hold.
- 15 ports per itinerary.
- 15 commodity items.
- 250 unloaded container in a single event.
- 50 unloaded break bulk groups in a single event.
- 10 unloaded bulk group in a single event.

The above items are within the core capacity of the machine used. The items can be extended to allow for more ports and ships if the OVERLAY and EXTENDED facilities are used (62). Other combinations can, of course, be established. In fact the size of the core is the only real limitation on the size of the program.

3.11 - PRINCIPAL USES

A simulation model of this kind has numerous uses. There is no practical method to enumerate all its different uses. However, some of the main possible are indicated below :-

(1) Investigate cargo movement allover a pre-determined network
(2) Test the feasibility of establishing a new route
(3) select a better ship construction among several alternatives.
(4) Test several scheduling or managerial policies beforehand
(5) Select optimum positions for cargo transshipment.
(6) Test the integration of inland modes of transportation with maritime networks.
(7) Test integration plans of several maritime fleets.
(8) Test the effect of speed on marginal profits.
(9) Investigate the impact of the advent of containers to the national fleet as well as their scheduling and iventroy decision rules.

It should be noted that upon using the model in any of these applications, standard statistical techniques of simulation sample size and experiments design should be carefully applied. Special attention should also be given to the system starting conditions. The use of files is of abvious significance in this connection.

APPENDIX (A)

In the following appendix, main block diagrams of the various subroutines are included. Detailed flow charts are thought to be rather voluminous. Therefore detailed figures referred to in these block diagrams are deliberately not included.

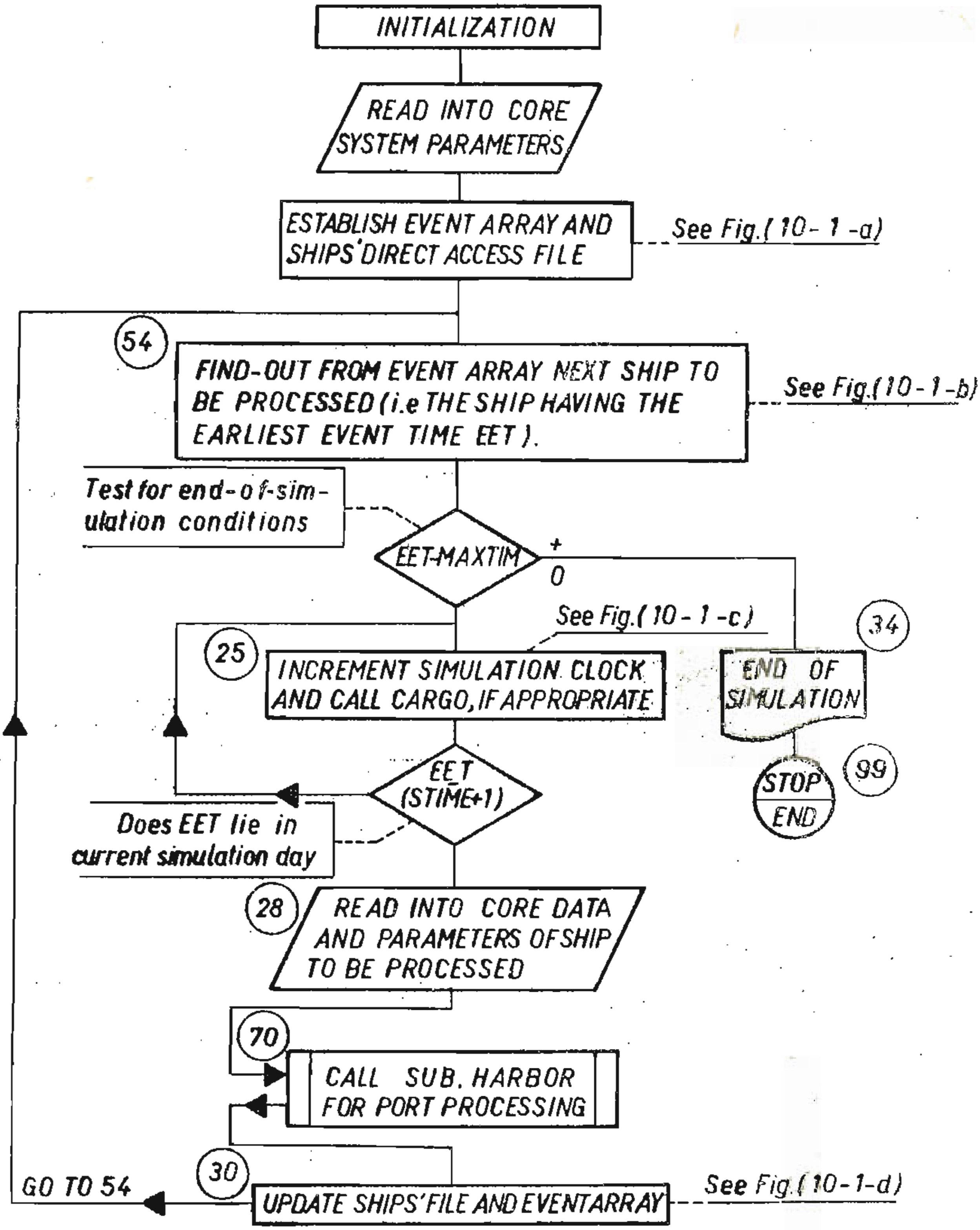


Figure (A - 1): General Block Diagram of the Executive Routine, MASTER

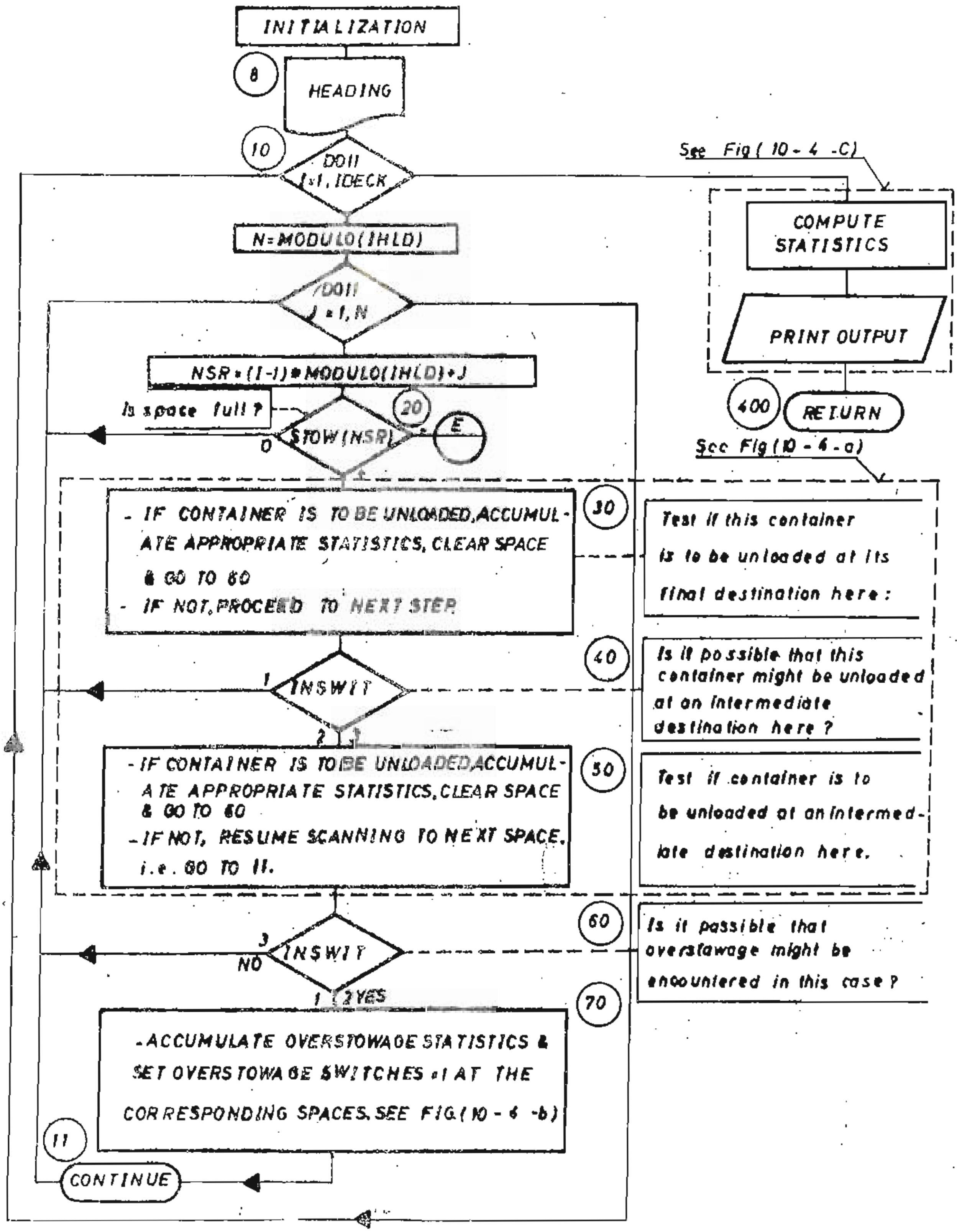


Figure A - 4 : General Block Diagram of subr. CONULG.

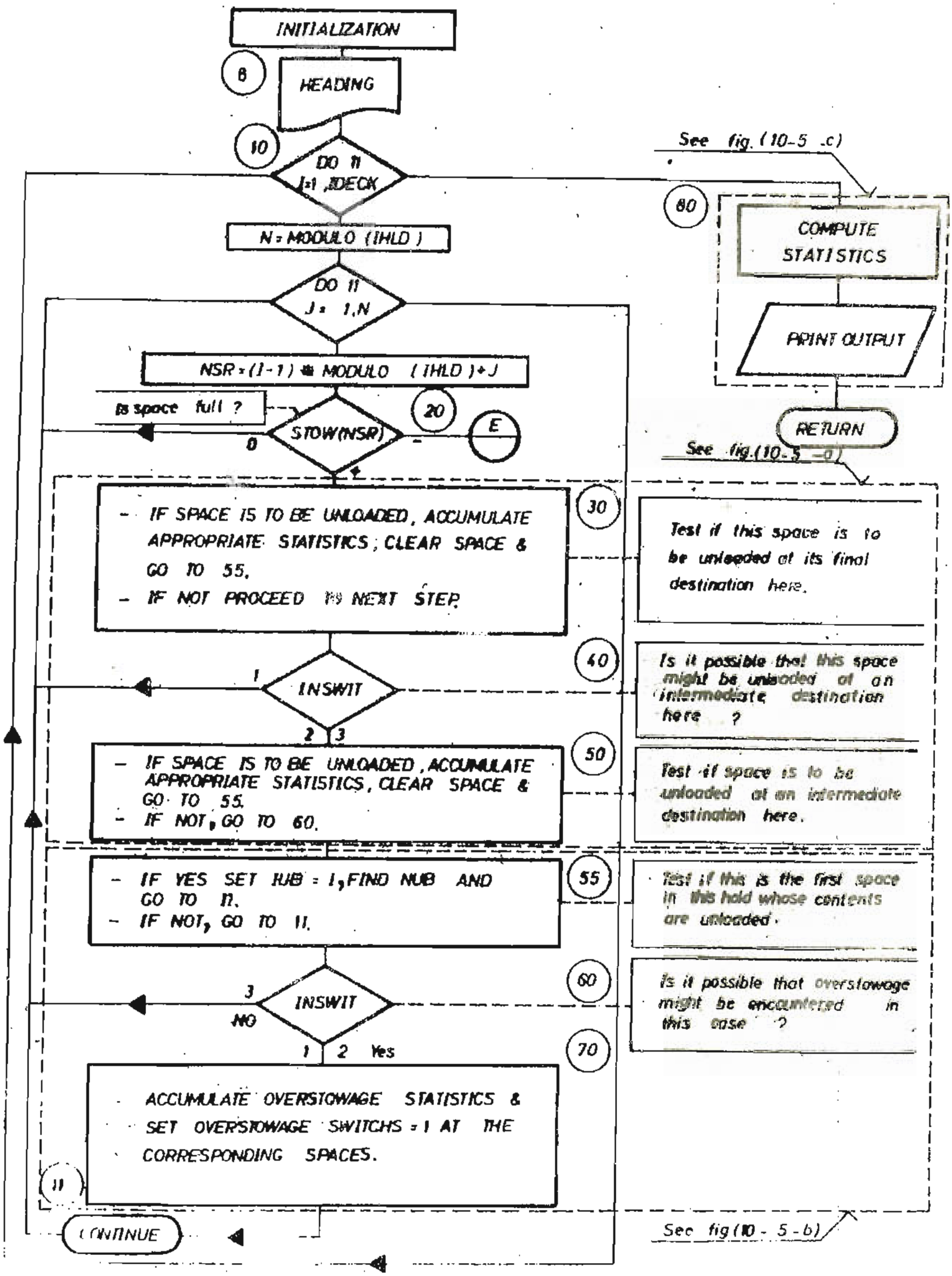
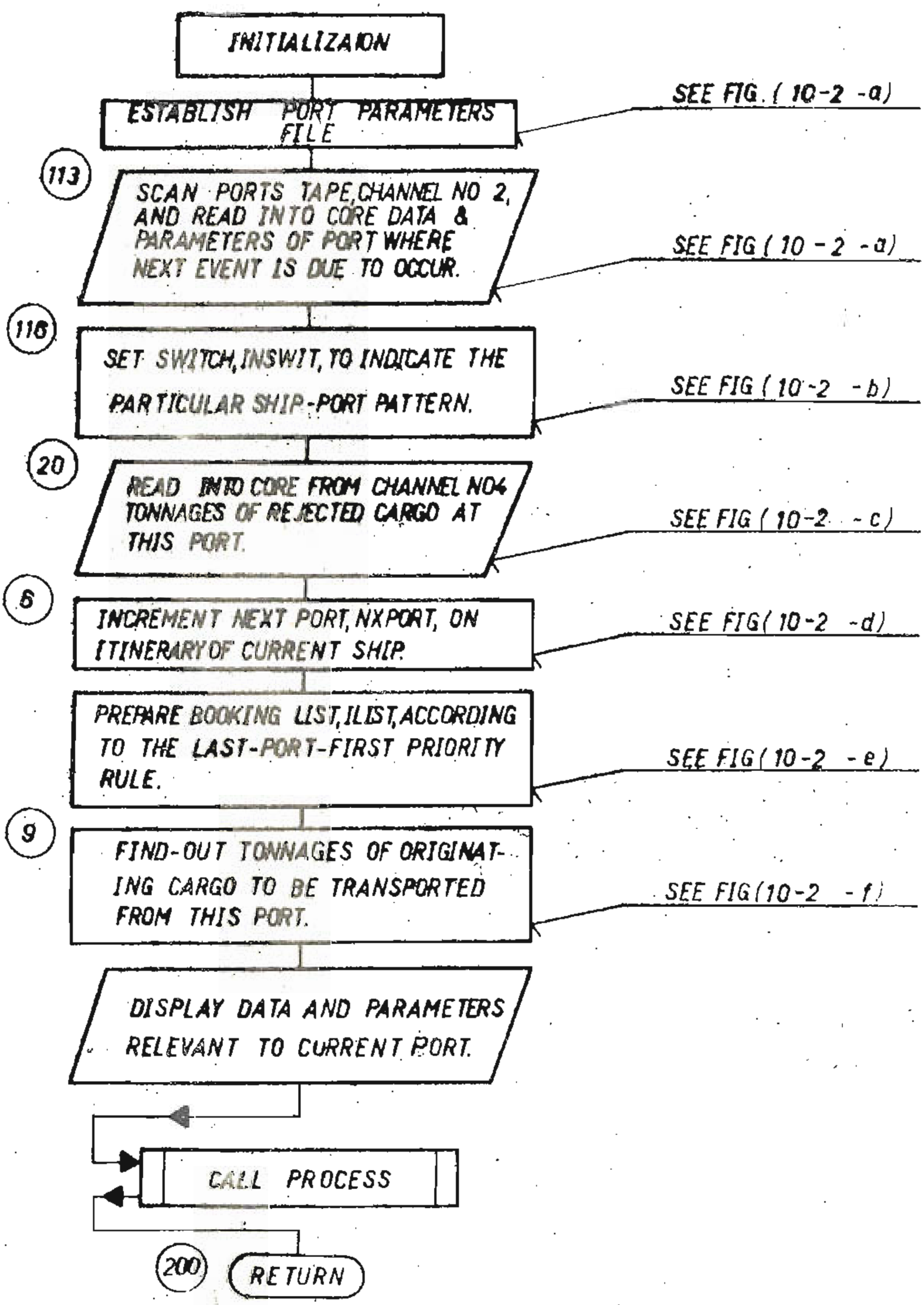


Figure 10-5 : General Block Diagram of subr. BBKULG



Figure(A -2): General Block Diagram of subr. HARBOR

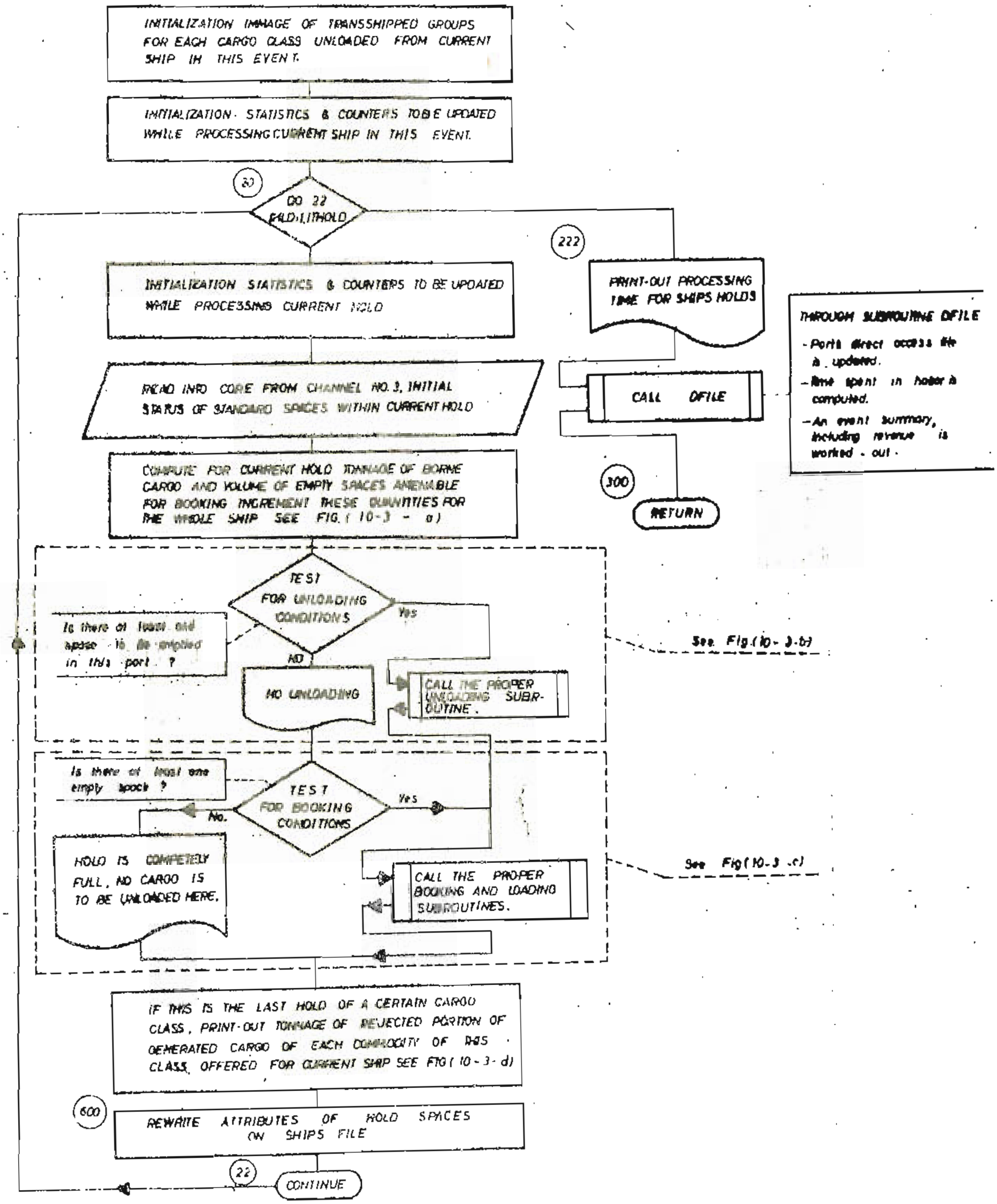


Figure A - 3 :General Block Diagram of subr. PROCESS.

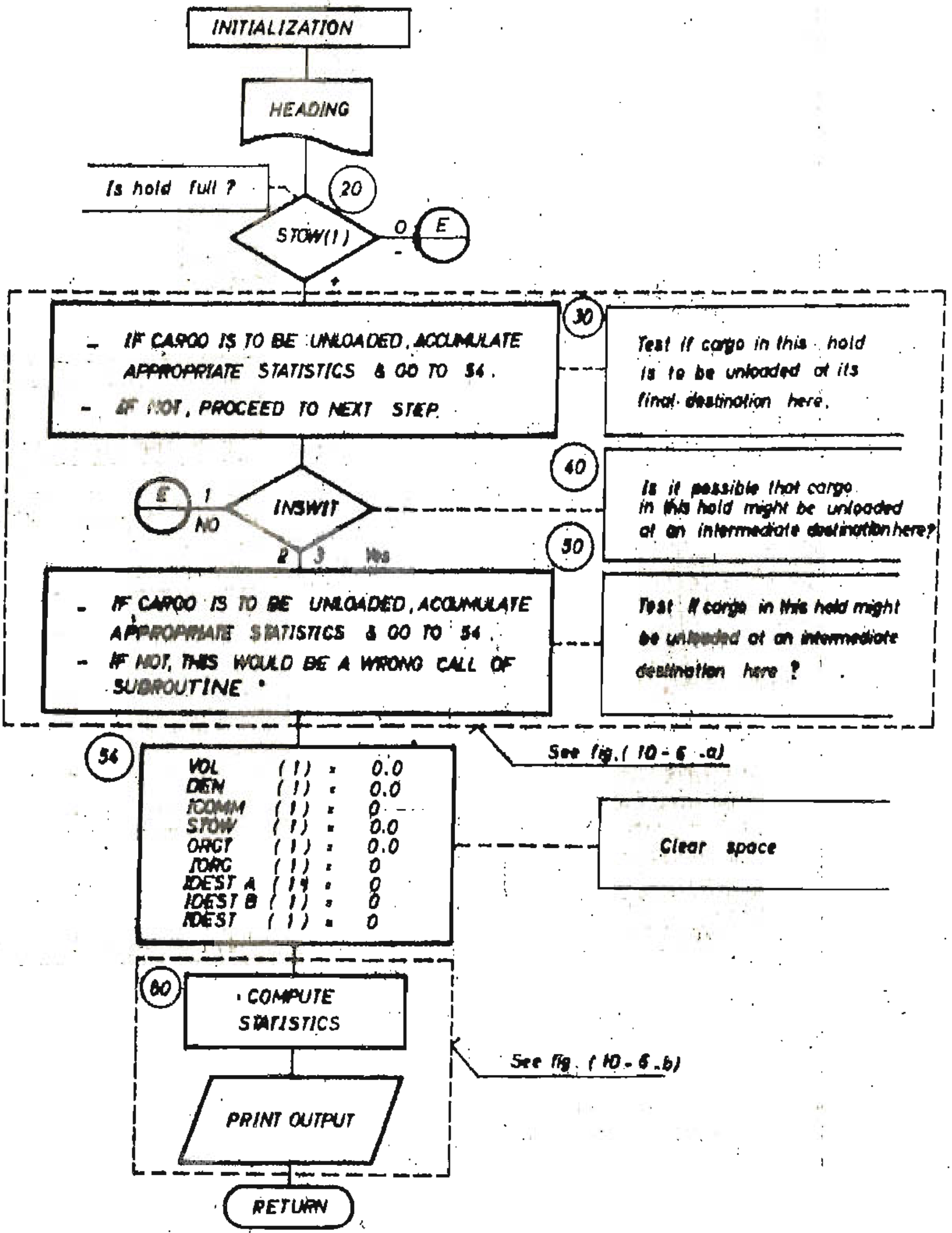


Figure A - 6 : General block diagram of subr. BLKULG.

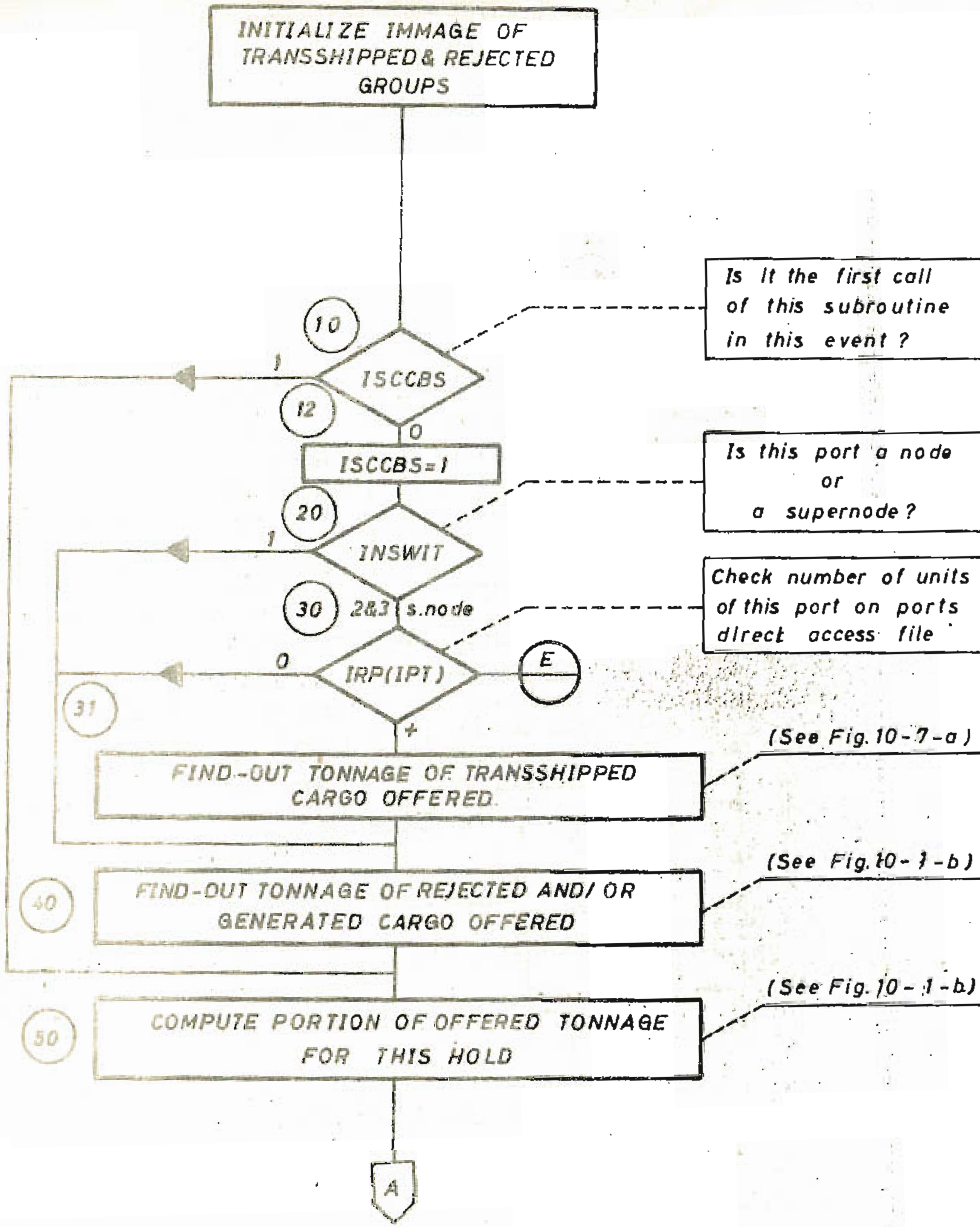


Figure 10-7 : General block diagram of subr. CONBKG.

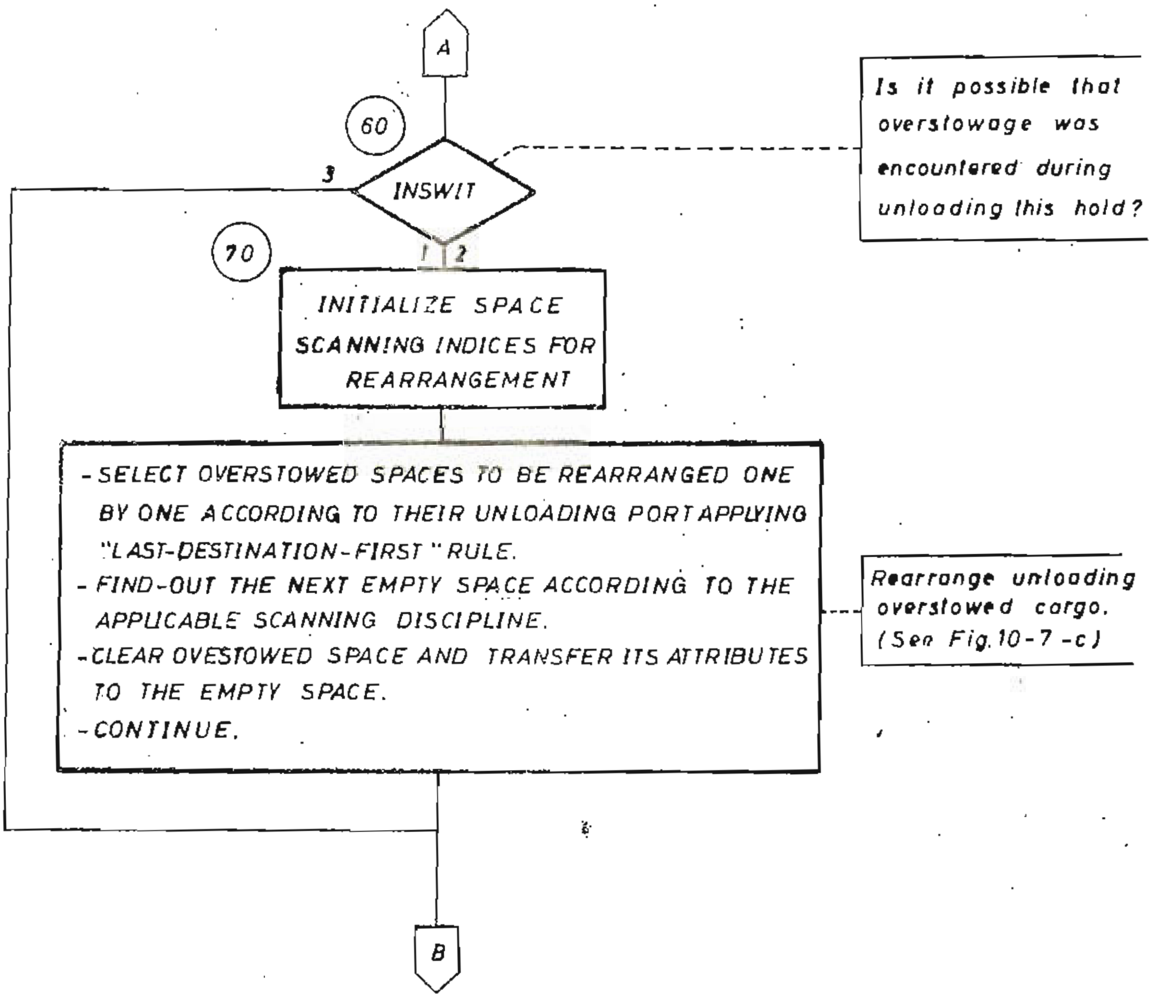


Figure A'-7 : General block diagram of subr. CONBKG (contd.)

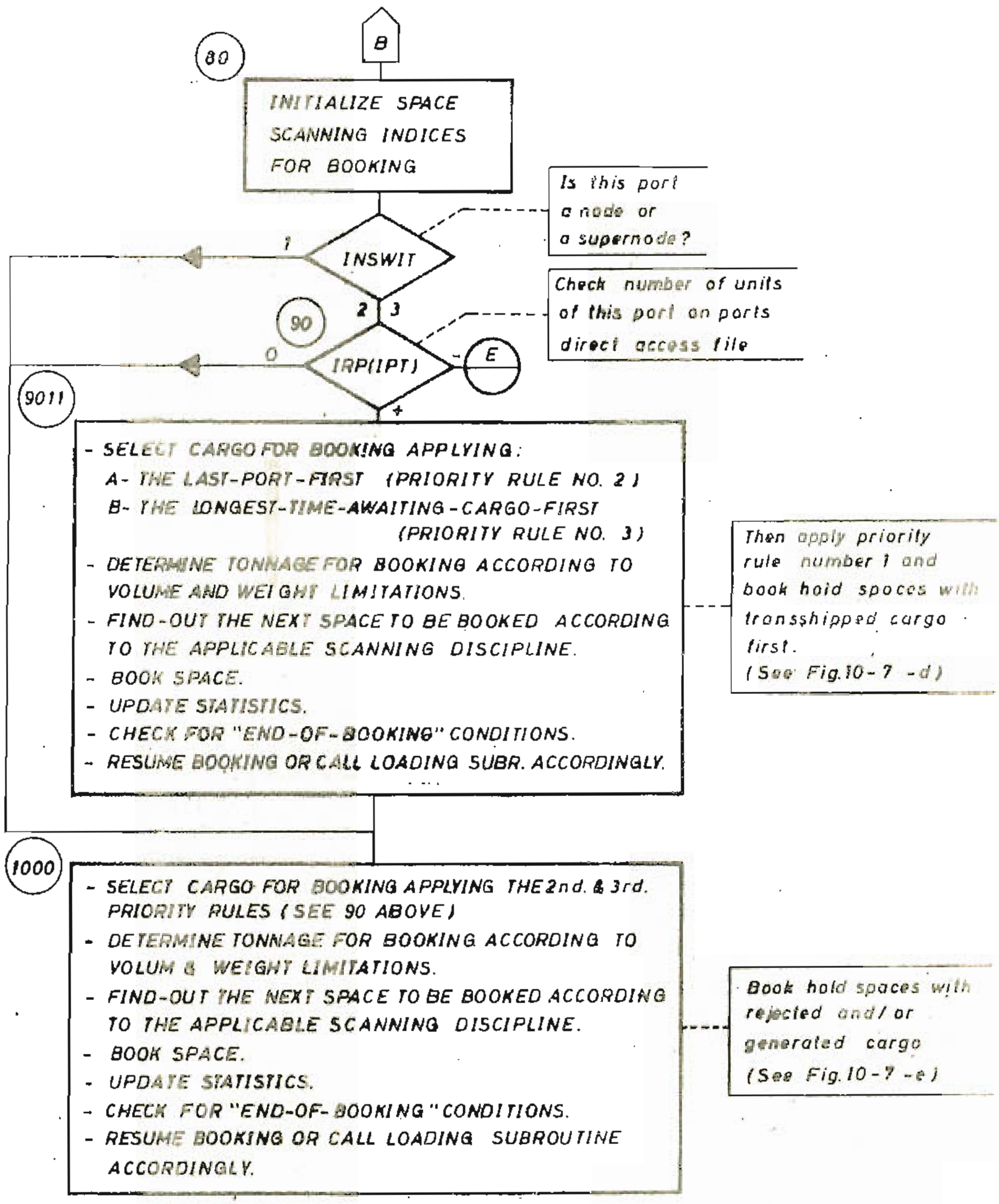


Figure A -7 : General block diagram of subr CONBKG (contd.).

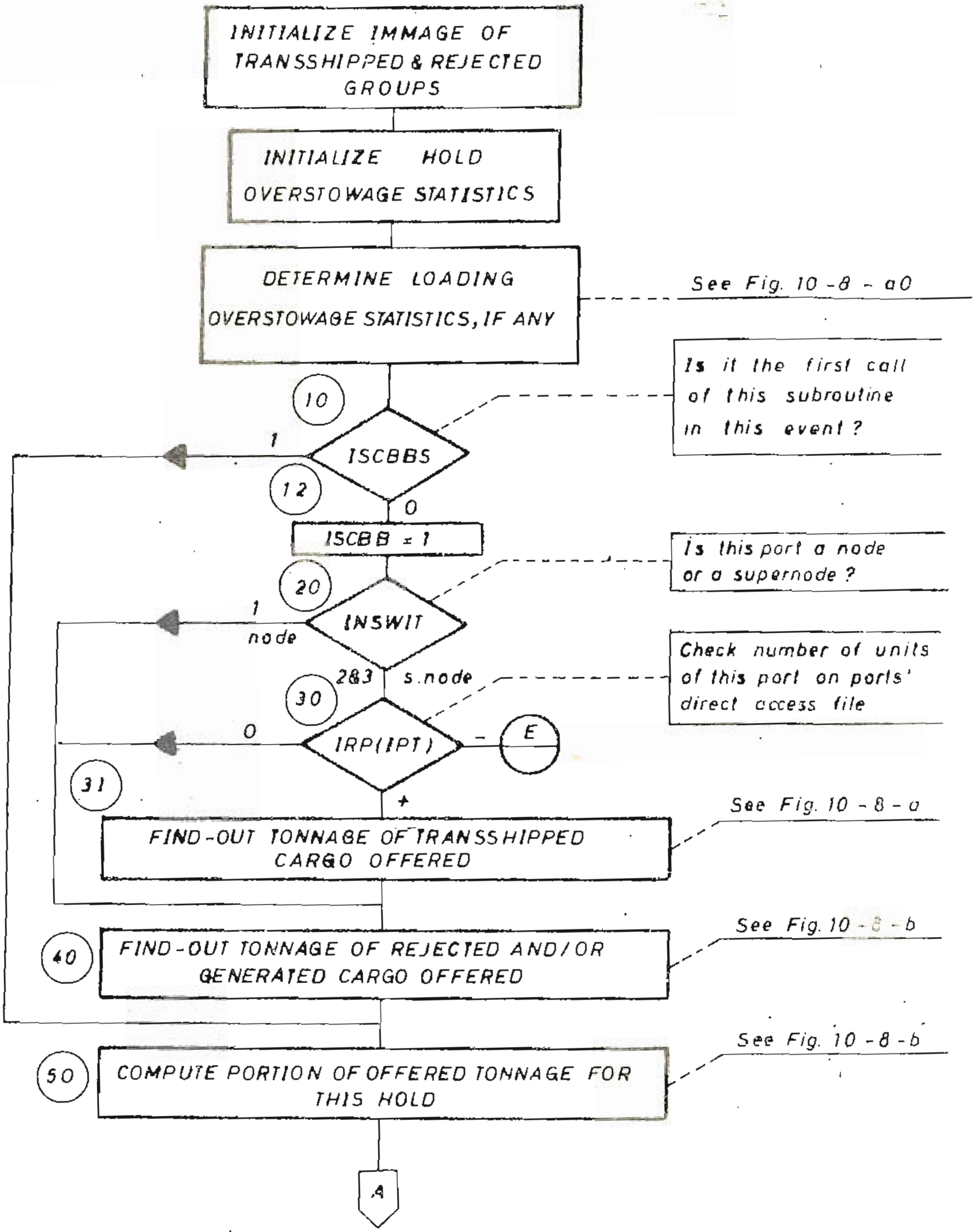


Figure A-8 : General Block Diagram of Subr. BBKBKG.

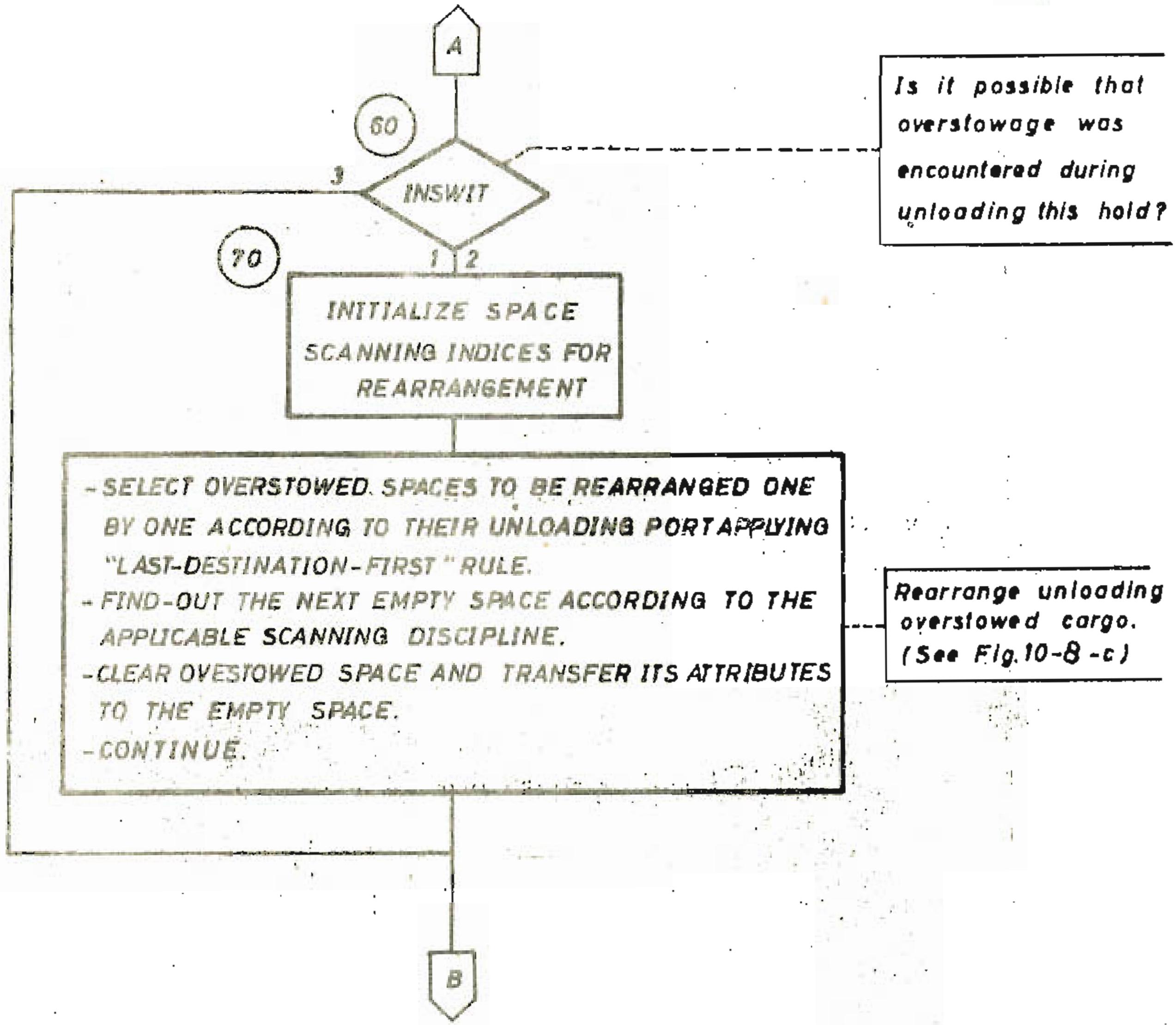


Figure A .- 8 : General block diagram of subr. BBKBKG (contd.)

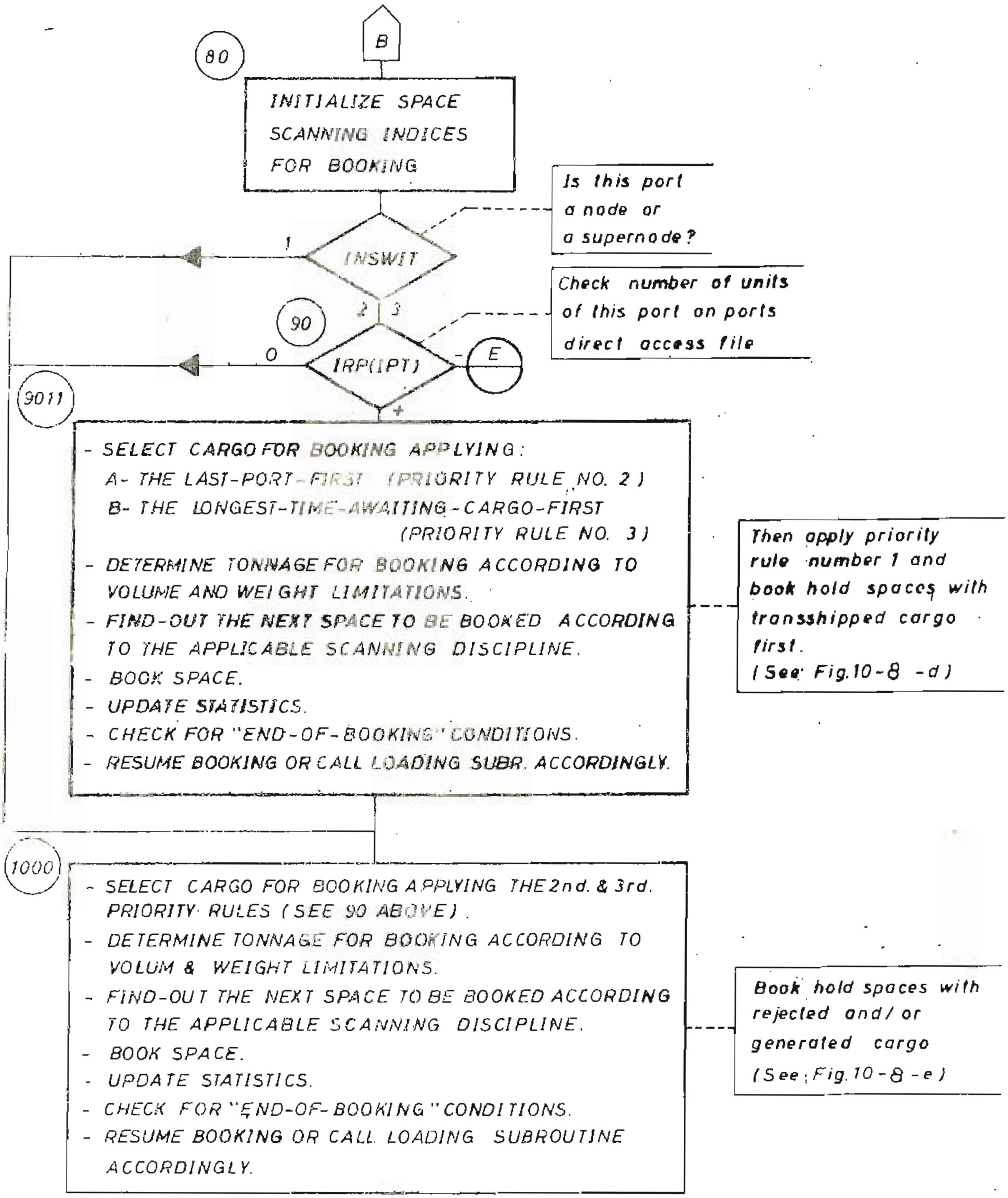


Figure A-8 : General block diagram of subr BBKBKG (contd.).

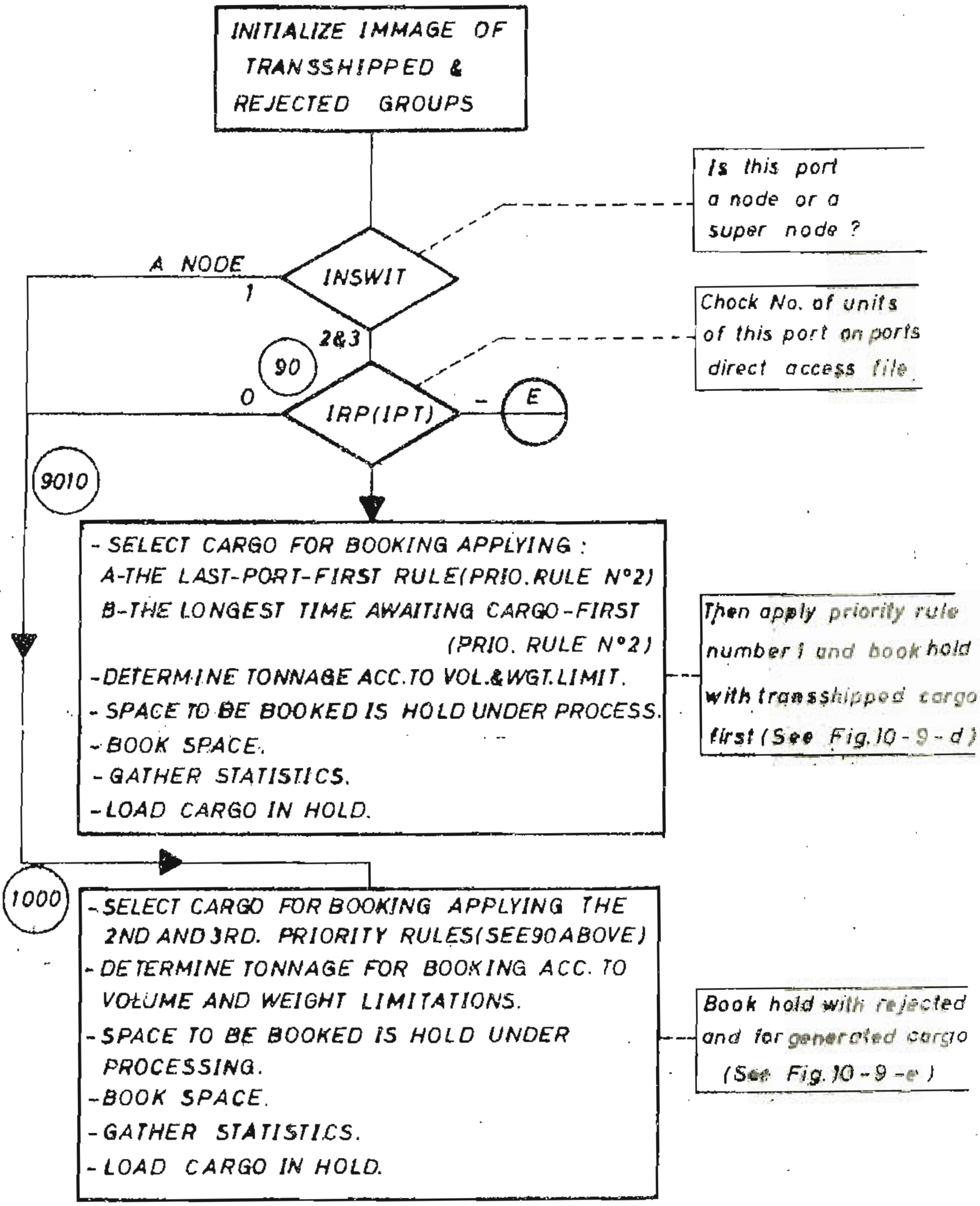


Figure A -9 : General Block Diagram of Subr. BLBKLG

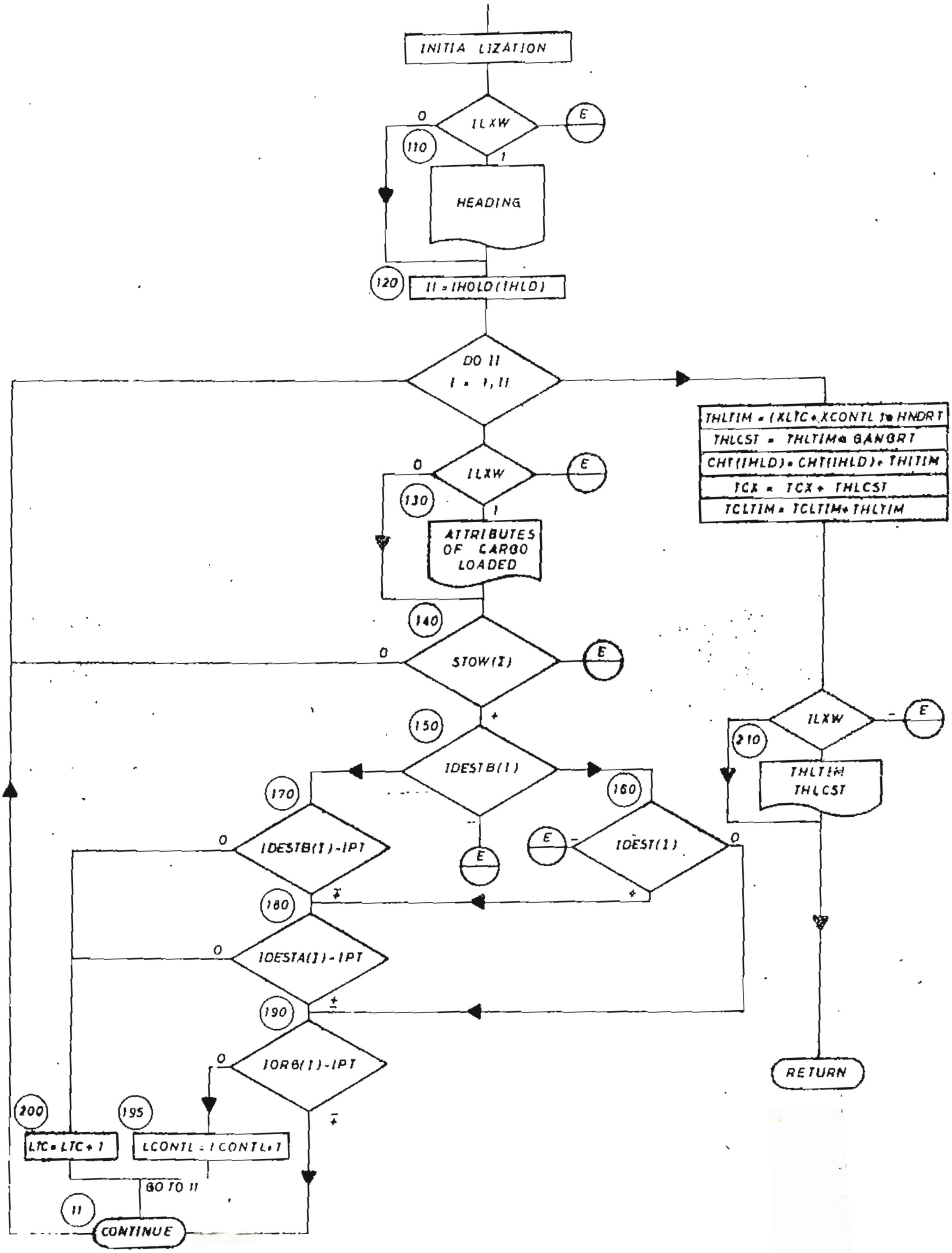


Figure A.10 Flow chart of subr. CONLDG

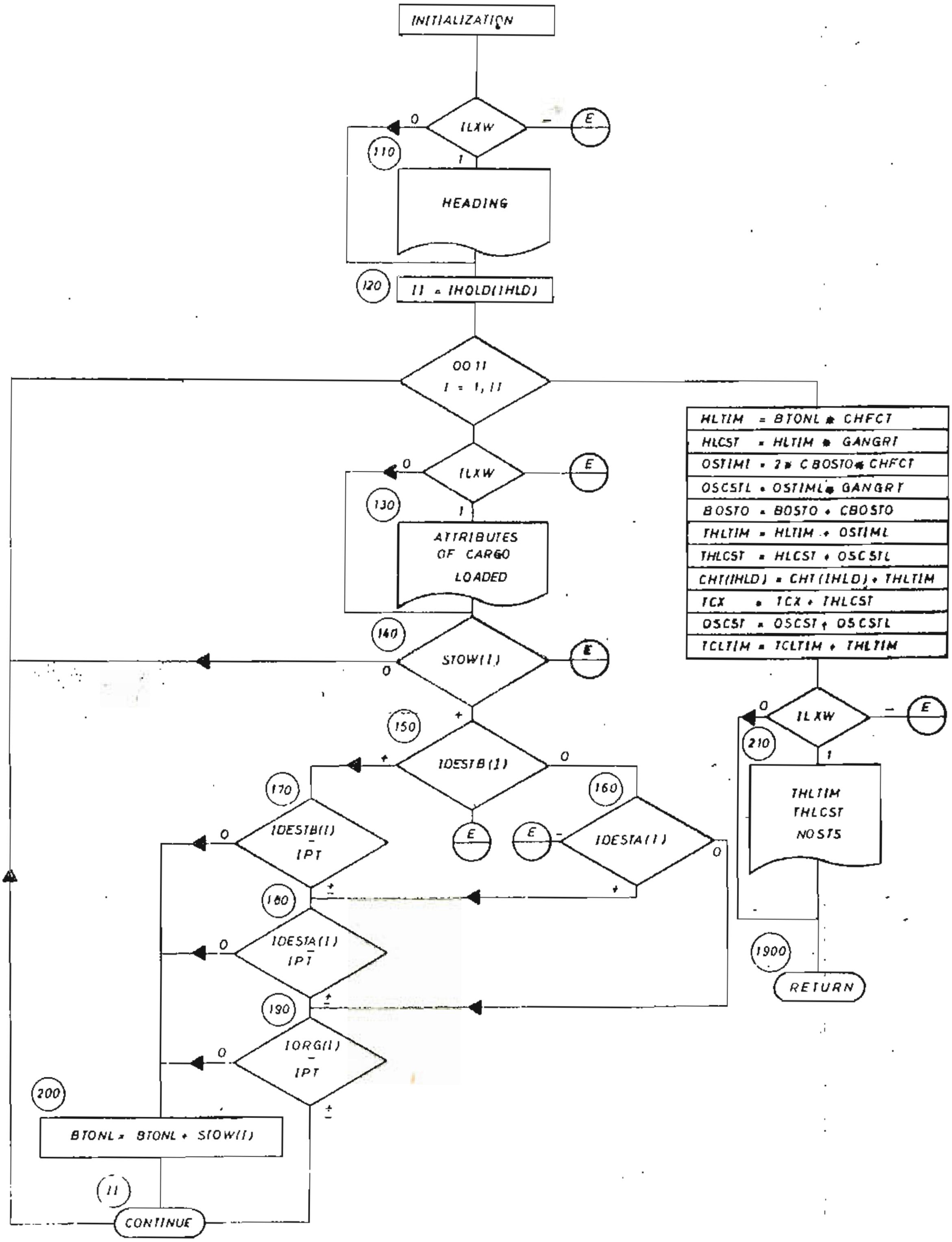


Figure ꓲꓲ - 11 Flow churt of subr. BBKLDG

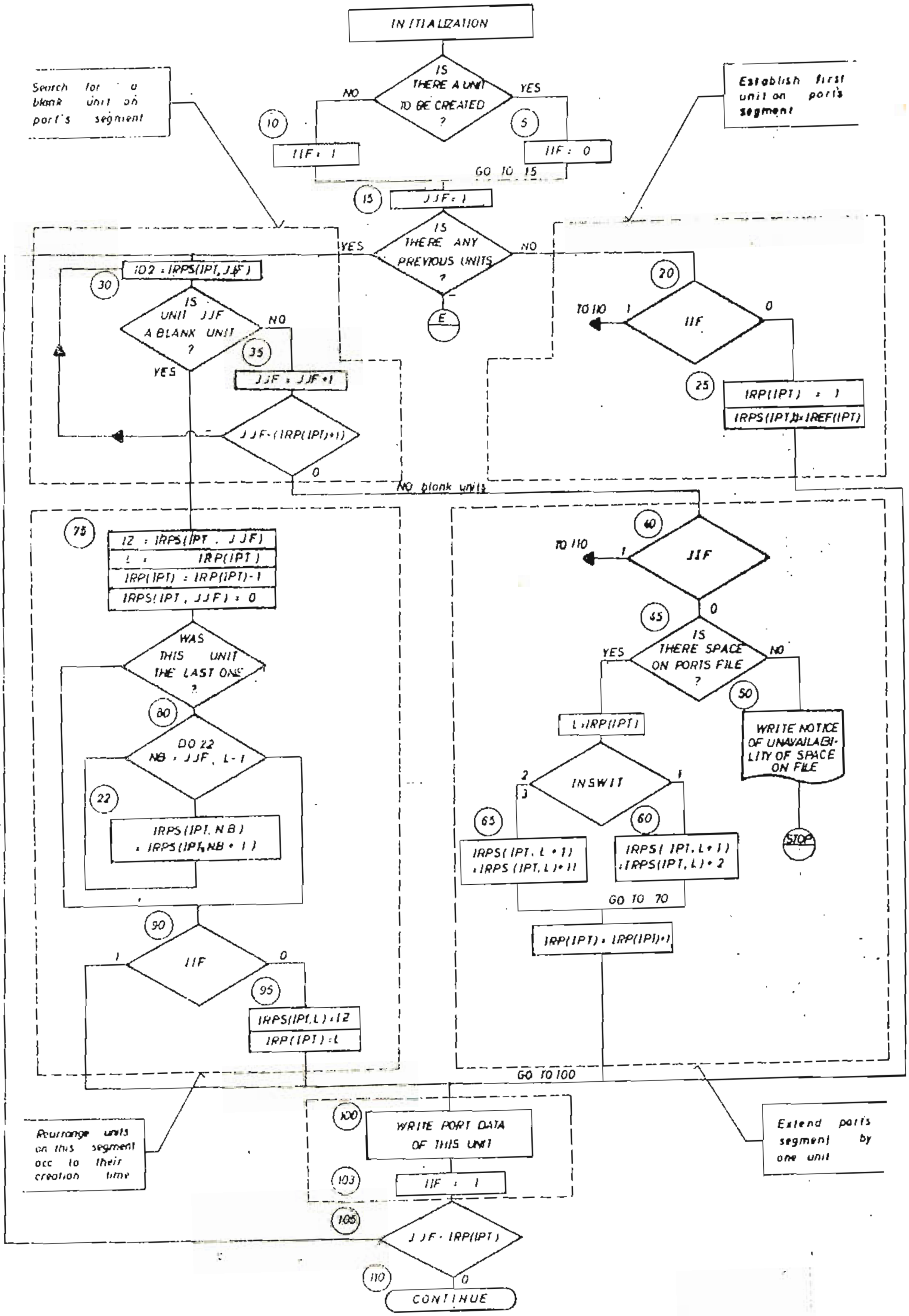


Figure A-12 : Flow chart of subroutine DFILE

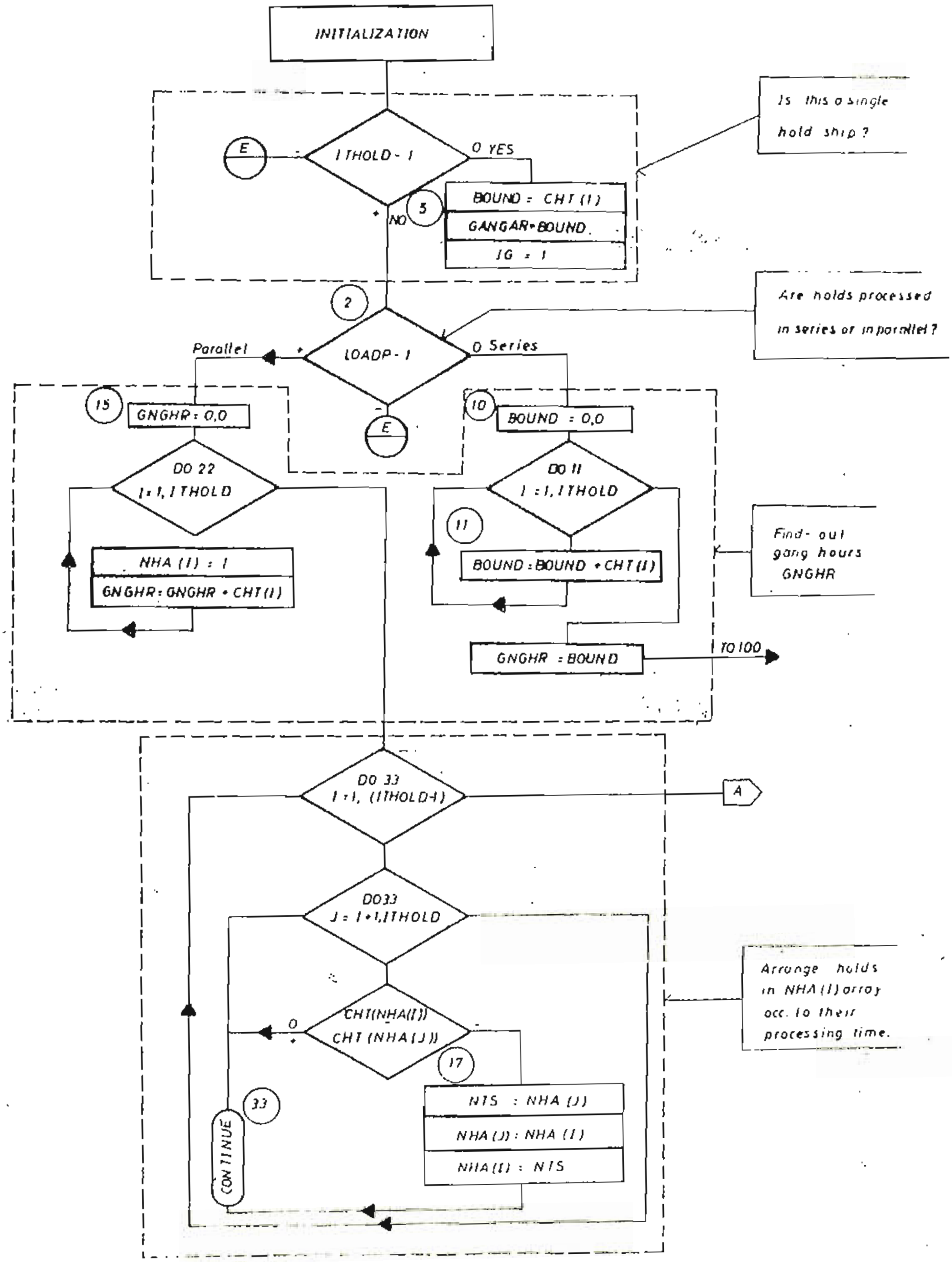
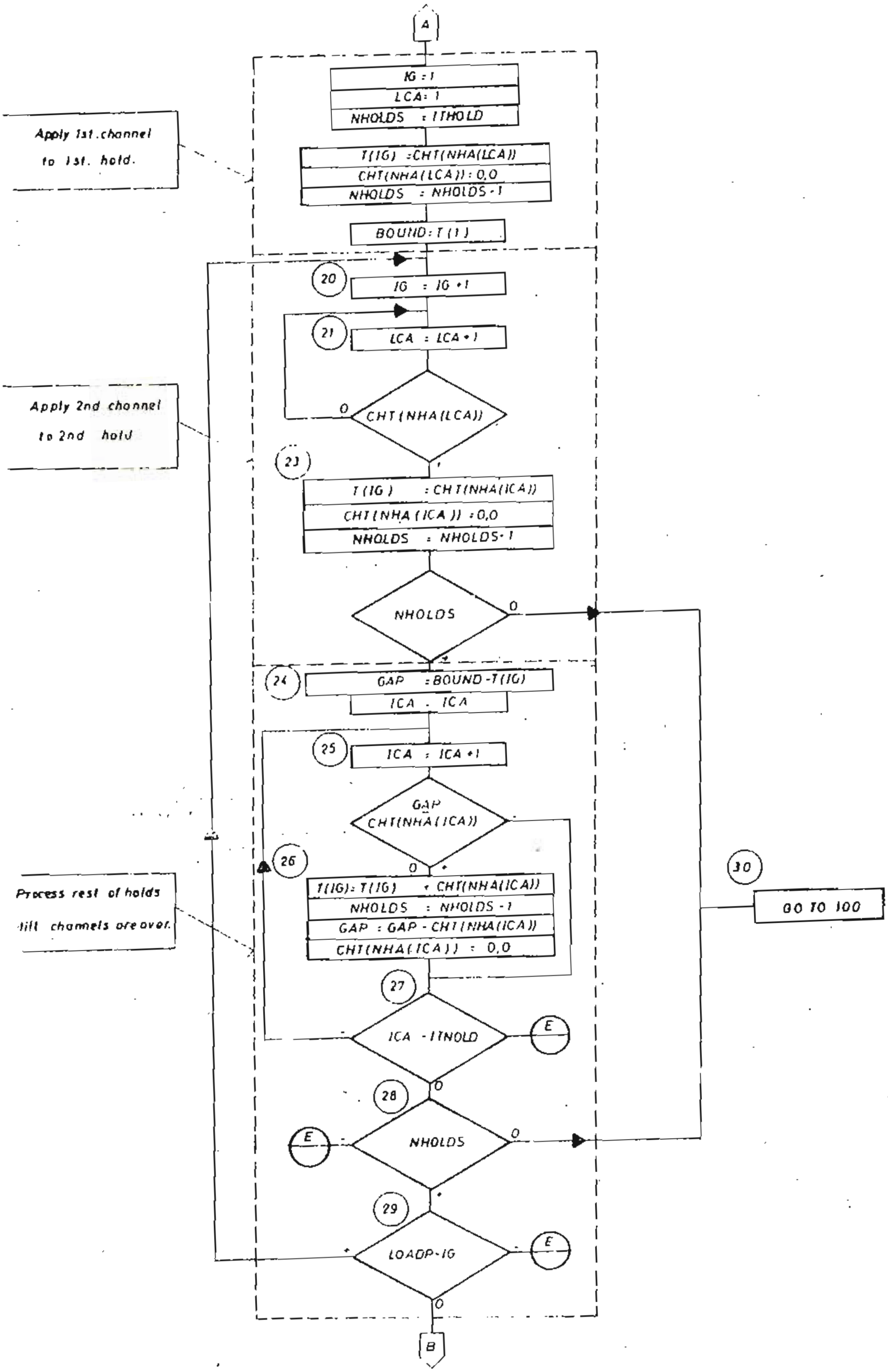


Figure A-13: Flow chart of subr. TIME



Figur A I· Flow [illegible] of s[illegible]
[illegible]

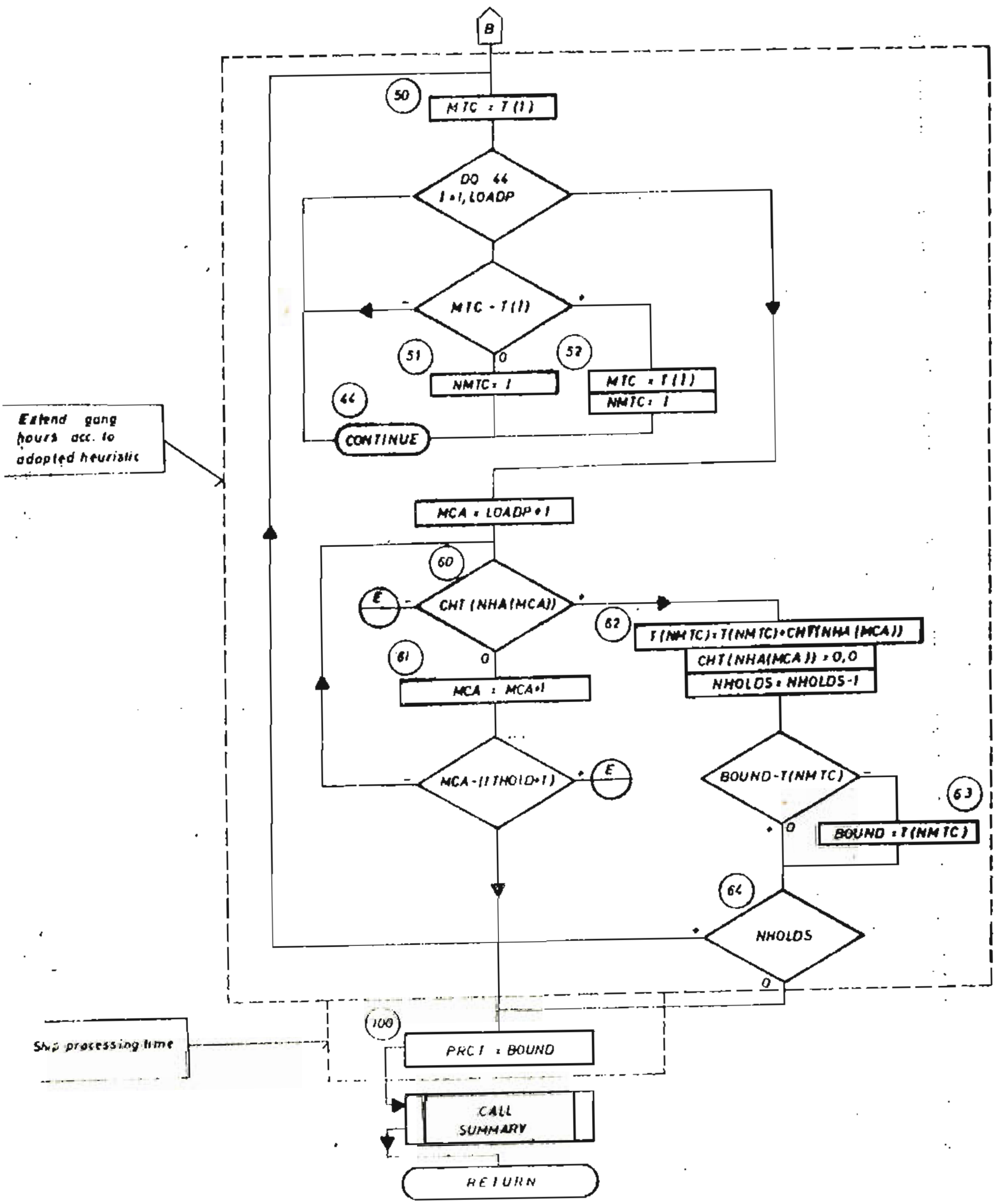


Figure A-13 : Flow chart of subr. TIME (contd)

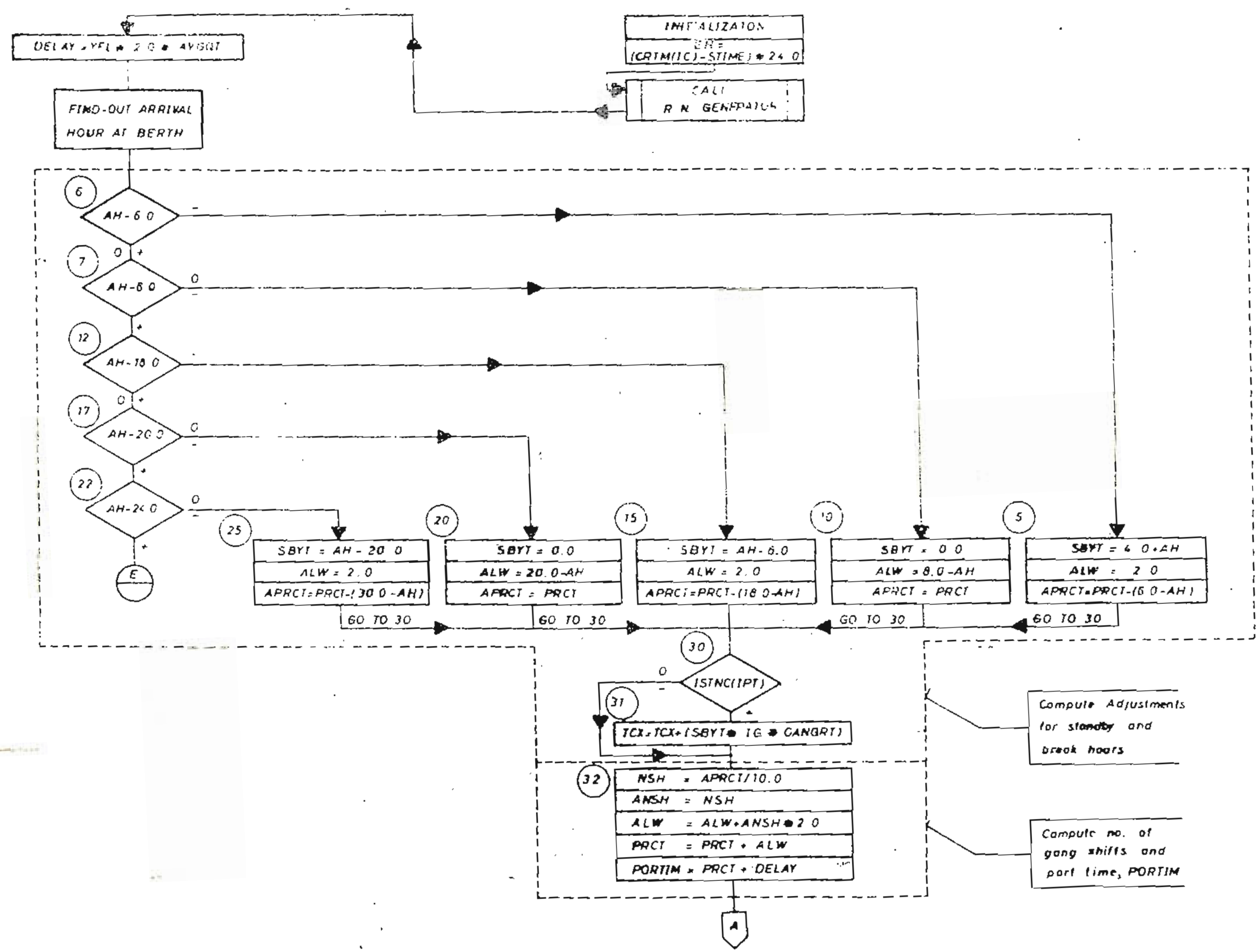


Figure A-14 : Flow chart of subr. SUMMARY

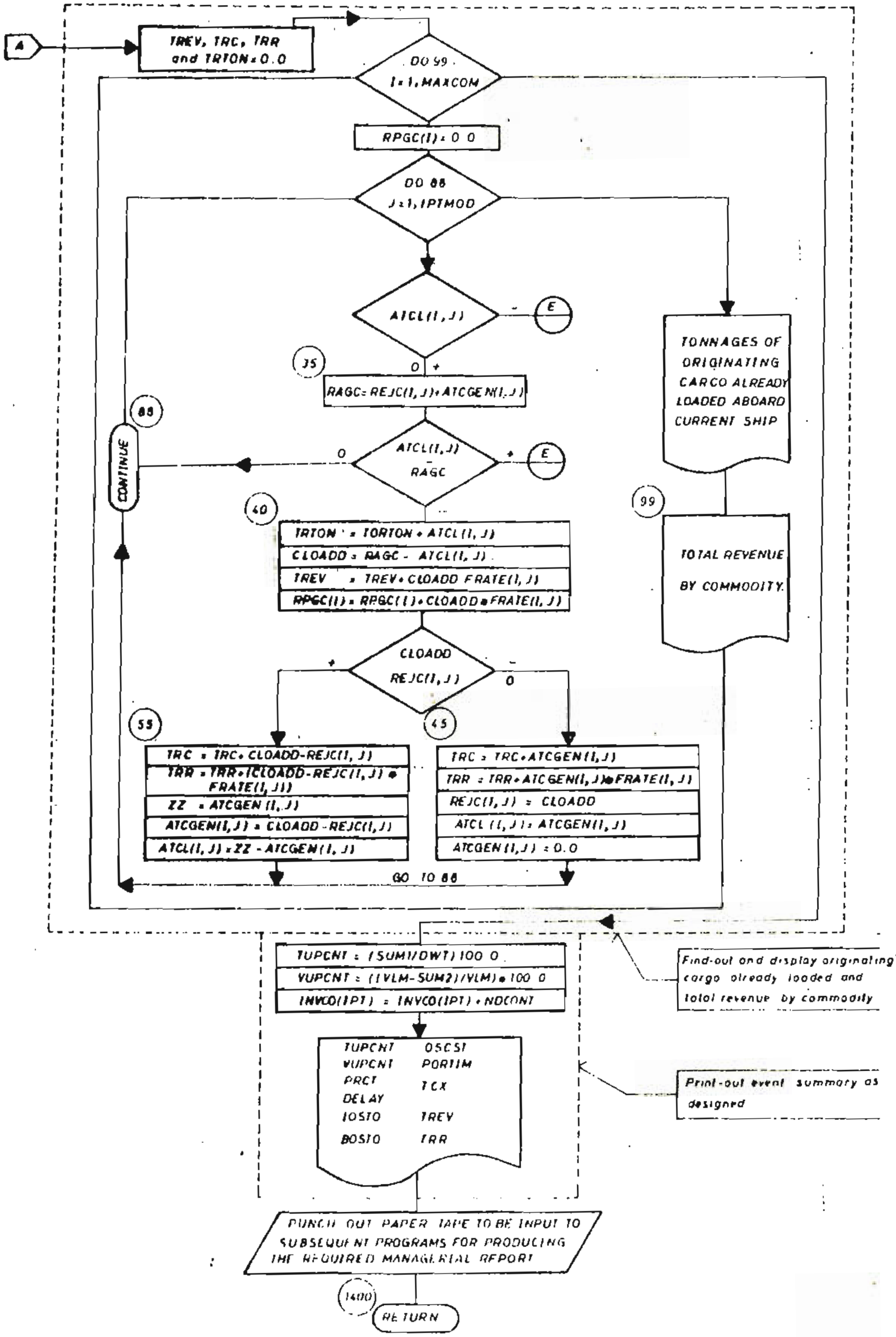


Figure A-14 Flow chart of subr. SUMMARY (Contd.)

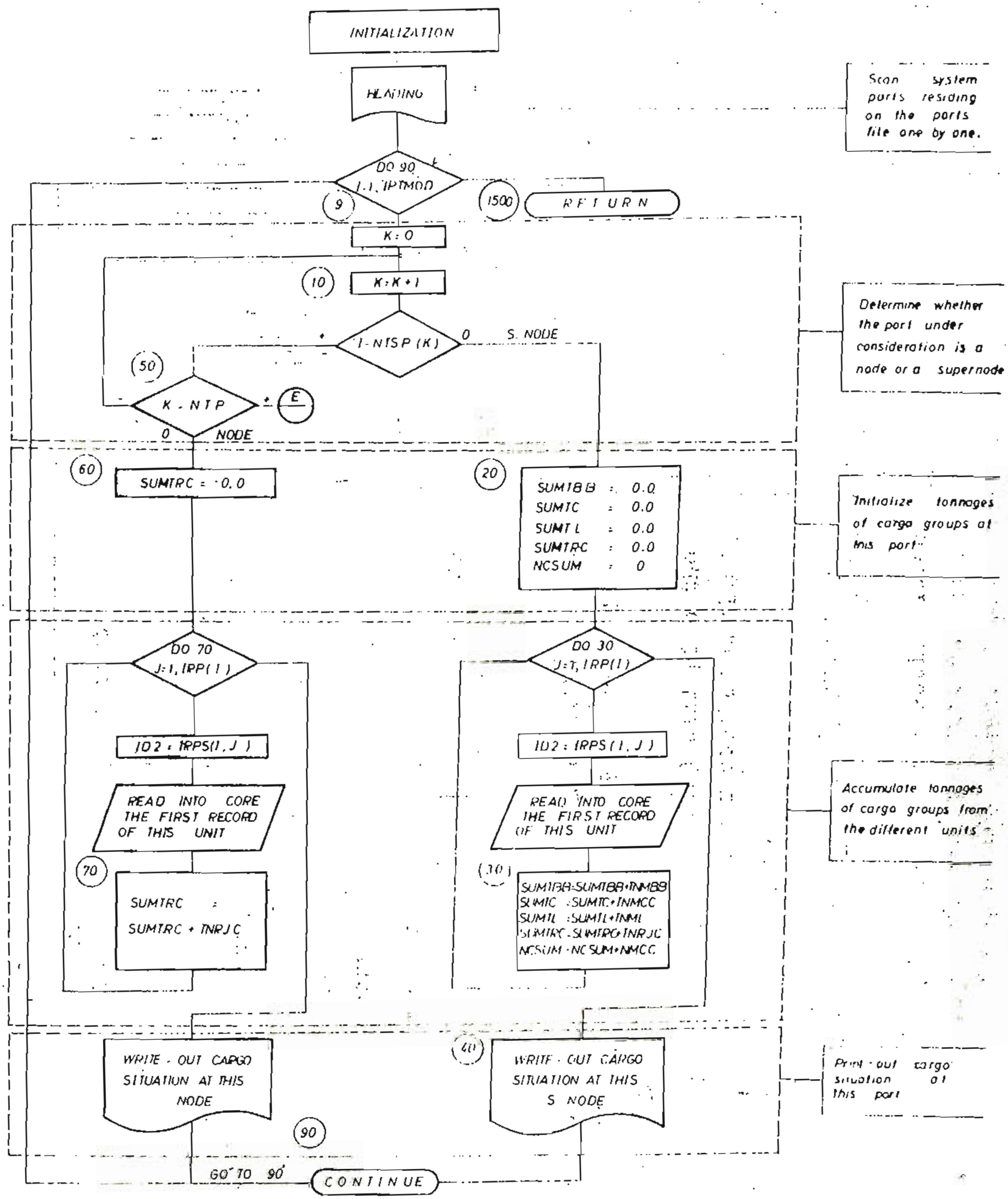


Figure 10-15 A :Flow chart of subr.CARGO